TP 15581

Using passive acoustic monitoring from gliders for near real-time detection of North Atlantic right whales (*Eubalaena glacialis*) to inform management decisions related to the Laurentian Channel dynamic shipping zones and the Cabot Strait voluntary slowdown area (2022-2023)

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Un sommaire en français se trouve avant la table des matières.

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16. Abstract

This project used right whale detections from gliders to trigger dynamic vessel management in the traffic separation scheme within Dynamic Shipping Zones C and E (DSZ C and E) and the Cabot Strait Voluntary Slowdown. Two profiling gliders equipped with hydrophone systems were deployed for 134, 76, and 39-day missions, from April through November 2022. The gliders reported daily detections of five baleen whale species that were validated by a trained human analyst and then sent to Transport Canada. The glider detected right whales in near real-time in DSZ C on one survey day but did not detect any at any time in the Cabot Strait. In response to the glider detection, a speed limit was imposed in DSZ C for 15 days, or 11.2% of the survey period. The false positive rate estimated for right whale detections at the daily scale was 0% in the DSZ, and the false negative rates for this species at the daily scale were 5% and 0% in the DSZ and Cabot Strait, respectively.

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16. Résumé

Dans le cadre de ce projet, des détections de baleines noires ont été utilisées par les planeurs pour déclencher une gestion dynamique des navires dans le dispositif de séparation du trafic au sein des zones de transport maritime dynamiques (ZTMD) C et E et la zone de ralentissement volontaire dans le détroit de Cabot. Deux planeurs de profilage équipés d'un système d'hydrophone ont été déployés pour des missions de 134, 76 et 39 jours, d'avril à novembre 2022. Les planeurs ont signalé des détections quotidiennes de cinq espèces de baleines à fanons, qui ont été validées par un analyste formé, puis envoyées à Transports Canada. Le planeur a détecté des baleines noires en temps quasi réel dans la ZTMD C lors d'une journée de relevé, mais n'en a détecté aucune à aucun moment dans le détroit de Cabot. En réponse à la détection du planeur, une limitation de la vitesse a été imposée dans la ZTMD C pendant 15 jours, soit 11,2 % de la période de relevé. Le taux de faux positifs estimé pour les détections de baleines noires à l'échelle journalière était de 0 % dans la zone de transport maritime dynamique, et les taux de faux négatifs pour cette espèce à l'échelle journalière étaient respectivement de 5 % et 0 % dans la zone de transport maritime dynamique et le détroit de Cabot.

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EXECUTIVE SUMMARY

Multiple right whale-vessel strikes have occurred in the Gulf of St. Lawrence since 2017. In response, Transport Canada, in collaboration with industry and academia, initiated a series of management measures that included dynamic management of vessel traffic in the shipping lanes in the Laurentian Channel north and south of Anticosti Island. Prior to 2019, slowdowns to reduce the risk of vessel strike in the dynamic shipping zones (DSZs) were solely triggered by real-time detections of right whales made visually. Visual detection has key limitations, including that it cannot be done in poor weather conditions (high wind, storms), or at night. This project was initiated to continue the use of gliders fitted with passive acoustic monitoring equipment (PAM) to detect and report in near real-time the calls and hence the presence of North Atlantic Right Whales (NARW; *Eubalaena glacialis*; hereafter right whales). The 2022 work builds on a 2019 pilot study that used a PAM equipped glider in the Honguedo Strait, and two subsequent expanded seasons of glider monitoring in the Gulf of St. Lawrence in 2020 and 2021. This study was conducted in response to a request from Transport Canada to adopt autonomous mobile underwater gliders equipped to acoustically monitor for whale presence via whale calls. Since 2020, near real-time whale detections collected both visually (from airplanes and an aerial drone) and acoustically using gliders have been used to implement ship slowdowns in the Gulf of St. Lawrence.

The primary goals of this project were to (1) use right whale detections made from a glider to trigger mandatory vessel slowdowns in the traffic separation scheme within Dynamic Shipping Zones C (DSZ C) and E (DSZ E), and (2) operate a second glider within the Cabot Strait voluntary seasonal slowdown zone during periods in the spring and fall, to gather information on whale presence in this whale migration corridor. The performance of the gliders and their near real-time reporting system during the deployment were evaluated.

In 2022, a profiling electric glider equipped with a hydrophone system capable of detecting and classifying right whale upcalls in near real-time was deployed for a 134-day mission in the Laurentian Channel and monitored DSZ E from May 1st through June 29th and DSZ C from June 29th to August 23rd. A second glider was deployed in the Cabot Strait voluntary slowdown zone for a total of 115 days over two periods, first in the spring from April 21st through July 5th and second in the fall from October 4th through November 11th. The gliders reported daily detections of five species of baleen whales, including right whales, that were validated by a trained human analyst. Right whale confirmed detections (hereafter, 'definite detections') were distributed to Transport Canada to support any necessary management actions and for publication to the publicly available WhaleMap and Whale Insight websites.

During the DSZ deployments, the glider made 11 transits of an along-channel transect located between the inbound and outbound shipping lanes of both DSZ E and DSZ C, as well as one transit of DSZ B. The DSZ glider completed each transit within the predetermined designated clearance periods. On average, a DSZ E transit took 5.4 days (46-nm) and a DSZ C transit took 4.8 days (46-nm). Course deviations due to ocean currents were minimal (nominally < 1 nautical mile), and the glider was able to safely navigate between the shipping lanes. The glider made definite right whale detections in DSZ C on one survey day. A 10-knot speed limit in DSZ C was implemented within 24 hours of the real-time detection and remained in effect for 15 consecutive days. In response to the glider detection, a shipping speed limit was implemented in DSZ C for 11.2% of the entire survey period.

The Cabot Strait glider was deployed for a 76-day spring mission from April 21st to July 1st, where it performed 8 transits of a 26-nm along-strait (AS) line and 8 transits of a 33-nm cross-strait (CS) line. The average travel time for a transit was 4.8 days. The glider was deployed again for a 39-day fall mission from October 4th to November 11th, where it performed 4 transits of the AS line and 4 transits of the CS line. The average travel time for a transit was 4.9 days. During this mission, the pilots programmed the glider to turn around before completing its last CS transit to ensure it was in a suitable recovery location for its end-of-season retrieval.

After the gliders were recovered, the raw audio data files that had been stored on board were analyzed in detail for the presence of right whale calls, with results from this analysis compared to the near real-time reported data. The false positive detection rate in the near real-time reports for right whale detections at the daily scale was 0% in the DSZ, and the false negative rates for this species at the daily scale were 5% and 0% in the DSZ and Cabot Strait, respectively. These fall within normal operating parameters for this monitoring system. Thus, the mission objectives were successfully fulfilled. The experiences of the research team conducting this and many other glider missions in the Gulf of St. Lawrence suggest that gliders can be successfully deployed to survey almost anywhere in the region.

SOMMAIRE

Plusieurs collisions entre des baleines noires et des navires ont eu lieu dans le golfe du Saint-Laurent depuis 2017. En réponse, Transports Canada, en collaboration avec l'industrie et le milieu universitaire, a mis en œuvre une série de mesures de gestion comprenant la gestion dynamique du trafic maritime dans les voies de navigation du chenal Laurentien au nord et au sud de l'île d'Anticosti. Avant 2019, les ralentissements visant à réduire le risque de collision avec les navires dans les zones de transport maritime dynamiques (ZTMD) étaient uniquement provoqués par des détections visuelles en temps réel de baleines noires. La détection visuelle présente des limites importantes, notamment le fait qu'elle ne peut pas être effectuée dans de mauvaises conditions météorologiques (vent fort, tempêtes) ou la nuit. Ce projet a été lancé pour poursuivre l'utilisation de planeurs équipés d'un matériel de surveillance acoustique passive (SAP) afin de détecter et de signaler en temps quasi réel les appels et donc la présence des baleines noires de l'Atlantique Nord (Eubalaena glacialis; ci-après baleines noires). Les travaux de 2022 s'appuient sur une étude pilote réalisée en 2019 à l'aide d'un planeur équipé d'un matériel de SAP dans le détroit d'Honguedo, ainsi que sur deux saisons étendues suivantes de surveillance au moyen d'un planeur dans le golfe du Saint-Laurent en 2020 et 2021. Cette étude a été menée en réponse à la demande de Transports Canada d'adopter des planeurs sous-marins mobiles autonomes équipés pour assurer une surveillance acoustique de la présence de baleines par l'intermédiaire de leurs appels. Depuis 2020, les détections de baleines en temps quasi réel, recueillies à la fois visuellement (à partir d'avions et d'un drone aérien) et acoustiquement à l'aide de planeurs, ont été utilisées pour mettre en œuvre des ralentissements de navires dans le golfe du Saint-Laurent.

Les buts principaux de ce projet étaient (1) d'utiliser les détections de baleines noires faites à partir d'un planeur pour provoquer des ralentissements obligatoires des navires dans le dispositif de séparation du trafic au sein des zones de transport maritime dynamiques C et E, et (2) d'utiliser un second planeur dans la zone de ralentissement saisonnier volontaire du détroit de Cabot pendant des périodes au printemps et à l'automne, afin de recueillir des renseignements sur la présence de baleines dans ce couloir de migration des baleines. Les performances des planeurs et de leur système de signalement en temps quasi réel pendant le déploiement ont été évaluées.

En 2022, un planeur électrique de profilage équipé d'un système d'hydrophone capable de détecter et de classer les appels de baleines noires en temps quasi réel a été déployé pour une mission de 134 jours dans le chenal Laurentien et a surveillé la ZTMD E du 1er mai au 29 juin et la ZTMD C du 29 juin au 23 août. Un second planeur a été déployé dans la zone de ralentissement volontaire du détroit de Cabot pendant un total de 115 jours sur deux périodes : la première, au printemps, du 21 avril au 5 juillet, et la seconde, à l'automne, du 4 octobre au 11 novembre. Les planeurs ont signalé des détections quotidiennes de cinq espèces de baleines à fanons, dont des baleines noires, qui ont été validées par un analyste formé. Les détections confirmées de baleines noires (ci-après « détections confirmées ») ont été communiquées à Transports Canada pour qu'il appuie toute mesure de gestion nécessaire et qu'il les publie sur les sites Web WhaleMap et Baleine-en-vue, qui sont accessibles au public.

Au cours des déploiements dans la zone de transport maritime dynamique, le planeur a effectué 11 passages sur un transect à travers le chenal entre les voies de navigation entrantes et sortantes des ZTMD E et C, ainsi qu'un passage dans la ZTMD B. Le planeur de la zone de transport maritime dynamique a effectué chaque passage au cours des périodes d'autorisation prédéterminées. Un passage dans la ZTMD E prenait en moyenne 5,4 jours (46 nm) et un passage dans la ZTMD C prenait en moyenne 4,8 jours (46 nm). Les déviations de trajectoire résultant des courants océaniques ont été minimes (nominalement < 1 mille nautique) et le planeur a pu se déplacer en toute sécurité entre les voies de navigation. Le planeur a détecté des baleines noires dans la zone de transport maritime C lors d'une journée de relevé. Une limitation de la vitesse à 10 nœuds dans la ZTMD C a été mise en œuvre dans les 24 heures suivant la détection en temps réel et est restée en vigueur pendant 15 jours consécutifs. En réponse à la détection du planeur, une limitation de la vitesse de navigation a été mise en œuvre dans la ZTMD C pendant 11,2 % de l'ensemble de la période de relevé.

Le planeur du détroit de Cabot a été déployé pour une mission printanière de 76 jours, du 21 avril au 1er juillet, au cours de laquelle il a effectué 8 passages d'une ligne de 26 milles nautiques le long du détroit et 8 passages d'une ligne de 33 milles nautiques de part et d'autre du détroit. La durée moyenne d'un passage était de 4,8 jours. Le planeur a été à nouveau déployé pour une mission de 39 jours en automne, du 4 octobre au 11 novembre, au cours de laquelle il a effectué quatre passages de la ligne le long du détroit et quatre passages de la ligne de part et d'autre du détroit. La durée moyenne d'un passage était de 4,9 jours. Au cours de cette mission, les pilotes ont programmé le planeur pour qu'il opère un demi-tour avant d'effectuer son dernier passage de part et d'autre du détroit, afin de s'assurer qu'il se trouve dans un endroit propice à sa récupération en fin de saison.

Une fois les planeurs récupérés, les fichiers audio bruts stockés à bord ont été analysés en détail pour détecter la présence d'appels de baleines noires, et les résultats de cette analyse ont été comparés aux données communiquées en temps quasi réel. Le taux de détection de faux positifs dans les signalements en temps quasi réel pour les détections de baleines noires à l'échelle quotidienne était de 0 % dans la ZTMD, et les taux de faux négatifs pour cette espèce à l'échelle quotidienne étaient respectivement de 5 % et 0 % dans la ZTMD et le détroit de Cabot. Ces résultats sont conformes aux paramètres de fonctionnement normaux de ce système de surveillance. Les objectifs de la mission ont donc été remplis avec succès. L'expérience de l'équipe de recherche qui a mené cette mission et de nombreuses autres dans le golfe du Saint-Laurent montre que des planeurs peuvent être déployés avec succès pour effectuer des relevés presque partout dans la région.

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TERMINOLOGY

AS	Along-Strait
CEOTR	Coastal Environmental Observation Technology and Research group
CS	Cross-Strait
CTD	Conductivity, Temperature, and Depth measurement instrument
DMON	Digital Acoustic Monitoring Instrument
DSZ	Dynamic Shipping Zone
GPS	Global Positioning System
GSL	Gulf of St. Lawrence
G3s	Current model of Slocum glider commercially available
G3	Next most advanced model of Slocum glider, but production discontinued
LFDCS	Low-Frequency Detection and Classification system
NASP	National Aerial Surveillance Program
NAVWARN	Navigational Warnings
PAM	Passive Acoustic Monitoring
RUDICS	Router-based Unrestricted Digital Interworking Connectivity Solution communications system
TC	Transport Canada
TSS	Traffic Separation Scheme

1.0 INTRODUCTION

The Government of Canada is working to reduce the maritime sector's potential negative impacts on the North Atlantic right whale (*Eubalaena glacialis*) in Canadian waters. Entanglements in fishing gear and vessel strikes are considered the primary threats to the right whale population in Eastern Canada (Davies and Brilliant 2019, Pettis et al. 2022). One of the ways in which the government has been able to reduce the risk of vessel strikes is by implementing management measures, such as mandating reduced ship speeds in areas of high vessel traffic when right whales are detected in the area, while permitting normal operational speeds when they are not detected (referred to as 'dynamic management'). Shipping lanes in the Laurentian Channel located in the Gulf of St. Lawrence (GSL) have been divided into dynamic shipping zones (DSZ), which have been implemented annually since 2018 (DSZs A, B, C, and D) and 2019 (DSZ E) (Fig. 1).

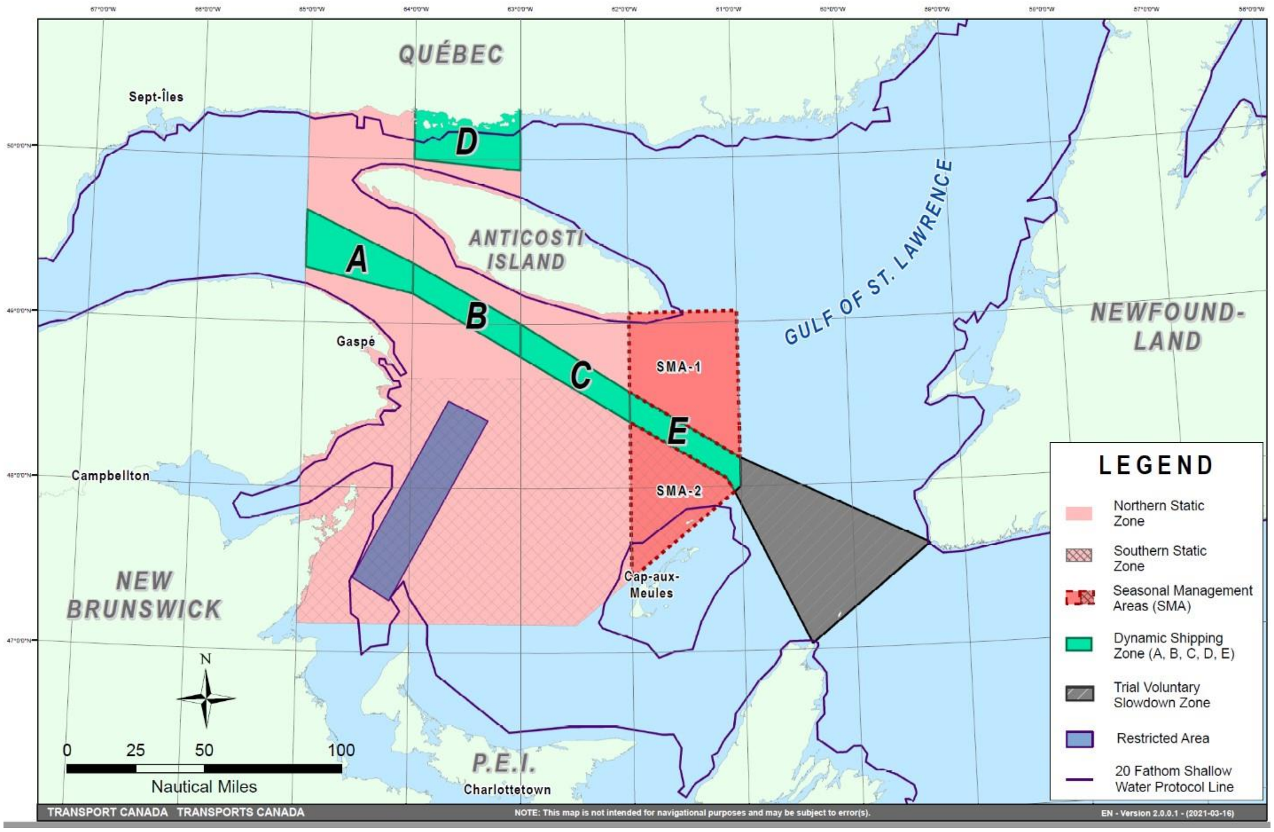


Fig. 1. Map of the 2022 Gulf of St. Lawrence vessel management system area showing the dynamic shipping zones and the various management regimes implemented to protect right whales. Map produced by Transport Canada ([2022 traffic management measures to protect North Atlantic Right Whales in Canada (dfo-mpo.gc.ca)]).

Dynamic management that minimizes impact on industry is reliant on regular surveillance for whales. A 10-knot speed restriction may be implemented in a DSZ under one of two conditions: either a right whale is detected within its boundaries, or as a precaution where no surveillance effort can occur in a zone over a set period due to poor weather conditions[1]. Before April 2020, the only monitoring method that had been used by Transport Canada (TC) to detect right whales in real-time in the DSZ was aerial surveillance, whereby trained observers watched for visual indicators of right whales at the surface of the ocean. Like all whale monitoring tools, visual detection has limitations: it is only possible when the surface of the water is visible during daytime hours and in the absence of fog; it requires wind speeds at the surface of the water that are sufficiently low to allow observers to distinguish a whale or its blow from whitecaps; it relies on operators seeing the whales when they surface, considering that right whales spend the majority of their time underwater; it relies on aircraft availability; and it is expensive relative to other detection platforms. Finally, visual surveillance is known to underestimate right whale presence when low densities of whales occur, because individual right whales are difficult to visually detect (Durette-Morin et al., 2019).

In addition to the DSZs, a trial seasonal voluntary slowdown (10-knot speed restriction; Fig. 1) has been implemented in an area within the Cabot Strait during spring and fall in 2020 (April 28th – June 15th and October 1st – November 15th), 2021 (April 28th – June 29th and September 29th – November 15th), and 2022 (April 20th – June 28th and September 28th to November 15th). Very little is known about the seasonality and spatial distribution of right whale use in this area (e.g., Crewe et al. 2021), however, it is believed that the Strait represents the major migration corridor for right whales accessing the Gulf during their spring-autumn feeding period. To date, real-time detections have not been used in this area to implement mandatory slowdowns, as there is still little knowledge of when and for how long whales are present in the Cabot Strait. Glider work monitoring for right whale calls in the voluntary slowdown zone of the Cabot Strait began in 2021 with a 107-day deployment in late-summer/early-fall and continued through 2022 with separate spring and fall deployments, providing much needed data on right whale presence in the area. The data are helping to inform current and future management measures.

Autonomous platforms such as buoys, moorings, and gliders are all being used as tools by the Government of Canada to enhance right whale monitoring in the Gulf of St. Lawrence. Gliders are mobile autonomous vehicles that can be deployed for months at a time and tasked with repeatedly surveying an area of ocean to persistently monitor for whale calls using passive acoustic monitoring (PAM) from omnidirectional hydrophones. This technology has been demonstrated to be effective at detecting right whale vocalizations automatically and relaying the data to shore in near real-time (Baumgartner et al. 2013). Acoustically monitoring the DSZs with gliders presents challenges, notably ship noise that may mask whale calls, the risk of collision between vessels and gliders when the gliders surface to transmit data, and currents that can cause gliders to deviate from their planned courses. Nonetheless, a pilot study to assess the feasibility of using glider technology near busy shipping lanes, conducted in 2019 in the Honguedo Strait, proved that these challenges were surmountable with careful study design and that gliders can provide useful and accurate information on the presence of vocalizing whales in near real-time (Davies 2020).

The primary goals of this year's work were to (1) use right whale detections made by a glider to trigger mandatory vessel slowdowns in the traffic separation scheme within DSZ C and E, and (2) deploy a second glider in the Cabot Strait voluntary seasonal slowdown zone to gather information on whale

[1] In 2022, this set period was defined as at least one complete survey of the zone per 14 days from April 20th to May 31st & from Sept 21st to November 15th, and at least one complete survey of the zone per seven days from June 1st to September 20th.

presence in this believed-to-be whale migration corridor. To accomplish this, the project tapped into the glider fleet and experienced glider personnel of Dalhousie University (Davis et al. 2018) and the expertise of the Davies' laboratory at the University of New Brunswick (Davies 2021).

2.0 METHODOLOGY

2.1 Observational Technology

2.1.1. Autonomous Electric Profiling Gliders

The autonomous platforms used in this study were Slocum electric gliders (models G3 and G3s; Teledyne Webb Research, Schofield et al. 2007, Baumgartner et al. 2020). The G3s model has replaced the G3 model, which is no longer sold. Both the G3 and G3s gliders are battery powered, long-endurance platforms and, depending on the battery type, can support a deployment length of four to six months. For this project, the two deployed gliders were equipped with non-rechargeable lithium primary extended batteries to provide maximum time at sea. A third glider was prepped and held on shore to be ready on short notice to replace either of the gliders on mission, should they malfunction. Gliders profile the water column in an undulating manner, moving up and down by using a piston in their nose, known as a buoyancy pump, to change their density (and therefore, buoyancy) relative to the surrounding water (Fig. 2). They collect science data along a pre-programmed track and surface at fixed intervals. At the surface, they obtain a GPS fix, send a subset of the science and flight data to a shore-station server, and, if necessary, receive commands from a shore-based glider pilot. Gliders are equipped with an Iridium modem to transmit data and receive commands from shore via the global Iridium RUDICS (Router-based Unrestricted Digital Interworking Connectivity Solution) network each time they surface. For this project, the gliders were configured to surface every four hours. The surface interval is programmable, and four hours is a typical interval that is a good temporal trade-off between collecting data underwater and surfacing to send data.

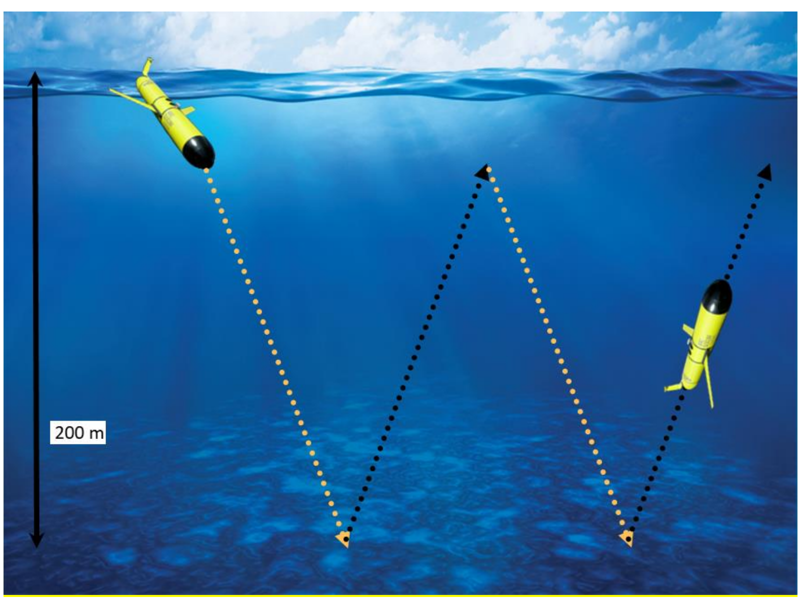


Fig. 2. Schematic showing the flight pattern of a Slocum glider.

The gliders used for this mission were each equipped with a 350-m buoyancy pump, meaning they could reach a maximum operational depth of 350-m. To minimize collision risk with ships, the minimum sampling depth was set to 25-m, which is below the draft of most vessels that transit in this region. Slocum gliders can carry a variety of science sensors. For these missions, the gliders each carried four sensors including a CTD (unpumped CTD, RBR Ltd), an oxygen sensor (Aanderaa data systems), an acoustic tag receiver (Innovasea Systems Inc.), and a DMON omnidirectional hydrophone (Johnson and Hurst 2007, Baumgartner et al. 2013, 2019). The hydrophone recorded and archived all acoustic data up to one kHz, which is well within the frequency range of the right whale call repertoire (Parks et al. 2011). Environmental (science) data and statistics on the operating status and parameters of the glider (flight data, such as battery status, compass heading, and GPS positions) were recorded at a 0.2 – 1 Hz sampling rate.

2.1.2 Near Real-Time Acoustic Detection System

The project employed a technology that is now commonly used in Canadian waters to acoustically monitor the tonal calls of right, sei, fin, humpback, and blue whales in near real-time while simultaneously measuring environmental conditions. The technology consists of a glider-mounted omnidirectional digital acoustic monitoring (DMON) hydrophone and a low frequency detection and classification system (LFDCS, Baumgartner et al. 2013, 2019, 2020). The latter automatically detects the call signatures of select whale species in the audio data. This technology has been used successfully to monitor baleen whales in near real-time on the Scotian Shelf and in the southern Gulf of St. Lawrence right whale habitats since 2014 and has been operational in the USA since 2012.

The DMON-LFDCS detects low-frequency (<1 kHz) tonal sounds from an acoustic record and classifies the statistical attributes of the whale sounds through a comparison with a stored library of known calls that is pre-programmed into the glider software. A subset of the attribute and detection data (eight kb per hour) can be sent to shore when the glider surfaces approximately every four hours, where North Atlantic right, fin, humpback, and sei whale sounds are validated by an experienced analyst using a conservative and well-tested protocol (Baumgartner et al. 2020). Data are scored in 15-minute increments called tally periods. Scoring options are 'Definite Detection', 'Possible Detection', or 'Not Detected' based on the strength of the objective statistical data and contextual information in the 15-minute period (Baumgartner et al 2019, 2020). For this project, blue whale sounds were also recorded and noted to be prevalent in the acoustic record; a protocol for scoring North Atlantic blue whale detections is now included in the LFDCS reference guide (Wilder et al 2023). In addition, a regional blue whale call library drawing on data from a variety of sources including this project is currently being compiled for future iterations of real-time monitoring, as any information on this endangered species' distribution is valuable from a conservation standpoint. The real-time protocol should result in a 0% false acoustic detection rate for North Atlantic right whales, but it can miss true right whale calls that were recorded by the glider, especially if such calls are low amplitude or rare. Generally, a 17.9% daily missed detection rate is anticipated based on previous studies (Baumgartner et al. 2020). For example, 2020 work in the Gulf of St. Lawrence resulted in a 12.5% daily missed detection rate (Davies 2021). These rates can be assessed post-recovery of the glider by comparison with the complete raw archival audio data collected and stored on the gliders during their missions.

For this project, the glider recorded and processed all passive acoustic data while profiling and surfaced to transmit a subset of the whale detection and classification data to a shore station every four hours (see details in Baumgartner et al. 2013). Dr. Davies and her trained lab members validated the whale detections daily, seven days a week, during the deployment. Validated detections were disseminated via various automated systems for online publication, including WhaleMap[2], the Whale Alert App[3], Robots4Whales[4], and Whale Insight[4]. The data were sent directly to the Transport Canada Situation Centre and Marine Safety and Security through automated email notification. Based on these notifications, appropriate vessel management measures (i.e., slowdowns) were implemented or extended by Transport Canada when a right whale was acoustically detected within the limit or buffer zone of the DSZs.

2.2 Mission Plan

For the 2022 field season, gliders were operated in two primary areas: the DSZ C/E region, as well as the Cabot Strait region. The glider monitoring the DSZ C/E regions will be referred to as the DSZ glider and the glider monitoring the Cabot Strait region will be referred to as the Cabot Strait glider.

2.2.1 Glider Flight Plan

There were three flight plans developed: DSZ C/E, Cabot Strait spring, and Cabot Strait fall.

DSZ C/E

In 2022, the dynamic shipping zone (DSZ) glider was deployed on April 21st at 47° 24.25' N, 60° 14.74' W. The gliders are not designed for operating near sea ice. Ice conditions in the Gulf of Saint Lawrence reported by the Canadian Ice Service Sea Ice website were monitored prior to the deployment, and deployments occurred when conditions were deemed to be safe. Upon arrival at the predetermined deployment sites, the glider mission began after the glider successfully passed the pilots' pre-mission verification tests. Due to weather conditions, the DSZ glider was deployed alongside the Cabot Strait glider. After deployment, the DSZ glider started transiting to the eastern border of DSZ E. The glider was closely monitored for the first 24 hours of this mission as its systems adjusted to the complex water density and temperature conditions in the Gulf of St. Lawrence.

The glider conducted multiple transits of the entire length of the DSZ E shipping lane from May 1st until June 29th, subsequently moving to DSZ C (Fig. 3 and Table 1). The clearance requirements, defined as a complete transit of a DSZ in one direction, were 14 days from April 20th to May 31st, and 7 days from June 1st to September 20th. The glider was deemed to be at the end of a transit line once it reached to within at least 4 km of the border of the zone. Depending on glider depth, it has been estimated that there is a 0.33 probability of detection of a single right whale upcall occurs when the whale calls at distances of between 8.6 and 13.4 km (Johnson et al. 2022). The probability of a definite detection of a right whale is predicted to increase significantly at all ranges if more than one call is produced. Therefore, the whole of the DSZ and the 4.6 km buffer zone were considered for this study to be 'acoustically covered', even if the glider was turned back at distances of up to 4 km from the end of its

[2] WhaleMap
[3] Whale Alert | Home (whale-alert.io)
[4] Robots4Whales: Autonomous Real-time Marine Mammal Detections (whoi.edu)
[4] Whale Insight (dfo-mpo.gc.ca)

transit. Nevertheless, the glider pilots were directed to notify TC if they expected a problem with any given zone clearance.

The glider left DSZ C on August 23rd and performed a transit through DSZ B until August 29th before heading for retrieval off Rivière-au-Renard (Québec). It was recovered with the Dalhousie zodiac on September 1st at 49^{o} 02.62’ N, 64^{o} 13.40’ W, as its battery neared depletion.

Cabot Strait spring mission

The Cabot Strait glider was deployed on April 21st at 47^{o} 24.63' N, 60^{o} 14.72' W, near the point of intersection of the Along Strait (AS) and Cross Strait (CS) transects. Again, the mission began after the glider successfully passed the pilots’ pre-mission verification tests. The glider was closely monitored for the first 24 hours of this mission as its systems adjusted to the water density and temperature.

Both Cabot Strait missions consisted of the glider alternatively performing the AS transect (26 nm, 48 km) followed by the CS transect (33 nm, 60 km). While performing the CS transect, the gliders had to cross three shipping lanes. Since these shipping lanes pose a collision threat to gliders when they are at or near the sea surface, we minimized the time the gliders spent near the surface by pausing near real-time data transfer for the period when the gliders transited across each shipping lane. No clearance times were imposed on this glider mission.

The glider was recovered on July 5th at 47^{o} 06.13' N, 60^{o} 42.91' W from the Dalhousie Zodiac, ensuring enough battery remained for the Fall mission.

Cabot Strait fall

The Cabot Strait fall mission deployment and transects mimicked the preceding spring mission. After a short deployment delay due to infrastructure damage and fuel shortages in Cape Breton caused by Hurricane Fiona, the Cabot Strait glider was deployed on October 4th at 47^{o} 18.44’ N, 60^{o} 21.86' W. The glider was recovered on November 11th at 47^{o} 18.49' N 60^{o} 19.87' W, as its battery neared exhaustion.

General glider settings and considerations

The shallow inflection point of the glider was set to 25 m depth in order to avoid the risk of collisions with passing large vessels. By contrast, the deep inflection point was set to 350 m or 12 m above the seafloor depth, whichever was shallowest. The gliders’ vertical descent and ascent rates were set to not exceed 15 cm/s to minimize flow noise caused by its motion.

The glider was programmed to surface every 4 hours unless transiting through a shipping lane. When transiting through shipping lanes, the glider was set to surface every 6 hours to obtain a GPS position, which was essential to controlling its course. During these shipping lane surfacings, the glider did not transmit any data to minimize its time at the surface where it would be vulnerable to ship strikes.

The thruster was not used at any time during 2022, therefore, no thruster usage was recorded. See Figure 3 for deployment and recovery locations of the gliders, and Table 1 for a summary table of the missions.

Table 1. Summary of glider mission timelines and transits performed.

Area covered	DSZ E/C/B	Cabot Strait (Spring)	Cabot Strait (Fall)
Deployment date	2022-04-21	2022-04-21	2022-10-04
Arrival at zone	DSZ E: 2022-05-01 DSZ C: 2022-06-29 DSZ B: 2022-08-23	2022-04-21	2022-10-04
Departed zone	DSZ E: 2022-06-29 DSZ C: 2022-08-23 DSZ B: 2022-08-29	2022-07-01	2022-11-11
Retrieval date	2022-09-01	2022-07-05	2022-11-11
Days at sea	134	76	39
Transits	DSZ E: 11 DSZ C: 11 DSZ B: 1	AS: 8 CS: 8	AS: 4 CS: 4

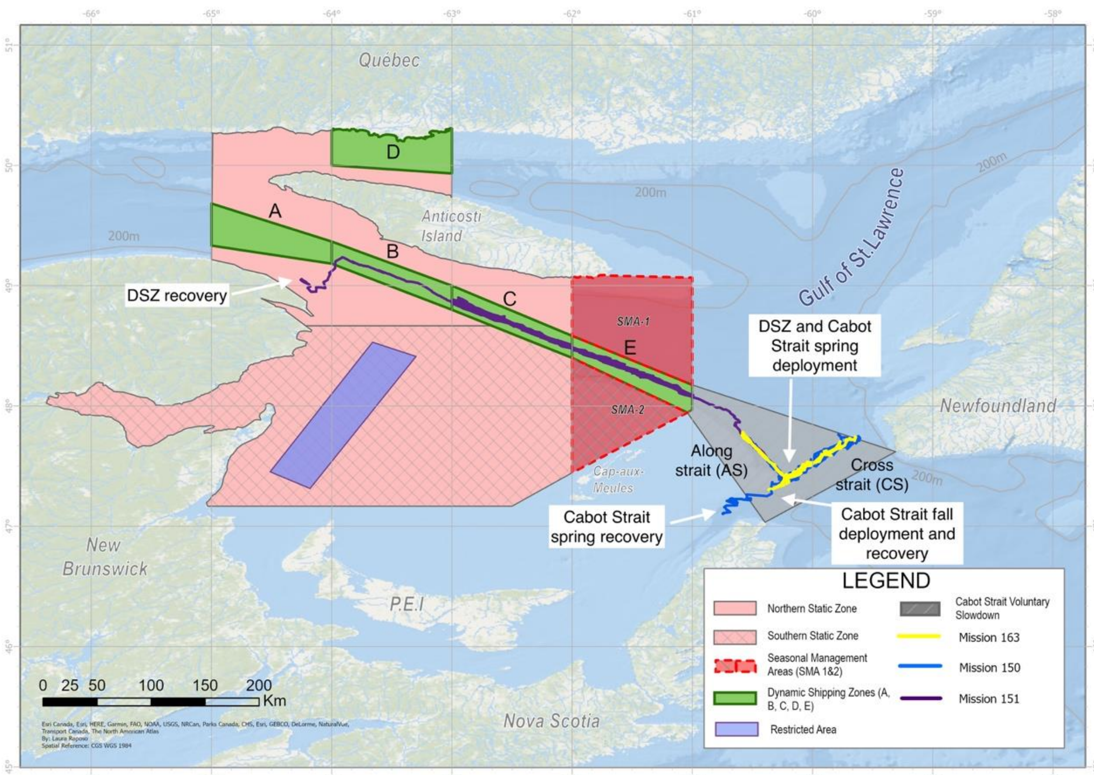


Fig. 3. Map of the glider tracks in relation to the management zones. The blue and yellow lines correspond to missions 150 and 163, the Cabot Strait spring and fall missions, respectively. The purple line corresponds to mission 151, which was the DSZ mission.

2.3 Data Analysis

Real-time detections of five species of baleen whales were classified by the gliders' LFDCS and subsequently validated by the onshore analysts as either 'definite', 'possible', or 'not detected' (see Section 2.1.2). This study's protocol required at least 3 upcalls in a 15-minute period to be transmitted in real-time, at least one of which must have been classified by the right whale detector, in order to score 'detected' for a survey day. Validation by a trained analyst also accounted for the quality of the calls, as well as the prevailing environmental context (e.g., the presence of other, similar sounds) in their assessment. Because of the impacts that a mandatory vessel slowdown can have on the shipping industry, such as increased costs and time expenditures, the protocol ensures that these measures are only triggered when there is 100% certainty a right whale is present.

After the gliders were recovered at the end of a deployment, archived raw acoustic data were uploaded and reviewed by a trained acoustic analyst using a desktop version of the LFDCS software (Baumgartner and Mussoline 2011, see also Section 2.1.1 above). The LFDCS directed the analyst to possible North Atlantic right whale detections that were then reviewed audially and visually to make a final determination of whether a right whale was 'present' or 'absent'. For the purposes of assessing real-time detection performance, a minimum of three right whale upcalls had to be present in the archived acoustic record in a 24-hour period for the analyst to score that day as having right whales present (Davis et al. 2017, Durette-Morin 2021). This 3-call standard has been established as the minimum threshold required to be entirely confident that right whales are definitively present at a daily scale in an archival record (Davis et al. 2017).

After the missions were completed, daily archival data were compared to daily real-time data to calculate detection rates for true positives, true negatives, false positives, and false negatives (Table 2). Detection rates were calculated for these four categories by comparing the three real-time classification types (definite, possible, or not detected) to the two archival classifications (present or absent). In rate calculations, the numerator is the number of detection classifications from the archival record and the denominator is the number of detection classifications in near real-time (Table 2). For example:

$$\text{True positive detections} = \frac{\text{Detections in the archival record}}{\text{Definite detections in real time}} \times 100\%$$

For these calculations, real-time possible detections are treated as 'absent' because levels of confidence in them indicating the true presence of a right whale are low.

Table 2. Definitions of detection rates calculated in this study.

	True Positive	False Positive	True Negative	False Negative
Calculation	Archival Present / Real-Time Definite	Archival Absent / Real-Time Definite	Archival Absent / Real-Time Possible or Absent	Archival Present / Real-Time Possible or Absent

3.0 RESULTS

3.1 Glider Flight Characteristics

DSZ

During 2022, the DSZ glider travelled 2,578 km, performed 11 transits of DSZ E, 11 transits of DSZ C, and one transit of DSZ B over a period of 134 days at sea (Table 1). On average, it took 5.4 days to transit through DSZ E and 4.8 days to transit through DSZ C.

False inflections, a problem where the glider inflects shallower then expected due to an error in its altimeter, affected this glider. Although the problem persisted throughout the mission, its effects were minimized when operating in deeper water. After April 28th, the glider was in water deep enough to set the effective minimum dive of the glider to 200 m to ensure proper dives. See section 4.4 for further details about the glider's false inflections. We believe that this issue had minimal to no effect on the glider's probability of detecting a right whale.

Although the water currents weren't as problematic in 2022 as in 2021, the glider ran into unfavorable currents from April 25th to April 29th. The glider continued to advance during this time, but progress slowed to about 5 km/day, slower than the normal 12km/day average. On May 3rd, the glider was pushed by currents into the northern shipping lane. Current correction was activated, and the glider progressed to its intended track. On May 6th, the currents became variable and current correction was deactivated. When current correction is activated the glider onboard navigation algorithm accounts for the direction of the currents when calculating its heading. This setting works well to keep the glider in local areas where the currents are consistent and does so without increasing the glider's speed or noise. However, when the currents are variable, the correction algorithm doesn't work well because it compensates for the currents that previously affected the glider and could easily cause the glider to head in a wrong direction.

On May 19th, the glider failed to connect to the Iridium server at its expected call-in time. The Cabot Strait glider also missed this connection event, and we believe that there was either a technical problem with the Iridium system or an unfortunate unfavorable alignment of satellite orbits. On August 21st, the glider did not surface for 12 hours due to a suspected Iridium outage. This outage delayed data transmission and occurred close to the time when the glider was supposed to be directed to DSZ B. The outage caused a short delay in the initiation of moving the glider towards the new zone. As soon as communications were reestablished, the settings were updated and the glider continued progress to DSZ B.

Cabot Strait

The spring Cabot Strait glider traveled 1,291 km and performed 8 transits of the AS line and 8 transits of the CS line over a period of 76 days. On average, it took 3.6 days to perform an AS transit and 4.7 days to perform a CS transit.

The fall Cabot Strait glider traveled 670 km and performed 4 transits of the AS line and 4 transits of the CS line over a period of 39 days. On average, it took 3.2 days to perform an AS transit and 3.7 days to perform a CS transit. The last CS transit did not cover the full transit length, as the glider had to be directed to its planned recovery location. This last transit was not used in the calculation to determine the average transit time. Due to unfavorable weather, it held station at the recovery point for 11 days until it was eventually recovered.

Currents posed a slight problem at the intersection point of the AS and CS transects in these missions. The most prominent example occurred between May 6th and 10th when the glider's forward progress stalled until the pilots enabled current correction and adjusted the glider's buoyancy engine settings. These currents were present during the glider's transit to Cape Breton for its spring recovery, as well as while the glider was holding station awaiting its fall recovery. These currents were noticed by the glider team in previous years and preemptive action was taken to prevent the glider from getting pushed close to land by adjusting the glider's waypoints.

Compared to the 2021 glider mission, the glider did not have difficulty getting to the western end of the AS transect. The glider team suspects that moving the AS line into deeper waters improved the glider's flight enough to manage unfavorable currents.

As the glider transited through the shipping lanes, a backlog of data built up that often needed more than one surfacing to completely offload. There is a section of the CS transect where 2 shipping lanes are close together. Initially, only one surfacing waypoint was placed between them, providing the glider only one chance to complete its data transfer as it transited the lanes. On June 7th, a second waypoint was added between these shipping lanes to give the glider a second chance to perform its data offload. See section 4.4 for a more detailed description of the issue.

3.2 North Atlantic right whale detections

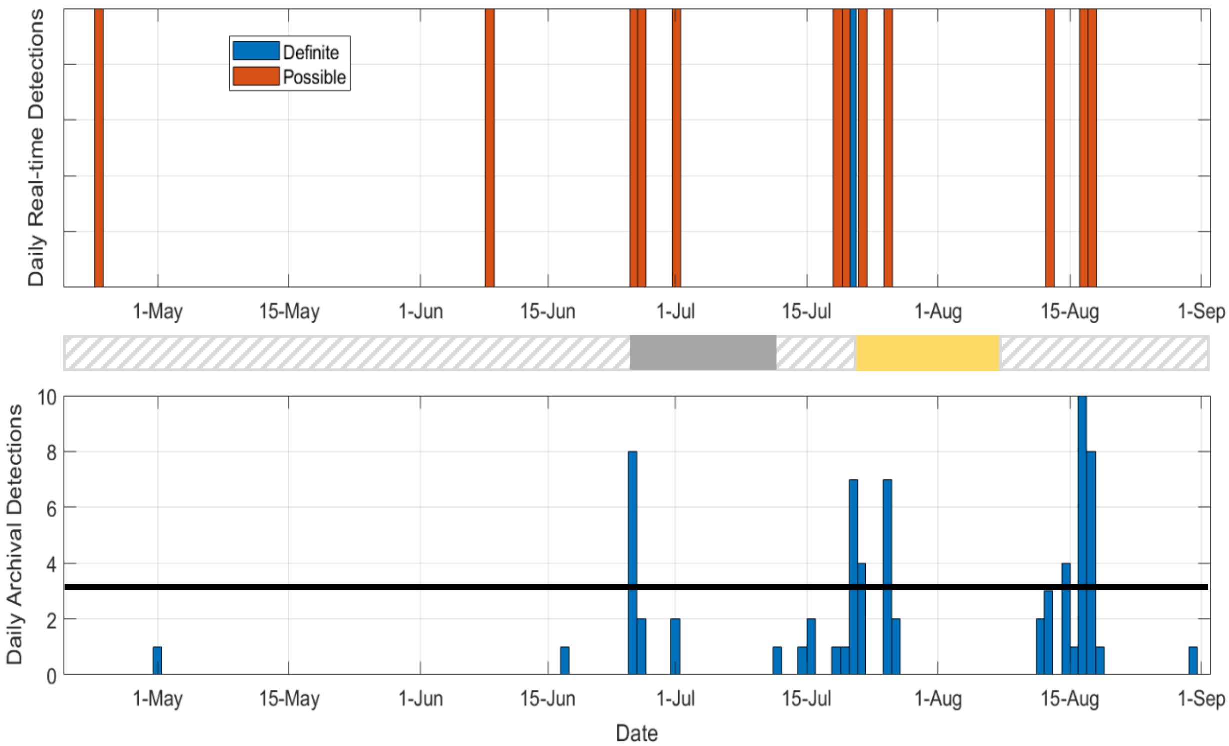
3.2.1 Near Real-Time Detections and Dynamic Speed Limits

DSZ

Definite detections of North Atlantic right whales were made in near real-time on one survey day (Fig. 4). Possible detections were made in near real-time on an additional 12 survey days (Fig. 4). Although possible detections were scattered throughout the season, the majority were made in the latter half of the deployment (i.e., July and August). The single definite detection was made when the glider was within DSZ C. There were no definite right whale detections during the glider's transits in DSZ E at the start of the deployment, nor during its single transit through DSZ B at the end of the deployment.

Despite regular coverage over or near the shipping lanes by aerial surveillance surveys during the 134-day deployment period, only one confirmed visual observation of right whales was made within DSZ C (Fig. 5). This single visual detection was made on a different day than the single acoustic detection (June 26th for the former, July 22nd for the latter), and therefore the visual detection on its own triggered a 15-day 10-knot speed limit in DSZ C in late-June. It is worth noting that the confirmed visual observation of right whales in June occurred on the same day as possible acoustic detections were recorded on the glider in the same area, demonstrating the complementary capabilities of these survey platforms.

Navigational warnings (NAVWARN) of a 10-knot speed limit in DSZ C were to be issued within 24 hours of a real-time acoustic detection, if no speed limit was in place at the time the detection was made. If a speed limit was already implemented when a new real-time acoustic detection was made, the speed limit was reset for an additional 15-day period starting on the day of the new detection, provided the new detection occurred in the last seven days of a previous slowdown. Acoustic detections resulted in one 15-day period of speed restrictions in DSZ C over the 4.5-month deployment (Fig. 4). The speed limit was implemented on July 22nd and remained in effect until August 8th, 2022. In total, a speed limit was in place in DSZ C for 11.2% of the 134-day glider deployment period, as a direct result of acoustic



detections.

Fig. 4. Comparison for the DSZ glider between daily near real-time North Atlantic right whale upcall detections (top panel) and the number of calls autodetected and reviewed audio-visually from the archival data after the deployment (bottom panel). The implementation of the slow zone in DSZ C is shown by the bars between the two panels; dark gray indicates a slowdown triggered by visual observations from aerial surveillance, yellow indicates a slowdown triggered by acoustic detections made on the glider, and the light gray hatching indicates that no slowdown was in place. A minimum of three upcalls per day in the Daily Archival Detections series is required to score right whales as present on that day (see Section 2.3). The black line in the bottom panel represents the daily three-call threshold required to score whales as 'present'.

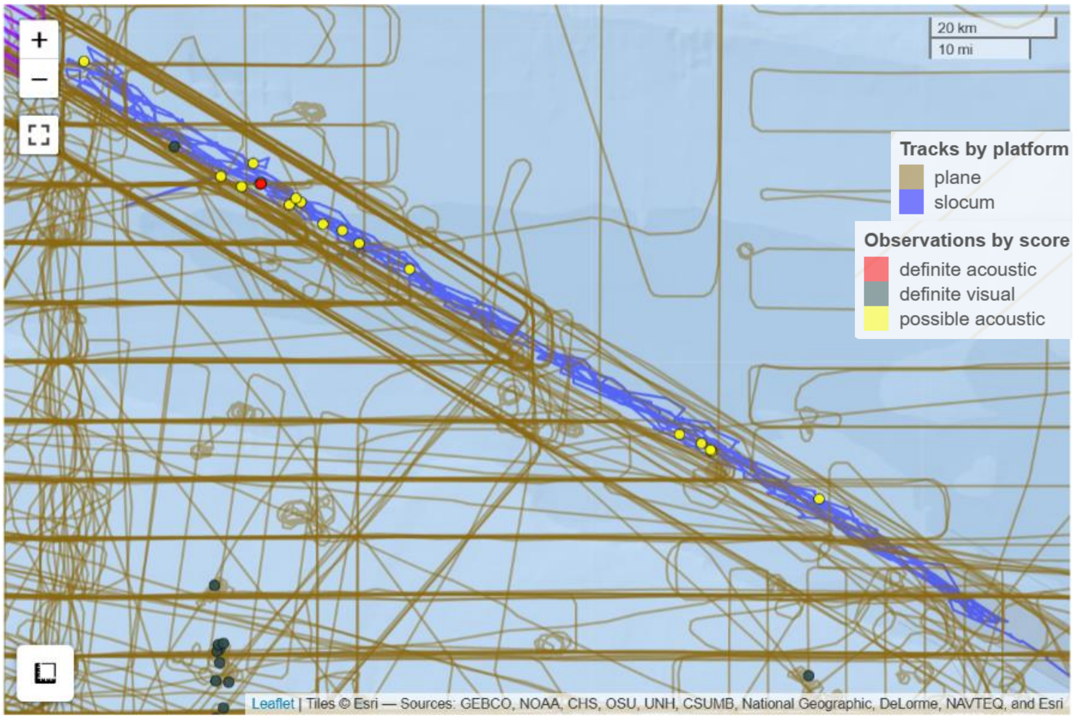


Fig. 5. Map and time series of visual (brown tracks) and near real-time acoustic (blue tracks) survey effort between May 1st and August 23rd, 2022, in DSZ C/E. The red dot indicates a definite acoustic detection, yellow dots indicate possible acoustic detections, and gray dots indicate definite visual detections. Map produced using open-access layers on the WhaleMap (Johnson et al. 2021) internet site (https://whalemap.org/).

Cabot Strait

No definite detections of North Atlantic right whales were made in near real-time during either the spring or fall deployments, although possible detections were made on one survey day during the spring deployment (Fig. 6). Despite aerial surveillance efforts (particularly April – July) over or near the Cabot Strait during the 76- and 39-day spring and fall deployments, respectively, there were no confirmed visual observations of right whales in the area (see Fig. 7 for aerial surveillance coverage).

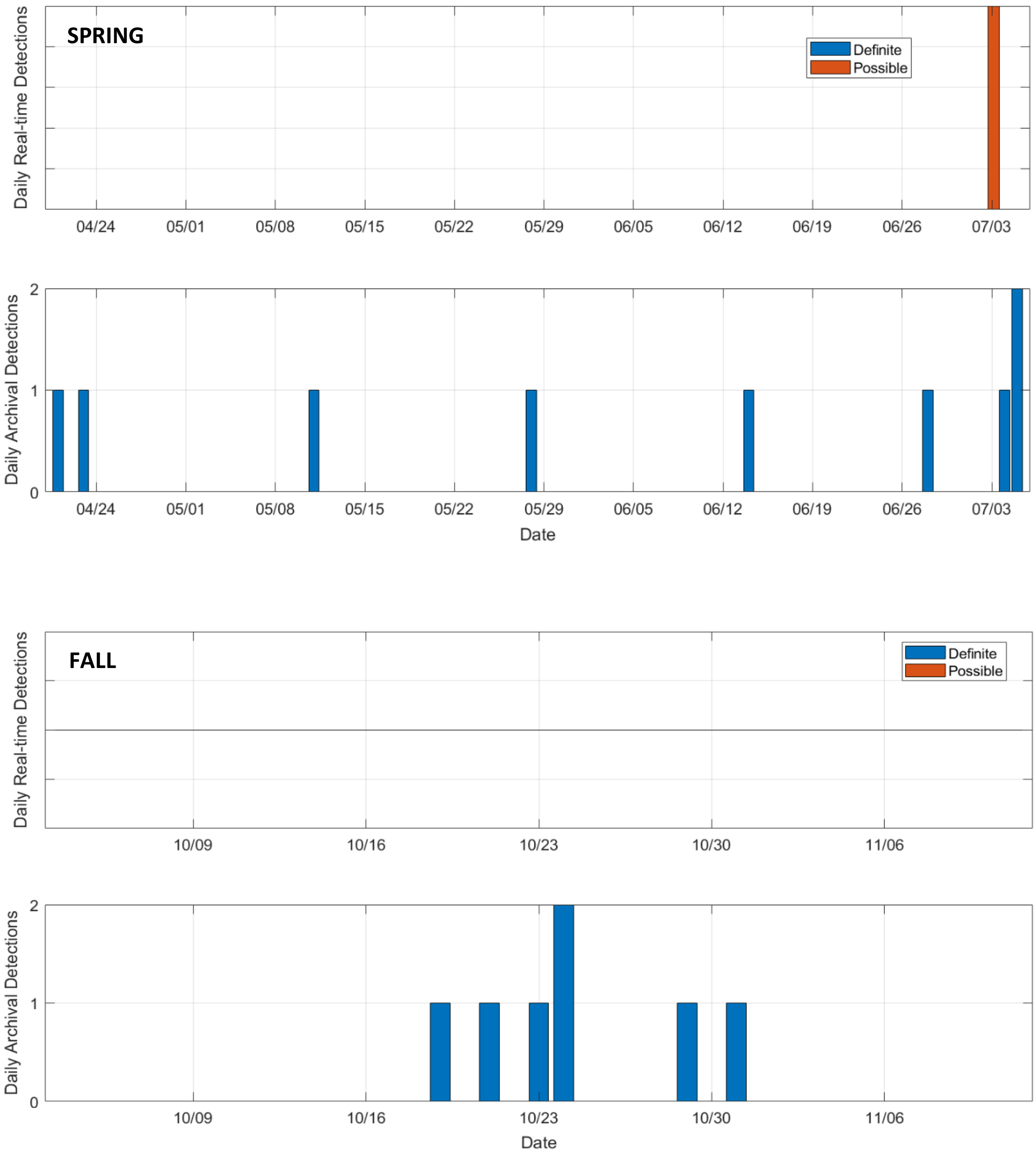
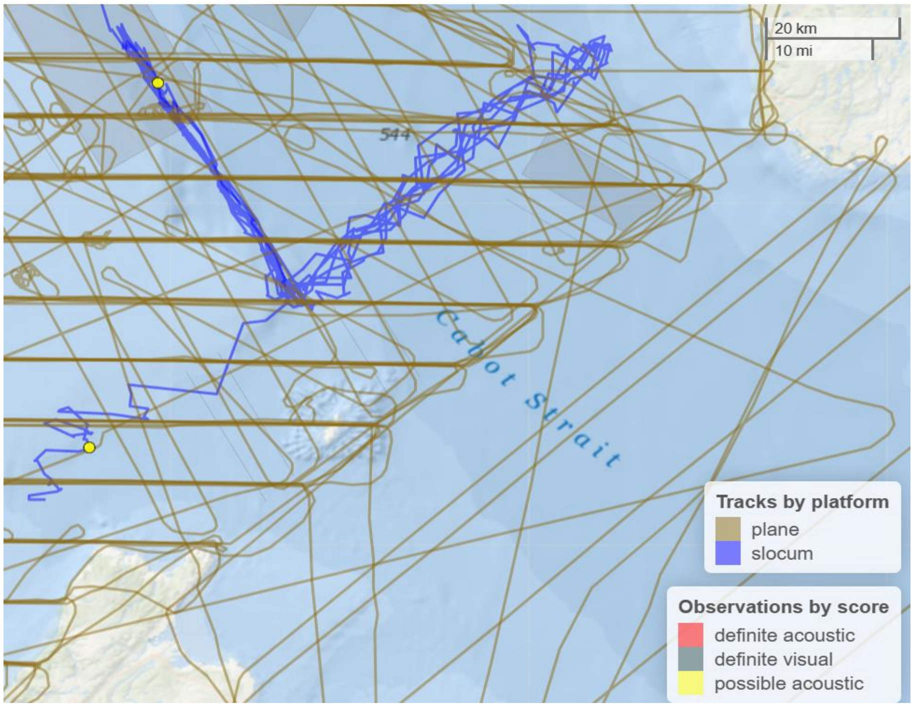


Fig. 6. Comparison for the Cabot Strait glider between daily near real-time North Atlantic right whale upcall detections (top panels) and the number of calls autodetected and reviewed audio-visually from the archival data (bottom panels) after the spring and fall deployments. A minimum of three upcalls per day in the Daily Archival Detections series was required to score right whales as present on that day (see Section 2.3).

SPRING



FALL

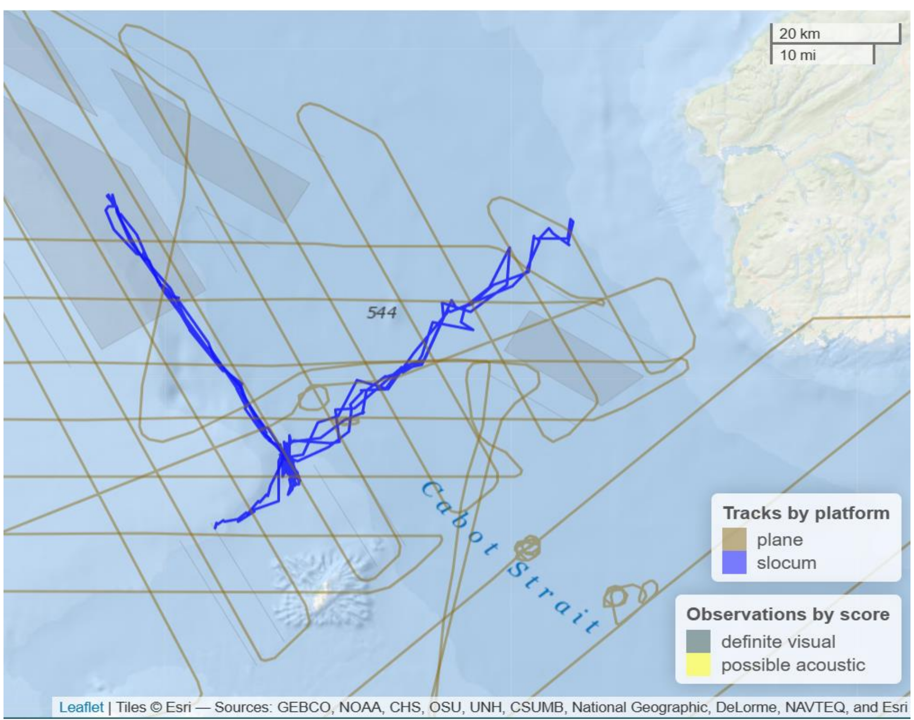


Fig. 7. Map and time series of visual (brown tracks) and near real-time acoustic (blue tracks) survey effort between April 21st – July 7th in the spring and October 4th – November 11th in the fall of 2022, in Cabot Strait. Map produced using open-access layers on the WhaleMap (Johnson et al. 2021) internet site (https://whalemap.org/).

3.2.2 Archival Acoustic Data Analyses

DSZ

Right whale upcalls were detected in the archival acoustic record on 22 days of the 134 days surveyed (Fig. 4), but only eight of those days had three or more calls and were subsequently scored by the analysts as having whales 'present'. Right whales were present in the archival record on the single day they were scored as definitely detected in real-time (true positive), and on seven days when they were scored in real-time as either possibly being present or not detected (false negative). This translates into a false positive rate of 0% and a false negative rate of 5% over the deployment period (Tables 2 and 3). Although the confirmed visual observation in June and definite acoustic detection in July meant that there were 30 days of speed restrictions in place that spanned much of June and July's clusters of possible/definite right whale presence (Fig. 4), there was an eight-day period in mid-August that included four days when right whales were present in the archival record but were not scored as detected in near real-time. Therefore, no slowdown was triggered in DSZ C, meaning that there may have been an increased risk to these whales during this period.

Possible detections were reported on 12 days in near real-time, but right whales were scored as absent in the archival record on six of these days (Table 3). Right whales were scored as not detected in near real-time on 121 days and were confirmed archivally as absent on all but one of these days.

Table 3. Summary of all detections of right whales for the DSZ glider in 2022, and percentages of detections that were True Positives, True Negatives, False Positives, and False Negatives. A description of terms and calculations is provided in Table 2 and section 2.3 of the report, respectively.

	Archival Present (days):	Archival Absent (days):
Real-time Definite	1	0
Real-time Possible	6	6
Real-time Not Detected	1	120
	Rates (%):	
True Positive	100	
False Positive	0	
True Negative	95	
False Negative	5	

Cabot Strait

The Cabot Strait deployments resulted in few days with right whale upcalls, and the calls that occurred were produced at very low densities (Fig. 6). Less than three upcalls were present in the archival acoustic record on eight days of the spring survey and six days of the fall survey (Fig. 6). The days with recorded calls during the spring survey were relatively evenly distributed across the deployment, while those with calls during the fall survey were concentrated in late-October. However, no day had three or more calls during either the spring or fall deployments and, therefore, none were scored as having right whales 'present' for the purposes of assessing glider real-time detection performance. Right whales were scored as absent in the archival record on the only day they were scored as possibly being present in near real-time (July 3rd) and were scored as archivally absent on all 114 days they were scored as not detected in near real-time. True and false positive rates were not calculated for this mission as there were no days when right whales were scored as definitely present during the 115-day deployment.

Table 4. Summary of all detections of right whales for both Cabot Strait glider deployments in 2022 (i.e., the 76-day spring deployment plus the 39-day fall deployment), and percentages of detections that were True Positives, True Negatives, False Positives, and False Negatives. A description of terms and calculations is provided in Table 2 and section 2.3 of the report, respectively.

	Archival Present (days):	Archival Absent (days):
Real-time Definite	0	0
Real-time Possible	0	1
Real-time Not Detected	0	114
	Rates (%):	
True Positive	N/A	
False Positive	N/A	
True Negative	100	
False Negative	0	

3.2.3 Year-to-year acoustic comparisons

Year-to-year comparisons of acoustic detections (Tables 5 and 6) highlight several important results from the multiyear glider program: false negative rates are consistently low (i.e., $\leq$ 5%), meaning that there have been few days over the years of the study where definite NARW upcalls were missed in near real-time; true positive rates are consistently high, particularly in the DSZs (i.e., $\geq$ 93%), meaning that near real-time acoustic monitoring has a rare potential to generate results that will trigger the implementation of costly dynamic management measures when whales are not actually present. Right whales are detected frequently by gliders in the DSZs, whereas they are detected significantly less often in Cabot Strait and for this reason near real-time monitoring has proven effective in the shipping lanes, resulting in 120 days of speed limits across three survey years. Right whales were detected infrequently in the Cabot Strait suggesting they have irregular and infrequent calling as the migrate through this area. Thus acoustic monitoring from gliders for right whales appears to be less reliable in the Cabot Strait voluntary slowdown zone.

Table 5. Year-to-year comparisons of the DSZ B/C/E glider deployments from 2020 – 2022.

DSZ B/C/E		**2020**	**2021**	**2022**
Deployment length (days)		68	116	134
Near real-time acoustic detections	Definite	7	14	1
	Possible	10	30	12
Archival acoustic detections	Definite	8	18	8
	Possible	9	21	14
Detection rates (%)	True Positive	100	93	100
	False Positive	0	7	0
	True Negative	98	95	95
	False Negative	2	5	5
Number of days with speed limit		33	72	15
Percentage of days with speed limit		47.8	62.1	11.2

Table 6. Year-to-year comparisons of the Cabot Strait glider deployments in 2021 and 2022.

Cabot Strait		**2021**	**2022 – Spring**	**2022 – Fall**
Deployment length (days)		107	76	39
Near real-time acoustic detections	Definite	2	0	0
	Possible	13	1	0
Archival acoustic detections	Definite	2	0	0
	Possible	4	8	6
Detection rates (%)	True Positive	50	N/A	N/A
	False Positive	50	N/A	N/A
	True Negative	99	100	100
	False Negative	1	0	0

4.0 SYSTEM PERFORMANCE AND OPERATIONS CONSIDERATIONS

4.1 System Performance

The gliders' flight performance and real-time detection system performed as anticipated and intended during the deployments. The false positive and false negative rates reported for North Atlantic right whale calls in other studies are nominally 0% and 17.9%, respectively (Baumgartner et al. 2020), which is consistent with the results of this study. As demonstrated by previous glider deployments (Davies et al. 2020, Davies et al. 2021), the gliders were able to consistently navigate well along their intended track lines. Importantly, the DSZ C glider did not enter the shipping lanes, meaning risk to the glider was minimized with this survey design.

In response to the Laurentian Channel glider detections, a speed limit in DSZ C was implemented for 11.2% of the survey period (i.e., one 15-day period). This is in stark contrast to 2021, when glider detections were responsible for vessel slowdowns during 62.1% of the survey period (Table 5). Nevertheless, the false negative rates between the two years were the same (5% for both 2021 and 2022), and well within what is expected by the detection system/protocol. The difference in detections between the two years likely reflects the once again changing distribution and movement patterns of whales that were observed in the southern Gulf of St. Lawrence foraging grounds this year, which may have influenced their migration routes and proximity to the shipping lanes during the season. Nevertheless, these results indicate that the gliders continue to be an effective monitoring method to support dynamic shipping management in DSZ C. It is expected that gliders could perform similarly in the other three DSZs in the Laurentian Channel (DSZ A, B or E) because the other three DSZs are similar in shape, size, orientation relative to ship traffic, currents, water characteristics, and bathymetry.

There were minimal numbers of right whale detections in the Cabot Strait for the second year, even though incoming and outgoing whales moving to and from the Gulf of St. Lawrence surely must pass through this area (Table 6). This could be the result of several factors, such as high noise levels in the Strait from vessel traffic degrading glider hydrophone performance, low monitoring effort by the gliders near the coast if the whales migrate there, a limited upcall detection range, and a single mobile platform covering a large area in one deployment (e.g., Johnson et al. 2022). However, low calling rates by whales during migration are suspected to be the primary limiting factor to detection in this area. Background noise levels in the frequency range of right whale upcalls (i.e., 100 – 300 Hz), were not significantly different across the deployments, regardless of location (Figure 8). Noise levels in the DSZ were predominantly between 55 – 75 dB re 1 $\mu Pa^2/Hz$ in the upcall frequency range. For the spring Cabot Strait deployment, noise levels in the same range were lower than this, between 50 – 70 dB re 1 $\mu Pa^2/Hz$, whereas during the fall Cabot Strait deployment noise levels were slightly higher than those in the DSZ, between 65 – 80 dB re 1 $\mu Pa^2/Hz$ (Figure 8). Given that the spring deployment in Cabot Strait was actually quieter than the one in the DSZ, and that possible archival detections were similar across the lower levels in spring (n = 9) and higher levels in fall (n = 7) for the two Cabot missions, there is little to indicate that the observed differences in near real-time and archival detections (i.e., more in the DSZ, fewer in Cabot Strait) were attributable to differential acoustic masking between locations. Therefore, this provides qualitative support for lower right whale calling rates during their migration through the Cabot Strait.

A challenge for the monitoring program is the conservative approach that is taken for real-time monitoring, which aims to minimize false positives at the expense of false negatives. By requiring a minimum of three calls at least 10 dB above the background noise to be pitch-tracked in one 15-minute tally period to score a 'definite' detection, the program is under-sampling whale presence due to quieter calls and/or those that only occur once or twice in a 15 minute period. This is especially important to consider, given that travelling whales during migration are believed to vocalize at lower rates than during other behavioural states across their ecological range (e.g., Davis et al. 2017). However, this year's false negative rate of 0% was even smaller than 2021's false negative rate of 1%, while the two years combined only had two definite acoustic detections made in near real-time, two days with right whales present in the archival data, and 18 days with right whales possibly present in the archival data, despite a total of 222 survey days across both years. This means that right whale upcalls are simply not being detected at high densities as they pass through the Cabot Strait (with or without a conservative protocol), suggesting that irregular and unreliable acoustic activity may render real-time monitoring using the same protocols as in the DSZs ineffective for accurately monitoring whale movements through this area. As assets by other government departments are being deployed in the region (i.e., long-term, bottom-moored acoustic recorders by DFO) that will continue to provide data on NARW acoustic behavior in Cabot, facilitate opportunities to refine monitoring methodologies, and better characterize patterns of whale calling during periods of migration, it is recommended that Transport Canada focus their glider deployments in the Dynamic Shipping Zones, as this has proven effective over several years and is an integral component of their dynamic management measures in the Gulf of St. Lawrence.

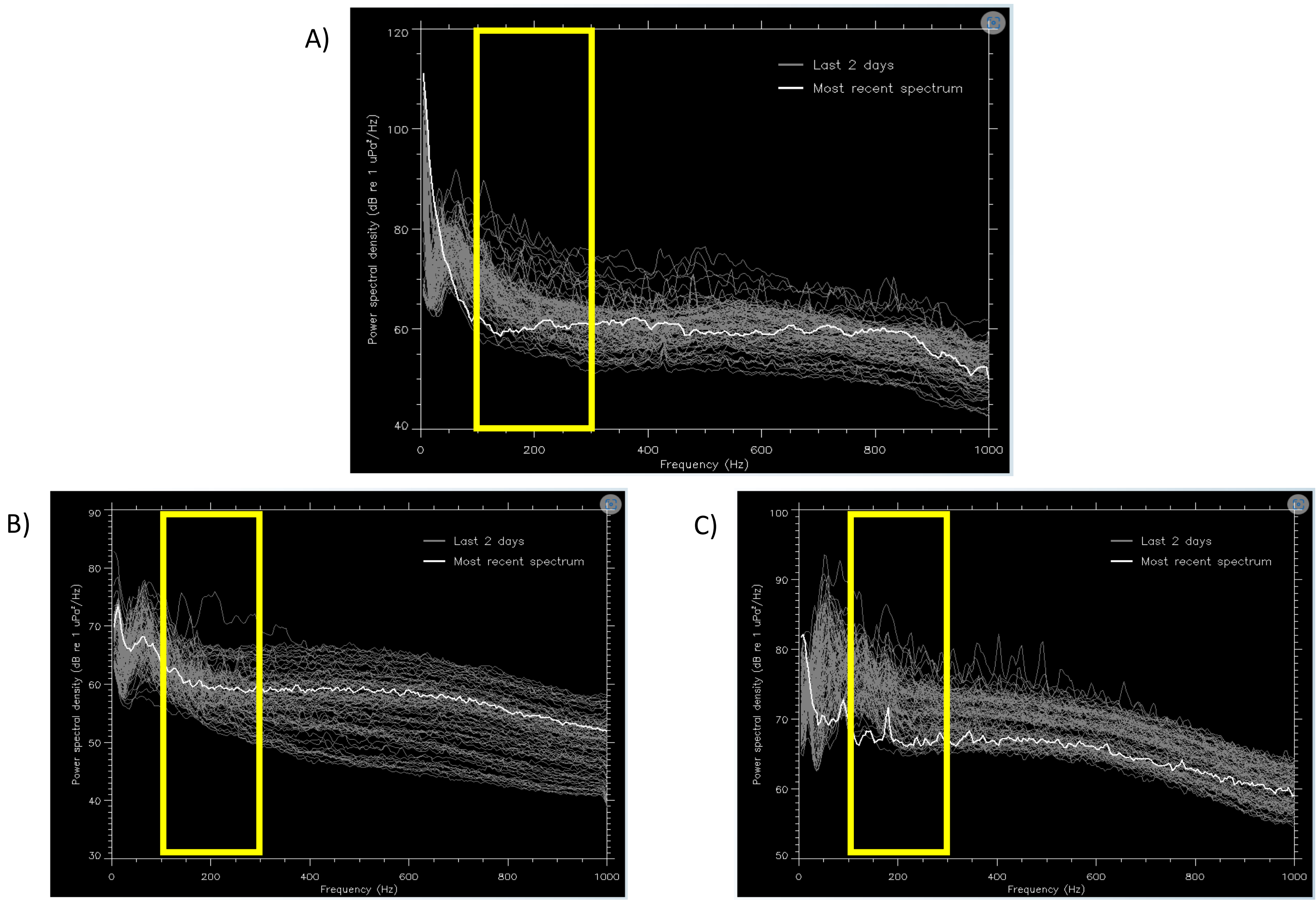


Figure 8. Daily average power spectra across the deployments in A) DSZ B/C/E, B) Cabot Strait in the spring, and C) Cabot Strait in the fall. The yellow boxes indicate the frequency range of North Atlantic right whale upcalls (i.e., 100 – 300 Hz).

4.2 Glider power requirements

The Slocum gliders used in the 2022 monitoring season were top-of-the-line model G3s. Although they have advantages such as increased computing power, these gliders come with increased power consumption compared to the older G3 model.

One new feature enabled by the G3s model gliders that was implemented during this year's work was file compression before sending data ashore via the Iridium satellite system. This decreased the operating time for the power-hungry Iridium modem. The compression worked well for some data sources and cut down glider surfacing times, however, the data files recorded by the DMON were unable to be compressed. This limited overall power savings to a certain extent.

In 2022 the AS line in the Cabot Strait was moved into deeper waters. This action resulted in power savings by reducing buoyance engine draw on the batter. The glider's buoyancy engine consumes power twice per dive/climb cycle. Since shallow dives consume as much energy as deep dives, but cover less distance over the ground, operating in deeper water allows the glider to cover more area per dive. Operating in deeper water reduces battery use and allows the glider to remain at sea for longer.

In December 2022, a new glider software update was issued by the glider manufacturer and one of the key features was a general revamp of protocols and algorithms with the intention of reducing the power consumption of G3s gliders during deployments. The gliders that will be used for the 2023 mission are scheduled to get this software upgrade during winter 2022-23 and the glider team looks forward to improved power availability during future missions. Since it is unclear how much power will be saved, mission longevity for 2023 will be conservatively planned using battery consumption statistics from the 2022 missions.

The false inflections suffered by the DSZ glider led to an increase of power consumption due to the increased use of the buoyancy engine during shallow dives. Once the glider was in deeper waters, about 7 days into the mission, the glider's altimeter was set to only turn on after 200 m, which minimized use of the buoyancy engine. See section 4.4 for further details.

4.3 Glider data backlog

Although occurrences of backlogs of data were reduced in 2022 compared to previous years, there were still occasions where backlogs occurred. This was most notable for the Cabot Strait glider and a principal cause was problems with the Iridium network that were beyond our control. The major Iridium network outages were mentioned and discussed in section 3.1 of this report. The second cause of backlogs in 2022 resulted from the transit between shipping lanes of the Cabot Strait glider.

When the glider crossed shipping lanes, it remained under water for 6 hours at a time and only surfaced briefly to obtain a GPS position with no time taken to send data. These surfacings typically only last 2-5 minutes to minimize the time the glider spent at higher risk of a ship strike. Our gliders were set to begin data transmission once they had transited through a shipping lane and reached the next programed waypoint. Once the glider begins data transmission, it will generally transfer all the data it has to send unless the positioning of the Iridium satellites causes the link to break. When a connection break occurs, the glider remains at the surface trying to reconnect to the Iridium network until a surface timer triggers the glider to continue its mission. Even in times when iridium signal strength is poor a glider can normally complete a data offload within two to three surfacings. However, in the Cabot Strait where the in/out shipping lanes are close together (Fig. 8; reference waypoint CS 8), the glider's data backlog could often not be offloaded until it crossed the second shipping lane many hours later. During the 2022 deployments, following several occasions when not all the data were transferred during the single surfacing scheduled for the waypoint between the in/outbound shipping lanes, a second waypoint was added between these shipping lanes. This second waypoint gave the glider another chance to complete its data transmission and prevented delays in relaying near real-time data telemetry. It is recommended that this approach be taken with any shipping lane crossings in the 2023 season.

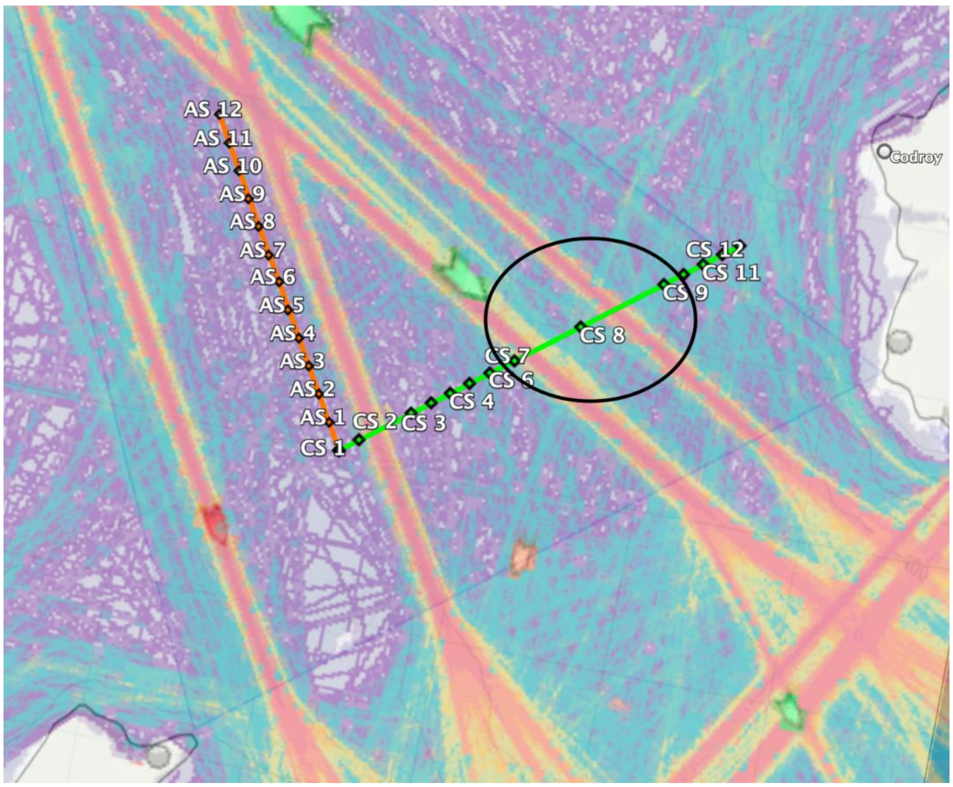


Fig. 9. Map of the Cabot Strait monitoring region with the glider's waypoints. The AS and CS transects are shown in orange and green, respectively. The colours of the background represent ship traffic density where warmer (e.g., red/orange) colours represent more ship traffic and cooler (e.g., blue/green) colours represent less ship traffic. The region highlighted by a black circle is where the glider was scheduled to perform one data transfer before transiting under a second shipping lane. Map produced by Dalhousie University's CEOTR group.

4.4 False inflections

Slocum gliders have an altimeter to measure the distance between the glider and the seafloor. The manufacturer recently changed the circuitry of their altimeter sensor and the newly purchased glider deployed in the DSZ had this changed circuitry. In its manufacturer default settings, the glider often measured the seafloor as being shallower than the true depth. The glider's internal settings were modified by the CEOTR team after a discussion with the manufacturer, but unfortunately, the performance didn't improve. Once the glider was in deeper waters, the depth at which the glider dives was manually programmed by the pilots, which improved the glider's flight.

After conversations with other glider users in November 2022, a new series of settings have been identified to improve the performance of the new altimeter. These settings will be implemented in future missions with gliders that have these new circuit boards, unless the manufacturer informs us of alternative fixes that they have developed. If a problem continues to exist, our pilots will continue to manually program depths, as needed.

4.5 Glider mission aborts due to science logging errors

Science logging errors persisted at a low frequency in the 2022 glider missions and originate from an as-yet-unidentified problem in the manufacturing of the glider. This science logging error causes the glider to abort out of its pre-programed mission. If left unattended after an abort, the glider will enter a 'station keeping' mode where it attempts to hold station. This process consumes more battery power. To prevent the station keeping mode from activating, the CEOTR team developed an automated script to monitor for glider aborts and in the event of an abort, return the glider to its pre-programed mission. This automated script is a temporary measure until the manufacturer solves the underlying issue. Since it is not possible to develop a script to handle every scenario, there were occurrences where the script would not send the glider back on mission and a glider pilot would have to manually intervene and command the glider back on its mission. See Table 7 for the number of times the script managed the abort and times when manual intervention was required. To verify that the script took proper control of the glider, pilots made sure to activate a setting to receive mobile phone notifications any time the glider aborted. Over the course of the missions, the script was further optimized whenever a new issue was discovered. Overall, this combination of script and pilot fixes kept the gliders successfully completing their planned missions during the 2022 season.

Table 7. Comparison of glider operational aborts that were able to be managed remotely by implementing scripts vs. recovery and manual interventions.

	DSZ glider	Cabot Strait glider
Abort managed by the script	7	2
Abort managed by a pilot	7	4

5.0 CONCLUSIONS AND RECOMMENDATIONS

Glider operations in 2022 to support right whale monitoring efforts in the Gulf of St. Lawrence DSZ C and in the voluntary speed reduction zone in the Cabot Strait successfully detected the presence of right whales and four other baleen whale species. Right whale detections, when they were confirmed, were rapidly reported to managers who used the information to implement necessary protection measures. Based on glider detections in DSZ C, mandatory vessel speed reductions were implemented for 11.2% of the 134-day glider mission. Aerial flights over DSZ C during the period the glider was monitoring only sighted right whales on one occasion. However, the confirmed visual observation, together with the single acoustic detection made by the glider, resulted in speed reductions that were implemented for a total of 22.4% of the deployment period. This provides a strong rationale for combining visual and acoustic surveys when possible and reiterates that PAM equipped gliders are clearly a useful tool in supporting the Government of Canada's multifaceted protection efforts for this endangered species in the Gulf of St. Lawrence. No fatalities of right whales were reported in the Gulf of St. Lawrence in 2022.

A second glider deployed in 2022 to the Cabot Strait did not detect any right whale calls in this area in near real-time. The Strait is believed to be the primary migration corridor for right whales to seasonally enter and exit the Gulf of St. Lawrence and why the whales do not seem to call in this area is the subject of current research. The lack of calls may indicate that the whales reduce or in some cases stop calling while they are migrating, which means that near real-time acoustic monitoring may not be a valuable, cost-effective option for this area in the long-term.

The primary challenges to glider operations in 2022 were water currents, satellite communications, and technology faults. Regarding currents, while they sometimes delayed forward progress, their effects were manageable. As the glider technical team gains experience with and knowledge of the conditions in the Gulf, future mission plans will be designed so that the missions will be minimally impacted by currents. Satellite communication issues are beyond the control of the project participants, outside of complaining about poor service, and must be left to the Iridium network to resolve. The Iridium network is the only communications link able to connect to the project gliders. The communication issues the project faced in 2022 affected many additional Iridium customers, hence it is in the company's best interests to fix these issues. With regards to technology faults in the gliders, these are complex machines and things will occasionally fail. The challenges faced in 2022 with regards to mission aborts and false inflections were minor in the sense that the gliders could continue their planned missions as desired. The manufacturer is aware of these issues, and we are confident that a software or hardware fix will eventually be developed by the manufacturer. The experienced technical team that operated the gliders in 2022 will be in place for the 2023 season, and a stand-by glider will be ready to replace any glider that has a technical issue.

<u>Recommendations for the future</u>

Based on the knowledge gained by the project team, the following recommendations are proposed for subsequent deployment years:

- Continue incorporating the lessons learned from the previous years' operations into plans for unanticipated events in future years. For 2023, follow limits set in 2022 on how long to wait for unexpected currents that are encountered to subside and the amount of effort to be devoted to attempting to move out of such currents before changing the glider's flight plan.
- Continue glider monitoring for right whale calls focused in the DSZs. Based on data from the 2020 – 2022 glider missions, we know that whales are calling when they are in the vicinity of the shipping lanes and that real-time monitoring is effective in detecting them in these areas. We also recommend combining/overlapping visual and acoustic surveys when practicable, as this season demonstrated the increased probability of detecting whales, and subsequent implementation of speed restrictions, when both platforms cover the same area.
- As there were so few detections in the Cabot Strait over two years, we feel it is the best use of Transport Canada's assets to prioritize glider deployments in the DSZs throughout the season, where they have a direct impact on dynamic management measures.

- If Transport Canada judges that the glider program is a cost-effective and valuable tool to detect and protect right whales and should be extended or expanded, begin discussions regarding the steps that should be taken.

- Once a regional blue whale call library is established, added to LFDCS, and detection ranges of common calls are estimated, we strongly recommend that they be considered for inclusion in future iterations of near real-time dynamic management measures, as they too are an at-risk species that are acoustically active and seasonally abundant in the Gulf of St. Lawrence.

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