UQAR Université du Québec à Rimouski

SUR LES TRACES DE LA BALEINE NOIRE DE L'ATLANTIQUE NORD

Utilisation de l'habitat côtier par les cétacés du sud de la Gaspésie

ON THE TRAIL OF THE NORTH ATLANTIC RIGHT WHALE

Use of coastal habitat by cetaceans in southern Gaspé

Mémoire présenté
dans le cadre du programme de maîtrise en océanographie
en vue de l'obtention du grade de maître ès sciences

PAR
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Novembre 2025

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Dépôt initial le 08 Août 2025 Dépôt final le 28 Novembre 2025

« L’océan est le cœur bleu de la planète »   Sylvia Earle

REMERCIEMENTS

Je souhaite tout d'abord remercier ma directrice de recherche, Lyne G. Morissette pour son accompagnement précieux, ses conseils avisés et la confiance qu'elle m'a accordée tout au long de ce travail, me permettant de développer mes réflexions et de gagner en autonomie. Je remercie également mes co-directeurs, David Deslauriers et Benjamin de Montgolfier, pour leur confiance, leurs relectures attentives, et nos discussions enrichissantes. Je vous remercie tous les trois pour votre soutien, tant dans la diffusion de mon projet au sein de la communauté académique que dans sa vulgarisation auprès du grand public.

Je suis profondément reconnaissante envers le Regroupement des Pêcheurs Professionnels du Sud de la Gaspésie (RPPSG) de m'avoir offert l'opportunité de mener ce projet à leurs côtés. Je remercie O'Neil Cloutier, directeur général du RPPSG et Jean Côté, directeur scientifique, ainsi que l'ensemble des pêcheurs du regroupement pour leur confiance et leur bienveillance. Je tiens à adresser un merci tout particulier à Jean pour sa disponibilité, son aide précieuse durant ces deux ans et le soin apporté à la relecture de ce mémoire. Je tiens également à souligner l'appui financier essentiel apporté par le RPPSG et l'organisme MITACS, qui a permis le bon déroulement de cette étude.

Je tiens à remercier du fond du cœur, Marie-Pierre Suchira Turcotte, Sylvie Bernier, Clara Lebreux Berger, Romane Tréhin ainsi que Joël Berthelot capitaine du *Sea La Vie*, avec qui j'ai eu l'honneur de partager les saisons de terrain de 2024 et 2025, déterminantes pour ma recherche. Merci pour votre bonne humeur et ces moments inoubliables passés à échanger, à explorer la côte gaspésienne, et à observer baleines et oiseaux marins. Un merci tout particulier à Marie-Pierre, Sylvie, Jean et Joël, votre générosité, votre engagement, votre bienveillance et la passion avec laquelle vous m'avez transmis votre savoir ont fait de cette expérience de terrain une aventure à la fois humaine et professionnelle inoubliable, profondément formatrice.

Je remercie également Pierre Cauchy, David Deslauriers, Benjamin de Montgolfier et Aquasearch pour le prêt des hydrophones SoundTrap, qui ont permis à cette étude de prendre une nouvelle dimension, enrichissant considérablement mes recherches. Je remercie aussi chaleureusement Gilles et Annie Duguay ainsi que l'équipe terrain, pour leur soutien précieux lors des pauses et des récupérations des hydrophones à bord du *Miss Amyline*. Enfin je tiens à remercier Marion Poupard pour sa formation en acoustique de grande qualité, son accompagnement et son aide. Sans son expertise et son soutien, les données précieusement récoltées n'auraient pas pu être exploitées de manière aussi pertinente.

Je remercie l'ensemble du personnel de l'ISMER pour son professionnalisme et sa bonne humeur. Je tiens à adresser une mention spéciale à Martine Belzile pour son accueil et son aide lors de notre arrivée de France, à El Mahdi Bendif et Laury-Ann Dumoulin pour leur aide avec les échantillons, et à Marine Holbach pour m'avoir permis de travailler à ses côtés et pour son soutien précieux dans la vulgarisation et le partage de nos recherches. Je remercie également Audrey-Maude Falardeau, Martin PM et l'ACFAS de m'avoir donné l'occasion de partager mes travaux à petits et grands sous forme de bande dessinée.

Un grand merci à mes amies du Pont et du Némo, avec qui j'ai partagé de précieux moments, entre rires, joies et doutes. Merci aussi à mes ami·es gaspésien·nes pour votre accueil si chaleureux et tous ces souvenirs inoubliables, mon aventure québécoise n'aurait pas été la même sans vous. Une pensée toute particulière à ma formidable colocataire Éloïse : merci pour tout. Toutes ces personnes ont largement contribué à rendre mes deux années de maîtrise à l'ISMER et en Gaspésie, à la fois enrichissantes et épanouissantes, tant sur le plan intellectuel que personnel.

Enfin, un immense merci à ma famille, ma maman, mon papa, ma sœur, mes grands-parents. Votre soutien et vos encouragements m'ont permis de m'épanouir et de grandir à l'autre bout du monde. Merci aussi à mes copains de France, dont les visites, que ce soit dans le froid glacial- ou sous le soleil québécois, ont marqué cette aventure de souvenirs inoubliables. Enfin du fond du cœur, je remercie mon conjoint : Guillaume, merci pour ton écoute, ta confiance et ton soutien sans faille. Merci d'avoir partagé cette sublime aventure québécoise.

AVANT-PROPOS

J'ai développé un attachement particulier pour l'étude des cétacés depuis mon stage de master 2, effectué au sein du bureau d'étude Aquasearch en Martinique et de l'association OMMAG en Guadeloupe aux côtés de Benjamin de Montgolfier et Laurent Bouveret. En étudiant les populations de globicéphales tropicaux, leur comportement et la dynamique de leur population, j'ai pu développer mes compétences pratiques et théoriques dans ce domaine. C'est ce qui m'a conduite à réaliser une nouvelle maîtrise, cette fois-ci au Québec, afin de consolider mes connaissances et compétences, de gagner en autonomie et de me former à une approche intégrative combinant observation visuelle et acoustique passive, sur le terrain comme en laboratoire. Cette maîtrise, portant sur l'utilisation de l'habitat côtier par les cétacés dans le sud de la Gaspésie, s'inscrit au cœur du projet « *Pêcheurs et baleines en Gaspésie* : *vers une coexistence sur le territoire maritime* » initié par les pêcheurs de homard du regroupement des pêcheurs professionnel du sud de la Gaspésie (RPPSG), sous la direction d'O'Neil Cloutier, directeur général du RPPSG, de Jean Côté, directeur scientifique du RPPSG et de Lyne G. Morissette, professeure associée à l'ISMER-UQAR et directrice générale de M-Expertise Marine.

Le présent manuscrit se compose de quatre parties : une introduction générale rédigée en français présentant le contexte de cette étude et les espèces observées ; elle est suivie du premier chapitre, rédigé en anglais sous forme d'un article scientifique. Intitulé "*Cetacean Use of Shallow Lobster Fishing Areas in Southern Gaspé (2019–2024): Relevance for North Atlantic Right Whale (Eubalaena glacialis, Müller 1776) Protection Measures in the Gulf of St.Lawrence*", cet article a été publié par le *Canadian Journal of Zoology,* dans le cadre d'un numéro spécial pour le RAQ intitulé « *Sustainable aquaculture, commercial and recreational fisheries development* ». En tant que première auteure, j'ai contribué à la formulation de la problématique et des objectifs de l'article, à l'acquisition des données pour l'année 2024, ainsi qu'au traitement et à l'analyse des six années de données d'observation et de comportement. J'ai également rédigé la version originale du manuscrit. Jean Côté, Benjamin de Montgolfier, David Deslauriers et Lyne G. Morissette ont, chacun selon leur expertise, participé au développement de la réflexion scientifique, à la définition des objectifs, à la mise en place de la méthodologie de terrain, ainsi qu'à la révision approfondie de l'article.

Le second chapitre de cette maîtrise, également rédigé en anglais sous forme d'un article scientifique, s'intitule "*Acoustic presence of Humpback whales (Megaptera novaeangliae) and North Atlantic right whales (Eubalaena glacialis) in the southern Gaspé coastal zone: overview based on long-term recordings*". En tant que première auteure, j'ai également contribué à l'élaboration de la problématique et des objectifs de l'article, à l'acquisition des données lors de la saison estivale 2024, ainsi qu'au traitement et à l'analyse des trois mois de données d'enregistrement continu concernant le rorqual à bosse et la baleine noire de l'atlantique Nord. J'ai également rédigé la version originale du manuscrit. Marion Poupard, seconde auteure de l'article, a été d'une aide précieuse pour le développement de la méthode d'analyse, pour le traitement et l'analyse des données, ainsi que pour la révision de l'article. Jean Côté, Benjamin de Montgolfier, David Deslauriers et Lyne G. Morissette ont, encore une fois chacun selon son expertise, participé au développement de la réflexion scientifique, à la définition des objectifs de ce chapitre, à la mise en place de la collecte de données sur le terrain et à la révision de l'article. Le fruit de ce travail sera soumis au sein de la revue *Marine Mammal Sciences*, après la révision par le jury.

La conclusion générale de ce mémoire est, pour terminer, consacrée à la synthèse des principaux résultats obtenus dans les deux chapitres. Elle met en évidence les nouvelles pistes de recherche qui en découlent et replace les conclusions dans un contexte plus large afin de montrer en quoi ce travail contribue à l'avancement des connaissances actuelles.

Durant ces deux années d'études, j'ai eu l'occasion de partager les principaux résultats de cette maîtrise. En plus des présentations orales destinées au milieu académique, j'ai également eu la chance de partager ces recherches avec le grand public à travers des produits de vulgarisation, tel qu'une bande dessinée (Annexe, C, B, D), lors du Vulgarisathon de l'ACFAS, une infographie de l'article issue du premier chapitre (Riou et al., 2025 ; Annexe E) une vidéo YouTube (soutenue et financée par le RAQ).

RÉSUMÉ

La baleine noire de l'Atlantique Nord (*Eubalaena glacialis,* BNAN), espèce en danger critique d'extinction, est emblématique des défis de conservation, sa survie étant menacée par les collisions avec des navires et les empêtrements dans les engins de pêche. Cette maîtrise, s’inscrit dans un projet initié par le regroupement des pêcheurs professionnels du sud de la Gaspésie, et a combiné six années de suivis visuels (2019-2024) à trois mois de surveillance acoustique passive (2024). L’objectif était de mieux comprendre la présence spatio-temporelle des cétacés fréquentant la zone de pêche au homard sud Gaspésienne et de fournir des informations pertinentes à la coexistence des pêcheurs et des BNAN.

Entre 2019 et 2024, les inventaires visuels ont révélé une utilisation dynamique et opportuniste de la zone par le petit rorqual, le marsouin commun, le rorqual à bosse et le rorqual commun, dont les comportements de déplacement et d'alimentation semblent liés à la disponibilité des proies. Aucune baleine noire n’a été observée dans la zone d’étude au cours de ces six années, probablement parce que la densité de proies de *Calanus spp.* est insuffisante et que la composition de la communauté de proies locale n’est pas adaptée à leur régime alimentaire. L’analyse acoustique a complété ces observations, montrant une présence quasi quotidienne du rorqual à bosse, avec un pic d'activité en juin, indiquant que cette zone pourrait servir de halte migratoire et de zone d'alimentation. Les détections des *up-calls,* ces vocalisations typiques des BNAN, bien que plus rares, étaient concentrées en août, suggérant une utilisation transitoire de la zone comme corridor migratoire, actuellement en dehors de la saison de pêche, réduisant le risque d'empêtrement.

Cette approche intégrative révèle, de manière rigoureuse, qu’il n’y a actuellement pas ou peu de risque de chevauchement temporel entre la présence de la BNAN et la pêche au homard dans la zone d’étude. Cependant, une vigilance continue reste indispensable, car les dynamiques écosystémiques pourraient évoluer, modifiant cette situation. La réussite de ce projet démontre la viabilité d’un modèle collaboratif, où scientifiques et pêcheurs génèrent ensemble des données fiables à l'échelle locale contribuant directement à l’adaptation des protocoles de gestion.

Mots clés : Cétacés, Baleine noire de l’Atlantique Nord, Inventaire Visuel, Comportement, Acoustique, Rorqual à bosse, Coexistence, Homardier, Golfe du Saint-Laurent.

ABSTRACT

The North Atlantic right whale (*Eubalaena glacialis,* BNAN), a critically endangered species, is emblematic of conservation challenges, with its survival threatened by collisions with ships and entanglement in fishing gear. This study is part of a project initiated by a group of professional fishermen in southern Gaspé, combining six years of visual monitoring (2019-2024) with three months of passive acoustic monitoring (2024). The objective was to better understand the spatial and temporal presence of cetacean species frequenting the southern Gaspé lobster fishing zone and to provide relevant information for the coexistence of fishermen and BNAN.

Between 2019 and 2024, visual surveys revealed dynamic and opportunistic use of the area by minke whales, harbour porpoises, humpback whales, and fin whales, whose movement and feeding behaviors are probably linked to prey availability. No right whales were observed in the study area during these six years, probably because the density of *Calanus spp.* prey is insufficient and the composition of the local prey community is not suited to their diet. Acoustic analysis complemented these observations, showing an almost daily presence of humpback whales, with peak presence in June, indicating that this area could serve as a migratory stopover and feeding area. Detections of *up-calls,* the vocalizations typical of BNAN, although rarer, were concentrated in August, suggesting a transient use of the area as a migratory corridor, currently outside the lobster fishing season, reducing the risk of entanglement.

This integrative approach rigorously reveals that there is currently little or no risk of temporal overlap between the presence of the BNAN and lobster fishing in the study area. However, continued vigilance remains essential, as ecosystem dynamics could evolve, changing this situation. The success of this project demonstrates the viability of a collaborative model, where scientists and fishermen work together to generate reliable data at the local level that directly contributes to the adaptation of management protocols.

Keywords: Cetaceans, North Atlantic right whale, Visual inventory, Behavior, Acoustics, Humpback whale, Coexistence, Lobster fishing, Gulf of St. Lawrence.

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ACCOL	Anderson Cabot Center for Ocean Life du New England Aquarium
ADC	Analog-to-Digital Converter
BNAN	Baleine Noire de l'Atlantique Nord
CBI	Commission Baleinière Internationale
CNN	Convolutional Neural Network
COSEPAC	Comité sur la Situation des Espèces Sauvages en Péril Au Canada
dB	Decibel
DFO	Department of Fisheries and Oceans Canada
EBSA	Ecologically and Biologically Significant Area
GLM	Generalized Linear Model
GPS	Global Positioning System
GSL	Golfe du Saint-Laurent
Hz	Hertz
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
LEP	Loi sur les Espèces en Péril
LFA	Lobster Fishing Area

MMO	Marine Mammal Observer
MMON	Marine Mammal Observation Network
MMPA	Marine Mammal Protection Act
MPO	Ministère des Pêches et des Océans Canada
NARW	North Atlantic Right Whale
NFFT	Number of points in the Fast Fourier Transform
NGO	Non-Governmental Organizations
ONG	Organisation Non Gouvernementales
PAM	Passive Acoustic Monitoring
ROMM	Réseau d'observation de mammifères marins
RPPSG	Regroupement des Pêcheurs Professionnels du Sud de la Gaspésie
SARA	Species At Risk Act
UICN	Union Internationale pour la Conservation de la Nature
ZPH	Zone de Pêche au Homard

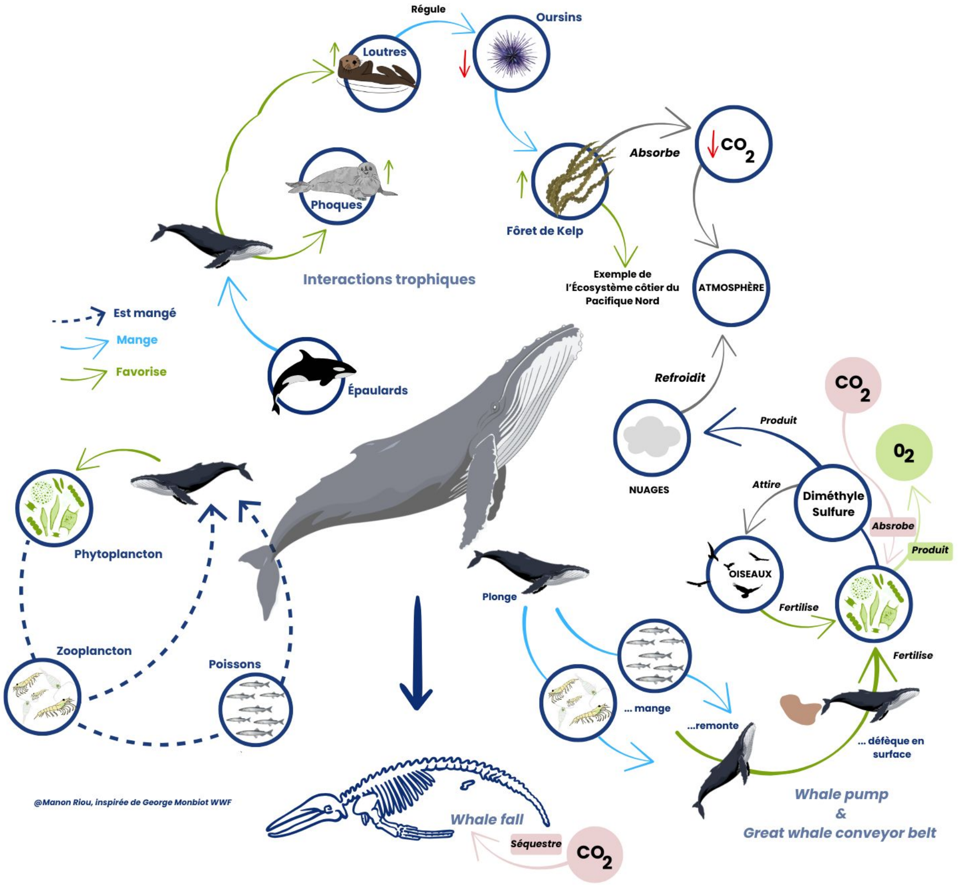
INTRODUCTION GÉNÉRALE

Ce mémoire s'inscrit dans le cadre du projet « *Pêcheurs et baleines en Gaspésie : vers une coexistence sur le territoire maritime* ». Cette introduction présente d'abord le contexte de la recherche, puis la zone d'étude et les espèces qui la fréquentent. Enfin, nous exposerons les objectifs de cette recherche ainsi que la méthodologie adoptée pour les atteindre.

1. CONTEXTE DE RECHERCHE

Les cétacés, mammifères marins emblématiques et prédateurs à longue durée de vie, sont des acteurs clés dont la présence est fondamentale à l'intégrité et au fonctionnement des écosystèmes marins (Estes, 2009 ; Monreal et al., 2025). Leur rôle s'étend bien au-delà de leur position trophique (contrôle *top-down* ; Estes, 2006 ; Kiszka et al., 2015), agissant comme de véritables ingénieurs de l'écosystème (Roman et al., 2014), étant de précieux indicateurs de la santé des océans (Moore et al., 2009 ; Roman et al., 2014 ; Nelms et al., 2021 ; Cheeseman et al., 2024) et considérés comme des espèces parapluies pertinentes (Savoca et al., 2024). Par conséquent, la conservation des cétacés est intrinsèquement liée à des enjeux écologiques, économiques et culturels majeurs (Nelms et al., 2021).

Une compréhension récente met en lumière leur rôle en tant que solutions fondées sur la nature pour atténuer les effets du changement global (Figure 1). En effet, en participant à la captation du carbone (Pershing et al., 2010) et en redistribuant le flux d'éléments minéraux, tant verticalement vers la surface (*Whale pump* ; Lavery et al., 2010 ; Roman et al., 2014) qu'horizontalement sur de longues distances pour les espèces migratrices (*Great whale conveyor belt* ; Roman et al., 2014), ils stimulent la croissance phytoplanctonique (Roman et al., 2014 ; Figure 1). Ce dernier, en tant que producteur primaire à la base de la chaîne alimentaire, produit de l'oxygène et capture le carbone, établissant ainsi un cercle vertueux fondamental à l'équilibre océanique (Roman et al., 2014 ; Monreal et al., 2025). De plus, à la mort de l’animal, la carcasse, riche en protéines et lipides, transfère et séquestre d’importantes quantités de carbone de la surface vers les eaux profondes, enrichissant ainsi des milieux souvent pauvres en nutriments (Roman et al., 2014 ; Figure 1). Roman et al. (2014) estiment que les “*Whale falls*”, contribuent au transfert de 190 000 tonnes de carbone par an de l’atmosphère vers les fonds marins. Ainsi les cétacés méritent une protection renforcée, en sauvegardant leur diversité et en maintenant leur abondance, dans une optique de restauration des fonctions écologiques largement réduites à la suite de leur déclin historique (Estes, 2006 ; Hoyt, 2012).



@Manon Riou, inspirée de George Monbiot WWF

Figure 1. Schéma représentant les rôles des grandes baleines comme solutions fondées sur la nature pour atténuer les effets du changement global. Inspirée de @WWF

En effet, la chasse à la baleine du XX^e siècle a eu des conséquences écologiques désastreuses, poussant les baleines du monde entier au bord de l'extinction à un rythme insoutenable, sans précédent (Roman et al., 2014 ; Nelms et al., 2021 ; Monreal et al., 2025). Ayant entraîné le déclin de 66 à 90% des populations de grandes baleines, soit environ 10 millions de baleines tuées et une perte de 85% de biomasse, cette surexploitation a non seulement impacté les populations marines en modifiant les interactions trophiques (Estes, 2006 ; Morissette et al., 2012), mais a aussi généré d'importantes rétroactions biogéochimiques, modifiant la productivité primaire et les processus de séquestration du carbone dans les océans (Monreal et al., 2025). Malgré un moratoire international en 1982, interdisant partout dans le monde la chasse commerciale à la baleine (*International Whaling Commission*, 1982), 25% des espèces de mammifères marins, dont certains cétacés, sont encore considérés comme menacés selon la liste rouge de l'Union Internationale pour la Conservation de la Nature (UICN ; Nelms et al., 2021). En effet, les menaces actuelles, auxquelles font face 98% des mammifères marins - le changement global, la pollution, qu'elle soit chimique, sonore ou plastique, les empêtrements et captures accidentelles dans des engins de pêche, les collisions avec des navires, le dérangement par les humains durant des activités essentielles - combinées aux traits d'histoire de vie - tels qu'un faible taux de reproduction, et des spécificités particulière pour la reproduction et l'alimentation - font peser de nouveaux et puissants facteurs de stress sur de nombreuses espèces et populations de cétacés, même dans les régions les plus reculées (Nelms et al., 2021 ; *ex* : Bettridge et al., 2015 ; Desforges et al., 2018 ; Villagra et al., 2021 ; Jung et Madon 2021).

Parmi les espèces les plus emblématiques de cette crise, la baleine noire de l'Atlantique Nord (*Eubalaena glacialis*, Müller 1776 ; BNAN), a été poussée au bord de l'extinction par la chasse à la baleine (Kraus et Rolland, 2007). Son nom anglais « *Right whale* », vient du fait qu'elle était considérée comme la « bonne » baleine à chasser, en raison de son déplacement lent, de la flottabilité de sa carcasse et de son rendement élevé en huile et en fanons (Kraus et Rolland, 2007). Historiquement, la BNAN a été chassée de manière intensive depuis plus de 1 000 ans, d'abord par les Basques, puis par des flottes commerciales du XVII^{e} au début du XX^{e} siècle, jusqu'à la quasi-disparition de ses populations originelles à l'Est comme à l'Ouest de l'Atlantique Nord (*International Whaling Commission*, 2001 ; Kraus et Rolland, 2007). Aujourd'hui, une seule population semble subsister, distribuée dans l'Atlantique Nord-Ouest (celle dont on parlera dans ce mémoire ; Kraus et Rolland, 2007). Bien que des observations occasionnelles aient été rapportées en dehors de leur aire de répartition habituelle, comme près de la Norvège (Jacobsen et al., 2004), de l'Islande (Knowlton et al., 1992 ; Hamilton, 2018 ; Harcourt et al., 2019), au large des côtes françaises (Pettis, 2019) et au Groenland (Mellinger et al., 2011), ces occurrences restent rares. La population de l'Atlantique Nord-Ouest continue de décliner malgré une croissance démographique lente observée jusqu'en 2010 (augmentation de 2,8% par an, passant de 270 individus en 1990 à 483 en 2010 ; Moore et al., 2021 ; Figure 2). Depuis, la population a chuté d'environ 20%, compromettant ainsi son rétablissement (356 individus en 2020 ; Moore et al., 2021 ; Figure 2). Une légère augmentation de ses effectifs est observée pour 2023, avec 372 individus (IC 95 % : 360–383 ; Figure 2) recensés, dont 70 femelles reproductrices (Pettis et Hamilton, 2025). Elle est aujourd'hui considérée comme une espèce en danger critique d'extinction par l'UICN (Cooke, 2020) et est protégée par la Loi sur les espèces en péril (LEP) du Canada depuis 2005 (MPO 2021 ; LEP https://www.laws-lois.justice.gc.ca/eng/AnnualStatutes/2002_29/page-16.html, consulté le 9 juillet 2025). Selon le Comité sur la situation des espèces sauvages en péril au Canada (COSEPAC, 2003), il est très difficile de mettre en place des stratégies de protection efficaces pour la BNAN, en raison de la complexité de sa biologie, de sa présence dans les zones littorales et côtières, ainsi que du manque de connaissances sur le lien entre sa reproduction et son habitat.

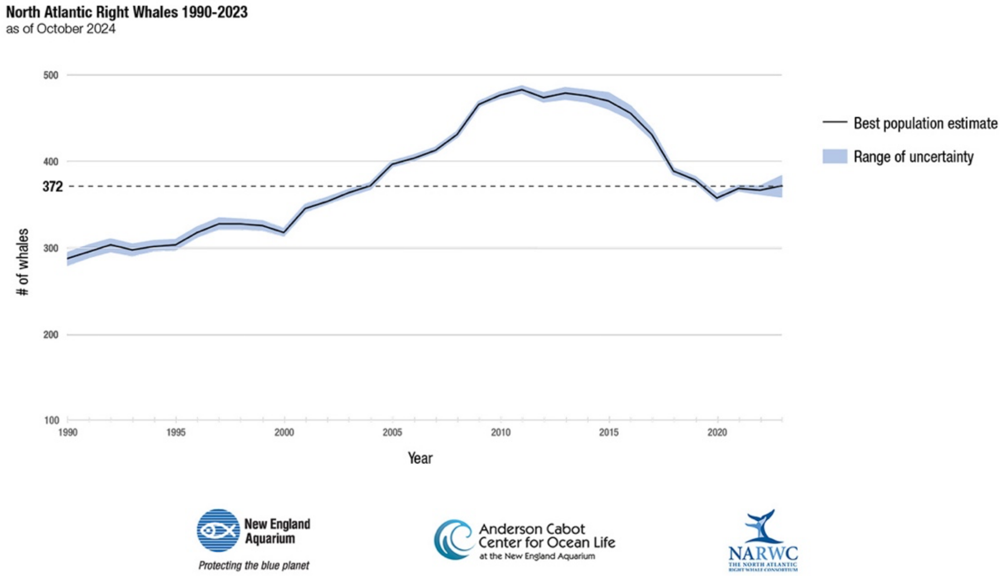


Figure 2. Évaluations de la population BNAN entre 1990 et 2023. L'estimation pour 2023 était de 372 +11/-12. Données issues du *North Atlantic Right Whale Catalog* (catalogue des baleines noires de l'Atlantique Nord) au 3 septembre 2024 (Pettis et Hamilton, 2025)

À la différence de la baleine franche australe (*Eubalaena australis* ; Desmoulins, 1822), dont les effectifs se sont bien rétablis et dont les causes de mortalité sont principalement naturelles, la BNAN est confrontée à un défi unique. Les traumatismes causés par les activités humaines, principalement les empêtrements dans les engins de pêche et les collisions avec les navires, constituent le principal obstacle à son rétablissement (Sharp et al., 2019 ; Pettis et Hamilton, 2025). Impliqués dans près de 90% des décès documentés depuis 2003 aux États-Unis et au Canada, ces incidents affectent également les jeunes individus à un rythme alarmant (Sharp et al., 2019). Combinés à un faible taux de reproduction, ils compromettent gravement le renouvellement de la population (Kraus et Rolland, 2007 ; Sharp et al., 2019 ; Moore et al., 2021 ; Reamer et al., 2023). Cette situation est aggravée par la distribution de l'espèce dans l'Atlantique Nord, près des régions côtières les plus densément peuplées par les humains, ce qui intensifie les interactions anthropiques à risque (Kraus et Rolland, 2007 ; Brillant et al., 2017 ; Moore et al., 2021). Depuis 2015, le taux de mortalité a augmenté dans l'ensemble de l'aire de répartition des BNAN (Bourque et al., 2020). Les années 2017 et 2019 ont notamment enregistré un nombre sans précédent de BNAN retrouvées mortes ou empêtrées dans le Golfe du Saint-Laurent (GSL, MPO, 2021). Ces événements soulignent les défis de coexistence entre les activités humaines et cette espèce vulnérable (Koubrak et al., 2021). Ils ont également marqué un tournant dans la reconnaissance du GSL comme zone de fréquentation importante, jusqu'alors peu documentée (voir la partie 2 de cette introduction générale pour plus de détails).

Les BNAN, effectuent des migrations saisonnières bien établies (Winn, 1986 ; Brillant et al., 2015 ; Moore et al., 2021). Chaque hiver, elles rejoignent les eaux chaudes de la Floride et de la Géorgie pour se reproduire (Brillant et al., 2015). Elles migrent ensuite vers les eaux froides du Nord-Ouest de l'Atlantique pour se nourrir, utilisant principalement les eaux canadiennes en été et en automne, notamment au large de la Nouvelle-Écosse (Brown et al., 2009 ; Brillant et al., 2015 ; MPO, 2021 ; Durette-Morin et al., 2022). Ces mouvements saisonniers ont été confirmés par une surveillance acoustique passive et des relevés aériens (Durette-Morin et al., 2022). Un changement significatif dans leur schéma de distribution printanier et estival a été observé au cours de la dernière décennie (Simard et al., 2019 ; Crowe et al., 2021). Autrefois concentrées dans des zones d'alimentation telles que la baie de Fundy, la baie de Cape Cod, le Grand Chenal Sud, et le bassin de Roseway (Kraus et Rolland, 2007), les BNAN fréquentent davantage le GSL depuis 2015, comme l'ont démontré des suivis acoustiques et visuels (Simard et al., 2019 ; Crowe et al., 2021 ; Bishop et al., 2022). Crowe et al. (2021) estiment que 40% de la population utilise désormais ce secteur de mai à octobre, avec des observations répétées interannuelles, et Bishop et al. (2022) suggèrent que la présence de femelles reproductrices et de leurs petits pourrait indiquer une transmission intergénérationnelle de ce nouveau comportement migratoire.

Ce déplacement d'habitat s'expliquerait par des changements océanographiques et écosystémiques. Entre 1999 et 2016, les *Calanus spp*, en particulier le copépode *Calanus finmarchicus* (Gunner, 1765 ; Mayo et Marx 1990), principale proie de la BNAN, ont connu une diminution importante dans les zones d'alimentation traditionnelles de cette dernière telles que la baie de Fundy ou le bassin de Roseway, en raison d'un réchauffement des eaux

(Sorochan et al., 2019). La raréfaction de cette ressource alimentaire expliquerait donc le changement de répartition spatiale et le déplacement de la BNAN vers le GSL, où de fortes concentrations de proies sont observées (Meyer-Gutbrod et Greene, 2018 ; Sorochan et al., 2019, 2023 ; Gavrilchuk et al., 2021). Cette réponse comportementale souligne l'urgence de mettre en place des stratégies de conservation dans cette région où les risques liés aux activités humaines sont importants pour cette petite population. En effet, initialement dépourvu de toute protection en raison de l'imprévisibilité de son utilisation, le GSL est désormais reconnu comme essentiel à la survie de l'espèce (Crowe et al., 2021 ; Moore et al., 2021 ; Meyer-Gutbrod et al., 2023 ; Sorochan et al., 2023) et fait l’objet de politiques de conservation, conformément à la Loi sur les espèces en péril du Canada (Koubrak et al., 2021 ; MPO, 2021). Depuis 2018, cette reconnaissance s’est traduite par la mise en œuvre de mesures de gestion dynamique, notamment des fermetures temporaires de zones de pêche déclenchées par détection acoustique ou visuelle de BNAN. Ces fermetures couvrent une superficie d’environ 2 000 km² pendant 15 jours, renouvelables en cas de nouvelle détection, et s’inscrivent dans une coordination élargie impliquant Pêches et Océans Canada, Transport Canada, les scientifiques et le secteur de la pêche (MPO, 2021 ; Ratelle et al., 2024 ; Cole et Brillant, 2025). Bien que ces dispositifs soient en amélioration constante, ils représentent une avancée importante dans l’intégration de données scientifiques en temps quasi réel à la gestion des risques d’interactions entre les BNAN et les activités humaines (Davies et Brillant, 2019 ; MPO, 2025).

2. PROJET « PÊCHEURS ET BALEINES EN GASPÉSIE : VERS UNE COEXISTENCE SUR LE TERRITOIRE MARITIME »

La BNAN est confrontée à un défi de conservation complexe, soulevant des enjeux à la fois écologiques et socio-économiques (Morissette et al., 2022 ; Reamer et al., 2023). Les menaces majeures, que sont l’empêtrement dans les engins de pêche et les collisions avec les navires (Knowlton et Krauss, 2001 ; Sharp et al., 2019 ; Bourque et al., 2020), nécessitent une approche multidisciplinaire impliquant l'ensemble des parties prenantes pour protéger efficacement l'espèce (MPO, 2020*a* ; MPO, 2021 ; Morissette et al., 2022). Comme le souligne Nelms et al. (2021), le succès de la conservation repose fortement sur l'interdisciplinarité et une communication solide entre scientifiques et acteurs.

Le déplacement des BNAN dans le GSL (Simard et al., 2019 ; Crowe et al., 2021) couplé à la crise sans précédent de 2017, lorsqu'au moins 12 BNAN sont mortes dans les eaux canadiennes (soit 2% de la population ; Daoust et al., 2017 ; Meyer-Gutbrod et Greene, 2018 ; Sharp et al., 2019) et huit autres en août 2019 (Bourque et al., 2020), ainsi que les nombreux cas d'empêtrements dans le GSL (MPO, 2021); a mis en évidence le besoin urgent d'un modèle de coexistence complet. Cette situation était d'autant plus critique qu'avant 2017, très peu de relevés étaient consacrés à l'espèce dans le GSL, et aucun plan d'action n'incluaient cette zone (se concentrant dans ses habitats essentiels de la baie de Fundy et du bassin de Roseway ; Brown et al., 2009 ; MPO, 2014), sa présence était imprévisible et non anticipée (Brillant et al., 2015 ; Meyer-Gutbrod et Greene et al., 2018 ; Moore et al., 2021). C'est en réponse à cette urgence que le gouvernement canadien a réagi dès 2018, en renforçant et en élargissant la surveillance tout en instaurant des mesures de gestion visant à réduire les risques d'empêtrement dans les engins de pêche et de collision avec les navires (MPO, 2021 ; Koubrak et al., 2021).

À la suite des mortalités inhabituelles, principalement d'origine anthropique, survenues en 2017 (Daoust et al., 2017), le MPO a rapidement mis en place des mesures d'urgence. Dès 2018, des fermetures de zones de pêche ont touché des communautés côtières canadiennes (Koubrak et al., 2021). Ces fermetures s'inscrivaient dans un cadre évolutif de mesures de protection, influencé par des facteurs internationaux, comme le *Marine Mammal Protection Act* des États-Unis (Federal Register, 2016) et par des politiques nationales comme le Plan de protection des océans lancé en 2016, exigeant une action rapide de la part du gouvernement canadien. Un exemple marquant de ces mesures a été pris à la suite de l'observation de deux BNAN à 10 kilomètres au large de Newport, entraînant la fermeture de la zone de pêche au homard (ZPH 20), au sud de la péninsule gaspésienne, entre Percé et

Port-Daniel-de-Gascons. Cette fermeture, décidée même en l'absence de détection de BNAN dans la zone très côtière de pêche au homard, a provoqué des pertes économiques significatives pour les pêcheurs, estimées à 2,77 millions de dollars canadiens (Morissette et al., 2022). Ces mesures de gestion drastiques et précautionneuses, prises sans réelle consultation du secteur de la pêche, ont mis en péril la subsistance des professionnels de l'industrie, et ébranlé leur confiance ainsi que celle de la communauté côtière envers les mesures de gestion imposées par le gouvernement canadien (Morissette et al., 2022 ; plus de détails sur cette crise environnementale et socio-économique sont disponibles dans l'introduction du chapitre 1 et dans le livre « Pêcheurs et baleines en Gaspésie »). Se sentant exclus des processus décisionnels, les pêcheurs ont réagi à l'hiver 2018-2019, en s'associant au dépôt du rapport du Comité permanent des pêches et des océans à la Chambre des communes (Chambre des Communes, 2018). Cette démarche a contraint le MPO à modifier et adapter les mesures de gestion pour prendre en compte la réalité des communautés côtières (Morissette et al., 2022). Malgré tout, les associations de pêcheurs dont le Regroupement des Pêcheurs Professionnels du Sud de la Gaspésie (RPPSG), souhaitait des mesures régionales basées sur des faits et la science pour évaluer le niveau de risque d'empêtrement et l'efficacité des mesures de gestion strictes qui les impactaient grandement, dans une région très côtière ou aucune BNAN n'avait jamais été observée (Morissette et al., 2022).

C'est dans ce contexte qu'est né le projet « *Pêcheurs et baleines en Gaspésie* : *vers une coexistence sur le territoire maritime* », lancé en 2018 par la firme M - Expertise Marine en collaboration avec le RPPSG. Le savoir et l'expérience des pêcheurs sont alors valorisés et les pêcheries considérées comme faisant partie de la solution plutôt que du problème (Chambre des communes, 2018 ; Morissette et al., 2022). Le RPPSG souhaitait pouvoir agir et émettre des recommandations aux divers ministères, instances et intervenants impliqués dans la gestion des pêches gaspésienne dans l'objectif « d'améliorer le plan de protection de la BNAN dans un cadre intégré, permettant aussi à l'industrie des pêches québécoise de se développer de façon durable » (Morissette et al., 2022). En effet, la prise en compte de l'engagement des communautés de pêcheurs ayant un lien culturel profond avec l'océan (Nelms et al., 2021), est plus que cruciale pour garantir une coexistence entre les cétacés du

GSL (dont la BNAN) et les activités anthropiques, telles que la pêche au homard en Gaspésie, qui a des retombées socio-économiques importantes pour les communautés côtières (Morissette et al., 2022). Depuis 2018, un groupe consultatif réunissant des pêcheurs, des scientifiques, des organisations non gouvernementales (ONG) et Pêches et Océans Canada (MPO), évalue et ajuste chaque année les mesures de gestion et de protection de la BNAN, dans une logique de co-construction et d'adaptation (MPO, 2020*b*). Ainsi, depuis 2019, le MPO a mis en place un protocole dynamique pour les eaux peu profondes afin d'encadrer plus efficacement les fermetures dans les zones de pêche de moins de 20 brasses (environ 37 mètres) et prendre en compte la réalité côtière. Une question est au cœur de nombreuses discussions et débats lors des réunions : la BNAN fréquente-elle les eaux côtières peu profondes de pêche au homard, notamment dans le sud de la Gaspésie ? (MPO, 2020*a*).

Dans le cadre du projet « *Pêcheurs et baleines en Gaspésie* : *vers une coexistence sur le territoire maritime* », le RPPSG et M - Expertise Marine, ont décidé d'étudier cette thématique directement dans leurs zones de pêche au homard, soit dans un territoire de 20 brasses (37 mètres) entre Saint-Georges-de-Malbaie, au nord, et Port-Daniel-Gascons, au sud, de la péninsule gaspésienne. Ce projet d'étude des cétacés fréquentant la zone côtière sud gaspésienne est en cours depuis 2019, et permet au RPPSG de fournir des données concrètes aux instances gouvernemental (Morissette et al., 2022).

3. ZONE D'ÉTUDE

La zone d'étude, qui comprend les zones de pêche au homard 20A et 20B, se situe le long de la côte sud de la péninsule gaspésienne. Elle s'étend de Saint-Georges-de-Malbaie (48° 39' N ; 64°13'O) au nord à Port-Daniel-Gascons (48° 9' N ; 64° 58' O) au sud (Figure 3). Cette côte gaspésienne (secteur Gaspésie-sud et nord de la Baie des Chaleurs) représente une zone de transition écologique, passant d'un milieu côtier peu profond et abrité ; la baie des

Chaleurs (en moyenne 60 mètres) ; à un environnement marin profond, ouvert sur le GSL (Gagnon, 1997).

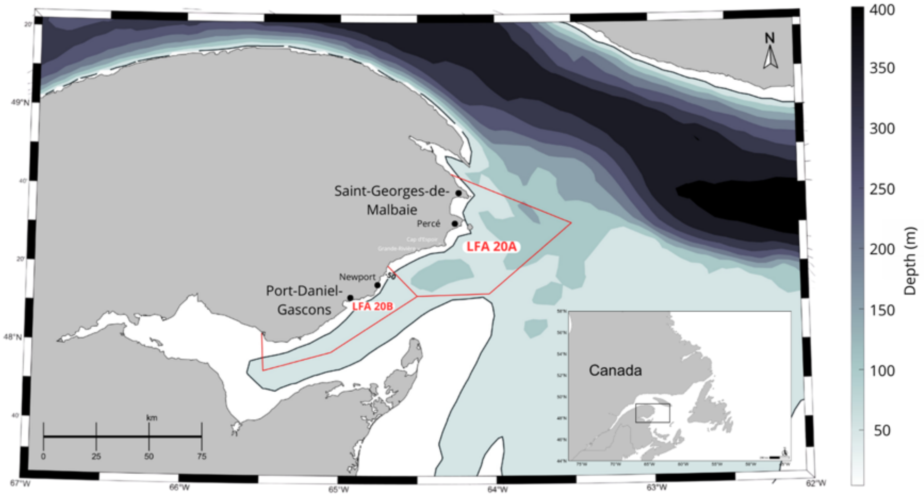


Figure 3. Emplacement de la zone d'étude dans le golfe du Saint-Laurent au Nord-Ouest de l'Atlantique. Le contour bathymétrique de 50 mètres y est représenté par une ligne bleu foncé, avec des isobathes en mètres. La zone d'étude est située dans la partie sud de la péninsule Gaspésienne, les deux zones de pêche au homard (ZPH) sont identifiées par la ligne rouge, ZPH 20A et ZPH 20B (LFA : Lobster Fishing Area). Source Natural Earth, geospatial data.

3.1 Milieu physique

Le secteur Gaspésie-sud et Baie des Chaleurs se situe à l'extrémité ouest du plateau madelinien, un immense plateau dont la profondeur est inférieure à 200 mètres, délimité au nord par les eaux profondes du chenal Laurentien et occupant toute la partie sud du GSL (Gagnon, 1997 ; Sklar et al., 2024). Cette région présente une morphologie complexe marquée par des hauts-fonds, dont deux se trouvent dans la zone d'étude : l'un en face du cap d'Espoir, nommé haut-fond Leander (48° 24' N 64° 18' O ; Gagnon, 1997 ; Base de données des noms géographiques du Canada 2024, Figure 4) ; l'autre près de l'île Plate (48° 37' N ;

64° 9' O ; Base de données des noms géographiques du Canada 2024). On y trouve également des fosses orientées nord-sud et plusieurs petites îles (Gagnon, 1997 ; Sklar et al., 2024 ; Figure 4). En été des remontés d'eaux profondes riches en nutriments sont observées dans l'ensemble de la zone d'étude (Lauzier et Marcotte, 1965 ; Brunel, 1971 ; Bonardelli et al., 1993 ; Gagnon, 1997). La fosse de la Baie des Chaleurs, s'étendant depuis la baie jusqu'au chenal Laurentien au large de Gaspé, est l'un des éléments structurant le relief local. Cette région est influencée à la fois par les eaux douces fluviales provenant de plusieurs rivières de la Baie des Chaleurs et par les eaux riches en nutriments du courant de Gaspé. Ce courant descend le long de la côte sud de la péninsule depuis l'estuaire du Saint-Laurent (Filteau et Tremblay, 1953 ; Lauzier, 1967 ; Gagnon, 1997 ; Figure 4). Gagnon (1997) délimite trois grandes zones géomorphologiques dans le secteur Gaspésie-sud et Baie des Chaleurs : l'estuaire de la rivière Ristigouche (hors de la zone d'étude), la Baie des Chaleurs, et la zone des bancs de pêche (Figure 4).

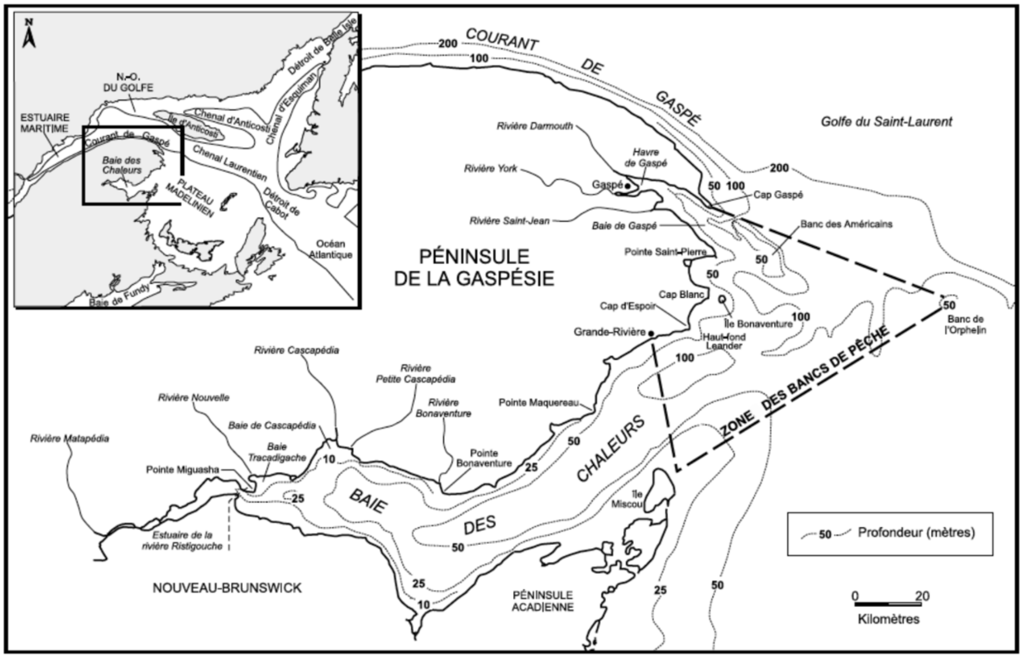


Figure 4. Physiographie du secteur Gaspésie-sud-Baie-des-Chaleurs. Tiré de Gagnon (1997).

3.2 Habitats et communautés aquatiques

Le secteur Gaspésie-sud-Baie-des-Chaleurs est pourvu d'une mosaïque d'habitats côtiers, benthiques et pélagiques qui soutiennent une biodiversité importante et une forte productivité biologique, allant des organismes benthiques, petits poissons pélagiques jusqu'aux prédateurs pélagiques supérieurs. Cette biodiversité marine joue un rôle central pour les communautés côtières sud Gaspésienne, qui représente une autre composante de ce riche écosystème.

Afin de dresser un portrait complet il est nécessaire d'inclure toutes les composantes de l'écosystème, dont les différentes pêches (commerciales et récréatives) font partis. L'écosystème pélagique de ce secteur inclut des prédateurs de haute importance tant trophique que commerciale, tel que le thon rouge (*Thunnus thynnus*, Linnaeus, 1758) et diverses espèces de poissons pélagique comme la morue franche (*Gadus morhua*, Linnaeus, 1758), le flétan atlantique (*Hippoglossus hippoglossus*, Linnaeus, 1758) ou la plie canadienne (*Hippoglossoides platessoides*, Fabricius, 1780) ; mais aussi de nombreux poissons fourrage (Gagnon, 1997). Ces grandes concentrations de poissons, qui utilisent cette zone tant pour l'alimentation, la reproduction et la migration, sont à leur tour exploitées par les oiseaux marins, tel que le fou de bassan (*Morus bassanus*, Linnaeus, 1758), différentes espèces d'alcidé ou encore des mouettes tridactyle (*Rissa tridactyla*, Linnaeus, 1758 ; Gagnon, 1997, Cotter et Rail, 2007). Des requins sont aussi de plus en plus observés dans cette région (Gallant, 2025). La faune benthique est également riche et diversifiée, le prédateur supérieur côtier étant le homard américain (*Homarus americanus*, Milne Edwards, 1837). Les plus grandes profondeurs abritent quant à elles des concentrations importantes de crabe des neiges (*Chionoecetes opilio*, Fabricius, 1788). Les barachois et quelques baies abritées, sont propices au développement des herbiers de zostère, abritant une faune d'invertébrés benthiques dominée par les polychètes, les gastéropodes et les mollusques bivalves, dont la mye commune (*Mya arenaria,* Linnaeus, 1758), soutenant des pêches récréatives. Ainsi, cette richesse et diversité biologique, qu'elles soient pélagiques ou benthiques, constituent la base d’un écosystème hautement productif dont la santé permet aux communautés côtières de la région sud Gaspésienne de prospérer et pour qui les ressources aquatiques sont un pilier de subsistance et d’identité culturelle (Gagnon, 1997 ; Morissette et al., 2022).

La richesse environnementale de cette région, contribue à faire de ce secteur un des milieux les plus productif du GSL, notamment en zooplancton et en poissons fourrages, qui sont des proies importantes pour les cétacés (Gagnon, 1997 ; Lesage et al., 2007 ; McQuinn et al., 2012 ; Faille et al., 2019 ; Côté et al., 2021). Le milieu pélagique est dominé par une production phytoplanctonique atteignant un pic au printemps, principalement composée de diatomées, soutenant la chaîne trophique de la zone (Gagnon, 1997). En été, cette production, dominée par les microflagellés, alimente une biomasse zooplanctonique tout aussi importante, notamment dans la Baie des Chaleur et près des hauts-fonds (banc des Américains, le haut-fond Leader et les environs de l’Île Bonaventure ; Figure 4), concentrée en surface à cause d’une stratification marquée (Gagnon, 1997). La communauté zooplanctonique est dominée par l’espèce *Temora longicornis* (Müller, 1785), un petit copépode abondant au début de la saison estivale dans la Baie des chaleurs, et par le *Calanus finmarchicus* (Gunner, 1765), un gros copépode riche en lipides présent dans la zone bancs de pêche (Gagnon, 1997), qui sont essentiels pour de nombreuses espèces de poissons et de baleines de juillet à septembre (Gagnon, 1997 ; Lesage et al., 2007 ; Mc Quinn et al., 2012 ; Mc Quinn et al., 2015). De nombreux poissons fourrages tels que le hareng atlantique (*Clupea harengus* ; Linnaeus 1758), le maquereau (*Scomber scombrus* ; Linnaeus 1758) et le capelan (*Mallotus villosus* ; Müller 1776) utilisent les herbiers côtiers et les barachois comme frayères et nourriceries pour les larves et les juvéniles, ainsi que les eaux plus profondes et les hauts-fonds pour l’alimentation des adultes (Gagnon, 1997 ; McQuinn et al., 2012 ; Côté et al., 2021).

La forte disponibilité saisonnière en zooplancton et en poissons fourrages rend cette zone attractive pour les mammifères marins, qui exploitent la concentration de proies le long des fronts et des structures côtières (Gagnon, 1997 ; Lesage et al., 2007 ; Faille et al., 2019). L’une des zones d’intérêt pour les cétacés est le banc des Américains (Réseau d’observation de mammifères marins, ROMM, 2015, 2019 ; Faille et al., 2019). Cette élévation sous-marine, qui atteint 12 mètres de profondeur, prolonge la pointe de la Gaspésie (Faille et al., 2019 ; Sklar et al., 2024 ; Figure 4). Ce site protégé, d'une superficie de 1 000 km^2, est caractérisé par deux plateaux séparés par une crête abrupte, offrant une multitude d'habitats à diverses espèces marines, dont des espèces fourragères (ROMM, 2015 ; McQuinn et al., 2012, 2015 ; Faille et al., 2019).

4. LES CÉTACÉS

Depuis plusieurs centaines d'années, le GSL est reconnu comme un habitat clé pour de nombreuses espèces de cétacés, attirées par la nourriture abondante dans ses eaux. L'histoire des cétacés dans le GSL est riche, allant de l'exploration, l'exploitation à l'écotourisme. Les premiers récits d'explorateurs, comme ceux de Charlevoix (1744) et Saint-Cyr (1886), témoignent déjà de l'abondance des cétacés dans la région de l'Est Canadien (Mérindol, 2023). Cette concentration, notamment côtière, a d'abord favorisé une chasse à la baleine qui a atteint son apogée entre le XIX^{e} et le XX^{e} siècle (Lesage et al., 2007), avant d'être remplacée par des activités d'observation des baleines, encadrées par la loi (Nadeau, 2021). Aujourd'hui, l'écotourisme est devenu une activité importante dans l'estuaire du Saint-Laurent ou encore en Gaspésie (ROMM, 2015, 2019).

La présence des cétacés, leur distribution et abondance dans le GSL dépendent de plusieurs facteurs environnementaux favorisant la concentration de leurs proies dans certaines zones spécifiques (Kingsley et Reeves, 1998 ; Lesage et al., 2007 ; McQuinn et al., 2012, 2015 ; Gavrilchuk et al., 2021, *cf. 4.2*). Le gouvernement, les universités et certaines ONG, utilisent diverses méthodologies pour les étudier. Les suivis aériens et en mer ou utilisant l'acoustique passive permettent de décrire au mieux leur occurrence et comportement (Kingsley et Reeves, 1998 ; Lesage et al., 2007 ; Delarue et al., 2022). Les données recueillies, ciblant des espèces ou des régions, ont permis d'apporter de nouvelles informations sur la distribution spatiale, l'occurrence saisonnière, le régime alimentaire ou encore les comportements sociaux, acoustiques et interspécifiques de plusieurs espèces dans l'estuaire et le GSL, notamment pour les espèces menacées comme la BNAN (Ramp et al., 2010, 2015 ; Comtois et al., 2010 ; Simard et al., 2019, 2024 ; Gavrilchuk et al., 2021 ; Sorochan et al., 2023).

La côte sud de la Gaspésie est une zone qui a été peu explorée dans le cadre d'études sur les cétacés. Les recherches se sont concentrées sur la tête du chenal Laurentien, l'établissement du parc marin du Saguenay-Saint-Laurent ayant stimulé de nombreux travaux dans ce secteur (Lesage et al., 2017 ; Martins et al., 2022 ; MPO, 2022 ; Mérindol, 2023). Néanmoins, les études sur les cétacés dans l'est du Canada ne se limitent pas à cette région. D'autres régions d'intérêt incluent le détroit de Jacques-Cartier, les îles Mingan et le bassin d'Anticosti (Ramp et al., 2010, 2015 ; Comtois et al., 2010), ainsi que plusieurs sites le long de la côte est canadienne : Terre-Neuve-et-Labrador, le détroit de Belle Isle, le plateau Néo-Écossais ou encore la baie de Fundy (*p.ex.* Perkins et Whitehead, 1977 ; Whitehead et Carlson, 1988 ; Brown et al., 2009 ; Johnson, 2018 ; Kowarski et al., 2018, 2019, 2022 ; Delarue et al., 2022). Malgré le manque d'études spécifiques à la zone côtière sud gaspésienne, des recherches à l'échelle du GSL ou ciblant une partie de la péninsule, notamment le banc des Américains (Figure 4), ont permis d'identifier quelques tendances de distribution des cétacés autour de la Gaspésie (Gagnon, 1997 ; Lesage et al., 2007 ; Faille et al., 2019 ; Meyer-Gutbrod et al., 2023). Le nord de la péninsule gaspésienne est notamment reconnu pour sa riche biodiversité, qui inclut de nombreux cétacés (Kingsley et Reeves, 1998 ; Lesage et al., 2007 ; McQuinn et al., 2015 ; Faille et al., 2019). Cette richesse a d'ailleurs stimulé le développement des activités d'observation en mer dans cette zone (ROMM, 2015, 2019).

Ce sont 10 espèces de cétacés qui fréquentent plus ou moins fidèlement le GSL (Kingsley et Reeves, 1998). Cette zone constitue pour beaucoup d'entre eux une aire d'alimentation estivale (*p.ex.* Clapham, 2000 ; Bettridge et al., 2015 ; Mc Quinn et al., 2015 ; Faille et al., 2019 ; Moore et al., 2021, Sorochan et al., 2023). Les précédentes saisons d'observation réalisées dans le cadre du projet « *Pêcheurs et baleines en Gaspésie* : *vers une coexistence sur le territoire maritime »* ont permis de mettre en évidence la fréquentation de la zone d'étude par au moins quatre espèces de cétacés (de Montgolfier et al., 2020, 2022, 2024). On y observe notamment le rorqual commun (*Balaenoptera physalus* ; Linnaeus, 1758 ; Lesage et al., 2007), une espèce considérée comme préoccupante au COSEPAC (COSEPAC, 2019) ainsi que vulnérable sur la liste rouge de l'UICN (Cooke, 2018*a*). D'autres espèces telles que le petit rorqual (*Balaenoptera acutorostrat* ; Lacepede, 1804), le marsouin commun (*Phocoena phocoena* ; Linnaeus, 1758), ou encore le rorqual à bosse (*Megaptera novaeangliae* ; Borowsk, 1781), peuvent également être observées dans la zone (Kingsley et Reeves, 1998 ; Lesage et al., 2007 ; ROMM, 2019 ; Riou et al., 2025). Ce projet permettra de combler les lacunes actuelles en documentant la présence et le comportement des cétacés dans la zone côtière sud gaspésienne, qui a été jusqu'à présent peu étudiée.

4.1 Petit rorqual de l'Atlantique Nord (*Balaenoptera acutorostrata* ; Lacepede, 1804)

Le petit rorqual est la plus petite espèce de baleine à fanons, mesurant entre 6 et 10 mètres à l'âge adulte (Jefferson et al., 2011 ; Risch et al., 2019 ; Perrin et al., 2018 ; Figure 5). On distingue deux espèces, l'une fréquente les eaux australes (*Balaenoptera bonaerensis* ; Burmeister, 1867), l'autres les eaux de l'hémisphère Nord (*Balaenoptera acutorostrata* ; Lacepede, 1804 ; Anderwald, 2009 ; Risch et al., 2014, 2019). Leur petite taille, leur comportement discret et leur répartition saisonnière dans des habitats pélagique et de glace de mer, parfois éloignés, contribuent au manque de connaissances sur ces deux espèces (Risch et al., 2019). Les connaissances actuelles proviennent souvent d'étude sur les populations fréquentant les habitats côtiers ou de dossiers historiques de chasse à la baleine (Risch et al., 2019).

Figure 5. Petit rorqual de l'Atlantique Nord (*Balaenoptera acutorostrata* ; Lacepede, 1804) @Baleine en direct

L'espèce de l'hémisphère Nord (*Balaenoptera acutorostrata* ; Lacepede, 1804) fréquente les eaux tempérées et froides de l'Atlantique et du Pacifique Nord. Elle est observée aussi bien en milieu côtier qu'océanique (Perkins et Whitehead, 1977 ; Lynas et Sylvestre, 1988 ; Perrin et al., 2018). Les petits rorquals du Saint-Laurent appartiennent au stock de la côte est du Canada (Risch et al., 2014 ; Anderwald, 2009), estimé à environ 4 000 individus. Ce stock représente l'un des quatre stocks de la population de l'Atlantique Nord, qui compte environ 200 000 individus (Anderwald, 2009). Les petits rorquals de ce stock présentent un comportement migratoire saisonnier assez peu connu, mais moins marqué que chez les grands rorquals. Ils séjournent dans les zones d'alimentation estivale des hautes latitudes et dans les zones de reproduction hivernale plus tempérées voir subtropical (Stewart et Leatherwood, 1985 ; Jefferson et al*.,* 2011 ; Perrin et al., 2018, ; Risch et al., 2019). Toutefois, certains individus peuvent rester dans les zones libres de glace au nord en hiver, suggérant une variabilité individuelle (Anderwald, 2009 ; Risch et al., 2014, 2019 ; Jefferson et al., 2011 ; NOAA, 2020). En effet la distribution des petits rorquals varie en fonction de l'âge, du statut reproducteur et du sexe (Anderwald, 2009 ; NOAA, 2020).

Le petit rorqual est le plus commun des trois rorquals fréquentant les aires d'alimentation de l'estuaire et du GSL pendant la saison estivale (Lynas et Sylvestre, 1988 ; Kingsley et Reeves, 1998 ; Doniol-Valcroze et al., 2007 ; Lesage et al., 2007). Kingsley et Reeves (1998) estiment la population à environ 1 000 individus dans le GSL (relevés aériens du MPO de 1995 et 1996, ne tenant pas compte des animaux en plongée). Il utilise les eaux côtières de l'estuaire et du GSL pour se nourrir d'espèces fourragères, passant plus de la moitié de son temps à chasser et s'alimenter durant la période estivale (Baleines en direct, 2025). Cette espèce se nourrissant par engouffrement, a une alimentation variée, qui dépend de la saison et de la disponibilité des proies (Sergeant, 1963 ; Jefferson et al., 2011 ; Anderwald, 2009 ; Perrin et al., 2018). Elle se nourrit principalement de krill et de petits poissons pélagiques vivant en banc ; tels que le hareng, le maquereau ou le capelan (Sergeant, 1963 ; Lynas et Sylvestre, 1988 ; Anderwald, 2009, Perrin et al., 2018). Bien qu'il s'agisse d'une espèce principalement solitaire, comme observé par Perkins et Whitehead (1977) dans le nord de Terre-Neuve, des groupes de 15 individus ou plus peuvent se rassembler dans des zones de forte densité de proies (Lynas et Sylvestre, 1988 ; Anderwald, 2009).

Le petit rorqual ne figure actuellement pas sur la liste des espèces en péril, en vertu de la LEP, et désignée comme non à risque par le COSEPAC (2007). Malgré son statut mondial de préoccupation mineure selon l'UICN (Cooke, 2018*b*), le petit rorqual tout comme de nombreux cétacés du GSL, est touché par les activités anthropiques. Les prises accidentelles dans les engins de pêche, la pollution sonore, chimique et plastique, la dégradation de son habitat, et sa chasse toujours effective en Islande, Norvège et au Japon, sont autant de pressions croissantes sur cette espèce côtière.

4.2 Marsouin commun (*Phocoena phocoena* ; Linnaeus, 1758)

Le marsouin commun (*Phocoena phocoena* ; Linnaeus, 1758) est le plus petit cétacé des eaux canadiennes (Fenton et al., 2017 ; Figure 6). Ce petit odontocète est présent dans les eaux tempérées et boréales côtières de l'hémisphère Nord (Bjørge et Tolley, 2018). On distingue au moins trois sous-espèces, réparties dans l'Atlantique Nord (*Phocoena phocoena phocoena*)*,* le Pacifique Nord *(Phocoena phocoena vomerina*) et la mer Noire (*Phocoena phocoena relicta*). Ces trois sous-espèces, sont reproductivement isolées et présentent des différences génétiques et morphologiques (Bjørge et Tolley, 2018). La sous-espèce atlantique (*P.p.phocoena*) est celle qui est retrouvée en abondance dans l'Est Canadien (Kingsley et Reeves, 1998 ; Fenton et al., 2017 ; COSEPAC, 2022), de la baie de Fundy jusqu'au nord de l'île de Baffin (Gaskin, 1992). Les eaux de l'Est du Canada ne représentent toutefois qu'un quart de l’aire de répartition de la sous-espèce (COSEPAC, 2022). En 2016, on estimait à 207 632 individus (CV = 0,391) le nombre total d’individus occupant le GSL, le plateau néo-écossais ainsi que la partie canadienne de l’aire de répartition de la baie de Fundy et du golfe du Maine (Lawson et Gosselin, 2018 ; COSEPAC, 2022). Les marsouins communs sont très abondants dans le GSL en été, principalement au nord mais aussi le long de la côte gaspésienne et dans la baie de Chaleurs (Fontaine et al. ,1994 ; Kingsley et Reeves, 1998).

Figure 6. Marsouin commun (*Phocoena phocoena* ; Linnaeus, 1758) @Baleine en direct

Ce cétacé occupe les zones côtières peu profondes à l'année, sa présence étant liée à son écologie alimentaire opportuniste (Camphuysen, 2004 ; Marubini et al., 2009 ; Bjørge et Tolley, 2018 ; Torres et al., 2021). Il se nourrit principalement de petits poissons benthiques et pélagiques, abondants dans ces eaux côtières peu profondes (Bjørge et Tolley, 2018 ; Elliser et al., 2020). Dans les eaux de l’Est du Canada le marsouin commun montre une préférence pour les petits poissons pélagiques riches en énergie, tels que le hareng, le maquereau, ou le capelan (COSEPAC, 2022). Les proies sont localisées et chassées à l’aide du même type de clic d’écholocalisation ultrasonique utilisé pour la communication entre individus (Miller et Wahlberg, 2013). Il existe très peu de données issues d’études comportementale à cause de la difficulté à observer leurs comportements tant ils sont petits et discrets (Amundin et Amundin, 1973 ; Graner, 2003). Il est néanmoins admis dans la littérature que les marsouins communs sont plutôt solitaires, avec de très petites tailles de groupe, proche en moyenne de deux individus (Berrow et al., 2014 ; Stern et al., 2017 ; Keener et al., 2018). Bien qu’ils aient longtemps été considérés comme peu sociaux, à la différence des dauphins, Torres et al. (2021) ont montré que les marsouins communs pouvaient adopter des stratégies de chasse collaborative dans les eaux peu profondes (1 à 20 mètres) et être retrouvés en groupes de plusieurs individus.

Grâce à sa distribution très côtière le marsouin commun est une excellente espèce sentinelle notamment dans les eaux canadiennes (Fenton et al., 2017). La population de l'Atlantique Nord-Ouest, fréquentant le GSL, a été désignée comme étant préoccupante par le Comité sur la situation des espèces sauvages en péril au Canada, COSEPAC en 2022, et est inscrite à titre d'espèce menacée en vertu de la Loi sur les espèces en péril du Canada (https://www.laws-lois.justice.gc.ca/eng/AnnualStatutes/2002_29/page-16.html, consulté le 9 juillet 2025). Ce statut préoccupant est dû à l'extrême vulnérabilité des marsouins communs à l'empêtrement dans les filets maillants et les engins de pêche, à la pollution chimique ou sonore ainsi qu'à la difficulté de récolter des données sur l'espèce (Fontaine et al., 1994 ; COSEPAC, 2022).

4.3 Rorqual à bosse (*Megaptera novaeangliae* ; Borowski, 1781)

Espèce emblématique, le rorqual à bosse (*Megaptera novaeangliae* ; Borowski, 1781), est un grand cétacé atteignant en moyenne 14-15 m (Stevick, 1999 ; COSEPAC, 2003 ; Bettridge et al., 2015 ; Figure 7). D'une importance écologique, culturelle et spirituelle majeure à travers le globe, il est présent dans l'ensemble des bassins océaniques et visite de nombreuses zones côtières (Bettridge et al., 2015). On distingue trois sous-espèces à l'échelle mondiale, chacune occupant l'un des trois grands bassins : les rorquals à bosse du Pacifique Nord (*Megaptera novaengliae kuzira*), de l'Atlantique Nord (*Megaptera novaengliae novaengliae*) et de l'hémisphère Sud (*Megaptera novaengliae australis* ; Bettridge et al., 2015). Bien que ces trois sous-espèces suivent des trajectoires évolutives divergentes, elles continuent de maintenir des échanges, certes limités (Engel et al., 2008 ; Jung, 2017). Longtemps victimes de la chasse à la baleine, les rorquals à bosse sont en voie de rétablissement grâce à des mesures de protection adaptées, ce qui en fait un symbole de la réussite des politiques de conservation (Nelms et al., 2021). À l'échelle mondiale, l'espèce est classée « préoccupation mineure » dans la liste rouge de l'UICN (Cooke et al., 2018*c*).

Néanmoins, tout comme l'ensemble des cétacés, elle n'échappe pas aux menaces d'origine anthropique. Des cas de famine ont même été observés ces dernières années, notamment dans l'hémisphère Nord (Cheeseman et al., 2024), en raison de la raréfaction des proies et de la diminution de leur valeur nutritive due au réchauffement des eaux.

Les rorquals à bosse fréquentant le GSL appartiennent à la sous-espèce de l'Atlantique Nord et au segment de population des Antilles, comptant environ 11 570 individus. Ce chiffre est probablement sous-estimé et est en croissance (COSEPAC, 2003 ; Bettridge et al., 2015). Elle a d'abord été désignée comme « menacée » en 1982, puis comme « préoccupante » en 1985 par le COSEPAC avant d'être considéré comme « non en péril » depuis 2003, illustrant son rétablissement (COSEPAC, 2003). Le groupe occupant les eaux de l'Est du Canada est estimé à environ 6 000 individus (Lawson et Gosselin, 2018). Ce groupe serait divisé en trois stocks, définis selon leur aire d'alimentation ; le golfe du Maine (comprenant aussi les individus du plateau néo-écossais), le GSL et Terre-Neuve-et-Labrador (comprenant les individus du détroit de Belle-Isle ; Katona et Beard, 1990 ; COSEPAC, 2003), même si des échanges peuvent avoir lieu.

Figure 7. Rorqual à bosse (*Megaptera novaeangliae* ; Borowski, 1781) @Baleine en direct

À l'exception de la population de la mer d'Arabie (Minton et al., 2008), l'ensemble des rorquals à bosse effectuent de longues migrations saisonnières (Braithwaite et al., 2015 ; Clapham, 2018). Lors de ces migrations, ils consomment de grandes quantités d'énergie, puis jeûnent dans les zones de reproduction, ce qui les oblige à se nourrir intensément dans les eaux froides et riches des régions polaires et subpolaires, comme le GSL, en été (Clapham, 2000 ; Bettridge et al., 2015). Ils passent ensuite l'hiver dans les zones de reproduction tropicales, où ils s'accouplent, mettent bas et allaitent leurs petits (Clapham, 2000 ; Ratsimbazafindranahaka et al., 2024). Ces routes migratoires, transmises culturellement de la mère au petit, représentant un exemple rare et documenté de coévolution gène-culture dans le règne animal (Richard et al., 2018). De nombreuses études, dont des études de surveillance par acoustique passive (*Passive Acoustic Monitoring*, PAM) dans les eaux de l'Est du Canada, ont démontré que certains individus restaient dans les hautes latitudes en hiver, bien après le début de la saison de reproduction et pouvaient même y rester toute l'année (COSEPAC, 2003 ; Kowarski et al., 2018, 2022, Davis et al., 2020 ; Delarue et al., 2022).

Les rorquals à bosse, se nourrissent généralement le long des côtes et ont un régime alimentaire généraliste, en fonction de la disponibilité et des zones d'agrégation des proies (Piatt et al., 1989). Ces rorquals engouffrent de grandes quantités de proies, petits poissons pélagiques (hareng, maquereau, lançon ou encore capelan) et/ou krill (Baker, 1985 ; Clapham, 2000 ; Bettridge et al., 2015). La taille des groupes de rorquals à bosse se nourrissant ensemble peut varier en fonction du type de nourriture, la taille des bancs de poissons, et de leur stratégie d'alimentation (comme la technique des filets de bulles ; Hain et al., 1982 ; Whitehead et Carlson, 1988 ; Clapham, 2000).

Le rorqual à bosse, une espèce hautement communicante, possède un répertoire vocal riche et varié, composé de chants et de vocalises non chantées (Dunlop et al., 2007 ; Stimpert et al., 2011 ; Kowarski et al., 2022). Ce répertoire acoustique est spécifique à chaque population, le développant au fil du temps et pouvant constituer un marqueur culturel par apprentissage vocal (Whiten et al., 2019 ; Garland et McGregor, 2020). Les chants sont produits exclusivement par les mâles, principalement durant la saison de reproduction, dans les basses latitudes (entre décembre et avril dans l'Atlantique Nord ; Payne et McVay, 1971 ; Winn et Winn, 1978). Il est composé d'une structure hiérarchique complexe, d'abord en phrases puis en thèmes, dont l'objectif est de maximiser le succès reproducteur (Payne et

McVay, 1971 ; Payne, 1983 ; Cholewiak et al., 2013). Ce chant est principalement enregistré dans les zones de reproduction, mais il peut également être détecté lors de la migration et dans les zones d'alimentation, notamment à l'est du Canada (Mattila et al., 1987 ; McSweeney et al., 1989 ; Kowarski et al., 2018, 2019). Les vocalises non chantées, sont quant à elles produites par les deux sexes, de tous âges et toute l'année dans l'ensemble des habitats de l'espèce (Tyack, 1982 ; Dunlop et al., 2008 ; Zoidis et al., 2008 ; Rekdahl et al., 2017 ; Kowarski et al., 2018, 2022). Ces vocalises sont probablement liées à des interactions sociales et à des comportements de nourrissage (Cerchio et Dahlheim, 2001 ; Dunlop et al., 2008 ; Zoidis et al., 2008 ; Videsen et al., 2017 ; Ratsimbazafindranahaka et al., 2024).

4.4 Rorqual commun (*Balaenoptera physalus* ; Linnaeus, 1758)

Le rorqual commun est le deuxième plus grand mammifère marin vivant sur terre, pouvant atteindre 25 mètres à l'âge adulte (COSEPAC, 2019 ; Figure 8). Il est présent dans les deux hémisphères, avec deux sous-espèces géographiquement et reproductivement distinctes : *Balaenoptera physalus physalus,* dans l'hémisphère Nord et *Balaenoptera physalus quoyi* dans l'hémisphère Sud (Rice, 1998 ; Aguilar, 2002 ; Notarbartolo-Di-Sciara et al., 2003 ; COSEPAC, 2019). Au Canada, appuyé par des données génétiques (Archer et al., 2013), le COSEPAC (2019), considère les rorquals communs de l'Atlantique Nord et du Pacifique Nord comme des unités distinctes. Le stock de l'Atlantique Nord est encore mal compris et fait l'objet de plusieurs travaux, notamment au sein de la Commission baleinière internationale (CBI. ; Bérubé et al., 2006 ; Daníelsdóttir et al., 2006 ; Gunnlaugsson et Vikingsson, 2006) et aux Canada (COSEPAC, 2019). La CBI reconnaît sept stocks de gestion dans l'Atlantique Nord, dont deux passent l'été dans les eaux canadiennes (« Terre-Neuve/Labrador » et « Nouvelle-Écosse »). Il est également suggéré que les rorquals communs du GSL formeraient un groupe relativement isolé (Mitchell, 1974 ; Sergeant, 1977). Un relevé aérien en 2016 a estimé à 1 664 (IC à 95 % : 807-3 451) le nombre d'individus occupant les eaux du plateau continental du Labrador et de la Nouvelle-Écosse

(COSEPAC, 2019). Par ailleurs, une estimation par photo-identification dans le nord du GSL a quantifié le nombre de rorquals communs à 328 (IC à 95 % : 306-350 ; COSEPAC, 2019 ; Schleimer et al., 2019). Aucune tendance d'abondance n'est disponible pour les eaux de l'est du Canada dans leur ensemble, mais le COSEPAC (2019), suggère finalement que ces rorquals communs formeraient un seul stock, avec des sous-groupes liés.

Figure 8. Rorqual commun (*Balaenoptera physalus* ; Linnaeus, 1758) @Baleine en direct

Le rorqual commun est une espèce cosmopolite, davantage observé dans les eaux tempérées froides et subpolaires, dans les milieux océaniques comme côtiers (COSEPAC, 2019). Il effectue de longues migrations saisonnières, avec une aire de répartition estivale qui s'étend jusqu'à l'Arctique, et une aire de répartition hivernale jusqu'aux Caraïbes (Gambell, 1985). Toutefois, certains individus sont observés à des latitudes élevées en hiver (Moors-Murphy et al., 2018) et à des latitudes plus basses en été, suggérant un profil de migration complexe (COSEPAC, 2019). Dans les eaux de l'est du Canada, le rorqual commun a souvent été détecté sur le plateau continental au large de la Nouvelle-Écosse et du Labrador (Perkins et Whitehead, 1977 ; Whitehead et Carslon., 1998 ; Delarue et al., 2018 ; Lawson et Gosselin, 2009, 2018), ainsi que dans le GSL (Roy et al., 2019, Delarue et al., 2018) jusqu'à Tadoussac (Simard et Lavoie, 1999). L'aire de répartition estivale de cette espèce est déterminée par la répartition de ses proies (Gambell, 1985 ; COSEPAC, 2019), qui se compose d'une grande variété d'espèces dont de petits poissons en banc (principalement du capelan ; Whitehead et Carscadden, 1985) et du krill (Gavrilchuk et al., 2014). Ce généraliste, qui fait preuve d'une certaine flexibilité alimentaire, semble cohabiter avec d'autres espèces de baleines à fanons, comme les baleines à bosse dans le GSL (Doniol-Valcroze et al., 2007, Ramp et al., 2015), la baie de Fundy et au large de Terre-Neuve (Whitehead et Carscadden, 1985, Katona et al., 1993). Il a également été observé en association avec des BNAN dans la partie inférieure de la baie de Fundy (Woodley et Gaskin, 1996) et sur le plateau néo-écossais (Mitchell et al., 1986).

En raison du déclin rapide de ses populations, causé par la chasse à la baleine du XX^e siècle, le rorqual commun est inscrit comme vulnérable sur la liste rouge des espèces en voie de disparition de l'UICN (Cooke et al., 2018*a*). Cette chasse se poursuit dans les eaux de l'Islande, du Groenland, de la Norvège et du Japon (COSEPAC, 2019). L'entité de l'Atlantique Nord est considérée comme préoccupante par le COSEPAC (2019) et figure sur la liste des espèces préoccupantes en vertu de la Loi sur les espèces en péril (https://www.laws-lois.justice.gc.ca/eng/AnnualStatutes/2002_29/page-16.html, consulté le 9 juillet 2025). Comme beaucoup de cétacés, il fait face à plusieurs menaces d'origine anthropique : la pollution sonore et chimique, les collisions avec les navires, empêtrement dans les engins de pêche ou encore la dégradation de l'habitat (COSEPAC, 2019).

4.5 Baleine noire de l'Atlantique Nord (*Eubalaena glacialis* ; Müller, 1776 ; BNAN)

La BNAN, est l'une des baleines les plus menacées au monde, avec seulement 372 individus (IC 95 % : 360–383), recensés en 2023, dont 70 femelles reproductrices (Pettis et Hamilton, 2025). La population, la seul de l'espèce, est distribuée dans l'Atlantique Nord-Ouest. Elle a été abondamment chassée aux cours des siècles précédents et continue de faire face à une mortalité importante et à un faible taux de reproduction, ce qui ne permet pas de soutenir son rétablissement (COSEPAC, 2013 ; Kraus et Rolland, 2007 ; Moore et al., 2021 ; IUCN, 2023 ; Pettis et Hamilton, 2025). Elle occupe les eaux côtières du nord-est des États-Unis et de l'Est du Canada (notamment la Baie de Fundy, la Baie de Cap Code ou encore le GSL) pour se nourrir en été, et les côtes de la Géorgie et de la Floride pour se reproduire en hiver (Kraus et Rolland, 2007 ; Brown et al., 2009 ; Durette-Morin et al., 2022).

Historiquement concentrée dans des zones d'alimentation de la baie de Fundy, du bassin de Roseway, du Grand Chenal Sud ou encore de la baie de Cape Cod (Kraus et Rolland, 2007), environ 40 % de la population occupe désormais le GSL entre mai et octobre, où l'utilisation de cet habitat semble être transmise aux veaux (Crowe et al., 2021 ; Bishop et al., 2022). Plus d'information sur l'espèce, ses menaces et sur sa présence dans le GSL sont à retrouver dans la partie 1. Contexte de recherche.

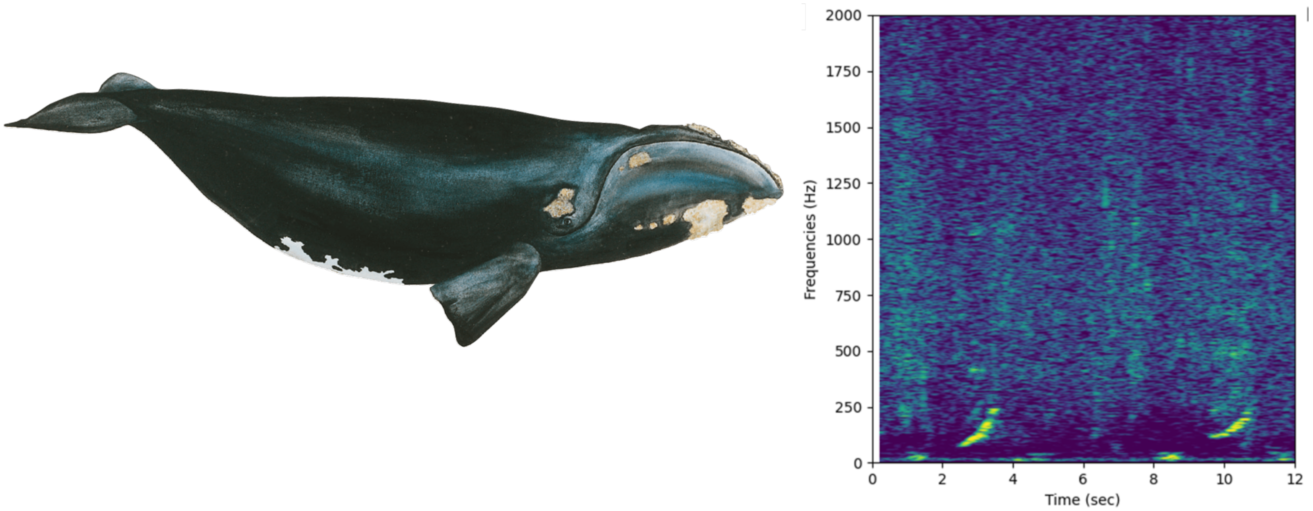


Figure 9. Baleine noire de l'Atlantique Nord (*Eubalaena glacialis* ; Müller, 1776) @Baleine en direct et sa vocalise caractéristique, le *up-call*, enregistrée le 19 août 2019 au large de Pointe Verte, Gaspésie, QC.

Contrairement aux rorquals qui s'alimentent par engouffrement (*lunge feeding*), la BNAN (baleine franche) utilise une stratégie dite de *skim feeding* : elle nage lentement à la surface ou en sub-surface, la bouche ouverte, en filtrant continuellement de grandes quantités d'eau chargée de copépodes. Cette méthode, observée notamment en baie de Fundy, lui vaut parfois le surnom de « baleine écrémeuse » (Mayo et Marx, 1990). Son régime alimentaire est presque exclusivement composé de copépodes du genre *Calanus spp*., dont sa proie principale est le *Calanus finmarchicus* (Mayo et Marx, 1990 ; Baumgartner et al., 2003 ; Sorochan et al., 2023). Les zones à forte densité de *Calanus spp.*, semblent déterminer les zones d'alimentation saisonnières de l'espèce (Mayo et Marx, 1990 ; Baumgartner et al., 2003). Les concentrations de proies, et par conséquent de BNAN, se situent principalement dans la vallée de Shediac ainsi que dans la partie nord du bassin d'Anticosti, dans le GSL (MPO, 2021 ; Gavrilchuk et al., 2021 ; Sorochan et al., 2023 ; Meyer-Gutbrod et al., 2023 ; Simard et al., 2024). Ces zones peu profondes (≈ 60-80 m) sont alimentées par le transport advectif de copépodes en phase de diapause depuis le chenal Laurentien via le courant de Gaspé, qui les concentre contre le fond (Brennan et al., 2021). Cette configuration océanographique génère des densités de *Calanus spp*. 5 à 6 fois plus élevées que dans les eaux profondes du GSL (Gavrilchuk et al., 2021 ; Sorochan et al*.,* 2023). Ces proies abondantes sont particulièrement rentables sur le plan énergétique pour les baleines, car elles peuvent se nourrir efficacement en restant à des faibles profondeurs, ce qui réduit considérablement l'effort de recherche (Mayo et Marx, 1990 ; Baumgartner et al., 2003).

Les BNAN produisent une variété de vocalises, principalement composées de sons de basse fréquence (inférieure à 1 000 Hz ; Clark, 1982a ; Parks et Tyack, 2005, Figure 9). Le plus courant, et le plus utilisé dans les suivis par acoustique passive (*Passive Acoustic Monitoring*, PAM), est l'*up-call* ou appel de contact (Clark, 1982a ; Gervaise et al., 2019 ; Simard et al., 2019). Ce son très stéréotypé (en raison de sa structure stable et répétitive) dure environ une seconde et présente une modulation de fréquence ascendante entre 50 et 200 Hz, ces paramètres pouvant varier de façon légère naturellement (Clark, 1982a ; Matthews et al., 2001 ; Parks et al., 2011 ; Mussoline et al., 2012 ; Simard et al., 2019). Il joue un rôle important dans le maintien du contact entre individus sur plusieurs kilomètres et est émis par les deux sexes, de tout âge et toute l'année (Clark, 1982b ; Clark et al., 2010). Simard et al. (2019) ont notamment utilisé l'*up-call* pour démontrer l'augmentation de la présence des BNAN dans le GSL à partir de 2015. En plus de l'*up-call*, la BNAN émet diverses autres vocalises tel que des *gunshots* (produit surtout par les mâles), ainsi que des sons plus complexes comme le *screams* ou *warbles* (Parks et Tyack, 2005).

5. OBJECTIFS DE RECHERCHE

Cette maîtrise se place au cœur du projet collaboratif « *Pêcheurs et baleines en Gaspésie* : *vers une coexistence sur le territoire maritime* », dans le cadre du volet écologique visant à caractériser la présence de la BNAN dans la zone côtière (20 brasses, soit 37 mètres) sud-gaspésienne. Depuis 2019, des inventaires visuels annuels de la mégafaune marine sont menés entre Saint-Georges-de-Malbaie et Port-Daniel-Gascons, dans la zone de pêche au homard des 20 brasses, pendant et après la saison de pêche.

L'objectif de cette maîtrise de recherche est double :

1) Valoriser les cinq années (2019-2023) de données de présence et de comportements des cétacés et y ajouter une sixième année (2024 ; Chapitre 1 ; Riou et al. 2025)

2) Enrichir ces données visuelles avec une nouvelle méthode non invasive inédite ; la bioacoustique passive (*Passive Acoustic Monitoring* ; PAM ; Chapitre 2)

Le Chapitre 1 (Riou et al., 2025), publié dans le *Canadian Journal of Zoology*, propose la première description de l'utilisation de l'habitat côtier par les cétacés dans les eaux très côtières du sud de la Gaspésie. S'appuyant sur six années de suivi d'observation, il examine la présence et la diversité des cétacés à différentes échelles temporelles ainsi que leurs comportements dans la zone de pêche au homard (ZPH 20A et 20B, Figure 3). Ce chapitre est basé sur des suivis visuels par bateau effectués entre mai et août, de 2019 à 2024, soit pendant et après la saison de pêche au homard. Ces relevés ont été réalisés dans la zone de pêche au homard (jusqu'à 37 mètres de profondeur), entre Saint-Georges-de-Malbaie et Port-Daniel-Gascons (Figure 3), selon la méthode du transect, reconnue pour son efficacité dans l'étude des cétacés et garantissant une couverture large et homogène de la zone d'étude (Buckland et al., 2001). Cette méthode limite en effet les biais directionnel offrant ainsi une meilleure couverture de la zone et une bonne représentation de la distribution réelle des cétacés, ce qui est essentiel pour réaliser des analyses robustes (Buckland et al., 2001 ; Strindberg et al., 2004).

Les sorties en mer ont été réalisées lorsque les conditions environnementales garantissaient un suivi de qualité (vent inférieur à 5 Beaufort et visibilité minimale de 1000 mètres). La collecte des données a suivi le protocole standardisé du *Anderson Cabot Center for Ocean Life du New England Aquarium* (Boston, MA, États-Unis ; Heather Pettis, ACCOL, communication personnelle), et s'inscrit dans un processus collaboratif avec la communauté scientifique. Chaque année, ces protocoles sont partagés, discutés et ajustés avec les membres du *North Atlantic Right Whale Consortium*, et les données d'observation ainsi recueillies sont ajoutées aux bases partagées du Consortium afin d'alimenter les efforts de suivi et d'analyse à l'échelle de l'aire de répartition de l'espèce. Pour chaque observation de cétacé, les métadonnées associées ont été notées, notamment : la date et l'heure de l'observation, la position GPS, l'identification de l'espèce, le nombre d'individus, le comportement, ainsi que la présence de groupe intra- et interspécifique. Les espèces ont été identifiées à la résolution taxonomique la plus basse possible, en mer et à partir de photographies. Plus de détails sont à retrouver dans la partie « Matériels et méthodes » du Chapitre 1.

Le Chapitre 2 documente la présence acoustique des rorquals à bosse et des BNAN dans cette même zone, complétant ainsi les travaux réalisés lors du Chapitre 1 (Riou et al., 2025). En effet, afin d'avoir une compréhension plus détaillée et complète de la présence de ces deux espèces dans la zone côtière, cette étude a utilisé la surveillance par acoustique passive (*Passive Acoustic Monitoring*, PAM). Cette méthode couramment utilisée pour étudier la distribution spatiale et temporelle des cétacés (Zimmer, 2011 ; Munger et al., 2012 ; Browning et al., 2017 ; Delarue et al., 2022), nous a permis d'étudier la présence des rorquals à bosse et des BNAN de manière continue et complète en capturant leurs vocalises pendant presque trois mois durant la saison estivale 2024. Ces deux espèces sont des candidates idéales pour la PAM, grâce à leurs vocalisations stéréotypés, caractéristiques et facilement distinguables du bruit de fond de l'environnement marin (Clark, 1982a ; Dunlop et al., 2008 ; Gervaise et al., 2019 ; Ross-Marsh et al., 2022). Compte tenu de la quantité importante de données générées par cette approche, nous avons choisi de nous concentrer spécifiquement sur ces deux espèces : la BNAN, en lien avec la problématique de notre étude, et le rorqual à bosse, qui est un candidat idéal pour le suivi acoustique. À partir d'enregistrements acoustiques passifs continus (24 heures sur 24 ; 7 jours sur 7) réalisés en juin, août et septembre 2024, grâce à deux stations PAM, équipées d’hydrophone SoundTrap (Ocean Instruments Inc., NZ), cette étude fournit un aperçu spatio-temporel de la présence vocale des deux espèces, permettant d'évaluer leur saisonnalité, leurs tendances diurnes et les fluctuations spatio-temporelles de leur présence acoustique dans cet habitat côtier. Plus de détails sont à retrouver dans la partie « Matériels et méthodes » du Chapitre 2.

Ce projet de maîtrise a permis d’effectuer une analyse approfondie et aussi complète que possible de l’utilisation de l’habitat côtier par les cétacés entre 2019 et 2024, en utilisant une approche intégrative, combinant données visuelles et enregistrement d’acoustiques passives pour les rorquals à bosse et la BNAN. Une telle étude fournit des informations précieuses et pertinentes pour la conservation non seulement de la BNAN, mais aussi pour les autres espèces fréquentant la zone côtière du sud de la Gaspésie. Elle permet également de mieux comprendre les variations spatiotemporelles d'utilisation de cet habitat peu documenté, et d'éclairer l'élaboration de mesures de gestion adaptées au contexte régional.

CHAPITRE 1

CETACEAN USE OF SHALLOW LOBSTER FISHING AREAS IN SOUTHERN GASPÉ (2019-2024): RELEVANCE FOR NORTH ATLANTIC RIGHT WHALE (*EUBALAENA GLACIALIS*, MÜLLER 1776) PROTECTION MEASURES IN THE GULF OF SAINT LAWRENCE.

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ABSTRACT

The North Atlantic right whale (*Eubalaena glacialis*, Müller 1776) is a critically endangered species threatened by vessel strikes and gear entanglement, like other large whales. In southern Gaspé Peninsula, lobster fishers face the challenge of balancing their fishing activities with protection measures for right whales as implemented by DFO. To gather data on cetacean presence and distribution, including the North Atlantic right whale, the *Regroupement des pêcheurs professionnels du sud de la Gaspésie* (RPPSG) launched a cetacean inventory program. Surveys were conducted annually (2019-2024) along the southern coast of the Gaspé Peninsula in lobster fishing areas ranging from 0 to 37 meters in depth. A total of 541 cetacean sightings were recorded between 2019 and 2024, with behavioral data collected by experienced marine mammal observers. The study revealed the presence of four species of piscivorous cetaceans: minke whale (*Balaenoptera acutorostrata,* Lacepede 1804), harbour porpoise (*Phocoena phocoena*, Linnaeus 1758), humpback whale (*Megaptera novaeangliae*, Borowski 1781) and fin whale (*Balaenoptera physalus*, Linnaeus 1758). Spatial and temporal variations in the areas use appear associated with food resource availability. No North Atlantic right whales were sighted in these lobster fishing areas. This study highlights the potential of fisher-led initiatives to support scientific research.

Keys words: North Atlantic right whale, habitat use, marine mammal – fisheries interactions, visual survey, lobster fisheries, coexistence, cetaceans, behavior, Baie des Chaleurs, harvesters-led project, stakeholders-driven research, Regroupement des pêcheurs professionnels du sud de la Gaspésie (RPPSG).

1. INTRODUCTION

Marine mammals play an essential role in ecosystems (Roman et al., 2014; Nelms et al., 2021). They are seen as engineers structuring their environment and associated communities (Roman et al., 2014). Whales, like the North Atlantic right whale (*Eubalaena glacialis*, Müller 1776), help regulate and maintain ocean food chains (Roman et al., 2014). The North Atlantic right whale is one of the world's most endangered whales and has been considered Critically Endangered (Cooke 2020; IUCN 2023), listed under Species at Risk Act (SARA) since 2005 (Brown et al., 2009; DFO 2021). Decimated by centuries of commercial hunting, the population slowly increased by around 2.8% per year, from median point estimates of 270 individuals in 1990 to 483 in 2010 but has not recovered (Pace et al., 2017; Moore et al, 2021). Since then, despite management measures, the existing population has declined by 20% (Moore et al., 2021), making it impossible to maintain a recovery trajectory (Pace et al., 2017). Due to its distribution in the North Atlantic (Winn et al., 1986), the North Atlantic right whale is exposed to anthropogenic threats (Kraus et al., 2007; Moore et al., 2021). Since 2003, almost 90% of known mortalities have been attributed to anthropogenic origins, mainly entanglement in fishing gear and collisions with ships (Sharp et al., 2019). Juvenile whales, are also suffering from anthropogenic trauma at an alarming rate, reducing the population's potential for recovery (Sharp et al., 2019; Moore et al., 2021).

North Atlantic right whales are distributed along the eastern coast of North America, where their presence reflects a well-documented pattern of seasonal migration (Winn et al., 1986; Brillant et al., 2015; Moore et al., 2021). During winter, individuals migrate to southern waters to calve, while in spring and summer, they travel to northern areas, such as the northwest Atlantic, for feeding (Brown et al., 2009; Brillant et al., 2015; Durette-Morin et al., 2022). These seasonal movements have also been confirmed through passive acoustic monitoring (Durette-Morin et al., 2022) and aerial surveys. Oceanographic changes at the scale of this basin have a direct impact on the feeding ecology of North Atlantic right whale and consequently on its distribution (Sorochan et al., 2023; Meyer-Gutbrod et al., 2023). Indeed, the reduced abundance of the main prey, *Calanus finmarchicus* (Gunner 1765; Mayo and Marx 1990), in traditional feeding areas has led to a significant shift in the spatial distribution of North Atlantic right whales since 2010 (Meyer-Gutbrod and Greene 2018; Sorochan et al., 2019; Gavrilchuk et al., 2021). Through studies using acoustic and visual data, increased use of the Gulf of St. Lawrence has been demonstrated since 2015 (Simard et al., 2019; Crowe et al., 2021; Bishop et al., 2022). Crowe et al., (2021) estimated that around 40% of the species occupies the Gulf of St. Lawrence between May and October, with inter-annual re-sightings. This new habitat exposed North Atlantic right whales to anthropogenic threats in an area where no conservation measures had been implemented, as their presence in the Gulf of St. Lawrence was unpredictable and had not been anticipated (Brillant et al., 2015; Meyer-Gutbrod and Greene et al., 2018; Moore et al., 2021). The unusual mortality event in the waters of the Gulf of St. Lawrence, with the deaths of at least 12 whales in the summer of 2017 (Daoust et al., 2017; Sharp et al., 2019) and eight in August 2019 (Bourque et al., 2020), highlights the new challenges of coexistence between North Atlantic right whales and deleterious human activities (Koubrak et al., 2021). Mortalities (over 2% of the species in 2017; Meyer-Gutbrod and Greene 2018) and injuries that may be associated with the use of this habitat pose a significant threat to the species' recovery (Crowe et al., 2021). As an increasing number of breeding females utilize the Gulf of St. Lawrence, there is potential for this migratory behavior to be transmitted to their offspring (Bishop et al., 2022). Given this trend, and the fact that this region currently supports approximately 40% of the population (Crowe et al., 2021), a comprehensive understanding of habitat use in this area is essential for informing effective conservation strategies (Bishop et al., 2022).

The case of the North Atlantic right whale is complex due to the ecological and socio-economic challenges it imposes (Morissette et al., 2022; Reamer et al., 2023). It is within this framework that the "*Pêcheurs et baleines en Gaspésie*: *vers une coexistence sur le territoire maritime"* initiative was born, launched in 2018 by the consulting firm M - Expertise Marine inc., in collaboration with the *Regroupement des Pêcheurs Professionnels du Sud de la Gaspésie* (RPPSG). This initiative aims to study the coexistence of the North Atlantic right whale and lobster (*Homarus Americanus*; Milne Edwards 1837) fishers in the southern Gaspé Peninsula. Following the 2017 unusual mortality event, management measures were put in place by Fisheries and Oceans Canada. Little data were available on the risk zone for interactions between North Atlantic right whale and lobster fishing gear. Fishing area closures, including in areas of less than 20 fathoms (37 meters) deep, were implemented on an emergency basis, often without taking into account the actual presence of North Atlantic right whale (Morissette et al., 2022). For example, on June 15th, 2018, the lobster fishery was closed during 18 days in coastal grid cells of the Lobster Fishing Area (LFA) 20. Three weeks before the end of their season, 65 lobster harvesters from LFA 20A4 to LFA 20B2, between Percé and Port-Daniel-Gascons, had to remove their traps from the water, despite the fact that no North Atlantic right whale had been detected on their fishing grounds during this period (Morissette et al., 2022). In this case, the closure was implemented based on the precautionary approach of Fisheries and Oceans Canada's (DFO), despite the absence of right whale sightings in the lobster fishing area. Once a closure is triggered, it remains in effect for a designated period, regardless of whether further whale sightings occur in subsequent flight surveys (Morissette et al., 2022).

The lobster fishery in the Gaspé Peninsula has since been subjected to a dynamic closure system based on the presence of North Atlantic right whales, as part of DFO management measures to mitigate entanglement risks. These closures were part of a larger evolution of protective measures, initiated in response not only to the 2017 mortality event but also to international regulatory pressures. In particular, the 2016 proposed rule under the U.S. Marine Mammal Protection Act (MMPA), requiring countries exporting fish and seafood products to the United States to demonstrate equivalent protection for marine mammals, played a significant role in accelerating the implementation of mitigation measures in Canadian fisheries (Federal Register, 2016). This context, combined with the launch of the Canadian Oceans Protection Plan in 2016, provided a dual impetus for DFO to act. Following the 2018 closures, DFO introduced the Shallow Water Protocol in 2019 to better reflect the actual risk to North Atlantic right whales in waters shallower than 20 fathoms. This protocol defined specific response criteria for dynamic closures in nearshore lobster fishing areas based on confirmed whale detections and gear configurations. For example, on May 22, 2024, a Notice to Harvesters announced a 7-day closure of several grid cells under this protocol following a confirmed sighting of a right whale in waters less than 20 fathoms deep off the coast of Miscou and Lamèque Islands, New Brunswick (DFO 2024). The study described in this paper took place entirely within the zone subject to this Shallow Water Protocol. Since 2018, the Fisheries-Right Whale Interaction Advisory Group has been meeting annually to review and adapt these protective measures. This group, composed of harvesters, scientists, NGOs, and DFO representatives, provides an essential forum for integrating new scientific knowledge about whale distribution and fishing practices into management decisions. As a result, the system of dynamic and static closures, including the Shallow Water Protocol, has evolved year by year to better balance protection and feasibility (DFO, 2020a). These nearshore fishing areas represent an important territory for Gaspé harvesters, and their closures have led to major socio-economic impacts (Morissette et al., 2022). An essential question arises, as highlighted by the National Marine Mammal Peer Review Committee (DFO, 2020b): are North Atlantic right whale present in this zone shallower than 20 fathoms (37 meters)? The objective of this study is thus to assess the presence or absence of cetacean species in the area, including North Atlantic right whales.

The southern part of the Gaspé Peninsula (*i.e.*, the Gaspésie-Sud-Baie-des-Chaleurs sector between Matapédia and Cap Gaspé, Figure 10) is characterized by a transition from a shallow, sheltered brackish environment to a deep marine environment open to the Gulf of St. Lawrence (Gagnon et al., 1997). This area is influenced by the fresh waters of the rivers and the rich marine waters of the Gaspé current, which are transported to the Baie des Chaleurs along the south shore of the Gaspé Peninsula (Filteau and Tremblay 1953; Lauzier 1967; Legendre and Watt 1970; Bonardelli et al., 1993; Gagnon et al., 1997). The proximity of the Gulf of St. Lawrence influences the presence of coastal currents affecting the area. Coastal upwellings are observed during the summer, as far south as the study area (Lauzier and Marcotte 1965; Brunel 1971; Bonardelli et al., 1993; Gagnon et al., 1997). This area is also located in the western part of the Magdalen Shallows, a plateau less than 200 m deep, bounded to the north by the deep waters of the Laurentian Channel and occupying the entire southern part of the Gulf of St. Lawrence (Gagnon et al., 1997). Two shoals have been observed in the study area, one opposite *Cap d'Espoir*, named haut-fond Leander (48° 24' N

64° 18' W; Gagnon et al., 1997; Canadian Geographical Names Database 2024); the other near *Ile Plate* (48° 37' N; 64° 9' W; Canadian Geographical Names Database 2024).

Unlike the St. Lawrence Estuary, Baie des Chaleurs' coastal zone has received little coverage in the literature. The presence of the Saguenay-St. Lawrence Marine Park has favoured cetacean studies at the head of the Laurentian Channel (Lesage et al., 2017; Chion et al., 2018; DFO,2020c; Mérindol et al., 2023). A few studies on cetacean distribution in the Gulf of St. Lawrence, provides a glimpse on the presence of cetaceans around the Gaspé Peninsula (Gagnon et al., 1997; Lesage et al., 2007; McQuinn et al., 2015; Faille et al., 2019; Meyer-Gutbrod et al., 2023). The northern Gaspé Peninsula is an area rich in cetacean diversity (Kingsley et Reeves 1998; Lesage et al., 2007; Faille et al., 2019), with several whale watching company services (ROMM 2019). Fin whales, a species considered vulnerable on the IUCN (International Union for Conservation of Nature) Red List (Cooke 2018), can, for example, be observed in this area (Lesage et al., 2007). This ecologically based project aims to characterize the presence of the North Atlantic right whale and all cetaceans south of the Gaspé Peninsula. Led by the lobster harvesters, a marine megafauna inventory effort has been carried out every year during and after the lobster fishing season since 2019 (de Montgolfier et al., 2020, 2022, 2024).

By focusing on the presence and diversity of cetaceans in the inshore lobster fishing areas at different temporal scales, as well as on group size, behavior and interspecific interactions, this work, based on six years of surveys, aimed to provide an essential basis for understanding the use of this inshore habitat by cetaceans. This collaborative study, based on the past and current experience of lobster fishing professionals present on the water daily during the summer season, is the first description of habitat use of the inshore lobster fishing zone by cetaceans in the waters of the southern Gaspésie.

2. MATERIALS AND METHODS

2.1 Study area

Annual cetacean surveys have been carried out in the waters south of the Gaspé Peninsula and the mouth of Baie des Chaleurs since 2019 (Figure 10). They have been conducted during and after the lobster fishing season, in lobster fishing areas (LFA) LFA 20A4 to LFA 20B2, from May to August, in 2019 through 2024. The fishing season occurred between May 1 to July 10 in 2019, May 09 to July 16 in 2020, April 24 to July 1 in 2021, April 25 to July 2 in 2022, April 29 to July 4 in 2023 and April 27 to July 4 in 2024 (Table1).

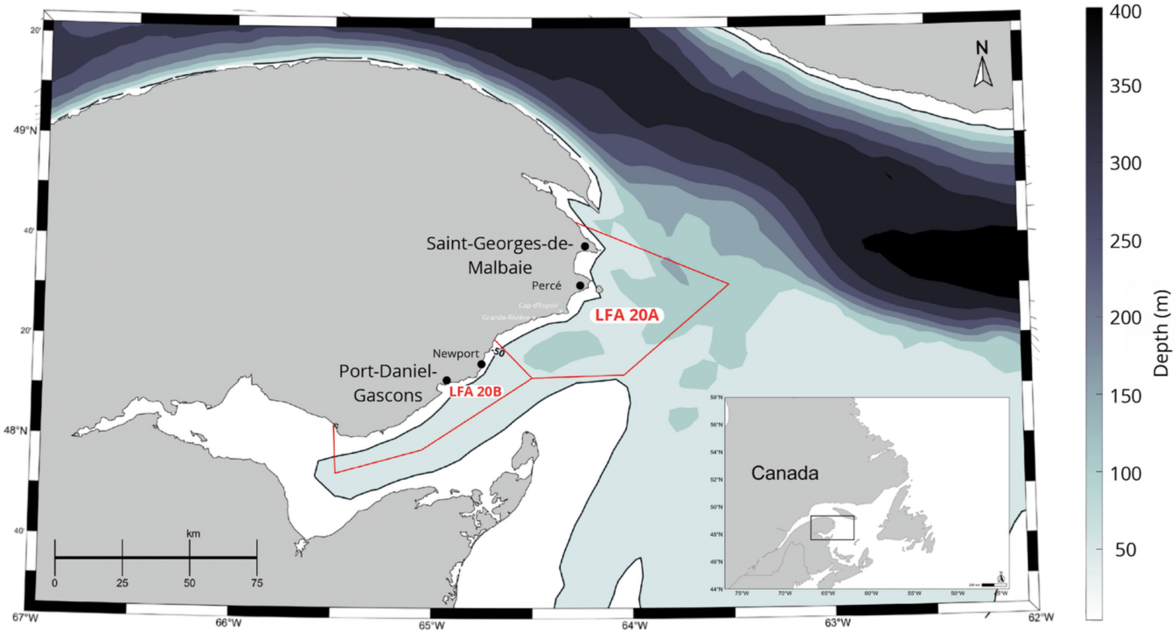

Figure 10. Location of the study area in the Northwest Atlantic, within the Gulf of St. Lawrence, highlighting the 50-meter coastal bathymetric contour (represented by the dark blue line, with isobaths in meters). The study area is located in the southern coastal Gaspé Peninsula, the two lobster fishing areas are identified with the red boundary line, LFA 20A and LFA 20B. Source Natural Earth, geospatial data.

Table 1. Opening and Closing Dates of the Lobster Fishing Season, between 2019 and 2024, in Lobster Fishing Areas 20A4 and 20B2, waters south of the Gaspé Peninsula and the mouth of Baie des Chaleurs.

Years	Lobster Fishing Season Opening Date, Southern Gaspé and Baie des Chaleurs	Lobster Fishing Season Closing Date, Southern Gaspé and Baie des Chaleurs
2019	May 01	July 10
2020	May 09	July 16
2021	April 24	July 01
2022	April 25	July 02
2023	April 29	July 04
2024	April 27	July 04

The study area covers part of the lobster fishing areas, *i.e.*, depths of less than 20 fathoms (less than 37 m), extending from Saint-Georges-de-Malbaie (48° 39' N; 64°13'W) in the north to Port-Daniel-Gascons (48° 9' N; 64° 58' W) in the south. Between 2019 and 2021, transects extended from Percé (48° 31' N; 64° 12' W) in the north to Port-Daniel-Gascons in the south. Since 2022, transects have been carried out between Saint-Georges-de-Malbaie to the north and Newport (48° 16' N; 64° 44' W) to the south (Table 2). This adjustment was made to focus research efforts on an area with a higher frequency of whale sightings, notably observed by lobster harvesters and previous studies (e.g. Lesage et al., 2007; Faille et al., 2019; ROMM 2019), thus ensuring more relevant and meaningful data collection. The northern sector also includes critical feeding and migratory habitats for cetaceans, as well as active fishing grounds where interactions between whales and fishing gear, particularly entanglements, are a known concern. Prioritizing this area over the southern sector, where whale observations are scarce, enhances the study’s relevance and effectiveness addressing for conservation efforts. Moreover, this study area and specific period were defined to meet our scientific needs assessing potential overlap between fishing activities and the presence of North Atlantic right whale during summer. Indeed, although the probability of occurrence of North Atlantic right whale in shallow waters is low, it is not zero. Additionally, given the distance this species can travel in a short space of time, the threat of interaction with fishing gear or vessels can be high in the vicinity of aggregation zones, such as the Shediac Valley to the south of the study area (DFO,2020d). It is therefore essential to obtain robust information on its coastal presence.

Table 2. Summary of transect geographic extent, in Lobster Fishing Areas 20A4 and 20B2, waters south of the Gaspé Peninsula and the mouth of Baie des Chaleurs, between 2019 and. 2024.

Years	Northern Limite (Lat, Long)	Southern Limit (Lat, Long)	Depth Rang
2019	Percé (48°31'N ; 64°12'W)	Port-Daniel-Gascons (48° 9' N;64° 58' W)	< 20 fathoms (less than 37 m)
2020	Percé (48°31'N ; 64°12'W)	Port-Daniel-Gascons (48° 9' N;64° 58' W)	< 20 fathoms (less than 37 m)
2021	Percé (48°31'N ; 64°12'W)	Port-Daniel-Gascons (48° 9' N;64° 58' W)	< 20 fathoms (less than 37 m)
2022	Saint-Georges-de-Malbaie (48° 39' N; 64°13'W)	Newport (48° 16' N; 64° 44' W)	< 20 fathoms (less than 37 m)
2023	Saint-Georges-de-Malbaie (48° 39' N; 64°13'W)	Newport (48° 16' N; 64° 44' W)	< 20 fathoms (less than 37 m)
2024	Saint-Georges-de-Malbaie (48° 39' N; 64°13'W)	Newport (48° 16' N; 64° 44' W)	< 20 fathoms (less than 37 m)

2.2 Data Collection

The study was conducted over six years (2019-2024), with surveys taking place from May through August, during and after the lobster fishing season previously described (Table 1). Each year, 12 surveys were planned. In 2019 and 2021, there were 13 and 11 surveys, respectively, due to challenging weather conditions. In 2019, one northern survey was conducted over two separate days, resulting in an additional survey trip for that year. In contrast, in 2021, due to difficult conditions, both the northern and southern sectors were surveyed on the same day, leading to one fewer trip than usual. Data were collected along zigzag transects, with six survey repetitions per year, ensuring broad and consistent coverage of the study area (Buckland et al., 2001; Figure 11). Each repetition consisted of two surveys: one covering the northern part of the study area and the other the southern part. Only one trip was conducted per day, with both surveys occurring within a few days of each other at most to minimize temporal gaps and enhance data comparability. This type of transect limits biases, such as directional bias, and provides better coverage of the area and thus a better representation of the actual distribution of cetaceans, which is essential for robust analyses (Buckland et al., 2001; Strindberg et al., 2004).

The search effort started when leaving the harbor, *L'Anse-à-Beaufils*, and finished when returning to the harbor, for both northern and southern ends of the zone. Survey were carried out when environmental conditions guaranteed quality monitoring (without fog, wind < 5 Beaufort scale and a minimum visibility of 1000 m). Data collection followed the standardized protocol of the Anderson Cabot Center for Ocean Life at the New England Aquarium (Boston, MA, USA; Heather Pettis, ACCOL, personal communication). This protocol was implemented as the project was initially established in collaboration with ACCOL to complement existing vessel surveys in the southern Gulf of St. Lawrence and ensure methodological consistency, thereby facilitating comparable results across the range of North Atlantic right whales. This effort is part of a larger right whale monitoring research effort involving multiple research institutions, studying areas in the Gulf of St. Lawrence that were previously under-surveyed. While this protocol also encompasses other marine mammals, it remains fundamentally a right whale survey method, developed by leading right whale experts within a collaborative research framework to specifically address conservation concerns for this species. The survey boat (8.14 meters long) operated at a speed of eight knots during the transects. Two observers (including at least one Marine Mammal Observer, MMO, certified through the Marine Mammal Observation Network, MMON) were on duty at all times during the survey, scanning the water with the naked eye at a 90° angle from the bow. Fifteen-minute breaks were taken hourly to limit observer fatigue. Observers were equipped with 7x50 Bushnell marine binoculars and a Nikon D7200 camera with 70-300mm lens to document and collect photographs that could be used to identify animals encountered. This approach makes it possible to detect the blow of a whale, visible from several kilometers away on a clear day. For each cetacean observation, the associated metadata were noted, which included: date and time of observation, GPS position, species identification, number of individuals, behavior; observers estimated distance and position relative to the boat. Species were identified at the lowest possible taxonomic resolution, at sea, and from photographs.

A group was defined as all the individuals located within a 250 m radius of each other and displaying similar behavior (Heimlich-Boran 1993; Clapham 2000; Jourdain et al., 2017; Alves et al., 2018). Behaviors were classified into five categories: (i) travelling - moving animals, normally on a regular trajectory, independent of whether they are slow or fast; (ii) resting - stationary animals in the same place, almost without movement; (iii) socializing, clear and constant interaction between animals of the same group, normally stationary in the area; (iv) feeding or foraging - very active animals, with unsynchronized movements, often involving the presence of aggregations of birds and (v) breach - jumping out of the water (adapted from Evans 1982; and Alves et al., 2018). Behaviors were identified using binoculars, and in cases where behavior could not be determined at a distance, the research team approached the group following strict protocols outlined in the Species at Risk Act (SARA) permits, issued by Fisheries and Oceans Canada (DFO) each year. When behavior could not be reliably assessed, those observations were recorded separately, ensuring a distinction between the total number of sightings and the subset where behaviors were confidently classified. This distinction was carefully maintained throughout the analysis. Interspecific observations were also reported. They are considered as such when two or more species were observed together within the same restricted geographical area and exhibited similar behavior (Alves et al., 2018). To ensure methodological consistency, only interactions occurring within a defined spatial range (i.e., within direct observation distance where behavioral cues were clearly visible) were considered interspecific observations. Interspecific aggregation phenomena are defined as an interspecific group in which at least one of the individuals was classified as feeding (adapted from Jourdain et al., 2017; Syme et al., 2021).

In addition, all environmental parameters were recorded at the start of each trip and whenever there was a change, including visibility, wave height, weather conditions and the presence of oceanic fronts (visually identified as surface bands likely associated with temperature or water mass differences). The track lines of surveys and cetacean observations were recorded using a Global Positioning System (GPS), acquired by the Garmin eTrex 20 GPS. Spatial representation of transects and cetacean observations were obtained using Qgis geographic information software version 3.28.4. All cetacean observations and associated metadata were compiled in a database covering all observations in the study area 2019-2024.

2.3 Data Analysis

All information concerning sampling effort, both spatial and temporal, has been grouped together. Three levels of sampling period were defined for all analyses: the years 2019, 2020, 2021, 2022, 2023 and 2024; the months May, June, July and August; and the period, the lobster fishing period (Table 1) and the non-lobster fishing period. The data collected both during and outside the lobster fishing season account for the dynamic nature of the annual fishing schedule. For each year between 2019 and 2024, observations were classified based on the official opening and closing dates of the lobster fishing season in Lobster Fishing Areas 20A4 and 20B2. This approach allowed for a clear and accurate distinction between observations made during active fishing periods and those recorded outside of them. Moreover, the relative frequency of observations of each species was determined to assess the structure of the cetacean community.

Variations in the number of cetacean observations, inter-annually, inter-monthly and between the lobster fishing and non-lobster fishing periods, were assessed by analyzing the number of observations per survey, a proxy for cetacean presence in the study area, weighted by sampling effort (*i.e.*, sightings per unit of effort or the number of kilometers covered during the survey). To determine significant differences in the observation per survey of cetaceans between the years, month and lobster fishing period, the normality distribution (Shapiro's test) and homoscedasticity (Levene's test) were tested. Then, significant differences ($\alpha = 0.05$) were tested with a Kruskal-Wallis test followed by a Dunn test; or a one-way ANOVA followed by a Tukey post-hoc test, if the data were parametric.

Hotspot maps by year were produced using the Spatstat package (Baddeley et al., 2015) on the R studio. The Spatstat package was used to identify, analyze and visualize areas where cetacean observations were spatially concentrated (Baddeley et al., 2015). The density function performs point density smoothing, *i.e.,* it calculates the point density in each region of the study area. This generates a density map where each cell corresponds to an estimate of the number of points in degree^2 (degree of latitude and longitude; Baddeley et al., 2015).

Analysis of species biological factors focused on group size, species behavior and interspecific groupings (adapted from Alves et al., 2018).

All statistical tests and plots (ggplot 2; Wickham 2016) were carried out in R studio version 4.4.1 (R Core Team 2024).

Table 3. Summary statistics per year, period and months, showing the number of observations for each taxon between 2019 and 2024, based on a total of 72 surveys and 541 observations. Species are ranked by decreasing order of their relative contribution (Rel. Cont.). Blanks represent zeros.

Taxa	Sampling period						Total	Mean ± *SD*	Range	Rel. Cont. (%)
	2019	2020	2021	2022	2023	2024				
Minke whale	10	9	32	172	12	62	297	49.5 ± 63.4	9-172	54.9
Harbour porpoise	24	21	37	34	46	21	183	30.5 ± 10.2	21-46	33.9
Humpback whale				38		13	51	8.5 ± 15.4	13-38	9.4
Fin whale				3		1	4	0.67 ± 1.2	1-3	0.7
Rorqual spp.	1			5			6	1.0 ± 2.0	1-5	1.1
Total observation	35	30	69	252	58	97	541	90.2 ± 82.9	30-252	100
Mean (± *SD*) number obs. per trip	3.9±2	2.7±1.3	6.3±4.9	21±18.4	5.3±4.4	10.8±10.2				
Number of taxa	3	2	2	5	2	4	5	3.0 ± 1.3	2-5	
Number of surveyed days	13	12	11	12	12	12	72	12.0 ± 0.6	11-13	
Daily observation rate %	69.2	91.7	100	100	91.7	75		89.3 ± 13.8	69.2-100	87.5
	Lobster fishing period			**Non-lobster fishing period**						
Minke whale	249			48			297	148.5 ±142.1		54.9
Harbour porpoise	103			80			183	91.5 ± 16.3		33.9
Humpback whale	50			1			51	25.5 ± 34.6		9.4
Fin whale	4						4	4		0.7
Rorqual spp.	5			1			6	3 ± 2.8		1.1
Total observation	411			130			541	122 ± 56.6		100
Mean (± *SD*) number obs. per trip	12.4 ± 14			4.3 ± 3.7						
Number of taxa	5			4			5	4.5 ± 0.7		
Number of surveyed days	35			37			72	36 ± 1.4		
Daily observation rate %	94.3			81				87.7 ± 9.3		87.5
	May	**June**	**July**	**August**						
Minke whale	15	225	43	14			297	74.2 ± 101.4	14-225	54.9
Harbour porpoise	1	76	86	20			183	45.7 ± 41.6	1-86	33.9
Humpback whale		50	1				51	25.5 ± 34.6	1-50	9.4
Fin whale		4					4			0.7
Rorqual spp.		5		1			6	3.0 ± 2.8	1-5	1.1
Total observation	16	360	130	35			541	135.2 ± 157.9	16-360	100
Mean (± *SD*) number obs. per trip	16	15.6 ± 15.6	4.8 ± 3.7	2.9 ± 2.1						
Number of taxa	2	5	3	3			5	3.2 ± 1.3	2-5	
Number of surveys	3	23	30	16			72	18.0 ± 11.5	3-30	
Observation rate per trip %	33.3	100	90	75				74.6 ± 29.4	33.3-100	87.5

3. RESULTS

3.1 Observation effort

A total of 72 surveys were conducted over the six years of the study, which corresponds to 415h, and 35 min spent at sea, with an annual average of 12 surveys (*SD* = 0.63, range = 11-13) surveys (Table 3). All years combined; the average monthly coverage was 18 (*SD* = 11.5, range = 3-30) surveys (Table 3), July being the month with the most effort (Table 3). A total of 35 surveys were carried out during the lobster fishing season, all years combined (Table 3). This represents 8.6% of the 408 total fishing days between 2019 and 2024, but increasing since 2022, with 11% of the fishing season covered in 2022 and 15% in 2023 and 2024. Altogether, 37 surveys were made outside the lobster fishing season, all years combined (Table 3). A total of 8869.94 km was covered along the southern Gaspé coast, with an average of 1478.32 km per year (divided into six replicates per year, *SD* = 159.95, range = 1186.86 km - 1615.32, Figure 11). This sampling effort led to recording 541 cetacean sightings in survey area between 2019 and 2024, with an average of 90.2 (*SD* = 82.9, range = 30-252) sightings per year. Cetaceans were observed on 87.5% of surveys (Table 3). The majority of sightings were observed under good (≥ 3; 2000 to 5000 m; 93.7%) or excellent (≥ 4; > 5000 m; 86%) visibility conditions as well as very good with very few waves sea conditions (state ≤ 2; <15cm, ripples; 84%).

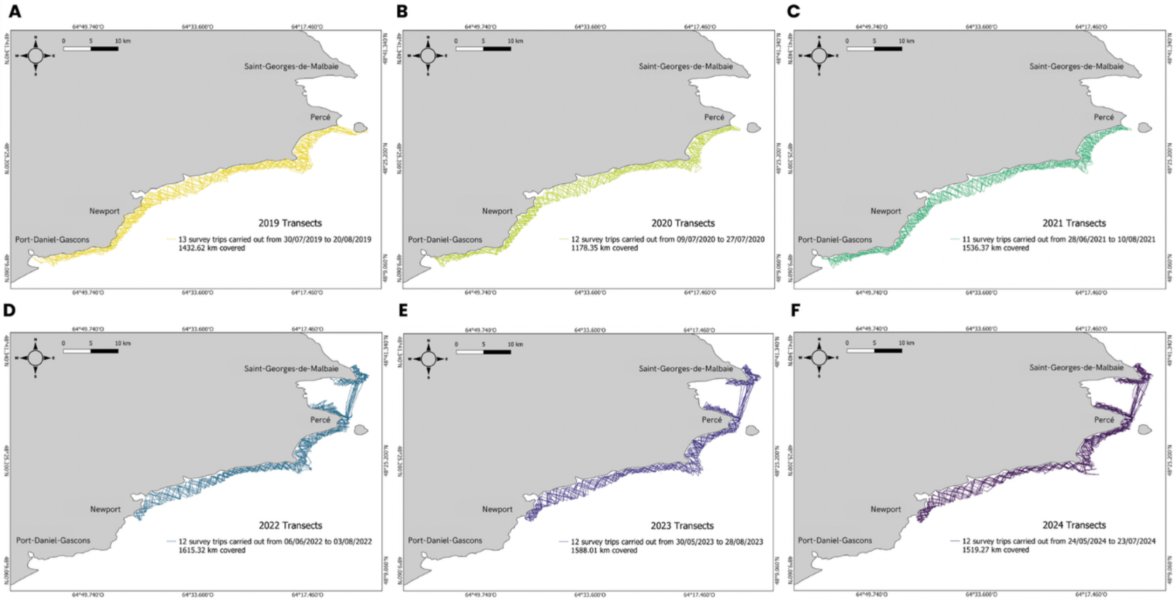

Figure 11. Chart with the search effort of zig-zag transects, between 2019 to 2024, transects from Percé in the north to Port-Daniel-Gascons in the south for (A) 2019, (B) 2020, (C) 2021 and from Saint-Georges-de-Malbaie to the north and Newport to the south for (D) 2022, (E) 2023 and (F) 2024, providing a coverage of the entire study area. Source Natural Earth, geospatial data.

3.2 Observation analysis

A total of four cetacean taxa were recorded, corresponding to identified species (Table 3)[1]. Additionally, some individuals were recorded as *rorqual spp.* when species-level identification was not possible. There were inter-annual, inter-monthly and period variations (during or outside the lobster fishing season) in the number of observations for each species, as well as in the total number of observations for all cetacean species combined (Table 3). Most frequently observed species (>25% of observations) by decreasing order were the

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[1] Supplementary material (Annexe A) with graph of the number of cetacean and shark sightings by species and year in the southern Gaspé lobster fishing area between 2019 and 2024.

minke whale (*Balaenoptera acutorostrata,* Lacepede 1804) with 297 observations, *i.e.*, 54.9% of observations (Table 3), followed by harbour porpoise (*Phocoena phocoena*, Linnaeus 1758) with 183 observations, *i.e.,* 33.9 % of observations (Table 3). The combined relative frequency sightings of these two species comprised 89% of the total observations. The other species represent less than 10% of observations, namely humpback whale (*Megaptera novaeangliae*, Borowski 1781), with 51 observations, *i.e.*, 9.4% of observations (Table 3), fin whale (*Balaenoptera physalus*, Linnaeus 1758), with four observations, *i.e.*, 0.7% of observations (Table 3) and the category *rorqual spp*. with six observations, *i.e.*, 1.1% of observations (Table 3). The species most often found in the study area were, in decreasing order, the harbour porpoise, observed in 77.8% of surveys, followed by the minke whale, observed in 62.5% of surveys. The other species were observed in less than 15% of surveys, humpback whale (13.9%), fin whale (2.8 %) and the category *rorqual spp.* (6.9 %).

The number of observations, as well as the average number of observations per trip, all taxa combined, are highest for the year 2022 (n = 252, mean = 21, *SD* = 18.4, range = 1-52; Table 3), during the lobster fishing season (n = 411, mean = 12.4, *SD* = 14, range = 1-52; Table 3), and in the month of June (n = 360, mean = 15.6, *SD* = 15.6, range = 1-52; Table 3). In order to limit biases related to sampling effort, we focused on effort-corrected observations per trip, weighted by the distance traveled per trip (in km), as a proxy for cetacean presence in the study area (Figure 12). The mean number of effort-corrected observations per trip is the lowest in 2020 (mean = 0.026, *SD* = 0.008, range = 0.011 - 0.038, Figure 12A) and the highest in 2022 (mean = 0.159, *SD* = 0.145, range = 0.008 - 0.424, Figure 12A), with an overall annual mean of 0.067 (*SD* = 0.049, range = 0.025 - 0.159). The number of effort-corrected cetacean observations per trip differed between years (Figure 12A; n = 63, p=0.0151 df =5, Kruskal-Wallis test). The mean observations per trip weighted by sampling effort is lower in the non-lobster fishing period (Figure 12B; mean = 0.066, *SD* = 0.09, range = 0.006 - 0.215) than in the lobster fishing period (Figure 12B; mean = 0.072, *SD* = 0.09, range = 0.007 - 0.424), a difference between the two periods that is statistically significant (Figure 12B; n = 63, p = 0.00521, df = 1, Kruskal-Wallis test). There was only one trip for May in any year, with 0.129 effort-corrected observations. The mean number of observations per trip weighted by sampling effort is lowest in August (Figure 12C; mean = 0.067, *SD* = 0.09, range = 0.007 - 0.215) and highest in June (Figure 12C; mean = 0.084, *SD* = 0.1, range = 0.007 - 0.424), with an overall monthly mean of 0.087 (*SD* = 0.029, range = 0.066 - 0.129). The number of effort-corrected cetacean observations per trip differed between months (Figure 12C; n = 63, p = 0.001428, df = 3, Kruskal-Wallis test), and the number of effort-corrected cetacean observations per trip being significantly higher in June than in July and August (Figure 12C).

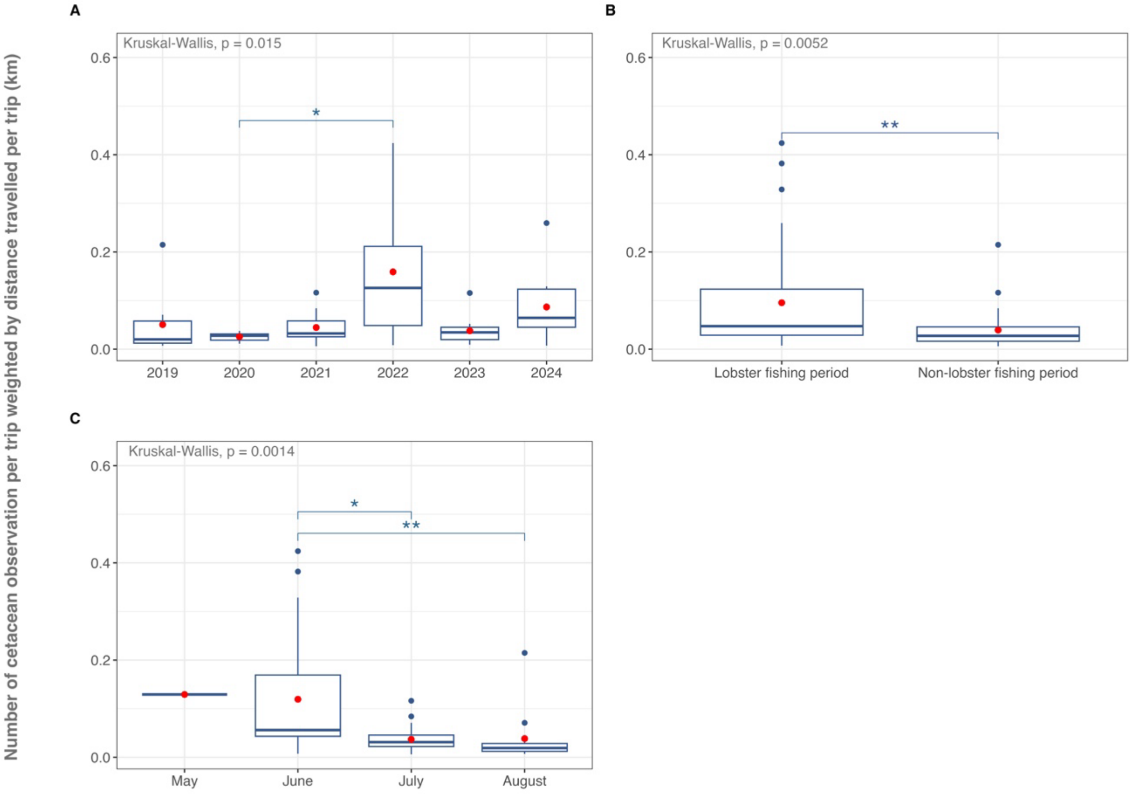
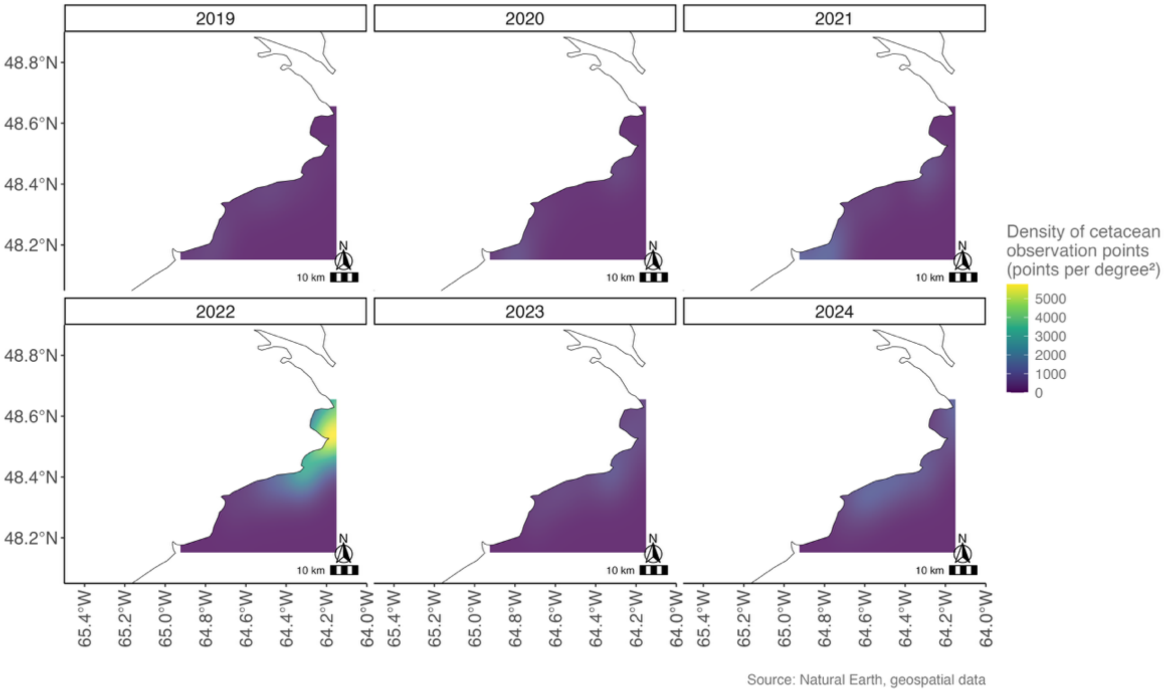


Figure 12. Boxplot of effort-corrected number of cetacean observations per trip in the study area between 2019 and 2024; as a function of (A) years, (B) lobster fishing period or non-lobster fishing period and (C) months, between 2019 and 2024 (n=63; six years, two periods, four months). Middle bold lines indicate median values, red points indicate the mean, upper and lower lines of boxes encompass the spread of data from the first to the third quartile, and upper and lower horizontal bars show minimum and maximum group sizes unless outliers

are present (blue points). Significant differences are indicated by * ($p < 0.05$) and ** ($p < 0.01$).

The maps of hotspots by year (Figure 13) show the spatial distribution of cetacean sightings in the study area, in the form of smoothed density maps. In 2022, the year with the most cetacean sightings, two major hotspot densities (point per degree²) can be observed to the north of the lobster fishing areas: one opposite Percé and the other opposite *Cap d'Espoir* (Leander shoal). Generally, the concentration of cetaceans appears to be slightly higher to the north of the study area, around *Cap d'Espoir*, (bright color) than in the south (dark color; Figure 13).



Source: Natural Earth, geospatial data

Figure 13. Hotspot maps of the spatial distribution of cetacean sightings in the southern Gaspé lobster fishing areas, exploited for lobster fishing, between 2019 and 2024. In this density map, each cell corresponds to an estimated number of points in degrees² (degree of latitude and longitude), making it possible to visualize the areas where cetacean sightings were spatially concentrated.

3.3 Biological factors

Group sizes were assessed for 541 observations, *i.e.*, 100% of observations for all taxa combined, and are summarized in Table 4. The harbour porpoise is the species with the largest mean group size (mean = 2.37, *SD* = 1.79, range = 1-11; Table 4), and the minke whale is the most solitary species (mean = 1.19, *SD* = 0.92, range = 1-12; Table 4).

Table 4. Summary statistics for group sizes for cetacean present in study area that is used for lobster fishing, between 2019 and 2024.

Species	Mean	*SD*	Range	Nombre d'individus
Minke whale	1.19	0.92	1-12	297
Harbour porpoise	2.37	1.79	1-11	183
Humpback whale	1.72	1.18	1-6	51
Fin whale	2.25	0.5	2-3	4
Rorqual spp.	1.67	1.21	1-4	6

Behavior was assessed for 503 observations, *i.e.*, 92.9% of observations, for all taxa. Statistics on observed natural cetacean behavior are presented in Table 5. Travelling is the behavior with the highest number of observations for all taxa, apart from the category *rorqual spp.* This behavior was also the most frequently observed in the study area between 2019 and 2024, accounting for 78.3% of the observations. This was followed by feeding behavior (19.7%), then resting (1.2%) and breach (0.8%). No socialization behavior was observed. There are intermonth variations in the behavior of the two most frequently observed species, minke whale and harbour porpoise (Figure 14). The greatest diversity of behaviors was observed in June for both species, with at least three distinct behavior categories recorded (Figure 14). Travelling behavior was observed every month for minke whales, and only in June, July and August for harbour porpoises (Figure 14). The greatest number of travelling observations were recorded in June (n = 155) for minke whales and in July for harbour porpoises. (n = 78; Figure 14). Feeding behavior was observed in May, June and July for both species. The highest number of feeding observations was recorded in June for both species (minke whale n = 62; harbour porpoise n = 4; Figure 14). The other two behavioral categories, *i.e.*, resting and breach, were poorly represented for both species. Breaching behavior was further observed in humpback whales.

Table 5. Number of behaviors observed, per species, and total frequency (all taxa combined) of behaviors. Blanks represent zeros

Species	Travelling	Feeding	Resting	Breach	Socializing	n
Minke whale	216	68	1	1		286
Harbour porpoise	159	8	4			171
Humpback whale	17	20	1	3		41
Fin whale	1	1				2
Rorqual spp.	1	2				3
Total	394	99	6	4		503
Frequence	78.3	19.7	1.2	0,8		

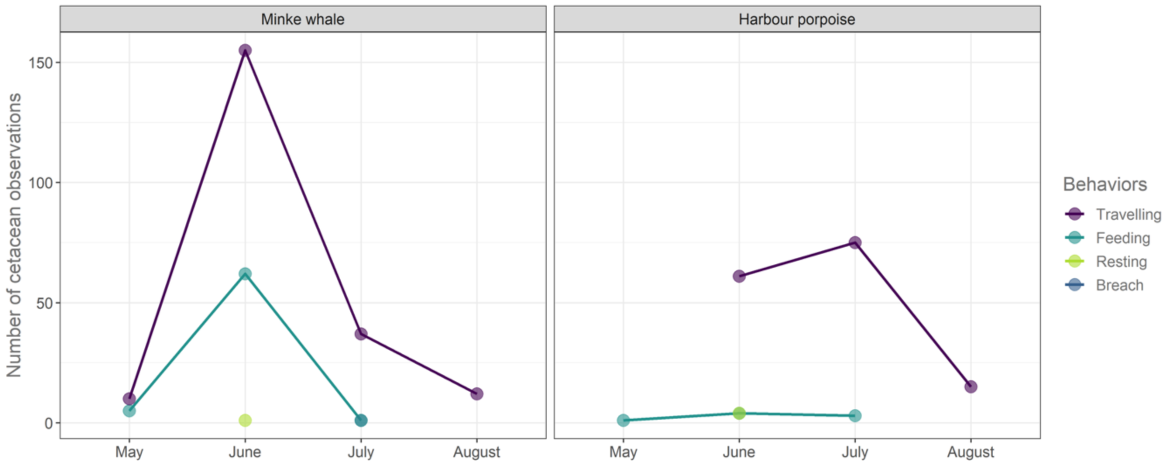


Figure 14. Month-by-month variations in the natural behavior of the two most commonly observed cetacean species in the southern Gaspé lobster fishing areas between 2019 and 2024.

A total of 25 interspecific groupings were recorded in the study area. Of these, 24 (96%) involved two species and one (4%) three species. All four species were involved in interspecific groupings. Minke whales and humpback whales were the two most observed species for this type of association. Minke whales were present in 93% (n = 23) of interspecific groupings and humpback whales in 68% (n = 17) of these associations (Figure 15). These two species were also the most frequently observed together, accounting for 56% (n = 14) of interspecific groupings (Figure 15). Harbour porpoises (present in 36% of events, n = 9) and fin whales (present in 8% of events, n = 2) were both less represented in the groupings. The phenomenon of aggregation for resources, illustrated by feeding behaviors during interspecific grouping, was mostly observed in the study area, accounting for 56% (n = 14) of events (Figure 15). Minke whales and humpback whales were the two species most often observed feeding together. The other categories of behavior adopted by the species, which may be random, together account for 44% (n = 11) of interspecific events (Figure 15).

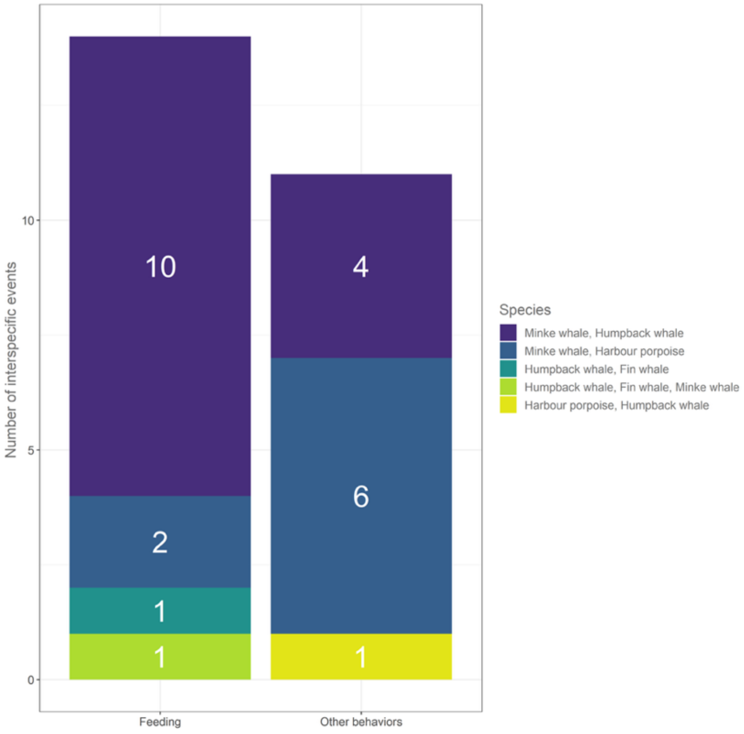


Figure 15. Number of interspecific events per behavior, either feeding or other behavior, according to interspecific groupings in the southern Gaspé lobster fishing areas between 2019 and 2024.

4. DISCUSSION

This study presents the first systematic vessel-based cetacean survey results in Baie des Chaleurs along the southern Gaspé coast. To date, few multi-species studies have been conducted on this taxonomic group in this region. Available data remain limited and come mainly from seasonal aerial surveys, such as those in 1995 and 1996 by Kingsley and Reeves (1998) or those carried out by DFO since 2018. Thus, most information on cetaceans is based on local knowledge and grey literature. This study stands out as one of the first to adopt a coastal approach, conducting vessel-based transects in a lobster fishing areas to document the presence and distribution of cetaceans. This type of approach, like complementary aerial survey transects, is particularly important for species at risk that are shifting to new habitat areas and whose distribution remains uncertain. This study was conducted to help develop effective conservation strategies and inform management decisions (Buckland et al., 2001; Strindberg et al., 2004). By focusing on the presence and diversity of species at different temporal scales, during lobster fishing season or not, as well as on intraspecific group size, behavior and interspecific groupings, this study provides new information on the cetacean communities and the behavioral dynamics adopted by these cetaceans when present in the coastal lobster fishing area, using mainly a descriptive approach. This harvesters-led project, a first in this area, provides an essential basis for understanding the use of this inshore habitat by cetaceans. It also demonstrates the societal value of collaborative and community-based science, extending beyond the ecological framework. It bridges local ecological knowledge with rigorous data collection in a co-constructed approach to building a rich dataset on cetacean behavior and habitat use data that would otherwise have been difficult to obtain. Finally, the project helps to strengthen confidence in and acceptance of protective measures and improve risk mitigation, while filling significant gaps in knowledge about the presence of whales in shallow coastal habitats (Morissette et al., 2022).

4.1 Habitat use of a Gaspé lobster fishing areas by cetaceans

This study highlights the presence of four species of cetaceans in the shallow waters of southern Gaspésie, the same area used by the lobster fishers. The number of sightings confirms that the southern coast of the Gaspé Peninsula is frequented by whales, similar to other regions, including northern Newfoundland and adjacent waters (Perkins and Whitehead 1977), the St. Lawrence Estuary (Edds and Macfarlane 198), Newfoundland (Whitehead and Carlson 1988), Gulf of St. Lawrence (Kingsley and Reeves 1998 ; Comtois et al., 2010), and both Estuary and Gulf of St. Lawrence (Lesage et al., 2007). The detection of the minke whale, harbour porpoise, humpback whale and fin whale, corresponds to what was observed offshore the Gaspé Peninsula by Kingsley and Reeves (1998), Lesage et al., (2007) and ROMM (2019).

The minke whale and the harbour porpoise use these shallow waters area quite frequently. Unsurprisingly, as both species are typically known to frequent coastal waters, particularly shallow waters less than 50 meters deep (Perkins and Whitehead 1977; Lynas and Sylvestre 1988; Camphuysen 2004; Doniol-Valcroze et al., 2007; Marubini et al., 2009; Bjørge and Tolley 2018; Torres et al., 2021). The humpback whale is also found in coastal habitats (Clapham 2000) and is considered both as a pelagic and coastal species. It is typically encountered over shallow banks and in shelf waters while feeding or breeding but may go across open ocean when migrating. The last species, the fin whale, prefers deeper waters, explaining the low number of sightings in the shallow waters surveyed (Perkins and Whitehead 1977; Aguilar and García-Vernet 2018). However, during the six years of the study, the most endangered species of all large whales, the North Atlantic right whale, was never observed, nor was the blue whale (*Balaenoptera musculus,* Linnaeus, 1758), another SARA-listed endangered species.

4.2 Cetacean behavior

The inclusion of behavioral data in cetacean studies is becoming increasingly widespread in the western Atlantic (e.g., Whitehead 1981; Whitehead 1988). Data collection and the study of cetacean behavior is essential to understanding their presence in the study area. This study shows that the coastal area of southern Gaspé is mainly a cetacean travelling area, although it can be a feeding area when the resource is present. No socialization behaviors were observed and resting and breach behaviors are very infrequent. The presence of cetaceans in the study area is likely linked to prey availability, as has been observed in other regions of the North Atlantic (Lynas and Sylvestre 1988; Whitehead and Carlson 1988; Clapham 2000; Doniol-Valcroze et al., 2007); with feeding activity, either within the lobster fishing areas or further offshore. For example, whales can use *the Banc-des-Américains* marine protected area, close to the northern boundary of our study area, whose topography creates a significant biomass accumulation of krill and small pelagic fish (Faille et al., 2019; ROMM 2019).

The Gaspé offshore Peninsula is indeed a feeding area, considering seasonal occupancy, the different species present, and the physical and biological conditions of the area (Gagnon et al., 1997; Lesage et al., 2007; Mcquinn et al., 2015; Faille et al., 2019). It is an important feeding habitat for mysticetes via the presence of high concentrations of krill in the north of the peninsula (favored by the Gaspé current; Mcquinn et al., 2015; Faille et al., 2019) and more generally for all piscivorous cetaceans (Gagnon et al., 1997; Lesage et al., 2007; McQuinn et al., 2012; Faille et al., 2019; ROMM 2019). In fact, this environment is a breeding, nursery and feeding ground for many small pelagic forage fish, such as capelin (*Mallotus villosus*; Müller 1776), Atlantic herring (*Clupea harengus*; Linnaeus 1758) and blue mackerel (*Scomber scombrus*; Linnaeus 1758), on which marine predators feed. However, the primary natural behavior observed for cetaceans within the study area is travelling, accounting for 78.3% of all behaviors recorded. This behavior can manifest itself in movements between feeding patches, whose distribution varies in space and time (Jangaard 1974; Gagnon et al., 1997), which may be located inside or outside the study area (e.g., Faille et al., 2019; ROMM 2019). Behavior that was interpreted as feeding behavior was the second most common behavior with 19.7% of observations.

The behavioral component is important to integrate into detection and observation efforts, as it is essential for a better understanding of the presence and use of the habitat necessary for better species management (e.g., Jourdain et al., 2017; Alvez et al., 2018; Bishop et al., 2022), following the pioneering principles of systematic and sustained behavioral observation (Goodall, 1986). Our approach confirms that it is possible to collect this behavioral data efficiently, without complicating the collection protocol. Unlike other methods focused solely on location, which struggle to provide reliable behavioral context (Würsig et al., 2017), the systematic collection of behavioral activity, as carried out here, gives the data greater ecological and management value (e.g., Senigaglia et al., 2016). Indeed, knowledge and understanding of behavior in a particular location allows managers to establish proactive and more nuanced conservation strategies, constituting a useful step forward in mitigating risks in these dynamic coastal habitats while considering coexistence with human activities.

4.3 Spatial and temporal distribution of cetaceans

This study highlights north-south variations in cetacean distribution, with a highest concentration of whales in the north of the study area, especially in 2022. This may be explained by the distribution of food resources, which has a direct impact on the spatio-temporal distribution of cetaceans, as demonstrated in other studies in the North Atlantic (Clapham 2000; Camphuysen 2004; MacDougall and Robinson 2025). Indeed, the northern part of the study area is closer to the Gaspé EBSAs and the Banc-des-Américains marine protected area (Faill et al., 2019; ROMM 2019), areas characterized by a generally diverse megafauna because they are fulfilling nutritional functions for all marine mammals, making it a passage and feeding area for many migratory species (Lesage et al., 2007;Mcquinn et al., 2015; Faille et al., 2019). Moreover, the Leander shoal (*Cap d'Espoir*) and *Île Plate* shoal in the study area are two major focal points for cetacean observations. The physical characteristics of these shoals allow for an accumulation of food, making them ideal feeding grounds for whales (Gagnon et al., 1997; Correia et al., 2021).

Temporal variations in cetacean use of the study area can be correlated with temporal variations in resource availability. The year 2022 is an exceptional one in terms of cetacean sightings, with a higher number of sightings per day (and which is significantly different from 2020; Figure 12A; n = 63, p = 0.02, Z= -3.17, Dunn Test). It was only in this year, and more recently in 2024, that humpback and fin whale observations occurred, along with the highest number of minke whale sightings, almost three times more than the year with the second highest number of minke whale sightings (see Table 3). The year 2022 seems to have been a year of exceptionally high prey availability in the coastal zone, attracting a large number of cetaceans to feed there. Humpback whales, for example, do not show any particular spatial fidelity and are therefore absent in certain years due to the sporadic nature of their prey (Clapham 2000). This is illustrated in our study by numerous humpback whale sightings in 2022 and 2024 only and none in other years.

June is the month with significantly more cetaceans present per day, with a greater diversity of species using the lobster fishing areas, as well as a greater diversity of behaviors observed. In June, capelin spawn on the study area's mid-littoral habitats, and other small pelagic fish are present for various biological functions, attracting many whales that come to feed (Gagnon et al., 1997; McQuinn et al., 2012). This is the case for humpback and fin whales, which only visited the study area in June when observed in 2022 and 2024. The greater availability of food in June attracts piscivorous species such as humpback whales and fin whales, which are not usually seen, and attracts more minke whales and harbour porpoises, which regularly frequent the study area (Sergeant 1963; Jangaard 1974; Mitchell and Kozicki 1975).

4.4 Intra- and Interspecific cetacean groupings

Cetaceans were observed in intraspecific groups in the study area. For humpback whales and fin whales, the size of feeding intraspecific groups differs according to the type of food and the size of fish shoals, that could be observed in the study area (Clapham et al., 1993; Whitehead and Carlson 1988). The mean group size of harbour porpoises observed in the study area is consistent with results reported in previous studies on this species (Berrow et al., 2014; Forney et al., 2014; Stern et al., 2017; Keener et al., 2018). Furthermore, the study by Torres et al., (2021) shows that harbour porpoises, although considered a non-social species, adopt a collaborative hunting strategy in shallow waters (1-20 m). Similar behavior could potentially occur in the southern Gaspé coastal zone. The minke whale is the most solitary species, as observed by Perkins and Whitehead (1977) in northern Newfoundland, where minke whales moved and fed alone, without their conspecifics.

In addition, 25 interspecific groupings were observed in the study area, mostly during aggregation for the resource, illustrated by feeding behavior. Minke whales and humpback whales are the two species most often seen feeding in the same area. In fact, rorquals are considered "gulp feeders" and are frequently observed feeding in the same feeding area as other rorquals of different species (Whitehead and Carlson 1988; Baker et al., 1992). The lobster fishing area can, under the right conditions, be a feeding ground for whales. Given that no interspecific socialization behavior has been documented, we can assume that the majority of interspecific groupings observed are due to aggregations around food resources, resulting from the presence of feeding areas exploited by several cetacean species (Waser, 1982; Powell, 1985; Syme et al., 2021). Other interspecific events, whose behaviors are not feeding but rather travelling, may be the result of random encounters (Waser 1982; Whitesides 1989; Syme et al., 2021).

4.5 Is North Atlantic right whale using the less than 20 fanthom waters in Baie des Chaleurs?

No North Atlantic right whale has been observed in the southern Gaspé lobster fishing areas between 2019 and 2024. In contrast of the four engulfing cetacean species feeding on small pelagic forage fish observed in the study area, the North Atlantic right whale feeds almost exclusively on copepods of the genus *Calanus spp* and does not integrate into piscivorous community (Mayo and Marx 1990; Pendleton et al., 2009; Patrician and Kenney 2010; Sorochan et al., 2023). This difference reflects distinct feeding strategies, as rorquals (englulfing cetaceans) primarily feed on schooling fish using lunge feeding (Shadwick et al., 2019), whereas balaenids like the North Atlantic right whale are specialized continuous filter feeders targeting small copepods like *Calanus spp*. (skimmer whales; Tanaka 2022). Moreover, the presence of North Atlantic right whale is correlated with the density of its preferred prey (Pendleton et al., 2009; Patrician and Kenney 2010; Plourde et al., 2019; Gavrilchuk et al., 2021; Sorochan et al., 2023). Although North Atlantic right whale can be observed feeding in nearshore copepod aggregations in the northern Gulf of St. Lawrence (Lesage et al., 2007), this skimmer whale feeds differently from engulfing whales and its absence from the study area between 2019 and 2024 may suggests that the prey present might not have been suitable for its diet.

Nevertheless, vigilance is called for due to the temporal and spatial variability of the local distribution of *Calanus spp.* abundance, which fluctuates on scales ranging from a few days to several weeks, and from a few kilometers to tens of kilometers (Record et al., 2019; Sorochan et al., 2023). It is therefore all the more important to document not only the presence of North Atlantic right whale, but also its behavior, as some critical areas may represent transit corridors or feeding habitats. Observations of the basking shark (*Cetorhinus maximus*; Gunnerus, 1765), also a megazooplanktivore (Sims and Merrett 1998), in the study area at the end of the lobster fishing season, underlines the importance of regular monitoring of cetacean's community. Indeed, the presence of this species can be an indicator of a high density of copepod calanoids in the area where it feeds (Sims and Merrett 1998; Sims et al., 2005).

5. CONCLUSION

No right whales were observed in this particular surveyed area (depth <37m), between 2019-2024, an area used by Gaspé lobster fishers. However, four species of piscivorous cetaceans were observed in the shallow waters of the southern Gaspé peninsula. Their use of the area varies both in time and space as it is directly linked to the availability of food resources. The fish-eating cetacean's community that uses the coastal zone between May and August does not correspond to the North Atlantic right whale feeding pattern, which might explain why no North Atlantic right whale were observed during the six years of the study. They were also not seen transiting through this coastal zone. This study therefore highlights that there is a real need to include behavioral studies in whale surveys in order to understand their habitat use.

For many years, Gaspé lobster fishery was temporally out of phase with the presence of the right whale, drastically limiting the risk of entanglement (Brillant et al., 2015). However, the variable nature of *Calanus spp*. aggregations, combined with the effects of climate change, complicates the situation by leading to variations in prey availability and, consequently, right whale distribution (Mayo and Marx 1990; Patrician and Kenney 2010; Plourde et al., 2019; Sorochan et al., 2019; Koubrak et al., 2021). Increased vigilance is therefore essential to anticipate and prevent any changes in the use of the lobster fishing area by North Atlantic right whale.

By integrating the perspectives and expertise of local stakeholders with rigorous scientific methodologies, such collaborative study has produced a robust dataset that contributes significantly to our understanding of cetacean use of the shallow waters area, the same grounds used by the Gaspé lobster harvesters. Conservation measures work when stakeholders are directly involved (Reynolds III et al., 2009). In our case, the inclusion of lobster harvesters was essential, contributing to the encouragement of greater adherence to conservation measures (Morissette et al., 2022).

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CHAPITRE 2

ACOUSTIC PRESENCE OF HUMPBACK WHALES (*MEGAPTERA NOVAENGLIAE*) AND NORTH ATLANTIC RIGHT WHALES (*EUBALAENA GLACIALIS*) IN THE SOUTHERN GASPÉ COASTAL ZONE: AN OVERVIEW BASED ON LONG-TERM RECORDINGS.

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ABSTRACT

Humpback whales and North Atlantic right whales (NARW), two migratory baleen whales, use the Gulf of St. Lawrence (GSL) as their summer feeding ground. These GSL whales face anthropogenic threats such as entanglement in fishing gear and collisions with ships. These pressures are directly linked to the observed decline of NARW in the Northwest Atlantic, designated as critically endangered by the IUCN. Since 2015, NARWs have been visiting the GSL more frequently, creating major challenges for coexistence with coastal lobster fisheries. In response, the *Regroupement des pêcheurs professionnels du sud de la Gaspésie (RPPSG)* chose to be part of the solution by launching a cetacean monitoring program in 2019 in an area that had been little studied until then. Our 2024 study, conducted within this framework, uses passive acoustic monitoring (PAM), a non-invasive method that continuously detects the distinctive vocalizations of both species, complementing visual observations. The results reveal an almost daily coastal presence of humpback whales during the 2024 summer season, characterized by high vocal presence in June. Although PAM documented minimal vocalization, it revealed fine spatio-temporal variations and diel trends, indicating potential use of the area as a migratory stopover and feeding ground for humpback whales. NARW, on the other hand, were detected mainly in August, suggesting that the area is used as a migratory corridor between two feeding areas: the Shediac Valley and the northwest of Anticosti Island. The results of this collaborative project with fishermen highlight the effectiveness of this method for documenting coastal cetacean use and supporting their conservation.

Keys words: North Atlantic right whale, Humpback whales, Passive Acoustic Monitoring, Lobster Fisheries, Coexistence, Cetaceans, Behavior, Harvesters-Led Project, Vocalisations

1. INTRODUCTION

Humpback whales (*Megaptera novaeangliae*, Borowski 1781) and North Atlantic right whales (NARW; *Eubalaena glacialis*, Müller 1776; NARW), two medium-sized baleen whales, migrate seasonally each year between their breeding grounds, where they mate and give birth in winter, and their feeding grounds, where they feed in summer (Stone et al., 1990; Bettridge et al., 2015; Brillant et al., 2015; Moore et al., 2021). North-West Atlantic humpback whales spend the winter in their breeding grounds in the Caribbean and Cape Verde Islands (Whitehead 1982; Jann 2003) and feed in several high-latitude prey concentration areas, notably off the east coast of Canada, in the Gulf and the St. Lawrence Estuary (Katona et al., 1990; Clapham 2000; Comtois et al., 2010; DFO 2022). The NARW is distributed along the east coast of North America, breeding in the southeastern United States, near Florida and Georgia (Kraus and Rolland 2007), and feeding along the Canadian east coast, in the Gulf of Maine, the Bay of Fundy, and the Gulf of St. Lawrence (GSL ; Brown et al., 2009; Brillant et al., 2015; Durette-Morin et al., 2022). Both species use the GSL to feed and move between well-known feeding patches. Humpback whales, as engulfing feeders, feed on forage fish and krill in the St. Lawrence Estuary (McQuinn 2012, 2015; DFO 2022; Martins et al., 2022), the Mingan Islands, the Anticosti Basin (Comtois et al., 2010; Ramp et al., 2010, 2015) and the Belles-Isles Strait (Delarue et al., 2022). NARWs are specialized continuous filter feeders that depend on high concentrations of copepods of the genus *Calanus spp* found in the Shediac Valley (southwest of the GSL, Gavrilchuk et al., 2021; Sorochan et al., 2023) and northwest of Anticosti Island (Crowe et al., 2021; Gavrilchuk et al., 2021; Simard et al., 2024).

Anthropogenic threats, particularly entanglement in fishing gear and collisions with vessels, affect all large whales (Nelms et al., 2021), including those in the GSL (Truchon et al., 2018). These pressures are directly linked to the continued decline of the NARW, designated as critically endangered by the IUCN (Cooke 2020; IUCN 2023) and listed under Canada's Species at Risk Act (SARA) since 2005 (Brown et al., 2009; DFO 2021). Since

2010, oceanographic changes across the northwestern Atlantic basin have led to a decline in the availability of the NARW's main prey (Meyer-Gutbrod and Greene 2018; Sorochan et al., 2019; Gavrilchuk et al., 2021), causing the species to shift toward the GSL (Simard et al., 2019; Crowe et al., 2021; Bishop et al., 2022; Meyer-Gutbrod et al., 2023). Its growing presence in this region since 2015, estimated at 40% of the population between May and October (Crowe et al., 2021), has exposed it to anthropogenic threats in an area where conservation measures were absent, as its presence in the GSL was unpredictable and unexpected (Brillant et al., 2015; Meyer-Gutbrod and Greene et al., 2018; Moore et al., 2021). The unusual mortality events of 2017 and 2019 (Daoust et al., 2017; Sharp et al., 2019; Bourque et al., 2020) illustrate the significant risks associated with this new area of use, highlighting the urgent need to better understand the species' spatial ecology. In response, and in accordance with the Species at Risk Act (SARA), which requires the Canadian government to develop recovery strategies for threatened species, emergency management measures have been implemented by Fisheries and Oceans Canada (*i.e.,* DFO 2021). These include the closure of lobster fishing areas, with significant consequences for coastal communities in the Gaspé Peninsula (Morissette et al., 2022).

Thus, since 2018, the coexistence of lobster fishing and NARW in the GSL has raised complex ecological and socio-economic issues (Morissette et al., 2022; Reamer et al., 2023). This is the context for the present study, conducted as part of the "*Pêcheur et baleines en Gaspésie*" project (an initiative of the *Regroupement des Pêcheurs Professionnelles du Sud de la Gaspésie* in collaboration with M - Expertise Marine Inc). Unlike the St. Lawrence Estuary, this area remains poorly documented in the scientific literature. Although a few studies have revealed a significant diversity of cetaceans around the Gaspé Peninsula, highlighting its nutritional role (Gagnon et al., 1997; Lesage et al., 2007; McQuinn et al., 2015; Faille et al., 2019), gaps remain. The recent study conducted as part of the same project revealed the coastal presence of humpback whales but reported no visual observations of NARW (Riou et al., 2025). However, the absence of observations does not necessarily mean that the species is absent from the coastal area. Indeed, visual detection is limited by weather conditions, daylight, and observation duration (Munger et al., 2012). To gain a more detailed and comprehensive understanding of the occurrence of these two species in this coastal area, our present study uses Passive Acoustic Monitoring (PAM). This approach, which has become a commonly used method for studying the spatial and temporal distribution of cetaceans (Zimmer 2011; Munger et al., 2012; Browning et al., 2017; Davis et al., 2017; Delarue et al., 2022), allows to detect cetacean presence continuously by capturing vocalizations. Humpback whales and NARW are ideal candidates for long-term Passive Acoustic Monitoring thanks to their distinctive vocalizations, which are easily distinguishable from other species and background noise in the marine environment (Clark 1982a; Dunlop et al., 2008; Gervaise et al., 2019; Ross-Marsh et al., 2022). Theses non-invasive and continuous PAM method enables effective detection of acoustic signals, complementing visual observations over large spatial and temporal scales.

Humpback whales have a very large and varied vocal repertoire, generally categorized into songs and non-song vocalizations (Dunlop et al., 2007; Stimpert et al., 2011; Kowarski et al., 2022). Songs, produced only by males, are associated with the breeding season (Payne and McVay 1971; Winn and Winn 1978); mainly in winter between December and April in the North Atlantic. They are characterized by a complex hierarchical structure: repetitive phrases form themes, which come together to create a complete song, aimed at maximizing reproductive success (Payne and McVay 1971; Payne 1983; Cholewiak et al., 2013). Although predominant in breeding areas, these songs are also detected during migration and in feeding areas (Mattila et al., 1987; McSweeney et al., 1989; Kowarski et al., 2018, 2019). In contrast, non-song vocalizations are known as individual sound units (Tyack 1983; Dunlop et al., 2008; Kowarski et al., 2018) and are emitted by individuals of both sexes and all ages throughout their range and throughout the year (Zoidis et al., 2008; Rekdahl et al., 2017; Kowarski et al., 2022). These are potentially associated with social and feeding behaviors (Cerchio and Dahlheim 2001; Dunlop et al., 2008; Zoidis et al., 2008; Videsen et al., 2017; Ratsimbazafindranahaka et al., 2024). Vocalizations, whether sung or not, can be recorded at distances ranging from 3 to 100 km in summer off the coast of Nova Scotia, depending on ambient sound levels (Kowarski et al., 2018), and on average at 50 km in eastern Canada (Delarue et al., 2022; The data were captured by autonomous multichannel acoustic recorders, AMARs, JASCO Applied Sciences - moored 55 m above the seafloor at depths of 1,400 to 1,900 m for Kowarski et al., 2018, and moored at depths of 44 to 2,002 m for Delarue et al., 2022). Although humpback whale vocalizations are mainly recorded in eastern Canada during the summer season (Kowarski et al., 2019, 2022; Delarue et al., 2022), PAM studies have revealed that part of the population resides in high-latitude waters during the winter or migrates late (Kowarski et al., 2018, 2022; Davis et al., 2020; Delarue et al., 2022).These results highlight the presence of the species in eastern Canada during much of the year, illustrating the effectiveness of PAM, using both song and non-song vocalizations, for long-term monitoring of the species.

NARW are known to produce a variety of vocalizations, most of which are below 1,000 Hz (Clark 1982a; Parks and Tyack 2005). The most common sound, and the one most frequently used in PAMs, is the *up-call*, or contact call (Clark 1982a; Gervaise et al., 2019; Simard et al., 2019). This typical sound lasts about one second and has a stereotypical ascending frequency modulation between 50 and 200 Hz, parameters that can be affected by natural variability (Clark 1982a; Matthews et al., 2001; Parks et al., 2011; Mussoline et al., 2012; Simard et al., 2019). It plays a key role in maintaining contact between individuals over several kilometers, is produced by both sexes, by all age classes, and throughout the year (Clark 1982b; Clark 2010a). Furthermore, thanks to its recurrence, its long propagation range due to its low frequency, and its high source level, the *up-call* has proven to be the best candidate for detection via PAM (Mellinger et al., 2007; Gervaise et al., 2019). It can be detected up to around 35km in the GSL, suggesting NARW presence or coastal passage (the data were captured by autonomous underwater recorder, AURAL-M2, Multi-Electronique - was deployed ~5−50 m off the bottom; Simard et al., 2019). This signal was used, for example, by Simard et al. (2019) to demonstrate the increase in the presence of NARW in the GSL from 2015 onwards, illustrating the effectiveness of this monitoring method for long-term tracking of the species.

In this context, the present study aims to document the acoustic presence of humpback whales and NARW in the coastal area of the southern Gaspé Peninsula, a region that remains poorly documented in terms of spatio-temporal occupancy by these two species. It thus complements the work of Riou et al., (2025) on their coastal occurrence in this region. Based on passive acoustic recordings collected in June, August, and September 2024, this study provides a spatio-temporal overview of the vocal presence of both species, allowing for an assessment of their seasonality, diel trends, and spatio-temporal fluctuations in their occurrence in this coastal habitat. It is important to note that these data represent only the minimum presence of vocalizations; the absence of calls does not imply the absence of whales, as individuals may be silent, undetected by our instruments, or masked by ambient noise. Thus, our results should be interpreted as indicating the minimum presence of both species.

This study contributes to a better understanding of the use of this area by humpback whales, and particularly the NARW, a critically endangered species, in support of conservation efforts dedicated to it. It is part of an initiative launched and led by lobster harvesters through the *"Pêcheurs et baleines en Gaspésie"* project, which aims to reconcile sustainable fishing with the protection of this cetacean.

2. MATERIAL AND METHODS

2.1 Data Collection

Acoustic data collected as part of *Pêcheur et baleines en Gaspésie* program were recorded at several PAM stations equipped with SoundTrap hydrophones (Ocean Instruments Inc., NZ). Two campaigns were conducted. The first, between May 31, 2024, and June 19, 2024, focused on a single deployment at station 1 equipped with a SoundTrap ST600 HF hydrophone (recording bandwidth: 20 Hz ± 3dB - 150 kHz ± 3dB; sample rate up to 384 KHz; Ocean Instruments Inc. NZ) deployed off *Pointe Verte*, north of Malbaie Bay (Station1-

Campaign1; 48.60912°N, -64.17303°W; Figure 16). The second campaign took place between August 2, 2024, and September 24, 2024, with two deployments equipped with SoundTrap ST640 HF hydrophones (recording bandwidth : 20Hz ± 3dB - 150 kHz ± 3dB; sample rate up to 384 KHz; Ocean Instruments Inc. NZ) : one at the same station opposite *Pointe Verte* (Station1-Campaign2; 48.60912°N, -64.17303°W), and the other opposite *Cap d'Espoir*, near the Leander Shoal (Station2-Campaign2; 48.39937°N, -64.33833°W; Figure 16). The two stations are approximately 26.30 km apart. The three deployments discussed in this study are therefore: Station1-Campaign1, Station1-Campaign2, and Station2-Campaign2. These three hydrophones from both campaigns were mounted in the water column, three meters above the seafloor, with the two deployments opposite *Pointe Verte* at a depth of 26 meters and the deployment on Leander Shoal at a depth of 29 meters, in order to limit background noise from the surface and the seafloor. Acoustic data were recorded continuously during the three deployments, with a sampling frequency of 128 kHz. The gain was set to the maximum level before saturation, *i.e.*, 173 dB re (*referenced to*) 1 µPa, ensuring an optimal dynamic range to capture both faint and loud acoustic signals without distortion. The system incorporates four SAR-type analog-to-digital converters (ADCs), each with 16-bit resolution, ensuring precise digitization of the acoustic signals. Each SoundTrap hydrophone features very low self-noise levels (less than 37 dB re 1 µPa above 2 kHz) and factory calibration with a calibration certificate at 250 Hz, which guarantees accurate conversion of recorded signals to absolute acoustic pressure levels.

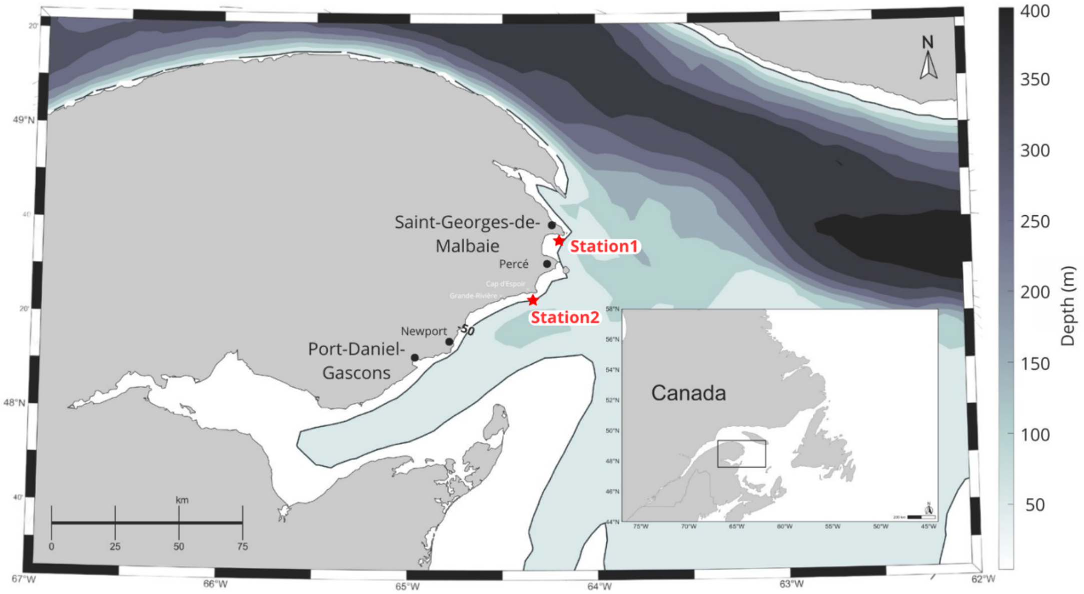

Figure 16. Location of the study area in the Northwest Atlantic, in the Gulf of St. Lawrence, highlighting the 50-metre coastal bathymetric contour (represented by the dark blue line, with isobaths in metres). The study area is in the southern part of the Gaspé Peninsula coast. Passive Acoustic Monitoring (PAM) Station1 (off *Pointe Verte*, north of Malbaie Bay; 48.60912°N, -64.17303°W) and PAM Station2 (opposite *Cap d'Espoir*, near the Leander Shoal; 48.39937°N, -64.33833°W) are represented by red stars. Source Natural Earth, geospatial data.

2.2 Acoustic data analysis

The acoustic data processing was conducted in two phases, following a strict and rigorous protocol designed, on the one hand, to optimize the detection of the two species, humpback whales and NARW, off the South coast of Gaspé Peninsula, and on the other hand, to ensure the quality of the detections. The first phase involved applying pre-trained deep learning models, and the second phase consisted of manually verifying the detections through visual inspection and auditory validation.

Two open-access models, implemented in Python and based on Convolutional Neural Networks (CNNs), were used for automatic detection of acoustic signals. Starting from raw audio files (.wav format, initially lasting 2 hours and 15 minutes and then cut into 2-minute segments), the programs generate audio representation (spectrograms), used as input for the neural network to detect humpback whale vocalizations, including non-song calls and songs (Best 2022), and NARW *up-calls* (Padovese et al., 2023). The first model, Ceta-CNNs, is based on a Sparow architecture developed by Best (2022) and inspired by Grill, T., & Schlüter, J. (2017). This model is designed to analyze humpback whale vocalizations and is pre-trained with data collected in the Caribbean (Best 2022). For more information on data collection and the use of datasets for model training, please refer to Best (2022).This neural network uses a log-normalised spectrogram as input (SR = 48 kHz, Fourier transform - NFFT = 2048, hop size = 512, #Mel Filters = 128, fmin = 2 kHz, fmax = 30 kHz; Best 2022). It outputs detection probabilities between 0 and 1 every 5 seconds of recording, with a score of 1 indicating 100% certainty of the model (Best 2022). This model is available online: https://gitlab.lis-lab.fr/paul.best/ceta-cnns (Best 2022). The second model used to detect NARW *up-call* vocalizations is based on a ResNet-18 architecture and is called "NARW_detection_tool" (Padovese et al., 2023). It was pre-trained for a binary classification task aimed at distinguishing NARW *up-calls* from a wide range of background noise recorded mainly off the east coast of Canada (GSL and Emerald Bassin off the coast of Nova Scotia) and the US (Gulf of Maine off the coast of Massachusetts; Padovese et al., 2023). For more information on data collection, specific deployment locations, and the use of these three datasets for model training, please refer to Padovese et al. (2023). The input to the convolutional neural network consists of magnitude spectrograms derived from an audio signal that has been resampled at 1 kHz, with a window of 0.256s, a step size of 0.032s, and a Hamming window (Padovese et al., 2023). The spectrograms are then normalized (mean zero, standard deviation 1). The model outputs are probability scores between 0 and 1, with a score of 1 meaning 100% certainty of the model (Padovese et al., 2023). At a recall of approximately 0.81, the ResNet model achieved the best performance corresponding to a precision of about 0.87 (Padovese et al., 2023). Recall identifies the proportion of positive samples in the test set that were correctly classified as positive by the model (recall = TP / (TP + FN)), where TP is the number of true positives, validated by an expert, and FN is the number of false negatives. This high recall value indicates that the detector has successfully captured most of the true positive cases (Padovese et al., 2023). Detections are also determined by the false detection probability threshold set at 0.5, above which detections are considered positive (Gervaise et al., 2019; Padovese et al., 2023). This model is available online: https://git-dev.cs.dal.ca/meridian/NARW_detection_tool/-/tree/main (Padovese et al., 2023).

Based on the detection results of the two convolutional neural network models, the second step of the protocol consisted of manually validating these detections through visual inspection followed by auditory validation. Visual inspection of detection probabilities was performed using Python. Acoustic recordings were processed and explored using libraries *SciPy* for audio handling (Virtanen et al., 2020), *Matplotlib* for spectrogram visualization (Hunter 2007), and *NumPy* (Harris et al., 2020) and *Pandas* (Reback et al., 2020), for data manipulation and annotation support. Spectrograms were generated using a Hann window with 7000 sample overlap and a fast Fourier transform (NFFT) size of 8000. To examine humpback whale social calls, spectrograms were displayed five seconds before and five seconds after detection with a frequency range limited to 0-3000 Hz (frequency generally ranging from [50 Hz to 10 kHz], although the majority of social calls are < 3kHz; Zoidis et al., 2008; Stimpert et al., 2011; Recalde-Salas et al., 2020; Molder et al., 2024). To analyse NARW *up-calls*, spectrograms were displayed in 10-second windows with a frequency range limited to 0-500 Hz to focus on NARW *up-calls* (main frequency support [50, 200 Hz]; Clark 1982a; Parks and Tyack 2005; Mussoline et al., 2012; Simard et al., 2019).

Regarding the results of the Ceta-CNNs model for humpback whales, a classification threshold was applied to the detection probabilities in order to retain only the most probable acoustic events and reduce the risk of false positives. This threshold was determined iteratively. Initially set at 0.90, it was lowered to 0.80 when more than 50% of detections at 0.90 were manually validated. However, at 0.80, less than 50% of detections were considered true positives after manual verification. This compromise led to the final threshold being set at 0.80 for all three deployments. All detections with a probability greater than or equal to 0.80 were verified manually by visual inspection of the spectrogram generated via the Python script described above and then by listening to the corresponding signal using Audacity 3.7.1 software (Audacity Team, 2023). The spectrograms in Audacity were configured on a linear scale, with a minimum frequency of 0 and a maximum frequency of 3000 Hz, a window size of 8192 points, a Hann window, and a zero-padding factor of 2. Any false detections identified during the manual process were excluded from the final three datasets.

The threshold of 0.5, defined in the "*NARW_detection_tool*" model as a positive detection value (Gervaise et al., 2019; Padovese et al., 2023), was retained for manual analysis. All detections with a probability greater than or equal to this threshold were first examined visually using spectrograms generated via the Python script described above. The detections deemed relevant at this stage were then systematically validated by listening to the corresponding signal using Audacity 3.7.1 software (Audacity Team, 2023). In Audacity, the spectrograms were configured on a linear scale, with a minimum frequency of 0 and a maximum frequency of 500 Hz, a window size of 8192 points, a Hann window, and a zero-padding factor of 2. Detections were only considered positive if the initial frequency of the *up-call* was ≤200 Hz. Calls starting above 250Hz were excluded as potentially non-attributable to NARW (main frequency support [50, 200 Hz]; Clark 1982a; Parks and Tyack 2005; Clark et al., 2010b; Gervaise et al., 2019).

An important issue in acoustic studies of NARWs has been to distinguish their vocalizations from those of humpback whales (Waite et al., 2003; Mellinger et al., 2007; Mussoline et al., 2012), and this was also the case in this study. Indeed, detection methods, whether automatic or manual, can be prone to errors in the presence of humpback whale vocalizations, which can produce *upsweeps* very similar to NARW *up-calls* (Mussoline et al., 2012). This issue is all the more important given that the presence of humpback whales has been confirmed in our study area, particularly at the two stations (Riou et al., 2025). Humpback whale vocalizations include a variety of frequency-modulated sounds, generally with stronger harmonics than NARW calls (Mellinger et al., 2007; Munger et al., 2008). These sounds occur frequently in regular sequences, even outside the breeding season, with repetitive patterns (Payne and McVay 1971) and inter-call intervals often between 3 and 5 seconds (Mellinger et al., 2007). Conversely, NARW *up-calls* are less often emitted in regular series, and when they are, these sequences are generally short-lived, with longer and more irregular intervals than those of humpback whales (Matthews et al., 2001; Vanderlaan et al., 2003; Mellinger et al., 2011). A rigorous analysis protocol, adapted from Mellinger et al., 2007, was therefore implemented during this manual verification stage in order to maximize the discrimination between the sounds produced by these two species. The criteria used to distinguish vocalizations included: i) the presence of repetitive acoustic patterns (Payne and McVay 1971); ii) more pronounced harmonics in humpback whales (Mellinger et al., 2007), iii) shorter and more stable periodicity (3-5s) of the acoustic sequences of humpback whales, as opposed to NARW *up-call* sequences, which generally have longer and more irregular periods (Mellinger et al., 2007), and iv) the co-occurrence of *gunshot* and *up-call* sounds in NARW (Clark 1982a, Parks and Tyack 2005). Thus, through careful auditory and visual analysis, we made cautious distinctions between the two species and excluded all uncertain calls from the analysis (Figure 17).

All false detections identified during manual validation protocol (first visual, then auditory) were excluded from the final dataset for each of two species for all three deployments.

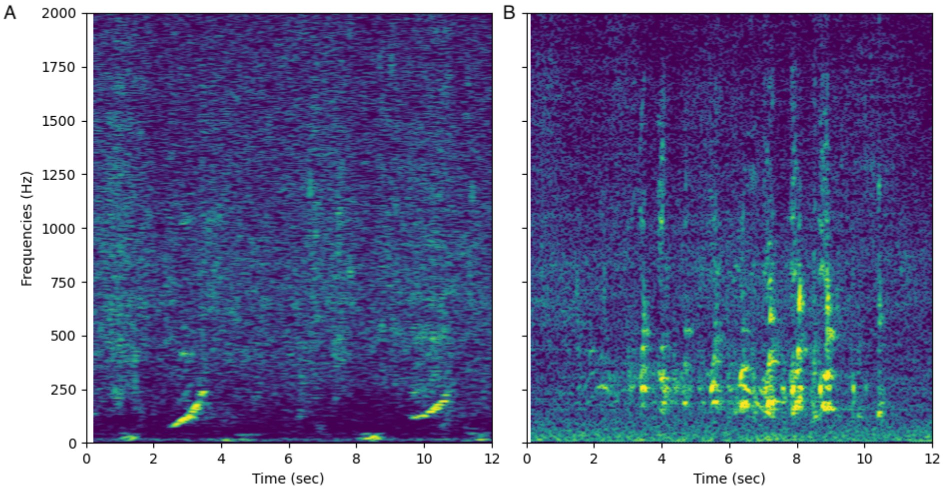

Figure 17. Examples of North Atlantic right whale *up-calls* (A) recorded on August 19, 2024, and humpback whale vocalizations (B) recorded on June 4, 2024, in Station 1 (Pointe verte). Spectrogram resolution of 3 Hz and 0.021 s.

2.3 Acoustic data statistical analysis

For each deployment (Station1-Campaign1; Station1-Campaign2; Station2-Campaign2; Table 1), the two-step protocol, deep learning CNN models and manual validation, yielded distinct datasets for humpback whales and NARW, reflecting acoustic detections confirmed after manual validation. Based on these results, final datasets were compiled for each species/deployment combination. These datasets include temporal information (time, day, month) and the number of 2-minute files with corresponding positive detections or no detections (assigned value of 0), enabling analysis of the spatio-temporal distribution of vocalizations of both species near the Gaspé coast. For each species across the three deployments, we calculated the total number of days with detections and the number of hours containing at least one acoustic detection. To assess whether deployment had a significant effect on the number of 2-minute files with detections, we used either a Kruskal-

Wallis (non-parametric data ; Kruskal & Wallis, 1952) test with Dunn's post-hoc correction (Dunn, 1964) or an ANOVA (parametric data ; Fisher; 1934) with Tukey's post-hoc test (Tukey, 1949), depending on data normality (Shapiro test; Shapiro & Wilk, 1965) and homogeneity of variance (Levene test; Levene, 1960).To investigate temporal variability at Station 1 off *Pointe Verte* (Station1-Campaign1 VS Station1-Campaign2) and spatial variability during Campaign 2 (Station1-Campaign2 VS Station2-Campaign2), several statistical tests were conducted. First, an exact Fisher's test (Fisher, 1922) was used to detect potential differences in the proportion of days with detections between the two campaigns (temporal) on the one hand and the two stations (spatial) on the other. Next, the proportion of hours with acoustic detections per day, defined as the number of hours with at least one acoustic detection divided by the total number of hours recorded per day (*i.e.*, 24 hours in this case), accounting for any variability in recording effort, was compared. Depending on data characteristics, a Mann-Whitney test (non-parametric data; Mann & Whitney, 1947) or a Student's t-test (Student, 1908) for independent samples (parametric data) was used, with a significance level set at α = 0.05.

For Station 1, detection data from both campaigns (Station1-Campaign1 & Station1-Campaign2) were combined to generate monthly heat maps per species, visualizing the temporal distribution of detections. Similarly, heat maps were generated for each species at Station2-Campaign2. This approach enabled the visualization of acoustic presence patterns with high temporal resolution (Stafford et al., 2021; Kowarski et al., 2022; Poupard et al., 2022). In order to analyse the temporal variability in acoustic detections at Station 1 off *Pointe Verte* (comparing Station1-Campaign1 and Station1-Campaign2), monthly statistical analyses were performed. We analysed two aspects: i) Acoustic presence: the number of hours with detections (including zero detections) was tested across months. Depending on data characteristics, either a Kruskal-Wallis test (non-parametric data ; Kruskal & Wallis, 1952; followed by Dunn's post-hoc test; Dunn, 1964) or an ANOVA (parametric data ; Fisher; 1934; followed by Tukey's post-hoc test; Tukey, 1949) was applied; ii) Acoustic intensity during presence: for periods with positive detections, the acoustic intensity was analysed across months, as the number of 2-minute files per positive hour. Again, depending on data characteristics, either a Kruskal-Wallis test (non-parametric data; Kruskal & Wallis, 1952; followed by Dunn's post-hoc test; Dunn, 1964) or an ANOVA (parametric data; Fisher; 1934; followed by Tukey's post-hoc test; Tukey, 1949) was used.

The detection calendar also allows diel and hourly variations in detections to be visualized. To better characterise acoustic presence patterns throughout the day, a diel profile analysis was carried out. For each species/deployment combination, a chi-square statistic was used to test for a significant difference between the observed number of detections at each hour and the expected number, equal to the total number of detections divided by 24-hours (adapted from Munger et al., 2012). A Generalized Linear Model (GLM; McCullagh, 2019) with a Poisson distribution was then fitted to model the number of acoustic detections recorded every two minutes (response variable) as a function of the time of day (continuous variable), the source (Deployment, station-campaign combination, categorical variable), and their interaction. This model allows us to evaluate both the main effects of time and deployment, as well as how the effect of time varies according to deployment. Diel trends in vocalization production were also studied by dividing the 24-hour day into five distinct periods based on local times during the deployment months in the Gaspé Peninsula. The hours chosen for these periods varied each day, which is why the time intervals were averaged to determine generalized start and end times for an average day in the Gaspé Peninsula during the summer season. To define representative diel periods, sunrise and sunset times were calculated for each day between May 31 and September 24, 2024, using the coordinates of Percé (48.2578°N, 64.2222°W) and the R package *suncalc* (v.0.5.1, Thieurmel & Elmarhraoui, 2017), which estimates solar positions and phases. The resulting daily values were then averaged to derive consistent temporal boundaries for each light phase throughout the summer monitoring period. These periods are defined as follows: Dawn (3:00 a.m. to 5:00 a.m.), Morning (5:00 a.m. to 12:00 p.m.), Afternoon (12:00 p.m. to 6:00 p.m.), Dusk (6:00 p.m. to 8:00 p.m.), Night (8:00 p.m. to 3:00 a.m.). This temporal classification allows us to analyse the distribution of vocalizations according to natural light phases and identify possible diel patterns in the acoustic presence of the species studied (*i.e.*, Ross-Marsh et al., 2022). To determine whether vocalizations varied significantly between these time periods, data from the three deployments were studied by species. Depending on data characteristics, either a Kruskal–Wallis test (Kruskal & Wallis, 1952) followed by Dunn's post-hoc test (non-parametric data; Dunn, 1964), or a one-way ANOVA (Fisher; 1934) followed by Tukey's post-hoc test (parametric data; Tukey, 1949) was applied (α = 0.05).

All statistical tests and plots (ggplot 2; Wickham 2016) were carried out in R studio version 4.4.1 (R Core Team 2024).

Table 6. Summary of acoustic monitoring deployments, recording parameters and species detections off the Gaspé Peninsula (summer 2024).

	Campagne 1	Campagne 2		Total
Deployment	Station1-Campaign1	Station1-Campaign2	Station2-Campaign2	
Location	*Pointe verte* North of Malbaie Bay	*Pointe verte* North of Malbaie Bay	Leander Shoal Off Cap d'Espoir	South coast of Gaspé Peninsula
Coordinate	48.60912°N, -64.17303°W	48.60912°N, -64.17303°W	48.39937°N, -64.33833°W	
Depth (m)	26 And 3 m above the seafloor	26 And 3 m above the seafloor	29 And 3 m above the seafloor	26-29
Recording period	May 31- June 19, 2024 20 days	August 02-September 24, 2024 54 days	August 02-September 24, 2024 54 days	74 days of continuous recording, including 54 days with two hydrophone stations, resulting in a total effort of 128 station-days.
Recording system	SoundTrap ST600 HF hydrophone	SoundTrap ST640 HF hydrophone	SoundTrap ST640 HF hydrophone	
Sampling rate (kHz)	128	128	128	128
Recording Data (Go and	426.81 Go	1.22 To	1.22 To	2.86 To
Recording time (Hours)	458	1,273	1,273	3,004
Recording 2-minute files	13,740	38,190	38,190	90,120
Number of 2-minute files with humpback whale detection	334	391	155	880
Number of 2-minute files with NARW detection	8	64	18	90

3. RESULTS

A total of 74 days of continuous recording were completed, including 20 days for Station1-Campaign1 and 54 days for Campaign 2 at Stations 1 and 2 simultaneously. This represents a cumulative sampling effort of 128 station days (Table 6). These recordings, spread over the three deployments (Station1-Campaign1, Station1-Campaign2 and Station2-Campaign2), enabled the collection of 3,004 hours of data, corresponding to 90,120 files of 2 minutes each, *i.e.*: 458 hours (426.81 Go ; 13,740 files) for Station1-Campaign1 and 1,273 hours (1.22 To; 38,190 files) for Station1-Campaign2; and 1,273 hours (1.22 To ; 38,190 files) for Station2-Campaign2; Table 6).

3.1 Humpback whale vocalization

Humpback whale vocalizations were detected during both acoustic monitoring campaigns using a two-step protocol combining deep learning (Ceta-CNNs model) and manual validation (example in Figure 17B). During Station1-Campaign1, 334 two-minute files (2.43%) contained humpback whale detections, 391 files (1.02%) for Station1-Campaign2 and 155 files (0.40%) for Station2-Campaign2 (Table 6). During the Station1-Campaign1 deployment, acoustic detections were recorded on 18 days (90%), or 151 hours (32.9%), with at least one acoustic presence of humpback whales. During Campaign 2, detections occurred on 49 days (91%) at Station 1 and 39 days (72%) at Station 2, corresponding to 223 hours (17.5%) and 110 hours (8.63%) respectively with at least one acoustic event. A Kruskal-Wallis test revealed a significant effect of deployment on the number of files with detections (Kruskal-Wallis test, N = 3007, $\chi^2 = 158.75$, $df = 2$, *p-value* $< 2.2 \times 10^{-16}$), indicating that detection distributions differ significantly between the three deployments (Shapiro test, N=3007, $W = 0.3819$, *p-value* $< 2.2 \times 10^{-16}$; Levene test, N=3007, $df = 2$, F *value* $= 86.2$, *p-value* $< 2.2 \times 10^{-16}$). Dunn's post hoc tests (Holm correction) confirmed significant differences between all pairs of deployments (N = 3007, *p.ajd* $< 10^{-9}$). To better understand these differences, a generalised linear model (GLM) was adjusted. It confirmed a significant effect of the different periods and sites across the three deployments. A significant decrease in the number of 2-minute files with detection was observed at both stations during campaign 2, respectively Station1-Campaign2 (β = -1.10) and Station2-Campaign2 (β = -2.02), compared to Station1-Campaign1. This corresponds to an estimated decrease of approximately 66% and 87% respectively (1-exp(β)*100). These results corroborate the existence of marked spatial and temporal variation. The effect of time and its interactions with deployment, an indicator of daily variations, are detailed in the Diels Trends section.

3.1.1 Temporal variability of Humpback whale acoustic detections at Station 1 (Pointe Verte North of Malbaie Bay)

A detailed comparison between campaigns 1 and 2 at Station 1 (*Pointe Verte*, north of Malbaie Bay) showed high and comparable proportions of days with acoustic detection of humpback whales, 90% and 91% respectively. A Fisher exact test revealed no significant difference in the proportion of days with detections between the two campaigns (N=74, *p-value* =1, *odds ratio* = 1.09, 95% CI [0.10-7.40]), indicating stable acoustic occurence. The proportion of hours with acoustic detection per day, defined as the number of hours with at least one detection divided by the total number of hours recorded per day, correcting for variations in recording between campaigns, was then compared. The median proportion of hours with detection was significantly higher in Campaign 1 (0.33 ; Shapiro test, N=20, *W = 0.95163, p-value = 0.3925*) than in Campaign 2 (0.17; Shapiro test, N=54, *W = 0.901, p-value = 0.0003069*), indicating greater acoustic presence during the first campaign (Mann-Whitney test, N= 74, *W*=765.5, *p-value*=0.006).

This monthly variability is illustrated in Figure18A. The detection schedule highlights periods of high acoustic presence, particularly in June. The period between 2 and 10 June 2024 corresponds to the most acoustically active phase of the two campaigns conducted at Station 1, with up to nine 2-minute files containing detections per hour (Fig 18A). In contrast, during the second campaign (August-September), no block of several consecutive days with acoustic presence as intense as that observed in June was recorded. However, a gradual increase in detections (daily and hourly) was observed from 10 September 2024 until the end of the deployment (Figure 18A). These observations are corroborated by monthly statistical analyses, showing significant normality testing (Shapiro test, $N = 1733$, $W = 0.45219$, $p < 2.2 \times 10^{-16}$) indicated that the data were not normally distributed, justifying the use of non-parametric tests. Accordingly, Kruskal-Wallis analyses revealed significant monthly differences in (1) the distribution of the number of hours with detections according to the month ($N=1733$, $\chi^2 = 64.38$, $df = 3$, *p-value* = $6.79\ 10^{-14}$) and (2) the acoustic intensity during humpback whales presence (the number of 2-minute files per positive hour ; $N=374$, $\chi^2 = 7.85$, $df = 3$, *p-value* = 0.049). Although the medians of the number of hours with detections were zero for the three months studied, the distribution differed significantly: June had a higher proportion of hours with acoustic detections, thus explaining the statistical difference observed between June and August; June and September (Dunn's post hoc tests with Holm correction; N=1733, *p-adj* < 0.001). This is also the case for September, which has a higher proportion of hours with acoustic detections than August (Dunn's post hoc tests, Holm correction; *p-ajd* < 0.001). Furthermore, the acoustic intensity in June is significantly higher than in August (Dunn's post hoc test; N=374, *p-ajd* = 0.038) but does not differ significantly from that in September (N=374, *p-ajd* = 0.797).

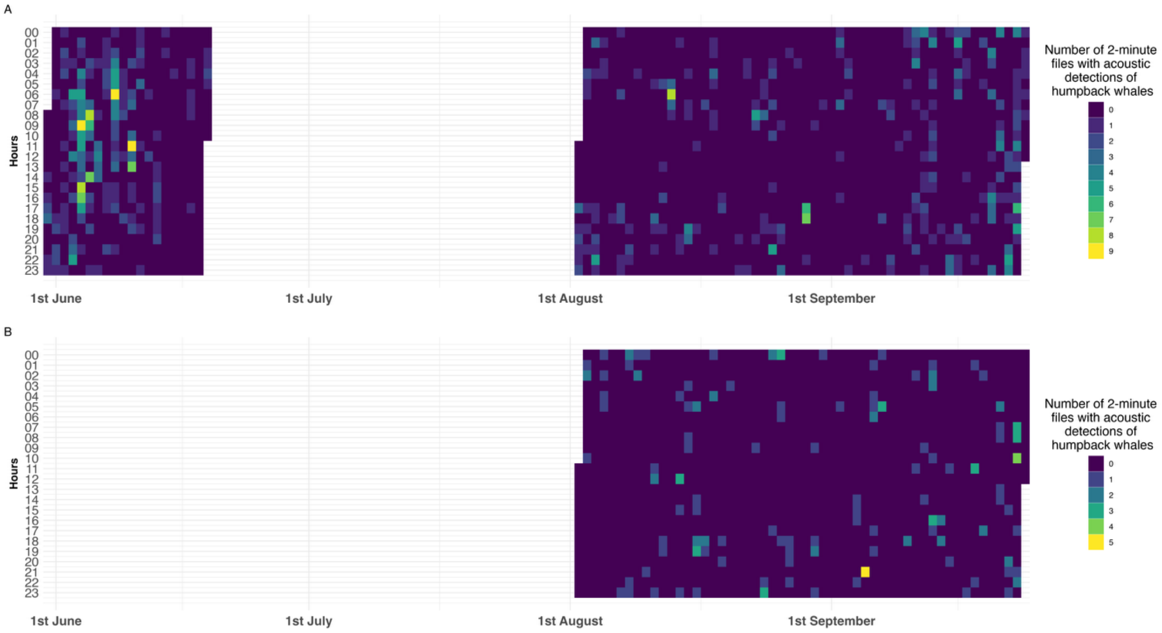

Figure 18. Schedule for acoustic detection of humpback whale vocalizations: (A) at Station 1 (off *Pointe Verte, north of Malbaie Bay)*, deployments Station 1-Campaign 1 (between 8 a.m. on 31 May 2024 and 10 a.m. on 19 June 2024) and Station 1-Campaign 2 (between 11 a.m. on 2 August 2024 and 12 p.m. on 24 September 2024) and (B) at Station 2-Campaign 2 (Leander Shoal off *Cap d'Espoir;* between 2 August 2024 at 11 a.m. and 24 September 2024 at 12 p.m.).

3.1.2 Spatial variability of Humpback whale acoustic detections during campaign 2 (Pointe Verte North of Malbaie Bay VS Leander Shoal Off Cap d'Espoir)

The two stations in Campaign 2 were also compared in detail. On a daily basis, the proportion of days with acoustic detection of humpback whales was significantly higher at Station 1 (91%) than at Station 2 (72%) during the second campaign (Fisher's exact test; N=54, *p-value* =0.02, *odds ratio* = 0.27, 95% CI [0.07-0.86]). The *odds ratio* of 0.27 indicates that on any given day, the probability of acoustic detection of humpback whales was approximately 3.7 times higher (1/*odds ratio*) at Station 1 than at Station 2. The proportion of hours with positive detection was also significantly higher at Station 1 (median

= 0.17; Shapiro test, N=54, *W = 0.901, p-value = 0.0003069*) than at Station 2 (median = 0.08; Shapiro test, N=54, *W = 0.88125, p-value = 6.804e-05*) during campaign 2 (Mann-Whitney test, N=108, *W*=2025, *p*=0.0004). This difference highlights a marked spatial variability in acoustic presence, as illustrated in Figure 18A and Figure 18B. The detection schedule reveals more sustained activity at Station 1 than at Station 2 (Figure 18). From 10 September onwards, an intensification of acoustic presence was observed at Station 1 (Figure 18A), spread throughout the day. In comparison, detections at Station 2 were more irregular (Figure 18B).

3.1.3 Diels Trends of Humpback whale vocalizations

Chi-square tests revealed a significantly non-uniform hourly distribution of detections for all deployments (Table 7). These results indicate marked diel variations in acoustic presence for the three deployments. The GLM model confirms a significant effect of time for Station1-Campaign 1, with a negative coefficient ($\beta = -0.014$), indicating a gradual decrease in the detection rate over the course of the day (Table 7; Figure 19A). Conversely, the interactions between time and the two deployments in Campaign 2 reveal the opposite dynamic: positive coefficients for Station1-Campaign2 ($\beta = 0.021$) and Station2-Campaign2 ($\beta = 0.021$) suggest an increase in detections during the day (Table 7; Figure 19B; Figure 19C). This reversal of trend also reflects variability in daily rhythms depending on deployment. The model's residual deviance (3222) was lower than the null deviance (3598), explaining a significant portion of the data variability. A moderate AIC value (4381) indicates a satisfactory fit and a reasonable trade-off between model complexity and goodness of fit, supporting the model's adequacy.

Table 7. Summary of statistical test results for Humpback whale diel variation analyses (ns = not significant).

Test	Station Campaign	N	Test statistic	df	*p-value*	β / Post hoc	Direction & Trend
Chi-square	Station1 Campaign1	24	$\chi^2 = 61.6$	23	< 0.001		Non-uniform
Chi-square	Station1 Campaign2	24	$\chi^2 = 69.6$	23	< 0.001		Non-uniform
Chi-square	Station2 Campaign2	24	$\chi^2 = 36.5$	23	0.036		Non-uniform
GLM (time)	Station1 Campaign1	24			< 0.001	$\beta = -0.014$	Decrease through day
GLM (time×station)	Station1 Campaign2	24			< 0.001	$\beta = +0.021$	Increase through day
GLM (time×station)	Station2 Campaign2	24			< 0.001	$\beta = +0.021$	Increase through day
Shapiro test	Station1 Campaign1	24	W = 0.95	4	0.2885		ns
Levene test		24	F = 0.41	4	0.7986		ns
ANOVA		24	F = 19.04	4	< 0.001	Significant Tukey	Morning > others
Shapiro test	Station1 Campaign2	24	W = 0.93	4	0.0945		ns
Levene test		24	F = 0.50	4	0.7326		ns
ANOVA		24	F = 2.86	4	0.052	ns Tukey	Dusk > others (trend)
Shapiro test	Station2 Campaign2	24	W = 0.90	4	0.0212		Significant
Levene test		24	F = 0.53	4	0.7147		ns
Kruskal-Wallis		24	$\chi^2 = 9.98$	4	0.041	Dunn with Holm correction(ns)	Dusk/night > others (trend)

An analysis of variance (ANOVA ; Table 7) revealed a significant effect of the period of time on the number of 2-minute files containing at least one acoustic detection at Station 1 during the first campaign (Station1-Campaign1; Table 7; Figure 19A), whereas no significant variation was observed during the second campaign at the same station (Station1-

Campaign2; Table 7; Figure 19B). At Station2-Campaign2, Kruskal-Wallis non-parametric analysis indicates a globally significant effect of the time of day on the number of 2-minute files with detection (Table 7; Figure 19C). For Station1-Campaign1, acoustic presence is highest in the morning (*mor* ; mean of 19.3 2-minute files), followed by dawn (mean of 17.0 2-minute files ; Tukey's *diff mor* = –10.57, *p-value* = 0.0025), afternoon (mean of 16.5 2-minute files, Tukey's *diff mor* = –10.07, *p-value* < 0.001), dusk (mean of 10 2-minute files, Tukey's *diff mor* = 9.29, *p-value* = 0.0082) and night (mean of 6.4 2-minute files, Tukey's *diff mor* = –12.86, *p-value* < 0.001). These results confirm that acoustic presence was significantly highest in the morning, with a pronounced decline towards dusk and night (Figure 19A). In contrast, Station1-Campaign2 (morning: mean of 14; dawn: 17; afternoon: 11; dusk: 25; night: 19.9 2-minute files) and Station2-Campaign2 (morning: mean of 5.7; dawn: 4.5; afternoon: 4.3; dusk: 11; night: 8.3 2-minute files) showed trends towards higher acoustic presence at the end of the day, in dusk and night, although these differences were not statistically significant (Table 7; Figure 19B; Figure 19C). Overall, these results indicate a shift in diel patterns between campaigns, with acoustic presence significantly concentrated at the start of the day in Campaign 1 and a tendency towards increased presence later in the day in Campaign 2 (Table 7; Figure 19A; Figure 19B; Figure 19C).

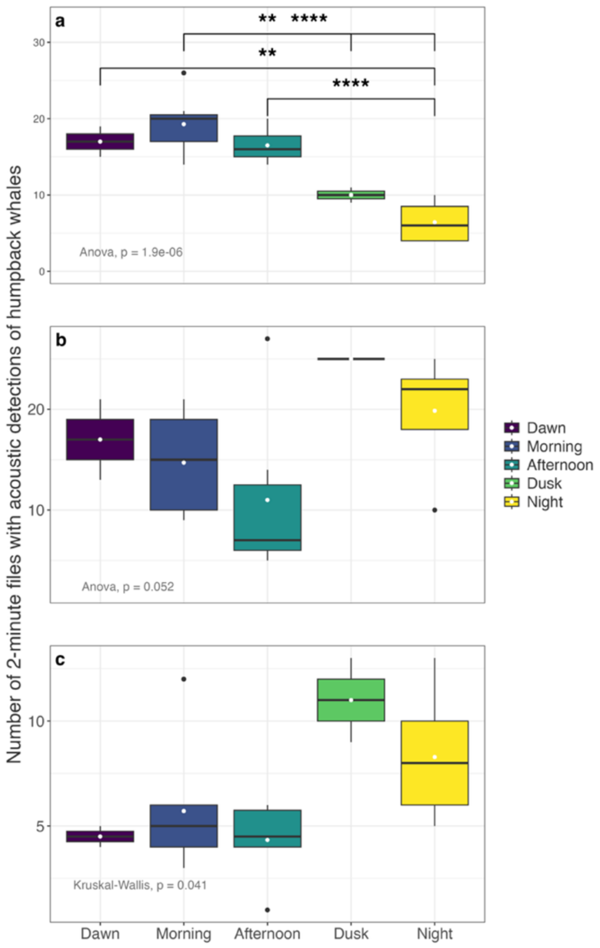

Figure 19. Box plot of the number of 2-minute files with humpback whale vocalization detection, depending on deployment: (A) Station 1-Campaign 1, (B) Station 1-Campaign 2, (C) Station 2-Campaign 2 and the period of day. The thick lines in the middle indicate the median values, the white dots indicate the mean, the upper and lower lines of the boxes encompass the dispersion of data from the first to the third quartile, and the upper and lower horizontal bars indicate the minimum and maximum sizes of the groups, except in the presence of outliers (black dots). Significant differences are indicated by ** ($p < 0.01$), **** ($p < 0.0001$).

3.2 NARW *up-calls*

NARW *up-calls* were detected during both campaigns, thanks to the application of a strict two-step protocol combining a deep learning model ("*NARW_detection_tool*") and manual validation (detections through visual inspection and auditory validation; example in Figure 17A). Only eight files of 2 minutes (0.058%) contained detections of NARW *up-calls* during deployment Station1-Campaign1, 64 (0.17%) Station1-Campaign2 and 18 (0.047%) Station2-Campaign2 (Table 6). NARW *up-calls* were recorded on five days (25%), at six distinct hours (1.31%) with at least one acoustic event during Station1-Campaign1 deployment. During campaign 2, detections occurred on 18 days (33.33%) at Station 1 and 13 days (24%) at Station 2, corresponding to 45 hours (3.53%) and 17 hours (1.33%) respectively with at least one NARW acoustic presence. The distributions of the number of 2-minute files with detections differed significantly between the three deployment (Kruskal-Wallis test, N=3007, χ^2 = 16.368, *df* = 2, *p-value* = 0.0003; Shapiro test, N=3007, *W = 0.082555*, *p-value* $< 2.2 \times 10^{-16}$; Levene test, N=3007, *df = 2*, *F value = 8.65*, *p-value =0.0001787*). Dunn's post hoc tests (Holm correction) confirmed significant differences between the two deployments of Station 1 (Station1-Campaign1 and Station1-Campaign 2, Dunn test, N=3007, *p.ajd* = 0.01) and between the two Stations in campaign 2 (Station1-Campaign2 and Station2-Campaign2, Dunn test, N=3007, *p.ajd* = 0.0005). The GLM model confirmed the significant effect of the different periods and sites of the three deployments (Station1-Campaign1, Station1-Campaign2, and Station2-Campaign2) on the number of 2-minute files with detections. Compared to Station1-Campaign1 (model reference), there was an 85% increase in the number of 2-minute files with detections for Station1-Campaign2 (β = 0.614). Conversely, deployment at Station 2 during Campaign 2 showed a 42% decrease in the number of 2-minute files with detections (β = -0.546). All of these results confirm the existence of spatial and temporal variation in the acoustic presence of NARW in the form of *up-calls*. As with the analysis of humpback whale vocalizations, the effect of time and its interactions with deployment, an indicator of daily variations, are detailed in the Diels Trends section.

3.2.1 Temporal variability in NARW up-call detections at station 1 (Pointe Verte North of Malbaie Bay)

At Station 1, a comparison of campaigns 1 and 2 revealed low proportions of days with detection of NARW *up-calls* (25% and 33%, respectively). Fisher's exact test did not show a significant difference between these two campaigns (N=74, *p-value* = 0.58, *odds ratio* = 1.49, 95% CI [0.42-6.09]), suggesting that, despite a possible increase in acoustic presence (1.5 times more likely to be detected in campaign 2; 1/*odds ratio*), this trend cannot be statistically confirmed due to the low occurrence of detections. The median proportion of hours per day with detection of *up-calls* was also very low (close to 0) in both campaigns (Campaign 1: Shapiro test, N=20, $W = 0.58292$, $p\text{-value} = 1.969e^{-06}$; Campaign 2: N=54, Shapiro test $W = 0.64093$, $p\text{-value} = 3.094e^{-10}$). This low occurrence limited the statistical power of the comparisons, and the Mann-Whitney test revealed no significant difference (Mann-Whitney test, N=74, *W*=468, *p-value* =0.29).

Figure 20A reveals monthly variability in acoustic presence, with periods of more intense detection. The most active phase of both campaigns at Station 1 was from 12 to 31 August, when up to 13 two-minute files contained at least one NARW *up-call*. In June, detections of *up-calls* were very limited and sporadic, occurring during only six distinct hours (over the entire deployment) when at least one acoustic presence was recorded. Similarly, detections were also minimal to absent between 1 and 24 September, the end date of the deployment. These observations are corroborated by monthly statistical analyses, demonstrating significant differences in the distribution of the number of hours with detections by month (Kruskal Wallis test; N=1733, $\chi^2 = 30.84$, $df = 3$, *p-value* =$9.19\text{x}10^{-7}$; Shapiro test, N=1733, $W = 0.1026$, $p\text{-value} < 2.2e^{-16}$). Although the medians of the number of hours with detections were zero for the three months studied, the distribution differed significantly: August had a higher proportion of hours with NARW *up-call* detections. This explains the significant differences observed between August and June (Dunn's post hoc tests with Holm correction; N=1733, *p-adj* < 0.001) and August and September (Dunn's post hoc tests with Holm correction; N=1733, *p-adj* < 0.00001).

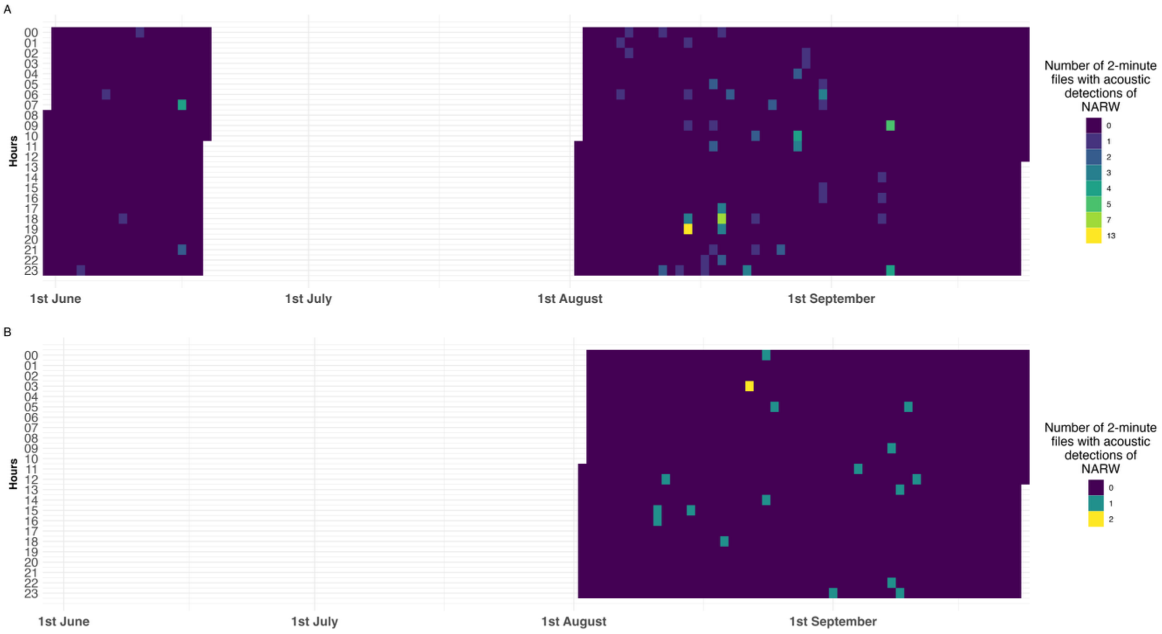

Figure 20. Schedule for acoustic detection of NARW *up-calls*: (A) at Station 1 (off *Pointe Verte, north of Malbaie Bay)*, deployments Station 1-Campaign 1 (between 8 a.m. on 31 May 2024 and 10 a.m. on 19 June 2024) and Station 1-Campaign 2 (between 11 a.m. on 2 August 2024 and 12 p.m. on 24 September 2024) and (B) at Station 2-Campaign 2 (*Leander Shoal Off Cap d'Espoir;* between 2 August 2024 at 11 a.m. and 24 September 2024 at 12 p.m.).

3.2.2 Spatial variability in NARW up-calls detected during campaign 2 (Pointe Verte North of Malbaie Bay VS Leander Shoal Off Cap d'Espoir).

No significant difference was observed in the proportion of days with detection of NARW *up-calls* between the two stations in campaign 2 (Fisher's exact test, N=54, *p-value* = 0.40; *odds ratio* = 0.64, 95% CI [0.25–1.59]). Although this result is not statistically significant, this *odds ratio* indicates a trend towards a higher daily detection frequency at Station 1 (33% of days with detection, approximately 1.56 times more likely; 1/*odds ratio*) compared to Station 2 (24% of days with detection). A non-parametric Wilcoxon test was used to compare the distributions of the proportions of hours with NARW *up-call* detections at Station 1 (Shapiro test, N=54, $W = 0.901$, $p\text{-value} = 0.0003069$) and Station 2 (Shapiro test, $W = 0.88125$, $p\text{-value} = 6.804e^{-05}$) during campaign 2. Although the test did not show a statistically significant difference (N=108, $W = 1762$, $p\text{-value} = 0.061$), the p-value close to the significance threshold (0.05) suggests a trend towards spatial variation in acoustic presence between the two stations. The detection schedule for campaign 2 reveals more sustained acoustic presence at Station 1 than at Station 2 (Figure 20A & Figure 20B). Specifically, Station 2 recorded a maximum of only two 2-minute files with detections per hour (once on 22 August 2024), while Station 1 recorded up to 13 per hour (Figure 20A & Figure 20B). Overall, Station 1 thus recorded a globally higher number of detections than Station 2 (Figure 20A & Figure 20B).

3.2.3 Diels Trends of NARW up-calls

As with the study of humpback whale vocalizations, the detection schedule can be used to visualise diel and hourly variations in detections. In order to better characterise acoustic presence patterns throughout the day, where appropriate, a diel profile analysis was carried out. Chi-square tests revealed a significantly non-uniform hourly distribution of detections for Station1-Campaign1 and Station1-Campaign2 (Table 8). In contrast, the Station2-Campaign2 deployment demonstrated a uniform hourly distribution of NARW *up-call* detections (Table 8). The GLM model confirms a significant effect of time on the detection rate for Station1-Campaign1 and Station1-Campaign2, with positive coefficients (β=0.0045 and β=0.047, respectively). This suggests a slight increase in the detection rate during the day for these deployments (Figure 21A & Figure 21B). The model's residual deviance (921.5) was lower than the null deviance (995.3), explaining a significant portion of the data variability. A moderate AIC value (1092) provides an index of model fit that, while not interpretable in absolute terms, suggests a reasonable trade-off between model complexity and goodness of fit, supporting the adequacy of the model.

Table 8. Summary of statistical test results for North Atlantic right whale diel variation analyses (ns = not significant).

Test	Station Campaign	N	Test statistic	df	*p-value*	β / Post hoc	Direction & Trend
Chi-square	Station 1 Campaign 1	24	$\chi^2 = 47.6$	23	< 0.002		Non-uniform
Chi-square	Station 1 Campaign 2	24	$\chi^2 = 100.04$	23	1.38×10 −11		Non-uniform
Chi-square	Station 2 Campaign 2	24	$\chi^2 = 19.33$	23	0.68		Uniform
GLM (time)	Station 1 Campaign 1	24			< 0.001	β = +0.0045	Increase through day
GLM (time×station)	Station 1 Campaign 2	24			< 0.001	β = +0.047	Increase through day
Shapiro test	Station 1 Campaign 1		W = 0.52		*$9.255e^{-08}$*		Significant
Levene test		24	F = 0.62		0.6625		ns
Kruskal-Wallis			$\chi^2 = 4.09$	4	0.39		ns
Shapiro test	Station 1 Campaign 2	24	W = 0.82	4	0.000628		Significant
Levene test		24	F = 0.62	4	0.6519		ns
Kruskal-Wallis		24	$\chi^2 = 11.19$	4	0.02	Dunn with Holm correction	Dusk > others
Shapiro test	Station 2 Campaign 2	24	W = 0.778	4	0.0001		Significant
Levene test		24	F = 0.21	4	0.9266		ns
Kruskal-Wallis		24	$\chi^2 = 2.77$	4	0.60		ns

A non-parametric Kruskal-Wallis analysis revealed a significant effect of the period of day on the number of 2-minute files containing at least one detection of *up-calls* at Station1-Campaign2 (Table 8; Fig 21B). The Dunn post hoc test, with Holm correction, revealed significantly higher acoustic presence at dusk than afternoon (N=24, *diff* = -2.93, *p-adj* = 0.03; Fig 21B). On average, acoustic presence was therefore significantly higher at dusk (mean of 14 2-minute files) than in the morning (mean of 4.4 2-minute files), at night (mean of 3.57 2-minute files), at dawn (mean of 1.5 2-minute files) or in the afternoon (mean of 1.17 2-minute files). These results confirm a trend toward a concentration of NARW vocal contact presence at the end of the day during the second campaign at Station 1 (Table 8; Figure 21B). However, no significant differences were detected regarding the period of day for the other two deployments: Station 1-Campaign 1 (Table 8*;* Figure 21A) and Station 2-Campaign 2 (Table 8; Figure 21C). The absence of a statistically significant diel trend for these deployments is probably due to the very low occurrence of detections rather than actual uniformity. Nevertheless, at Station1-Campaign1, the average detections were mostly observed in the morning (mean of 0.7 2-minute files), followed by at night (mean of 0.57 2-minute files), at dusk (mean of 0.5 2-minute files), and no detections at dawn and in the afternoon. At Station2-Campaign2, average detections of *up-calls* were mainly recorded in the afternoon (mean of 1.17 2-minute files), followed by dusk (mean of 1 2-minute files 1 file), night (mean of 0.57 2-minute files), morning (mean of 0.57 2-minute files) and finally dawn (mean of 0.50 2-minute files).

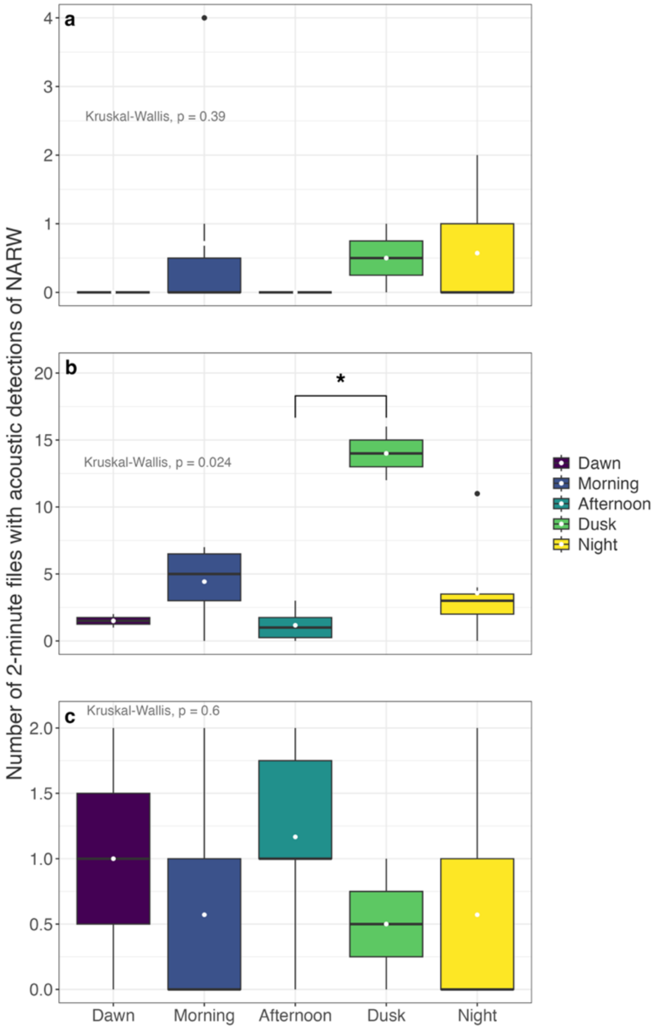

Figure 21. Box plot of the number of 2-minute files with NARW *up-calls* detection, depending on deployment: (A) Station1-Campaign1, (B) Station1-Campaign2, (C) Station2-Campaign2 and the period of day. The thick lines in the middle indicate the median values, the white dots indicate the mean, the upper and lower lines of the boxes encompass the dispersion of data from the first to the third quartile, and the upper and lower horizontal bars indicate the minimum and maximum sizes of the groups, except in the presence of outliers (black dots). Significant differences are indicated by * ($p < 0.05$).

4. DISCUSSION

This study used Passive Acoustic Monitoring (PAM) to analyze the occurrence and vocalization patterns of humpback whales and NARW in the southern Gaspé Peninsula coastal area. Our results complement those of Riou et al., (2025), obtained through visual surveys and behavioral studies in the lobster fishing zone, providing a more detailed understanding of the spatio-temporal presence of these two species. Although PAM is a valuable data collection tool, its inherent limitations must be considered when interpreting acoustic presence as an indicator of actual animal presence. Even though the detectability of humpback whale vocalizations and NARW *up-calls* was maximized through a robust two-step protocol (pre-trained CNNs model and manual validation), we interpret our results here as indicating the minimum presence of both species, as the absence of vocalizations does not mean that the animals are absent, in fact individuals may be silent, undetected by our instruments, or masked by ambient noise.

4.1 Humpback whale minimum presence

Our recordings revealed a significant acoustic presence of humpback whales near the southern Gaspé coast during late spring and summer 2024, with regular detections during the three deployments of the two campaigns. Although the songs are typical of males in breeding areas, non-song vocalizations (produced by all sexes and ages) and song fragments, or even complete songs, are also recorded during migration (Clapham and Mattila 1990; Norris et al., 1999) and in high latitude feeding areas (McSweeney et al., 1989; Clark and Clapham 2004; Vu et al., 2012; Kowarski et al., 2018). Like Delarue et al. (2022), the high number of days with detections in our three deployments, despite the absence of manually identified complete songs, confirms the ability of a robust protocol to detect the minimum presence of humpback whales via non-song vocalizations or song fragments (*i.e* Kowarski et al., 2019; Delarue et al., 2022; Ross-Marsh et al., 2022).

The coastal presence of humpback whales is well established both visually and acoustically (Clapham 2000; Delarue et al., 2022; DFO 2024; Riou et al., 2025). Their vocalizations, detectable at distances of 3 to 100 km in summer off Nova Scotia (Kowarski et al., 2018) and up to about 50 km on average annually in eastern Canada (Delarue et al., 2022), have a more limited range than those of blue or fin whales (Delarue et al., 2022; The data were captured by autonomous multichannel acoustic recorders, AMARs, JASCO Applied Sciences - moored 55 m above the seafloor at depths of 1,400 to 1,900 m for Kowarski et al., 2018, and moored at depths of 44 to 2,002 m for Delarue et al., 2022). This confirms the relevance of our acoustic detections in confirming the coastal presence of humpback whales. A six-year study in the Gaspé lobster fishing zone, including our stations 1 and 2, had already demonstrated this occurence through presence and behavioral data (Riou et al., 2025). Our results reinforce and complement this research by confirming a significant daily acoustic detection of humpback whales near the southern Gaspé coast in June, August, and September 2024. Our results also reveal marked spatio-temporal variation in the acoustic presence of humpback whales in the study area. Detection rates were highest at Station1-Campaign1, decreasing significantly during the second campaign (Station1-Campaign2 and Station2-Campaign2). Statistical tests (Kruskal-Wallis, Dunn post hoc) and the GLM model confirm this trend, quantifying an estimated decrease of 66% for Station1-Campaign2 and 87% for Station2-Campaign2 compared to the first campaign. This suggests that the period and location of deployment influence the probability of acoustic detection of humpback whales. Spatio-temporal variability was also observed on a large scale in the marine protected area of the St. Anne's Bank (GSL outlet; DFO 2024), in Nova Scotia and in the Bay of Fundy (Kowarski et al., 2019), as well as in the study conducted by Delarue et al., (2022) in eastern Canadian waters.

4.1.1 Spatio-temporal variation of Humpback whale acoustic detections in the Gaspé coastal zone

At station 1 (*Pointe Verte*), both campaigns showed very high and comparable proportions of days with acoustic detection (90% and 91%), confirming a stable acoustic occurrence. However, the proportion of hours with detection per day was significantly higher in campaign 1, illustrating more intense presence (Figure 18). Monthly analyses revealed that June 2024 stands out with a higher proportion of hours and greater acoustic intensity compared to August and September 2024. This is consistent with Riou et al., (2025), who documented a significantly higher presence of cetaceans, including humpback whales, in June in the south Gaspé coastal area. This concentration can be explained by the increased availability of prey such as capelin and other forage fish, favoured by their spawning (Gagnon et al., 1997; Johnson 2018; McQuinn et al., 2012; Riou et al., 2025). Capelin abundance is also a key factor explaining a significant portion of the variation in humpback whale numbers in an eastern Canadian coastal area (Piatt et al., 1989). Although humpback whales are rarely observed in this lobster fishing area, they were spotted exclusively in June 2022 and 2024, highlighting the importance of this period (Riou et al., 2025). Our records in June 2024 corroborate these visual observations and reinforce the link between temporal variations in area use and resource availability (Clapham 2000; Riou et al., 2025). Beyond the food aspect, June marks the peak arrival of humpback whales in the GSL. The Gaspé Peninsula could be a migratory stopover (Lesage et al., 2007; McQuinn et al., 2015; Faille et al., 2019; Riou et al., 2025) before they move on to other recognized feeding areas such as the head of the Laurentian Channel in the St. Lawrence Estuary (DFO 2022; Martins et al., 2022), the Strait of Jacques Cartier, the Mingan Islands, and the Anticosti Basin (Ramp et al., 2010, 2015; Comtois et al., 2010), or even further north in the Strait of Belle Isle (Lesage et al., 2007; Delarue et al., 2022).

During the second campaign (August and September 2024), despite a comparable daily occurrence, there was not as much acoustic presence as in June 2024 (Figure 18). This is probably due to the majority of humpback whales moving northward in the GSL to reach their main feeding grounds. This migration is confirmed by peaks in observations in July and August in key areas such as the Strait of Jacques Cartier, the Mingan Islands, and the Anticosti Basin (Comtois et al., 2010; Ramp et al., 2015), as well as at the head of the Laurentian Channel in the St. Lawrence Estuary (DFO 2022; Martins et al., 2022). Furthermore, significant differences in acoustic presence during this second campaign reinforce this observation: the probability of detection was 3.7 times higher at *Pointe Verte* (Station1-Campaign2, north) than at Leander Shoal (Station2-Campaign2, south), illustrating spatial variability.

A gradual increase in detections (daily and hourly) was observed starting on September 10, 2024, with acoustic presence statistically comparable to that of June 2024. This high presence at the end of the summer season at Station 1 indicates a significant presence of humpback whales near the Gaspé Peninsula. This phenomenon could be explained by the departures observed at the end of August from the Strait of Jacques Cartier (Ramp et al., 2015) and in September from the St. Lawrence Estuary (DFO 2022; Martins et al., 2022). Another explanation is the training of adult males before their migration to breeding grounds (Clark and Clapham 2004; Kowarski et al., 2019) and/or juveniles learning to sing, both of which produce song fragments (Herman et al., 2013; Kowarski et al., 2019), as observed in our recordings during this period. This behavior has been documented in September and autumn in the Bay of Fundy (Kowarski et al., 2019) and the northwestern Atlantic (Kowarski et al., 2022). Longer deployments would undoubtedly have allowed the evolution of these fragments into regular songs to be observed (Kowarski et al., 2019, 2022).

The spatial variability between stations 1 and 2 was marked during the second campaign with station 1 (*Pointe Verte*) showing a probability of detecting humpback whales up to 3.7 times higher than station 2 (Leader shoal). These results corroborate those of Riou et al. (2025) and can be explained by the proximity of the Ecologically and Biologically Significant Areas (EBSAs) of Gaspé and the American Bank Marine Protected Area (Lesage et al., 2007; Faille et al., 2019; ROMM 2019). These areas, rich in megafauna and providing essential nutritional functions, are crucial passageways and feeding grounds for humpback whales (Lesage et al., 2007; McQuinn et al., 2015; Faille et al., 2019). It is possible that station 2 would also have recorded numerous detections in June, as the Leader shoal is an important observation area (Riou et al., 2025) due to its physical characteristics that favour food accumulation (Gagnon et al., 1997; Correia et al., 2021).

4.1.2 Diels Trends of Humpback whale acoustic detections in the southern Gaspé coastal zone

Our results highlight a marked intraday variation in the acoustic presence of humpback whales in the southern Gaspé Peninsula. The first campaign at station 1 revealed greater presence early in the day, gradually decreasing thereafter. Conversely, the two deployments of the second campaign showed a trend toward increased presence at the end of the day, characterized by more acoustic detections at dusk and at night. This reversal in the diel acoustic rhythm between late spring and summer suggests a change in behavior among humpback whales. In June 2024, humpback whales were frequently observed feeding in the morning and early afternoon (Riou et al., 2025). An abundance of prey throughout the day, as observed in June, could explain the diel acoustic presence, which is potentially linked to feeding and social cohesion for hunting (Cerchio & Dahlheim, 2001; Vu et al., 2012; Johnson, 2018). In contrast, the reversal of diel patterns during the second campaign could be explained by a decline in summer food resources (Gagnon et al., 1997; McQuinn et al., 2012). This scarcity would encourage whales to adapt their behavior, focusing on nocturnal hunting, as many prey species are known to display diel vertical migrations, rising to the surface at night (Blaxter 1965; Simmard 1986; Davoren et al., 2006; Jansen et al., 2019). Furthermore, this trend could also be linked to our hypothesis that adult and juvenile males produce song fragments in September. Kowarski et al., (2019) noted that humpback whale vocalizations (songs or song fragments) are more frequent at night in the Bay of Fundy. This pattern of nocturnal vocalization has also been observed off Nova Scotia (Kowarski et al., 2018), in the Gulf of Maine (Huang et al., 2016), during migration (Ross-Marsh et al., 2022), and in breeding areas (Au 2000; Cholewiak 2008; Sousa-Lima 2008; Cerchio et al., 2014), thus suggesting that this is a characteristic of humpback whale acoustic behavior, independent of season or location (Kowarski et al., 2019).

4.2 NARW minimum presence

Our recordings revealed low acoustic presence of NARWs near the southern Gaspé coast during late spring and summer, with few detections during the three deployments of the two campaigns, compared to humpback whales. Less than 1% of the two-minute files contained *up-calls*, stereotypical vocalizations essential for NARW communication (Clark 1982a, Parks & Tyack 2005, Parks et al., 2009, 2011, Trygonis et al., 2013; Simard et al., 2019), suggesting that these whales may have been absent or present but acoustically silent. The study by Riou et al. (2025) confirms our low acoustic detections of NARW, having recorded no observations of these whales in the southern Gaspé lobster fishing area, although it should be noted that individuals may be silent, and/or that vocalizations may not have been detected by our instruments, or may have been masked by ambient noise. The proportion of days with at least one detection ranged from 24% to 33%. These figures are comparable to those observed by Simard et al. (2024) in the GSL, including off the southern coast of Gaspé. Although *up-calls* can be detected up to 10 km away in urbanized areas (such as ports, areas with high concentrations of humans activity, as is the case in the north of the American continent, Clark et al., 2010b; Simard et al., 2019), or up to 35 km according to Simard et al., (2019), for hydrophones off *Percé* and *Cap d'Espoir*, this relatively limited range suggests the presence or at least coastal passage of NARWs near the southern Gaspé Peninsula (the data were captured by autonomous underwater recorder, AURAL-M2, Multi-Electronique - was deployed ~5−50 m off the bottom; Simard et al., 2019). The low detection rate is probably due to their concentration in the main feeding areas, located in the Shediac Valley, south of our study area, and then northwest of Anticosti Island, further north (DFO 2020; Crowe et al., 2021; Gavrilchuk et al., 2021; Tao et al., 2023; Simard et al., 2024). Despite this low overall detection rate, we were able to identify spatial and temporal variation. Station 1 (*Pointe Verte*) showed more detections during the second campaign, and within this campaign, more detections than at station 2 (Leander shoal). Statistical tests (Kruskal-Wallis, Dunn post hoc) and the GLM model confirm this trend, quantifying, for example, an estimated increase of 85% compared to the first campaign. This highlights that the probability of acoustic detection of NARWs strongly depends on the period and location, a spatio-temporal variability also observed on a larger scale in the GSL (Simard et al., 2024; DFO 2024) and eastern Canada (Delarue et al., 2022).

4.2.1 Spatio-temporal variation of acoustic NARW detections in the southern Gaspé coastal zone

At station 1, *up-calls* were 1.5 times more likely to be detected during the second campaign, highlighting the temporal variability in acoustic presence. This observation is consistent with the two waves of NARW arrivals in the GSL: a first wave in late May-early June, concentrated in the southwest (Crowe et al., 2021; Simard et al., 2024), explaining our low sporadic detections in June 2024; and a second from mid-July to mid-August (Simard et al., 2024). We noted a peak in acoustic presence at the same station in August 2024, with a significantly higher proportion of hours with *up-calls* than in June and September 2024, illustrating more intense acoustic presence. This seasonal pattern, peaking between mid- and late August 2024, is consistent with previous visual and acoustic studies in the GSL (Crowe et al., 2021; Simard et al., 2024) and off the southern Gaspé Peninsula (Simard et al., 2024). The observations of Crowe et al., (2021) show a geographical progression of NARWs across the GSL from June to October, with an expansion of their area of use from the southwest to the northwest. This peak therefore suggests that whale's transit near the peninsula when moving between their main feeding grounds in the southwest GSL (Shediac Valley) and northwest of Anticosti Island (Crowe et al., 2021; Gavrilchuk et al., 2021; Simard et al., 2024). This hypothesis is reinforced by the spatial difference observed during the second campaign, where *up-calls* were 1.6 times more likely at station 1 (*Pointe Verte* to the north) than at station 2 (Leander Shoal, to the south), and acoustic presence was significantly more sustained. Station 1 is indeed located closer to the potential migration corridor of NARWs to Anticosti, a phenomenon already noted by Simard et al., (2024) with higher detections off Percé (near *Pointe-Verte*, Station 1) than off *Cap d'Espoir* (Leander Shoal, Station 2). In September 2024, our detections were very low or even absent at both stations. This may be explained by a reduction in inter-zone movements as NARWs establish themselves in their main feeding areas (Crowe et al., 2021; Gavrilchuk et al., 2021; Meyer-Gutbrod et al., 2023; Sorochan et al., 2023).

4.2.2 Diels Trends of NARW acoustic detections in the southern Gaspé coastal zone

Diel trends were observed among NARWs in southern Gaspé. During both campaigns at station 1, more pronounced acoustic presence was recorded at the end of the day, with a significant increase in *up-calls* at dusk during the second campaign. This peak in dusk presence has also been reported in other studies on right whales, notably by Mussoline et al. (2012) for NARW in the Wilkinson Basin, Jacobs et al. (2022) for the Southern Right Whale population in the southeastern Pacific, and Webster et al., (2019) for the same species but in the sub-Antarctic area near the Auckland Islands. This increase could indicate that NARW feed during the day, when they vocalize very little or not at all (Parks et al., 2012; Simard et al., 2019; Jacobs et al., 2022), as observed in other baleen whales such as the blue whale (Stafford et al., 2005; Oleson et al., 2007; Matthews et al., 2014). Dusk, when prey disperses, could therefore coincide with a decrease in feeding and an increase in vocalizations, potentially linked to behavioral changes, group composition, and/or the number of individuals present (Clark 1982b; Mussoline et al., 2012). In addition, reduced visibility at these times could favour increased acoustic communication to maintain social contact (Schmidt et al., 2013; Jacobs et al., 2022). It should be noted that these trends are not universal; Mellinger et al., (2007) observed a peak in *up-calls* during the day on the Scotian Shelf, suggesting regional variations. A uniform distribution of detections was observed at Station2-Campaign2, potentially due to a lack of data rather than actual vocal presence throughout the day.

4.3 Challenges of Passive Acoustic Monitoring for effective spatial management

The use of PAM has become established over several years as an essential tool for tracking cetaceans such as humpback whales (Kowarski et al., 2018, 2019; Delarue et al., 2022; Ross-Marsh et al., 2022) and for monitoring endangered species such as the NARW (Davis et al., 2017 ; Gervaise et al., 2019; Simard et al., 2019), effectively complementing visual observations that are limited by weather conditions (Munger et al., 2012). In the GSL, acoustic detection is at the heart of a major collective monitoring effort. This effort relies on a network of sophisticated devices, including fixed acoustic buoys, providing continuous monitoring along recognized migration corridors and feeding areas, as well as acoustic gliders for more mobile coverage in large areas (Davis et al., 2017, 2020; Gervaise et al., 2019; Davies, 2020; DFO, 2021; Durette-Morin et al., 2022). Our results, which focus on the southern Gaspé coast, are therefore directly integrated into this effort. However, although PAM provides essential presence information, its direct application to fisheries management reveals a significant positioning bias. Except in cases of advanced triangulation using multiple hydrophones, acoustic detection only provides presence information within the hydrophone's listening range (Johnson et al., 2020; Delarue et al., 2022; Fleishman et al., 2023). Indeed, given that many low-frequency calls can travel long distances underwater (*i.e.*, Delarue et al., 2022), the position reported during near-real-time acoustic detection may be uncertain (Johnson et al., 2020). Nevertheless, managers are forced to assume, by default, that the position of the hydrophone is the position of the right whale, in order to trigger dynamic fishing area closures (Johnson et al., 2020). This lack of rigorous spatial information is a legitimate source of frustration for coastal fisher; the inaccuracy leading to the closure of potentially very large areas undermines local stakeholders' confidence in the management methodology and their willingness to collaborate (Morissette et al., 2022). Research efforts must therefore focus on multiple hydrophone systems and advanced location methods to provide accurate positions, moving from management based on potential risk (detection) to management based on precise location (triangulation). This approach would enable the implementation of effective right whale conservation measures while minimizing socio-economic impacts.

5. CONCLUSION

This study revealed the near-daily presence of humpback whales in the southern Gaspé coastal area in June, August, and September 2024, contrasting with a much lower occurrence of NARW. We also highlighted spatio-temporal variations and daily trends for both species. It is important to note that these data provide a record of the minimum presence of vocalizations and that the absence of vocalizations does not mean the absence of the species; whales may be silent, produce vocalizations that are not detected by CNNs, or be masked by ambient and anthropogenic noise (Delarue et al., 2022). Nevertheless, it is unlikely that these results do not accurately represent their overall occurrence in the area. These data, which cannot be obtained through visual surveys (Munger et al., 2012), complement the study conducted by Riou et al. (2025) in the southern Gaspé lobster fishing area. Humpback whales show a marked coastal occurrence, with significantly higher acoustic presence in June 2024, suggesting potential use of the area as a feeding ground and migratory stopover site. In order to test our hypotheses and study the behavior of humpback whales in this coastal area in greater detail, it would be essential to classify and quantify the different types of vocalizations produced by these whales in our recordings. As for NARW, which were not observed visually by Riou et al. (2025), they appear to frequent the coastal area mainly in August. The recorded *up-calls* may belong to NARW moving between their two large aggregation areas, the Shediac Valley and the northwest of Anticosti Island, using the Gaspé coast as a migration corridor. This period of highest coastal occurrence is offset from the lobster fishing season, which significantly reduces the risk of entanglement (Brillant et al., 2015). However, it is essential to remain vigilant about the coastal presence of NARW in the Gaspé Peninsula to protect them effectively. These results highlight the effectiveness of Passive Acoustic Monitoring as a valuable tool for understanding the presence and spatio-temporal frequency of cetaceans, providing continuous data that complements visual surveys, as part of a collaborative project led by lobster harvest. In addition, thanks to these recordings, future studies could be carried out on other cetaceans present in the study area, such as minke whales, harbour porpoises, fin whales, and white-sided dolphins during the summer season. To conclude, a more detailed and comprehensive study classifying and quantifying humpback whale and NARW vocalizations would provide further insight into their behavior in the study area.

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CONCLUSION GÉNÉRALE

Au cœur d'un projet initié par les pêcheurs de homard du *Regroupement des Pêcheurs Professionnel du Sud de la Gaspésie* (RPPSG), pendant la crise de la baleine noire au Québec ; cette maîtrise de recherche visait à analyser en profondeur l'utilisation de l'habitat côtier par les cétacés dans le sud de la péninsule gaspésienne, entre 2019 et 2024. L'objectif était d'apporter une dimension académique à ce projet tout en prolongeant les efforts de suivi par une sixième année de suivis visuels ; afin de 1) mieux comprendre quelles espèces fréquentent la zone de pêche et pour quelles raisons, 2) étudier les comportements des espèces présentes 3) intégrer une composante d'acoustique passive, offrant ainsi une surveillance continue de la zone côtière. En combinant six années de données d'observations visuelles sur les cétacés à trois mois d'enregistrements acoustiques passifs (2024), ciblant la BNAN et le rorqual à bosse, cette approche intégrative a permis de mieux documenter la présence spatio-temporelle des cétacés fréquentant la zone côtière du sud de la Gaspésie tout en apportant des éléments essentiels pour la coexistence de la BNAN et des pêcheries de homard dans cette zone.

De 2019 à 2023, des inventaires visuels de la mégafaune marine ont été menés entre Saint-Georges-de-Malbaie et Port-Daniel-Gascons, dans la zone de pêche au homard des 20 brasses (37 mètres), pendant et après la saison de pêche. Une sixième année a été réalisée entre mai et juillet 2024 dans le cadre de cette maîtrise. Cette étude est l'une des premières à adopter une approche côtière, en effectuant des transects à partir de navires dans une zone de pêche au homard afin de documenter l'occurrence et la répartition des cétacés. En se concentrant sur la présence et la diversité des espèces à différentes échelles temporelles, pendant et en dehors de la saison de pêche au homard, ainsi que sur leur comportement, le premier chapitre de ce mémoire fournit de nouvelles informations sur la communauté de cétacés et la dynamique comportementale adoptée par ces espèces lorsqu'elles sont présentes dans la zone côtière de pêche au homard sud gaspésienne, en utilisant une approche principalement descriptive.

Bien qu'aucune BNAN n'ait été observée dans la zone côtière de pêche au homard (2019-2024), quatre espèces de cétacés sont régulièrement recensées : le petit rorqual, le marsouin commun, le rorqual à bosse, le rorqual commun ; les deux premières étant dominantes. Leur utilisation spatio-temporelle de la zone semble liée la disponibilité des proies. Le déplacement, observé dans 78,3 % des cas, est le comportement prédominant, ce qui suggère que les cétacés se déplacent entre diverses zones d'alimentation situées dans ou à proximité de la zone d'étude. Ce constat appuie l'hypothèse d'une utilisation dynamique et opportuniste de cette section côtière, qui serait potentiellement une zone de passage et d'exploration. Le comportement alimentaire, représentant 19,7 % des observations, indique une exploitation locale ponctuelle des ressources. La disponibilité de ces proies varie significativement selon les mois et les années ; par exemple avec le frai du capelan, dont l'intensité et la localisation très variables expliquent une part majeure des fluctuations d'abondance des rorquals à bosse dans l'Est canadien (Piatt et al., 1989). Des regroupements interspécifiques d'alimentation confirment cependant le rôle de cette zone en tant qu'aire d'alimentation partagée. Cette observation est cohérente avec la richesse écologique de la zone, notamment en petits poissons pélagiques tel que le capelan, le hareng de l'Atlantique ou le maquereau bleu, qui utilisent cette région comme aire de reproduction, de pouponnière ou de nourricerie à différents moments de l'année. L'analyse comportementale a permis de mieux cerner les fonctions potentielles de cet habitat côtier pour les différentes espèces observées, en complément des simples données de présence.

Quant à la BNAN, sa non-observation dans cette zone peut s'expliquer par son régime alimentaire mégazooplanctivore, incompatible avec la nature piscivore de la communauté de cétacés locale ainsi que par une disponibilité potentiellement insuffisante de sa proie principale ; le zooplancton du genre *Calanus spp*. La BNAN est en effet principalement concentrée dans des zones d'alimentation distinctes et riches en *Calanus spp.,* comme le sud du GSL (vallée de Shediac) et le nord-ouest de l'île d'Anticosti. Ces résultats soulignent l'importance d'intégrer les données comportementales et écologiques propres à chaque espèce dans les études sur les cétacés, afin d'affiner notre compréhension de leur utilisation de l'habitat et d'orienter les stratégies de conservation.

L’étude acoustique menée en juin, à la station 1 en face de Pointe Verte ainsi qu’août et septembre 2024, aux station 1 (Pointe Verte) et station 2, en face de Cap d’Espoir, complète les données d’observation du chapitre 1, et permet de mieux comprendre la présence des rorquals à bosse et des BNAN dans la zone côtière sud Gaspésienne. Elle révèle la présence quasi quotidienne des rorquals à bosse contrastant avec l’occurrence bien plus faible de la BNAN. Des variations spatio-temporelles ont été mise en évidence pour les deux espèces, suggérant des dynamiques d’utilisation différentes, comme suggéré dans le chapitre 1.

L’intensité de l’activité acoustique des rorquals à bosse, particulièrement marquée en juin, indique que la zone est utilisée comme aire d’alimentation lorsque la ressource est disponible et/ou comme halte migratoire avant de rejoindre d’autres sites d’alimentation du golfe et de l’estuaire du Saint-Laurent. En fin de saison estivale, nous avons observé une augmentation de l'activité acoustique, qui pourrait être liée au départ des baleines vers leurs zones de reproduction et/ou à l'entraînement des mâles et des jeunes, produisant des fragments de chants. De plus, nous avons constaté une variation marquée de l'activité quotidienne des rorquals à bosse entre juin et septembre 2024. Alors qu’elle est plus élevée le matin en juin, elle se concentrait au crépuscule et la nuit en août et septembre. Cette inversion suggère un changement de comportement, peut-être lié à une stratégie alimentaire qui évoluerait du jour à la nuit, ou à une augmentation des vocalisations sociales nocturnes, telles que les fragments de chants.

Les *up-calls* caractéristiques des BNAN, bien que moins fréquents, ont principalement été enregistrés en août. Cette présence acoustique ponctuelle suggère que les BNAN utilisent la zone côtière comme un corridor migratoire transitoire, en dehors de la saison de pêche, ce qui contribue à réduire le risque d'empêtrement dans la zone d'étude. Ce faible taux de détection s'explique probablement par leur concentration dans les principales zones d'alimentation, situées dans la vallée de Shediac, au sud de notre zone d'étude, puis au nord-ouest de l'île d'Anticosti (MPO 2020 ; Crowe et al., 2021 ; Gavrilchuk et al., 2021 ; Tao et al., 2023 ; Simard et al., 2024). Le pic d'activité en août renforce l'hypothèse d'un transit près de la péninsule gaspésienne. Cette hypothèse est d'ailleurs corroborée par nos observations lors de la deuxième campagne : les *up-calls* étaient plus fréquents au nord de la zone d'étude, près du corridor de migration (station 1, Pointe Verte). De plus, nos résultats révèlent que les BNAN vocalisaient davantage en fin de journée, en particulier au crépuscule. Ce comportement, également observé chez d'autres populations de baleines franches, pourrait indiquer un passage d'activités de nourrissage diurnes, souvent silencieuses, à une communication sociale accrue lorsque la visibilité diminue (Clark 1982b ; Mussoline et al., 2012 ; Schmidt et al., 2013 ; Jacobs et al., 2022). Cette dynamique souligne l'importance des conditions environnementales et sociales dans la modulation de l'activité acoustique, tout en rappelant que ces tendances peuvent varier d'une région à l'autre.

Il est important de souligner que ces données acoustiques recueillent une présence minimale : l'absence de vocalisations ne signifie pas nécessairement l'absence d'individus, en raison de la variabilité des comportements vocaux, des limites de détection, et des bruits ambiants (Delarue et al., 2022). Néanmoins, ces enregistrements fournissent une perspective complémentaire et précieuse aux suivis visuels, en permettant une surveillance continue.

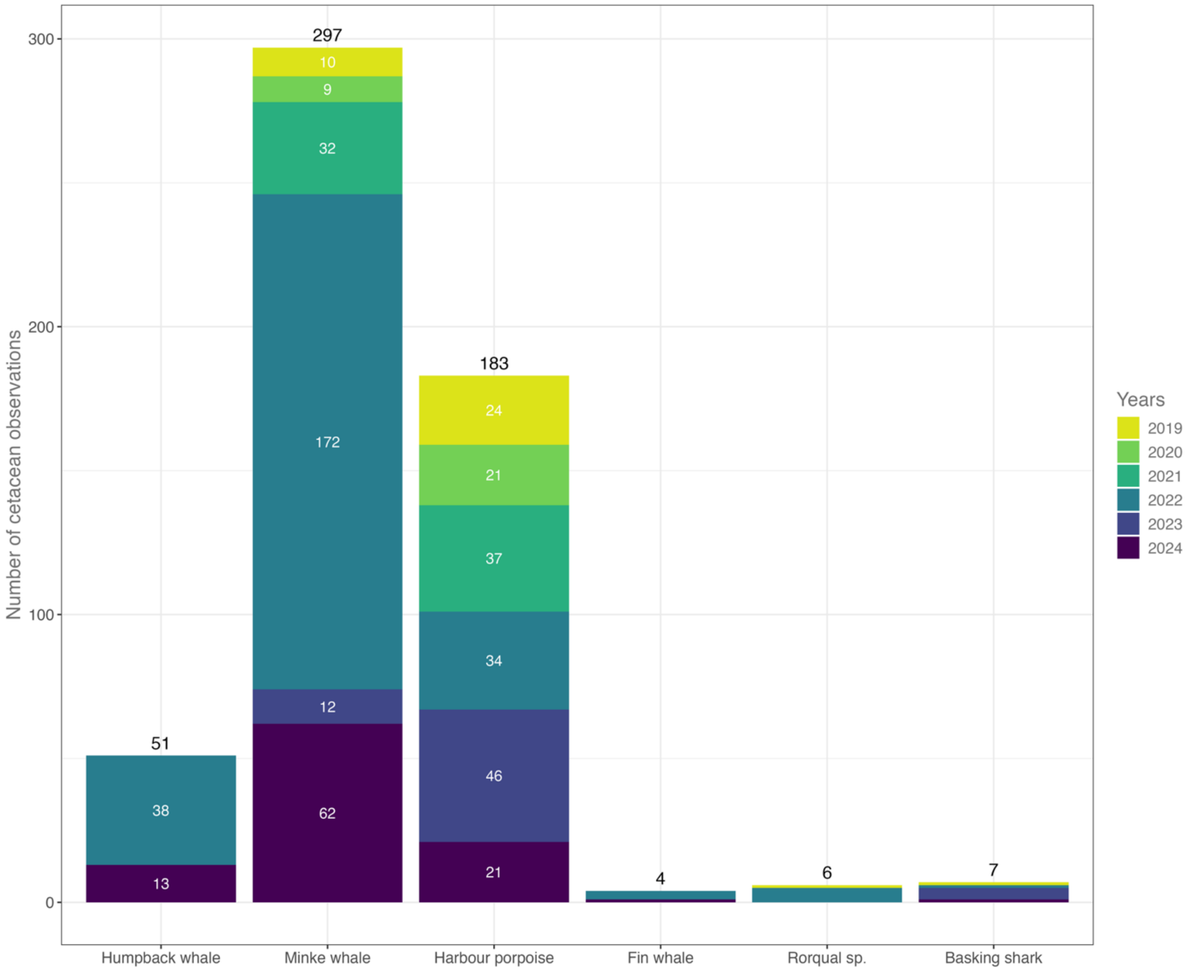
Ce travail de maîtrise, pionnier par son déploiement en zone côtière de pêche au homard (un contexte où la recherche scientifique intègre rarement les savoirs issus des pêcheurs), a révélé l'utilisation dynamique et opportuniste de cet habitat par différentes espèces de cétacés. Les données issues des observations visuelles et de la surveillance acoustique passive (PAM) ont fourni des informations complémentaires et essentielles sur la présence et les comportements de ces espèces. Pour consolider et étendre ces connaissances, plusieurs pistes de recherche restent à explorer. Premièrement, il serait pertinent d'élargir la couverture spatio-temporelle des inventaires visuels. Pour cela, il faudrait prolonger les observations jusqu'en octobre, avant la migration des BNAN, et étendre l'effort de surveillance plus au large, notamment vers le corridor de migration des BNAN qui pourrait se situer dans les zones de pêche au crabe. L'intégration de ces données visuelles dans des modèles spatio-temporels prédictifs permettrait d'anticiper la présence des cétacés dans la zone d'étude en fonction des conditions environnementales impactant la disponibilité de leur proie. Deuxièmement, une étude ciblée sur l'écologie trophique côtière locale, notamment sur la variabilité de la distribution de proies importantes telles que le capelan, le maquereau ou le hareng pour les cétacés piscivores et le *Calanus spp.* pour la BNAN, permettrait d'améliorer la compréhension des dynamiques de fréquentation. Troisièmement, la surveillance par acoustique passive pourrait être intensifiée, en classant et en quantifiant les vocalisations des rorquals à bosse et BNAN afin de mieux comprendre leur comportement, puis en étudiant l'ensemble des espèces identifiées dans la zone. Pour optimiser cette approche, il serait également important de calculer la portée de détection de chaque espèce dans la zone d'étude (*conf* Delarue et al., 2022) et de déployer des hydrophones sur un plus grand nombre de stations et sur des périodes plus longues. Enfin, il est essentiel de poursuivre les suivis interannuels pour renforcer nos conclusions et explorer des phénomènes intéressants, comme les regroupements interspécifiques, rarement documentés dans ce contexte côtier. L'amélioration de nos connaissances dans ces domaines contribuera à une meilleure gestion de cette zone côtière et à la conservation des espèces qui l'utilisent.

En conclusion, ce projet collaboratif a mis en évidence un point important : l'absence actuelle de chevauchement temporel entre la pêche au homard dans le sud de la Gaspésie et la présence de la BNAN. Historiquement, la saison de pêche se terminait avant l'arrivée potentielle des baleines, ce qui réduisait déjà les risques d'empêtrement. Nos six années de suivi visuel et acoustique confirment cette tendance, montrant une présence de BNAN principalement en août, soit après la saison de pêche au homard. Cependant, les impacts du changement global pourraient modifier cette situation à l'avenir.

En tant que projet fondé sur une étroite collaboration entre chercheurs et pêcheurs, nous avons pu recueillir des données robustes qui enrichissent notre compréhension de l'utilisation des eaux côtières par les cétacés. Ce modèle de suivi combinant approches visuelle et acoustique est une méthode viable pour obtenir des données fiables à l'échelle locale. Ce projet démontre également la valeur sociétale de la science collaborative, dépassant le cadre écologique et renforçant la confiance et l'acceptation des mesures de protections. En 2025, ce projet a déjà contribué à la révision du protocole dynamique de fermeture de zone de pêche côtière, grâce à des discussions conjointes avec les associations de pêcheurs (dont le RPPSG), le gouvernement et les experts. Ces modifications, éclairées par la collaboration entre pêcheurs et scientifiques, visent à assurer la coexistence entre pêcheurs et baleines ; protéger les BNAN tout en minimisant les perturbations pour les activités de pêche côtières comme celle du homard (MPO 2025).

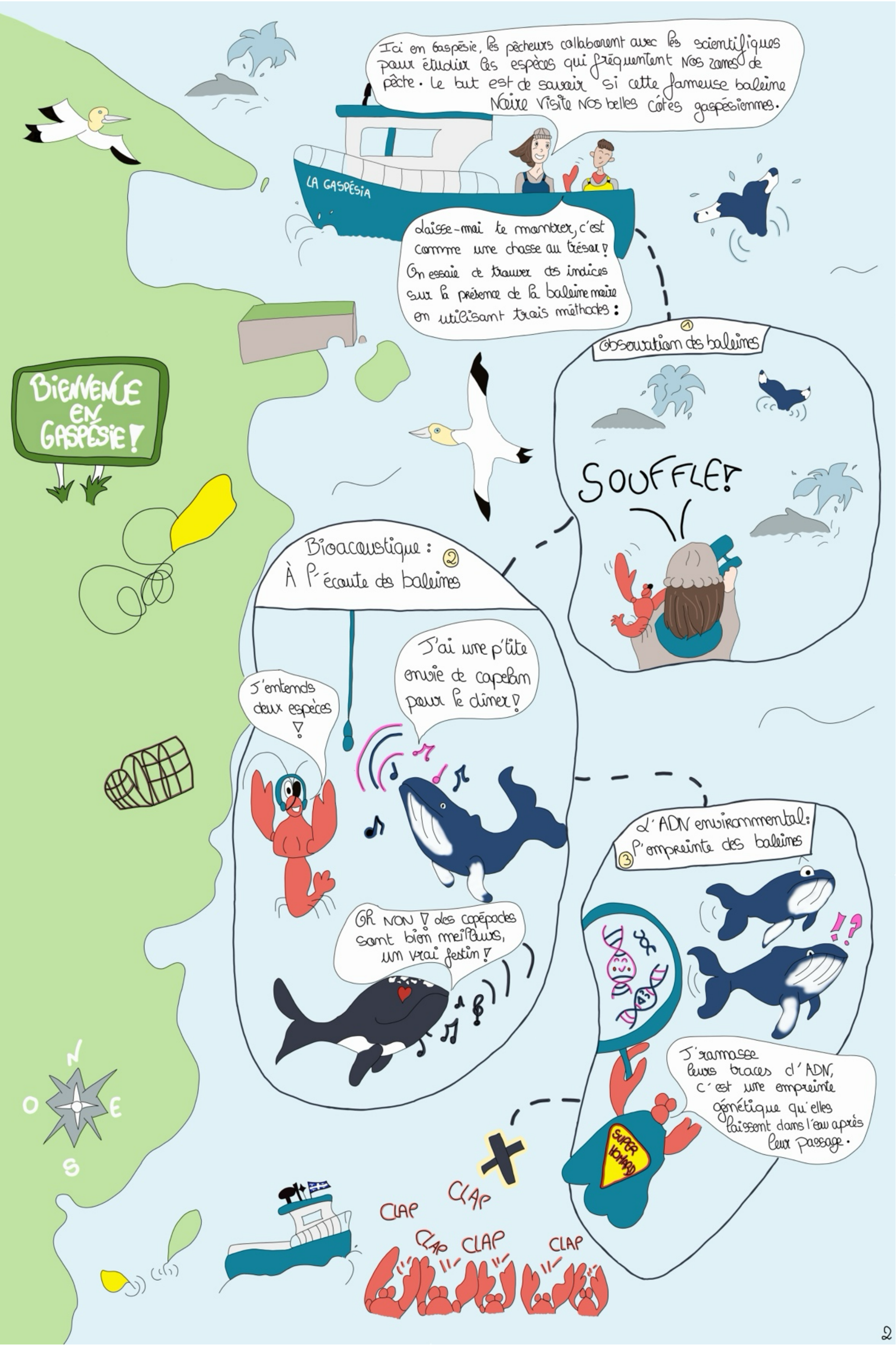
Enfin pour que ces efforts de conservation portent leurs fruits, il est primordial de rendre la science accessible à toutes les parties prenantes. Ceci passe par la vulgarisation des résultats et la diffusion de l'information de différentes manières, à différentes audiences, afin de garantir que les actions soient les plus efficaces et que les mesures soient comprises et adoptées par les communautés. La bande dessinée fournie, réalisée dans le cadre du vulgarisathon de l'ACFAS (annexes B, C et D), ainsi que l'infographie (annexe E) permettant de partager les résultats de Riou et al., (2025), en sont des exemples concrets, permettant à la science de rencontrer le grand public à travers un langage commun.

ANNEXES



Annexe A - Number of cetacean observations by species and by year in the southern Gaspé lobster fishing areas between 2019 and 2024.

Annexe B – Planche 1 « Baleine noire es-tu là ? »



Annexe C– Planche 2 « Baleine noire es-tu là ? »

Annexe D– Planche 3 « Baleine noire es-tu là ? »

Les cétacés dans les zones de pêche au homard du sud de la Gaspésie : implications pour la protection de la baleine noire de l'Atlantique Nord (2019-2024)

Canadian Journal of **Zoology**

ISMER UQAR

Regroupement des pêcheurs professionnels du sud de la Gaspésie

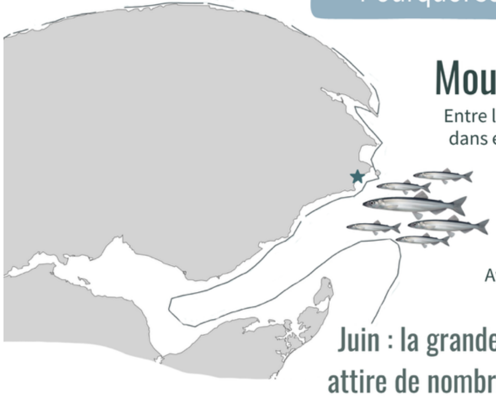
- Transects de 0 à 37 m de profondeur
- Pendant et après la saison du homard

Identification des espèces / Comportement / Métadonnées

2019 2020 2021 2022 2023 2024

72 jours d'observation

Pourquoi sont-ils ici ? Que font-ils ?



Mouvement 78,3 %

Entre les patchs d'alimentation : dans et en dehors des zones de pêche au homard

Alimentation 19,7 %

Avec regroupement interspécifique

Juin : la grande disponibilité des proies attire de nombreuses baleines piscivores

Petit rorqual 297

Marsouin commun 183

Rorqual à bosse 51

Rorqual commun 4

Les **cétacés piscivores** utilisent ces eaux côtières de manière **dynamique** et **opportuniste**, suivant des schémas spatio-temporels qui dépendent de la disponibilité et de l'abondance des proies

Baleines engouffreuses

0

Baleine écrémeuse

Baleine noire de l'Atlantique Nord (BNAN)

Filtreur continu spécialisé dans les petits copépodes (*Calanus spp.*)

Vigilance pour anticiper et prévenir tout changement dans l'utilisation des zones de pêche au homard

Pas de chevauchement temporel **actuel** entre la pêche au homard et la BNAN

Science collaborative + savoirs locaux

- Éclaire l'usage des zones de pêche au homard du sud de la Gaspésie par les baleines
- Valorise les **initiatives des pêcheurs** qui soutiennent la recherche
- Renforce l'efficacité de la conservation grâce à l'**implication des parties prenantes**
- **Allie valeur sociétale et valeur écologique**

@Manon RIOU

Annexe E – Infographie pour le papier Riou et al., 2025 (Chapitre 1)

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