REPORT

16 February 2018

BAFFINLAND IRON MINES CORPORATION

2017 Bruce Head Shore-based Monitoring Program

Submitted to:
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Report Number: 1663724-041-R-Rev0

Distribution:

1 copy - Baffinland Iron Mines Corporation

Record of Issue

Company	Client Contact	Version	Date Issued	Method of Delivery
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Baffinland	Megan Lord-Hoyle	0	16 February 2018	e-mail

Executive Summary

The Mary River Project (hereafter, “the Project”) is an operating open pit iron ore mine located in the Qikiqtani Region of North Baffin Island, Nunavut (Figure 1-1). Baffinland Iron Mines Corporation (Baffinland) is the owner and operator of the Project. The operating Mine Site is connected to a port at Milne Inlet (Milne Port) via the 100-km long Milne Inlet Tote Road. Future but yet undeveloped components of the Project include a South Railway connecting the Mine Site to a future port at Steensby Inlet (Steensby Port).

A Project Certificate No. 005, amended by the Nunavut Impact Review Board (NIRB) on 27 May 2014, authorizes the Company to mine up to 22.2 million tonnes per annum (Mtpa) of iron ore from Deposit No. 1. Of this 22.2 Mtpa, the Company is currently authorized to transport 18 Mtpa of ore by rail to Steensby Port for year-round shipping through the Southern Shipping Route (via Foxe Basin and Hudson Strait), and 4.2 Mtpa of ore by truck to Milne Port for open water shipping through the Northern Shipping Route using chartered ore carrier vessels.

To date, Baffinland has been operating in the Early Revenue Phase of the Project, which includes shipping up to 4.2 Mtpa of ore via Milne Port during the open-water season (July to late October). Shipping of ore from Milne Inlet during the ERP began in 2015 and is expected to continue for the life of the Project (20+ years). During the first year of ERP Operations in 2015, Baffinland shipped ~900,000 tonnes via 13 ore carrier voyages. The amount of ore shipped during the 2017 open-water season has since increased to ~4.2 million tonnes in 2017 via 56 return ore carrier voyages.

This report presents the results of shore-based monitoring of narwhal and vessel traffic in Milne Inlet near Bruce Head during the 2017 open-water season. Initiated in 2013, the Bruce Head shore-based monitoring study was designed to specifically address Project Certificate (PC) conditions related to evaluating potential disturbance of marine mammals from shipping activities that may result in changes in animal distribution, abundance, and migratory movements in the study area. The primary objective of the shore-based study was to investigate narwhal response to shipping activities along the Northern Shipping Route in Milne Inlet. The 2017 shore-based study represents the fifth consecutive year of environmental effects monitoring undertaken at Bruce Head in support of the Mary River Project. The 2017 study design was similar to that applied in previous survey years (2014-2016), with data collected on narwhal Relative Abundance and Distribution (RAD) within a defined Stratified Study Area (SSA); and on group composition and behavior within a 1-km Behavioral Study Area (BSA). Additional data were also collected on environmental conditions and anthropogenic activities (e.g., shipping and hunting activities) to distinguish between the potential effects of Project-related shipping activities and confounding factors which may also affect narwhal behavior. Data from previous survey years (2014-2016) were included in the raw data plots for a visualization of between-year variability.

The Bruce Head shore-based study took place between 31 July and 29 August 2017, with a total of 27 surveys completed. Poor weather conditions prevented data collection on 14 and 27 August. Based on automated ship tracking information, a total of 30 large vessels (>100 m in length) completed 58 one-way transits through the SSA during the survey period. Of the 58 one-way transits, 43 were made by Project-related bulk (ore) carriers, 10 were made by Project-related cargo vessels, and 2 were made by Project-related fuel tankers. Passenger vessel transits (n = 3) were the only large vessels that were non-Project-related to transit through the SSA. During the active surveys, large vessels were recorded in the SSA on 16 of 23 survey days and included 21 Project-related vessel transits and one passenger vessel (not Project-related).

A total of 160 unique RAD surveys were conducted in the SSA over the 2017 study period, resulting in an average of 6 RAD surveys per day. A total of 11,969 narwhal sightings were recorded in the SSA during 2017. Total daily narwhal counts ranged from zero (31 July 2017) to 1,261 (20 August 2017), with an average count of 75 narwhal per RAD survey (460 per day). In general, narwhal counts were lowest in the northern strata (Strata A) and highest in the southern strata (Strata G, H and I), consistent with observed trends in distribution reported in previous survey years (Smith et al. 2017). Relative to the cross-channel (east-west) distribution of narwhal in the SSA, the majority of narwhal sightings occurred in the central portions of the inlet (5,478 sightings in Substrata 2), followed by the nearshore strata (4,427 sightings in Substrata 1), with lowest narwhal counts occurring in the offshore strata (1,505 sightings in Substrata 3).

Key findings from the 2017 Bruce Head Shore-based Monitoring Program include the following:

- Relative abundance and distribution:
  - 2017 model results indicate that the 'direction of travel' of large vessels transiting through Milne Inlet (inbound vs. outbound) did not have a significant effect on narwhal presence/absence in the SSA. This finding was inconsistent with previous survey results (2014-2016), in which a significant higher number of narwhal were shown to be present when an outbound (i.e., exiting) vessel approached a given substratum compared to periods when no vessels were present (Smith et al. 2017). It is currently unclear whether this discrepancy in findings is due to variation in analytical approach between years (e.g., the use of distance from vessel as a continuous variable during analysis of 2017 data). It is therefore recommended that the full dataset (2014-2017) be analyzed using the current model to increase sample size and provide insight into inconsistencies between survey years.
  - A significant interaction was observed between 'vessel distance from substratum' and 'vessel orientation[1]' – indicating that narwhal counts in a given substratum were shown to change depending on the proximity of the vessel to the substratum, although this effect was dependant on whether the vessel was moving towards (approaching) the substratum or moving away (departing) the substratum. Incorporation of the 2014-2016 RAD data into the model may help further refine this relationship.
- Data collected on group composition and behavior revealed a number of notable findings in 2017:
  - Group size - Mean narwhal group size was smaller when large vessels were present within 15 km of the BSA compared to when no large vessels were present (vessels >15 km from BSA), although model results indicate that vessel distance from the BSA did not have a significant effect on group size.
  - Group composition - Model results indicate that distance of large vessels from the BSA and orientation of large vessels relative to the BSA (i.e., approaching/departing) were significant predictors of presence/absence of adult and mother/offspring groups in the BSA. At very close distances, adult groups >1 were estimated to be observed less and mother/offspring groups were estimated to be observed more when a large vessel was departing the BSA compared to when a large vessel was approaching the BSA.
  - Group spread – Narwhal were more often observed in tight associations compared to loose associations under both vessel presence and vessel absence scenarios. During passage of a large vessel within 15 km of the BSA, loosely spread groups were more likely to occur when vessels were at greater distances from the BSA and exiting Milne Inlet compared to entering.

[1] Vessel orientation = whether a vessel was approaching the substratum or departing the substratum

- Group formation – Narwhal were usually observed in parallel formation under both vessel presence and vessel absence scenarios. When large vessels were within 15 km of the BSA, the presence of linear groups, while rare, was estimated to increase with increasing distance of the vessel from the BSA, whereas parallel group formation was most likely to occur when large vessels were close to the BSA, according to model results.
- Group direction – Narwhal groups were predominantly observed travelling south through the BSA. When large vessels were within 15 km of the BSA, narwhal were most often observed travelling south when the vessel was exiting Milne Inlet, regardless of orientation of the vessel to the BSA. When a vessel was entering Milne Inlet, narwhal groups were observed travelling both north and south upon approach of the vessel, whereas groups were observed travelling predominantly north when vessels were entering Milne and departing the BSA, except for groups within ~2km of the vessel which were often observed travelling south. Narwhal tended to travel south in large groups and north in small groups.
- Travel speed – Approximately 91% of all narwhal observed in the BSA were engaged in 'travelling' behavior, with the majority travelling at a medium speed in both the presence and the absence of large vessels. When large vessels were present within 15 km of the BSA, narwhal groups were most commonly observed travelling at a fast speed when vessels were exiting Milne Inlet and departing the BSA. Model results indicate that large groups were more likely to travel fast, while small groups were more likely to travel slowly.
- Distance from Bruce Head shore - Narwhal were observed travelling inshore (<300 m) more often than offshore (>300 m) under both 'vessel presence' and 'vessel absence' scenarios. Model results indicate that, in the presence of large vessels, narwhal groups are more likely to be observed offshore (> 300 m) only when vessels are exiting Milne Inlet (outbound) and approaching the BSA.

When comparing between survey years (2014-2017), results should be interpreted with caution. Of note, discrepancies in the results presented between years do not necessarily imply that an ecologically significant change in narwhal relative abundance and distribution or group composition and behaviour has occurred. In order to provide more robust inference and modeling predictions, previous data collected by LGL are expected to be integrated into the current model to increase sample size and provide insight into inconsistencies between survey years.

Study Limitations

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Table of Contents

TABLES

FIGURES

APPENDICES

Abbreviations and Acronym List

AIC	Akaike's Information Criterion
AIS	Automatic Identification System
Baffinland	Baffinland Iron Mines Corporation
BB	Baffin Bay
BSA	Behavioural Study Area
CCGS	Canadian Coast Guard Ship
cm	centimetre
COSEWIC	Committee of the Status of Endangered Wildlife in Canada
CSAS	Canadian Science Advisory Secretariat
DD	Data Deficient
DFO	Fisheries and Oceans Canada
ERP	Early Revenue Phase
FEIS	Final Environmental Impact Statement
Golder	Golder Associates Ltd.
GPS	Global Positioning System
GT	gross tonnage
IQ	Inuit Qaujimajatuqangit
IWC	International Whaling Commission
km	kilometre
kt(s)	knot(s)
LGL	LGL Limited, environmental research associates
LSA	Local Study Area
m	metre
mv	motor vessel
MEEMP	Marine Environmental Effects Monitoring Program
MEWG	Marine Environment Working Group
MHTO	Mittimatalik Hunters and Trappers Organization
Mtpa	Million tonnes per annum
NGS	National Geodetic Survey (U.S.)
NIRB	Nunavut Impact Review Board
PC	Project Certificate
the Project	Mary River Project
QAQC	Quality Assurance/Quality Control
QIA	Qikiqtani Inuit Association
RAD	relative abundance and distribution
RSA	Regional Study Area
S-AIS	Satellite Automatic Identification System
SARA	*Species at Risk Act*
SSA	Stratified Study Area

1.0 INTRODUCTION

This report presents the results of shore-based monitoring of narwhal and vessel traffic in Milne Inlet near Bruce Head during the 2017 open-water season. The 2017 shore-based study represents the fifth consecutive year of environmental effects monitoring undertaken at Bruce Head in support of the Mary River Project. Visual survey data collected during 2017 was analyzed to evaluate potential response of narwhal (*Monodon monoceros*) to ship traffic in Milne Inlet. Several analyses included survey data from previous years (2014, 2015 and 2016) for comparative purposes.

1.1 Project Background

The Mary River Project (hereafter, “the Project”) is an operating open pit iron ore mine located in the Qikiqtani Region of North Baffin Island, Nunavut (Data Collection) (Figure 1-1). Baffinland Iron Mines Corporation (Baffinland) is the owner and operator of the Project. The operating Mine Site is connected to a port at Milne Inlet (Milne Port) via the 100-km long Milne Inlet Tote Road. Future but yet undeveloped components of the Project include a South Railway connecting the Mine Site to a future port at Steensby Inlet (Steensby Port).

A Project Certificate No. 005, amended by the Nunavut Impact Review Board (NIRB) on 27 May 2014, authorizes the Company to mine up to 22.2 million tonnes per annum (Mtpa) of iron ore from Deposit No. 1. Of this 22.2 Mtpa, the Company is currently authorized to transport 18 Mtpa of ore by rail to Steensby Port for year-round shipping through the Southern Shipping Route (via Foxe Basin and Hudson Strait), and 4.2 Mtpa of ore by truck to Milne Port for open water shipping through the Northern Shipping Route using chartered ore carrier vessels.

To date, Baffinland has been operating in the Early Revenue Phase of the Project, which includes shipping up to 4.2 Mtpa of ore via Milne Port during the open-water season (July to late October), and the deferral of ore shipments from Steensby Port. Shipping of ore from Milne Inlet during the ERP began in 2015 and is expected to continue for the life of the Project (20+ years). During the first year of ERP Operations in 2015, Baffinland shipped ~900,000 tonnes via 13 ore carrier voyages. The amount of ore shipped during the 2017 open-water season has since increased to ~4.2 million tonnes in 2017 via 56 return ore carrier voyages.

1.2 Regulatory Drivers and Community Engagement

The Bruce Head monitoring program focuses on issues of primary concern as identified through consultation with the applicable regulators, Project stakeholders and local communities to date.

In accordance with existing Terms and Conditions of Project Certificate #005, Baffinland is responsible for the establishment and implementation of the Marine Environmental Effects Monitoring Program (MEEMP) which comprises environmental effects monitoring studies that are conducted over a sufficient time period such to allow for the following objectives:

- To measure the relevant effects of the Project on the marine environment.
- To confirm that the Project is being carried out within the pre-determined terms and conditions relating to the protection of the marine environment.
- To assess the accuracy of the predictions contained in the Final Environmental Impact Statement (FEIS) for the Project.

Baffinland's MEEMP has integrated two major components: marine mammals (MEEMP – Mammals) and marine ecology (MEEMP – Ecosystem). While the regulatory drivers for both components are similar, reporting requirements for each component are undertaken separately.

The Bruce Head Shore-based Monitoring Program (the "Program") is one of several monitoring programs that collectively make up the MEEMP for marine mammals. Initiated in 2013, the shore-based monitoring study was designed to address Project Certificate (PC) conditions related to evaluating potential disturbance of marine mammals from shipping activities that may result in changes in animal distribution, abundance, and migratory movements in the study area. Specifically, this includes the following conditions:

- Condition No. 99 and 101 - "Shore-based observations of pre-Project narwhal and bowhead whale behavior in Milne Inlet that continues at an appropriate frequency throughout the Early Revenue Phase and for not less than three consecutive years".
- Condition No. 109 (for Milne Inlet specifically) - "The Proponent shall conduct a monitoring program to confirm the predictions in the FEIS with respect to disturbance effects from ships noise on the distribution and occurrence of marine mammals. The survey shall be designed to address effects during the shipping seasons, and include locations in Hudson Strait and Foxe Basin, Milne Inlet, Eclipse Sound and Pond Inlet. The survey shall continue over a sufficiently lengthy period to determine the extent to which habituation occurs for narwhal, beluga, bowhead and walrus".
- Condition No. 111 - "The Proponent shall develop clear thresholds for determining if negative impacts as a result of vessel noise are occurring".

In 2015, the Nunavut Impact Review Board (NIRB) developed updated EIS guidelines for the Project that reflected stakeholder concerns associated with potential Project-related effects on marine mammals. Primary concerns identified for marine mammals along the Northern Shipping Route included potential loss or alteration of narwhal calving and nursing habitat due to shipping, potential injuries or mortality of marine mammals due to ship strikes, and potential acoustic disturbance effects on marine mammals from shipping that may lead to changes in animal distribution, abundance, migration patterns, and subsequent availability of these animals for harvesting.

Since 2013, regular community engagement meetings regarding the Project have been carried out in Arctic Bay, Clyde River, Hall Beach, Igloolik, and Pond Inlet. Primary concerns identified by the communities with respect to potential Project effects on marine mammals along the Northern Shipping Route include:

- Loss or alteration of narwhal habitat due to port construction and shipping.
- Injuries or mortality of marine mammals due to ship strikes.
- Acoustic disturbance effects on marine mammals from port construction and shipping that may lead to changes in animal distribution, abundance, migration patterns, and subsequent availability of these animals for harvesting.

During the community engagement meetings, positive feedback was also provided, particularly with respect to on-going monitoring programs including the shore-based marine mammal monitoring at Bruce Head Peninsula.

1.3 Study Objective

The objective of the Bruce Head shore-based monitoring study is to investigate narwhal response to shipping activities along the Northern Shipping Route in Milne Inlet, with data collected on relative abundance and distribution (RAD), group composition and behavior. Additional data were also collected on environmental conditions and anthropogenic activities (e.g., shipping and hunting activities) to distinguish between the potential effects of Project-related shipping activities and confounding factors which may also affect narwhal behavior.

LEGEND

- PROJECT SITE
- COMMUNITY
- FUTURE SOUTH RAILWAY
- MILNE INLET TOTE ROAD
- NUNAVUT SETTLEMENT AREA
- SHIPPING ROUTE
- SIRMILIK NATIONAL PARK
- WATER

0 125 250

1:5,000,000 KILOMETRES

REFERENCE(S)

BASE MAP: © ESRI DATA AND MAPS (ONLINE) (2016). REDLANDS, CA: ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. ALL RIGHTS RESERVED.

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
PROJECT LOCATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2018-02-19
DESIGNED	DC
PREPARED	AA
REVIEWED	PR
APPROVED	PR

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2.0 NARWHAL BACKGROUND

2.1 Population Status and Abundance

Narwhal occur in deep Arctic waters, primarily in Baffin Bay, the eastern Canadian Arctic, and the Greenland Sea (Reeves et al. 2012). Seldom present south of 61º N latitude (COSEWIC 2004), two populations are recognized in Canadian waters; the Baffin Bay population and the Hudson Bay population. Of these, only the Baffin Bay population occurs seasonally in the Project area (Koski and Davis 1994; Dietz et al. 2001; Richard et al. 2010). A third recognized population of narwhal occurs in East Greenland and is not thought to enter Canadian waters (COSEWIC 2004). The populations are distinguished by their summering distributions, as well as a significant difference in nuclear microsatellite markers indicating limited mixing of the populations (DFO 2011).

Narwhal are identified as a species of Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2004), and are currently being considered for listing under the federal *Species at Risk Act* (SARA). The reported estimate of the Baffin Bay population is 45,000 individuals (COSEWIC 2004). The smaller Hudson Bay population is thought to number approximately 2,100 mature individuals (COSEWIC 2004).

For management purposes, Fisheries and Oceans Canada (DFO) has defined five narwhal stocks (i.e., resource units subject to hunting) in Nunavut: Somerset Island, Admiralty Inlet, Eclipse Sound, East Baffin Island, and Northern Hudson Bay (Richard et al. 2010). These stocks were selected based on tracking data indicating geographic segregation in summer (year-round segregation from the others in the case of the Northern Hudson Bay stock) and also on evidence from genetic and contaminants studies that supported this stock partitioning. Subdividing the management units was recommended as a precautionary approach that would reduce the risk of over-exploitation of a segregated unit with site fidelity in summer (Richard et al. 2010). Previous management had been on the basis of two narwhal stocks comparable to those considered in the COSEWIC (2004b) assessment: the High Arctic stock (also called Baffin Bay stock by the JCNB working group or Eastern High Arctic-Baffin Bay stock by COSEWIC) and the Northern Hudson Bay stock.

There have been multiple attempts to estimate the abundance of narwhal in the Canadian Arctic either in total or for specific populations, but until recently no survey had covered the entire distribution range of narwhal in Canada. One of the earliest assessment attempts was that of Koski and Davis (1994) in which an estimated 34,363 (± SE 8,282) narwhal were found to be present in offshore areas of Baffin Bay from May to July 1979. This survey did not, however, account for submerged animals and did not cover eastern Baffin Bay. Specific to the Eclipse Sound area, Kingsley et al. (1994) reported on replicate aerial surveys of narwhal conducted from 1987 to 1993, in which approximately 600 animals were detected annually. This estimate was also not corrected for submerged animals and, after including a correction for narwhal diving behaviour, it is likely that more than 1,500 narwhal could have been present (Kingsley et al. 1994). A re-analysis of 2002 to 2004 summer aerial surveys of narwhal estimated that there were more than 63,000 narwhal in the Canadian High Arctic (NAMMCO 2010a) and approximately 20,211 individuals in the Eclipse Sound area. DFO (2015) also provided abundance estimates of narwhal based on aerial surveys with diving correction conducted in the Canadian Arctic, and estimated that narwhal abundance in Eclipse Sound was approximately 20,000 individuals between 2002 and 2004. Confidence intervals for these years were large, however, and an abundance estimate of approximately half as many narwhal in 2013 (n = 10,489) was likely not representative of actual numbers.

The Canadian High Arctic Cetacean Survey conducted by DFO in August 2013 was the first complete survey of six major narwhal summering aggregations in the Canadian High Arctic (DFO 2015). The total abundance estimate, corrected for diving and observer bias, was 141,909 narwhal. Coefficients of variation ranged from 20%-65% for the different stocks and the corrected estimate for the Eclipse Sound area was 10,489 narwhal with a coefficient of variation of 24%. Although temporal trends cannot be established at the population level for narwhal in the eastern Arctic at the present time, IQ collected in northern Baffin Island communities suggest that narwhal numbers are increasing (Stewart 2001). For example, it was reported that, until the 1970's, narwhal in Clyde River were predominantly fall migrants whereas now, the whales tend to stay in the region from spring until fall (Stewart 2001). Hunters also believe that there are more narwhal in the area now than there were 20 to 30 years ago. Furthermore, annual variation in narwhal stock estimates between summering areas, Eclipse Sound and Admiralty Inlet, indicates that there is possible movement between these two summering locations (Thomas et al. 2015).

2.2 Geographic and Seasonal Distribution

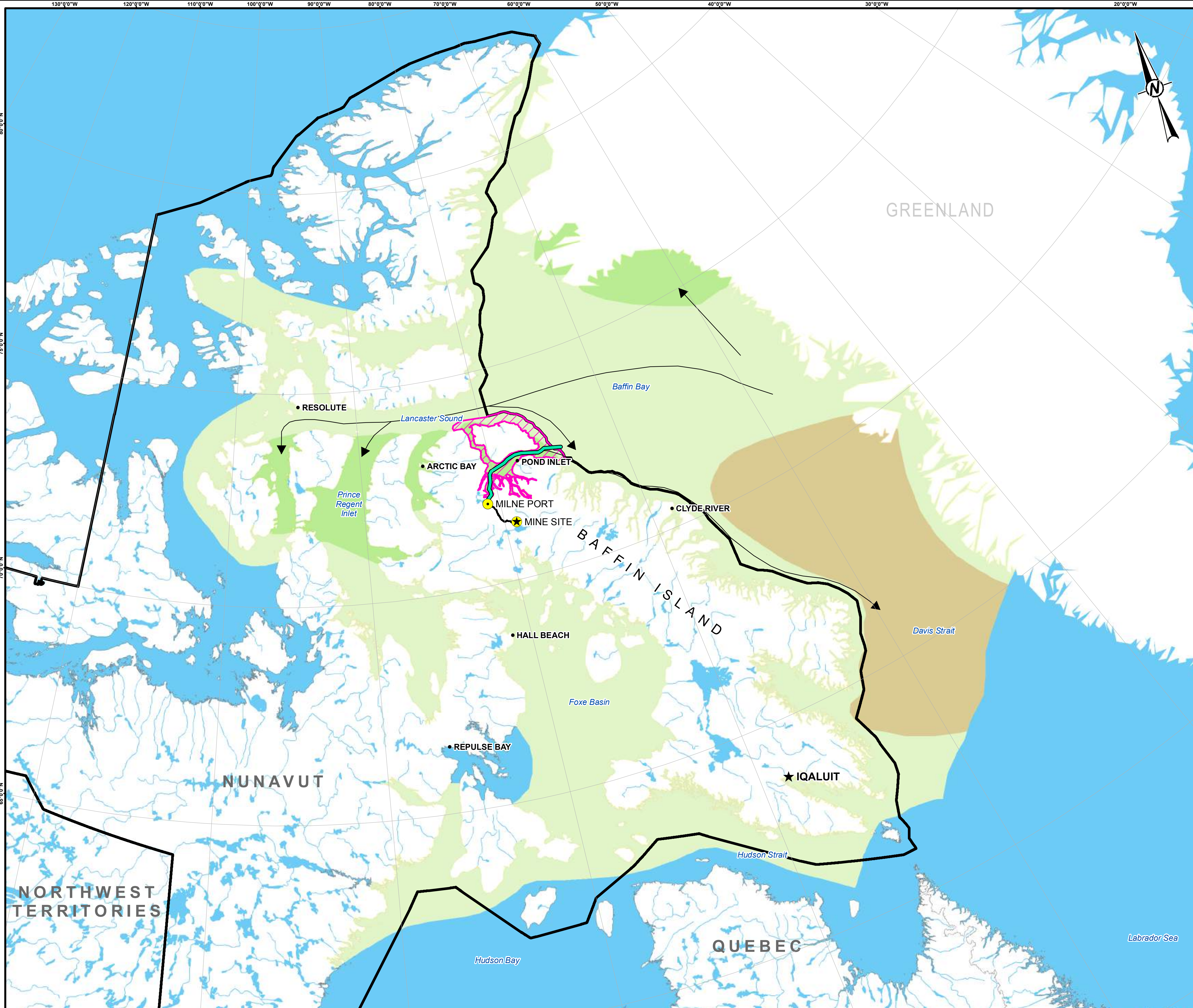
Narwhal show high levels of site fidelity, annually returning to well-defined summering and wintering areas (Figure 2-1) (Laidre et al. 2004). During summer, narwhal tend to remain in deep-water coastal areas that are thought to provide protection from the wind (Kingsley et al. 1994; Koski and Davis 1994; Richard et al. 1994). In winter, narwhal move onto feeding grounds located in deep fjords and the continental slope where water depths are 1000 to 1500 m, and where upwelling increases biological productivity and supports abundant prey species including squid and flatfish (i.e., turbot) (Dietz and Heide-Jørgensen 1995; Dietz et al. 2001).

IQ indicates that narwhal in the North Baffin Island region concentrate during the summer months in Milne Inlet, Eclipse Sound, Koluktoo Bay, Tremblay Sound, Tay Sound, Creswell Bay, Pond Inlet, Navy Board Inlet, and Admiralty Inlet. Eclipse Sound is considered a particularly important summering area (Koski and Davis 1994; DFO 2015) and satellite tracking studies of narwhal summering in Tremblay Sound have shown that summering narwhal remain in a relatively small area including western Eclipse Sound and inlets during August (Dietz and Heide-Jørgensen 1995; Dietz et al. 2001). The distribution of narwhal in Eclipse Sound, Milne Inlet, Koluktoo Bay, and Tremblay Sound during summer is thought to be determined by the presence and distribution of ice and by the presence of killer whales (Kingsley et al. 1994).

Narwhal generally begin migrating out of their summering areas in late September (Koski and Davis 1994). Individuals exiting Eclipse Sound and Pond Inlet migrate down the east coast of Baffin Island in late September (Dietz et al. 2001). Individuals summering near Somerset Island enter Baffin Bay north of Bylot Island in mid- to late October (Heide-Jørgensen et al. 2003). By mid- to late October, narwhal leave Melville Bay and migrate southward along the west coast of Greenland in water depths of 500 to 1000 m (Dietz and Heide-Jørgensen 1995). Narwhal generally arrive at their wintering grounds in Baffin Bay and Davis Strait during November (Heide-Jørgensen et al. 2003) where they associate closely with heavy pack ice comprised of 90 to 99% ice cover (Koski and Davis 1994). Elders have indicated that while the majority of narwhal overwinter in Baffin Bay, some animals remain along the floe edges at Pond Inlet and Navy Board Inlet (DEIS 2010). The Baffin Bay population winters in two discrete areas in the pack ice in central Baffin Bay (Koski and Davis 1994; Heide-Jørgensen et al. 2002; Laidre et al. 2004), and in polynyas at the north end of Baffin Bay (Richard et al. 1998).

During early April and May, narwhal wintering in Davis Strait and southern Baffin Bay follow the east coast of Baffin Island north to Lancaster Sound, where they move westward as ice conditions permit (usually late June and July) to summering areas in Barrow Strait, Peel Sound, Prince Regent Inlet, Admiralty Inlet, and Eclipse Sound (Cosens and Dueck 1991; Remnant and Thomas 1992; Kingsley et al. 1994; Koski and Davis 1994; Richard et al. 1994).

In Milne Inlet, narwhal are usually observed in small groups or clusters but may occur in herds of up to several hundred individuals. Visual observations from Bruce Head indicate that narwhal travel in clusters of 3.5 individuals (range: 1 to 25), and that they generally enter Koluktoo Bay in larger clusters than when they exit the bay (Marcoux et al. 2009). Marcoux et al. (2009) counted up to 642 such clusters making up a herd, with an average number of 22.4 clusters/herd. A cluster was defined as a group with no individual more than 10 body lengths apart from any other. The end of a herd was defined as the point when no narwhal were seen passing a shore-based observation point for 30 minutes.



LEGEND

- TERRITORY CAPITAL
- COMMUNITY
- MILNE PORT
- MINE SITE
- SHIPPING ROUTE (APPROXIMATE)
- MILNE INLET TOTE ROAD
- SEASONAL MOVEMENT
- NORTHERN SHIPPING ROUTE REGIONAL STUDY AREA
- NUNAVUT SETTLEMENT BOUNDARY
- KNOWN RANGE
- SUMMER CONCENTRATIONS
- WINTERING CONCENTRATIONS

0 200 400

1:10,000,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. COUNTRY BASE DATA © ESRI AND ITS LICENSORS. USED UNDER LICENSE, ALL RIGHTS RESERVED. NUNAVUT SETTLEMENT AREA DATA OBTAINED FROM NUNAVUT TUNNGAVIK INC., OCTOBER 9, 2012
PROJECTION: CANADA ALBERS EQUAL AREA CONIC DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
SEASONAL OCCURRENCE AND MIGRATION CORRIDORS FOR THE BAFFIN BAY NARWHAL POPULATIONS

CONSULTANT
Golder Associates

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DESIGNED	AA
PREPARED	AA
REVIEWED	PR
APPROVED	PR

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2.3 Reproduction

Female narwhal are believed to mature at 5 to 8 years and produce their first young at 7 to 13 years of age (COSEWIC 2004) while males mature at 11-16 years of age (COSEWIC 2004). Pond Inlet hunters reported that narwhal mating activity occurs in areas off the northern coast of Bylot Island and at the mouths of Navy Board and Pond Inlet at the floe edge. Eclipse Sound, Tremblay Sound, Milne Inlet, and Koluktoo Bay have also been reported as mating areas (Remnant and Thomas 1992). At least one presumed mating event was observed from the Bruce Head observation platform in southern Milne Inlet during the 2016 open-water season (Smith et al. 2017). Conception generally occurs between late March and late May but narwhal have also been observed mating in June at the Admiralty Inlet floe edge and in August in western Admiralty Inlet (Stewart 2001). Calving then takes place within inlets, bays, fjords, sounds, mouths of rivers, and the open water at the floe edge, however IQ indicates that calving can occur anywhere. Calving is known to occur in Pond Inlet, Navy Board Inlet, Eclipse Sound, Milne Inlet, and Koluktoo Bay (Remnant and Thomas 1992). On average, females are thought to produce a single calf approximately every three years until about 23 years of age (COSEWIC 2004), though many Inuit believe that narwhal give birth more frequently, perhaps annually (COSEWIC 2004). Gestation for narwhal is on the order of 14-15 months (COSEWIC 2004) and calves are generally weaned at 1-2 years of age.

2.4 Food Sources

Finley and Gibb (1982) surveyed the diet of 73 narwhal near Pond Inlet in June through September (1978-1979) and found food remains in 92% of the stomachs analyzed. Feeding was found to be most intensive at the floe edge and ice cracks in spring with limited feeding occurring in the fiords in late summer. Diet included Arctic cod (found in 88% of stomachs), Greenland halibut, and squid while deep-water fish such as redfish and polar cod were consumed mainly by males and are indicative of feeding at >500 m depth. At the floe edge, stomachs contained mainly Arctic cod but there was a shift toward halibut as the narwhal moved through Pond Inlet on their summer migration.

It has been suggested that narwhal do not feed extensively while at their summering grounds but rely on feeding in the winter or spring (Mansfield et al. 1975; Finley and Gibb 1982; Laidre et al. 2004; Laidre and Heide-Jørgensen 2005). Of note, Mansfield et al. (1975) found that in spite of “huge runs” of anadromous char in Eclipse Sound near Pond Inlet, no char were found in the stomachs of the 62 narwhal netted in the region during the summer. Rather, very little food was found in the stomachs sampled and the only identifiable remains were Arctic cod and squid beaks. Finley and Gibb (1982) speculated that the significance of the traditional summering areas to narwhal is related to calving requirements; noting that narwhal blubber thickness decreased in females during the summer but not in males. Several mixed-species (narwhal, belugas, harp seals and seabirds) “feeding frenzies” were observed in late August and September in the Pond Inlet area when high abundances of Arctic cod were present (Finley and Gibb 1982).

Observations by Martin et al. (1994) of the diving activity of tagged adult narwhal in Tremblay Sound found that a relatively small proportion of time was spent undertaking presumed foraging activity. Specifically, approximately 10% of the time was spent actively foraging in the bottom segment of dives while approximately 29% of time was spent on activities associated with foraging (including the time spent getting to and from depths and ventilation time between dives). Similarly, Laidre and Heide-Jørgensen (2005) noted that some narwhal stomachs sampled in Eclipse Sound in summer contained Arctic cod, polar cod and squid, but most were empty, whereas Greenland halibut was consumed as a major food source, at least for West Greenland narwhal, in fall and winter.

Killer whales are well known to prey on narwhal. Laidre et al. (2006) observed an attack on tagged narwhal in Admiralty Inlet in August 2005 in which at least 4 narwhal were killed by 12-15 killer whales within 6 hours. Before the attack but in the immediate presence of killer whales, narwhal moved slowly and quietly, travelling close to the beach (often within 2 m of the shore) in very shallow water, and formed tight groups at the surface (Laidre et al. 2006). During the attack, narwhal beached themselves in sandy areas and made tail slaps. During the five days after the attack, the narwhal were widely dispersed and spatial use doubled from the pre-attack home ranges of 347 km^2 to 767 km^2. Shore observers determined that normal observable behaviour resumed approximately 1 hour after the killer whales left the area (Laidre et al. 2006). Polar bears and sharks may also prey opportunistically on narwhal, as unsuccessful attacks by both species have been reported by Inuit (Stewart 2001).

2.5 Potential Effects of Shipping

The potential effects of Project shipping on narwhal include behavioral disturbance and communication masking due to vessel noise exposure, and potential ship strikes on narwhal resulting in injury or mortality.

2.5.1 Vessel Noise

Cetaceans depend on the transmission and reception of sound in order to carry out virtually all critical life functions (i.e., communication, reproduction, navigation, detection of prey, and avoidance of predators) (Holt et al. 2013). Narwhal and other arctic cetaceans that are closely associated with sea ice also depend on sound for locating openings in the sea ice for breathing (Richardson et al. 1995, Heide-Jorgensen et al. 2013). Depending on the level and frequency of the sound signal, marine mammal groups with similar hearing capability will experience sound differently than other groups (Southall et al. 2007).

Shipping has the potential to effect narwhal distribution as their summer range overlaps with the Northern Shipping Route, and it is thought this this summering area is used for calving and mating. Underwater noise generated during shipping may elicit behavioral changes such as avoidance, evasive maneuvers (diving) or changes in swimming direction and/or speed. Mom-calf pairs traveling along the shipping corridor may be more sensitive to ship noise given their slower travel speeds and reduced manoeuvrability around vessel traffic. Although ore carriers are also slow moving; there are several narrow areas along the shipping route where narwhal are known to transit in large groups and ships have limited ability to change course.

Ship noise has been shown to result in temporary displacement of toothed whales, but no clear evidence is available that narwhal and other toothed whales have abandoned significant parts of their range because of vessel traffic (full review in Richardson et al. 1995 and Gordon et al. 2004). Many toothed whales show considerable tolerance of vessel traffic (Richardson et al. 1995). Little is known on how whales respond to repeated disturbance from ship traffic over time. Aerial-based photographic surveys conducted in Milne Inlet in 2015 indicate that large groups of transiting narwhal show temporary avoidance of ore carriers transiting along the shipping route (Thomas et al. 2015).

Since 2013, Baffinland has conducted shore-based monitoring at Bruce Head to study narwhal response to shipping traffic along the shipping route in Milne Inlet during the open-water season, with data collected on abundance, distribution, group composition, and behavior (Moulton et al. 2016). Most narwhal occurring along the shipping route near Bruce Head were shown to be in transit, with some evidence of nursing, mating and foraging behavior also observed. Approximately 40% of the group sightings included calves or yearlings, supporting the hypothesis that Southern Milne Inlet is an important area for calf rearing. Results collectively indicate that narwhal do not respond to large vessels by fleeing; but rather remain in the area with some individuals showing temporary avoidance behavior during active ship transits. Animals demonstrated a more pronounced avoidance behavior to ships approaching from the south (Milne Port) than from the north. No changes in yearly relative abundance or distribution were observed, nor any evidence of long-term displacement or avoidance behavior (Moulton et al. 2016).

Narwhal are considered mid-frequency (MF) cetaceans (Southall et al. 2007) with their most sensitive hearing range occurring from 20 to 100 kHz (Richardson et al. 1995). Using sound for foraging, navigation, and social purposes, they are a highly vocal species with call types consisting of echolocation clicks, pulsed tones, and whistles. No behavioural or electrophysiological audiograms are available for narwhal; however, their hearing abilities at high frequencies are exceptionally well developed. This likely is related to their use of high frequency sounds for echolocation. Narwhal vocalization studies indicate that this species primarily vocalizes in the 300 Hz to 24 kHz range (Ford and Fisher 1978; Marcoux et al. 2011; Marcoux et al. 2012). Ship noise generally dominates ambient noise at low frequencies, with most energy occurring between 20 to 300 Hz and some components extending into the 1 to 5 kHz range (Richardson et al. 1995). Ship noise is therefore emitted at frequencies at which narwhal have lower hearing sensitivity.

Nonetheless, studies suggesting that narwhal respond to vessel traffic by huddling in groups, ceasing sound production, exhibiting a “freeze response”, becoming displaced, or generally altering their behavior warrants further investigation into the potential effects of vessel noise on these animals (Cosens and Dueck 1988; Finley et al. 1990; Heide-Jorgensen et al. 2013).

2.5.2 Vessel Strikes

The Northern Shipping Route represents an important marine corridor for the transport of iron ore into and out of Milne Port during the open-water season (July-October). Shipping activities within these confined waterways are known to seasonally overlap with several marine mammal species and their habitats (Luque and Ferguson 2010; Doniol-Valcroze et al. 2015a; 2015b; Smith et al. 2017), thus putting individual animals at risk of potential collision with Project vessels (Hartsig et al. 2012).

Collisions between cetaceans and vessels, known as vessel strikes, are considered a key threat to cetaceans in Canadian waters (Laist et al. 2001; Vanderlaan and Taggart 2007; Vanderlaan et al 2008; DFO 2013a; DFO 2013b; DFO 2016). Vessel strikes on narwhal may result in serious injury or even death by means of blunt force trauma from direct impact with the hull of a vessel, or from lacerations due to contact with rotating propellers (Knowlton and Kraus 2001; Silber et al. 2010; Neilson et al. 2012). Depending on the severity of the strike and the injuries inflicted, the animal may or may not recover. The Baffin Bay population of narwhal occur in large densities throughout the Project area during summer months and are known to rely on habitat that overlaps directly with the Northern Shipping Route as preferred calving grounds (Marcoux et al. 2009).

In general, most lethal and severe injuries are linked to large vessels with bulbous bows travelling at speeds greater than 13 knots (Laist et al. 2001; Jensen and Silber 2003; Dolman et al. 2006). This vessel speed is considered to be the critical threshold above which vessel strikes resulting in severe injury and/or mortality are more likely to occur (Dolman et al. 2006; Jensen and Silber 2003). The probability of a lethal vessel strike is thus positively correlated with vessel speed and gross tonnage of the vessel (Dolman et al. 2006; Vanderlaan and Taggart 2007).

Species-specific behavioral and physical differences are also factors that determine a given species' vulnerability to a vessel strike (Laist et al. 2001; Nichol et al. 2017). There are relatively few documented cases of vessel strikes in toothed whales (Wells and Scott 1997; Richardson et al. 1995; Van Waerebeek et al. 2007) and none for narwhal specifically. These animals are considered to be at relatively low risk of vessel strike owing to their fast swimming speed, manoeuvrability and agility (Richardson et al. 1995; Laist et al. 2001; Jensen and Silber 2003, Silber et al. 2010; Lawson and Lesage 2013). Narwhal also possess sensitive hearing and the ability to actively perceive their environment using biosonar (i.e., echolocation), enabling them to effectively detect and avoid approaching vessels However, the gregarious nature of this species means that if one animal is impacted by vessel strike, many are likely to be (Marcoux et al. 2009; Lawson and Lesage 2013; Smith et al. 2017; Smith et al. 2016; Smith et al. 2015). Furthermore, the large number of slow-moving mom-calf pairs present within the LSA puts these individuals at greater risk of vessel strike relative to other toothed whales along the Northern Shipping Route.

3.0 SUMMARY OF 2014 - 2016 KEY FINDINGS

Shore-based monitoring of narwhal was conducted by LGL Limited (LGL) at Bruce Head during the open-water seasons of 2014-2016. The main objective of the monitoring study was to identify potential changes in narwhal distribution, relative abundance, group composition and/or behavior in Milne Inlet, as observed from Bruce Head, in response to large vessel traffic servicing Milne Port as part of the Mary River Project. Other variables considered in the study included tide, weather, time of day, small vessel movements and hunting activities. A secondary objective of the study was to determine if narwhal exhibited evidence of habituation following repeated exposure to ship traffic over the study period. Shore-based monitoring of narwhal was conducted from an observation platform located on the Bruce Head peninsula at ~215 m above sea level. Survey data for relative abundance and distribution (RAD) were collected in nine distinct geographic strata (26 substrata) extending across Milne Inlet, collectively referred to as the stratified study area (SSA). A generalized linear mixed model (GLMM) was used for conducting statistical analyses of the pooled RAD survey data. Group composition and behavioral data were collected within ~1000 m of shore (referred to as the Behavioral Study Area or BSA), as animals transited in front of the platform. Group size was assessed using a one-way ANOVA and post-hoc tests on trimmed means. Categorical group characteristics were investigated using a Pearson's Chi-square test. Detailed results of the 3-year monitoring study are presented in Smith et al. (2017), with key findings provided below.

- The number of narwhal in the SSA was significantly[2] (statistically) related to tide, time of day, and date. Relatively more narwhal were observed in the SSA during ebb tide events. Throughout a 24-hour period, narwhal counts in the SSA were highest around 14:00 EDT. Throughout the survey season, narwhal counts peaked in the SSA around 22 August.

- Results of the GLMM analysis indicate that narwhal respond differently to ore carrier traffic depending on the direction of ship travel in the SSA:

  - For northbound ore carriers travelling through the SSA, significantly higher numbers of narwhal (on average ~2.8x higher) were observed when ore carriers approached a given substratum compared to periods when no ore carriers were present. Significantly lower numbers of narwhal (on average ~1.8x lower) were observed during periods after a northbound ore carrier had departed from a given substrate compared to periods when no ore carriers were present. Results suggest that at least some narwhal demonstrate a localized avoidance response to northbound carriers.
  - For southbound ore carriers travelling through the SSA, no significant difference in narwhal numbers was observed, regardless of whether the vessel was approaching or departing a given substratum.

- Despite increased vessel traffic during the ERP and localized, temporary displacement of narwhal in response to northbound ore carriers, there was no significant change in overall narwhal abundance in the SSA during the 3-year study period.

- Narwhal within the BSA tended to swim closer to shore (<300 m vs. >300 m) and at faster speeds when a large vessel was present in the SSA.

[2] Any reference to significance throughout this report relates to statistical significance unless otherwise noted. Statistically significant findings discussed herein do not necessarily equate to findings being ecologically significant.

- Narwhal within the BSA occurred more often in a loose (rather than tight) and circular (rather than parallel) group formation when a large vessel was present in the SSA.
- Narwhal group size and group composition (including groups with and without calves) was not significantly affected by the presence of a large vessel in the SSA. Groups with calves/yearlings accounted for 39.7% of the groups of known composition.
- Observed behavioral responses to hunting activities (i.e., shooting) in the BSA included evasive diving behaviour and increased swim speed. Following a shooting event, narwhal returned to the area adjacent to the hunting camp within 30 minutes to >5 hours. GLMM results support visual observations with a statistically significant “time since shooting” effect identified. Narwhal counts tended to be zero or low during the first 2 to 3 hours following a shooting event, with numbers gradually increasing after a period of 4 to 9 hours.

4.0 METHODS

4.1 Study Team and Training

The 2017 shore-based study at Bruce Head took place over a 5-week period from 31 July 2017 to 29 August 2017. The study team consisted of three Golder biologists with previous marine mammal survey experience, and four local Inuit personnel (two marine mammal observers and two polar bear monitors). One full changeover of the study team occurred at the mid-point of the study period (10 August).

Prior to mobilization to Bruce Head, a one-day data collection and safety training workshop was held in Pond Inlet on 25 July 2017. The training and orientation session was led by Phil Rouget, a senior marine mammal biologist with Golder, with support from other members of the Golder study team. The safety component of the workshop aimed to familiarize all Inuit employees with the Health and Safety Plans that were developed for the programs, to review Golder's and Baffinland's health and safety policies and regulations, and to discuss general camp etiquette and expectations while living in close quarters in a remote location. The technical component of the workshop including practical (hands-on) training of Inuit study team members in observational survey procedures, data collection techniques, proper use of equipment, data recording and data entry, and post-processing of the survey data. During the training and orientation day, all participants were provided with a training manual (Appendix A) and obtained practical experience using the monitoring equipment including binoculars and the use of the theodolite to calculate distances.

Upon arrival to the Bruce Head field camp on 28 July 2017, the study team participated in an on-site orientation led by the Camp Manager, Max Bakken. Topics covered during the on-site orientation included familiarization with the camp grounds, proper use of camp facilities, and health and safety including rifle use storage and expectations while in camp, polar bear awareness, communication procedures, and identification of general hazards in and around camp. The second study team rotation received on-site orientation upon their respective arrival dates.

The first two days at the Bruce Head viewing platform (30 and 31 July) were dedicated to hands-on training of field equipment and data collection procedures, including the following study components:

- Spatial boundaries of the Stratified Study Area (SSA) and Behavioural Study Area (BSA)
- How to record narwhal sightings (such as number, group size, direction of travel)
- How to identify group formation and group composition
- How to identify different types of narwhal behaviour
- How to record weather conditions and sightability
- On-site practical use of the theodolite to measure distance
- How to record vessel presence (with appropriate geo-referencing)

In order to maintain continuity between the changeover teams, one member of Study Team #2 arrived at Bruce Head a week earlier to overlap with the first leg of the program. A detailed summary of daily survey effort and noteworthy field observations is provided in Appendix B.

4.2 Study Area

The shore-based study was based at the existing observation platform installed at Bruce Head, a high rocky peninsula on the western shore of Milne Inlet, Nunavut, overlooking the Project's Northern Shipping Route. The platform, located on a cliff at ~215 m above sea level (N 72° 4' 17.76", W 80° 32'35.52") approximately 40 km from Milne Port, provided a mostly-unobstructed view of Milne Inlet from the southern tip of Stephens Island in the north, to the embayment south of Agglerojaq Ridge in the south. The portion of the Northern Shipping Route that is viewable from the observation platform is bounded by two islands in close proximity to Bruce Head: Poirier Island to the east and Stephens Island to the north. Also viewable from the observation platform is the mouth of Koluktoo Bay, just south of the Bruce Head Peninsula and extending approximately 16 km westward of the Northern Shipping Route.

The observation platform at Bruce Head consists of a sheltered wooden structure and includes an enclosed area for storing equipment (Photograph 4.1 and 4.2). A weather station, mounted on the side of the observation platform, extended above the rooftop and consisted of a temperature probe and a wind monitor, which is further described in Section 4.3.3. The observation platform was located one kilometre from the Bruce Head camp (Photograph 4.3), necessitating that individuals participate in a 30 to 45 minute hike daily between the two sites. Prior to mobilizing to the observation platform each day, weather conditions were assessed to confirm travel to the platform could be conducted safely and survey conditions were acceptable.

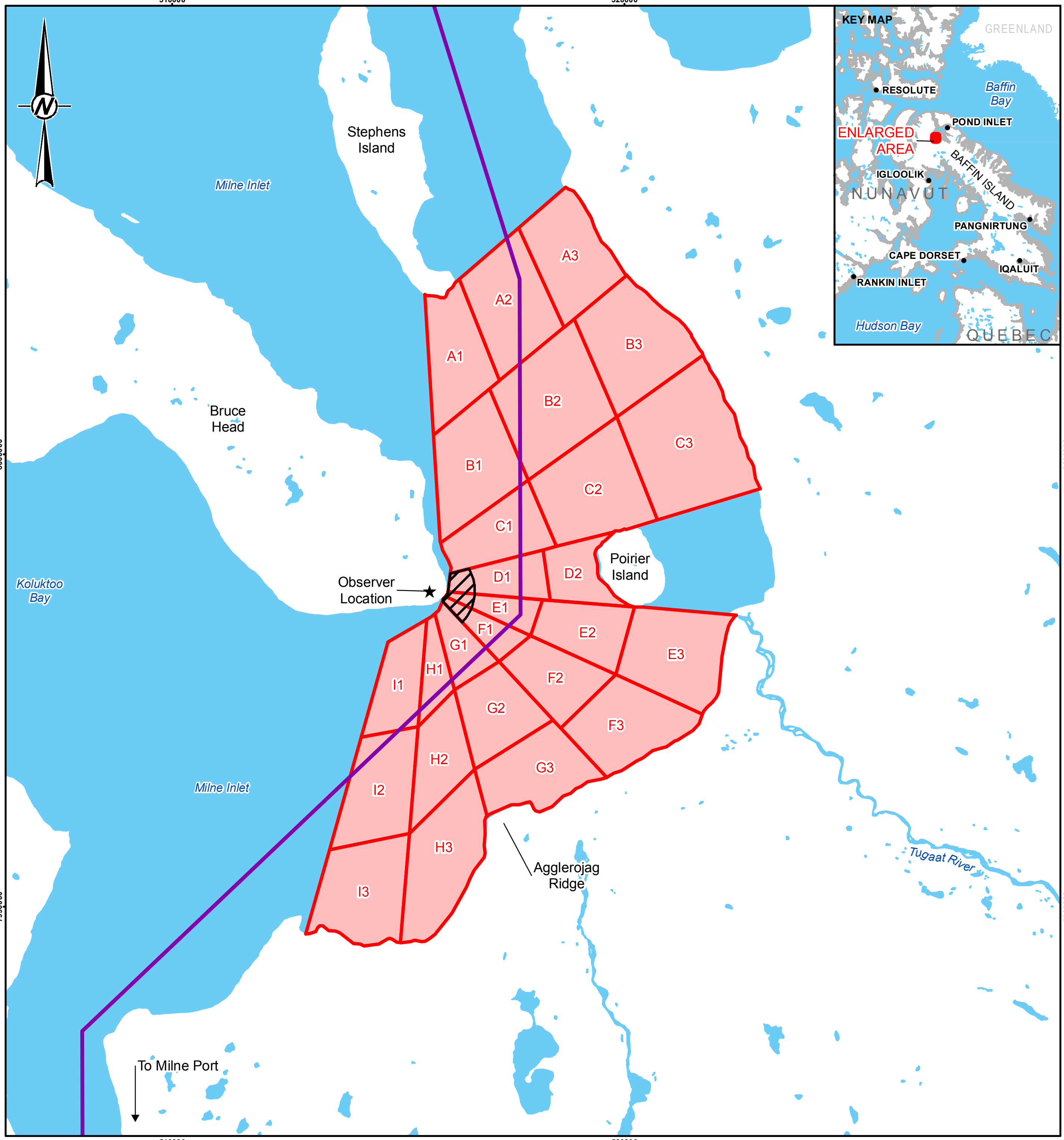
Two study areas were used for the 2017 shore-based study depending on the applicable data collection protocol. This included a broader Stratified Study Area (SSA) and a smaller Behavioral Study Area (BSA), nested within the SSA, (Figure 4-1).

4.2.1 Stratified Study Area

The SSA covers a total area of 82.5 km^2 and was designed for the collection of narwhal relative abundance and distribution data (RAD). The SSA is stratified into strata A (northernmost stratum) through I (southernmost stratum) and further separated into substrata 1 through 3 (1 being closest to the Bruce Head shore/observation platform and 3 being the furthest away). There are a total of 26 substrata within the SSA as stratum D is comprised of only 2 substrata, 1 and 2. These substrata boundaries have remained unchanged since 2014 and have been visually defined in the field using definitive land marks on the far shore of Milne inlet and nearby islands.

4.2.2 Behavioural Study Area

The BSA covers portions of strata D, E, and F that occur within 1 km of the shoreline below the Bruce Head observation platform. The BSA spatial boundary was designed for the collection of narwhal group composition and behaviour data. The shoreline adjacent to the BSA is a common narwhal hunting camp for local Inuit.



LEGEND

- • COMMUNITY
- ★ OBSERVER LOCATION
- APPROXIMATE SHIPPING ROUTE
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA
- WATERBODY

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
STRATIFIED STUDY AREA (SSA) WITH BEHAVIORAL STUDY AREA (BSA) NESTED WITHIN

CONSULTANT
Golder Associates

YYYY-MM-DD	2018-01-18
DESIGNED	KW
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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Photograph 4.1 Bruce Head platform with weather station overlooking Milne Inlet (1 August 2017).

Photograph 4.2 - Observer at Bruce Head platform using bigeyes binoculars (2 August 2017).

Photograph 4.3 - Camp at Bruce Head, Baffin Island (2 August 2017).

4.3 Data Collection

Visual survey data collected during the 2017 shore-based study included information on (1) narwhal relative abundance and distribution (RAD); (2) narwhal group composition and behavior; and (3) vessel traffic and other anthropogenic activity. During each daily shift, the study team was split into two separate groups. Group #1, comprised of two observers, was exclusively responsible for collecting data on RAD in the SSA. Group #2, comprised of 3 to 4 observers, was responsible for collecting data on group composition and behavior in the BSA, and vessel tracking and anthropogenic activities in the SSA. Both teams also collected data on environmental conditions during their respective survey efforts. A detailed description of data collection and survey methods employed for the 2017 shore-based study is provided in the training manual (Appendix A).

In general, daily observations were collected from the Bruce Head observation platform from late morning (09:00 - 10:00) until late evening (17:00 – 18:00) hours. Surveys were occasionally extended or shifted to capture large vessel transits, or reduced or cancelled altogether as a result of unfavorable weather conditions (Appendix B). In order to minimize potential observer fatigue, study team members rotated through the various observer and recorder roles throughout each daily observation period.

The following survey equipment were employed to collect sightings and positional data in the BSA and SSA:

- "Big Eye" binoculars (25 x 100 mm and 40 x 100 mm)
- Binoculars (Nikon 10 x 42 mm; 7 x 50 mm; Fujinon 10 x 42)
- Nikon D300S digital single lens reflex (DSLR) camera (12.3 megapixel) with AF-S NIKKOR 300 mm F2.8G ED VR2 lens
- Topcon DT-102 theodolite interfaced with a Global Positioning System (GPS) unit (Garmin GPSMap62st)

4.3.1 Relative Abundance and Distribution of Narwhal

Relative Abundance and Distribution (RAD) surveys were conducted throughout the SSA at the start of each daily observation period and every hour, on the hour. RAD surveys were also conducted continuously whenever a large vessel was present within the SSA, followed by a final RAD survey conducted upon departure of the vessel from the SSA. Observers were stationed at one of three pre-determined posts (~15 m apart) that provided an overview of strata A to C, D to F, and G to I.

Observations were made using survey and scan observation (Mann 1999) whereby the observer surveyed each stratum for a minimum of 3 minutes to identify narwhal groups[3] (including a solitary narwhal which was considered a group of 1) and counted all individuals within each group and their direction of travel. Once all narwhal present within each substratum were counted and their direction of travel recorded, the observer moved on to the next substratum. Where the majority of narwhal were travelling in one direction (e.g., north → south), the observer would begin counting strata from the opposite direction (e.g., south → north) in order to avoid /minimize double counting. During large vessel transits through the SSA, counting commenced in the stratum closest to the incoming vessel.

4.3.2 Group Composition and Behaviour of Narwhal

Group composition and nearshore behavioural data were collected on all narwhal that entered within the BSA (<1 km from shore below the observation platform). Survey and scan sampling protocols (Mann 1999) were used to record all pertinent data (Table 4-1) related to a sighting before moving onto the next sighting. Observations were made using a combination of Big Eye binoculars (25 x 100), 10 x 42 and 7 x 50 binoculars, and the naked eye. When large herding events took place and RAD team members were not in the middle of conducting a RAD, these individuals would assist in collecting group composition and behavioral data in the BSA.

[3] Narwhal group is defined as having individuals within one body length of one another.

Table 4-1: Group composition and behavioral data collected in the BSA.

Recorded Data	Description
Time of Sighting	Time of initial observation within the BSA
Sighting Number[1]	A sighting number was used as a unique identifier for each single whale, or group of whales
Marine Mammal Species	All marine species observed were recorded as a separate sighting
Group Size[2]	Number of narwhal within 1 body length of one another
Number of Narwhal with Tusks	■ Present ■ Absent ■ Unknown (i.e., head not visible)
Number of Narwhal by Age Category	Adult, juvenile, yearling, calf, unknown life stage
Spread of Group	■ Tight: narwhal ≤ body width apart ■ Loose: narwhal >1 body width apart
Group Formation	■ Linear ■ Parallel ■ Cluster/Circular ■ Non-directional line ■ No Formation
Direction of Travel	North, South, East, West
Speed of Travel	■ Fast / Porpoising ■ Medium ■ Slow ■ Not travelling / Milling
Distance away from Shore	■ Inner: <300 m ■ Outer: >300 m
Primary and Secondary Behaviour	See Table 6 (Behavioural Data) in Training Manual (Appendix A) for lists of primary and secondary behaviours recorded

Notes:
[1] If a group of animals remained in the BSA for a period exceeding 10 minutes, that group was 'resighted' every 10 minutes until the group exited the BSA.
[2] This included a group size of 1 individual.

4.3.3 Vessel Transits and Other Anthropogenic Activity

Vessel transits and anthropogenic activity within the SSA were tracked and recorded using a variety of methods. A combination of shore-based and satellite Automated Identification System (AIS) data was collected to provide accurate real-time data on all large vessel passages through Milne Inlet during the 2017 Bruce Head monitoring program. AIS is mandatory for all commercial vessels >300 gross tonnage and passenger ships. Information provided by the AIS includes vessel name and unique identification number, vessel size and class, position and heading, course, speed of travel, and destination port. The two datasets were used to complement one another as the AIS base station at Bruce Head provided higher resolution positional data, but only provided line-of-sight spatial coverage. The satellite-baed AIS data was lower resolution, but covered the entire Northern Shipping Route and beyond.

The study team also visually recorded vessel traffic in the SSA during daily observation periods. Vessels were classified by size (small <50 m, medium 50-100 m, and large >100 m in length), type of vessel, and general travel direction. A theodolite was used to obtain geographic coordinates of vessels transiting through the SSA by recording angles and calculating distance in relation to the geographic position of a known object (reference point). Tracking was conducted by visually following the vessel with the theodolite and taking a series of fixes at timed intervals. Fixes were taken where the stern of the vessel meets the water line every 4 minutes for large vessels and every 1 minute (or as often as needed based on the speed of the vessel and distance traveled) for medium and small vessels. Theodolite data served as the primary tracking for small and medium vessels that are not required to be outfitted with AIS.

The rocky shoreline at base of the cliff where the Bruce Head observation platform is situated serves as a major hunting camp for Inuit from local communities. Over the course of the 2014 - 2017 field programs, active shooting events associated with hunting were regularly witnessed by the study team both visually and acoustically from the observation platform. All hunting (i.e., shooting) events were recorded during each daily observation period, including the time of occurrence and duration of the event, number of shots fired, and target species.

4.3.4 Environmental Conditions

Environmental conditions were recorded at the start of the observation period, every hour, and whenever conditions changed. For the entire study area (SSA), cloud cover (percent [%]), precipitation, and ice cover (%) were recorded. Beaufort scale, glare, and an overall assessment of sightability were recorded for each substrata within the SSA and also in the BSA.

A weather station was installed on the observation platform which logged environmental conditions at the location every 60 seconds (Photograph 4.1; Onset HOBO USB Micro Station Logger) throughout the Program. The weather station contained a temperature sensor (Onset 12-bit Temperature Smart Sensor) and wind monitor (RM Young 05103). Data from the weather station was downloaded once weekly.

4.4 Data Management

At the end of each daily observation period, study team members reviewed field data sheets as a means for quality control and assurance. Any discrepancies/omissions in the data were addressed immediately while observers maintained a memory of the day’s events. All data sheets were photographed and saved as a digital record on both the laptop and an external hard drive, and original data sheets were filed in a binder at the Bruce Head camp. In addition, a brief summary was provided to Baffinland on the day’s activities, hours worked, and any noteworthy observations.

Upon completion of the field program, data was entered into a Microsoft Access© database customized for the 2017 shore-based study. Data entered into the database was quality checked a second time for missing and/or incorrectly entered fields, as well as discrepancies in data. Data was cross referenced with field notes taken during each daily observation period. Observations related to vessel traffic in the SSA were also cross referenced against theodolite and AIS data.

4.5 Data Analysis

4.5.1 Analytical Approach

The analysis detailed in this report included two components – relative abundance and distribution (RAD) and group composition and behavioural data analyses, similar to previous years (Smith et al. 2015; Smith et al. 2016; Smith et al. 2017). The generalized linear mixed hurdle model developed for RAD analysis evaluated how the relative abundance of narwhal (expressed as total count per substratum) was affected by various explanatory variables, such as date, stratum, sightability, and effects related to large vessel presence. While evaluating the effect of shipping traffic was the main focus of the analysis, it was important to include other potential explanatory variables in the model, to account for spatial and temporal trends, observer bias due to environmental conditions, and confounding factors such as anthropogenic effects that are not large-vessel related. The hurdle modeling approach allowed for analysis of count data with high occurrence of zeroes, while specifying an explicit spatial autocorrelation – i.e., accounting for the fact that narwhal are not distributed randomly and that counts at adjacent substrata will likely be more similar than counts at substrata far apart. The models were used for inference of statistical significance based on P values of coefficients, and model predictions were plotted against the data to visualize the estimated relationships between narwhal counts and the various explanatory variables. One difference in the analysis relative to previous work is the expression of large vessel effect as a continuous variable (vessel distance). This allowed for an evaluation of vessel effect as a continuous trend, therefore providing higher resolution data on the relationship between vessel movement and relative abundance of narwhal.

Golder's analysis of the 2017 data on group composition and behaviour differed from the approach previously taken by LGL (Smith et al. 2017). While previous analyses included ANOVA and χ^2 tests relative to scenarios of anthropogenic activity, the 2017 data were used to construct a set of models, similar to the RAD model described above. Instead of estimating narwhal counts (as the RAD models), the models developed for analysis of behavioural and composition data examined changes in group size, group composition, spread, formation, direction, speed, and distance from shore. The explanatory variables used for these analyses were similar to those used for RAD models, with the addition of hunting activity effects. The models were examined for significant effects, and estimated predictions were plotted against the explanatory variables to visualize patterns.

Further information on the 2017 modeling approach, along with detailed modeling results for RAD, group composition and behavioral analyses, are provided in Appendix C.

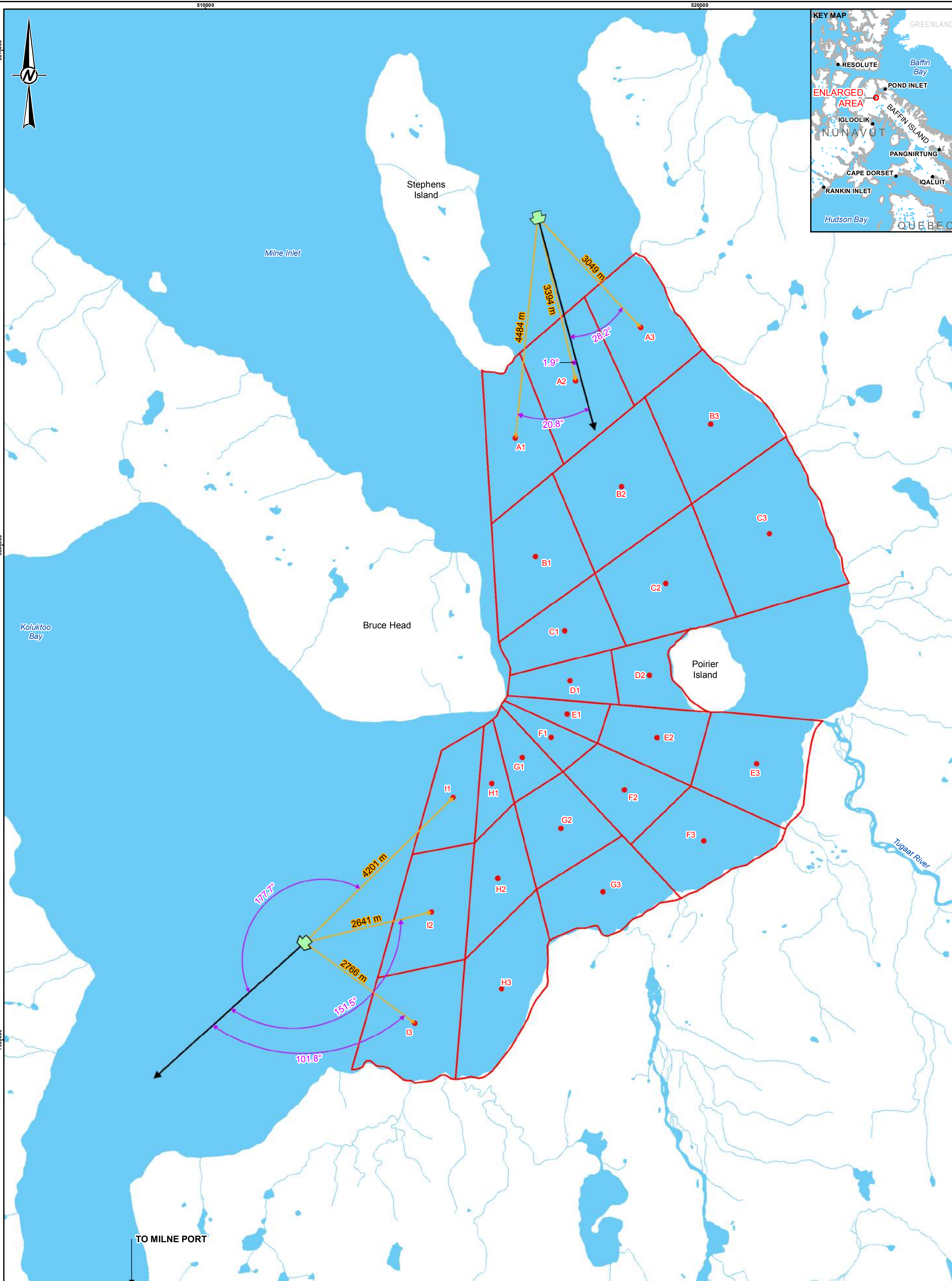
4.5.2 Data Preparation for Analysis

4.5.2.1 Automatic Identification System (AIS) Data

Satellite-based AIS data was merged with the AIS base station data. The full AIS dataset was clipped to only include ship tracking data collected in the Bruce Head study area (between Stephens Island and Milne Port) and during active survey periods at the platform. Each point in the compiled AIS dataset was used to calculate the distance and angle between the ship's position and each centroid of the 26 SSA substrata (Figure 4-2). The resulting distances were used as continuous predictors of narwhal response to vessel traffic. To account for the orientation of the vessel relative to the substrata, vessels that were nearing the substrata (angle >270º and <90º) were classified as "Approaching", whereas vessels that were moving away from the substrata (90º< angle <270º) were classified as "Departing". The interpretation of a vessel approaching or departing is therefore not that it departs the actual substratum, but that it is moving away from the substratum, acknowledging that an animal's response to a transiting vessel may vary depending on whether it is being approached by the vessel or is at her stern where the majority of radiated noise is generated. In other words, a vessel does not need to transit through a particular substratum to be recorded as departing from that substratum. The AIS data preparation was repeated in an identical way for the behavioural and composition dataset, using the BSA centroid as the reference point.

For each RAD count within a given substratum, AIS data was retrieved for each vessel present in the study area, including information on course, heading, and distance, and whether the vessel was approaching or departing relative to the substratum's centroid (recorded to the nearest time stamp). The data were then filtered using a temporal criterion: vessels whose positions were recorded more than 15 minutes either before or after each substratum's count were removed from analysis, leaving only relevant AIS data for the modeling. In addition, a spatial criterion was added – vessels that were more than 15 km away from a centroid were not considered to affect relative abundance or distribution of narwhal. This spatial filter corresponds to the longest distance between a vessel entering the SSA and a centroid of the furthest substratum (e.g., when a vessel is at the northern boundary of the SSA and the centroid of I3). Since previous work (Smith et al. 2017) only considered vessel traffic effects when large vessels were entering the SSA, the restriction of vessel distance to 15 km from a centroid enabled comparison between the 2017 results and previous findings. Data filtration was performed similarly for the behavioural and composition data. All data collected during conditions of impossible sightability were removed from the analyses.

In cases when two vessels were present in the study area during the RAD surveys, the corresponding data were omitted from the analyses, as these events were rare (89 out of 3,992 RAD counts with acceptable sightability) and corresponding sightings data were too limited to incorporate into the model. Given that narwhal are likely to be more reactive to a multi-vessel event than a single vessel passage, this scenario will be considered in future modelling efforts, following integration of the 2014-2016 sightings data into the 2017 model dataset.



LEGEND

- SAMPLE AIS VESSEL LOCATION
- STRATIFIED STUDY AREA (SSA) SUBSTRATA CENTROID
- ANGLE BETWEEN HEADING AND SUBSTRATA
- DIRECTION TO SUBSTRATA
- SAMPLE AIS VESSEL HEADING
- WATERCOURSE
- STRATIFIED STUDY AREA (SSA) SUBSTRATA
- WATERBODY

0 2 4

1:75,000 KILOMETRES

REFERENCE(S)

SUBSTRATA LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. HYDROGRAPHY DATA BY EAGLE MAPPING (2005), RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE, MAY 2017. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
EXAMPLE OF ESTIMATING ANGLES AND DISTANCES BETWEEN AIS SHIP LOCATIONS AND SUBSTRATUM CENTROIDS

CONSULTANT
Golder Associates

YYYY-MM-DD	2018-02-19
DESIGNED	SU
PREPARED	AA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	7000	0	4-2

4.5.2.2 Relative Abundance and Distribution Data

Narwhal RAD data collected in the SSA were summarized as the total number of narwhal observed in each substratum during each survey. The analysis of total narwhal counts provides information on the effect of shipping and other variables on narwhal relative abundance. Future work may also include analysis of the number of groups observed in each substratum, to examine the effects of vessel traffic on narwhal distribution.

4.5.2.3 Behavioural and Group Composition Data

Narwhal group composition and behavior data were plotted as time series, and also as a function of group size in relation to proximity and orientation of large vessels. All data on narwhal behavior and group composition collected during conditions of impossible sightability were removed from analysis.

4.5.2.4 Anthropogenic Data

Anthropogenic activities were categorized based on location (boat vs. shore) and by type of activity (travel, hunting, or recreation), in order to differentiate among anthropogenic effects on narwhal distribution, group composition and behaviour. For example, a boat pulled up on the shore with people camping was considered recreational, but changed to boat travel if they left the shore and traveled within the SSA. A hunting activity was only attributed to discrete shooting events when shots were heard. For each RAD survey, time since last shooting (in minutes) was calculated. The period between the onset of each survey and a shooting event (if any occurred) was classified as “no hunting activity”. Helicopter presence was also recorded, however these were not used for analysis in this report. Recreational activity (i.e., human presence at the hunting camp) was omitted from analysis due to data scarcity. It may be re-examined in future work.

Travel was expressed as the number of small vessels present within the SSA during each RAD survey. Small vessel traffic (without an AIS identification) was difficult to position using a theodolite due to a blind spot directly below the observation platform. Since the small vessels often remained close to shore, they were often not observed for part of their transit through the study area. Therefore, small vessel data were simplified to the number of small vessels recorded during a RAD survey. For the behavioural and composition data analysis, small vessel traffic was expressed as presence / absence of small vessels in the SSA, since the distribution of small vessel count was very limited, with only 8 cases of small vessel counts above one.

4.5.2.5 Environmental Data

Water temperature, conductivity, and depth were recorded at Milne Port using a RBR Concerto CTD 6Hz unit. The instrument was mounted directly below the ladder plate at the ore dock at Milne Port which was used as a benchmark for chart datum. The instrument collected a sample every 5 minutes[4] from 19 July to 2 November 2017.

[4] The sample reading were an average of the previous 5 minutes.

The data were processed from raw format using Ruskin software (version 1.13.13) with a clock drift of -11 seconds. Depth data were translated to elevation by subtracting the geodetic benchmark (2.84 m) from the recorded depths.

In addition to the depth data collected at Milne Port, modeled tidal data for Bruce Head were obtained from WebTide Tidal Prediction Model (v.0.7.1; WebTide 2017). These tide data were provided as elevation (m) relative to the mean low water. The direction of elevation change was calculated by subtracting from each data point from the previous recorded depth. No salinity data were collected at Bruce Head and, as local freshwater inputs likely had a strong effect on Port Milne salinity, the salinity time series did not reflect tidal fluctuations at Bruce Head (Figure 5-3). Therefore, salinity was not included in the models. Future efforts will include collection of water surface elevation, water temperature, and salinity data at Bruce Head, and the effect of environmental variables on narwhal distribution will be examined.

Weather data (air temperature, wind speed, wind gust speed, and wind direction) were obtained from the weather station installed at the Bruce Head Observation Platform. The data were averaged from 1 min resolution to hourly means, and the daily mean and 25th and 75th quantiles of each variable were calculated. The resulting estimates of means and daily variability were plotted as a time series. Mean hourly wind gust data were also examined as a potential covariate in the analysis of RAD data, to account for the potential subjectivity of assigning sightability.

4.5.3 Relative Abundance and Distribution (RAD) Model

The total count of narwhal in each SSA substratum during each RAD sampling event were used to examine whether vessel traffic affected relative abundance of narwhal in the area. Since only total counts of narwhal per substratum were used for modeling, herding events were retained for analysis. During these events, the field team recorded total number of narwhal per substratum, but did not record individual group sizes.

Certain variables were excluded as potential covariates in the RAD model, including hunting (i.e., time since last shot) and tidal effects. Although ‘time since last shooting’ was included in previous years’ analyses (Smith et al. 2017), hunting is more likely to occur when there are higher counts of narwhal present. Therefore, including ‘time since last shot’ events as predictors in the models results in higher predictions of narwhal shortly after hunting (Figure 4-3). Changes in tidal conditions may also affect narwhal RAD in the area, whether through influence on the distribution or movement of potential narwhal prey or through other processes. However, preliminary data exploration suggested no relationship between narwhal counts and tidal cycle (expressed as a combination of water surface elevation and amount of change in water surface elevation from previous reading). To assist with model convergence (which was problematic in preliminary modeling efforts), tidal data were therefore removed from subsequent analysis.

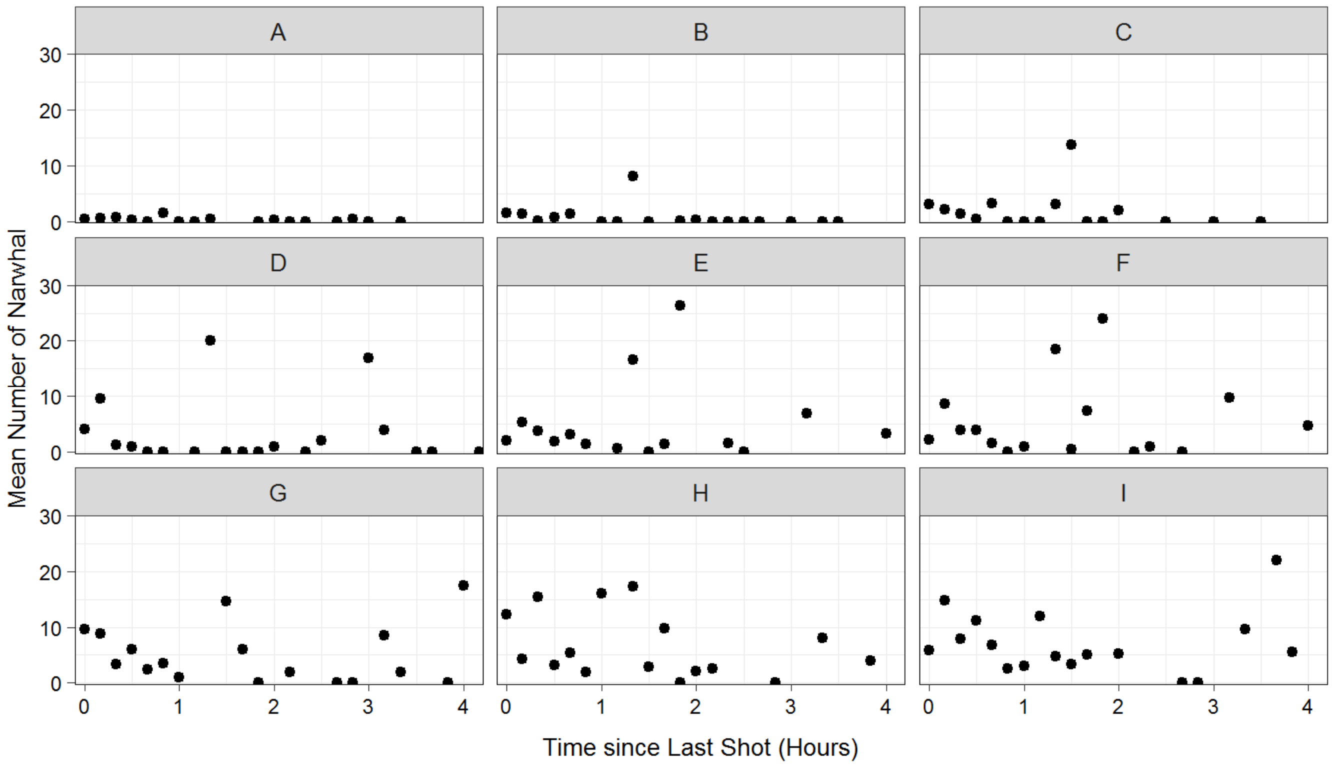


Figure 4-3: Mean narwhal counts in each substratum, plotted against time since last shot (binned into 10 minute intervals).

The following variables were examined as potential covariates in the RAD model (Appendix C):

- Sampling variables:
  - Sightability (as recorded by the RAD team); discrete variable with five levels: E (excellent), G (good), M (medium), and P (poor). Cases with impossible sightability (I) were removed from analysis
  - Stratum (discrete variable; A-I)
  - Substratum within stratum (discrete variable; 1-3)
  - Date (continuous variable, as day of year)
- Vessel traffic variables:
  - Distance and Approaching/Departing classification of each available vessel's AIS position from substratum centroid during RAD survey (continuous variable [m] and discrete variable, respectively)
  - Whether the vessel was entering or exiting Milne Inlet (discrete variable; Enter/Exit)
- Anthropogenic activity (other than shipping):
  - Number of small vessels in the SSA during a RAD survey (continuous variable)

The potential explanatory variables listed above were selected based on relationships established in previous studies at Bruce Head (Smith et al. 2017) and evaluation of the data collected in 2017. Day of year and stratum effects were included to account for the natural temporal and spatial differences in relative narwhal abundance in the Bruce Head area, respectively. Substratum (1-3), which is related to the distance between the observation point and each centroid, may affect the quality of recorded data, similar to sightability. For example, excellent sightability and an observation performed at a “1” substratum, close to the observation platform, represent optimal conditions for surveying. On the other hand, reduction in sightability or sampling of a more distant substratum may reduce the quality of the recorded data. The effects of vessel distance and whether the vessel was approaching or departing relative to each substratum’s centroid encompass information on proximity and direction of vessel relative to that substratum; both variables likely affect vessel sound generation.

Generalized linear mixed models (GLMMs) for RAD count data were developed to examine the effect of the explanatory variables detailed above on total counts per substratum. Due to the high incidence of zeroes, the data were modeled using hurdle models (Loeys et al. 2012), where the full dataset was analyzed using a logistic model for presence/absence of narwhal, and then the portion of the dataset with positive counts was analyzed using a negative binomial regression. The models were constructed, evaluated, and discussed separately, then the predictions from the two were combined into a single estimate per observation, plotted relative to the various predictor variables, and discussed. Five counts with >100 individuals were removed from the dataset to assist with model convergence; of these, two were herding events that took place on 4 August 2017.

The model of positive counts was constructed using a negative binomial distribution, to account for the over dispersion of data and the high frequency of zero counts. The random component of both models included terms for spatial autocorrelation (using substratum centroid UTM easting and northing) within each RAD survey. Due to the requirement of using a generalized linear model (to account for the negative binomial structure of positive count data and the binomial structure of presence / absence data) and the need for autocorrelation, quasi-likelihood methods were used to estimate the models. Quasi-likelihood models do not provide estimates of log-likelihood, which means that it is impossible to calculate Akaike’s Information Criterion (AIC) values (Burnham and Anderson 2002) or likelihood-ratio tests (Neyman and Pearson 1933), which are commonly used for model selection. Therefore, model selection was not performed. Instead, the full model was evaluated for significance of the various parameters using Type II p-values. Predictor variables were considered significant at the 0.05 level of significance.

To correctly represent cases where no large vessels were present, the vessel-related variables were assigned a zero for distance, and “Approaching” and “Exit” (which were selected as the reference levels) for the Exit / Enter and Approaching / Departing effects. In addition, a dummy variable was added to account for the absence of a large vessel within 15 km from the centroid. The variable value was assigned to zero when vessels were present, so that the vessel-related variables accounted for vessel-related variability, and to one when a vessel was absent. Similar to above, to preserve the principle of marginality, the variable for vessel absence was retained as long as any vessel-related variables were still present in the model.

The following model, containing main effects of interest and plausible interactions, was considered the full model for the binomial analysis of narwhal presence / absence:

- Day of year + (Day of year)^2 + Stratum + Substratum + Sightability + Number of small vessels in the SSA + Absence of large vessels within 15 km from the centroid + Vessel distance + Vessel distance^2 + Vessel distance^3 + Whether vessel was approaching or departing relative to the centroid + Whether the vessel was entering or exiting Milne Inlet +
- (Vessel distance + Vessel distance^2 + Vessel distance^3) × Approaching / Departing + Exit / Enter × Approaching / Departing + Exit / Enter × (Vessel distance + Vessel distance^2 + Vessel distance^3)

The negative binomial model of positive counts had a similar structure, however day of year was modeled as a third-degree polynomial, and distance from vessel was modeled as a second-degree polynomial, based on exploratory visual assessment of the dataset.

The model included an exponential autocorrelation structure that accounted for the spatial autocorrelation between substratum centroids within each RAD survey, as well as a random effect of RAD surveys. At this time, it was not possible to also add a temporal autocorrelation term, although this may be examined in future work.

The residuals of the interpreted models were visually examined for irregular patterns, since patterns are indicative of a mis-specified model structure. The fit of the negative binomial distribution to the data was also assessed using a rootogram, which is a graphical model evaluation technique for summarizing the distribution of a variable. Deviations between the observed and the fitted frequencies indicate potential mis-specification of distribution. Residuals were used to construct variograms to inspect spatial autocorrelation, and to construct partial autocorrelation plots to examine overall autocorrelation between residuals.

The predictions from the logistic model of presence/absence and the negative binomial model of positive counts of narwhal were multiplied to obtain the overall predictions of counts accounting for zero inflation. The 95% confidence intervals were estimated using bootstrapping, where RAD surveys were sampled with replacement, the models were refitted using the resampled data. The bootstrapped model predictions were multiplied to obtain a combined estimate of narwhal counts, accounting for zero inflation, within each bootstrapping iteration. The process was repeated 500 times and the 2.5th and 97.5th quantiles of combined predictions were used as the 95% confidence intervals.

All analyses were performed using R version 3.4.2 (R Core Team 2017) and the package MASS (Venables and Ripley 2002).

4.5.4 Group Composition and Behavior Models

Each variable recorded during the behavioural and composition study was analyzed using generalized linear models (GLMs) with environmental, sampling, anthropogenic, and shipping explanatory variables (Appendix C). Response variables included group size, composition, spread, formation, direction, travel speed, and distance from shore. Group size was analyzed using negative binomial generalized linear models, to account for the over dispersion of data and the high frequency of zero counts. Variables with binomial outcomes (group spread and distance from shore) were analyzed using logistic models, whereas variables with ordinal outcomes – i.e., categorical outcomes with more than two groupings (group composition, group formation, and travel speed) were analyzed using ordinal logistic regression.

Several changes from the RAD analysis were implemented: day of year was not included in the models, since temporal gradients were not expected for any of the behaviour variables. While it may be expected that group composition would have temporal effects, a preliminary examination of the 2017 dataset did not indicate the presence of such effects, and the variable was removed from analysis. Hunting activity and time from last shot were included in the models to examine whether hunting affected behaviour or group composition. Sightability was removed from the analysis of travel direction and speed, since it was not expected that sightability would affect the classification of either variable. Tide data were not included in the modeling of behavioural and composition data due to the limited amount of data at low tides likely biasing modeling results. Furthermore, previous studies have found no relationship between narwhal movements and tide (Born 1986, Dietz and Heide-Jorgensen 1995).

The following model was considered the full model:

- Sightability + Presence of small vessels in the SSA + Large vessel absence + Vessel distance from the BSA + Vessel approaching / departing + Whether the vessel was entering or exiting Milne Inlet + Vessel distance × Vessel approaching / departing + Whether the vessel was entering or exiting Milne Inlet × Vessel approaching / departing + Whether the vessel was entering or exiting Milne Inlet × Vessel distance

In addition to the full model, five more candidate models were constructed:

- The full model, but omitting the Entering / exiting Milne Inlet × Vessel distance interaction
- The full model, but omitting the Entering / exiting Milne Inlet × Vessel distance interaction and the Entering / exiting Milne Inlet × Approaching / Departing interaction
- The full model, omitting all three interactions
- The full model, omitting presence of small vessels in the SSA
- The full model, omitting presence of small vessels in the SSA and hunting activity variables

Akaike's Information Criterion (AIC) was used to perform model selection among these candidate models. The model with the lowest AIC among the set of candidate models was interpreted to have the strongest support, given the set of examined models and the collected data (Burnham and Anderson 2002). Therefore, once the set of candidate models was examined, the model with the lowest AIC value was selected for interpretation. Models with AIC scores within 2 units of each other were considered to have similar levels of support; therefore, the simplest model with the fewest parameters that was within 2 AIC units from the best-supported model was selected for interpretation (Arnold 2010).

For ordinal models, if the final model did not meet the assumption of proportional odds, as tested using the ordinal package (Christensen 2015), the overall model was reduced to a set of binomial models and the model fitting process was repeated separately, reclassifying the data as presence / absence of each of the original categories. For example, if the travel speed ordinal model did not meet the proportional odds assumption, the data were broken down into three subsets – presence/absence of groups moving at slow, medium, and fast speeds, where "presence" is whether a group was moving at a given speed (e.g., slow), and "absence" was whether a group was moving at a different speed classification (medium or fast).

The residuals of the interpreted models were examined for irregular patterns using tools appropriate for each model structure, as well as plots of residuals versus predictor variables and versus predicted estimates. All analyses were performed using R version 3.4.2 (R Core Team 2017) and packages MASS (Venables and Ripley 2002) and ordinal (Christensen 2015).

Model outputs included plots of model predictions relative to the variables retained in the final models, tables of model selection based on AIC values, and tables of exponentiated model coefficients, their 95% confidence intervals, and P values for logistic and negative binomial regressions. In the case of logistic regressions, the exponentiated coefficients are referred to as odds ratios, and they describe the change in the odds of observing a certain outcome with a one unit change in the respective predictor variable. For example, an odds ratio of 1.25 associated with a continuous variable (for example, distance between large vessel and the BSA) would indicate a 25% increase in the odds of observing the outcome with every 1 km increase in distance. An odds ratio <1 indicates a decrease in the odds with every unit of change. For categorical variables, the odds ratio indicate a change in odds relative to the reference levels. For example, an odds ratio of 0.7 associated with medium sightability would indicate that under medium sightability, the odds of observing the outcome are only 70% those estimated at the reference level of sightability (defined as excellent sightability for all models); that is, the odds of observing the outcome are decreased by a factor of 0.3 with a change in sightability from excellent to medium. Throughout the analyses, “Excellent” was the reference level for sightability, “Exit” was the reference level for the Exit / Enter variable, “Approaching” was the reference level for Approaching / Departing variable, and “Hunting” was the reference level for the hunting activity variable.

For negative binomial models, the exponentiated parameter coefficients are referred to as incidence rate ratios, and they describe the relative change in the variable (in this case, group size). For example, in the analysis of group size, an incidence rate of 1.05 associated with a continuous variable (for example, time since shooting) would indicate that with every additional 1 minute that passes from the last shooting event, group size is estimated to increase by 5%. An incidence rate of 0.7 associated with a categorical variable (for example, medium visibility) would indicate that under conditions of medium visibility, the response variable (for example, number of narwhal) was estimated to be 70% of the value under the reference value of excellent visibility.

4.5.5 Data Collected in 2014-2016

Previous survey data collected during the 2014-2016 shore-based programs at Bruce Head (Smith et al. 2015; Smith et al. 2016; Smith et al. 2017) are plotted herein to illustrate annual trends wherever possible. However, due to timing of Golder’s receipt of the previous survey data (late November 2017), it could not be incorporated into the present model. Previous survey data (2014-2016) will be incorporated into the analysis as part of the 2018 Program, to the extent that the data allows.

5.0 RESULTS

5.1 Observational Effort and Environmental Conditions

The 2017 shore-based study extended from 31 July to 29 August, and included a total of 27 days (173.1 hours) of observational effort by the five-person study team. Total daily observation effort averaged 6.4 h and ranged from 1.4 h to 8.7 h (Figure 5-1). The field team was limited to 10 h work days which included the hike to/from the Bruce Head observation platform. Inclement weather occasionally impeded survey effort. On two occasions during the 2017 program, severe weather was experienced at the Bruce Head camp and the hike to the observation platform was not attempted (14 and 27 August). In some cases, weather conditions deteriorated mid-survey to a point where sightability was severely compromised. In these situations, the field team ended the survey early and hiked back to camp. Several days at the start and end of the program were dedicated to equipment set-up and tear-down during which no surveys took place (29 July, 30 July, 30 August). A daily summary of field activities are provided in Appendix B.

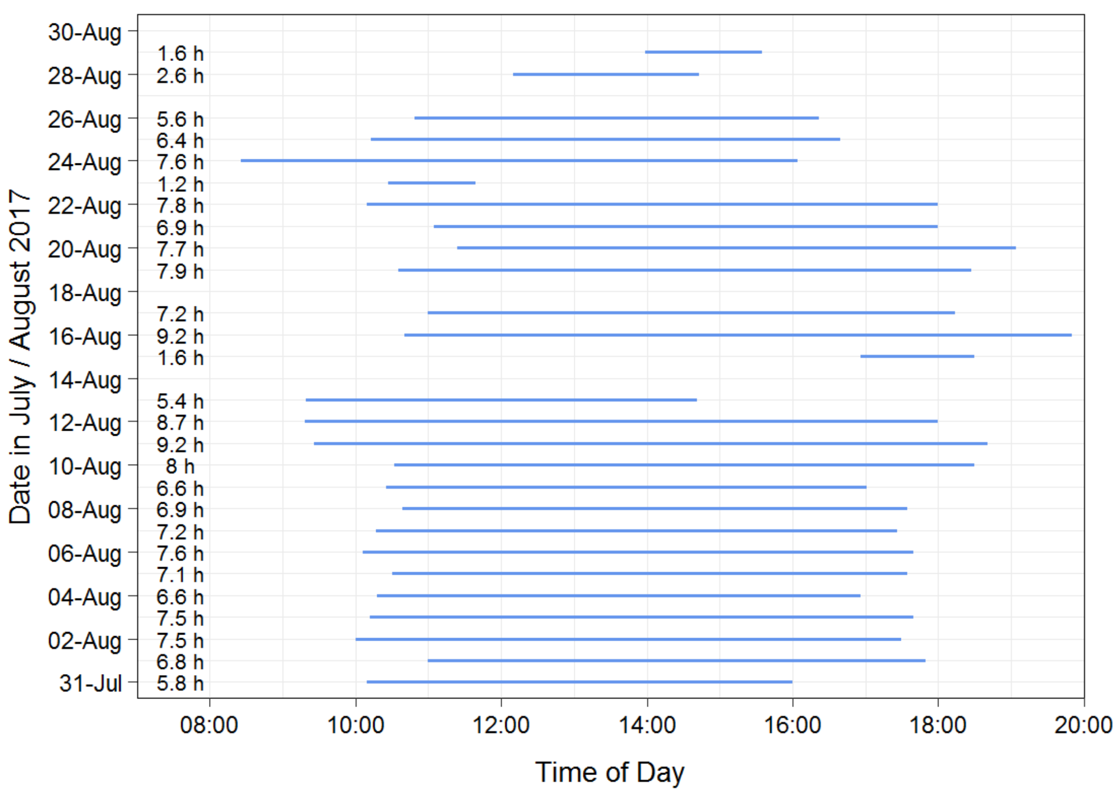


Figure 5-1 Observation effort (h) by day during the 2017 Program.

In general, the survey area was ice-free throughout the 2017 study. On 7 August, one large ice floe drifted into the SSA mid-survey and partially covered certain substrata (Photograph 5.1). Throughout the day, this ice floe covered approximately 70% of substratum I-1, then shifted covering approximately 60% of H-1, then shifted again covering approximately 90% of I-2, before drifting out of the SSA. Several small ice floes were observed within the SSA on 6 August, although did not impede observations.

Photograph 5.1 Ice floe partially covering the substrata. Photograph taken on 7 August 2017.

To reduce the effects of poor sightability on data quality, daily surveys were conducted primarily during good weather conditions when the Beaufort scale was 1, 2, or 3. In some cases, the field team remained at the observation platform during reduced weather conditions (Beaufort scale 4 and 5) to complete a survey or continue the survey during a ship transit.

Throughout the study period, mean daily air temperature measured at the observation platform ranged from 2.6°C to 12.1°C (median of 7.3°C) and mean daily wind speed ranged from 1.1 m/s to 14.4 m/s (median of 4.5 m/s; Figure 5-2). During periods of high winds, the wind direction was primarily from the north and northwest direction. Water temperature and salinity were predominantly inversely proportional with salinity increasing with decreasing water temperature (Figure 5-3). The time series of salinity and temperature did not follow the daily tidal fluctuations, indicating a strong influence of variables other than tide (e.g., fresh water inputs).

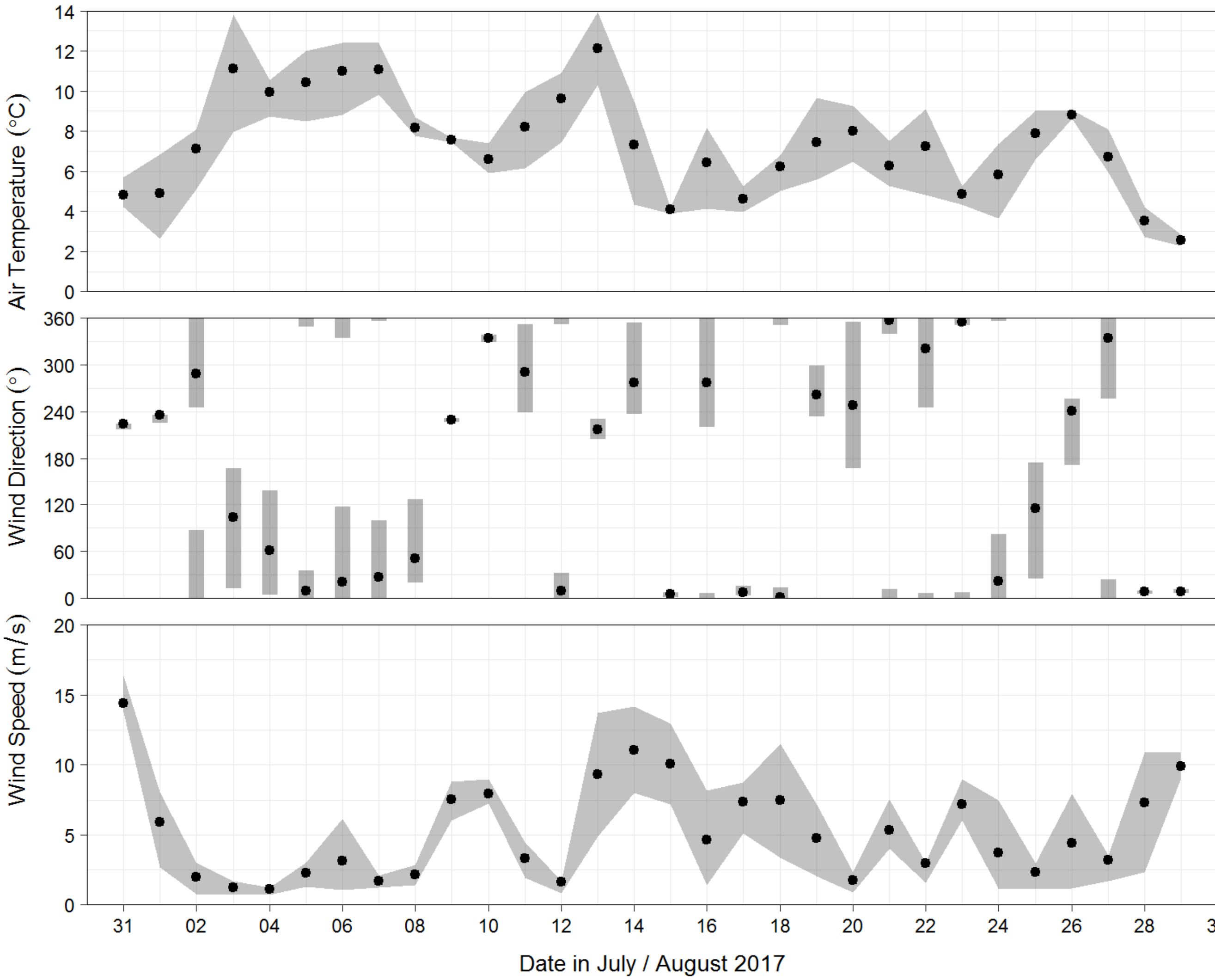


Figure 5-2 Air temperature (°C), wind direction (°), and wind speed (m/s) recorded at the Bruce Head Observation Platform.

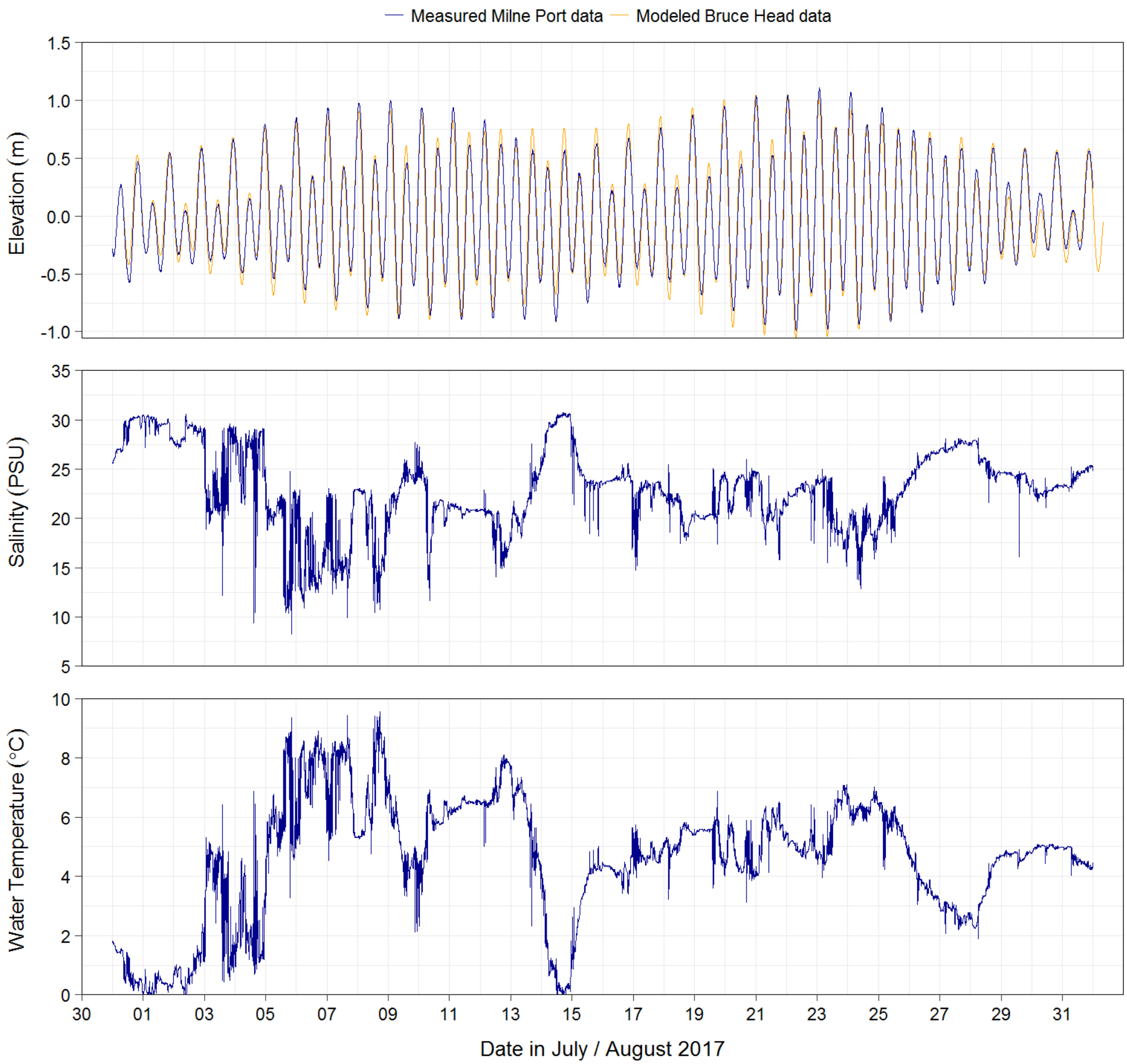


Figure 5-3 Tidal elevation (m), salinity (PSU), and water temperature (ºC) measured at Milne Port.

5.2 Vessel Transits and Other Anthropogenic Activity

5.2.1 Baffinland Vessels and Other Large/Medium Vessels

A summary of large vessels chartered by Baffinland as well as other vessels recorded in the SSA are provided in Appendix D (Table 5-1). A total of 58 one-way large vessel transits (30 vessels total) were recorded by either S-AIS or shore-based AIS within the SSA from 31 July to 29 August 2017. Daily observation periods overlapped with several of the large vessel transits (Figure 5-4). Large vessels (>100 m length) in the SSA were primarily Project-related bulk (ore) carriers, accounting for 43 of the 58 on-way vessel transits. Other large Project-related vessel transits were by general cargo vessels (n = 10) and oil tankers (n = 2). Passenger vessel transits (n = 3) were the only non-Project-related large vessels present in the SSA, including the National Geographic Explorer and Le Boreal. The tracklines of all large vessel transits through the SSA were plotted to provide a visual representation of vessel passages in the SSA throughout the Program study period (Figure 5-5).

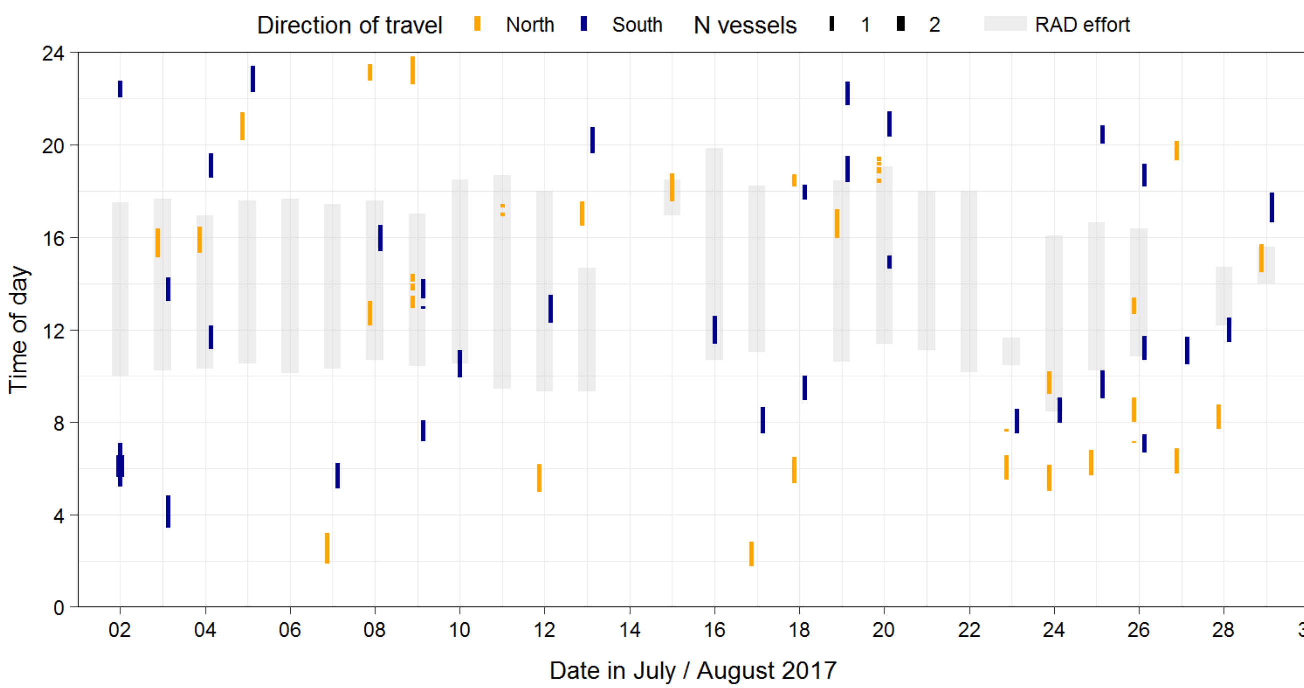
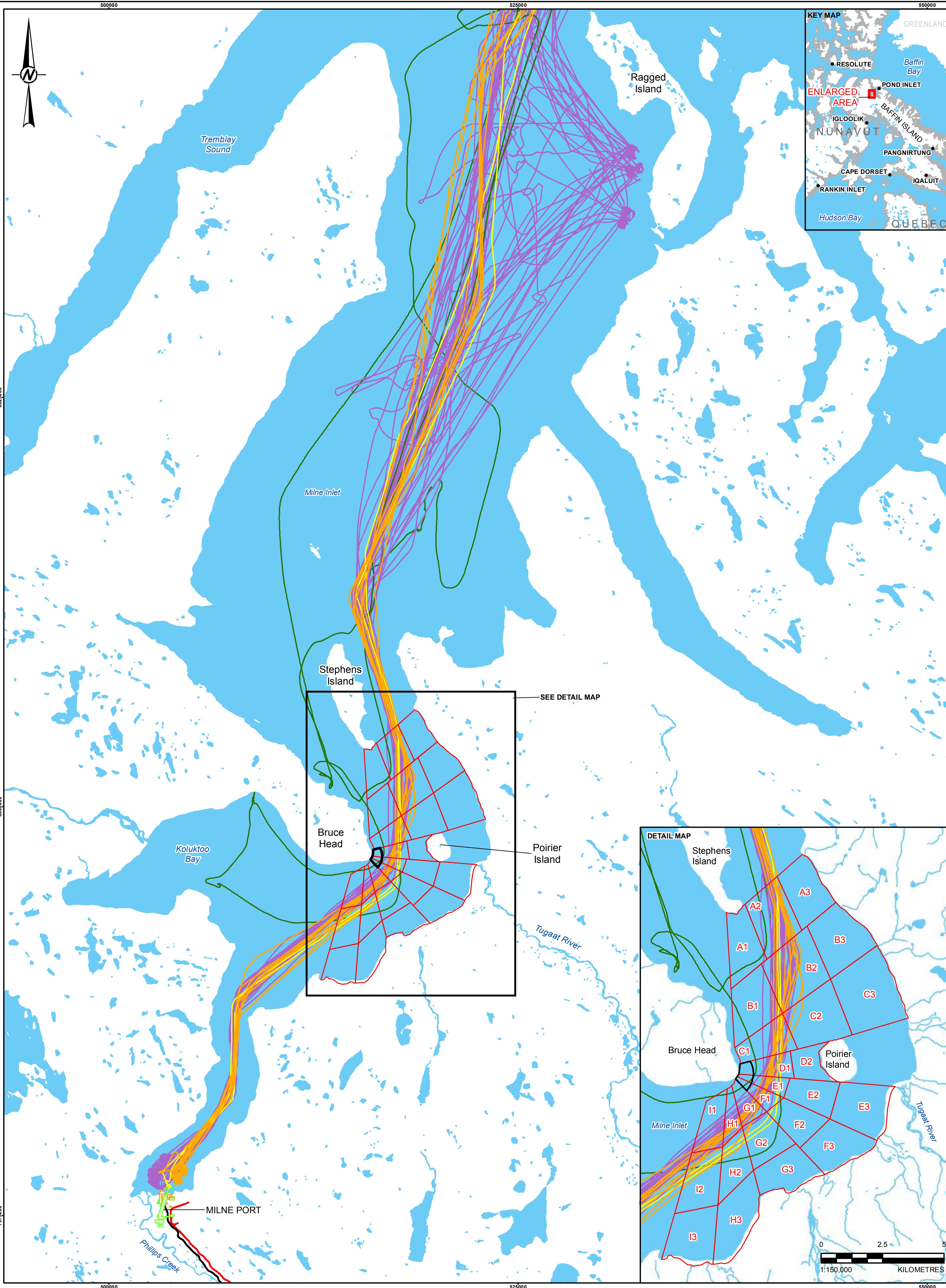


Figure 5-4: Daily Summary of large vessel transits through the SSA and survey effort. Grey boxes indicate daily observation periods, of which 16 overlapped with large vessels transiting through the SSA.



LEGEND

- • COMMUNITY
- MILNE INLET TOTE ROAD
- PROPOSED NORTH RAILWAY
- WATERCOURSE

VESSEL TRANSIT ROUTES BY CLASS

- BULK (ORE) CARRIER
- GENERAL CARGO
- OIL TANKER
- PASSENGER VESSEL

- BEHAVIOURAL STUDY AREA (BSA)
- EXISTING INFRASTRUCTURE
- PROPOSED PHASE 2 INFRASTRUCTURE
- STRATIFIED STUDY AREA (SSA) SUBSTRATA
- WATERBODY

0 5 10

1:225,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. SUBSTRATA DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. GEOGRAPHIC NAMES, HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

MARY RIVER PROJECT

TITLE

LARGE VESSEL TRANSITS THROUGH THE SSA BETWEEN 31 JULY AND 29 AUGUST 2017

CONSULTANT

Golder Associates

YYYY-MM-DD	2018-02-19
DESIGNED	AA
PREPARED	VV
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	7000	0	5-5

Vessel speeds were plotted for each vessel type, with ore carrier travel speeds generally restricted to between 6 and 10 knots, and cargo / fuel carrier travel speeds ranging between 8 and 14 knots (Figure 5-6; Appendix D). Vessel tracks and associated speeds of large vessel traffic through the SSA are presented in Figure 5-7, Figure 5-8, and Figure 5-9. As part of Baffinland's mitigation measures for the ERP, a speed limit of 9.0 knots along the Northern Shipping Route and 5.0 knots within Milne Port for all Project-related bulk (ore) carrier traffic has been imposed. In general, ore carriers transited at slower speeds compared to other large vessels and ranged from less than 9.0 knots to 11.2 knots. Twenty of the 43 Project-related ore carrier transits recorded in the SSA traveled at a speed less than or equal to 9.0 knots, while the remaining 23 vessels exceeded the 9.0 knot speed limit (though often by only 0.1 to 0.4 kts). The travel speed of other large Project-related vessels transiting through the SSA varied from approximately 9.2 knots up to 14.4 knots. Of note, general cargo vessels transited up to 14.4 knots and the single oil tanker (i.e., Sarah Desgagnes) transited up to 13.1 knots.

Non-Project-related vessels transited through the SSA at much higher speeds. One passenger vessel (the National Geographic Explorer), for example, reached a speed of 15.9 knots when travelling through the SSA. Passenger vessels also tended to deviate their course away from the standard route taken by the ore carriers and general cargo ships, at times entering into Koluktoo Bay and hugging the shoreline around Bruce Head Peninsula.

Two medium-sized non-Project-related vessels (50 to 100 m in length), the Archimedes and the Nuliajuk, were recorded by AIS transiting through the SSA. Both vessels travelled at speeds less than 9.0 knots. No medium Project-related vessels were recorded within the SSA during the 2017 Program.

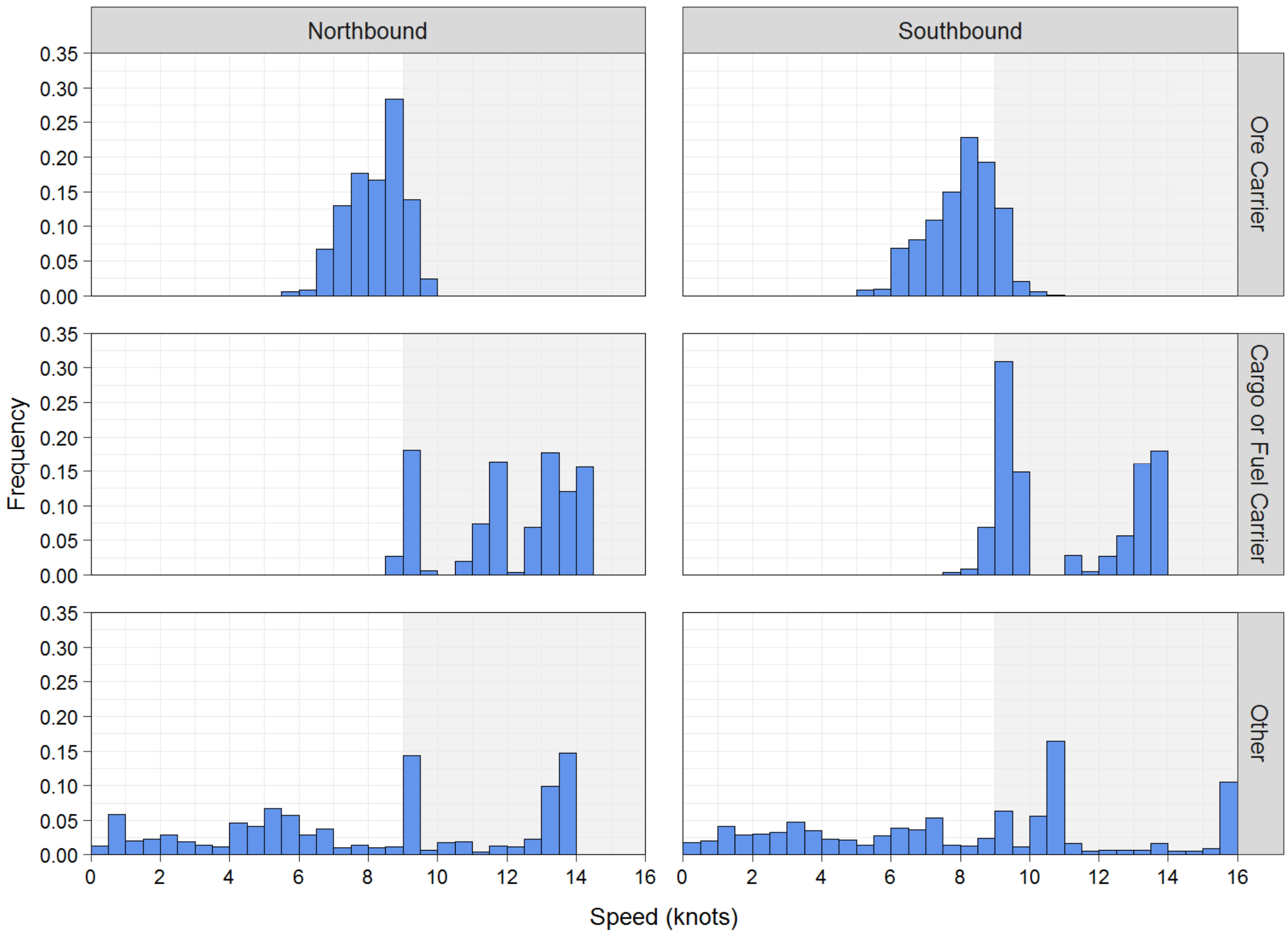


Figure 5-6: Vessel travel speed (kts) while transiting through the SSA - 2017 Bruce Head Program (31 July to 29 August).

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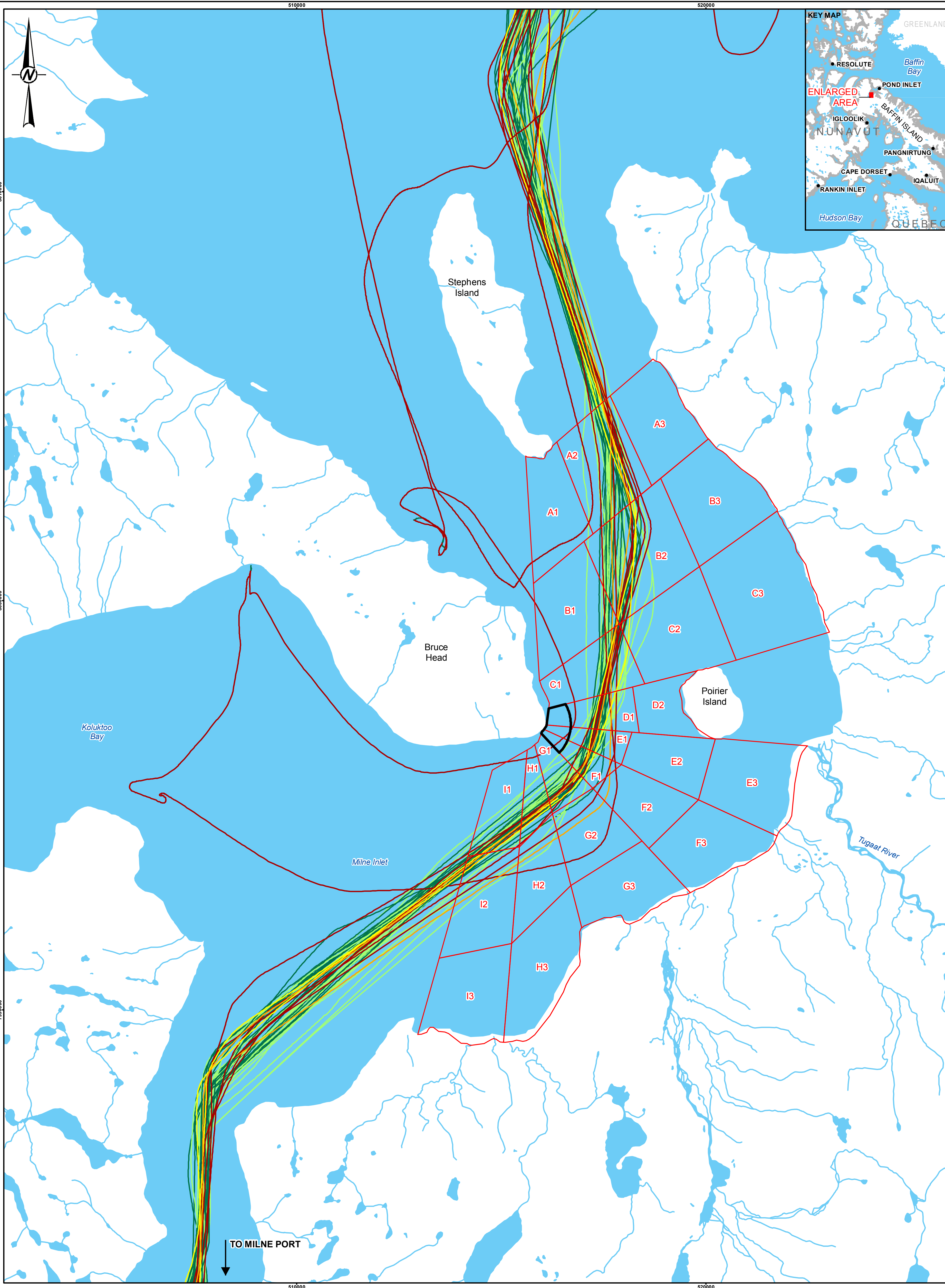

LEGEND

- COMMUNITY
- WATERCOURSE
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA
- WATERBODY

VESSEL SPEED

- < 9.0 kt
- 9.1 to 10.0 kt
- 10.1 to 11.0 kt
- 11.1 to 12.0 kt
- > 13.0 kt

0 2 4

1:90,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. SUBSTRATA DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. GEOGRAPHIC NAMES, HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
SPEED (KTS) OF ALL LARGE VESSEL TRANSITS THROUGH THE SSA BETWEEN 31 JULY AND 29 AUGUST 2017

CONSULTANT

Golder Associates

YYYY-MM-DD	2018-01-18
DESIGNED	AA
PREPARED	VV
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	7000	0	5-7

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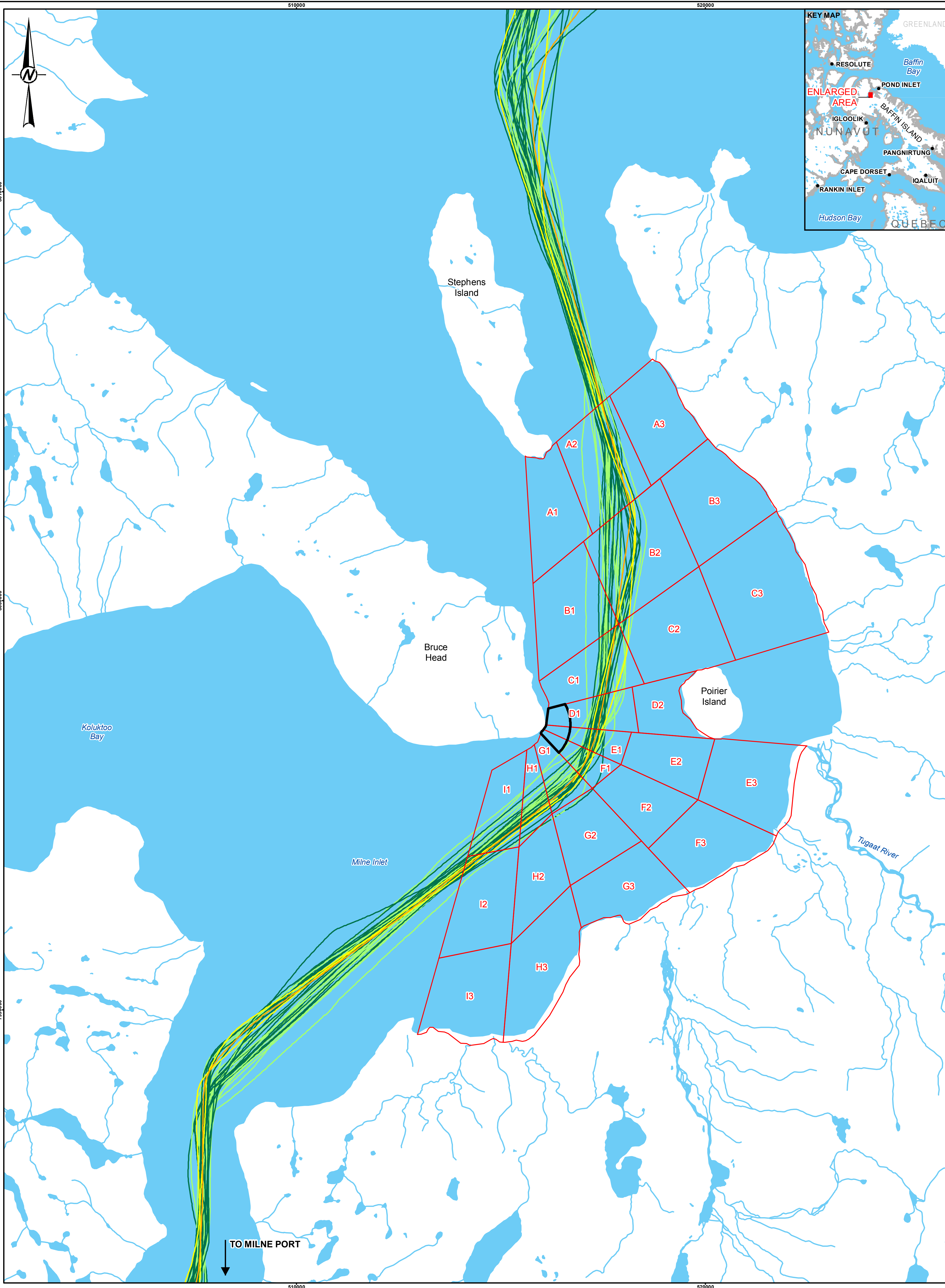

LEGEND

- COMMUNITY
- WATERCOURSE

VESSEL SPEED

- < 9.0 kt
- 9.1 to 10.0 kt
- 10.1 to 11.0 kt
- 11.1 to 12.0 kt

- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA
- WATERBODY

0 2 4

1:90,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. SUBSTRATA DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. GEOGRAPHIC NAMES, HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
SPEED (KTS) OF BULK (ORE) CARRIER TRANSITS THROUGH THE SSA BETWEEN 31 JULY AND 29 AUGUST 2017

CONSULTANT
Golder Associates

YYYY-MM-DD	2018-01-18
DESIGNED	AA
PREPARED	VV
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	7000	0	5-8

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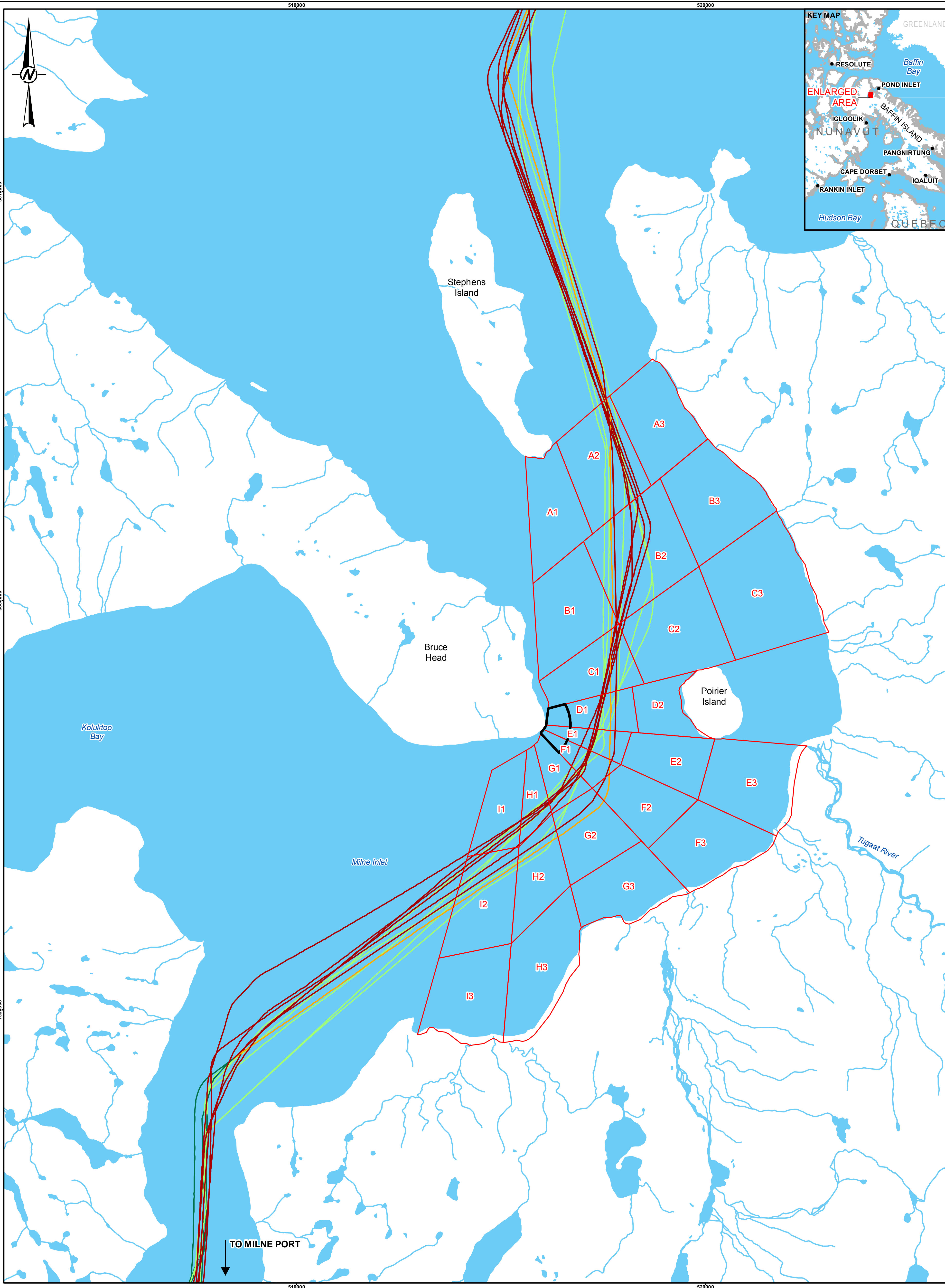

LEGEND

- • COMMUNITY
- WATERCOURSE
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA
- WATERBODY

VESSEL SPEED

- < 9.0 kt
- 9.1 to 10.0 kt
- 11.1 to 12.0 kt
- > 13.0 kt

0 2 4

1:90,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. SUBSTRATA DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. GEOGRAPHIC NAMES, HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
SPEED (KTS) OF OTHER PROJECT-RELATED VESSEL TRAFFIC THROUGH THE SSA BETWEEN 31 JULY AND 29 AUGUST 2017

CONSULTANT
Golder Associates

YYYY-MM-DD	2018-01-18
DESIGNED	AA
PREPARED	VV
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	7000	0	5-9

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

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Table 5-1: Average and maximum vessel speed (by vessel) during transits through the SSA in 2017.

	Vessel Name	Vessel Type	Median Speed (kt)[1]	Maximum Speed (kt)	N AIS Fixes	Percent Exceedance (%)[1]
Project-related	Arkadia	Bulk (ore)	9.2	9.7	225	67
	BBC Volga	Cargo	13.8	14.4	147	100
	Claude A. Desgagnes	Cargo	13.2	13.7	81	100
	Dolfijngracht	Cargo	9.1	9.2	98	67
	Golden Amber	Bulk (ore)	8.9	10.7	224	46
	Golden Diamond	Bulk (ore)	8.8	10.4	281	33
	Golden Ice	Bulk (ore)	8.2	8.9	259	0
	Golden Opal	Bulk (ore)	7.6	10.2	323	7
	Golden Opportunity	Bulk (ore)	8.2	9.0	372	0
	Golden Pearl	Bulk (ore)	8.3	9.8	270	30
	Golden Ruby	Bulk (ore)	8	9.2	225	5
	Golden Saguenay	Bulk (ore)	7.8	9.2	147	2
	Golden Strength	Bulk (ore)	8.7	9.2	275	6
	MV Golden Brilliant	Bulk (ore)	8.4	9.5	147	5
	MV Golden Bull	Bulk (ore)	8.5	9.2	344	1
	Mitiq	Cargo	9.4	9.7	109	92
	Nordic Oasis	Bulk (ore)	8.6	9.7	210	16
	Nordic Odin	Bulk (ore)	6.65	9.9	412	18
	Nordic Odyssey	Bulk (ore)	9	9.4	243	44
	Nordic Olympic	Bulk (ore)	6.9	7.8	268	0
	Nordic Orion	Bulk (ore)	8.9	9.4	277	12
	Nordic Oshima	Bulk (ore)	7.55	9.0	212	0
	NS Energy	Bulk (ore)	8.4	9.0	223	0
	NS Yakutia	Bulk (ore)	8	9.0	156	0
	Nunalik	Cargo	9.4	10	187	82
	Rio Tamara	Bulk (ore)	8.3	9.0	309	0
	Rosaire A. Desgagnes	Cargo	13.35	13.7	146	100
	Sagar Samrat	Bulk (ore)	7.5	8.6	306	0
	Sarah Desgagnes	Fuel	11.6	13.1	116	100
Other Large	Le Boreal	Cruise ship	7	15.9	363	33
	N G Explorer	Cruise ship	6.1	14	639	35
Other Medium	Archimedes	Freighter	5	5.3	3	0
	Nuliajuk	Research	7.6	8.2	76	0

Notes:
[1] The percent (%) exceedance is in relation to the maximum speed limit of 9 knots identified in Baffinland's Shipping and Marine Wildlife Management Plan (Baffinland 2016) to reduce impacts to marine mammals. The grey shaded numbers represent percent exceedances ≥ 50%.

5.2.2 Small Vessels

Small vessels (less than 50 m in length) were typically aluminum skiffs or canoes with outboard motors, operated by local Inuit for hunting, fishing, and camp access. Some small vessels passed through the SSA during transit to other locations while others pulled ashore or tied to the rocks below the Bruce Head observation platform.

Although small vessels were frequently observed tied up to shore at the base of the cliff below the observation platform, few small vessels were recorded in the SSA during the active RAD surveys (Figure 5-10). A higher number of small vessels was observed in the SSA occurred during the first two weeks of August, which coincided with favourable weather conditions in the area (low wind and warmer air temperatures) (Figure 5-2).

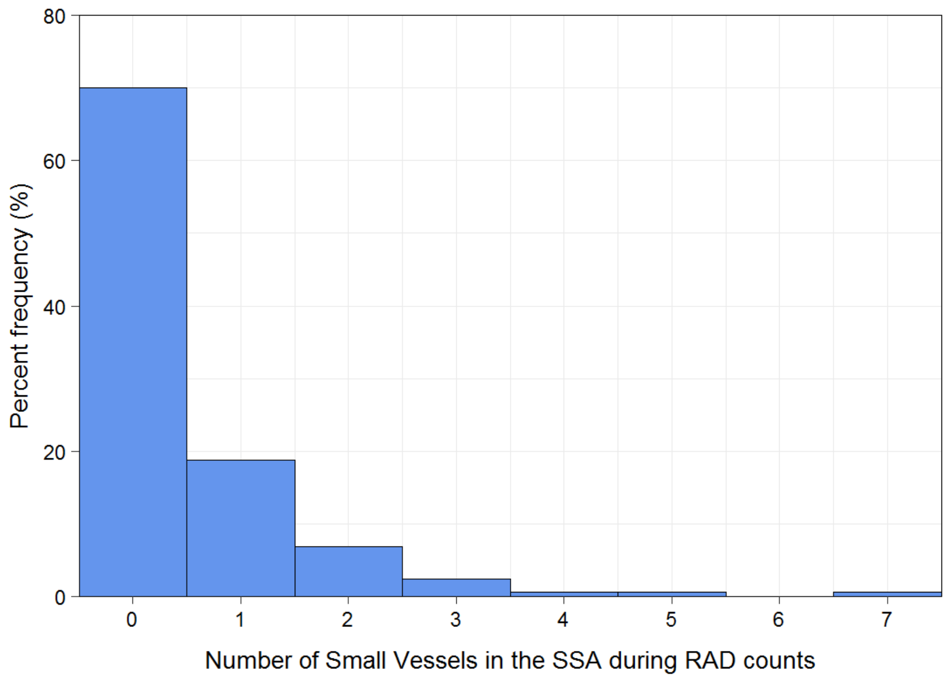

Figure 5-10 Counts of small vessels transiting within the SSA during the 2017 Program.

5.2.3 Other Anthropogenic Activities

The shoreline directly below the observation platform at Bruce Head is an established narwhal hunting site commonly used by local community members. Inuit were often observed camping with tents at the site for multiple days at a time, though others only stopped for several minutes to several hours. In total, the hunting camp was occupied during 20 of the 27 survey days. Hunting activity frequently occurred during daily surveys, with 13 separate days of hunting and a total of 59 events when one or more shots were fired within a short time period (shooting events [Smith et al. 2017]). The shooting events targeted narwhal (45 cases) and seal (1 case), while 6 events were non-directional, and in 7 cases, the target could not be identified by the observers. Shooting events in the air were indirectly targeting narwhal as the local Inuit observers explained that the intent was for the bullet to fall on the offshore side of the narwhal, spooking the animal so that it would flee towards the Bruce Head shoreline, closer to the hunters (A. Ootova per. comm. 2017).

Air traffic was observed in the SSA from 1 August to 25 August with a total of 19 helicopter flights. One helicopter over-flight was estimated at an elevation of 200 m, in close proximity to the observation platform, while others were flying at higher elevations and some were heard and not observed. On two separate low helicopter flights, observers recorded that a mom-calf pair dove in response to the helicopter approach while a group of narwhal that had been resting on the surface began moving in multiple directions before slowly resuming their initial orientation once the helicopter passed.

5.3 Relative Abundance and Distribution of Narwhal

A total of 160 unique RAD surveys were conducted over 27 days from 31 July 2017 to 29 August 2017, resulting in an average of 6 RAD surveys per day[5] (Table 5-2). The majority of the RAD surveys were complete with counts conducted for all nine strata (26 substrata). Of the 160 RAD surveys, 109 included a full survey of all substrata and were subsequently included in the analysis. A total of 51 RAD surveys had substrata that were partially obstructed or limited by ‘impossible’ sightability. In cases where sightability was listed as ‘impossible’, these data were removed from further analysis.

A total of 11,969 narwhal were observed in the SSA over the course of the 2017 shore based study, inclusive of all sighting conditions, with the exception of those categorized as ‘impossible’. Total daily narwhal counts ranged from zero (31 July 2017) to 1,261 (20 August 2017), with an average count of 75 narwhal per RAD survey (460 per day). In general, stratum totals increased from north to south, consistent with distribution trends observed during the 2016 Program (Smith et al. 2017). Strata G, H, and I had the greatest total counts of 1,799, 2,204, and 3,499 individuals, respectively, while stratum A had the lowest total count of 410. Standardized daily counts of narwhal observed between 2014 and 2017 are presented in Figure 5-11.

[5] One RAD survey incomplete because it was initiated with the travel direction of a herding event, and thus restarted from the opposite direction to avoid double counting.

Table 5-2: Summary of daily RAD survey effort and mean number of narwhal counted per survey, by date and stratum (2017 Program).

Date (2017)	Number of Narwhal										No. of RAD Surveys	Mean No. of Narwhal/ Survey
	Stratum									All Strata		
	A	B	C	D	E	F	G	H	I			
31-Jul	0	0	0	0	0	0	0	0	0	0	6	0
01-Aug	0	0	0	0	0	0	0	0	14	14	7	2
02-Aug	0	0	0	0	0	0	0	5	124	129	8	16
03-Aug	0	0	0	0	0	0	1	61	413	475	9	53
04-Aug	116	53	79	60	125	52	110	137	426	1,158	9	129
05-Aug	3	1	2	0	0	4	33	132	302	477	8	60
06-Aug	0	0	0	11	0	23	50	62	89	235	8	29
07-Aug	0	0	0	1	0	3	17	96	195	312	8	39
08-Aug	30	52	67	78	69	49	68	42	46	501	8	63
09-Aug	20	21	21	51	22	45	73	27	3	283	7	40
10-Aug	0	0	0	0	0	2	8	19	57	86	5	17
11-Aug	7	58	93	67	153	139	101	111	125	854	8	107
12-Aug	47	57	58	49	56	77	231	156	143	874	8	109
13-Aug	8	10	4	17	36	25	53	123	89	365	5	73
16-Aug	2	2	0	2	0	2	12	6	32	58	4	15
17-Aug	0	0	0	0	0	12	20	21	72	125	4	31
19-Aug	64	42	25	96	162	254	140	136	248	1,167	7	167
20-Aug	25	53	36	74	101	133	246	365	228	1,261	6	210
21-Aug	10	5	2	3	17	25	57	135	136	390	6	65
22-Aug	14	33	42	55	174	143	125	155	185	926	6	154
23-Aug	0	0	5	10	14	0	0	25	8	62	1	62
24-Aug	0	3	0	24	8	13	53	104	243	448	7	64
25-Aug	60	70	105	127	136	117	193	125	139	1,072	5	214
26-Aug	3	4	6	5	35	73	188	131	168	613	6	102
28-Aug	1	0	9	7	3	0	6	18	14	58	2	29
29-Aug	0	0	0	0	0	0	14	12	0	26	2	13
Overall	**410**	**464**	**554**	**737**	**1,111**	**1,191**	**1,799**	**2,204**	**3,499**	**11,969**	**160**	**75**

Notes: On 23-Aug, zero counts for Strata F and G were noted as ‘impossible’ sightability due to intense glare.

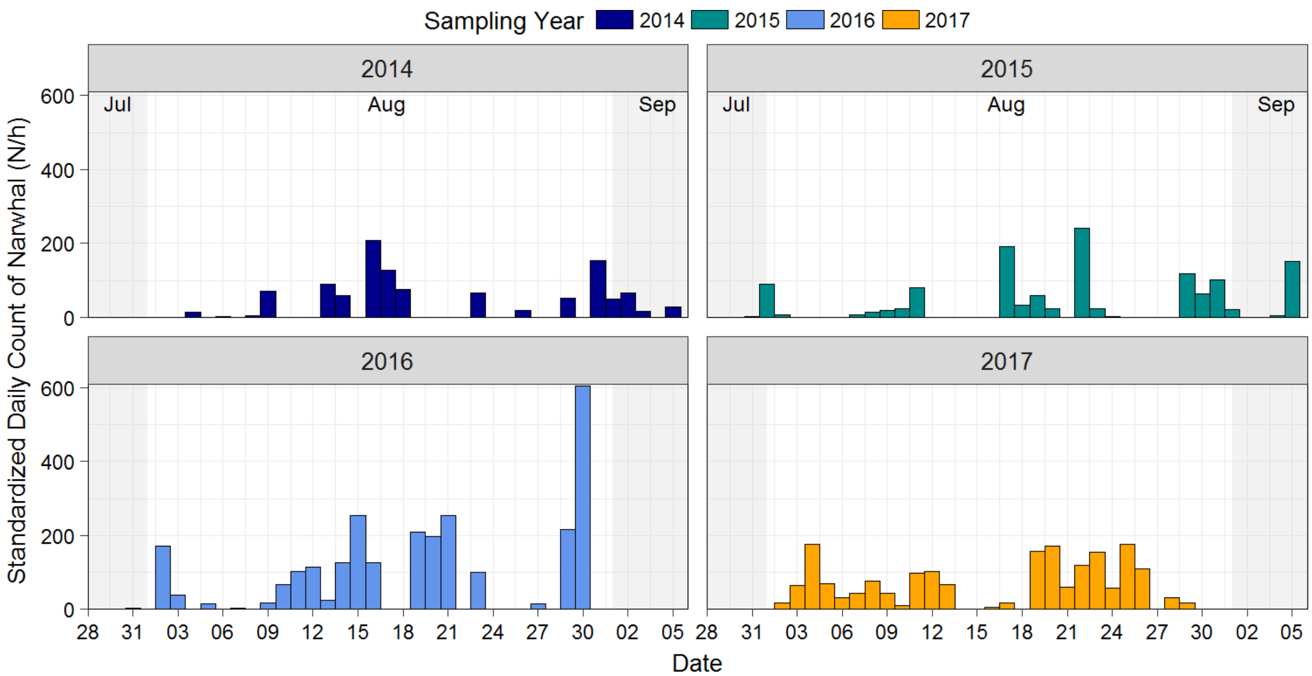

Figure 5-11: Standardized daily number of narwhal observed in the SSA between 2014 and 2017.

Narwhal numbers varied with substratum distance from the observation platform, with total counts of 4,427, 5,428, and 1,505 individuals at substrata 1, 2, and 3, respectively (Figure 5-12). Note that the values detailed herein exclude conditions of impossible sightability, and exclude one RAD survey conducted on 11 August 2017 in which counts were made in the same direction as a herding event and therefore had high potential for double counting.

Of the three substrata, 39% and 48% of total narwhal counts were recorded in substrata 1 and 2, respectively, while substratum 3 constituted only 13% of the total 2017 narwhal counts (Table 5-3). Within both substrata 1 and 2, the majority of counts were associated with sightability conditions that were deemed excellent, medium, or good, whereas counts associated with poor sightability were considerably lower. Conversely, in substratum 3, the proportion of counts associated with poor sightability was higher than counts made under excellent sightability conditions.

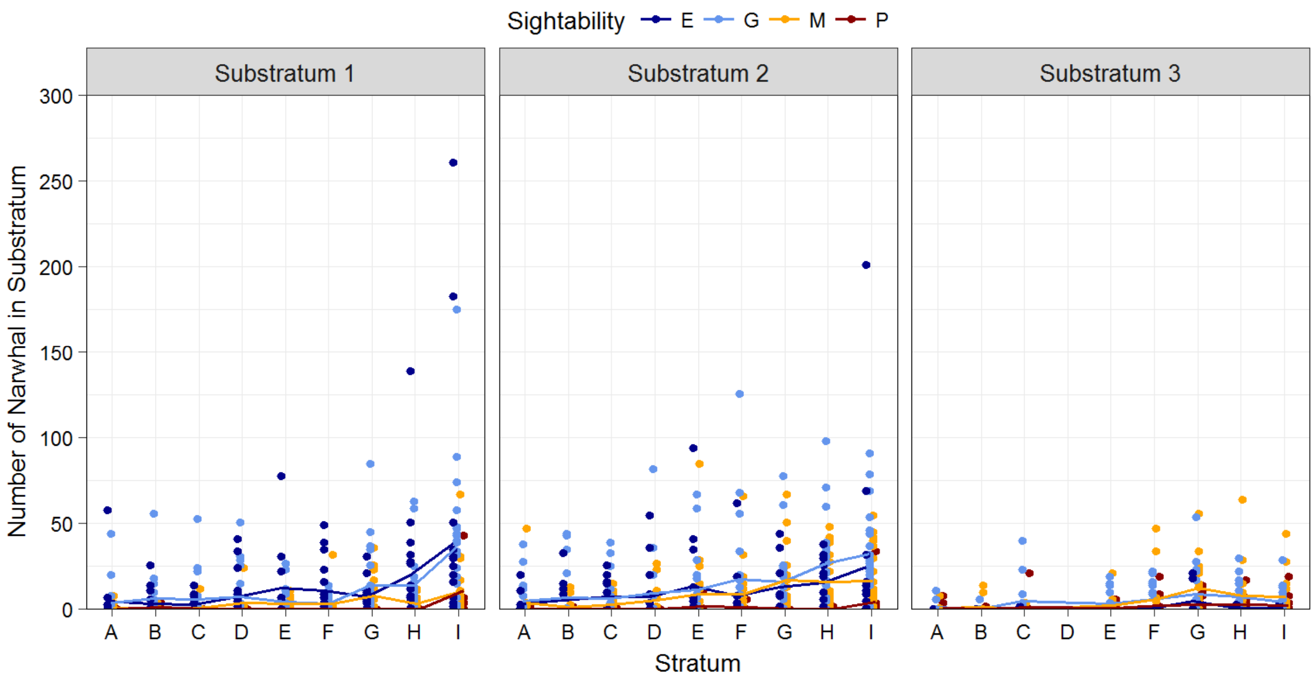

Figure 5-12: Count of narwhal per substratum relative to sightability conditions, when no large vessels are present within 15 km of the SSA. Small points depict raw data; lines represent model predictions.

Table 5-3: Proportion of narwhal counts in substrata 1, 2, and 3 under different sightability conditions.

Substratum	Sightability Condition				Total
	E	G	M	P	
1	0.161	0.180	0.043	0.005	**0.39**
2	0.108	0.232	0.132	0.006	**0.48**
3	0.004	0.057	0.051	0.020	**0.13**
Total	**0.27**	**0.47**	**0.23**	**0.03**	**1.00**

During the 2017 Program, large vessels transited through the SSA on 23 of the 27 survey days, overlapping with 16 of the daily observation periods (Figure 5-13). During this time, narwhal were observed in relation to 21 Project-related vessel transits and one passenger vessel transit that was not Project-related. Mean counts of narwhal in the SSA relative to proximity and orientation of large vessels within 15 km were examined for the 2017 Program (Figure 5-14). The majority of narwhal observed in the SSA occurred when no large vessels were present within 15 km of a given substratum (72%; n = 8,211) compared to when large vessels were present (28%; n = 3,149).

When a large vessel was within 15 km of a given substratum and entering Milne Inlet, a total of 569 and 647 narwhal were observed when the vessel was approaching and departing a substratum, respectively. When a large vessel was within 15 km of a given substratum and exiting Milne Inlet, a total of 1,221 and 712 narwhal were observed when the vessel was approaching and departing a substratum, respectively. Mean narwhal count per substratum observed under the four vessel passage scenarios ranged from 2.1 (vessel entering Milne Inlet and approaching a substratum) to 5.7 (vessel exiting Milne Inlet and approaching a substratum).

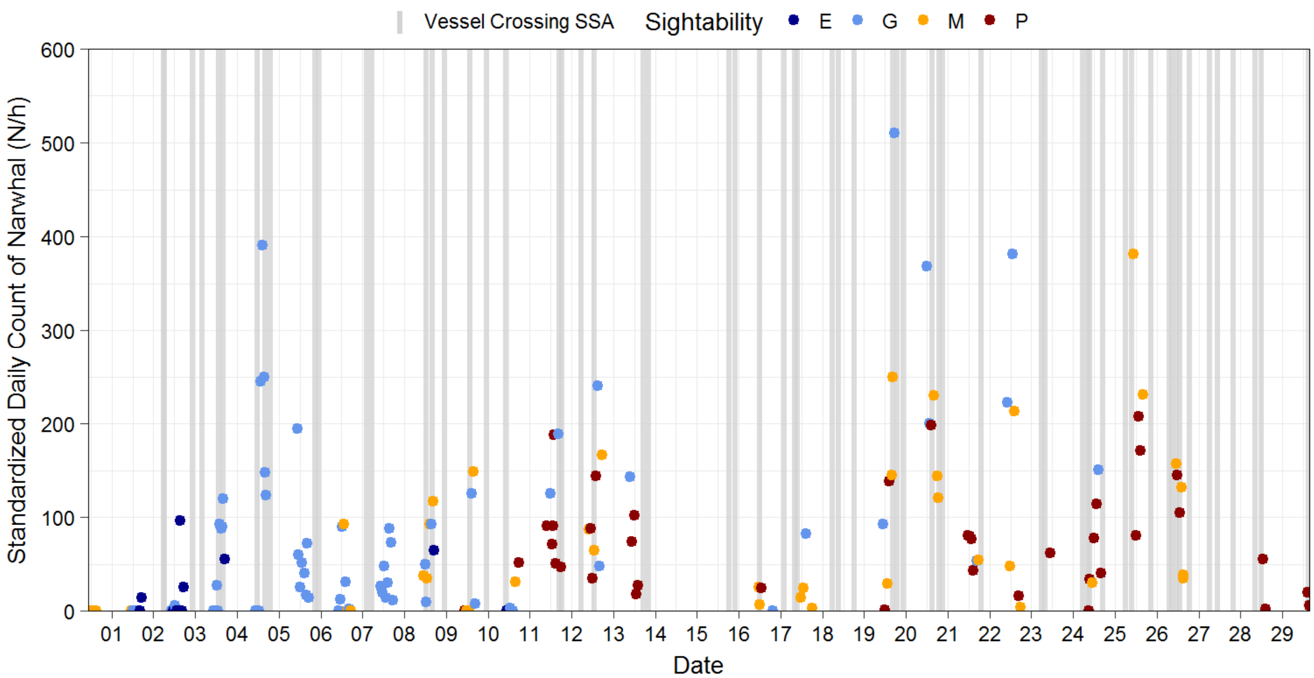

Figure 5-13: Standardized daily number of narwhal observed in the SSA (31 July 2017 – 29 August 2017). Grey bars represent large vessels transiting through the SSA.

A visual examination of mean narwhal counts relative to proximity and orientation of large vessels suggests differences in narwhal distribution relative to large vessel traffic (Figure 5-14). When no vessels were present within 15 km from a given substratum, mean narwhal count was 2.7 individuals per substratum (standard deviation of 8.1 individuals). When large vessels were exiting Milne Inlet and approaching substrata, mean narwhal counts within each 500 m distance bin were relatively higher (2.3-11.5 individuals) when vessels were near (≤3 km) compared to when vessels were further away. At approximately 10 km away from the vessel, however, high narwhal counts (average of 27.7-27.8 individuals) were observed for this vessel passage scenario. When vessels were exiting Milne Inlet and departing from the substrata, mean narwhal counts within each 500 m distance bin ranged from 0 to 15.3 individuals (median value of 2.0 individuals), with a decrease in mean counts when vessels were approximately 6-10 km from substrata. When vessels were entering Milne Inlet and approaching substrata, mean counts within each 500 m distance bin were lowest among the four vessel passage scenarios, with mean narwhal counts ranging from 0 to 7.8 individuals (median value of 1.0 individuals). Finally, when vessels were entering Milne Inlet and departing substrata, mean counts within each 500 m distance bin increased gradually with distance from the vessel, up to approximately 6-9 km. Under this vessel passage scenario, mean counts ranged from 0 to 10.5 individuals (median value of 2.7 individuals).

Detailed modeling results for analysis of RAD are provided in Appendix C.

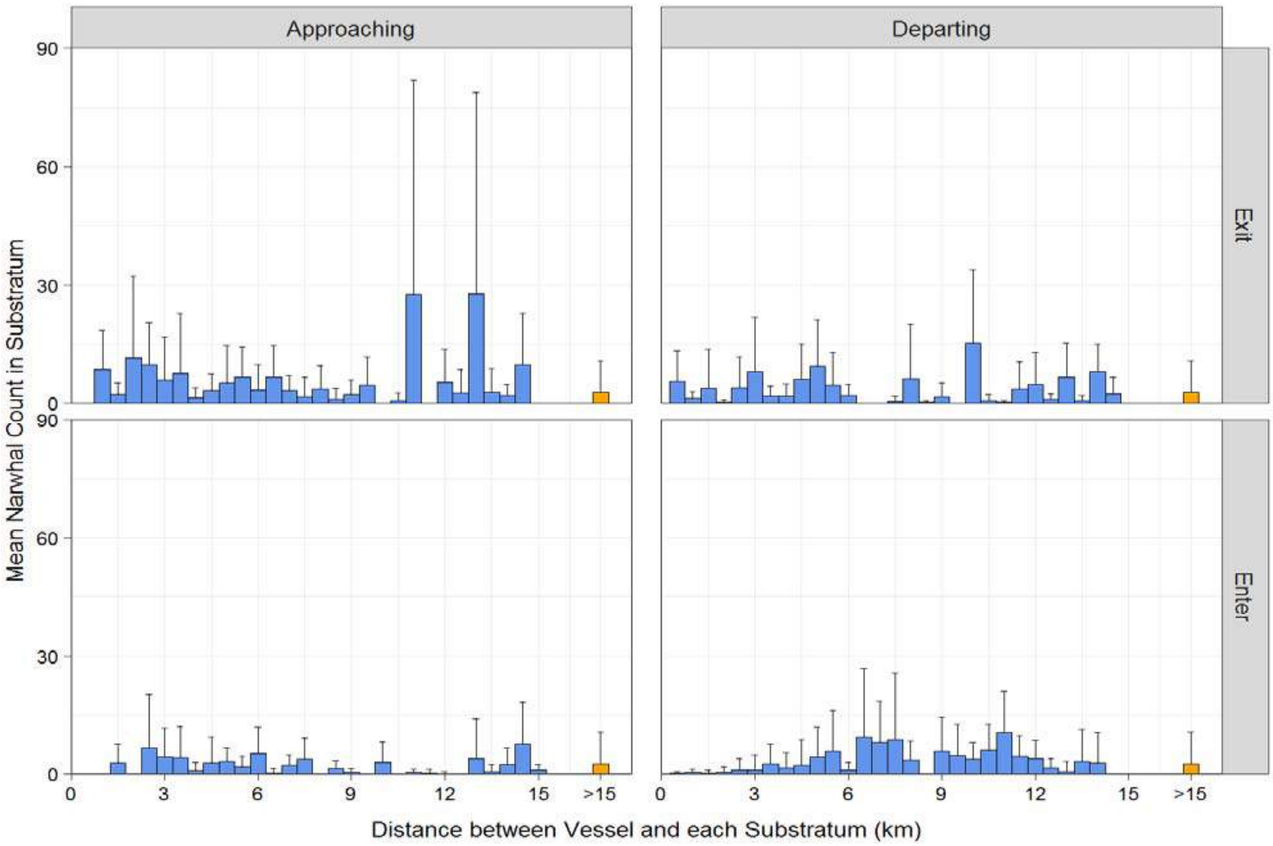

Figure 5-14: Mean narwhal count per substratum, relative to distance between vessel and substratum, binned to 0.5 km (31 July 2017 – 29 August 2017). Error bars are 1 standard deviation.

5.4 Group Composition and Nearshore Travel Behaviour

Data on group composition and behavior of narwhal within the BSA were collected over 27 days between 31 July 2017 and 29 August 2017 (see Figure 5-1 for daily survey effort). A total of 2,424 narwhal groups were observed to pass within the BSA during this time, with the majority of sightings occurring in the absence of anthropogenic activity (i.e. vessel transits, active shooting events). Of these 2,424 observations, 8 were conducted under conditions of 'impossible' sightability and were removed from further analysis.

Daily counts of narwhal observed in the BSA between 2014 and 2017, standardized by daily effort, indicate substantial differences in narwhal counts between sampling years and within years, with no apparent within-year temporal patterns (Figure 5-15). The greyed portion on the figure separates the survey months. It is important to note that the higher numbers observed in 2017 may be due to an enlarged BSA boundary relative to previous years. Specifically, the boundary of the BSA during the 2017 field season was defined to include portions of substrata D1, E1 and F1 up to 1,000 m from shore, whereas the BSA boundary during 2014-2016 surveys only included portions of substrata E1 and F1 up to 1,000 m from shore. This discrepancy in BSA boundary was due to inconsistencies in previous years' methods outlined in LGL documents (LGL Training Manual) and was only resolved after the completion of the 2017 field program.

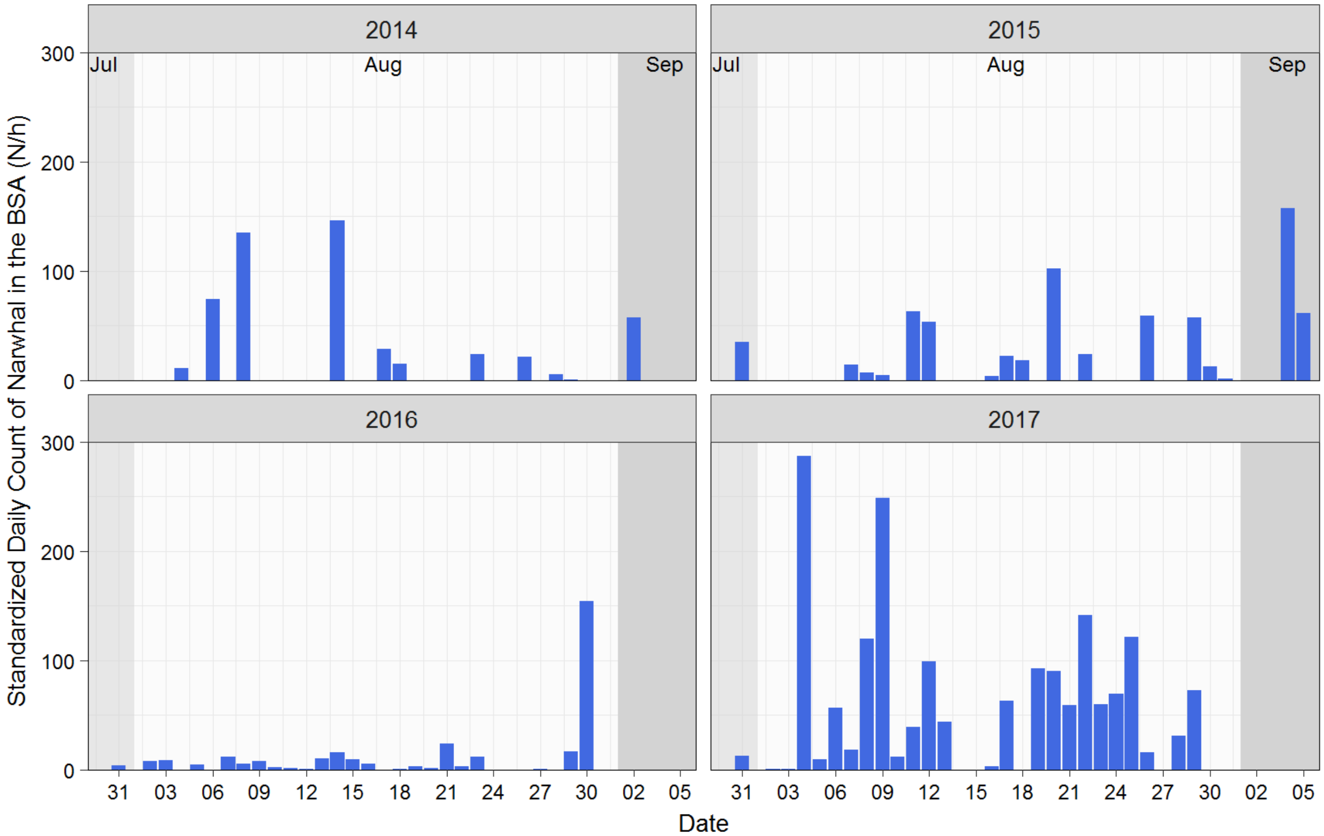

Figure 5-15: Daily counts of narwhal in the BSA between 2014 and 2017, standardized by total daily effort (h).

5.4.1.1 Group Size

Mean group size of narwhal observed in the BSA between 2014 and 2016 was 4.0 individuals (n = 1,299, range: 1 to 45 individuals; Figure 5-16) and increased (mean = 5.1 individuals) during periods when a large vessel was present (Smith et al. 2017). During the 2017 field program, mean narwhal group size observed was 3.7 individuals (n = 2,416, range: 1 to 23 individuals) and decreased (mean = 3.4 individuals) when large vessels were present within 15 km of the BSA.

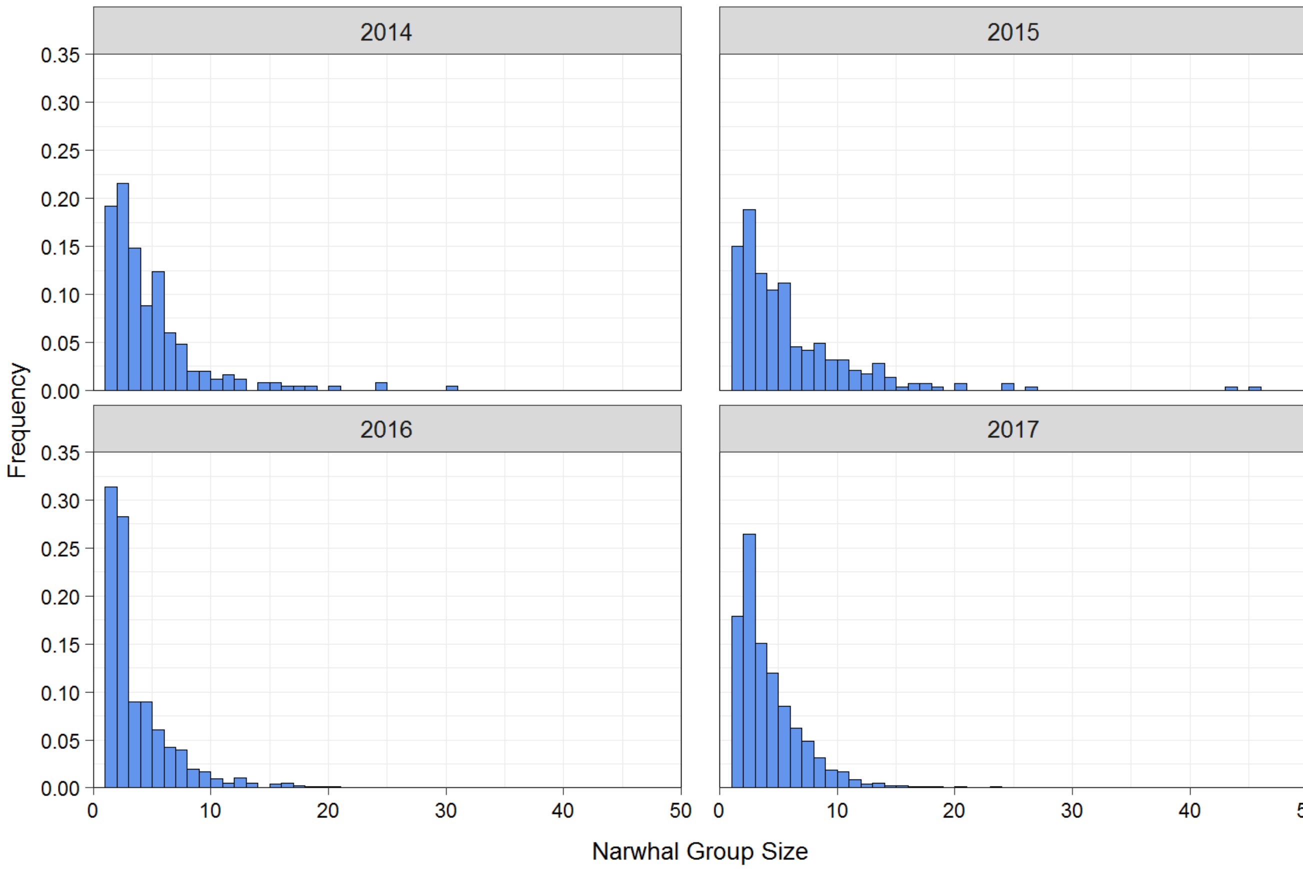

Figure 5-16: Distribution of group size of narwhal observed in the BSA between 2014 and 2017.

During the 2017 field program, the majority of narwhal sightings in the BSA occurred when no large vessels were present within 15 km of the BSA (n = 1,834; Table 5-4), at which time mean group size of narwhal was 3.7 individuals (standard deviation = 2.7). When large vessels were present within 15 km from the BSA, mean narwhal group size varied in relation to 1) distance from the vessel transiting through the SSA and 2) direction of travel and orientation of the vessel transiting through the SSA. When a large vessel was within 15 km of the BSA, a total of 544 narwhal groups were sighted with mean group size of 3.4 individuals. Of these, 189 and 119 groups were recorded when a vessel was exiting Milne Inlet and departing or approaching the BSA, respectively, and 140 and 96 cases were recorded when a vessel was entering Milne Inlet and departing or approaching the BSA, respectively. Mean group size of narwhal observed under these four vessel passage scenarios ranged from 1.0 (vessel exiting Milne Inlet and approaching the BSA) to 10.0 (vessel entering Milne Inlet and approaching the BSA; Figure 5-17).

Of the total 2,416 narwhal groups observed in the BSA, the remaining 38 groups (mean group size = 5.0 individuals) were observed when two large vessels were within the defined 15 km radius (two events, on separate days). Given the low occurrence of two-vessel passage and the variability inherent to the data, modeling the effect of two vessel passage on narwhal group size would not be feasible at this time. Therefore, events of two vessel passage were removed from analysis and are discussed in text only.

Detailed modeling results for analysis of group size are provided in Appendix C.

Table 5-4: Occurrence of narwhal groups observed in the BSA under various scenarios, 2017.

Scenario	Number of narwhal groups	Mean narwhal group size
No large vessels present within 15 km	1,834	3.7
One large vessels present within 15 km	544	3.4
Two large vessels present within 15 km	38	5.0
Total	**2,416**	**3.7**

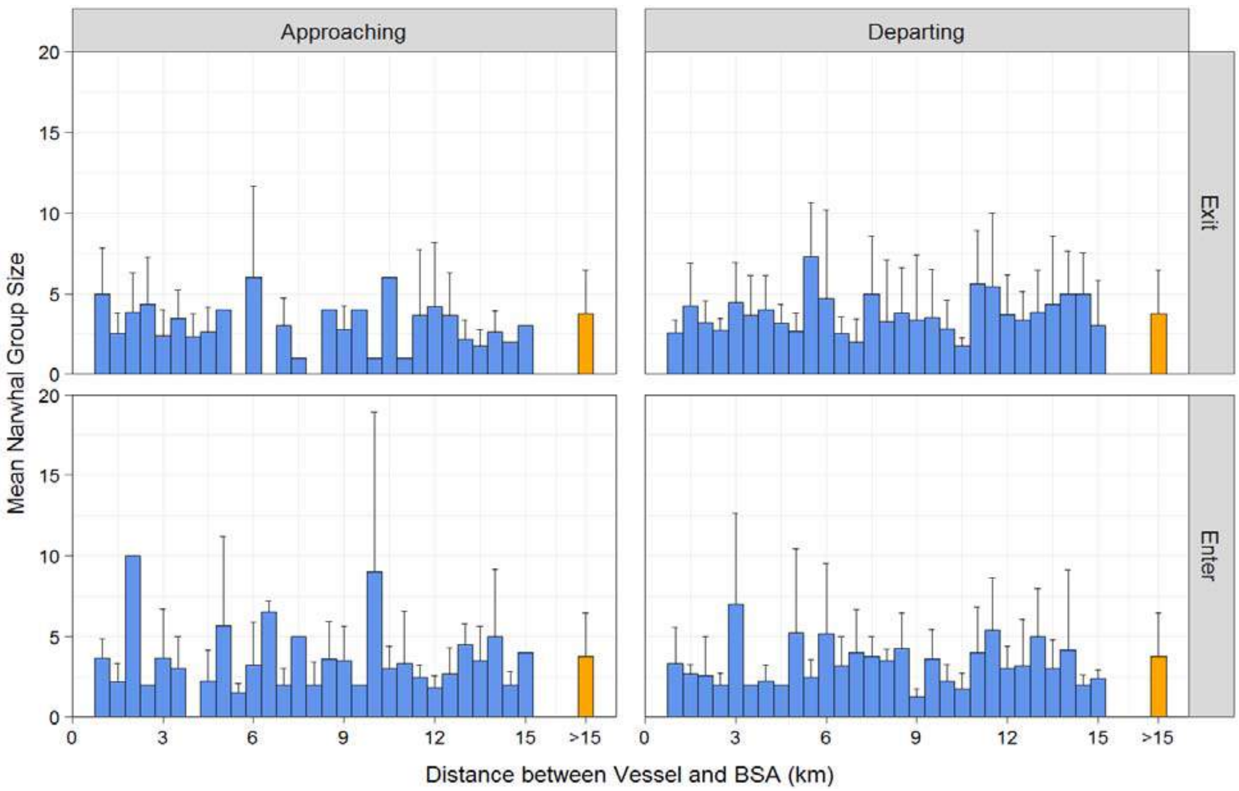

Figure 5-17: Mean narwhal group size observed in the BSA, relative to distance from vessel, binned to 0.5 km (31 July 2017 – 29 August 2017). Error bars are 1 standard deviation.

5.4.1.2 Group Composition

Narwhal observed in the BSA between 2014 and 2017 included animals of all life stages – adults, juveniles, yearlings, and calves (Figure 5-18). Throughout the duration of the Program (2014 – 2017), adult narwhal have consistently comprised the majority of sightings, while juveniles, yearlings and calves accounted for a smaller percent of animals observed. As yearlings were not recorded as a life stage during 2014 and 2015 (Smith et al. 2017), it is not clear whether these animals were considered calves (the younger age category) or juveniles (the older life stage). Based on a greater similarity of physical attributes between yearlings and juveniles compared with yearlings and calves, Golder has made the cautious assumption that yearlings were documented in the older life stage category (i.e., juveniles) and, for the purpose of comparison across years (Figure 5-18 only), has grouped yearlings recorded in 2016 and 2017 with juveniles.

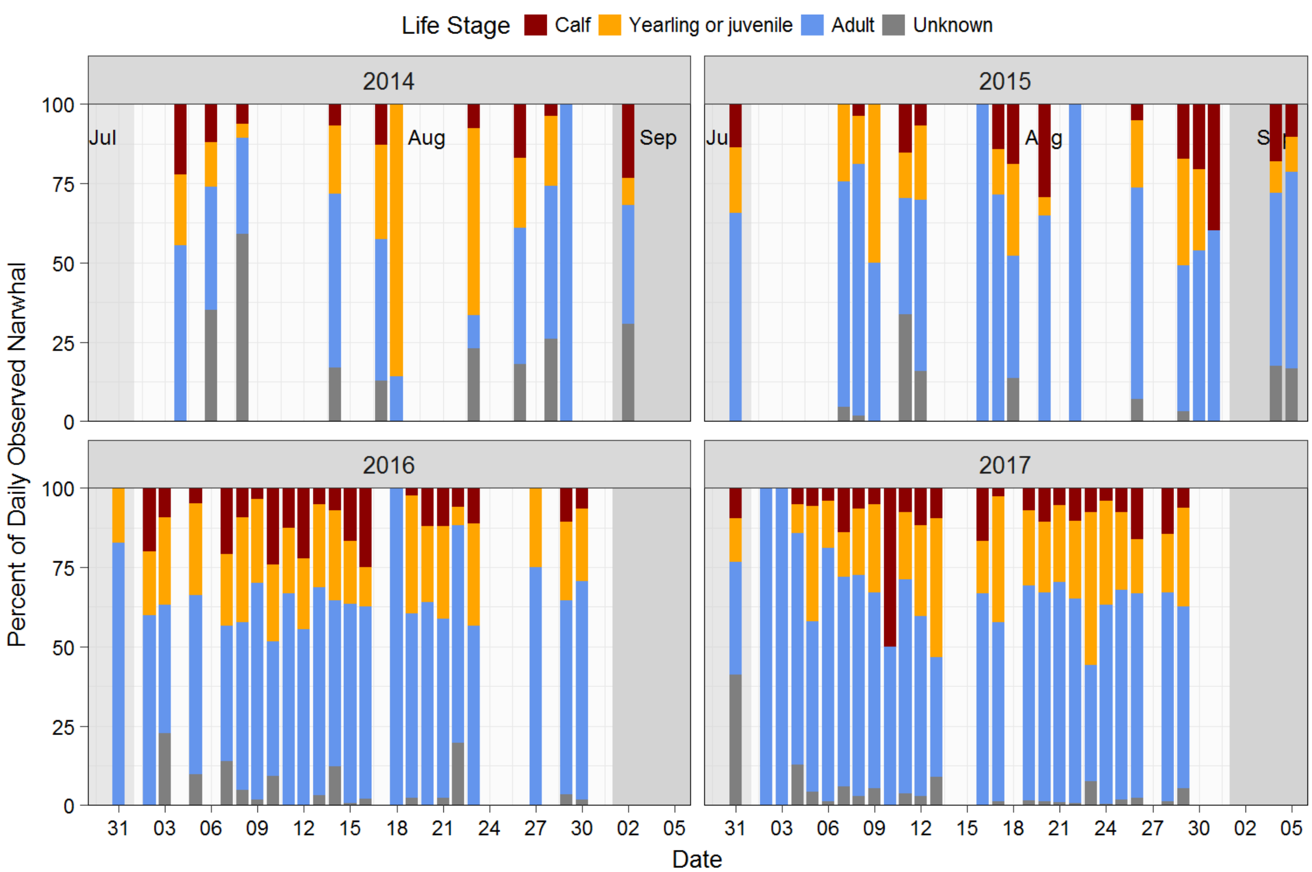

Figure 5-18: Daily distribution of narwhal life stages, 2014 – 2017.

For data collected between 2014 and 2016 by LGL, composition of narwhal groups was classified into six broad categories based on presence/absence of tusks and presence/absence of calves or yearlings. The following is a brief summary of key findings relating to composition of observed narwhal groups (Smith et al. 2017):

- More than half of the groups of known composition included narwhal without tusks.
- Mixed groups accounted for the largest group sizes and the majority of group sizes >10.
- Calves and yearlings were rarely observed in groups without adults/juveniles lacking tusks.

For data collected during the 2017 Program, classification of narwhal group composition was adapted to include the following five groups of interest, and a sixth group (‘other’) to capture those not categorized (Figure 5-19):

1) Adult group (n>1; includes adult(s) and/or juvenile(s), no calves and/or yearlings)
2) Mother/offspring group (n>1; includes adult(s) and/or juvenile(s) with no tusk, with calf/calves and/or yearling(s)
3) Mixed group (n>1; includes adult(s) and/or juvenile(s) with at least 1 tusk, with calf/calves and/or yearling(s)
4) Single adult or juvenile; with tusk
5) Single adult of juvenile, without tusk
6) Other (includes groups containing individuals of unknown life stage, unknown tusk, and others)

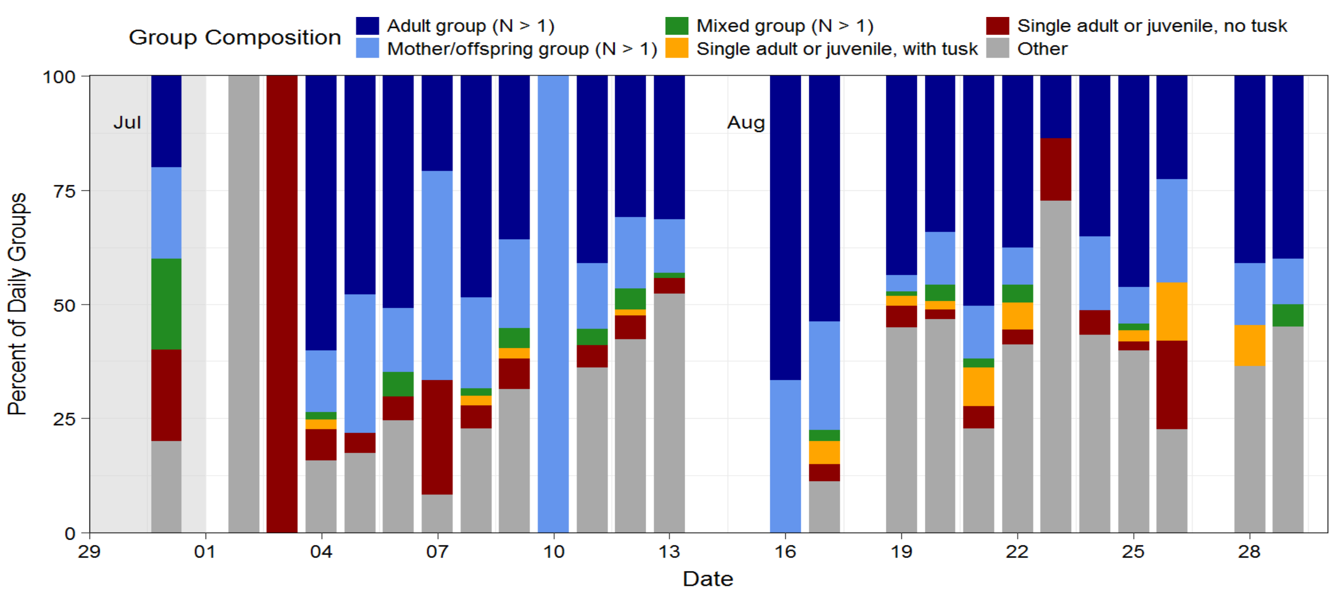

Figure 5-19: Daily distribution of narwhal group compositions of total number of groups recorded.

Of the five categories of known composition, adult groups accounted for the majority of narwhal groups of known composition observed in the BSA during the 2017 Program (64%), followed by mother/offspring groups (21%), and groups of mixed composition (4%; Figure 5-20). A greater number of single adults/juveniles without tusks (7.4%) was observed compared to single adults/juveniles with tusks (4.4%). Narwhal groups falling into the 'other' category made up for 35% of the total observed groups; this grouping is further categorized in Figure 5-21.

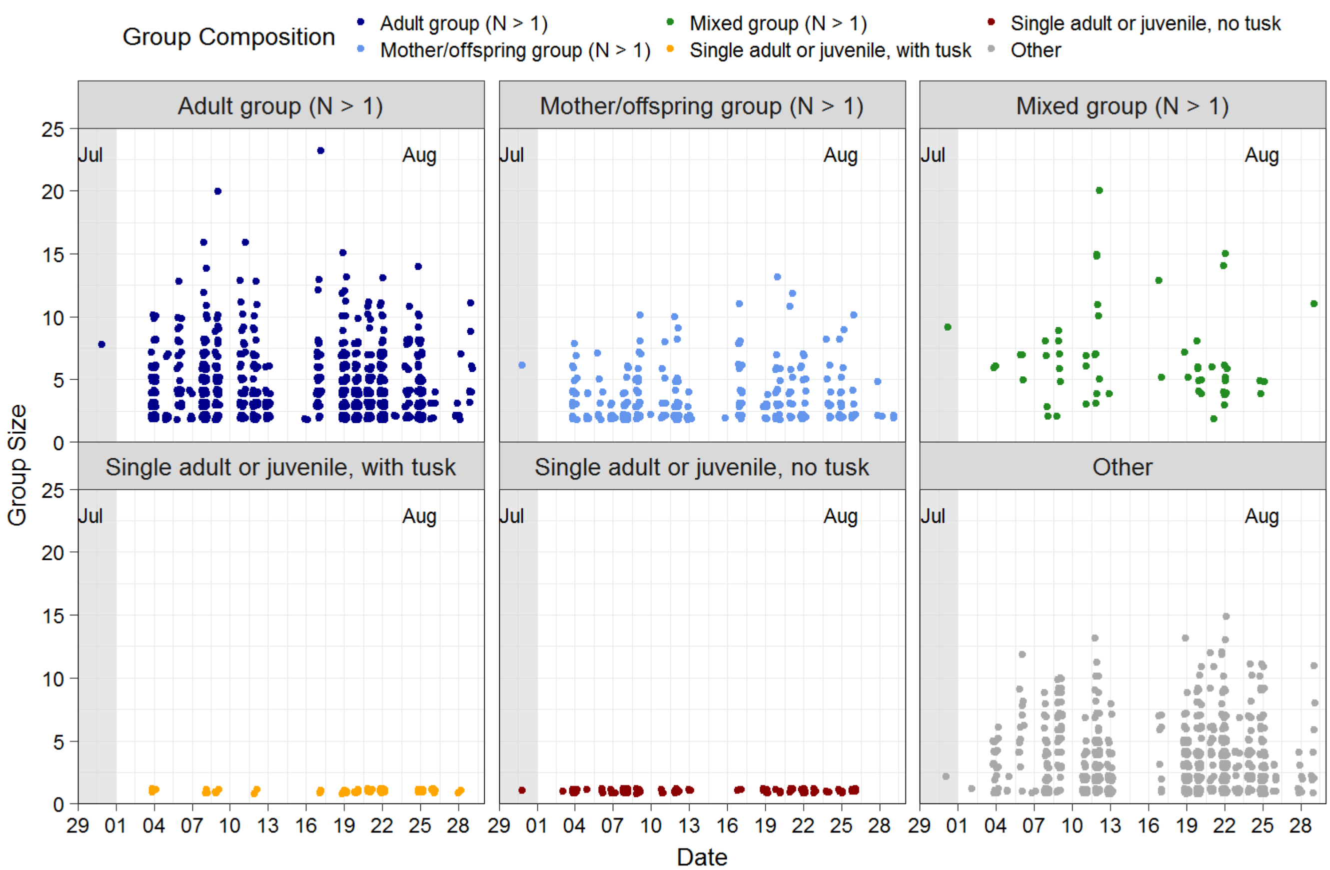

Figure 5-20: Daily distribution of group compositions out relative to date and group size; see Figure 5-21 for a breakdown of the "Other" category.

For narwhal groups that did not fall into one of the five classifications (Figure 5-21), 63% included groups having at least one adult/juvenile with unknown tusk, and a calf and/or yearling. Groups having this composition could be either a mother/offspring group or a mixed group and are therefore not considered a group of known composition. Of the remaining narwhal groups classified as ‘other’, 17% included groups of adults/juveniles with unknown tusk and no calf or yearling. ‘Miscellaneous’ groups accounted for 21% of ‘other groups’ observed and included, among others, calves and/or yearlings without an accompanying adult and/or juvenile, and narwhal of unknown life stage that do not fall into any of the aforesaid group composition classifications.

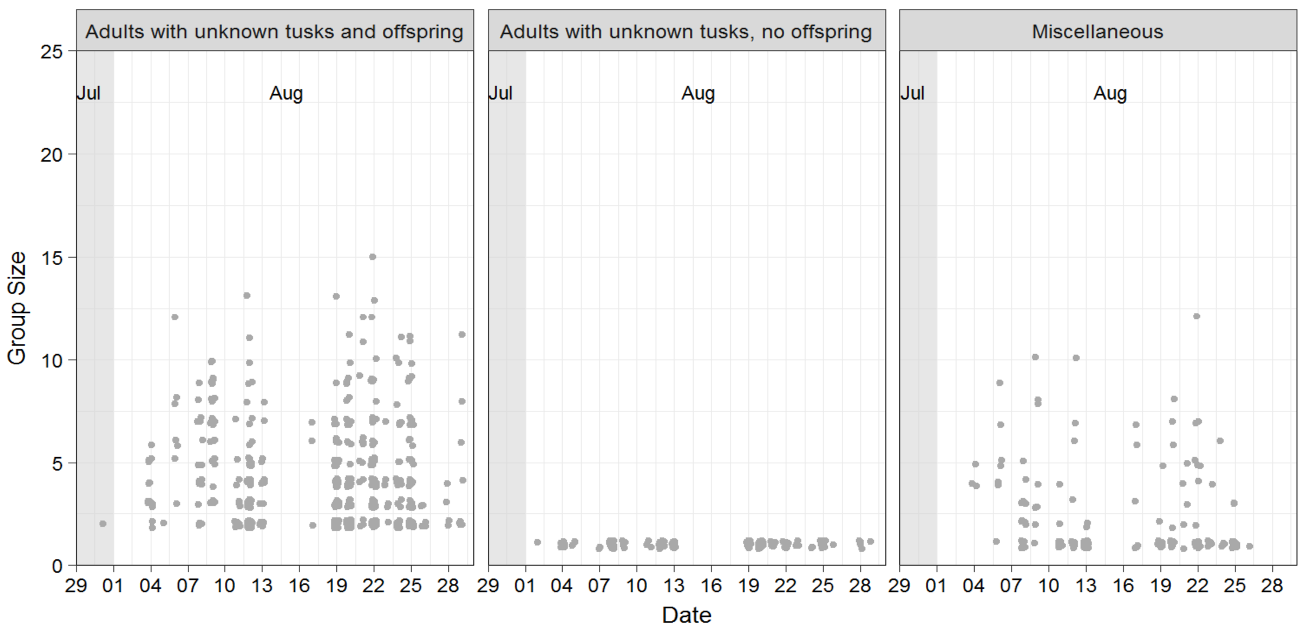

Figure 5-21: Daily distribution of constituents of the “Other” group composition.

Composition of narwhal groups observed in the BSA relative to proximity and orientation of large vessels transiting through the SSA is presented for the 2017 Program (Figure 5-22). During large vessel transits within 15 km from the BSA, 33% of total narwhal groups observed were classified as ‘other’. Of the five groupings of known composition, mother/offspring groups (16%) and adult groups (40%) were observed more frequently than mixed groups (3%) when vessels were present within 15 km from the BSA. Single adults/juveniles with tusks (2%) and single adults/juveniles without tusks (6%) were also observed during large vessel transits. Median group size of mixed groups (5-7 individuals) tended to be larger than adult groups (3-4 individuals) and mother/offspring groups (2-3 individuals) across all four vessel passage scenarios.

When no large vessels were present within 15 km from the BSA, median group size for mother/offspring and adult composition categories was similar (3 individuals). The variability of group sizes differed, however, with mother/offspring groups having 25th and 75th percentiles of 2 and 5 individuals respectively, and adult groups having 25th and 75th percentiles of 1 and 6 individuals, respectively. Overall, mixed groups tended to be larger during no-vessel scenarios, with a median group size of 5 individuals and 25th and 75th percentiles of 4 and 7 individuals, respectively. The largest group (n = 23) was recorded on 17 August and included 17 adults with tusks and 6 juveniles with tusks.

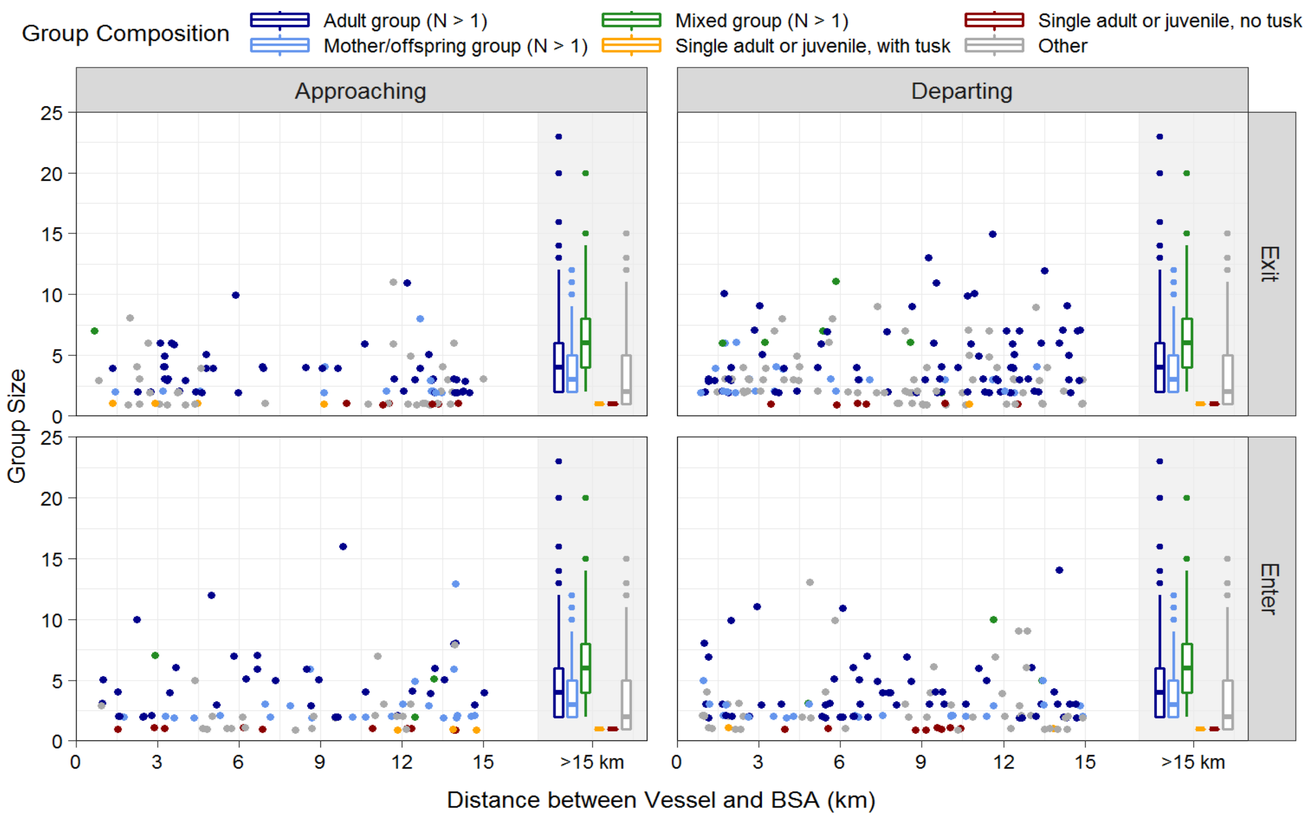

Figure 5-22: Composition of narwhal groups observed in the BSA relative to large vessels transiting through the SSA (31 July 2017 – 29 August 2017).

5.4.1.3 Group Spread

Narwhal groups observed in the BSA between 2014 and 2017 were classified as tight (i.e., individuals ≤1 body width apart) or loose (i.e., individuals >1 body width apart) based on the physical proximity of individuals to one another. Between 2014 and 2017, narwhal were more often observed in tight groups than in loose groups, regardless of whether individuals were exposed to anthropogenic activity (Smith et al. 2017; Figure 5-23).

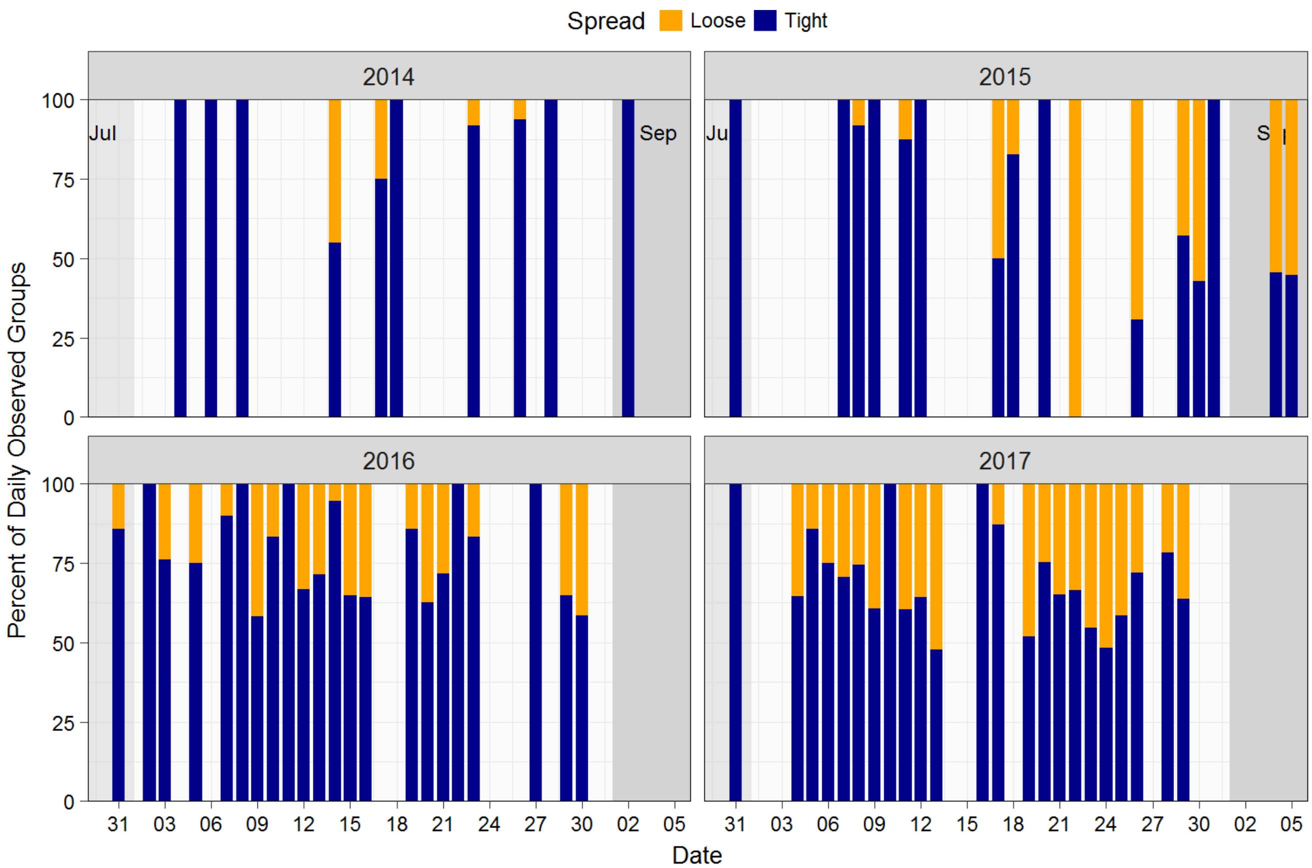

Figure 5-23: Group spread classification of narwhal groups observed in the BSA, 2014 – 2017.

Group spread of narwhal observed in the BSA relative to proximity and orientation of large vessels transiting through the SSA is presented for the 2017 Program (Figure 5-24). The proportion of narwhal groups exhibiting a tight spread or loose spread did not appear to be affected by direction of travel and orientation of large vessels transiting through the SSA. Of note, during passage of a large vessel within 15 km of the BSA, tightly spread groups were more common than loosely spread groups, regardless of whether the vessel was entering or exiting Milne Inlet or approaching or departing the BSA. Percentage of loosely spread groups observed ranged from 15% (vessel entering Milne Inlet and approaching the BSA) to 38% (vessel exiting Milne Inlet and departing from the BSA), with 29% of groups loosely spread when vessels exited Milne Inlet and approached the BSA, and 24% of groups loosely spread when vessels entered Milne Inlet and departed the BSA. No consistent pattern in group spread relative to group size or proximity to vessel was evident, though no loosely spread groups of ≥ 3 individuals were observed within 5 km of a vessel entering Milne Inlet and departing the BSA.

When no vessels were present within 15 km of the BSA, loosely spread groups tended to be larger, with a median group size of 4 individuals and 25th and 75th percentiles of 3 and 6 individuals, respectively. Under the same scenario (i.e., no large vessels present within 15 km of the BSA), narwhal groups tightly spread had a median group size of 3 individuals, with 25th and 75th percentiles of 2 and 5 individuals, respectively.

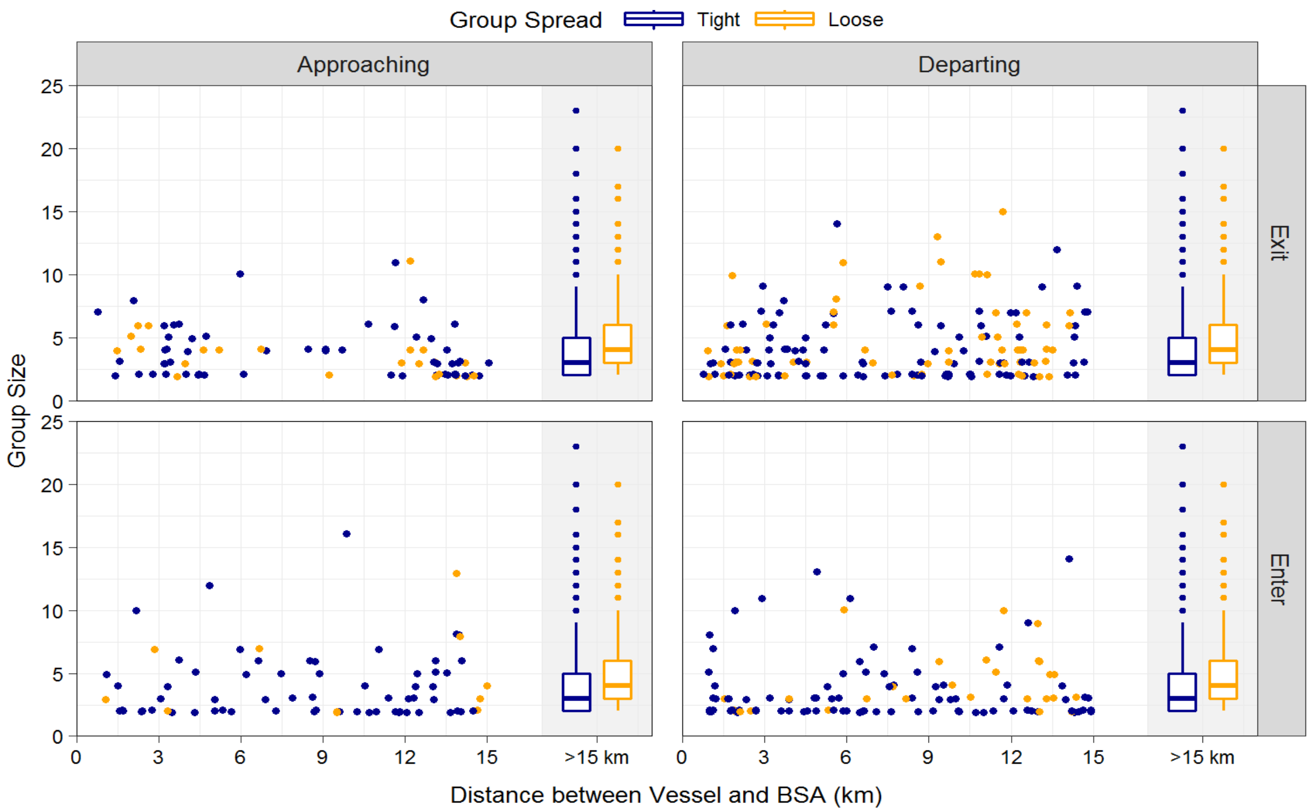

Figure 5-24: Spread of narwhal groups observed in the BSA relative to large vessels transiting through the SSA (31 July 2017 – 29 August 2017).

5.4.1.4 Group Formation

Narwhal groups observed in the BSA between 2014 and 2017 were primarily in parallel formation, followed by cluster (or circular), linear, and non-directional line formations, regardless of whether individuals were exposed to anthropogenic activity (Smith et al. 2017; Figure 5-25). Groups of single narwhal could not be assigned a formation and are therefore not presented in this analysis.

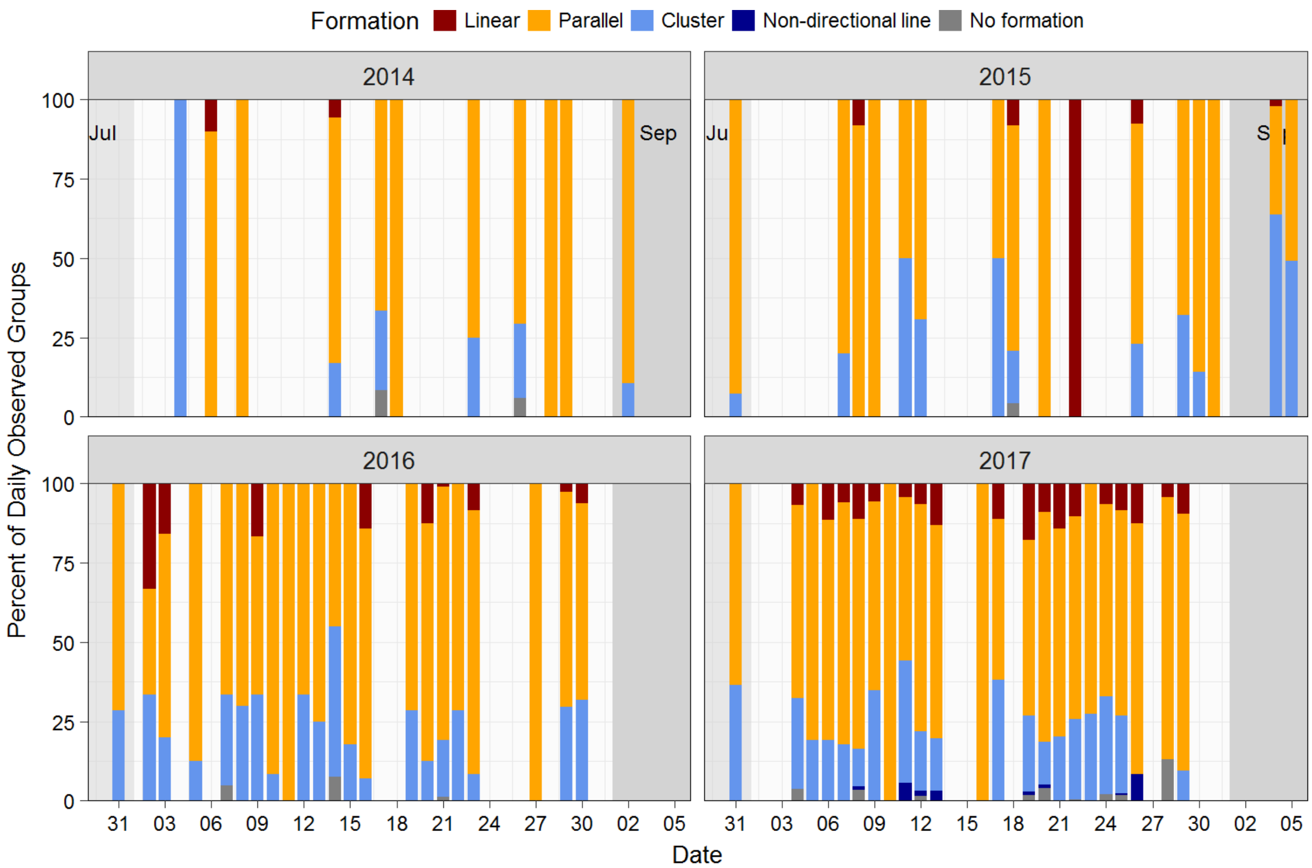

Figure 5-25: Formation of narwhal groups (N>1) observed in the BSA, 2014 – 2017.

Formation of narwhal groups observed in the BSA relative to proximity and orientation of large vessels transiting through the SSA is presented for the 2017 Program (Figure 5-26). When large vessels transited within 15 km from the BSA, parallel and cluster formations were commonly observed across all vessel distances while linear formations were more commonly observed when vessels were at greater distances from the BSA (≥ 12 km). Parallel formations were more frequently observed when large vessels entered Milne Inlet than when they exited (83% and 69-70%, respectively), while cluster formations were more frequently observed when vessels exited Milne Inlet (18-20%) than when they entered (12%). Linear formations were also more frequent when large vessels exited Milne Inlet compared to when they entered (11-14% and 4-6%, respectively).

Cluster formations were observed more frequently in larger groups and parallel formations were more commonly observed in smaller groups, regardless of large vessel presence. Specifically, median group size of individuals in cluster formation was 4.8 – 7.1 individuals when large vessels were present within 15 km from the BSA and 6.1 individuals when no large vessels were present. Median group size of narwhal in parallel formation was 3.1 – 3.9 individuals across all four vessel passage scenarios and 3.8 individuals when no large vessels were present. Of the three formation groupings, linear formations were the least frequently observed. Median group side of narwhal in linear formation was 2.4 individuals (when vessels were exiting Milne Inlet and approaching the BSA) to 4.3 individuals (when vessels were entering Milne Inlet and approaching the BSA). When no large vessels were present, median group size of narwhal in linear formation was 4 individuals.

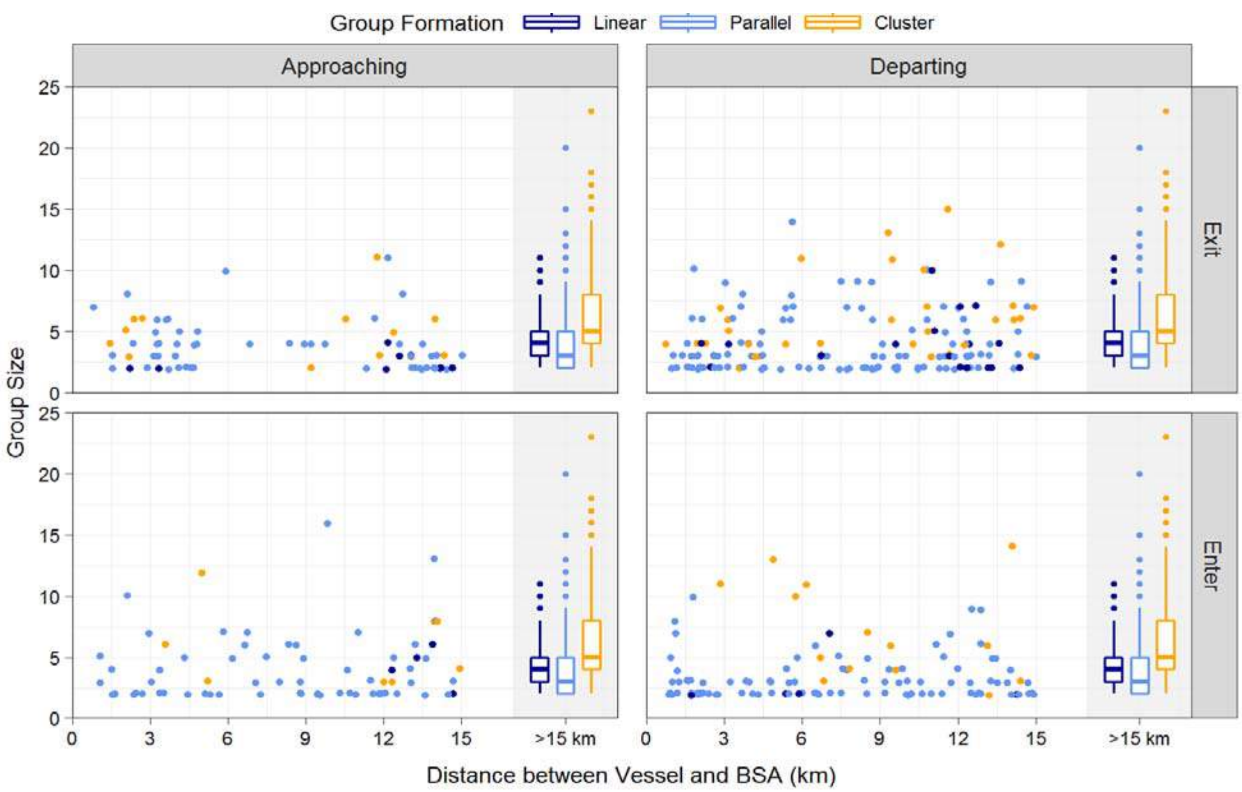

Figure 5-26: Formation of narwhal groups observed in the BSA (N>1) relative to large vessels transiting through the SSA (31 July 2017 – 29 August 2017).

5.4.1.5 Group Direction

Narwhal groups observed travelling through the BSA between 2014 and 2017 have predominantly been travelling south (Smith et al. 2017; Figure 5-27). For data collected between 2014 and 2016, the proportion of narwhal groups travelling south vs. north differed significantly depending on the type of anthropogenic activity that a given group was exposed to (i.e. large vessel traffic, small vessel traffic, or shooting event). Based on post-hoc pairwise comparisons, proportionally more animals travelled south in the presence of large vessels when compared to presence of small vessels or no anthropogenic activity (both adjusted p-values <0.001; Smith et al. 2017), though there was no difference in travel direction for groups in the presence of small vessels vs. no anthropogenic activity. Shooting events were not included in LGL's analysis of travel direction between 2014 and 2016 due to insufficient sample size.

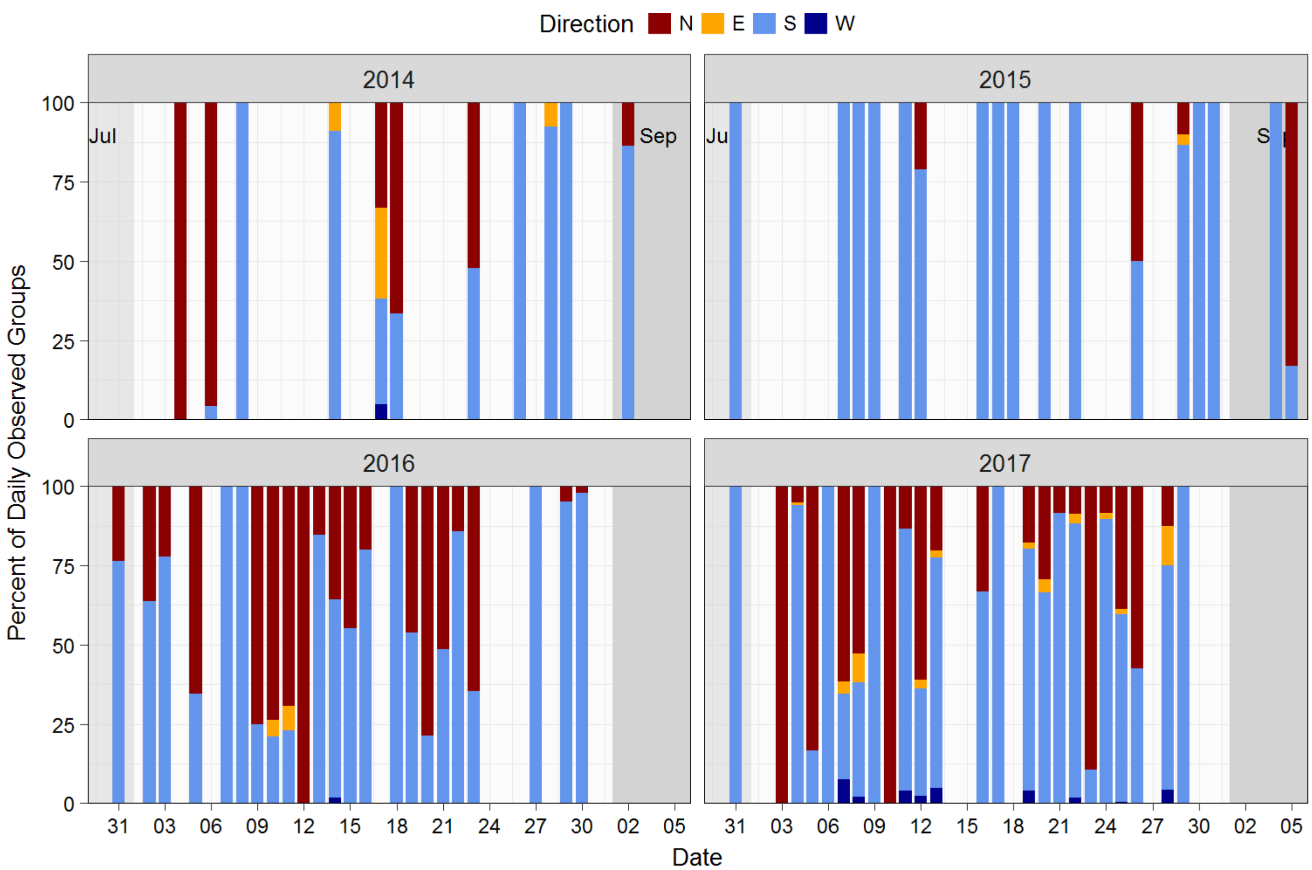

Figure 5-27: Narwhal travel directions observed in the BSA, 2014-2017. Data from 2017 were simplified to cardinal directions.

Travel direction of narwhal groups observed during the 2017 Program was examined in relation to proximity and orientation of large vessels transiting through the SSA to the BSA (Figure 5-28). When large vessels were within 15 km from the BSA, the majority of narwhal groups were observed travelling south when vessels were exiting Milne Inlet (73% for vessels approaching the BSA and 87% for vessels departing the BSA). For vessels entering Milne Inlet and approaching the BSA, narwhal groups were observed traveling both south (44%) and north (45%), and for those vessels entering Milne Inlet and departing the BSA, 80% of narwhal groups were observed traveling north with the majority of south-traveling groups occurring <3 km from the vessel. Narwhal traveling north had a median group size of 2 individuals for all four vessel passage scenarios. For narwhal traveling south, median group size was 2 individuals when vessels were entering Milne Inlet and departing the BSA, and 3 individuals for the three remaining vessel passage scenarios.

When no large vessels were present within 15 km from the BSA, narwhal groups traveling north tended to be smaller (median group size = 2 individuals, 25th and 75th percentiles = 1 and 3 individuals, respectively), while narwhal groups traveling south were generally larger (median group size = 4 individuals, 25th and 75th percentiles = 2 and 6 individuals, respectively).

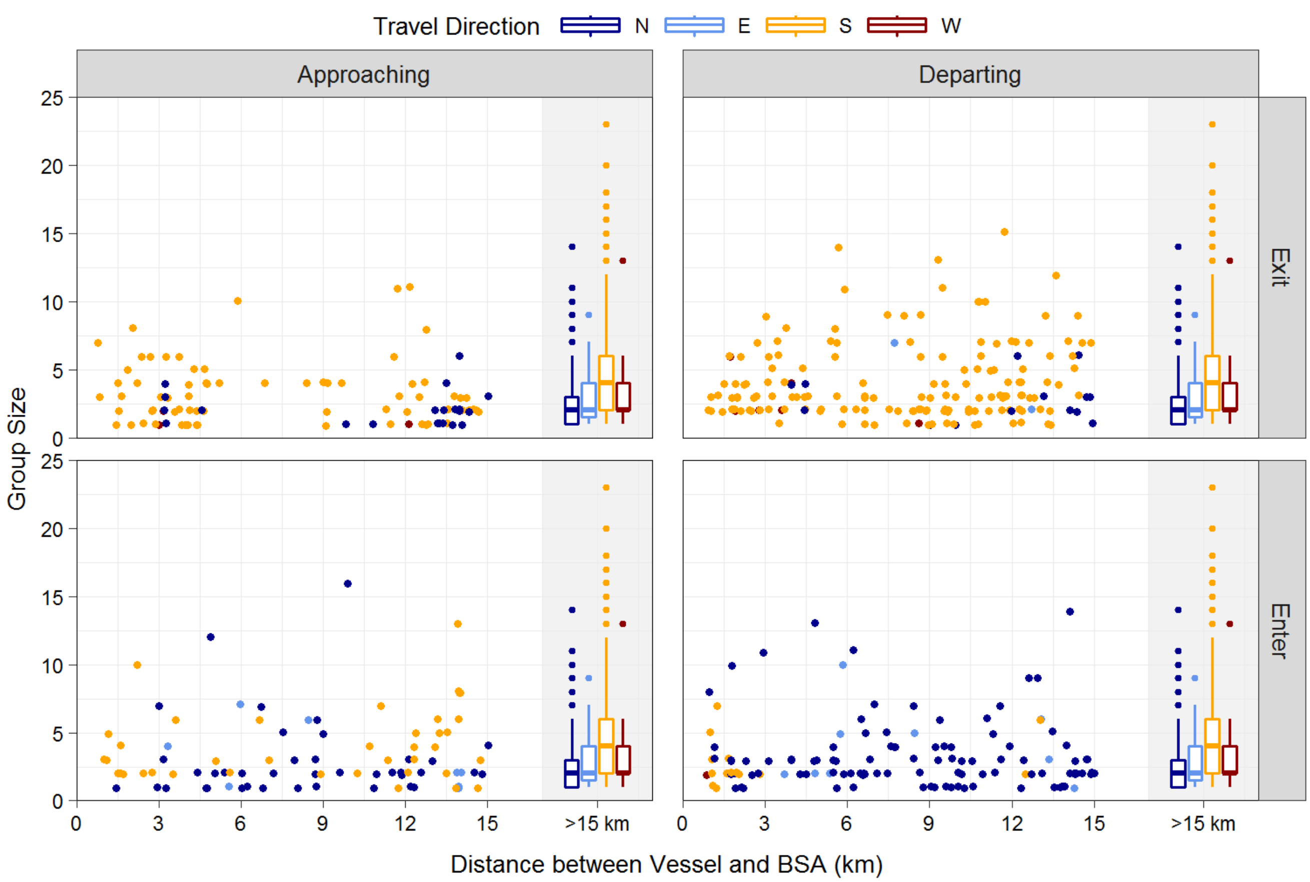

Figure 5-28: Travel direction of narwhal groups observed in the BSA relative to large vessels transiting through the SSA (31 July 2017 – 29 August 2017).

5.4.1.6 *Travel Speed*

Narwhal groups observed in the BSA during the 2014 – 2016 Program travelled predominantly at a 'medium' speed (Smith et al. 2017; Figure 5-29). In the presence of large vessels, however, proportionally more narwhal groups were observed traveling at a 'fast' speed compared to observations recorded under all other scenarios (i.e., small vessel presence, shooting events, no large vessel presence; P<0.001; Smith et al. 2017). Narwhal groups travelling at a 'slow' speed were excluded from LGL's analysis of 2014-2016 data given insufficient sample size.

During the 2017 Program, the proportion of daily groups that traveled at a slow speed ranged from 1% to 100% (median of 28%). The proportion of daily groups that traveled at a medium speed ranged from 19% to 100% (median of 64%), and the proportion of daily groups that traveled at a fast speed ranged from 2% to 52% (median of 13%).

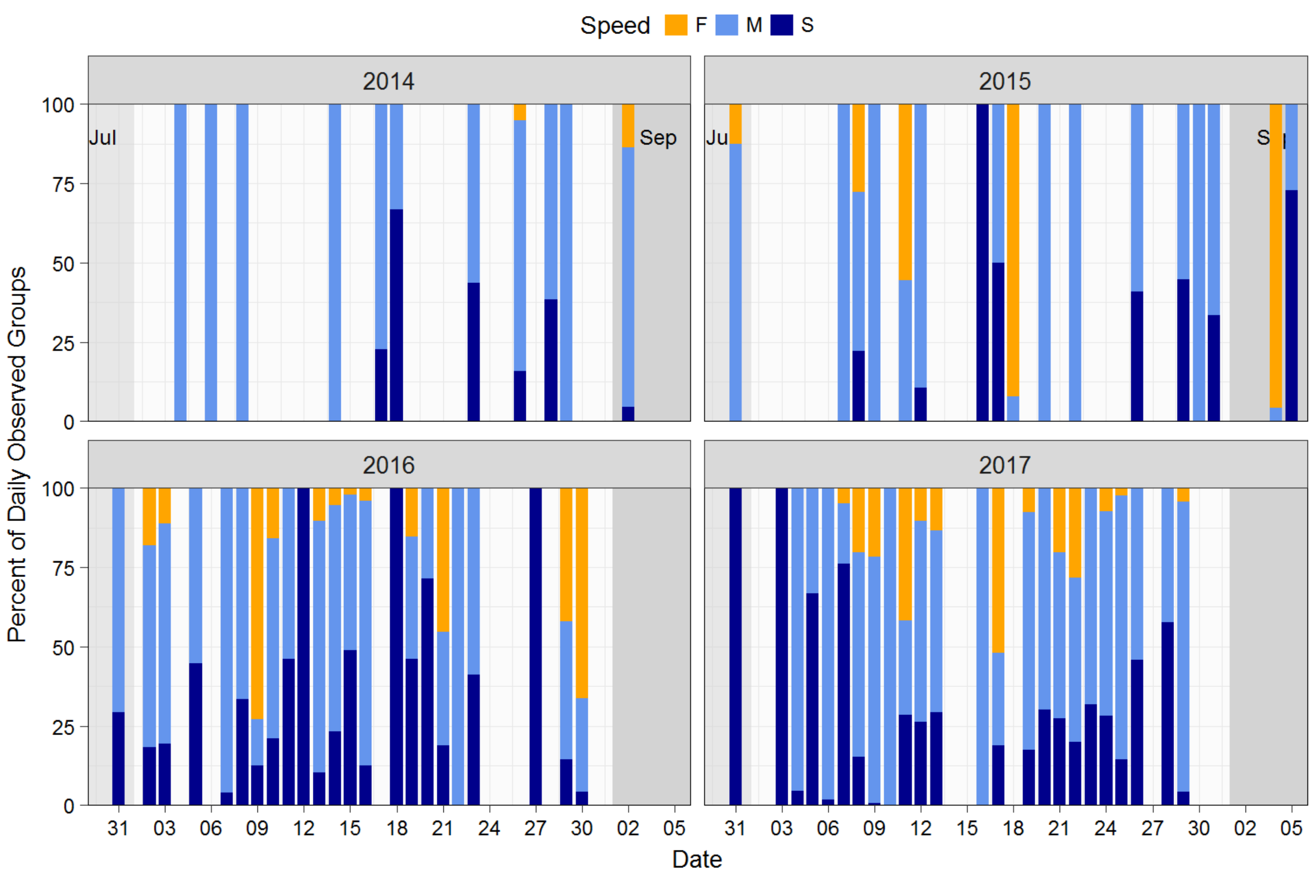

Figure 5-29: Narwhal travel speed observed in the BSA, 2014 – 2017.

Travel speed of narwhal groups observed during the 2017 Program was examined in relation to proximity and orientation of large vessels transiting through the SSA to the BSA (Figure 5-30). When vessels transited within 15 km from the BSA, the majority of observed narwhal groups travelled at a medium speed (from 56% of groups when vessels were entering Milne Inlet and approaching the BSA up to 69% when vessels were exiting Milne Inlet and approaching the BSA). Slow travel speed was observed least frequently when vessels were exiting Milne Inlet and departing the BSA (10%), and accounted for 23-30% of the observations in the remaining three vessel passage scenarios. Fast travel speed was observed least frequently when a vessel was exiting Milne Inlet and approaching the BSA (1%) and the most frequently when a vessel was exiting Milne Inlet and departing the BSA (22%).

When a large vessel was within 15 km from the BSA, slow-moving groups of narwhal were smaller, with a median group size of 2-2.5 individuals, while median group sizes for medium and fast groups were 2-3 narwhal and 2-4 individuals, respectively, depending on the vessel passage scenario. When no large vessels were present within 15 km from the BSA, slow-moving groups also tended to be smaller, with a median group size of 2 individuals (25th and 75th percentiles = 1 and 4 individuals, respectively). Groups travelling at a medium speed were generally intermediate in size (median group size = 3 individuals; 25th and 75th percentiles = 2 = and 5 individuals, respectively). Fast-moving groups tended to be the the largest, with median group size of 4 individuals (25th and 75th percentiles = 2 and 6 individuals, respectively).

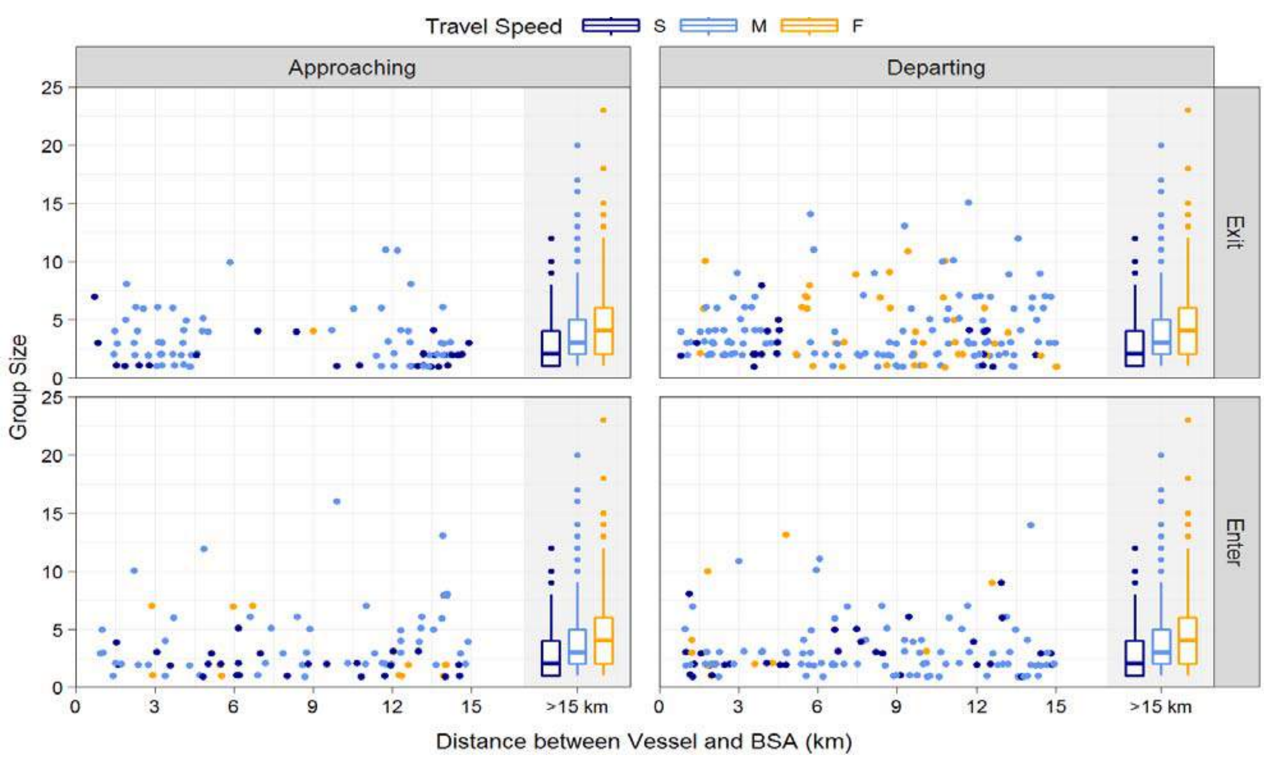

Figure 5-30: Travel speed of narwhal groups observed in the BSA relative to large vessels transiting through the SSA (31 July 2017 – 29 August 2017).

5.4.1.7 Distance from Bruce Head Shore

Data collected during the 2014 – 2016 Programs indicated that the proportion of narwhal groups swimming at a distance <300 m from the Bruce Head shore was greater than those swimming at a distance >300 m from shore (Figure 5-31). A significant difference was found in the proportion of animals swimming inshore (<300 m) vs. offshore (>300 m) depending on the type of anthropogenic activity that the group was exposed to ($p < 0.001$; Smith et al. 2017). Of note, proportionally more narwhal swam inshore in the presence of large vessels than in the presence of small vessels, shooting activity, or no anthropogenic activity (adjusted p-values <0.002 for all three pairwise comparisons, Smith et al. 2017).

In 2017, the percentage of narwhal groups recorded inshore ranged from 34% to 100% of daily observed groups (median of 74%), while the percentage of groups traveling offshore ranged from 4% to 100% (median of 44%).

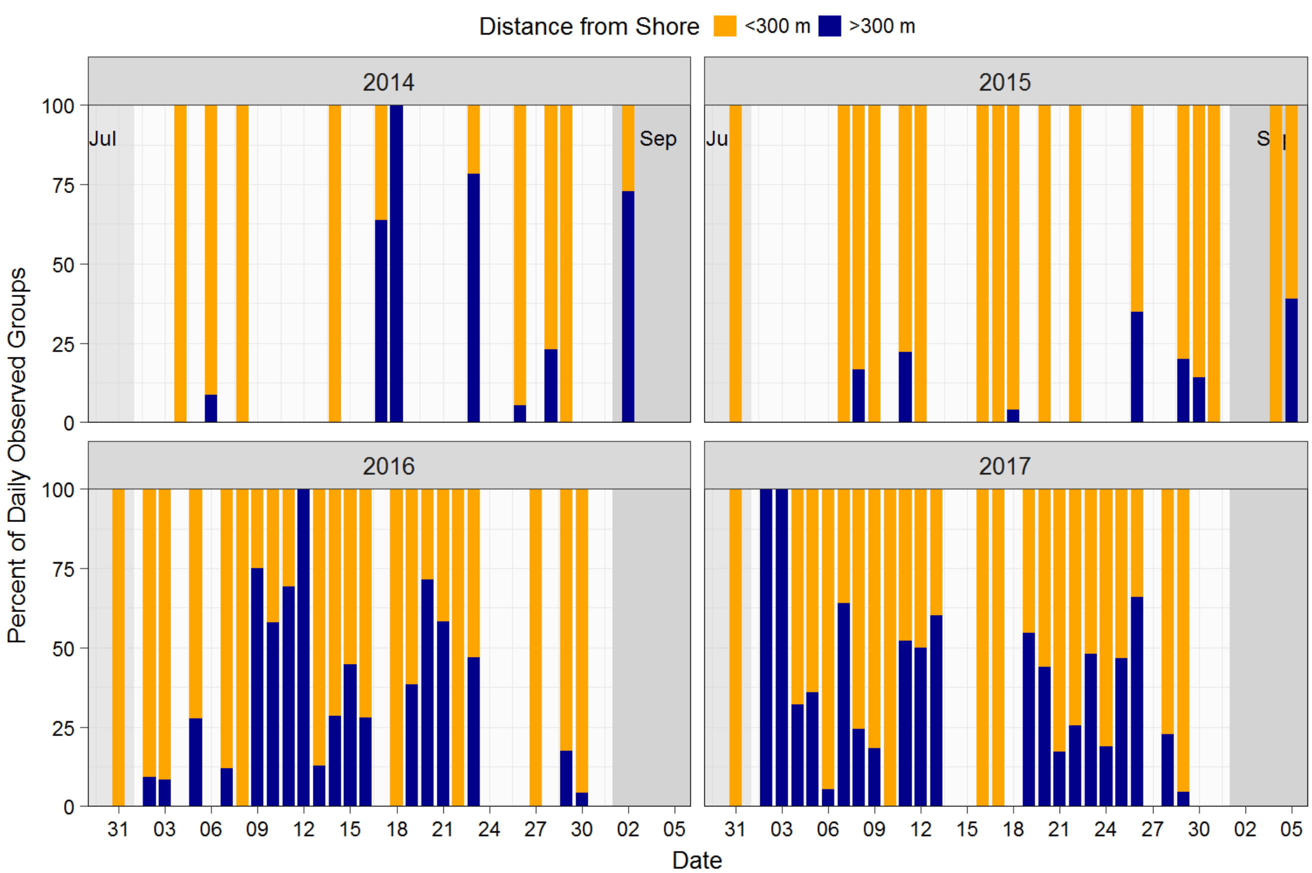

Figure 5-31: Narwhal distance from shore observed in the BSA, 2014 – 2017.

For data collected during the 2017 Program, distance of narwhal groups from the Bruce Head shore was analyzed in relation to proximity and orientation of large vessels transiting through the SSA to the BSA (Figure 5-32). In general, the majority of narwhal groups (64%) were observed offshore when vessels were exiting Milne Inlet and approaching the BSA. In the remaining three vessel passage scenarios, the majority of narwhal groups were observed inshore, with offshore groups accounting for 27% (vessel either entering or exiting Milne Inlet and departing the BSA) to 38% (vessel entering Milne Inlet and approaching the BSA) of all groups recorded.

Median group sizes were similar between inshore and offshore groups (median group size = 2-3 individuals) across the four vessel passage scenarios. When no large vessels were present within 15 km from the BSA, inshore groups tended to be slightly larger (median group size = 3 individuals; 25th and 75th percentiles = 2 and 5 individuals, respectively) than offshore groups (median group size = 2 individuals; 25th and 75th percentiles = 1.75 and 4 individuals, respectively).

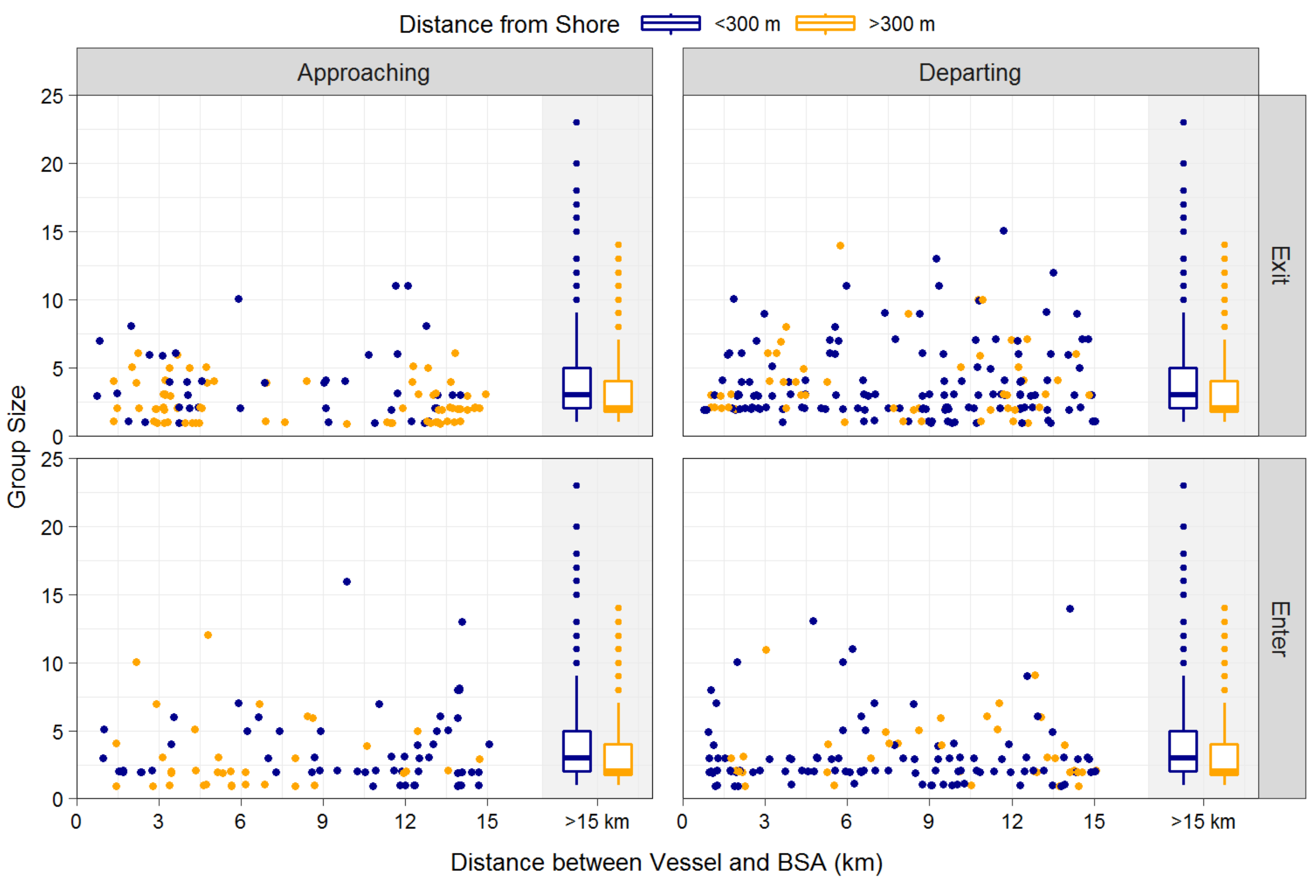

Figure 5-32: Distance from shore of narwhal groups observed in the BSA relative to large vessels transiting through the SSA (31 July 2017 – 29 August 2017).

5.5 General Observations

5.5.1 Primary Behavior

Primary behavior of narwhal groups observed in the BSA was documented throughout the 2017 Program. In general, the majority of narwhal groups (91%) were observed travelling through the BSA while a small proportion of groups were observed resting (5%), milling (2%), or engaged in some other behaviour outlined in Figure 5-33. Given the high proportion of narwhal groups observed travelling through in the BSA in comparison with other behaviors, primary behavior was not used as a predictor in the model.

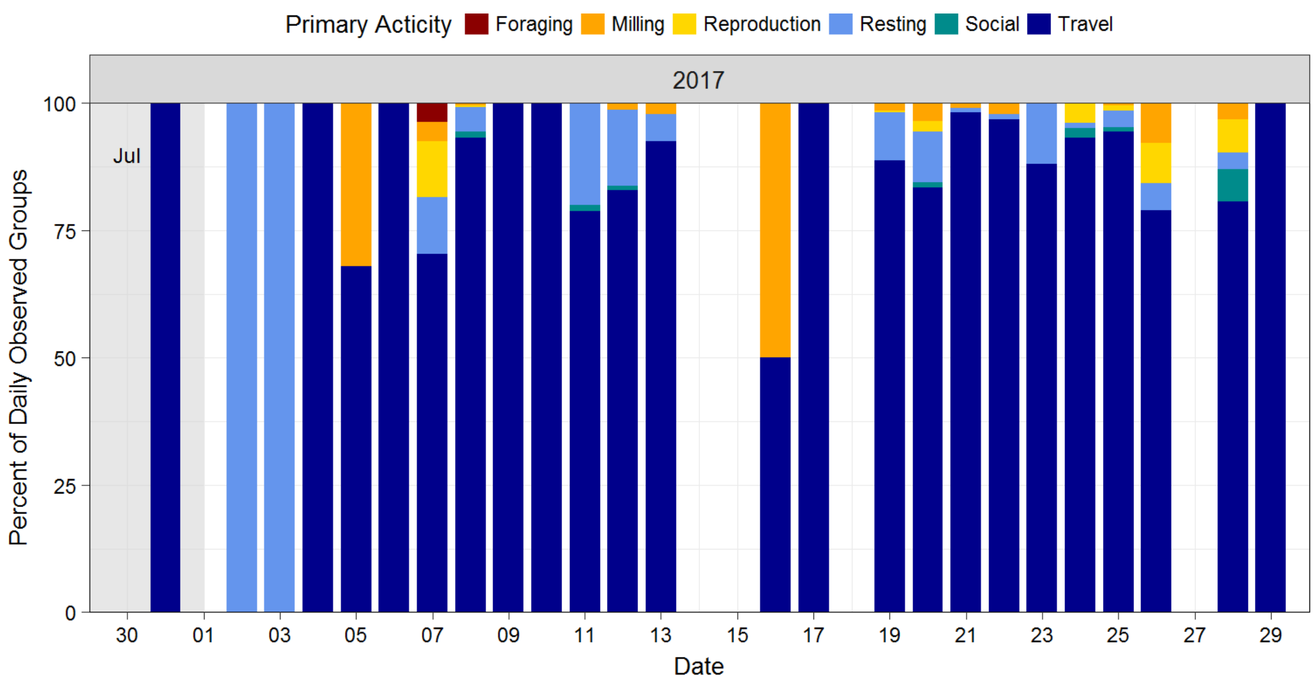

Figure 5-33: Narwhal group primary behaviour observed in the BSA (31 July 2017 – 29 August 2017).

5.5.2 Herding Events

Narwhal were considered part of a herding event when aggregations of groups travelled through the BSA (often in large numbers) (Marcoux et al. 2009; Smith et al. 2017). A total of 17 narwhal herding events were observed in the BSA throughout the 2017 Program (Table 5-5), with 82% occurring in the southbound direction and 18% beginning as a southbound herding event and then shifting to a northbound herding event. In general, narwhal observed herding through the BSA travelled at a medium or fast speed. Only one herding event included narwhal travelling at a slow speed.

It should be noted that number of narwhal observed in a herding event through the BSA may not be reflected in the daily counts of narwhal observed in the SSA as the timing of herding events did not always line up with a given RAD survey.

In some cases, herding events were thought to have been caused due to anthropogenic activity. It is possible that some herding events may be due to hunting further north, pushing animals south. This was also supported by *Ad lib* observations by the field team who heard distant shots prior to a herding event through the BSA/SSA. Several narwhal were also observed with wounds on their back, likely from hunting activity.

Table 5-5: Narwhal herding events observed in the Behavioral Study Area (BSA).

Date	Travel Speed of Narwhal[1]	Number of narwhal Observed	Travel Direction
31-Jul	S	70	Southbound
04-Aug	M	558	Southbound then turned Northbound
06-Aug	M	302	Southbound
08-Aug	M	247	Southbound
09-Aug	M	721	Southbound
11-Aug	F	262	Southbound
12-Aug	M	841	Northbound then turned Southbound
13-Aug	M	39	Southbound
17-Aug	F	341	Southbound
19-Aug	M	723	Northbound then turned Southbound
20-Aug	M	401	Southbound
21-Aug	M	88	Southbound
22-Aug	F/M	155	Southbound
22-Aug	M	822	Southbound
24-Aug	M	352	Southbound
25-Aug	M	428	Southbound
29-Aug	M	105	Southbound

Notes:
[1]Travel speed of narwhal: F = fast, M = medium, S = slow

5.5.3 Other Marine Mammals

Observations of marine mammals, other than narwhal, were recorded opportunistically in the SSA (Table 5-6). The dominant marine mammal species observed were seal species including ring seal (*Pusa hispida*), bearded seal (*Erignathus barbatus*) and harp seal (*Pagophilus groenlandicus*). The majority of the seals observed were unidentified as the field team focused efforts on narwhal observations and seals were more difficult to sight when sea surface conditions were moderate or poor due to their small size. A single bowhead whale (*Balaena mysticetus*) was observed entering the SSA from south Milne Inlet where it passed through the SSA along the eastern portion of the BSA and was not observed again.

Walrus (*Odobenus rosmarus*), polar bear (*Ursus maritimus*) or killer whales (*Orcinus orca*) were not observed in the SSA during the 2017 Program.

Table 5-6: Other marine mammals recorded in the SSA during 2017 surveys.

Date	Seal Species				Bowhead Whale
	Ring Seal	Bearded Seal	Harp Seal	Unidentified	
01-Aug-17	14	1		5	
02-Aug-17	47		2	69	
03-Aug-17	8			24	
04-Aug-17	11		1	158	
05-Aug-17				3	
06-Aug-17	1			5	
07-Aug-17	1			5	
11-Aug-17				2	1
13-Aug-17				1	
15-Aug-17				2	
16-Aug-17				3	
17-Aug-17				1	
20-Aug-17				3	
21-Aug-17				2	
22-Aug-17	1			1	
26-Aug-17				13	
31-Jul-17	1	3		1	
Total	**84**	**4**	**3**	**298**	**1**

6.0 DISCUSSION

6.1 Vessel Traffic and Other Anthropogenic Activities

A total of 58 one-way large vessels transits occurred through the SSA along the Northern Shipping Route during the 2017 Program. In light of the reduced work day to 10 h in 2017, the field team attempted to match the timing of observation effort with expected large vessel transits through the SSA. In some cases, however, vessels were either delayed or transited through the SSA earlier than scheduled, which resulted in the field team not being able to conduct surveys during many of the scheduled large vessel transits (see Figure 5-4). Improved communication with Baffinland regarding estimated arrival and departure times for vessels at Milne Port (and regular schedule updates given the dynamic nature of the shipping schedule) would allow for greater coordination of daily observation periods with large vessels passing through the SSA.

Mitigation measures established by Baffinland to minimize vessel-related impacts to marine mammals along the Northern Shipping Route include a maximum speed limit imposed for Project-related ore carrier traffic. Of note, ore carriers are to travel at a maximum speed of 9 knots upon entering Pond Inlet and 5 knots when entering Milne Port. According to satellite and shore-based AIS data, the majority of the ore carrier travel speeds recorded in Milne Inlet were in general compliance with speed restriction (rarely exceeding 10 knots). However, three Project-related cargo ships (Claude A. Desgagnes, Rosaire A. Desgagnes and the BBG Volga) and one fuel tanker (Sarah Desgagnes) were shown to travel exclusively in the 10 to 15 knot range while transiting in Milne Inlet. Although speed limits imposed by Baffinland are specific to Project-related bulk (ore) carriers only, it should be equally applied to other Project-related vessels, as vessel speed is an important factor with respect to the risk of noise exposure and vessel strikes on marine mammals along the shipping corridor.

During the 2017 Program, the hunting camp at the base of the cliff below the Bruce Head observation platform was occupied during 20 of the 27 survey days. This occupancy rate is similar to the 2016 Program, when the hunting camp was occupied during 22 of the 27 survey days. In comparison, during the 2015 Program, the hunting camp was occupied during 16 of the 30 survey days. Coinciding with these results is the increase in small vessel traffic (i.e., aluminum skiffs and voyageur canoes) in the SSA and the increase in hunting activity over survey years. A total of 59 shooting events took place during 2017, on 13 of the 27 survey days. Hunters directly targeted narwhal 76% of the time with shots fired as narwhal passed the Bruce Head Peninsula and non-directly 10% of the time with shots fired into the air as a strategy to spook the animals towards the Bruce Head shoreline. Hunting of narwhal in the SSA was considered as a confounding variable when assessing narwhal behavioral response to vessel traffic.

6.2 Relative Abundance and Distribution

The southern portion of Milne Inlet is a preferred summering ground for narwhal, with evidence from previous and current surveys suggesting that it is an important area for rearing of young based on observations of mom-calf nursing, mating, and foraging behaviour (Smith et al. 2017). During the 2017 Program, a total of 11,969 narwhal were observed with the SSA, with four survey days having more than 1,000 narwhal observed per day. On only one of the active surveying days did the field team document zero (0) narwhal in the SSA, compared with the 2016 Program in which narwhal were not observed on five (5) separate survey days. In general, narwhal counts in the SSA increased from north to south (stratum A to I), which is consistent with results from the 2016 Program (Smith et al. 2017).

Of the 27 days surveyed in 2017, narwhal were observed in relation to 21 Project-related vessel transits and one passenger vessel transit (not Project-related). The majority of narwhal observations in the SSA, however, occurred when no large vessels were present within 15 km of a given substratum. The statistical model of RAD data included three interactions between vessel-related variables: 1) between vessel distance and whether the vessel was approaching or departing a substratum, 2) between whether a vessel was approaching or departing a substratum and whether the vessel was entering or exiting Milne Inlet, and 3) between vessel distance and whether the vessel was entering or exiting Milne Inlet. The only significant interaction of the three considered was the interaction between vessel distance and whether the vessel was approaching or departing a substratum. Should this interaction be true, it would indicate that narwhal alter their behavior in relation to the proximity and orientation of a transiting vessel. However, the significance of this interaction is likely due to the increase in narwhal observed when vessels entering Milne Inlet / departing substrata were at approximately 6-9 km away from substrata (Figure 5-14) – a pattern opposite that recorded for approaching vessels (i.e. counts decreased at similar distances). It is therefore not clear whether the pattern is due to chance (i.e., spurious finding) or a result of narwhal behaviour in the presence of large vessels. Further investigation of narwhal response to proximity and orientation of large vessels, incorporating data from previous years, is therefore warranted to assess trends using consistent data collection and analysis techniques.

A key finding from 2014-2016 Programs was that for large vessels exiting Milne Inlet, a significantly higher number of narwhal were present when the vessel was approaching a given substratum compared to periods when no vessels were present (Smith et al. 2017). For the 2017 Program, however, none of the variables that included the effect of whether a vessel was entering or exiting Milne Inlet were statistically significant (i.e., interaction between vessel distance from substrata and entering/exiting Milne Inlet, interaction between entering/exiting Milne Inlet and approaching/departing substrata, and the main effect of entering/exiting Milne Inlet). This suggests that travel direction of large vessels through Milne Inlet (entering/exiting) did not affect narwhal relative abundance or distribution in the SSA in 2017. It is not currently clear whether this discrepancy in findings is due to variation in analytical approach between years (e.g., the use of distance from vessel as a continuous variable during analysis of 2017 data). It is therefore recommended that the full dataset (2014-2017) be analyzed using the current approach to increase sample size and provide insight into inconsistencies in findings.

The effect of sightability on the observers' ability to identify narwhal throughout the SSA should be considered in the planning of future monitoring studies. In general, the greater proportion of narwhal observed in the further substrata under medium and poor sightability conditions relative to excellent and good sightability conditions reflects the need to re-evaluate the spatial boundary of the SSA (Table 5-3). Although it is preferred that the boundary of the SSA span the full width of Milne Inlet out from the Bruce Head peninsula, model analyses (Appendix C) suggest that the validity of the data collected in the furthest substrata may be compromised by sightability. Furthermore, if the reduction in sightability was due to distance alone, it would have been expected that highest counts of narwhal would occur in substratum 1, intermediate counts would occur in substratum 2, and lowest counts would occur in substratum 3. Due to differences in the spatial extent of the three substrata boundaries (i.e. substrata become progressively larger with distance from the observation platform), however, substratum 2 had higher narwhal counts than substratum 1, which is closer to the observation platform. A better comparison of narwhal presence/absence across the three substrata would be to assess narwhal density estimates within each. This strategy, however, would require more robust analyses, incorporating correction factors for surfacing time and dive behavior, and is beyond the scope of this work. Therefore, the proportion of narwhal observed under the various sightability conditions within each of the three substrata is a more appropriate reflection of the reduction in sightability with distance. Other factors such as variable glare and sea state conditions must also be considered.

6.3 Group Composition and Nearshore Travel Behaviour

6.3.1 Group Size

Model results indicate that for narwhal observed within 15 km of a large vessel, vessel distance from the BSA did not have a significant effect on group size (Appendix C). Mean group sizes for narwhal observed in 2017 were, however, smaller when large vessels were present within 15 km of the BSA compared to when no large vessels were present. This finding may suggest that narwhal respond to the potential disturbance of transiting vessels by fragmenting into smaller groups or by having certain group members dive below the sea surface, out of the observer's sight. If this finding were true, however, it would be expected that narwhal group size would also be affected by vessel distance from the BSA, which it was not. Furthermore, combined data from the 2014 to 2016 Programs indicated that mean narwhal group size increased in the presence of large vessels (Smith et al. 2017). Inter-annual variation in mean narwhal group size and confounding factors such as sightability must also be considered in interpreting results. Further monitoring or narwhal group size is therefore warranted to increase sample size and gain insight into the biological validity of the 2017 findings.

6.3.2 Group Composition

Milne Inlet is an important summering ground for narwhal of all life stages, including adults, juveniles, yearlings, and calves. Group composition was similar between 2016 and 2017 with adult narwhal as the primary age class observed followed by yearling/juvenile and calf (Smith et al. 2017; Figure 5-18). Variation in group composition did not have obvious trends over the open-water season (end of July to end of August), and all narwhal age classes appeared to utilize Milne Inlet throughout the duration of the Program. Mother-calf pairs were observed on multiple occasions in the BSA and, in some cases, the calf was likely only hours to one day old. These observations are supported by previous surveys in which Milne Inlet near the Bruce Head peninsula was identified as an important calf rearing area (Smith et al. 2015, 2016, and 2017).

Model results of 2017 data indicate that the distance of large vessels from the BSA and orientation of large vessels relative to the BSA (i.e., approaching/departing) were significant predictors of presence/absence of adult groups (>1) and mother/offspring groups in the BSA (Appendix C). At close distances specifically, adult groups were estimated to be observed less and mother/offspring groups were estimated to be observed more when a large vessel was departing the BSA compared to when a large vessel was approaching the BSA. This finding may suggest that the respective groups possess different life history strategies and/or capabilities for temporarily avoiding the potential disturbance of a transiting vessel. For example, given that the majority of sound energy produced by large commercial vessels radiates from the propeller (i.e. stern) of the vessel (Veirs et al. 2016), adult groups may recognize this disturbance and attempt to move away from it while mother/offspring groups may not be able to do so given the pair's slower swimming speed and the calf's reliance on being closely associated with its mother in the "echelon" position (Marcoux et al. 2009). This result may be spurious, however, as the model also predicted that the presence of adult groups would increase as an approaching vessel moved nearer the BSA, contrary to what would be expected biologically. Further monitoring or narwhal group composition is therefore warranted to increase sample size and gain insight into the biological validity of the 2017 findings.

6.3.3 Group Spread

Between 2014 and 2017, narwhal were more often observed in tight associations compared to loose associations under both vessel presence and vessel absence scenarios. During passage of a large vessel within 15 km of the BSA, loosely spread groups were more likely to occur when vessels were at greater distances from the BSA and exiting Milne Inlet compared to entering (Appendix C), according to model results of 2017 data. It is believed that some cetacean species aggregate more closely together during periods of disturbance and/or stress as a strategy to better detect the subtle queues of group members and increase ability to respond to a potential threat (Mann et al. 2000). Narwhal, however, are a gregarious species and are closely associated with one another by nature (Marcoux et al. 2009), meaning that the larger proportion of groups observed tightly associated with one another is not necessarily indicative of animals responding to a perceived threat (i.e., a transiting vessel).

6.3.4 Group Formation

Results from the 2014-2017 programs indicate that narwhal were most often observed in parallel formation, followed by cluster (or circular), linear, and non-directional line formations under both vessel presence and vessel absence scenarios. According to model results of 2017 data (Appendix C), when large vessels were within 15 km of the BSA, the presence of linear groups, while rare, was estimated to increase with increasing distance of the vessel from the BSA, whereas parallel group formation was most likely to occur when large vessels were close to the BSA. Cluster formation was estimated to be most likely when group sizes were large, regardless of large vessel presence/absence. As knowledge regarding the context and function (if any) of narwhal aggregations is generally incomplete (Marcoux et al. 2009), further monitoring of narwhal group formation is warranted to better understand whether a given formation is indicative of a potential response to a perceived threat (i.e., a transiting vessel).

6.3.5 Group Direction

Narwhal groups were predominantly observed travelling south through the BSA during 2014-2017 field programs and tended to travel south in large groups and north in small groups. When large vessels were within 15 km of the BSA, narwhal were most often observed travelling south when the vessel was exiting Milne Inlet, regardless of orientation of the vessel to the BSA. When a vessel was entering Milne Inlet, narwhal groups were observed travelling both north and south upon approach of the vessel, whereas groups were observed travelling predominantly north when vessels were entering Milne and departing the BSA, except for groups within ~2km of the vessel which were often observed travelling south.

In general, travel north was primarily observed when narwhal groups were smaller and at greater distances from a large vessel and when the vessel was entering Milne inlet and departing the BSA (although this result is based on a limited sample size) (Appendix C). *Ad lib* observations recorded during the 2017 Program support these findings. For example, on 12 August 2017, an ore carrier transiting south through the SSA was approximately 3-4 km away from a group of narwhal that were transiting north through the SSA. The narwhal group was observed to stop swimming north and immediately turn around and begin swimming in the opposite direction (south). As the vessel approached the BSA (from the north), the narwhal group had stopped traveling and was close to the Bruce Head shoreline. Once the vessel departed the BSA, narwhal then turned back to their original traveling direction (north). Whether this particular event represents temporary avoidance of the transiting vessel by narwhal is undetermined due to insufficient sample size of narwhal in the presence of transiting vessels. Further monitoring of narwhal travel direction in the presence of large vessels is therefore warranted.

6.3.6 Travel Speed

The majority of narwhal groups recorded in 2017 travelled at a medium speed, regardless of large vessel presence/absence. When large vessels were present within 15 km of the BSA, narwhal groups were most commonly observed travelling at a fast speed when vessels were exiting Milne Inlet and departing the BSA (Appendix C). Similar to these results, data collected during 2014-2016 field programs revealed that proportionally more narwhal groups were observed travelling at a fast speed in the presence of large vessels compared to observations recorded under all other scenarios (i.e., small vessel presence, shooting events, no large vessel presence) (Smith et al. 2017). Similar to the antipredator response elicited in narwhal when interacting with killer whales (i.e., their top predator) (Breed et al. 2017), increased swimming speed in the presence of large vessel traffic may signify avoidance of a perceived threat by narwhal (Williams et al. 2002). Given that the large majority of narwhal groups were observed travelling at a medium speed under both vessel presence and vessel absence scenarios, however, the sample size for those travelling at slow and fast speeds was limited to confirm (or reject) this hypothesis. Therefore, further monitoring of narwhal travel speed in the presence of large vessels is warranted to assess whether narwhal groups increasing their swim speed is a potential escape response to a perceived threat (i.e., a transiting vessel).

6.3.7 Distance from the Bruce Head Shore

Results from the 2014-2017 field programs indicate that narwhal groups were observed more often at a distance <300 m of the Bruce Head shore compared to groups >300 m offshore under both vessel presence and vessel absence scenarios. Model results of 2017 data indicate that, in the presence of vessels, narwhal groups were more likely to be observed offshore (> 300 m) only when large vessels are exiting Milne Inlet and approaching the BSA (Appendix C). Furthermore, the odds of offshore travel were found to increase in the absence of hunting[6]. Given potentially spurious model results, however, further monitoring of narwhal distance from shore is needed to determine if findings from the 2017 Program are in agreement with those from previous years (2014-2016), in which proportionally more narwhal swam inshore in the presence of large vessels than in the presence of small vessels, shooting activity, or no anthropogenic activity (Smith et al. 2017). As narwhal tend to move close to shore when attempting to escape predation by killer whales (Steltner et al. 1984, Marcoux et al. 2009, Breed et al. 2017), it is conceivable that narwhal may also move closer to shore when exposed to other perceived threats (i.e., large vessel traffic). Monitoring of narwhal distance from shore is therefore an appropriate metric to assess habitat use and whether the proportion of inshore vs. offshore narwhal groups in dependant on anthropogenic activity.

[6] It is important to note that hunting activity within the BSA occurs most often when narwhal are at relatively close distances to the hunters' camp on shore and is considered herein as a confounding variable in assessing the behavioral response of narwhal to vessel traffic.

6.4 General Observations

Traveling was the most common behavior observed in the BSA in 2017, while a small proportion of narwhal groups were observed resting, milling, or engaged in other behaviour such as reproduction, foraging, and social behaviour. *Ad lib* observations note that on 3 August 2017, two schools of Arctic char were observed along the Bruce Head shoreline. While narwhal were not observed foraging during this event in 2017, during the 2016 Program, narwhal were observed actively feeding on Arctic char along the Bruce Head shoreline (Smith et al. 2017).

Narwhal herding through the BSA travelled at a medium or fast speed. Only one herding event included narwhal travelling at a slow speed.

The dominant marine mammal species observed other than narwhal were seal species, including ring seal, bearded seal, and harp seal. A single bowhead whale was observed entering the SSA from south Milne Inlet where it passed through the SSA along the eastern portion of the BSA and was not observed again. This behaviour is similar to those bowhead whales observed during the 2016 Program in which a bowhead whale was sighted and it dove and was not seen again (Smith et al. 2017).

6.5 Suitability of 2017 Study Design and Analysis

- The boundary of the BSA during the 2017 field season was defined to include portions of substrata D1, E1 and F1 up to 1,000 m from shore, whereas the BSA boundary during 2014-2016 surveys only included portions of substrata E1 and F1 up to 1,000 m from shore. This discrepancy in BSA boundary was due to inconsistencies in previous years' methods outlined in LGL documents (LGL Training Manual) and was only resolved after the completion of the 2017 field program.
- The Program has evolved from the first year in 2013 through to the current Program in 2017. From 2013 to 2016, LGL undertook the data collection, analysis and reporting, and in 2017 Golder undertook Program efforts. The data from 2013 to 2016 were not available prior to analysis of 2017 data; therefore, the 2014-2016 dataset was not included in the models.
- The quality of BSA and RAD survey data collected throughout the SSA was affected by sightability conditions, particularly in the substrata farthest from the observation platform (i.e., substratum 3; Figure 5-12).

7.0 CONCLUSIONS

The Bruce Head Shore-based Monitoring Program represents one of several environmental monitoring programs that collectively make up Baffinland's MEEMP for marine mammals. The Program was designed to specifically address Project Certificate conditions related to evaluating potential disturbance of marine mammals from shipping activities that may result in changes to animal distribution, abundance, and migratory movements in the study area. Specifically, the Program is to contribute to the following Project Certificate conditions:

- Condition No. 99 and 101 - "*Shore-based observations of pre-Project narwhal and bowhead whale behavior in Milne Inlet that continues at an appropriate frequency throughout the Early Revenue Phase and for not less than three consecutive years*".
- Condition No. 109 (for Milne Inlet specifically) - "*The Proponent shall conduct a monitoring program to confirm the predictions in the FEIS with respect to disturbance effects from ships noise on the distribution and occurrence of marine mammals. The survey shall be designed to address effects during the shipping seasons, and include locations in Hudson Strait and Foxe Basin, Milne Inlet, Eclipse Sound and Pond Inlet. The survey shall continue over a sufficiently lengthy period to determine the extent to which habituation occurs for narwhal, beluga, bowhead and walrus".*
- Condition No. 111 - "*The Proponent shall develop clear thresholds for determining if negative impacts as a result of vessel noise are occurring*".

The 2017 Program represents the fifth consecutive year of monitoring undertaken at Bruce Head and the first year that the Program was undertaken by Golder Associates. This report presents the findings of the 2017 Program specifically and, wherever possible, relates current findings to those of previous years (2014 – 2016). It is important to note that from Program inception in 2013, data collection and analysis have evolved and, in some cases, comparison of data across years was not always possible. However, the results herein present a solid framework to build on in succeeding years.

Key findings from the 2017 Bruce Head Shore-based Monitoring Program include the following:

- Relative abundance and distribution:
  - 2017 model results indicate that the 'direction of travel' of large vessels transiting through Milne Inlet (inbound vs. outbound) did not have a significant effect on narwhal presence/absence in the SSA. This finding was inconsistent with previous survey results (2014-2016), in which a significant higher number of narwhal were shown to be present when an outbound (i.e., exiting) vessel approached a given substratum compared to periods when no vessels were present (Smith et al. 2017). It is currently unclear whether this discrepancy in findings is due to variation in analytical approach between years (e.g., the use of distance from vessel as a continuous variable during analysis of 2017 data). It is therefore recommended that the full dataset (2014-2017) be analyzed using the current model to increase sample size and provide insight into inconsistencies between survey years.

  - A significant interaction was observed between 'vessel distance from substratum' and 'vessel orientation[7]' – indicating that narwhal counts in a given substratum were shown to change depending on the proximity of the vessel to the substratum, although this effect was dependant on whether the vessel was moving towards (approaching) the substratum or moving away (departing) the substratum. Incorporation of the 2014-2016 RAD data into the model may help further refine this relationship.

- Data collected on group composition and behavior revealed a number of notable findings in 2017:
  - Group size - Mean narwhal group size was smaller when large vessels were present within 15 km of the BSA compared to when no large vessels were present (vessels >15 km from BSA), although model results indicate that vessel distance from the BSA did not have a significant effect on group size.
  - Group composition - Model results indicate that distance of large vessels from the BSA and orientation of large vessels relative to the BSA (i.e., approaching/departing) were significant predictors of presence/absence of adult and mother/offspring groups in the BSA. At very close distances, adult groups >1 were estimated to be observed less and mother/offspring groups were estimated to be observed more when a large vessel was departing the BSA compared to when a large vessel was approaching the BSA.
  - Group spread – Narwhal were more often observed in tight associations compared to loose associations under both vessel presence and vessel absence scenarios. During passage of a large vessel within 15 km of the BSA, loosely spread groups were more likely to occur when vessels were at greater distances from the BSA and exiting Milne Inlet compared to entering.
  - Group formation – Narwhal were usually observed in parallel formation under both vessel presence and vessel absence scenarios. When large vessels were within 15 km of the BSA, the presence of linear groups, while rare, was estimated to increase with increasing distance of the vessel from the BSA, whereas parallel group formation was most likely to occur when large vessels were close to the BSA, according to model results.
  - Group direction – Narwhal groups were predominantly observed travelling south through the BSA. When large vessels were within 15 km of the BSA, narwhal were most often observed travelling south when the vessel was exiting Milne Inlet, regardless of orientation of the vessel to the BSA. When a vessel was entering Milne Inlet, narwhal groups were observed travelling both north and south upon approach of the vessel, whereas groups were observed travelling predominantly north when vessels were entering Milne and departing the BSA, except for groups within ~2km of the vessel which were often observed travelling south. Narwhal tended to travel south in large groups and north in small groups.
  - Travel speed – Approximately 91% of all narwhal observed in the BSA were engaged in 'travelling' behavior, with the majority travelling at a medium speed in both the presence and the absence of large vessels. When large vessels were present within 15 km of the BSA, narwhal groups were most commonly observed travelling at a fast speed when vessels were exiting Milne Inlet and departing the BSA. Model results indicate that large groups were more likely to travel fast, while small groups were more likely to travel slowly.

[7] Vessel orientation = whether a vessel was approaching the substratum or departing the substratum

- Distance from Bruce Head shore - Narwhal were observed travelling inshore (<300 m) more often than offshore (>300 m) under both ‘vessel presence’ and ‘vessel absence’ scenarios. Model results indicate that, in the presence of large vessels, narwhal groups are more likely to be observed offshore (> 300 m) only when vessels are exiting Milne Inlet (outbound) and approaching the BSA.

When comparing between survey years (2014 – 2017), results should be interpreted with caution. Of note, discrepancies in the results presented between years do not necessarily imply that an ecologically significant change in narwhal relative abundance and distribution or group composition and behaviour has occurred. In order to provide more robust inference and modeling predictions, previous data collected by LGL are expected to be integrated into the current model to increase sample size and provide insight into inconsistencies between survey years.

8.0 RECOMMENDATIONS

The following are a list of recommendations that Golder proposes be considered for future monitoring programs:

- Communication between Milne Port, Baffinland, and Golder field team:
  - Improved communication between chartered vessels and Baffinland/Milne Port Harbour Master regarding ship travel speeds along the Northern Shipping Route to reduce disturbance to narwhal and other marine mammal species.
  - Frequent updates communicated from Baffinland/Milne Port Harbour Master to Bruce Head field team regarding changes to the daily shipping manifesto and estimated arrival/departure times of ore carriers to Milne Port, so that the field team may better anticipate vessel transits through the SSA.
- Sampling equipment:
  - Installation of a CTD Unit for the 2018 Program to record depth, salinity, and water temperature offshore the Bruce Head Peninsula. These data would allow for salinity to be added to the model.
  - Construction of a new Bruce Head observation platform (following previous observation platform being damaged by high winds in September 2017). In constructing the platform, efforts should be made to avoid blind spots created by posts supporting the roof as they obscure theodolite fixes. A platform for the theodolite should also be incorporated to minimize the amount that the equipment needs re-calibrating as a result of being jarred.
  - A weather station should be installed near sea level. In its current location, the recordings do not accurately represent the conditions of the marine environment surrounding Bruce Head, and the data were therefore not incorporated into the model.
- Field team:
  - An Inuit field team lead who participates in daily survey decisions and post-survey day QA/QC of field data sheets would be an asset to the Program. This role could be extended to include entering field data into the customized database, further participation in results analysis, and report writing.
- Data collection:
  - Given decreased sightability of narwhal in substrata 3, boundaries of the SSA should be re-evaluated for the 2018 Program.
- Analysis methods:
  - Include data collected during 2014-2016 Programs in the RAD model and the group composition and behavior models to increase dataset size and incorporate pre-ERP data.
  - Investigate the feasibility of using generalized additive models (GAMs) for data analysis to increase modeling flexibility and include both spatial and temporal correlation while allowing for AIC-based model selection.
  - Include vessel length and vessel speed in the RAD and the group composition and behavior models once the data variability is sufficient for modeling.

9.0 CLOSURE

We trust the information contained in this report is sufficient for your present needs. Should you have any additional questions regard the project, please do not hesitate to contact the undersigned.

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APPENDIX A

Training Manual

21 July 2017

BRUCE HEAD 2017

Training Manual - Shore-based marine mammal monitoring

Submitted to:
Baffinland Iron Mines Corporation
2275 Upper Middle Road East, Suite 300
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REPORT

Report Number: 1663724-023-R-Rev0

Distribution:

1 copy - Baffinland Iron Mines Corporation
1 copy - Golder Assciates Ltd.

Table of Contents

TABLES

FIGURES

APPENDICES

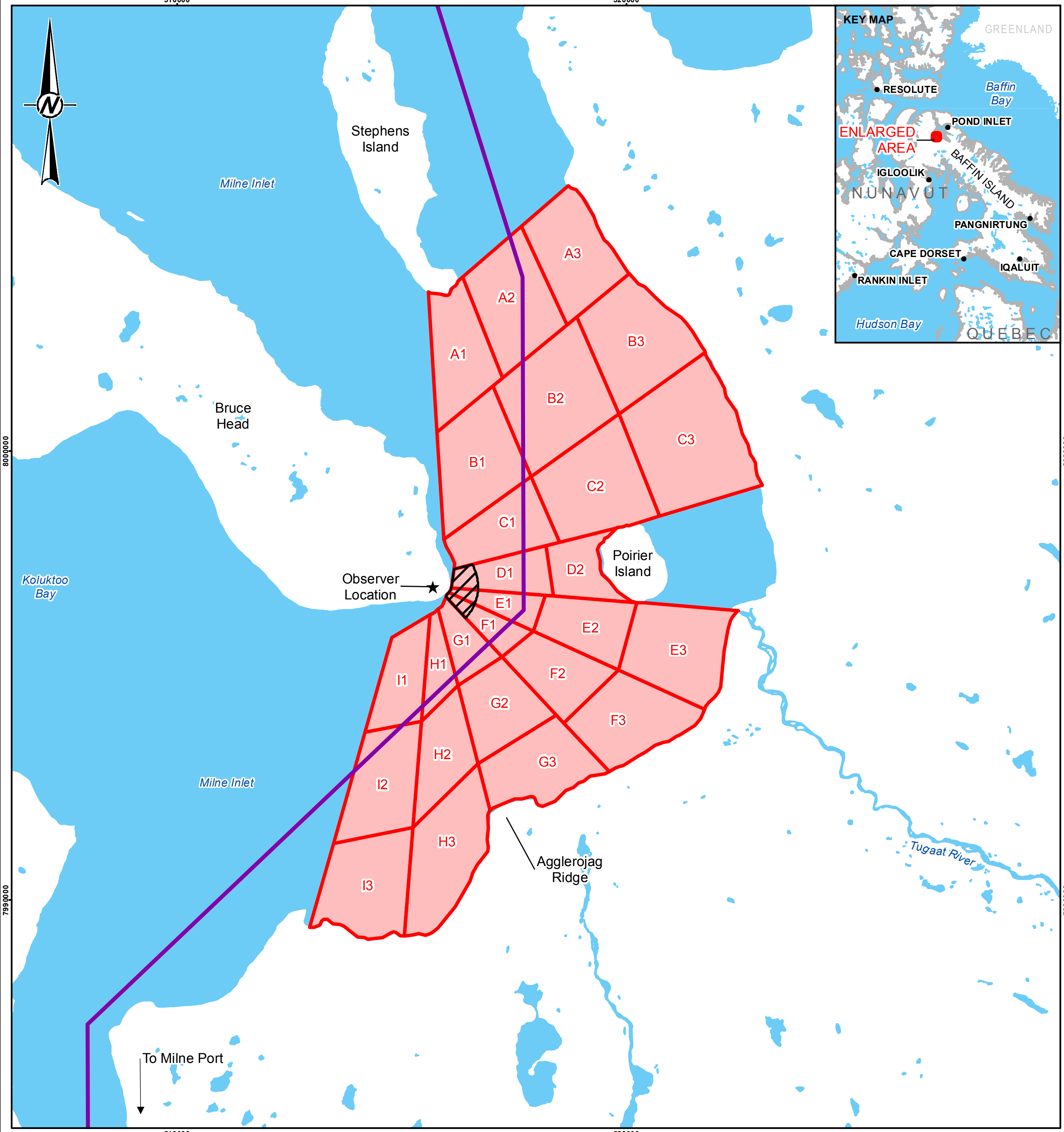
1.0 BACKGROUND

Golder will undertake and manage the 2017 Bruce Head Shore-based Monitoring Program that was previously developed and implemented by LGL Limited (LGL). The objective of this Program is to investigate narwhal behavioral response to vessel traffic serving Milne Port as part of Baffinland Iron Mines Corporation's Mary River Project (the Project). Data will be collected on narwhal group composition and behavior, relative abundance and distribution (RAD), as well as anthropogenic activity (e.g. vessel traffic and hunting events) and environmental conditions.

The Program will be based at Bruce Head, a high rocky peninsula on the western shore of Milne Inlet, Nunavut, overlooking the Project's Northern Shipping Route. The observation platform is located on the edge of Bruce Head (215 m above sea level) and provides a mostly-unobstructed view of Milne Inlet from the south end of Stephens Island in the north, to the embayment south of Agglerojaq Ridge in the south. The observation platform is a wooden structure with a partial roof that offers some protection from the elements and includes a "survival shack" for storing gear providing shelter during periods of bad weather.

1.1 Study Area

The Study Area is approximately 6 km wide on average and is comprised of the broader Stratified Study Area (SSA) and, nested within the SSA, the Behavioral Study Area (BSA) (Figure 1). The SSA is stratified into strata A (northernmost stratum) through I (southernmost stratum) and further separated into substrata 1 through 3 (1 being closest to the Bruce Head shore and 3 being the furthest away). There are a total of 26 substrata within the SSA as stratum D is comprised of only 2 substrata. The boundaries of each substratum are visually estimated in the field using land marks. The BSA covers portions of strata D, E, and F that are within 1 km of the Bruce Head shore where the observation platform is located.



LEGEND

- COMMUNITY
- OBSERVER LOCATION
- APPROXIMATE SHIPPING ROUTE
- BEHAVIOURAL STUDY AREA
- STRATIFIED STUDY AREA (SSA) SUBSTRATA
- WATERBODY

DRAFT

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT - BRUCE HEAD MARINE MAMMAL MONITORING PROGRAM 2017

TITLE
STRATIFIED STUDY AREA AND BEHAVIOURAL STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2017

CONSULTANT
Golder Associates

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DESIGNED	KW
PREPARED	AA
REVIEWED	
APPROVED	

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25mm

2.0 PROGRAM DESIGN

The Bruce Head Shore-based Monitoring Program will consist of three complementary surveys; the first survey conducted by a team of two individuals (i.e. Team 1) and the second and third surveys conducted by a team of three individuals (i.e. Team 2):

1) Relative Abundance and Distribution (RAD) surveys will be conducted throughout the SSA.
2) Group Composition and Behavior surveys will be conducted within the BSA.
3) Vessel tracking and characterization will be conducted throughout the SSA.

There will be some redundancy in data collected, albeit to varying degrees. Specifically, both teams will collect data on glare and sightability (Team 1 for each substratum throughout the SSA during RAD surveys; Team 2 for the BSA during each 50-minute survey) and both teams will collect data on vessel movement (Team 1 will note whether a vessel is entering/exiting Milne Inlet and approaching/departing individual substrata; Team 2 will track each vessel in detail using the theodolite). The reason for this is to ensure that the timing of these observations aligns with the data being collected.

The two teams will assist one another opportunistically. For example, when Team 1 is not conducting RAD counts, they may assist Team 2 in collecting photographs of narwhal within the BSA and of vessels within the SSA. Conversely, when narwhal are not present in the BSA, Team 2 may assist in collecting anecdotal information in the broader SSA.

2.1 Team 1

A team of two individuals (Team 1) will collect relative abundance and distribution data on narwhals, other cetaceans, and anecdotally on pinnipeds within the entire Stratified Study Area (SSA).

S*urvey* and *scan* sampling protocols will be used (Mann, 1999[1]) whereby the observer surveys each stratum for a minimum of 3 minutes to identify narwhal groups[2] (including a solitary narwhal which would be considered a group of 1) and count all individuals within each group. Once all narwhal present within each substratum have been counted and their direction of travel recorded, the observer moves on to the next substratum.

Data to be recorded for each substratum within the SSA:

- Number of narwhal groups and size of individual groups.
- Narwhal direction of travel (i.e., N,S,E,W, or N/A if group travel is multi-directional such as milling).
- Presence of other marine mammals. All other cetaceans observed are to be documented as a separate sighting while any sightings of pinnipeds (seals) or walrus are to be documented anecdotally in comments section of data sheet.
- Vessel presence and direction of travel.
- Beaufort scale, glare and a subjective assessment of sightability (see section 2.1.2.1).

[1] Mann, J. 1999. Behavioral sampling methods for cetaceans: a review and critique. Marine Mammal Science 15(1): 102-122.

[2] Group = individuals within one body length of one another.

2.1.1 Team 1 Roles and Responsibilities

Table 1: Team 1 roles, responsibilities, and monitoring equipment employed.

Team Role	Responsibility	Equipment
Person 1 – Marine Mammal Observer (MMO)	• Count all visible narwhals within each substratum and note group size and direction of travel whenever possible. • Note other marine mammal species observed in each substratum. Other whales observed are to be documented as a separate sighting while seals and walrus observed are to be noted in the comments section. • Report beaufort scale, glare and sightability within each substratum. • Anecdotally, note vessel traffic within each substratum and hunting/shooting activity whenever possible. This will be documented in greater detail by Team 2. • Communicate all observations to the Recorder.	10x42 binoculars
Person 2 - Recorder	• Record all information received from the Observer on the data sheet. • Document the time stamp when the Observer begins observations within each substratum. • All times should be recorded using the 24-hr clock (e.g. 2 pm is recorded as 14:00) • Communicate completion of each RAD count to Team 2 (who will be tracking ships with theodolite).	Data sheets[3]

2.1.2 Relative Abundance and Distribution (RAD) – Survey Protocol

- Observations of the SSA will be made by a team of two individuals (Team 1) from two pre-determined observation locations (15 m apart) that provide an overview of strata A to F, and G to I, respectively.
- RAD counts are to be undertaken at the start of each observation period and every hour, on the hour, during the 10-hr observation period.
- RAD counts are to be undertaken continuously upon visual detection of large vessels prior to entering the SSA (exact distance to be defined in the field) and for the full duration that the vessel is present within the SSA. A final RAD count is to be made once the large vessel has left the SSA. If a large vessel enters the SSA mid-way through conducting an hourly RAD count, that count is to be completed and another count will commence immediately after.
- General Rules:
  - If majority of narwhal are travelling in one direction (i.e. north → south), begin counting the strata from the opposite direction (i.e. south → north) in order to avoid / minimize double-counting.
  - During incoming vessels, begin counts in the stratum closest to the incoming vessel.

[3] Data Sheets: Relative Abundance and Distribution

- Other whales observed in each substratum are to be documented as an individual sighting while seals and walrus observed are to be documented in the comments section of the data sheet.
- The observer is to spend a minimum of 3 minutes scanning each stratum.
- Data will not be collected for a substratum that cannot be observed in its entirety due to weather. When a substratum is omitted due to weather, glare and sightability must still be documented.

2.1.2.1 Additional data to be collected

In addition to the RAD data collected by Team 1, the team will document the following during each RAD survey:

- Record all whale sightings as you would a narwhal sighting (as a separate line item in datasheet).
- For seal and walrus sightings within each substratum, include a descriptive comment in the data sheet including information on species, group size, and behavior (as possible). Always prioritize whale sightings.
- Vessel presence, vessel class[4], and direction of travel (i.e., entering or exiting Milne Inlet and approaching or departing substratum) within individual substratum.
- Specific environmental conditions for individual substratum:
  - Beaufort scale (see Appendix B)
  - Glare: severe (S), light (L), none (N).
  - Sightability (a subjective assessment of the overall viewing conditions):
    - Excellent (E): conditions such that 100% certain that marine mammals at surface would be detected.
    - Good (G): conditions such that marine mammals at surface would *very likely* be detected.
    - Moderate (M): conditions such that marine mammals at surface may be detected.
    - Poor (P): water is mostly obscured by fog, ice, or high sea state; detections severely impaired and unlikely.
    - Impossible (I): water is completely obscured by fog, ice, or high sea state.

2.2 Team 2

A team of three individuals (Team 2) will collect group composition and nearshore behavioral data on all narwhals that swim within 1 km from the shore where the observation platform is located (i.e. the BSA). S*urvey* and *scan* sampling protocols will be used (Mann, 1999). For each sighting[5], the team will collect data as per the survey protocol outlined below, after which the observer will move on to the next sighting.

[4] Vessel class: Small = 0-50m; medium = 50m-100m; large = ≥100m

[5] Sighting: Observation of a group of animals (including groups of 1).

Data to be recorded for the BSA:

- Narwhal group composition.
- Narwhal group primary and secondary behavior.
- Beaufort scale, glare and a subjective assessment of sightability (as per definitions in Section 2.1.2.1).

Team 2 will also track all vessel traffic within the SSA and collect data on hunting/shooting events (Section 2.2.3). Surveys will consist of 50-minute observation periods, abbreviated by 10-minute rest periods.

Data to be recorded for the entire SSA:

- Vessel presence, class (e.g., large, medium, and small) and direction of travel (tracked via the theodolite).
- Any hunting/shooting events, the associated time, and target species whenever possible.
- Environmental data.

2.2.1 Team 2 Roles and Responsibilities

Table 2: Team 2 roles, responsibilities and monitoring equipment employed.

Role	Responsibility	Equipment
Person 1 – Marine Mammal Observer (MMO)	• Document group composition as well as primary and secondary behavior of all narwhals within the BSA. Specific behavior (e.g. tusking) within each of the five behavioral categories should be documented whenever possible. • Note any other marine mammal species (and behavior) observed in the BSA • Report glare and sightability within the BSA every hour. • Communicate all observations to the Recorder.	Big eye binoculars
Person 2 – Vessel Tracker & Recorder	• Prior to large vessels entering the SSA (at a distance to be determined in the field), take theodolite fixes of the vessel every 4 minutes, until the vessel leaves the SSA. Once the vessel has left the SSA, continue to take theodolite fixes until Team 1 signals the completion of their final RAD count. • Take theodolite fixes of all medium and small vessels present within the SSA every 1 minute during RAD counts (tracking multiple vessels at a time if present) until Team 1 signals the completion of their final RAD count. • Classify vessel class and specify whether entering/exiting Milne Inlet and approaching/departing the BSA. • Record all vessel traffic data as well as hunting activity throughout the 10-hr observation period, the associated time, and the target species whenever possible.	Theodolite, Datasheet[6]
Person 3 – Recorder	• Record all information received from the MMO on the data sheet (note: the theodolite data will be recorded by Person 2). • Observe environmental conditions and complete the associated data sheet every hour and whenever conditions change. • Complement the data collected by taking photographs of narwhal within the BSA and of vessels in the SSA whenever time permits. • All times should be recorded using the 24-hr clock (e.g. 2 pm is recorded as 14:00)	HD camera, 10 x 42 binoculars, Datasheets[7]

[6] Datasheets: Vessel Passages and other nthropogenic Activity

[7] Datasheets: Group Composition and Behavior, Environmental Conditions

2.2.2 Group Composition and Behavior – Survey Protocol

- Observations of narwhal group composition and behavior will be made by the **Team 2 MMO** who will communicate findings to the **Team 2 Recorder.** The third individual from Team 2, the **Vessel Tracker**, will be responsible for collecting vessel traffic data exclusively for both the BSA and the broader SSA (see Section 2.2.3).
- The three individuals that are part of Team 2 will be stationed at the observation platform.
- Surveys will consist of 50-minute observation periods, abbreviated by 10-minute rest periods.
- General Rules:
  - Primary[8] (1) and secondary[9] (2) behavioral data are to be recorded for every sighting whenever possible, based on seven behavioral categories[10] (Table 6).
  - Unique behaviors[11] are also to be recorded in the datasheet whenever observed.
  - If majority of narwhal are travelling through the BSA in one direction (i.e. north → south), begin counting and characterizing the animals from the opposite direction (i.e. south → north).
  - Herding events[12]: If multiple groups pass through the BSA too quickly such that group composition and behavior cannot be recorded (based on best judgment of **Team 2 MMO**), counts should be conducted and the sightings grouped into 5-minute bins. One herding event may have multiple 5-minute sightings that will be added together at a later time to determine the total group size of the herding event. In this scenario, the **Team 2 Recorder** is to announce the completion of each 5-minute interval, the count is to be recorded, and the **Team 2 MMO** then begins counting (and characterizing whenever possible) the next sighting, beginning the count again at 1.
  - If a group of animals remains in the BSA for a period exceeding 10 minutes, that group is to be 'resighted' every 10 minutes until the group leaves the BSA. In this scenario, the initial sighting number is to be repeated as a new line item in the datasheet, along with the associated time.

The following tables outline the group composition data (Table 3 and associated tables) and the behavioral data (Table 6) that is to be recorded for each sighting[13] within each 50-minute survey.

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[8] Primary behavior = the behavior displayed by the majority of animals; the predominant behavior.

[9] Secondary behavior = the second most commonly observed behavior of a group of animals.

[10] Behavioral categories (see Table 6) = travelling, resting, milling, foraging, socializing, reproductive, other.

[11] Unique behaviors (see Table 6) = logging (LO), chase prey (CH), catch prey (CA), rubbing/petting (RU), rolling (RO), tusk (TU), tail slap (TS), nursing (NU), mounting (MO), sexual display (SX), bubble rings (BU), spyhopping (SP), breaching (BR), diving (DY).

[12] Herding event = numerous groups of animals swimming in the same direction.

[13] Sighting = observation of a group of animals (including groups of 1).

Table 3: Group composition and behavior data to be recorded.

Data to be recorded	Description
Time of sighting	For every sighting, time of passage through the BSA must be recorded. See 'General rule' for herding events above.
Sighting #	For each group of animals observed in the BSA, a sighting number is to be used as a unique identifier. If a group of animals remains in the BSA for a period exceeding 10 minutes, that group is to be 'resighted' every 10 minutes until the group leaves the BSA. In this scenario, the initial sighting number is to be repeated as a new line item in the datasheet, along with the associated time.
Whale species	Although narwhal are the focal species of this program, all other whale species observed are to be recorded as a separate sighting (with the same level of detail as would be provided for narwhal). Seals and walrus are to be noted in the comments section only.
Group size	Number of narwhal within 1 body length of one another. Includes group size of 1.
Number of narwhals with tusks	■ Present ■ Absent ■ Unknown (i.e. head not visible).
Number of narwhals in age categories adult, juvenile, yearling, and calf.	See Table 4 (Life stages).
Spread	■ Tight: narwhals ≤ body width apart ■ Loose: narwhals >1 body width apart
Group Formation	See Table 5 (Formation).
Direction of travel	N, S, E, W
Speed of travel	■ Fast / Porpoising ■ Medium ■ Slow ■ Not travelling / Milling
Distance away from shore	■ Inner: <300 m ■ Outer:>300m
Primary & Secondary Behaviour	■ See Table 6 (Behavioural Data).
Associated photo range	■ For each sighting where photos are taken, the numeric photo range should be recorded.

Table 4: Life stages of narwhal

	Adult	Juvenile	Yearling	Calf
Length	4.2 – 4.7 m	80-85% length of adult	2/3 of accompanying female	½ length of accompanying female, usually in "baby" or "echelon" position close to mother. Newborn calves are ~1.6 m in length.
Colouration	Black and white spotting on their back, or mostly white (generally old whales)	Dark grey; no or only light spotting on their back	Light to uniformly dark grey	White or uniformly light (slate) grey, or brownish-grey

Table 5: Group formation categories.

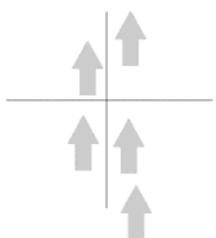
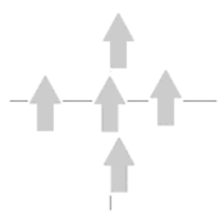
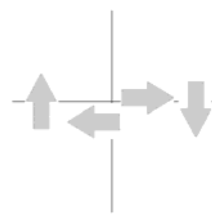
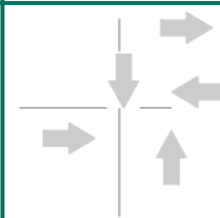
Linear	Parallel	Cluster / circular	Non-directional line	No formation
Directional line	Directional line	Directional line	Non-directional line	Non-directional line
Stretched longitudinal	Stretched laterally	Stretched longitudinal + lateral	Linear formation	Non-linear
One animal after another in a straight line	Animals swimming next to each other in a line formation	Animals swimming in cross formation (equally long as wide lines)	Animals in a linear line but facing different directions	Equal spread with no clear pattern
				

Table 6: Behavioral data (primary and secondary) to be recorded.

Behavior	Description of behavior	Unique behavior examples
Travelling	Animal(s) exhibiting directed movement; moving steadily in a constant direction	-
Resting	Animal(s) not moving	Logging (LO)
Milling	Animal(s) exhibiting non-directional movement; moving about haphazardly within a limited area	-
Foraging	Animal(s) chasing or catching prey species	Chase prey (CH) Catch prey (CA)
Socializing	Animal(s) in physical contact with one another; includes tail slaps	Rubbing or petting (RU) Rolling (RO) Tusk displays or tusk contact (TU) Tail slap (TS)
Reproductive	Animal(s) exhibiting behavior known to be related to reproductive function	Nursing (NU) Mounting (MO) Sexual display (SX)
Other	Animal(s) exhibiting behavior not known to be context-related. A description of behavior is to be included in comments.	Bubble rings (BU) Spyhopping (SP) Breaching (BR) Diving (DY)

2.2.2.1 *Additional Data to be collected*

In addition to Team 2 collecting group composition and behavioral data within the BSA, the following environmental conditions are to be observed for the entire SSA and documented by the **Team 2 Recorder** upon arrival to the observation site each day, every hour, and whenever conditions change:

- Ice cover (%) in entire SSA
- Precipitation type: rain, fog, snow, or none
- Cloud cover (%)

The following environmental conditions are to be observed by the **Team 2 MMO** and recorded by the **Team 2 Recorder** for the BSA upon arrival to the observation site each day, every hour, and whenever conditions change:

- Beaufort Scale (see Appendix B)
- Glare: severe (S), light (L), none (N)
- Sightability (a subjective assessment of the overall viewing conditions):
  - Excellent (E): conditions such that 100% certain that marine mammals at surface would be detected.
  - Good (G): conditions such that marine mammals at surface would *very likely* be detected.
  - Moderate (M): conditions such that marine mammals at surface may be detected.
  - Poor (P): water is mostly obscured by fog, ice, or high sea state; detections severely impaired and unlikely.
  - Impossible (I): water is completely obscured by fog, ice, or high sea state.

2.2.3 Vessel Tracking – Survey protocol

All vessel traffic present within the SSA (including the BSA) will be tracked using the theodolite, characterized, and documented by the **Team 2 Vessel Tracker**. This individual is also responsible for recording all shooting/hunting events observed.

- General rules:
  - For all vessel traffic present within the SSA, vessel class[14] is to be determined and documented.
  - Theodolite fixes are to be taken every 4 minutes for all large vessels (>100 m in length) approaching the SSA (distance to be defined in the field) and for the full duration that they are present within the SSA. Once the vessel has left the SSA, theodolite fixes will continue to be taken until Team 1 signals the end of their final RAD count.

[14] Vessel class: Small = 0-50m; medium = 50m-100m; large = >100m

  - Theodolite fixes are to be taken every 1 minute for all medium (50-100 m) and small vessels (i.e. hunting and pleasure crafts; <50 m) present within the SSA during RAD counts (tracking multiple vessels at a time if present).
  - Theodolite fixes are to be taken where the stern of the vessel meets the water line.
  - Fixed-wing aircraft and helicopters are to be noted in the 'comments' section of the data sheet if present, including aircraft travel direction.
- The **Team 2 Vessel Tracker** is to document the time, duration, and general location of all hunting activity observed (visually or aurally) during each 50-minute survey, recording the target species whenever possible.

2.2.3.1 Theodolite Instructions

The theodolite is a tool to determine geographic coordinates of distant objects (e.g. vessels) by recording angles and calculating distance. The **Team 2 Vessel Tracker** will take a "fix" of the vessel's stern every 4 minutes for all large vessels and every 1 minute for small and medium vessels during RAD counts.

The Tracker will be responsible for tracking all vessel traffic within the SSA using the theodolite.

Key points to note on the theodolite display screen:

- Upper line is vertical measurement (degrees, minutes, seconds)
- Lower line is horizontal measurement (degrees, minutes, seconds)
- "TILT" – indicates that tilt correction is turned on (good).
- If vertical scale is in "%" (bad), press "V/%" once.
- "HR" for horizontal scale as per compass (good)
- "HL" for horizontal scale is reverse compass (bad). Press "R/L" once
- Battery level indicator (3 bars – like cell phone)

Theodolite setup:

- Level the instrument – as per instruction manual
- Turn on the theodolite – press power button once
- Turn on vertical measurement – press "V/%" once
- Swing objective lens past horizontal (activates vertical angle measurement)
- Aim theodolite at reference landmark (mountain – to be determined) – press "0 SET" button twice. Landmark is now at 0^{o} horizontal angle

Pythagoras Program and Database:

- Open Pythagoras Program and Database
- Attach communication cable to the computer (use same USB port that worked previously)
- From the computer's *Control Panel*, access the *Device Manager*. Expand the *Ports (COM and LPT)* heading. Note which COM# is listed for the *USB to serial Comm port*. If the port Number is higher than 5, you can try a different USB port on the computer or you can force it to use a lower COM port number: under *USB to serial Comm port* properties, *Port Settings* tab, *Advanced* button, change the Com Port Number to one that is between 1 and 5 (that is not in use).
- Open the Pythagorus Program. Select the *Setup* tab, Theodolite. Make sure the same COM port is selected as determined above with the Topcon DT-102 theodolite make/model selected. COM port properties (*Configure Port* button) should be set to "1200 / 8 / None / 1 / None". Close theodolite setup.
- Select Program tab and Start Track.

Taking and Recording a Measurement:

- Use the sights on the top or bottom of the objective lens, to point lens towards the target.
- Looking through lens, adjust focus for distance, roughly align target with crosshairs.
- Use the vertical and/or horizontal tangent screws to fine tune the target in the crosshairs.
- Record the measurements: use the database to capture the measurements (or take photo of the display screen / record on data sheet).
- In Pythagorus Tracking window, select fix type / sub-type.
- Press Fix button to record vessel location. Measurements will appear in new line in the Tracking window.
- Use a new group number (Grp#) for a new vessel. Ensure that the correct group number is used when tracking more than one vessel concurrently.

Table 7: Vessel track data to be recorded

Data to be recorded	Description
Start / End time	Start and end time of each vessel transit.
Vessel sighting ID	Sequential numbering of each vessel transit.
Fix Numbers	Theodolite location fixes obtained from data logger.
Vessel direction of travel	
Vessel class	■ Large: ≥100 m ■ Medium: 50-100 m ■ Small: Hunting and pleasure crafts; <50 m
Associated photo range	■ For each vessel photographed, the numeric photo range is to be recorded.

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APPENDIX A

Glossary

Beaufort Scale – a scale of wind speed based on a visual estimation of the wind's effect, from Beaufort force 1 (calm) to Beaufort force 12 (hurricane). See Appendix B for the Beaufort Scale.

BSA – Behavioural Study Area covers portions of strata D, E and F that are within 1 km of the Bruce Head shore where the observation platform is located.

Glare – reflections of the sun on the water, categorized as either None, Light, or Severe.

Group Formation – The configuration of the shape that narwhals within a group swim together.

Group Size – all narwhals within one adult body length of each other.

Herding – numerous groups of narwhals swimming in the same direction.

Primary behaviour - the behavior displayed by the majority of animals; the predominant behavior.

RAD counts – Relative Abundance and Distribution counts of narwhals and any other marine mammals encountered within the SSA.

Secondary behaviour - the second most commonly observed behavior of a group of animals.

Sightability – categorized as Excellent, Good, Moderate, Poor, or Impossible. Sightability is a ranking descriptor for the overall 'detectability' of a marine mammal given the combined influence of sea state, visibility and glare conditions. For example, the combined effect of a low sea state, excellent visibility, and no sun glare would result in 'Excellent' sightability conditions, while the combined effect of high sea state, poor visibility, and high glare would result in 'Poor' or even "Impossible" sightability conditions.

- Excellent (E): conditions such that 100% certain that marine mammals at surface would be detected.
- Good (G): conditions such that marine mammals at surface would *very likely* be detected.
- Moderate (M): conditions such that marine mammals at surface may be detected.
- Poor (P): water is mostly obscured by fog, ice, or high sea state; detections severely impaired and unlikely.
- Impossible (I): water is completely obscured by fog, ice, or high sea state.

Spread – The extent, width, or area covered by narwhals in a group.

Tight spread – narwhals ≤ body width apart

Loose spread - narwhals >1 body width apart

Sighting – an observation of an individual or a group of animals, (including groups of 1).

SSA – Stratified Study Area, the larger study area of the program.

Stratum – Sections A to F of SSA

Substratum – Sections 1 to 3 within each stratum of the SSA.

APPENDIX B

Beaufort Scale

APPENDIX B
The Beaufort Scale

The Beaufort scale

No.	Knots	Mph	Description	Effects at sea	Effects on land
0	0	0	Calm	Sea like a mirror	Smoke rises vertically
1	1-3	1-3	Light air	Ripples but no foam crests	Smoke drifts in wind
2	4-6	4-7	Light breeze	Small wavelets	Leaves rustle; wind felt on face
3	7-10	8-12	Gentle breeze	Large wavelets; Crests not breaking	Small twigs in constant motion; Light flags extended
4	11-16	13-18	Moderate wind	Numerous whitecaps Waves 1-4ft high	Dust, leaves and loose paper raised. Small branches move.
5	17-21	19-24	Fresh wind	Many whitecaps, some spray; Waves 4-8 ft high	Small trees sway
6	22-27	25-31	Strong wind	Whitecaps everywhere; Larger waves 8-13 ft high	Large branches move; Difficult to use umbrellas
7	28-33	32-38	V. strong wind	White foam from waves is blown in streaks; waves 13-20ft high	Whole trees in motion
8	34-40	39-46	Gale	Edges of wave crests break into spindrift	Twigs break off trees; Difficult to walk
9	41-47	47-54	Severe gale	High waves; sea begins to roll Spray reduce visibility; 20ft waves	Chimney pots and slates removed
10	48-55	55-63	Storm	V. high waves 20-30 ft; blowing foam gives sea white appearance	Trees uprooted Structural damage
11	56-63	64-72	Severe storm	Exceptionally high waves; 30-45 ft high	Widespread damage
12	63	73	Hurricane	Air filled with foam; visibility reduced White sea; waves over 45ft high	Widespread damage; rare

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APPENDIX C

Marine Mammal Detection Cues

1.0 MARINE MAMMAL DETECTION CUES

Detection cues are useful to know as they can mark the presence of marine mammals even when they have not surfaced. Below is a list of detection cues that will be useful to know when looking for marine mammals.

Blows

Marine mammals exhale when they surface, often expelling a watery mist from their blow holes or mouths (pinnipeds). These can be seen from very far distances (>15 km for blue whale blows in ideal conditions), and they may also be heard. It is possible to utilize the size and shape of the whale blow to give clues as to what type of whale it might be. Toothed whales have one blowhole and therefore discharge a blow with one short wide plume, whereas baleen whales have two blowholes that sometimes make a V-shaped or heart-shaped blow plume (see Figure 1).

Figure 1: Toothed whale blow of a killer whale (left) versus baleen whale blow of humpback and bowhead whales (right)

Splashes in the water

Splashes may be a sign that a marine mammal is present and may occur due to porpoising at high speed, tail-slapping, chasing fish, etc.

Footprints

Footprints are when the surface of the water looks disturbed and are made when a marine mammal has just been on or near the surface of the water, or produced by water movement by near-surface tail flukes.

Birds

Birds feed on schooling fish just as many marine mammals. They may be present before the arrival of a marine mammal, or at the same time. Birds may be observed in the air, on the surface of the water or diving into the water.

APPENDIX D

Marine Mammal Identifications

1.0 MARINE MAMMALS IN BAFFIN ISLAND WATERS

Please see the following pages for species identification descriptions.

1.1 Whales

- Narwhal (*Monodon monoceros*)
- Beluga (*Delphinapterus leucas*)
- Bowhead whale (*Balaena mysticetus*)
- Killer whale (*Orcinus orca*)

Other possible but rare whales

- Minke whale (*Balaenoptera acutorostrata*)
- Northern Bottlenose whale (*Hyperoodon ampyllatus*)
- White-beaked dolphin (*Lagenorhynchus albirostris*)

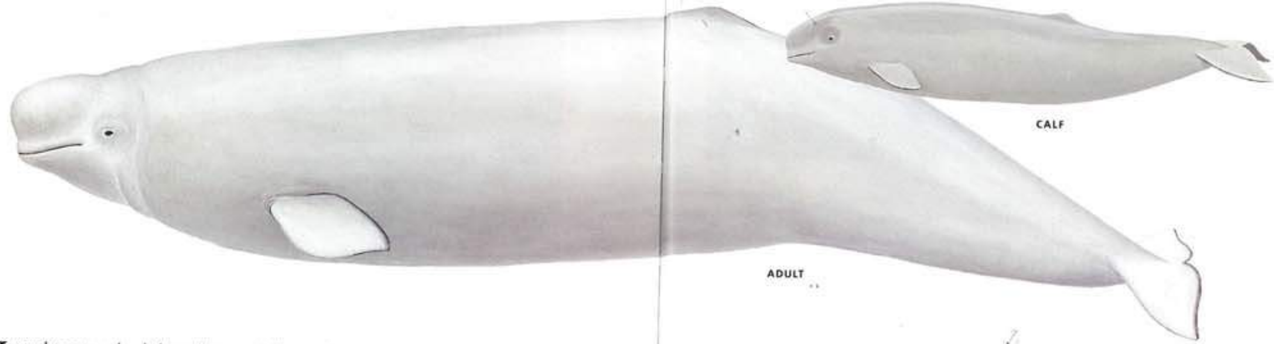
1.2 Seals and Polar Bear

- Harp seal (*Pagophilus groenlandicus*)
- Ringed seal (*Pusa hispida*)
- Bearded seal (*Erignathus barbatus*)
- Walrus (*Odobenus rosmarus*)
- Polar bear (*Ursus maritimus*)
- Hooded seal (*Crystophora cristata*) - rare

Beluga

***Delphinapterus leucas* (Pallas, 1776)**

- WHITE ADULT COLORATION
- ROUNDED, MALLEABLE MELON AND FLEXIBLE NECK
- SHORT BROAD BEAK WITH CLEFT UPPER LIP
- BROAD FLIPPERS AND ORNATELY SHAPED FLUKES
- LACK OF DORSAL FIN
- OCCURS ONLY IN HIGH LATITUDES OF NORTHERN HEMISPHERE



Known by some early whalers as "sea canaries" because of their loquacious natures, these whales are abundant and widespread in the Arctic and Subarctic. For many centuries, Belugas, also known as White Whales, have been a staple of arctic societies, providing food, fuel oil, and even soft durable leather. They were among the first cetaceans to be brought into captivity. Their resilience and adaptability, stunning appearance, engaging disposition, and trainability have made them popular performers in oceanariums. Several areas where Belugas congregate have become whale-watching meccas, most notably eastern Canada's lower St. Lawrence River and the Churchill River estuary in western Hudson Bay. Over the past 15 years, there has been a flurry of research on the species, much of it involving satellite telemetry. These studies have shown that the Beluga has impressive diving abilities and is even more ice-adapted and abundant than was previously believed.

DESCRIPTION The Beluga has a rounded midsection that tapers toward the head and tail. Its torso is markedly rotund when the animal is well fed. The head is unlike that of any other cetacean, with a bulging melon that one researcher described as feeling like a balloon filled with warm lard. A Beluga is able to change the shape of its melon at will, presumably by moving air around in various sinuses. The neck is unusually mobile because the cervical vertebrae are not fused, and Belugas readily turn or nod their heads. The beak is short and broad, with a cleft upper lip and a labile mouth that can be puckered. The belly and sides may be lumpy, with folds and creases of fat. There is no dorsal fin, but there is a narrow ridge on the back where a dorsal fin would otherwise be. The broad flippers are upcurled at the tips in large males. The flukes become increasingly ornate as the animal ages, and those of mature adults are strongly convex on the rear margin. There are eight to nine pairs of peg-like teeth in both the upper and lower jaws, sometimes worn down to the gum in older adults.

Young Belugas are evenly gray. They lighten as they age and eventually become completely white except for dark pigment on the dorsal ridge and along the edges of the flukes and flippers. The white skin of adults can sometimes have a yellowish cast when they begin congregating in estuaries in summer, but this disappears after they molt.

RANGE AND HABITAT Belugas have an essentially circumpolar distribution in the Northern Hemisphere, centered mainly between 50°N and 80°N. Nearly 30 stocks are provisionally recognized for management purposes. Stocks are defined primarily on the basis of summering grounds, most of which are centered on estuaries where the animals molt. Belugas exhibit a high degree of philopatry, or loyalty to a site, and individuals (females in particular) tend to return, year after year, to the estuary visited by their mother in the year of their birth. In fall, Belugas are driven away from bays and estuaries by ice, and they winter primarily in polynyas, near the edges of pack ice, or in areas of shifting, unconsolidated ice. They appear to be equally at home in shallow river mouths, where they may become stranded between tides, and in deep submarine

BELUGA
FAMILY MONODONTIDAE

MEASUREMENTS AT BIRTH		
LENGTH		4'11"–5'3" (1.5–1.6 m)
WEIGHT		176–220 lb (80–100 kg)
MAXIMUM MEASUREMENTS		
LENGTH	MALE	14–16' (4.2–4.9 m)
	FEMALE	13–14' (3.9–4.3 m)
WEIGHT	MALE	2,400–3,500 lb (1,100–1,600 kg)
	FEMALE	1,500–2,600 lb (700–1,200 kg)
LIFE SPAN		
At least 25 years, possibly more than 50		

- RANGE
- ? POSSIBLE RANGE
- EXTRALIMITAL RECORDS

trenches, where they dive to depths in excess of 2,600 feet (800 m).

SIMILAR SPECIES The Narwhal is the species most likely to be confused with the Beluga, but mainly in latitudes north of about 65°N. Adult male Narwhals usually have a spiraled tusk jutting forward from the upper lip, making them reasonably easy to distinguish, and the mottled or spotted skin of adult Narwhals is in contrast to the even gray or white of Belugas. In the Arctic and Subarctic at times, particularly from an aerial perspective, the silvery flashes from a shoal of Harp Seals may superficially resemble a pod of young Belugas rolling at the surface. The tails of seals, however, move from side to side rather than vertically, and Harp Seals tend to be quicker, more active, and inclined to remain at or just below the surface. Whitecaps, small bits of floating ice, and even seabirds can be difficult to distinguish from Belugas at a distance. One experienced researcher describes a Beluga at ½ to 1¼ miles (1–2 km) away as a white spot that appears, grows, shrinks, and disappears, remaining in view for about three seconds.

BEHAVIOR Belugas are highly social, occurring in close-knit pods, often of the same sex and age class. Groups of large males, numbering several hundred, are observed in summer, as are smaller groups consisting of mothers and their dependent calves. Aggregations of Belugas in estuaries can build to thousands of animals when undisturbed by hunting. Belugas have a diverse vocal repertoire that encompasses trills, squawks, bell-like sounds, sharp reports (possibly caused by jaw clapping), and a sound like that made by rusty gate hinges. Bill Schevill, a pioneer in the field of cetacean bioacoustics, described their "high-pitched resonant whistles and squeals, varied with ticking and clucking sounds slightly reminiscent of a string orchestra tuning up, as well as

ABOVE: *The Beluga's melon is bulbous and malleable. This animal's short, broad beak is well demarcated from the melon. Its skin appears to be in transition from gray to white as occurs as Belugas approach maturity.*
RIGHT: *The all-gray Beluga calves are easily distinguishable from the essentially all-white adults.*

A closely spaced pod of five adult Belugas moves along the coast of Alaska in pack ice. Adaptation to living in an icy environment has allowed the Beluga to disperse throughout most of the Arctic and Subarctic.

mewing and occasional chirps." Sometimes their calls reminded him of a crowd of children shouting in the distance. The most serious hazards for wild Belugas, apart from human hunters, are Killer Whales and Polar Bears. The bears quickly converge on areas where Belugas are ice-entrapped, taking a heavy toll by swiping at the animals with their powerful paws and dragging them onto the ice.

REPRODUCTION The timing of reproductive events varies by region. In general, conception takes place in late winter or spring when the animals are least accessible for observation (late February to mid-April in Alaska; May in eastern Canada and West Greenland). Credible estimates of the gestation period range from somewhat less than a year to 14½ months. Young Belugas are nursed for two years and may continue to associate with their mothers for a considerable time thereafter. The calving interval probably averages three years.

FOOD AND FORAGING The diets of Belugas vary according to regional and seasonal prey availability. Stomach contents of individuals from various regions demonstrate that the species' overall diet includes a great variety of organisms: fish (from salmon to arctic cod to herring and capelin), cephalopods (squid and octopuses), crustaceans (shrimps and crabs), marine worms, and even large zooplankton. Many prey items are bottom-dwelling organisms. This probably explains why many dives (monitored with time-depth recorders) have a "square" profile, characterized by a steep and continuous descent and ascent, with a distinct bottom phase in between. The whales are almost certainly foraging near the seabed, at depths of at least 1,000 feet (300 m). The Beluga's puckered lips serve to create suction as the animal forages (and also enable Belugas to shoot streams of water at oceanarium spectators).

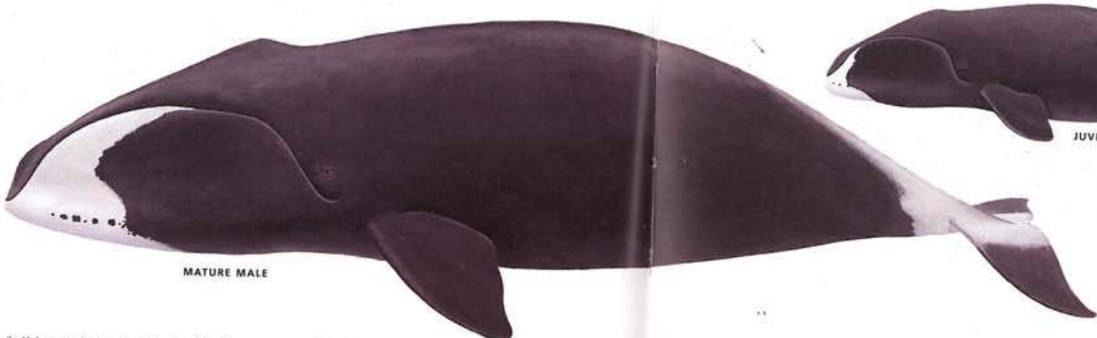
STATUS AND CONSERVATION Although there are well over 100,000 Belugas in the circumpolar Arctic today, their aggregate abundance was much greater in the past, before commercial hunting decimated some groups. Among the more robust populations today are those in the Beaufort Sea (40,000), the eastern High Arctic of Canada (28,000), western Hudson Bay (25,000), and the eastern Bering Sea (18,000). The whales in these four areas are hunted locally, but the removal rates are thought to be sustainable. In contrast, a number of other populations are in great peril and should not be, but are, still hunted. These include those in Cook Inlet, Ungava Bay, and some parts of southeastern Baffin Island and West Greenland. The animals in the St. Lawrence River have high contaminant burdens in their bodies and high cancer rates. Some formerly important Beluga estuaries are now infested with motorboats and hunters, rendering them unsuitable to support large aggregations of the whales. Hunt management is the most critical immediate imperative for Beluga conservation.

Bowhead Whale

Balaena mysticetus
Linnaeus, 1758

- LARGE AND ROTUND, WITH BROAD BACK AND NO DORSAL FIN
- ALL BLACK EXCEPT FOR WHITE CHIN PATCH
- HEAD ONE-THIRD BODY LENGTH, WITH BOWED MOUTHLINE
- PROMINENT "CROWN" AT BLOWHOLES, WITH DEPRESSION BEHIND
- OFTEN RAISES FLUKES WHILE DIVING
- V-SHAPED BLOW
- CIRCUMPOLAR IN HIGH LATITUDES OF NORTHERN HEMISPHERE


JUVENILE


MATURE MALE

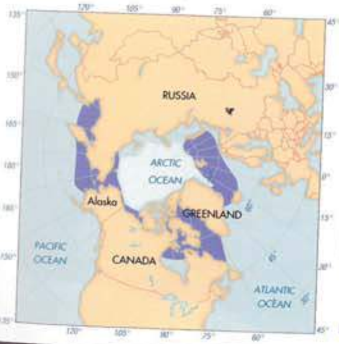
Of all large whales, the Bowhead is the most adapted to life in cold water, with a layer of blubber up to 1½ feet (50 cm) thick and a huge head that it uses to break through thick ice. Closely associated with sea ice through much of the year, the Bowhead Whale is found throughout arctic and subarctic areas in the Northern Hemisphere. Whalers hunted this species extensively until the early 20th century. The scientific name translates to "whale" (from the Latin words *balaena* and *cetus*) and "mustached" (from the Greek *mustakos*), referring to the very long baleen. The Bowhead is also known as the Greenland Right Whale.

DESCRIPTION The Bowhead Whale is large and very robust, with a huge head that in adults is fully one-third of its body length. The body is black, with a white chin patch that often has a line of black spots. The mouthline is strongly arched, and the rostrum very narrow. Baleen plates, numbering 230 to 360 on either side of the mouth, are black, narrow, and up to 14 feet (4.3 m) long. There is a peaked ridge, or "crown," before the blowholes and a notable depression behind them, particularly in adults. Bowheads have no dorsal fin and broad, triangular flukes with smooth margins, which they often raise during deep dives. Their blow is V-shaped when seen from the front or from behind.

RANGE AND HABITAT Bowhead Whales have a circumpolar distribution in high latitudes in the Northern Hemisphere. They are closely associated with ice for much of the year, wintering at the southern limit of the pack ice or in polynyas (large, semi-stable open areas of water within the ice), then moving northward as the sea ice breaks up and recedes during spring. A reverse movement occurs as ice cover spreads southward in autumn. There are five recognized populations of Bowheads. The largest winters in the Bering Sea and migrates northward into the Beaufort and Chukchi Seas in the spring. A second population summers along the western and perhaps northern portion of the Sea of Okhotsk, notably around the Shantar Islands; its wintering ground is largely unknown, but it is likely that most remain in the Sea of Okhotsk year-round. Three other populations occur in the Atlantic: in Davis Strait and Baffin Bay, Hudson Bay and Foxe Basin, and the area of Spitsbergen Island and the Barents Sea.

SIMILAR SPECIES The North Atlantic and North Pacific Right Whales, the only whales that might be confused with the Bowhead, are easy to distinguish by the callosities on their heads. Unlike Bowheads, northern right whales are frequently white or marbled underneath, and their baleen, while sometimes similar in length, is never longer than 9 feet (2.7 m). They occur rarely in the extreme southern portion of the Bowhead's range and are unlikely to be associated with ice.

BEHAVIOR Bowhead Whales show little stability in their social organization beyond the mother-calf pair bond. Most other associations between individuals last only for hours or at most a few days. However, given that Bowhead vocalizations can be easily heard over several miles, the



RANGE

BOWHEAD WHALE
FAMILY BALAENIDAE

MEASUREMENTS AT BIRTH

LENGTH	13–15' (4–4.5 m)
WEIGHT	2,000 lb (900 kg)

MAXIMUM MEASUREMENTS

LENGTH	65' (19.8 m)
WEIGHT	About 200,000 lb (90,000 kg)

LIFE SPAN

Recent research suggests that this species may live considerably longer than 100 years

existence of some loose herd structure at times is possible. It appears likely that some Bowhead sounds function as primitive echolocation, as vocalizing Bowheads have been observed to alter their course around icebergs and other obstructions well before they would have been able to detect them visually. Bowheads are adapted for traveling long distances under ice. Their massive heads can reportedly break through ice up to 6 feet (1.8 m) thick. Both the migration and the distribution of Bowheads during the summer feeding season appear to be somewhat segregated by age and sex. Mothers and calves are generally the last to migrate in spring, and juveniles and adults often feed in different regions. Breaching and lobtailing are commonly observed in this species, although the function of these behaviors is unclear. Virtually nothing is known about the behavior of Bowheads during late fall and winter, when ice conditions and arctic darkness make observations impossible.

REPRODUCTION Females give birth every three to four years. The gestation period has never been

OPPOSITE TOP: *A Bowhead dives, showing its broad triangular tail.*
OPPOSITE BOTTOM: *Two Bowhead Whales surface next to ice floes. The prominent white chin patch is an identifying feature of these whales.*
LEFT: *A Bowhead raises its head above the surface in the open water of an ice lead.*

confirmed, but the best data suggest it lasts 13 to 14 months, with most calves born during the spring migration north. Weaning probably occurs when calves are 9 to 12 months old. Most conceptions are thought to occur in late winter or early spring, although mating behavior has been observed at other times of the year. Due to the male's unusually large testes, the mating system of the Bowhead Whale is thought to be based in part on sperm competition, involving a female mating with multiple males. Good evidence exists that, like Humpbacks, Bowhead males produce songs that may serve to advertise for females. These vocalizations are heard primarily in spring.

FOOD AND FORAGING Like right whales, Bowhead Whales are skim feeders; however, their diet is much more varied. Their primary prey are copepods and krill, and they also eat a wide variety of other invertebrates. More than 60 prey species have been identified in the stomachs of Bowheads killed by the Inuit hunt in Alaska. Bowheads are usually solitary while foraging, although they occasionally echelon feed together.

STATUS AND CONSERVATION Like the right whales, the Bowhead was the target of intensive whaling in the pre-modern era. Whaling for Bowheads began in the North Atlantic in the 16th century, with thousands of animals killed in waters from Spitsbergen Island to Labrador. The Bering-Chukchi-Beaufort population was first hunted in the mid-19th century, and the Sea of Okhotsk population was exploited shortly thereafter. Of the five populations recognized today, all but one remain highly endangered. The exception is the Bering-Chukchi-Beaufort population, estimated at more than 8,000 animals and steadily increasing despite continued hunting by Inuit. The Spitsbergen population is believed to be close to extinction, while the populations in Hudson Bay–Foxe Basin and Davis Strait–Baffin Bay may number a few hundred animals. The size of the Okhotsk Sea population is unknown but is probably at most a few hundred due to exploitation by the Soviet Union that continued into the 1960s. With the exception of the strictly managed Inuit hunt in Alaska, Bowheads are protected throughout their range.

Killer Whale

Orcinus orca
(Linnaeus, 1758)

MALE

FEMALE

- TALL, ERECT DORSAL FIN, MORE PROMINENT IN ADULT MALE
- LARGE ROUNDED FLIPPERS
- DISTINCTIVE BLACK-AND-WHITE COLOR PATTERN
- LARGE SIZE RELATIVE TO OTHER DOLPHINS
- COSMOPOLITAN DISTRIBUTION

The Killer Whale's exposure on television, in movies, and at oceanariums has made the species an icon. As recently as the 1960s, Killer Whales, also known as Orcas, were feared and persecuted; however, after a few individuals were brought into captivity and trained, the public's view of them became transformed. Today these whales are much loved. Killer Whales are among the best-known cetaceans, thanks mainly to the work of researchers based on the west coast of North America, who for more than three decades have studied the pods off Washington, British Columbia, and Alaska. The world population of Killer Whales seems to consist of specialized subpopulations, each adapted to live off the resources available within its home range. In this sense, Killer Whales are much like wolves. Some scientists believe that differences in morphology, genetics, ecology, and behavior among different groups of Killer Whales are a sufficient basis for establishing different races, subspecies, and perhaps even species.

DESCRIPTION The Killer Whale's body is extremely robust; it is the largest delphinid. The head is conical and lacks a well-defined beak. The dorsal fin, situated at midback, is large, prominent, and highly variable in shape: falcate in females and juveniles, erect and almost spike-like in adult males. On males, the dorsal fin can reach a height of 3 to 6 feet (1–1.8 m). The flippers are large, broad, and rounded, very different from the typically sickle-shaped flippers of most delphinids. There are 10 to 14 pairs of large pointed teeth in both the upper and lower jaws.

The color pattern consists of highly contrasting areas of black and white. The white ventral zone, continuous from lower jaw to anus, narrows between the all-black flippers and branches behind the umbilicus. The ventral surface of the flukes and adjacent portion of the caudal peduncle are also white. The back and sides are black, except for white patches on the flanks that rise from the uro-genital region and prominent oval white patches slightly above and behind the eyes. There is a highly variable, gray to white saddle marking on the back behind the dorsal fin.

RANGE AND HABITAT Considered the most widespread cetacean, the Killer Whale is truly cosmopolitan and is not limited by such habitat features as water temperature, or depth. It occurs in highest densities at high latitudes, especially in areas with an abundance of prey. Its movements generally appear to track those of favored prey species or to take advantage of pulses in prey abundance or vulnerability, such as during times and in areas of fish spawning and seal pupping. In the Antarctic during summer, most Killer Whales position themselves near the ice edge and in channels within the pack ice, where they prey on baleen whales, penguins, and seals. It is uncertain how far, or where, they migrate. Some may remain in antarctic waters year-round. In the Arctic, Killer Whales rarely move close along or into the pack ice. Researchers studying Killer Whales in Washington and British Columbia have identified "resident" and "transient" pods,

RANGE

KILLER WHALE
FAMILY DELPHINIDAE

MEASUREMENTS AT BIRTH		
LENGTH	7′3″–8′6″ (2.2–2.6 m)	
WEIGHT	About 350 lb (160 kg)	
MAXIMUM MEASUREMENTS		
LENGTH	**MALE**	30′ (9 m)
	FEMALE	26′ (7.9 m)
WEIGHT	**MALE**	At least 12,000 lb (5,600 kg)
	FEMALE	At least 8,400 lb (3,800 kg)
LIFE SPAN		
MALE	50–60 years	
FEMALE	80–90 years	

Killer Whales evoke strong responses from people in part because they are at once large, intimidating, and playful. Here a young breaching animal displays the species' broad flippers and white ventral markings, while a larger animal in the foreground shows the impressive dorsal fin and the distinctive light "saddle" marking on the back immediately behind the fin.

although both types of pod are present year-round. Some individuals occupy very large ranges. For example, photo-identification studies have shown that some Killer Whales move between Alaska and California. (The range map for this species shows areas where Killer Whales are known to occur but probably under-represents the total range of the species.)

SIMILAR SPECIES The Killer Whale is among the easiest of the cetaceans to identify. However, at a distance, the relatively prominent dorsal fins of the False Killer Whale and Risso's Dolphin can cause confusion. Both species overlap with Killer Whales in tropical and temperate waters.

BEHAVIOR The basic social unit of resident Killer Whales in Washington and British Columbia is the matrilineal group, consisting of two to four generations of two to nine related individuals. Matrilineal groups are stable over long periods, and all members may contribute to calf rearing. A number of groups that spend much of their time together constitute a pod. The largest resident pod in the area of Washington and British Columbia contains close to 60 individuals. Resident pods greet one another by facing off in two tight lines, then mingling in a relaxed manner, as if to reaffirm their social bonds. While adult females tend to be associated with one or more pods, adult males are sometimes solitary.

Killer Whales often breach, spyhop, and slap the surface with their flukes or flippers. They exhibit varied responses to vessels, ranging from indifference to curiosity. Mass strandings occur occasionally, and pods sometimes become trapped in tidal ponds or inlets. Wind-blown or fast-forming ice can be a hazard for Killer Whales in the Arctic and Antarctic, forcing them to remain in small pools of open water for prolonged periods.

REPRODUCTION In the resident population off Washington and British Columbia, calving occurs year-round, with a peak between autumn and spring. The average calving interval is five years. Females usually stop reproducing after about 40 years of age. Studies of whales in captivity suggest that gestation lasts 15 to 18 months. Although Killer Whales begin eating solid food at a very young age, they continue to nurse for at least a year and may not be fully weaned until close to two years of age.

RIGHT: *These spyhopping Killer Whales belong to one of the populations that visit or reside in inshore waters of Washington state and British Columbia.*
BELOW: *This group of Killer Whales includes three adult males, each of them readily identifiable by the tall, triangular dorsal fin. The animals in the center of the group are either females or juvenile males.*

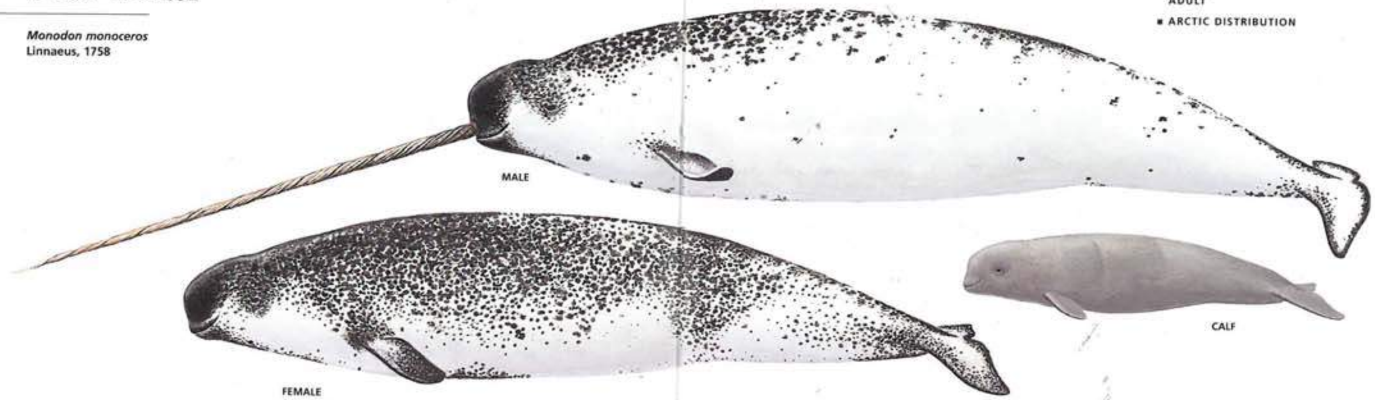
FOOD AND FORAGING Killer Whales eat a diet ranging from small schooling fish and squid to large baleen and sperm whales. Their prey items include sea turtles, otters, sirenians, sharks, rays, and even deer or moose, which they catch swimming across channels. Pods tend to specialize. For example, some depend largely on salmon, tuna, or herring, while others patrol pinniped haulouts or follow migratory whale populations, much as wolves follow caribou herds. Killer Whales obviously need to use cooperative hunting to harass and subdue large prey items, but they also cooperate to consolidate and maintain tight balls of baitfish, taking turns slicing through the schools to feed. Killer Whales also steal fish from longlines, scavenge on discarded fishery bycatch, and selectively eat the tongues of baleen whales. Prey may be strongly influenced by their fear of Killer Whales; pinnipeds flee from the water onto land or ice and whales and dolphins move into nearshore shallows or hide in cracks in pack ice.

STATUS AND CONSERVATION While as a species the Killer Whale is not endangered, whaling or live-capture operations have depleted some regional populations. Resident and transient populations off Washington and British Columbia number only in the low hundreds, and are threatened by pollution, heavy ship traffic, and possibly reduced prey abundance. There is concern that intensive whale-watching operations may influence the behavior of Killer Whales, and that the loud "seal-scarers" used to protect salmon pens from predation by pinnipeds may be driving Killer Whales away from their preferred inshore resting and foraging waters. About 8,500 Killer Whales are thought to occur in the eastern tropical Pacific, at least 850 in Alaskan waters, possibly close to 2,000 off Japan, and about 80,000 in the Antarctic during summer. Estimates from most other areas are in the hundreds or low thousands. Whalers in Japan, Indonesia, Greenland, and the West Indies continue to hunt Killer Whales; while the whales are killed in only small numbers, the effects of hunting on local populations could be substantial.

Narwhal

Monodon monoceros
Linnaeus, 1758

- LONG TUSK ON ADULT MALES
- SMALL ROUNDED HEAD WITH NO BEAK
- NO DORSAL FIN
- SPOTTED, BLACK-AND-WHITE DORSAL COLORATION IN ADULT
- ARCTIC DISTRIBUTION

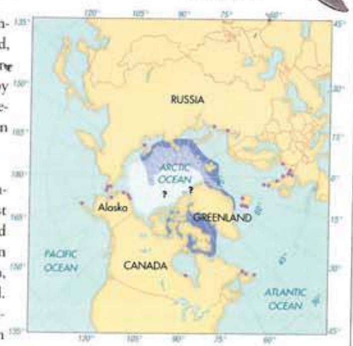


In the popular imagination, the Narwhal is inextricably linked with the fabled unicorn, and for good reason: The adult male's long, spiraled tusk came closer than anything else in nature to "proving" the unicorn's existence. In fact, from the Middle Ages onward, traders and chemists conspired to keep the existence of the Narwhal a secret, while selling its tusks as "unicorn horns" for immense profit. Although it is no longer linked to the mythical horned horse, the Narwhal is still a compelling creature because of the remoteness and harshness of its arctic environment as well as its unusual appearance. Thanks to the efforts of native local people and adventurous scientists equipped with powerful new high-tech tools, we are finally beginning to learn some of the details about the lives of Narwhals, even during the dark polar winter.

DESCRIPTION The Narwhal has a short rounded head with no beak. The melon is bluff, protruding somewhat forward of the small upturned mouth. The small flippers are broad but short. The flukes of adults are strongly convex on the rear margin; from an aerial perspective, they are reminiscent of butterfly wings. Like Belugas, Narwhals have no dorsal fin but rather a low fleshy ridge along the posterior half of the back. All Narwhals lack functional teeth inside the mouth, and most females remain essentially toothless throughout life. In males (and rarely females), the left of two upper-jaw teeth erupts through the lip at two or three years of age and keeps growing. The erupted portion of this tusk can be up to 9 feet (2.7 m) long, and the entire tusk can weigh more than 22 pounds (10 kg). In most cases, the surface of the tusk has a leftward spiral, but the axis is straight. Occasionally even the axis itself is twisted. The right tooth sometimes also erupts so that the animal is "double-tusked."

Adult Narwhals are spotted black and white on the back and upper sides. Old individuals can be almost completely white, with black areas limited to the center of the back, the top of the head, and the edges of the appendages. Newborn Narwhals are light gray but become almost black by the time they are weaned. Thereafter, they become mottled as white areas begin to appear on the belly and sides.

RANGE AND HABITAT Narwhals have a discontinuous arctic distribution. They are most abundant in deep waters that branch northward from the North Atlantic basin, especially Hudson Strait, northwestern Hudson Bay, Foxe Basin, Davis Strait, Baffin Bay, and Lancaster Sound. Another center of distribution is in the Greenland Sea, with small groups also occurring in parts of the northern Barents Sea. Their migrations are tuned to the formation and movement



NARWHAL
FAMILY MONODONTIDAE

MEASUREMENTS AT BIRTH

LENGTH	5′3″ (1.6 m)	
WEIGHT	176 lb (80 kg)	

MAXIMUM MEASUREMENTS

LENGTH	**MALE**	15′6″ (4.7 m)
	FEMALE	14′ (4.2 m)
WEIGHT	**MALE**	3,500 lb (1,600 kg)
	FEMALE	2,200 lb (1,000 kg)

LIFE SPAN
At least 25 years, possibly 50

Narwhals occasionally lift their flukes as they dive. The ornately curved flukes are distinctive in both color and shape.

of sea ice. As the ice disintegrates and breaks up in spring, Narwhals follow the receding edge of the pack ice and use small cracks and melt holes to penetrate deep sounds and fjords as quickly as possible. They reside in these areas throughout the summer and early fall. As the ice cover re-forms, they head for offshore wintering areas where the ice is constantly in motion, allowing them to find breathing space between the floes.

SIMILAR SPECIES The Beluga is the only species that might be confused with the Narwhal, primarily with females and juveniles since the tusk of adult male Narwhals is so distinctive. Belugas are either solid gray or white, never black, mottled, or spotted. Both species are fairly gregarious, and usually at least a few individuals within a group have readily identifiable features. Belugas can occur in all areas inhabited by Narwhals, and occasionally the two species are seen together. However, they normally do not form mixed groups or schools; both species tend to form large single-species concentrations, particularly in summer.

BEHAVIOR Narwhals often form large aggregations of several hundred animals during summer. Such aggregations, however, consist of smaller, fairly close-knit groups of a few up to about 20 individuals. These groups are typically homogeneous, consisting of animals of the same sex or a single age class. In winter while distributed in the pack ice, Narwhals seem to be more scattered and solitary, perhaps owing to the patchiness of cracks and holes in the ice. The presence of scars and wounds in the head region, and the high incidence of broken tusks, suggest that adult males fight one another. Such fighting could play a role in establishing dominance and thus access to mating opportunities. While Narwhals have been seen apparently crossing tusks above the surface, there is no concrete evidence that they fence with them. Polar Bears are known to kill Narwhals that are trapped in small pools of open water, and Killer Whales prey on them in their inshore summering areas. Although they do not mass strand like pilot whales, Narwhals are subject to catastrophic mortality from entrapment by wind-driven or fast-forming ice. The frequency and scale of such mortality are especially high in the Disko Bay region of West Greenland.

REPRODUCTION Narwhals mate during late winter and spring (peaking in April), when the animals are generally inaccessible for observation. Gestation lasts about 15 months, and most calves are born in summer (July–August, peaking around the first of August) when the animals are in fjords. Lactation and nursing lasts for at least a year, so the calving interval is at least two years and probably averages three.

FOOD AND FORAGING Narwhals are deep divers. They forage in the entire water column, taking pelagic fish (especially arctic cod), squid, and shrimp, as well as bottom-dwelling species such as Greenland halibut. Dives can last as long

As they migrate toward their summering areas in deep arctic fjords, Narwhals take advantage of cracks and leads in the pack ice, crowding one another for breathing space. The two individuals in the foreground appear to be young males, their tusks projecting forward for only a foot or two, and their dark bodies only beginning to whiten.

as 20 minutes and reach depths of more than 3,300 feet (1,000 m). Narwhals apparently suck prey into their mouth and swallow it whole. They do not use the tusk to spear fish.

STATUS AND CONSERVATION Narwhals have long been hunted by native peoples for food, oil, and ivory. The skin (called "maktaq," variously spelled) is considered a delicacy. Commercial whalers hunted Narwhals but generally only on a casual basis, as Bowhead Whales were their preferred quarry in the Arctic. For a brief period in the early 20th century, the Hudson's Bay Company purchased Narwhal skins and tusks for export (the former to be used to make soft leather gloves). Tusks continue to be profitable export items, and maktaq has high commercial value in northern towns in both Canada and Greenland. Population estimates based on aerial surveys are about 35,000 Narwhals in Baffin Bay, 1,400 in Hudson Strait, and 300 in Scoresby Sound (East Greenland). These numbers were not corrected to account for submerged animals, and the true range-wide abundance may be greater than 50,000. The principal known threat to Narwhal populations is hunting, particularly since it is now facilitated by fast motorized boats and high-powered rifles.

This aerial view of four Narwhals, taken in the eastern Canadian Arctic, shows many of the species' distinctive features, including the long spiraled tusk, the small rounded head, the mottled, black-and-white coloration, and the absence of a dorsal fin. The low dorsal ridge appears as a dark line along the middle of the back of the older whiter animals.

LEFT: *Largha Seals, also called Spotted Seals, are similar in body shape, size, and coloration to Harbor Seals, but Largha Seals haul out and breed principally on pack ice, compared to the terrestrial habitats preferred by Harbor Seals.* **RIGHT:** *Newborn Largha Seals also have a thick white lanugo pelage, which is shed when they are about three to four months old, revealing the adult spotted color pattern.*

in the open ocean, their behavior is virtually unstudied. They may occur in well-spaced family groups on the sea ice during the breeding season in spring.

REPRODUCTION Largha Seals are thought to be seasonally monogamous. During the breeding season, they are most often seen well spaced out on the ice in triads consisting of an adult female, her pup, and an adult male. Females give birth on the surface of ice floes from January through mid-April, with a peak in mid- to late March. Males are thought to join a female and her pup about a week after pupping, and the group remains together until the pup is weaned at three to four weeks old, at which time mating occurs and the male leaves the group. This system limits the mating opportunities of males during a breeding season; however, males that mate early in the season may later find an unattended female-pup pair or may displace another male from a triad. Mating evidently takes place in the water.

FOOD AND FORAGING Adults and juveniles eat a variety of schooling fish (pollock, capelin, arctic cod, and herring), epibenthic fish (especially flounder, halibut, and sculpin), and crabs and octopus at depths of up to 1,000 feet (300 m). Weaned pups apparently mostly eat amphipods, krill, and other small crustaceans.

STATUS AND CONSERVATION Native peoples along the eastern Russian coast and in Alaska have traditionally killed small numbers of Largha Seals for subsistence. The Soviet Union made some commercial harvests from the 1930s through the 1980s in the Sea of Okhotsk and the western Bering Sea, and Japan also commercially hunted these seals in the Sea of Okhotsk at times. Largha Seals occasionally drown in fishing nets set in coastal waters of northern Hokkaido, Japan. Population abundance is poorly known but has been estimated at around 350,000 to 400,000, with about half of the seals living in the Bering and Chukchi Seas.

Ringed Seal

Pusa hispida
(Schreber, 1775)

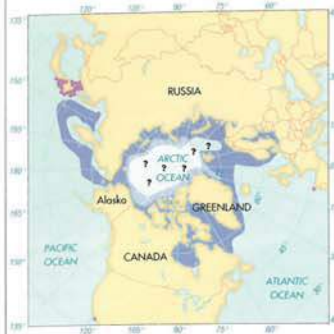
- DARK DORSAL PELAGE WITH SCATTERED, IRREGULAR LIGHT RINGS AND DARK BACKGROUND
- SMALLEST TRUE SEAL NEXT TO BAIKAL SEAL
- EXCAVATES BIRTH LAIRS BENEATH ICE SURFACE
- DISTRIBUTION CLOSELY ASSOCIATED WITH LANDFAST AND PACK ICE
- WIDELY DISPERSED IN ARCTIC BASIN AND BERING, OKHOTSK, JAPAN, AND BALTIC SEAS

The smallest and most common seals in the Arctic Ocean and the Bering and Baltic Seas, Ringed Seals have long been important prey for native inhabitants of the Arctic. They are also the top prey of Polar Bears, and during the breeding season, Ringed Seals excavate birth lairs in ice and snow to protect themselves against this predation. The Baikal Seal is the only other pinniped known to use such structures for giving birth and raising pups. Scientists recognize five subspecies of the Ringed Seal, including two freshwater populations. The Ringed Seal was formerly included in the genus *Phoca* along with the Baikal and Caspian Seals. However, taxonomists have recently reinstated these three species to the genus *Pusa*, which is derived from the common name for the Ringed Seal used by the Inuit of Greenland and various eastern North Atlantic cultures. The specific name is derived from the Latin word *hispidus*, meaning "hairy" or "bristly," and refers to the adult pelage, which is often stiffer than that of other phocid pinnipeds. The common name refers to the scattered irregular rings on the pelage.

DESCRIPTION The Ringed Seal has a small plump body and a small head. The snout is narrow, short, and cat-like. The flippers are small, with short slender claws on the hindflippers and robust claws on the foreflippers that may be more than an inch long. There are nine pairs of teeth in the upper jaw and eight pairs in the lower jaw.

The pelage of adults is dark dorsally with scattered irregular rings, and lighter and less ringed ventrally. Newborn pups have a woolly, white lanugo coat that they shed at about six to eight weeks old to reveal an unspotted pelage that is uniformly dark silver or gray dorsally and light silver ventrally. The ringed pattern develops at the first annual molt when seals are a little more than one year old.

RANGE AND HABITAT Ringed Seals have a circumpolar distribution throughout the Arctic Ocean, Hudson Bay, and Baltic and Bering Seas. They are closely associated with sea ice. In summer they often occur along the receding ice edge and farther north in denser pack ice. Five subspecies are recognized. The most widely dispersed form, *Pusa hispida hispida*, occurs in the Arctic Basin. *P. h. ochotensis* occurs in the Sea of Okhotsk and the Sea of Japan, and *P. h. botnica* occurs in the Baltic Sea. Freshwater populations



RINGED SEAL
FAMILY PHOCIDAE

MEASUREMENTS AT BIRTH
LENGTH 26" (60–65 cm)
WEIGHT 9–11 lb (4–5 kg)

MAXIMUM MEASUREMENTS
LENGTH 5'3" (1.6 m)
WEIGHT 240 lb (110 kg)

LIFE SPAN
25–30 years

RANGE
? POSSIBLE RANGE
VAGRANTS

include *P. h. saimensis* in Lake Saimaa in eastern Finland and *P. h. lagodensis* in Lake Ladoga, Russia. Vagrants from the marine populations have ranged as far south as Portugal in the Atlantic Ocean and California in the Pacific.

SIMILAR SPECIES Harbor, Harp, Hooded, Gray, Bearded, Ribbon, and Largha Seals may occupy similar habitats in various parts of the Ringed Seal's range. All but Harbor and Largha Seals can be readily distinguished by their body and head morphology and pelage patterns. Largha Seals, which may overlap in the Bering, Okhotsk, and Japan Seas, have a spotted rather than a ringed pelage pattern and are larger but more slender than Ringed Seals, with relatively longer, wider snouts. Harbor Seals prefer ice-free habitats and are rarely seen in ice.

BEHAVIOR Though there are areas of high density of Ringed Seals through the Arctic, these seals do not aggregate in large groups. Rather, they are largely solitary and space out from one another by hundreds of yards or more. During the breeding season, triads of an adult female, her pup, and an adult male form short-term family groups. These groups are not easily observed, however, as the seals remain in lairs in the ice and snow excavated by the females for pupping and nursing. The excavation of lairs in and under sea and lake ice is unique to Ringed Seals and is evidently an adaptation for escaping predation by Polar Bears. Some lairs are quite complex, with several chambers. Females evidently leave pups in the lairs for short periods while they forage nearby. Throughout winter, Ringed Seals maintain breathing holes by chewing away newly formed ice. Individuals may favor particular breathing holes, perhaps excluding other seals from loosely associated underwater territories. Ringed Seals molt in June and July; while molting, they spend more time basking on the surface of the ice than in other seasons. Ringed Seals are the primary prey of Polar Bears, and are also occasionally eaten by Walruses and Killer Whales.

REPRODUCTION The breeding system of the Ringed Seal is thought to be either mildly polygynous or serially monogamous, but is not well known because of the difficulty in finding and observing seals during the breeding season. Females excavate lairs in the pressure ridges or accumulated snow on sea or lake ice, and in Lake Saimaa in snowdrifts along the shoreline. They give birth in March and April in most areas, a little earlier in the Baltic Sea. Pups are weaned and mating occurs between April and May. Males evidently patrol under the ice searching for receptive females. They may stay with a female for several days until they mate, and then return to the water to patrol for another potential mate.

FOOD AND FORAGING When feeding along the sea-ice edge in summer, Ringed Seals eat mostly polar cod, even though the potential prey biomass there is dominated by pelagic crustaceans. The seals evidently selectively choose these prey, which represent about only 1 percent of the fish and crustacean biomass. In these areas, Ringed Seals eat smaller cod, evidently at shallower depths than the sympatric Harp Seals. Most dive depths for *P. h. hispida* are 35 to 150 feet (10–45 m) for sexually mature males, and 330 to 475 feet (100–145 m) for subadult males and postpartum females. Most dives last about 4 minutes for adult males and 7½ minutes for adult females. The longest dive recorded is about 23 minutes, although the seal may actually have been resting on the sea bottom rather than feeding.

STATUS AND CONSERVATION Ringed Seals have been key subsistence prey for native arctic peoples, who hunt them for food for humans and dogs as well as for skins to make clothing. Levels of PCBs are higher in seals taken by subsistence hunters in the European and Russian Arctic than in other arctic regions. These higher levels are thought to be due to continued use of PCBs in Russian electrical equipment. Though never completely surveyed, the species may number as many as 4 million. Ringed Seals in the Baltic Sea are considered to be at risk because of heavy pollution, which affects the seals' immune systems and reproductive success. Although about half of the Ringed Seals in Lake Saimaa breed in coastal areas located within national parks, poaching and threats associated with fisheries in other parts of the lake seriously threaten this small population.

OPPOSITE: *Ringed Seals have a robust body and small head and foreflippers. The dark pelage background with scattered light rings is characteristic of the species.* **RIGHT:** *Ringed Seals are the primary prey of Polar Bears and so are extremely wary when surfacing in their breathing holes, which may be staked out by patient, hungry bears. Ringed Seals maintain these breathing holes by abrading the ice with their canine teeth.*

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APPENDIX B

Daily Summary

Date	Daily Activities	
23-Jul-17	Golder team fly to Ottawa, ON and stay in Hotel. Sarah Proctor (SP), Phil Rouget (PR), Ainsley Allen (AA), Mitch Firman (MF), Julia Krizan (JK)	
24-Jul-17	Golder team arrives in Pond Inlet late due to flight electrical issues.	
25-Jul-17	Bruce Head training day with HTO Inuit employees at the Sauniq hotel, Pond Inlet, NU.	
26-Jul-17	Travel from Pond Inlet to Mary River Mine. JK returns home to Edmonton, SK. Team flight is delayed due to low cloud ceiling at Mary River Mine. Crew fly out at 6 pm with Inuit assistants: Elisha Kasarnak (EK), Nicholas Kasarnak (NK), Adrian Ootoova (AO), Johnny Takawgak (JT). Bus ride from Mine site to Milne Port at 1 am.	
27-Jul-17	Mary River site orientation in the morning. Weather day, as flight not possible from Port to Bruce Head due to low cloud ceiling.	
28-Jul-17	Max Bakken (MB, camp manager) and Golder/HTO staff fly to Bruce head (AA, MF, SP, PR, AO, JT, EK, NK).	
29-Jul-17	Equipment set up (AIS station, MOTE station, Bruce Head equipment).	
30-Jul-17	Equipment set up (AIS station, MOTE station, Bruce Head equipment). Crew hike to the observation platform to establish survey protocol and substrata visual delineation.	
31-Jul-17	Observation period:	10:00 - 16:00
	Total survey time:	6:00 hrs
	Weather:	Beaufort 3, Sightability Moderate. Survey ended due to high winds.
	Narwhal presence:	Behavioural Study Area (BSA) & Stratified Study Area (SSA)
	Narwhal herding event:	Traveling South (number observed [1])
	Other marine mammals:	Unidentified seal, bearded seal
	RAD surveys:	8
	Vessels observed:	None
	Other anthropogenic activities:	None observed, but heard via radio communication that hunting occurred north of Bruce Head.
	Shooting observed:	None
1-Aug-17	Observation period:	11:00 - 17:45
	Total survey time:	6:45 hrs
	Weather:	Beaufort 1, Sightability Excellent for most of the day.
	Narwhal presence:	SSA only
	Narwhal herding event:	None
	Other marine mammals:	unidentified seal, ringed seal, bearded seal
	RAD surveys:	7
	Vessels observed:	Small vessel
	Other anthropogenic activities:	Small vessel parked at Bruce Head shore camp, helicopter travel.
	Shooting observed:	None
2-Aug-17	Observation period:	10:00 - 17:30
	Total survey time:	7:30 hrs
	Weather:	Beaufort 0-1, Sightability Excellent.
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	None
	Other marine mammals:	unidentified seal, ringed seal, harp seal
	RAD surveys:	8
	Vessels observed:	Small vessel
	Other anthropogenic activities:	Small vessel parked at Bruce Head shore camp, helicopter travel.
	Shooting observed:	None
3-Aug-17	Observation period:	10:10 - 17:40
	Total survey time:	7:30 hrs
	Weather:	Beaufort 0, Sightability Excellent.
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	None
	Other marine mammals:	seal, ringed seal
	RAD surveys:	9
	Vessels observed:	Multiple large vessel
	Other anthropogenic activities:	Helicopter travel.
	Shooting observed:	None
4-Aug-17	Observation period:	10:10 - 17:15
	Total survey time:	7:05 hrs
	Weather:	Beaufort 0-1, Sightability Excellent
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1), then northbound
	Other marine mammals:	seal, harp seal, ringed seal
	RAD surveys:	7
	Vessels observed:	Multiple large vessel and small vessels
	Other anthropogenic activities:	Small vessel parked at Bruce Head shore camp.
	Shooting observed:	2 shooting events
5-Aug-17	Observation period:	10:30 - 17:35
	Total survey time:	7:05 hrs
	Weather:	Beaufort 1-2, Sightability Excellent
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	None
	Other marine mammals:	Unidentified seal
	RAD surveys:	8
	Vessels observed:	Multiple small vessels
	Other anthropogenic activities:	Small vessel parked at Bruce Head shore camp, several small vessels were pulled onto a large ice floe, helicopter travel.
	Shooting observed:	None

Date	Daily Activities	
6-Aug-17	Observation period:	10:00 - 17:40
	Total survey time:	7:40 hrs
	Weather:	Beaufort 1-3, Sightability Good to Excellent, some ice floe
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1)
	Other marine mammals:	unidentified seal, ringed seal
	RAD surveys:	8
	Vessels Observed:	Small vessel
	Other anthropogenic activities:	Small vessel parked at Bruce Head shore camp
	Shooting Observed:	None
7-Aug-17	Observation period:	10:05 - 17:30
	Total survey time:	7:25 hrs
	Weather:	Beaufort 1-3, Sightability Good to Excellent, large ice floe obscuring large parts of substrata
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	None
	Other marine mammals:	Unidentified seal, ringed seal, harp seal
	RAD surveys:	8
	Vessels observed:	Multiple small vessel
	Other anthropogenic activities:	Hunters set up at Bruce Head shore camp with a rifle ready to fire for the duration of the survey day
	Shooting observed:	None
8-Aug-17	Observation period:	10:39 - 17:35
	Total survey time:	7:04 hrs
	Weather:	Beaufort 1-2, fog/low cloud conditions in the morning obscured sightability at times, but otherwise Sightability Good to Excellent
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1)
	Other marine mammals:	Unidentified seal
	RAD surveys:	7
	Vessels observed:	Multiple large and small vessels
	Other anthropogenic activities:	Small vessel parked at Bruce Head shore camp, helicopter travel.
	Shooting observed:	None
9-Aug-17	Observation period:	10:15 - 17:00
	Total survey time:	6:45 hrs
	Crew change:	AA and NK left in the morning. Rob Hollingshead (RH), Trish Tomlison (TT), and Alex Penney (AP) arrived in the evening. New Inuit crew did not arrive, therefore EK, AO, and JT asked to stay another week. Health and Safety kick-off held for new crew.
	Weather:	Beaufort 1-2, Sightability Good. Light rain. Survey ended due to fog, wind, and rain.
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1)
	Other marine mammals:	None
	RAD surveys:	7
	Vessels observed:	Large and small vessel
	Other anthropogenic activities:	Helicopter travel.
	Shooting observed:	None
10-Aug-17	Observation period:	10:26 - 18:30
	Total survey time:	7:56 hrs
	Crew change:	MF, SP, and JT leave camp
	Weather:	Beaufort 2-3, Sightability Good
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	None
	Other marine mammals:	Ringed seal
	RAD surveys:	5
	Vessels observed:	Large and small vessel
	Other anthropogenic activities:	Small vessel parked at Bruce Head shore camp, helicopter travel.
	Shooting observed:	None
11-Aug-17	Observation period:	9:10 - 18:15
	Total survey time:	9:05 hrs
	Weather:	Beaufort 0-1, Sightability Good to Excellent
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1)
	Other marine mammals:	Bowhead whale, unidentified seal, bearded seal
	RAD surveys:	8
	Vessels observed:	Large vessel and multiple small vessels.
	Other anthropogenic activities:	Several small vessels parked at Bruce Head shore camp, helicopter travel.
	Shooting observed:	5 shooting events
12-Aug-17	Observation period:	9:10 - 18:00
	Total survey time:	8:50 hrs
	Weather:	Beaufort 1-2, Sightability Good to Excellent
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Northbound (1) switched direction to Southbound (1)
	Other marine mammals:	None
	RAD surveys:	8
	Vessels observed:	Large vessel and multiple small vessels.
	Other anthropogenic activities:	Small vessel parked at Bruce Head shore camp.
	Shooting observed:	2 shooting events, 1 narwhal killed.

Date	Daily Activities	
13-Aug-17	Observation period:	9:19-14:40
	Total survey time:	5:21 hrs
	Weather:	Beaufort 1-3, Sightability Moderate to Poor. Survey day ended due to high winds.
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1)
	Other marine mammals:	Unidentified seal
	RAD surveys:	5
	Vessels observed:	Multiple small vessels
	Other anthropogenic activities:	None
	Shooting observed:	None
14-Aug-17	Observation period:	NA - Weather day
	Total survey time:	0:00 hrs
	Weather:	Severe wind and ocean conditions had too many whitecaps, visible from camp.
15-Aug-17	Observation period:	16:55 - 18:30
	Total survey time:	1:35 hrs
	Crew change:	AP and AO left in the afternoon.
	Weather:	Beaufort 3-4, but subsided slightly in the afternoon to survey during an ore carrier transit
	Narwhal presence:	0
	Narwhal herding event:	None
	Other marine mammals:	Ringed seal
	RAD surveys:	0 (limited staff due to crew change, prioritized BSA during vessel transit)
	Vessels observed:	Large vessel
	Other anthropogenic activities:	None
	Shooting observed:	None
16-Aug-17	Observation period:	10:40 - 14:25 and 18:50 - 19:50
	Total survey time:	3:45
	Crew change:	Nicklas, Cornelius, Dave arrive in afternoon, also SP (MEEMP program) and Fran (DFO). Beacause MB (camp manager) was acting as only bear monitor, crew had to break survey day to receive new crew arrival at camp. Health and Safety kick-off held for new crew.
	Weather:	Beaufort 1, Sightability Good to Excellent
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	None
	Other marine mammals:	Unidentified seals
	RAD surveys:	4
	Vessels observed:	Large vessel and multiple small vessels
	Other anthropogenic activities:	None
	Shooting observed:	None
17-Aug-17	Observation period:	10:50 - 18:00
	Total survey time:	6:45 hrs
	Crew change:	Survey interupted for 25 min. Crew ended earlier than planned due to crew fatigue.
	Weather:	Beaufort 1-3, Sightability Good to Moderate
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1)
	Other marine mammals:	Unidentified seal
	RAD surveys:	4
	Vessels observed:	Multiple small vessels
	Other anthropogenic activities:	Small vessel parked at Bruce Head shore camp, Helicopter travel.
	Shooting observed:	3 shooting events.
18-Aug-17	Observation period:	NA - Weather day
	Total survey time:	0:00 hrs
	Weather:	Beaufort 5, not surveyable. Crew hiked to observation platform and returned to Camp.
19-Aug-17	Observation period:	10:25 - 18:27
	Total survey time:	8:02 hrs
	Weather:	Beaufort 1-2, Sigthability Moderate to Excellent
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1)
	Other marine mammals:	Unidentified seal, ringed seal
	RAD surveys:	7
	Vessels observed:	Large vessel and multiple small vessels
	Other anthropogenic activities:	Various small vessels parked at Bruce Head camp.
	Shooting observed:	2 shooting events.
20-Aug-17	Observation period:	11:10 - 19:00
	Total survey time:	7:50 hrs
	Weather:	Beaufort 1, Sightability Good to Excellent.
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1)
	Other marine mammals:	Unidentified seal, bearded seal
	RAD surveys:	6
	Vessels observed:	Multiple large and small vessels
	Other anthropogenic activities:	Various small vessels parked at Bruce Head camp.
	Shooting observed:	1 shooting event
21-Aug-17	Observation period:	10:55 - 18:00
	Total survey time:	7:05 hrs
	Weather:	Beaufort 2-3, Sightability Good to Excellent
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1)
	Other marine mammals:	None
	RAD surveys:	6
	Vessels observed:	Multiple small vessels
	Other anthropogenic activities:	Various small vessels parked at Bruce Head camp.
	Shooting observed:	6 shooting events, 1 narwhal killed

Date	Daily Activities	
22-Aug-17	Observation period:	10:00 - 18:00
	Total survey time:	8:00 hrs
	Weather:	Beaufort 0-1, Sightability Moderate to Excellent
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (2)
	Other marine mammals:	Seal
	RAD surveys:	6
	Vessels observed:	Multiple small vessels
	Other anthropogenic activities:	Various small vessels parked at Bruce Head camp.
	Shooting observed:	14 shooting events, 1 narwhal killed
23-Aug-17	Observation period:	10:10 - 11:38 (Weather Day)
	Total survey time:	1:28 hrs
	Crew change:	Megan Lord-Hoyle (MLH) arrives at camp.
	Weather:	Beaufort 2-5, Sightability Moderate. Survey day ended due to weather.
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	None
	Other marine mammals:	None
	RAD surveys:	1
	Vessels observed:	None
	Other anthropogenic activities:	Small vessel parked at Bruce Head camp.
	Shooting observed:	None
24-Aug-17	Observation period:	7:55 - 16:10
	Total survey time:	8:15 hrs
	Crew change:	MLH left camp in the late morning.
	Weather:	Beaufort 1-3, Sightability Poor to Excellent
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1)
	Other marine mammals:	Unidentified seal, ringed seal
	RAD surveys:	7
	Vessels observed:	Multiple large and small vessels
	Other anthropogenic activities:	Various small vessels parked at Bruce Head camp, helicopter travel.
	Shooting observed:	3 shooting events.
25-Aug-17	Observation period:	10:10 - 16:40
	Total survey time:	6:30 hrs
	Crew change:	DK leaves camp.
	Weather:	Beaufort 1-2, Sightability Moderate to Excellent
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1)
	Other marine mammals:	Unidentified seal
	RAD surveys:	5
	Vessels observed:	Large vessel and multiple small vessels
	Other anthropogenic activities:	Various small vessels parked at Bruce Head camp, helicopter travel.
	Shooting observed:	3 shooting events, 1 narwhal killed.
26-Aug-17	Observation period:	10:10 - 16:50
	Total survey time:	6:40 hrs
	Weather:	Light to no wind, periods of light rain and fog, Beaufort 1, Sightability Good to Excellent. Survey day ended due to rain and reduced visibility
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	None
	Other marine mammals:	Unidentified seal
	RAD surveys:	6
	Vessels observed:	Large vessel, medium vessel, and multiple small vessels
	Other anthropogenic activities:	Various small vessels parked at Bruce Head camp, boat-based hunting.
	Shooting observed:	13 shooting events, 1 narwhal killed
27-Aug-17	Observation period:	NA - Weather day
	Total survey time:	0:00
	Weather:	Thick and heavy low clouds, fog, and rain surrounding the Bruce Head camp.
28-Aug-17	Observation period:	11:15 - 14:50
	Total survey time:	3:35 hrs
	Weather:	Light rain and low cloud/fog obscuring visibility at times, Wind none to severe, Beaufort 2, Sightability Good to Poor. Survey day ended due to severe wind and cold.
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	None
	Other marine mammals:	Unidentified seal
	RAD surveys:	2
	Vessels observed:	Large vessel
	Other anthropogenic activities:	None
	Shooting observed:	None
29-Aug-17	Observation period:	14:10 - 16:20
	Total survey time:	2:10 hrs
	Weather:	Beaufort 3-4, Sightability Moderate to Impossible. Crew had to wait for snow flurries to subside before starting survey, and ended survey day due to severe wind impairing ability to hold binoculars.
	Narwhal presence:	BSA & SSA
	Narwhal herding event:	Southbound (1)
	Other marine mammals:	None observed
	RAD surveys:	2
	Vessels observed:	Large vessel
	Other anthropogenic activities:	Small vessel parked at Bruce Head camp.
	Shooting observed:	2 shooting events. Hunters came to visit the observation platform and informed that a narwhal had been killed (and sunk) prior to survey start time.
30-Aug-17	HTO staff travel by helicopter to Mary River Mine then community flight to Pond Inlet. Golder crew demobilized equipment from observation platform and package for shipping. MB and RH fly in helicopter to Tremblay MOTE station to secure for over winter.	
31-Aug-17	Remaining Bruce Head staff fly to Mary River Mine for evening charter flight to Montreal. Flight was postponed 24 hours due to weather conditions.	
1-Sep-17	Golder crew on standby at Mary River Mine until the evening charter flight to Mirabel.	
2-Sep-17	Golder crew arrived in Mirabel at 2 am and transit home to Victoria.	

APPENDIX C

Modeling Results

1.0 RELATIVE ABUNDANCE AND DISTRIBUTION OF NARWHAL

Analysis of RAD data included two steps – 1) analysis of presence / absence of narwhal in the SSA; and 2) for surveys with presence of narwhal, analysis of narwhal counts in the SSA. The model structure for both components was similar. Both models included effects of day of year, stratum, substratum within stratum, sightability, number of small vessels in the SSA, categorical variable for absence of large vessels within 15 km from the centroid of substrata, distance between large vessel and the centroid, orientation of the vessel to the centroid (approaching/departing), whether the vessel was entering or exiting Milne Inlet, and interactions between vessel distance and approaching/departing substrata, between approaching/departing substrata and entering/exiting Milne Inlet, and between vessel distance and entering/exiting Milne Inlet.

In both the binomial (presence / absence) and the negative binomial (positive counts) models of narwhal presence/absence, day of year, stratum, substratum within stratum, sightability, absence of large vessels within 15 km from the centroid, and the interaction between vessel distance and whether it was approaching or departing the centroid were all significant (Table C-1, Table C-2). The number of small vessels in the SSA was not a significant predictor of presence/absence or positive counts of narwhal. None of the parameters that included enter/exit effects were statistically significant (i.e., interaction between distance and entering/exiting Milne Inlet, interaction between entering/exiting Milne Inlet and approaching/departing substrata, and the main effect of enter/exit). This suggests that large vessel travel direction in Milne Inlet did not affect narwhal absence / presence or narwhal counts in the SSA.

The negative binomial model of narwhal positive counts estimated a significant, third degree polynomial effect of day of year on narwhal counts, capturing the bimodal distribution of counts during the 2017 Program (Figures 5-11, 5-12). The model estimated increasing counts of narwhal per stratum in the southward direction. The incidence rate ratios for strata B-E, while predicting increases of 13-38% in narwhal counts relative to stratum A, were not significantly different from stratum A (the 95% CIs of the incidence rate ratios overlapped 1). Strata F, G, H, and I were estimated to have the highest counts of narwhal per substratum, with substratum I counts 2.1 times higher than those estimated for substratum A. While substratum "3" had lower predictions of narwhal counts than substratum "1", as expected, the effect was not significant (*P* value of 0.928). This likely indicates that observers correctly classify visibility as lower when recording observations from the farthest substratum. On the other hand, the intermediate substratum, substratum "2", had significantly different odds ratio from the nearest substratum, with a 33% increase in odds of narwhal presence. Poor sightability had a significant effect on estimated narwhal counts (reduction of estimates by 36% relative to excellent sightability), while both good and medium sightability conditions were not significantly different from the reference level of excellent sightability. The only significant interaction of the three interactions included in the model was for vessel distance × whether the vessel was approaching or departing the substrata. This suggests that the effect of distance on narwhal counts did not depend on whether vessels were exiting or entering Milne Inlet.

The vessel distance × approaching / departing interaction was significant, likely due the increase in narwhal counts when entering / departing vessels were at approximately 6-9 km away from substrata (Figure 5-14) – a pattern opposite that recorded for approaching vessels. The absence of large vessels within 15 km from the substrata was not significantly different from the reference level (a vessel exiting Milne Inlet, approaching the substrata, at 0 km from the substratum; Table C-1). This may indicate a spurious finding or that the largest effect of vessel presence on narwhal counts is observed at a distance larger than 0 km from the substrata.

The logistic model of narwhal presence/absence estimated a significant, second degree polynomial effect of day of year on narwhal presence (Table C-2). The model estimated increasing odds of narwhal presence in the southward direction. The odds of narwhal presence in strata B and C were not significantly different from those for stratum A. From stratum D and onwards, the odds of narwhal presence were significantly different from those for stratum A, with odds increasing by a factor of 1.1, 2.0, 3.1, and 3.3 for strata D-F. Strata G, H, and I had very high odds ratios, predicting odds of narwhal presence than are 12, 18, and 26 times those of stratum A. However, all three of these strata had wide 95% CIs, indicating high uncertainty. Interestingly, while the negative binomial model of narwhal counts did not identify a significant effect of substratum "3", the logistic model results indicated that the odds of observing narwhal in the farthest substratum were significantly different than those in the nearest substratum. The odds of narwhal presence in the farthest substratum were 69% lower than in the nearest substratum. Similar to the negative binomial model findings, the odds ratio for substratum "2" was statistically significant, with a 32% increase in odds of narwhal presence in substratum 2 relative to substratum "1". As opposed to the negative binomial model, none of the effects related to large vessel traffic were significant in the logistic model of presence/absence of narwhal in the SSA.

Table C-1: Exponentiated coefficients estimates (incidence rate ratios) and their lower (LCI) and upper (UCI) 95% confidence intervals from negative binomial regression of narwhal counts in the SSA.

Parameter	Estimate	LCI	UCI	*P* value
Intercept (Excellent sightability, stratum A, substratum "1", a large vessel, exiting Milne Inlet and approaching the centroid is present at 0 km from the centroid)	6.84	2.76	16.93	<0.001
Day of year	1.04	1.00	1.08	0.038
Day of year²	1.00	1.00	1.01	0.011
Day of year³	1.00	1.00	1.00	0.011
Stratum B	1.13	0.79	1.64	0.507
Stratum C	1.21	0.84	1.72	0.312
Stratum D	1.29	0.91	1.82	0.152
Stratum E	1.38	1.00	1.91	0.054
Stratum F	1.41	1.02	1.95	0.041
Stratum G	1.70	1.25	2.32	0.001
Stratum H	1.50	1.11	2.03	0.010
Stratum I	2.11	1.56	2.86	<0.001
Substratum 2	1.32	1.15	1.53	<0.001
Substratum 3	0.99	0.81	1.21	0.928
Good sightability	0.99	0.83	1.18	0.937
Medium sightability	0.89	0.71	1.11	0.306
Poor sightability	0.64	0.45	0.91	0.013
Number of small vessels in the SSA	1.00	0.92	1.09	0.922
Absence of large vessel within 15 km from the centroid	0.62	0.27	1.42	0.261
Distance between large vessel and centroid	0.86	0.68	1.10	0.236
Distance²	1.01	0.99	1.02	0.230
Large vessel departing the centroid	0.31	0.12	0.80	0.017
Large vessel entering Milne Inlet	0.66	0.21	2.08	0.485
Vessel distance x Large vessel departing the centroid	1.44	1.08	1.92	0.014
Distance² x Large vessel departing the centroid	0.98	0.96	1.00	0.020

Parameter	Estimate	LCI	UCI	*P* value
Vessel distance x Large vessel entering Milne Inlet	1.06	0.78	1.45	0.693
Distance² x Large vessel entering Milne Inlet	1.00	0.98	1.01	0.634
Large vessel entering x Large vessel departing	1.27	0.68	2.39	0.459

Table C-2: Odds ratios and their lower (LCI) and upper (UCI) 95% confidence interval from logistic regressions of narwhal presence / absence in the SSA.

Parameter	Estimate	LCI	UCI	*P* value
Intercept (a large vessel, exiting Milne Inlet and approaching the centroid is present at 0 km from the centroid)	0.20	0.03	1.16	0.073
Day of year	1.20	1.12	1.28	<0.001
Day of year²	0.98	0.98	0.99	0.001
Stratum B	0.83	0.56	1.23	0.362
Stratum C	1.13	0.76	1.68	0.549
Stratum D	2.04	1.37	3.04	0.001
Stratum E	3.06	2.10	4.47	<0.001
Stratum F	3.28	2.24	4.79	<0.001
Stratum G	11.89	8.08	17.49	<0.001
Stratum H	18.27	12.41	26.90	<0.001
Stratum I	26.04	17.64	38.42	<0.001
Substratum 2	1.32	1.07	1.63	0.010
Substratum 3	0.31	0.23	0.41	<0.001
Good sightability	0.70	0.53	0.92	0.011
Medium sightability	0.48	0.34	0.70	<0.001
Poor sightability	0.20	0.12	0.34	<0.001
Number of small vessels in the SSA	1.08	0.85	1.37	0.525
Absence of large vessel within 15 km from the centroid	1.65	0.34	8.12	0.536
Distance between large vessel and centroid	1.15	0.77	1.72	0.498
Distance²	1.00	0.97	1.02	0.832
Large vessel departing the centroid	1.20	0.27	5.40	0.813
Large vessel entering Milne Inlet	0.19	0.02	1.60	0.127
Vessel distance x Large vessel departing the centroid	1.11	0.71	1.73	0.644
Distance² x Large vessel departing the centroid	0.98	0.96	1.01	0.264
Vessel distance x Large vessel entering Milne Inlet	0.94	0.57	1.55	0.811
Distance² x Large vessel entering Milne Inlet	1.01	0.98	1.04	0.448
Large vessel entering x Large vessel departing	1.12	0.34	3.61	0.856

Predicted narwhal counts accounted for the probability of narwhal presence, estimated via the logistic regression, and for the estimates of narwhal counts from the negative binomial model of positive counts. Reflecting the odds ratios and incidence ratio rates detailed above, predicted counts were lowest at the northern strata, at substratum “3”, and under poor visibility (Figure C-1). This result highlights the effect of sightability on the observers’ ability to identify narwhal. The reduced numbers of narwhal at substratum “3” may be due to the difficulty of reliably identifying narwhal at a distance, but it may also represent a spatial distribution effect. If only effects of sightability reduction due to distance were affecting narwhal counts, it would have been expected to have highest counts at substratum “1”, intermediate counts at substratum “2”, and low counts at the farthest substratum. Instead, substratum “2” had both higher predicted counts and odds of narwhal presence (Table C-1, Table C-2), resulting in elevated counts relative to substratum “1” (Figure C-1). This finding may be due to differences in substratum sizes (since many of the “1” substrata were small) or a spatial effect of narwhal distribution across Milne Inlet. A model of narwhal density, rather than total counts, would provide insight into spatial differences in narwhal densities in the SSA.

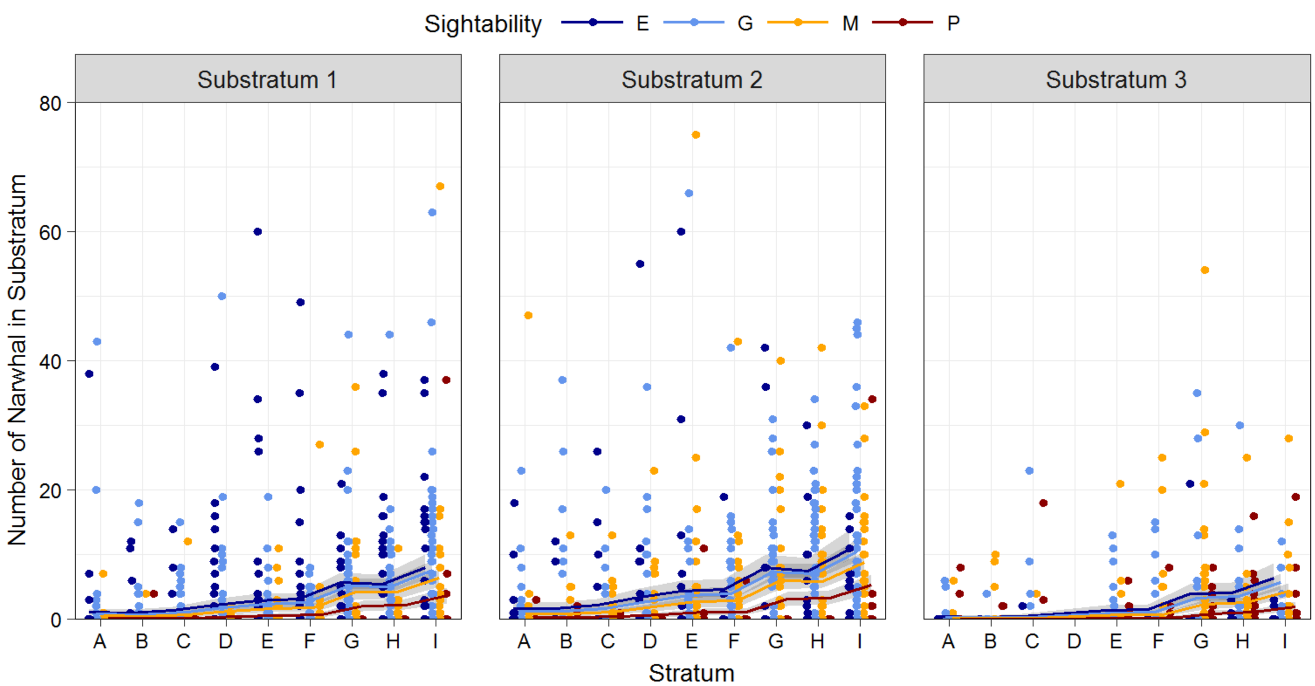

Figure C-1: Count of narwhal per substratum relative to stratum, sightability conditions (as colours), and substratum within stratum (as panels), when no vessels are within 15 km of SSA. Small points depict raw data; lines represent model predictions. Grey ribbons are 95% confidence intervals. Five counts of >100 narwhal were removed from the figure for legibility.

The combined predictions of a second degree polynomial temporal effect on narwhal presence and a third-degree polynomial temporal effect on narwhal counts resulted in a left-skewed distribution of predicted narwhal counts over the course of the 2017, peaking in late August (Figure C-2). This shape was driven by the relatively high occurrence of zero counts in early August and the relatively low occurrence of zeroes in late August, which strongly increased both the odds of presence and the predicted counts of narwhal.

The combined predictions of narwhal counts relative to large vessel scenarios reflected the significant interaction identified for the count model, between distance and approaching / departing orientation of large vessels relative to substratum centroid (Figure C-3). Predicted narwhal counts peaked when departing vessels were at intermediate distances, but decreased when approaching vessels were at similar distances, mirroring the pattern of counts versus distance from vessel (Figure 5-14).

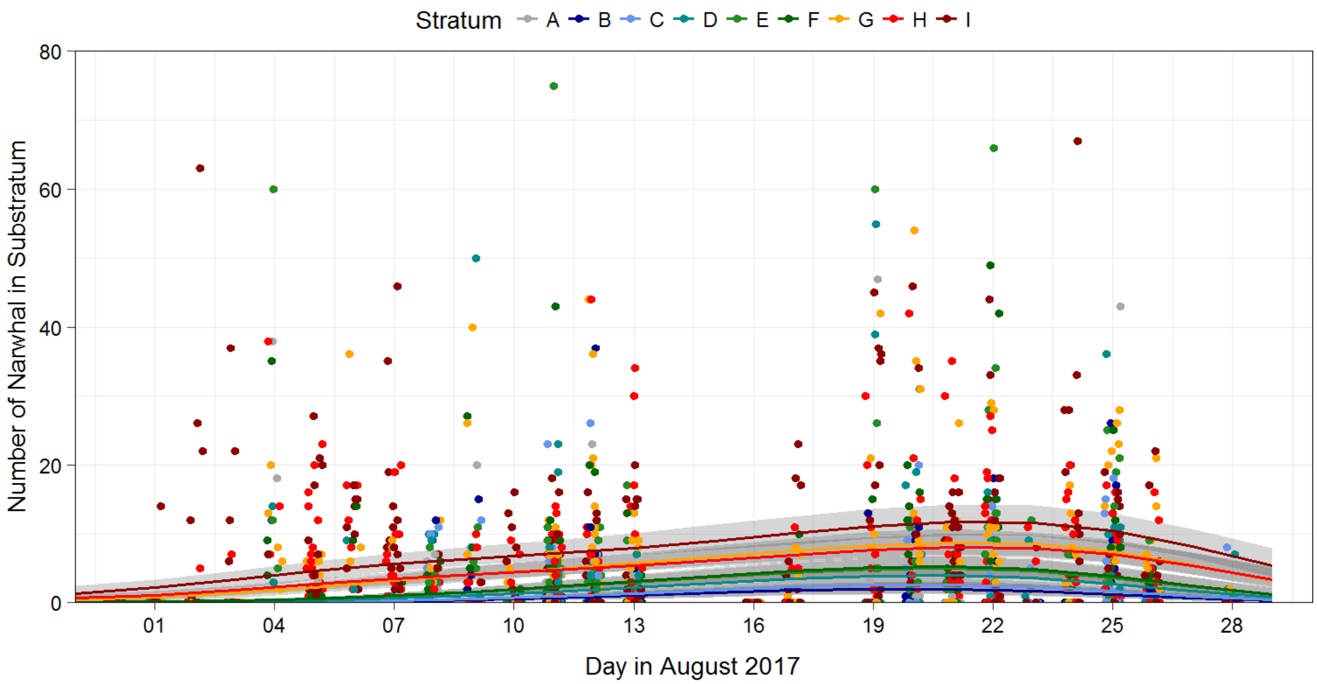

Figure C-2: Count of narwhal per substratum relative to date and stratum (as colours), when no vessels were within 15 km of SSA. Small points depict raw data; lines represent model predictions. Grey ribbons are 95% confidence intervals. Five counts of >100 narwhal were removed from the figure for legibility.

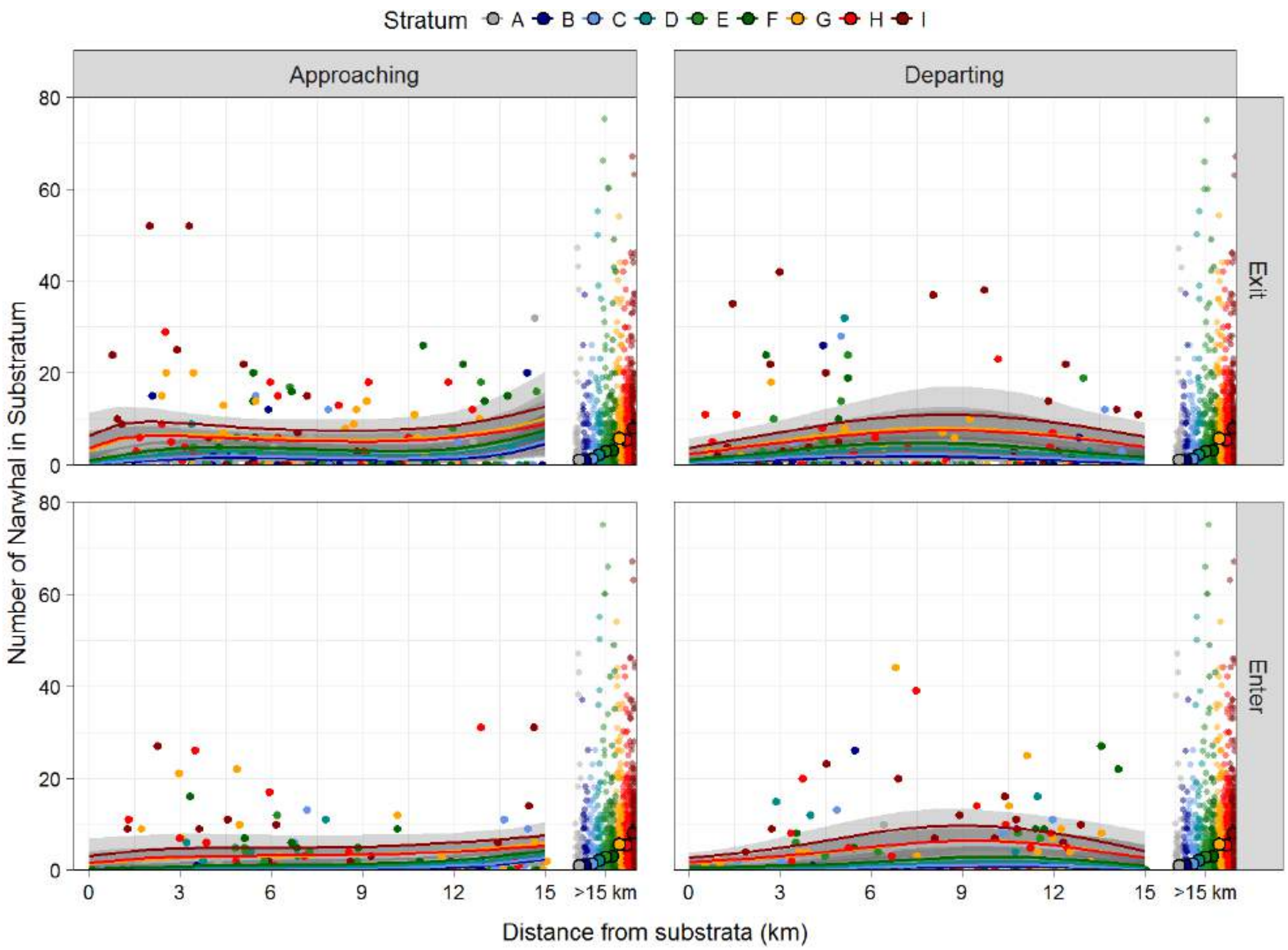

Figure C-3: Count of narwhal per substratum relative to distance from large vessels, stratum (as colours), relative to vessel presence within 15 km of SSA. Small points depict raw data; lines and large points represent model predictions. Grey ribbons and error bars are 95% confidence intervals. Five counts of >100 narwhal were removed from the figure for legibility.

2.0 GROUP COMPOSITION AND NEARSHORE TRAVEL BEHAVIOUR

2.1 Group Size

The full model of group size included effects of sightability, presence of small vessels in the SSA, categorical variable for absence of large vessels within 15 km from the BSA, distance between large vessel and the BSA, whether the vessel was approaching or departing the BSA, whether the vessel was entering or exiting Milne Inlet, and interactions between vessel distance and approaching/departing the BSA, between approaching/departing the BSA and entering/exiting Milne Inlet, and between vessel distance and entering/exiting Milne Inlet. Of the examined five candidate models, model #4, which included none of the interactions, was the most parsimonious model within 2 AIC units from the lowest AIC value, and was therefore selected for interpretation (Table C-3). The selected model included effects of sightability, presence of small vessels in the SSA, absence of large vessels within 15 km from the BSA, distance of vessels from the BSA, whether the vessel was approaching / departing the BSA, and whether the vessel was exiting / entering Milne Inlet.

Vessel distance from the BSA did not have a significant effect on group size (Table C-4), while vessel absence within 15 km from the BSA and whether the vessel was approaching the BSA or departing from the BSA were both significant. This result was unexpected, since it is unlikely that the effect of vessel approaching / departing would not depend on distance from the BSA. This suggests that the significance of the approaching / departing parameter may be spurious. The presence of small vessels in the SSA did not have a significant effect on group size.

Model estimates of group sizes recorded under good sightability conditions were not significantly different from those recorded under excellent sightability (Table C-4). On the other hand, the model estimated significant effects for medium and poor sightability, where group sizes were predicted to be 0.88 and 0.70 times those recorded at excellent sightability, respectively. This result suggests that observers recorded significantly smaller group sizes under medium and poor sightability conditions (Figure C-4).

Table C-3: Model selection for group size modeling.

Model	Parameters	AIC	ΔAIC
1	Sightability + presence/absence of small vessels in the SSA + absence of large vessels within 15 km of BSA + distance from large vessel + approaching / departing the BSA + entering / exiting Milne Inlet + vessel distance × approaching/departing + approaching / departing × entering / exiting + exiting / entering × vessel distance	10,563.4	1.5
2	Removed exiting / entering × vessel distance interaction	10,561.8	0.0
3	Removed exiting / entering × vessel distance and approaching / departing × entering / exiting interaction	10,564.5	2.7
4	Removed all three interactions	10,563.6	1.8
5	Removed presence of small vessels in the SSA	10,562.3	0.5

Table C-4: Exponentiated coefficients estimates (incidence rate ratios) and their lower (LCI) and upper (UCI) 95% confidence intervals from negative binomial regression of group size at the BSA.

Parameter	Estimate	LCI	UCI	*P* value
Intercept (Excellent sightability, a large vessel, exiting Milne Inlet and approaching the BSA is present)	3.11	2.65	3.64	<0.001
Good sightability	1.02	0.95	1.08	0.629
Medium sightability	0.88	0.80	0.96	0.004
Poor sightability	0.70	0.57	0.87	0.001
Presence of small vessels in the SSA	0.95	0.87	1.05	0.305
Large vessel absence within 15 km from the BSA	1.23	1.05	1.45	0.011
Large vessel distance from the BSA	1.00	0.99	1.02	0.513
Large vessel departing the BSA	1.16	1.03	1.31	0.017
Large vessel entering Milne Inlet	0.95	0.84	1.07	0.424

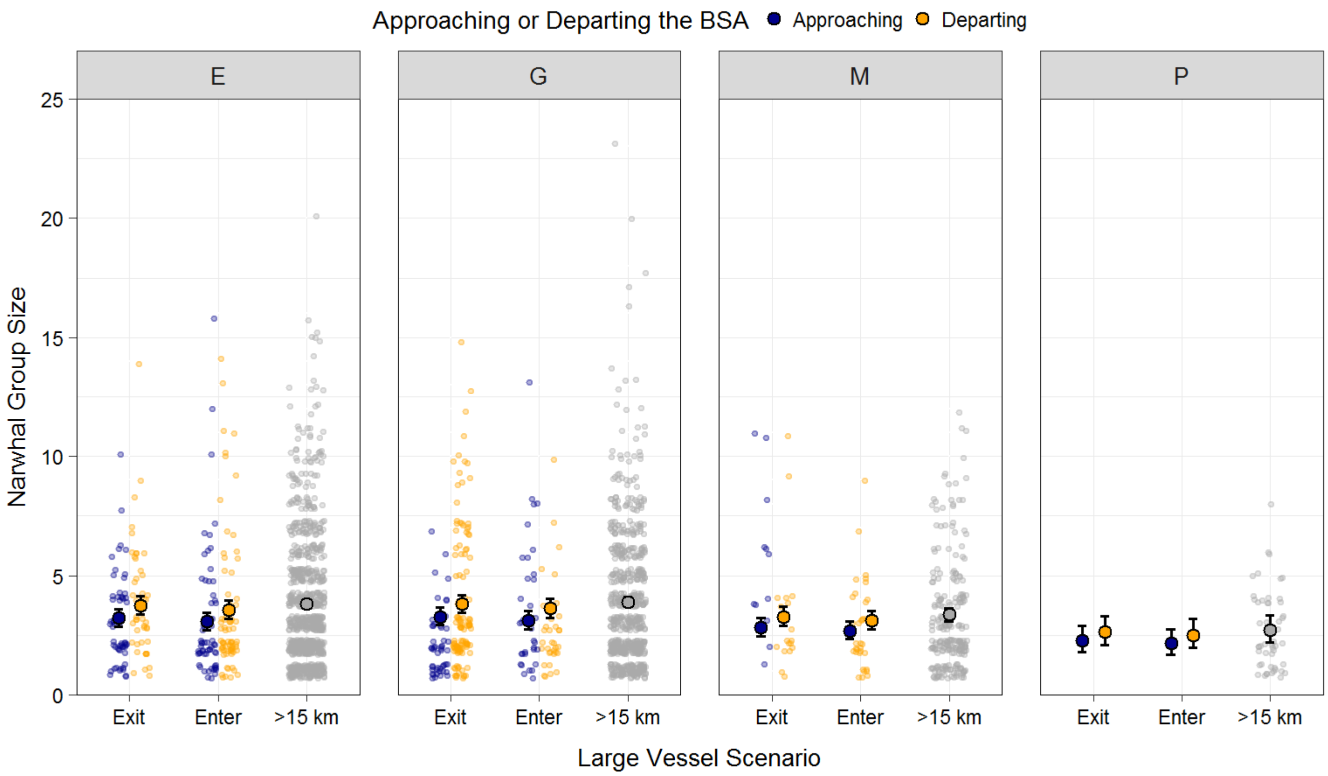

Figure C-4: Group size relative large vessel passage scenario and sightability (as panels). Small points depict raw data; large points represent model predictions. Error bars are 95% confidence intervals.

2.2 Group Composition

The ordinal model of group composition did not meet the ordinal modeling assumption of proportional odds, and analysis therefore proceeded as a set of three logistic regressions – for presence/absence of groups of adults/juvenile of two narwhal or more (adult group [n>1]), mother/offspring group, and single adult/juvenile group.

The candidate model with the best support in the analysis of adult groups with >1 narwhal did not include the effects of small vessel presence in the SSA or hunting activity (Table C-5). The model included a significant interaction between vessel distance and whether the vessel was approaching or departing the BSA (P value 0.001). The remaining interactions, as well as effects of sightability and whether the vessel was exiting or entering Milne Inlet were not significant (Table C-6). The model estimated that the odds of observing adult groups with >1 narwhal decreased by 67% when a large vessel was departing the BSA compared to a large vessel approaching the BSA, but only at very close distances (Table C-6, Figure C-5). The significant distance × Approaching / Departing interaction resulted in an increase of predicted probability of observing adult groups with >1 narwhal when approaching vessels get nearer the BSA and an increasing probability when a departing vessel gets farther from the BSA.

The candidate model with the best support in the analysis of mother/offspring groups did not include the effects of small vessel presence in the SSA or hunting activity (Table C-5). The model's results were opposite to those predicted for adult groups with >1 narwhal. The model estimated that the odds of observing a mother/offspring group increased by a factor of 5.1 when a large vessel was departing the BSA compared to a large vessel approaching the BSA, but only at very close distances (Table C-6, Figure C-6). The significant distance × approaching / departing interaction resulted in a predicted decrease in probability of mother/offspring group presence when approaching vessels get nearer the BSA, and a decreasing probability when a departing vessel gets farther from the BSA. The remaining interactions, as well as whether the vessel was exiting or entering Milne Inlet were not significant. Sightability did not have a significant effect on the odds of mother/offspring group presence. This result was unexpected, mother/offspring groups were relatively small (Figure 5-22) and group size analysis suggested that smaller group observations may be affected by sightability conditions (Section 2.1). It is possible that this result is due to insufficient sample sizes under various sightability conditions.

Model selection for single adult group presence/absence resulted in the selection of model #4, which included effects of sightability, presence of small vessels in the SSA, hunting, and all large vessel main effects (Table C-5). Of the variables included in the model, none were significant, with the exception of whether a large vessel was approaching or departing the BSA. It is unlikely that the effect of vessel approaching / departing (or the effect of vessel presence/absence) would be independent of distance from the BSA. This suggests that the significance of the approaching / departing effect may be spurious. It is likely that the 2017 dataset was not sufficient to detect vessel-related effects on presence/absence of single-animal groups due to the low sample size when vessels were present within 15 km from the BSA (Figure 5-22, Figure C-7).

Overall, vessel-related effects on group composition were found for adult/juvenile groups with >1 narwhal and for mother/offspring groups. In both cases, the distance of large vessels from the BSA and the orientation of the vessel relative to the BSA were significant predictors of presence/absence. However, predictions were inconsistent with expected trends, and the models' results should be interpreted with caution.

Table C-5: Model selection for group composition modeling.

Group	Model	Parameters	AIC	ΔAIC
Adult / juvenile group (N > 1)	1	Sightability + presence of small vessels in the SSA + hunting activity + time since last shooting event + absence of large vessels within 15 km of BSA + distance from large vessel + approaching / departing the BSA + entering / exiting Milne Inlet + vessel distance × approaching/departing + approaching / departing × entering / exiting + exiting / entering × vessel distance	1791.3	4.5
	2	Removed exiting / entering × vessel distance interaction	1792.1	5.2
	3	Removed exiting / entering × vessel distance and approaching / departing × entering / exiting interaction	1790.4	3.6
	4	Removed all three interactions	1800.1	13.2
	5	Removed presence of small vessels in the SSA	1790.6	3.8
	6	Removed presence of small vessels in the SSA and hunting activity	1786.8	0.0
Mother / offspring group	1	Sightability + presence of small vessels in the SSA + hunting activity + time since last shooting event + absence of large vessels within 15 km of BSA + distance from large vessel + approaching / departing the BSA + entering / exiting Milne Inlet + vessel distance × approaching/departing + approaching / departing × entering / exiting +	1459.9	3.0

Group	Model	Parameters	AIC	ΔAIC
		exiting / entering × vessel distance		
	2	Removed exiting / entering × vessel distance interaction	1460.0	3.1
	3	Removed exiting / entering × vessel distance and approaching / departing × entering / exiting interaction	1458.9	2.0
	4	Removed all three interactions	1467.8	10.9
	5	Removed presence of small vessels in the SSA	1460.8	3.9
	6	Removed presence of small vessels in the SSA and hunting activity	1456.9	0.0
Single adult / juvenile	1	Sightability + presence of small vessels in the SSA + hunting activity + time since last shooting event + absence of large vessels within 15 km of BSA + distance from large vessel + approaching / departing the BSA + entering / exiting Milne Inlet + vessel distance × approaching/departing + approaching / departing × entering / exiting + exiting / entering × vessel distance	1062.0	5.5
	2	Removed exiting / entering × vessel distance interaction	1060.1	3.6
	3	Removed exiting / entering × vessel distance and approaching / departing × entering / exiting interaction	1058.5	1.9
	4	Removed all three interactions	1056.7	0.2
	5	Removed presence of small vessels in the SSA	1060.3	3.7
	6	Removed presence of small vessels in the SSA and hunting activity	1056.5	0.0

Table C-6: Odds ratios and their lower (LCI) and upper (UCI) 95% confidence intervals from logistic regressions of group composition.

Group	Parameter	Estimate	LCI	UCI	*P* value
Adult / juvenile group (N > 1)	Intercept (a large vessel, exiting Milne Inlet and approaching the BSA is present)	2.94	1.10	8.44	0.037
	Good sightability	0.93	0.73	1.19	0.562
	Medium sightability	1.05	0.72	1.57	0.789
	Poor sightability	0.81	0.37	1.86	0.602
	Large vessel absence within 15 km from the BSA	0.72	0.25	1.92	0.521
	Vessel distance from BSA	0.96	0.87	1.06	0.398
	Large vessel departing the BSA	0.33	0.10	0.99	0.051
	Large vessel entering Milne Inlet	1.06	0.32	3.46	0.922
	Vessel distance × Large vessel departing the BSA	1.20	1.08	1.34	0.001
	Vessel distance × Large vessel entering Milne Inlet	1.14	0.43	3.01	0.798

Group	Parameter	Estimate	LCI	UCI	*P* value
	Large vessel entering Milne Inlet × Large vessel departing the BSA	0.91	0.82	1.01	0.087
Mother / offspring group	Intercept (a large vessel, exiting Milne Inlet and approaching the BSA is present)	0.17	0.05	0.54	0.005
	Good sightability	0.95	0.72	1.27	0.748
	Medium sightability	0.83	0.51	1.30	0.428
	Poor sightability	1.59	0.64	3.60	0.282
	Large vessel absence within 15 km from the BSA	1.53	0.48	5.72	0.498
	Vessel distance from BSA	1.03	0.92	1.16	0.586
	Large vessel departing the BSA	5.07	1.46	19.56	0.014
	Large vessel entering Milne Inlet	0.94	0.23	3.84	0.926
	Vessel distance × Large vessel departing the BSA	0.83	0.73	0.93	0.002
	Vessel distance × Large vessel entering Milne Inlet	0.78	0.25	2.41	0.671
	Large vessel entering Milne Inlet × Large vessel departing the BSA	1.10	0.97	1.24	0.141
Single adult / juvenile	Intercept (a large vessel, exiting Milne Inlet and approaching the BSA is present at 0 km from the BSA)	0.13	0.05	0.34	<0.001
	Good sightability	1.23	0.87	1.75	0.244
	Medium sightability	1.22	0.69	2.09	0.473
	Poor sightability	0.64	0.10	2.24	0.551
	Small vessel presence in the SSA	0.88	0.50	1.48	0.654
	No hunting activity	0.89	0.59	1.36	0.577
	Time since last shot	1.00	0.99	1.00	0.790
	Large vessel absence within 15 km from the BSA	1.07	0.43	2.91	0.885
	Vessel distance from BSA	1.03	0.95	1.11	0.506
	Large vessel departing the BSA	0.47	0.23	0.94	0.034
	Large vessel entering Milne Inlet	1.537	0.771	3.115	0.225

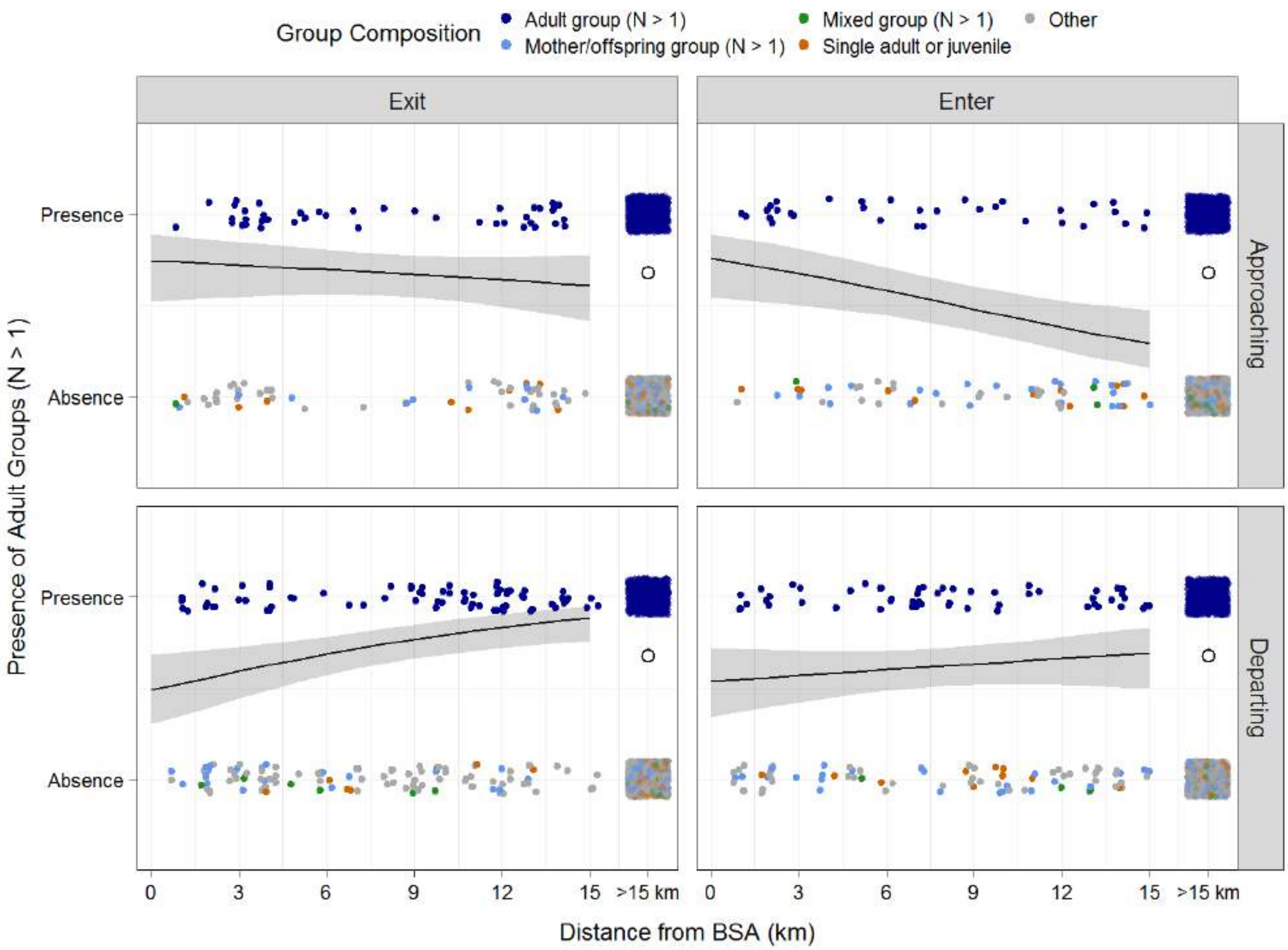

Figure C-5: Presence/absence of adult/juvenile groups of 2 narwhal or more in the BSA. Small points depict groups, colour-coded by group composition; lines and large points represent model predictions (as continuous probability between 0 – "absence" and 1 – "presence". Error bars and grey ribbons are 95% confidence intervals.

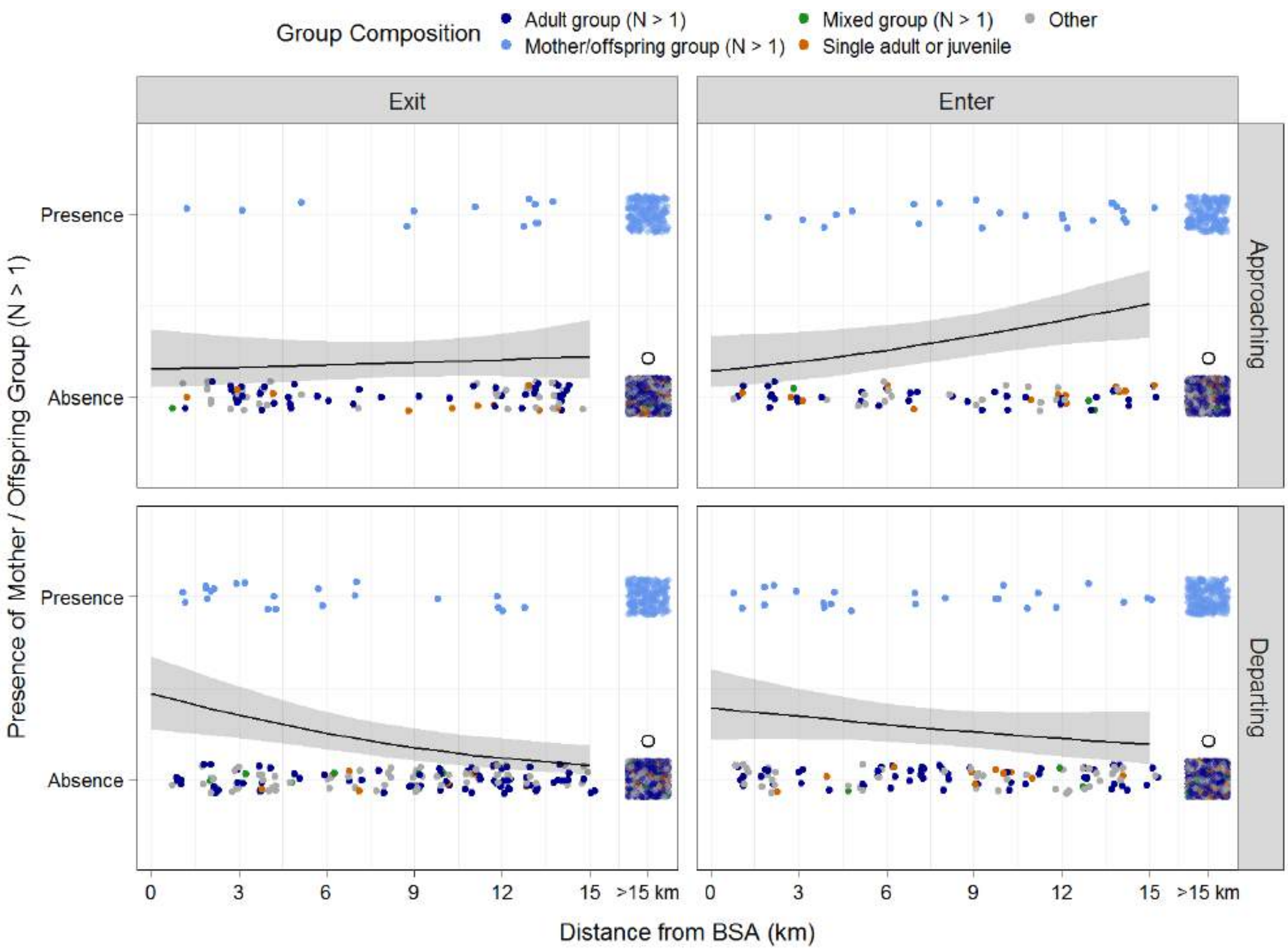

Figure C-6: Presence/absence of mother/offspring groups in the BSA. Small points depict groups, colour-coded by group composition; lines and large points represent model predictions (as continuous probability between 0 – "absence" and 1 – "presence". Error bars and grey ribbons are 95% confidence intervals.

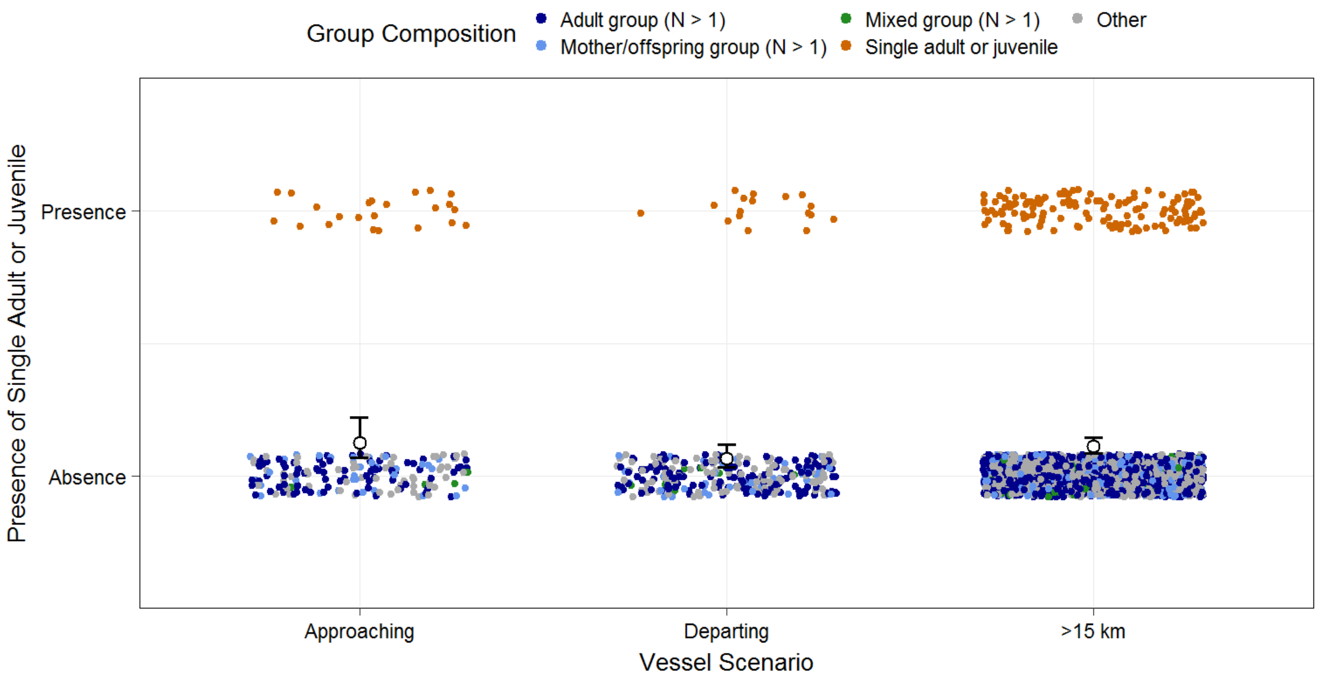

Figure C-7: Presence/absence of single adult/juvenile groups in the BSA. Small points depict groups, colour-coded by group composition; lines and large points represent model predictions (as continuous probability between 0 – "absence" and 1 – "presence". Error bars and grey ribbons are 95% confidence intervals.

2.3 Group Spread

It was expected that sightability may have an effect on group spread, if some types of group spread were easier to observe in reduced sightability. However, preliminary modeling indicated that while sightability had a significant effect on group spread (*P* value <0.05), the effect was likely spurious. The predicted probability of observing a loosely spread group was 0.36 (95% CIs of 0.33-0.40) under excellent sightability, 0.45 (95% CIs of 0.41-0.49) under good sightability, 0.39 (95% CIs of 0.32-0.45) under medium sightability, and 0.42 (0.27-0.59) under poor sightability. That is, predicted group spread probability did not change monotonically with sightability, as would have been expected. In addition, while good sightability was significantly different from excellent, medium and poor sightability were not (*P* values of 0.6 and 0.5, respectively). Therefore, the variable was removed from analysis.

The full model of group spread included effects of group size, presence of small vessels in the SSA, hunting activity, time since last shooting event, absence of large vessels within 15 km of BSA, distance from large vessel, whether the vessel was approaching or departing the BSA, whether the vessel was entering or exiting Milne Inlet, and interactions between vessel distance and approaching/departing the BSA, between approaching/departing the BSA and entering/exiting Milne Inlet, and between vessel distance and entering/exiting Milne Inlet. Of the examined five candidate models, model #4, which included none of the interactions, was the most parsimonious model within 2 AIC units from the lowest AIC value, and was therefore selected for interpretation (Table C-7).

The odds ratio of group size effect was 1.06, indicating that the odds of loose spread increased by 6% with the increase of group size by 1 narwhal (Table C-8), as reflected in the plotted predicted curves (Figure C-8).

The presence of small vessels in the SSA (odds ratio of 0.44) reduced the odds of loose spread by 56%. In the absence of large vessels within 15 km from the BSA, the odds of a loose formation were 2.52 times higher when compared to large vessel presence at distance of 0 km (95% CIs of 1.35-4.81). Narwhal were more likely to be in a loose formation when large vessels were far from the BSA (5% increase in odds with every 1 km), and when a large vessel was departing the BSA, rather than approaching it (71% increase in odds;

Table C-8). When a vessel was entering Milne Inlet, loose formation odds were 52% lower than when a vessel was exiting the inlet. Hunting activity was not found to have a significant effect on group spread.

Overall, loose formation was predicted to be more likely when no large vessels were present within 15 km from the BSA (relative to when a large vessel was at 0 km distance), when no small vessels were present, and when groups were larger. When large vessels were present within 15 km from the BSA, the odds of loose spread decreased as the vessel approached the BSA and increased with distance once the vessel passed the BSA. In addition, loose spread groups were more likely to be observed when a vessel exited Milne Inlet than when a vessel entered Milne Inlet.

Table C-7: Model selection for group spread modeling; the simplest model within 2 AIC units from the lowest AIC is selected for analysis.

Model	Parameters	AIC	ΔAIC
1	Sightability + presence/absence of small vessels in the SSA + absence of large vessels within 15 km of BSA + distance from large vessel + approaching / departing the BSA + entering / exiting Milne Inlet + vessel distance × approaching/departing + approaching / departing × entering / exiting + exiting / entering × vessel distance	2399.8	3.8
2	Removed exiting / entering × vessel distance interaction	2398.1	2.0
3	Removed exiting / entering × vessel distance and approaching / departing × entering / exiting interaction	2396.5	0.4
4	Removed all three interactions	2396.1	0.0
5	Removed presence of small vessels in the SSA	2417.6	21.5
6	Removed presence of small vessels in the SSA and hunting activity	2420.3	24.3

Table C-8: Odds ratios and their lower (LCI) and upper (UCI) 95% confidence intervals from logistic regression of group spread.

Parameter	Estimate	LCI	UCI	*P* value
Intercept (Excellent sightability, a large vessel, exiting Milne Inlet and approaching the BSA is present)	0.17	0.08	0.33	<0.001
Group size	1.06	1.03	1.10	0.001
Presence of small vessels in the SSA	0.44	0.30	0.64	<0.001
No hunting activity	1.22	0.96	1.56	0.110
Time since last shot	1.00	1.00	1.00	0.385
Large vessel absence within 15 km from the BSA	2.52	1.35	4.81	0.004
Large vessel distance from the BSA	1.05	1.00	1.11	0.040
Large vessel departing the BSA	1.71	1.07	2.78	0.028
Large vessel entering Milne Inlet	0.48	0.30	0.74	0.001

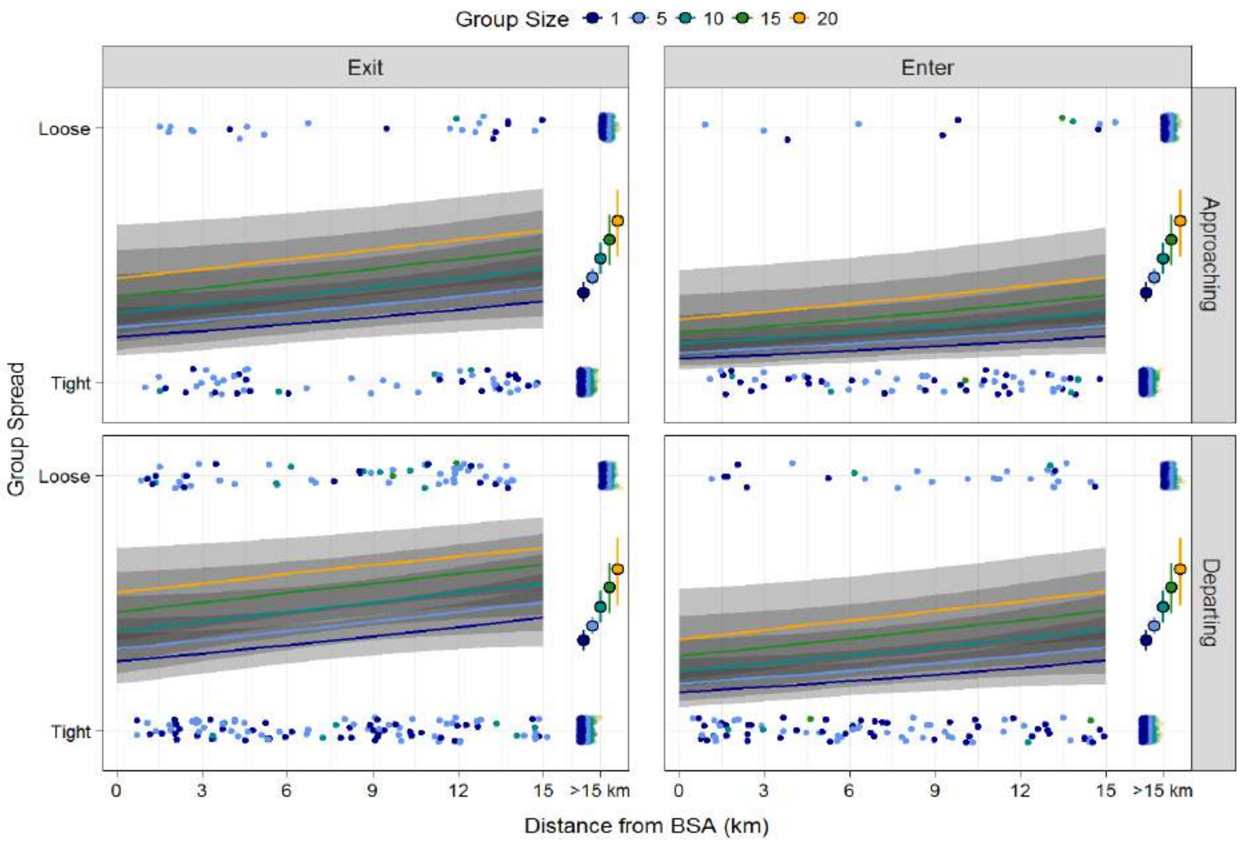

Figure C-8: Group spread relative to group size and large vessel scenario. Small points depict raw data, classified into "Tight" and "Loose" spreads, with group size rounded to the nearest value plotted; lines and large points represent model predictions (as continuous probability between 0 – "Tight" and 1 – "Loose"). Error bars and grey ribbons are 95% confidence intervals.

2.4 Group Formation

Group formation data did not meet the ordinal regression assumption of proportional odds, and data were therefore modeled using three sets of logistic regressions, of presence/absence of groups in linear, parallel, and clustered formation. The full logistic model of each group formation included effects of sightability, presence of small vessels in the SSA, group size, hunting activity, time since last shooting event, a categorical variable for absence of large vessels within 15 km from the BSA, distance between large vessel and the BSA, whether the vessel was approaching or departing the BSA, whether the vessel was entering or exiting Milne Inlet, and interactions between vessel distance and approaching/departing the BSA, between approaching/departing the BSA and entering/exiting Milne Inlet, and between vessel distance and entering/exiting Milne Inlet.

The candidate models of presence/absence of linear formation did not include any interactions between vessel-related variables, due to the low sample size during vessel presence (Figure 5-26). Of the three examined candidate models, model #3 was the simplest model within 2 AIC units of the lowest AIC value and was selected for interpretation (Table C-9). The model only included effects of sightability, group size, and large vessel main effects (Table C-10). Group size and sigthability did not have a significant effect on linear formation presence/absence ($P > 0.05$). Vessel distance from the BSA had a significant effect on linear formation presence/absence – with every 1 km increase in distance between a large vessel and the BSA, the model estimated a 15% increase in the odds of observing a linear formation, resulting in a trend of increasing probability with distance (Figure C-9). The odds of a linear formation were 60% lower when a vessel was entering Milne Inlet than when it was exiting. When no large vessels were present, the odds of observing a linear formation were 2.84 times higher than when an exiting / approaching vessel was at 0 km distance from the BSA. Note that these results are based on a very small sample size of linear formations in the presence of large vessels within 15 km from the BSA (Figure 5-26), and should therefore be interpreted with caution.

Model selection of presence / absence of parallel formation resulted in in the selection of model #4, which included effects of sightability, group size, presence of small vessels in the SSA, hunting, and all large vessel main effects (Table C-9) The selected model included significant effects of absence of large vessels within 15 km from the BSA, distance between vessel and the BSA, and whether the vessel was entering or exiting Milne Inlet (Table C-10). Hunting activity did not appear to have a significant effect on the presence/absence of groups in parallel formation. While good sightability conditions had a significant effect on the presence/absence of parallel formations relative to the reference level of excellent sightability, the effect appears to be due to chance, since both medium and poor sightability conditions were not significantly different from excellent sightability. With every 1 km increase in distance between a large vessel and the BSA, the model estimated an 8% decrease in the odds of observing a parallel formation, resulting in a decreasing trend with distance (Figure C-10). In addition, with every addition of 1 narwhal to the group, the model estimated a 22% decrease in odds of parallel formation, resulting in strongly reduced probabilities of parallel formation at large group sizes. The odds of a parallel formation were 2.1 times higher when a vessel was entering Milne Inlet than when it was exiting. When no large vessels were present within 15 km from the BSA, the odds of observing a parallel formation were 56% lower than when an exiting / approaching vessel was at 0 km distance from the BSA.

Model selection of presence / absence of cluster formation resulted in in the selection of model #4, which included effects of sightability, group size, presence of small vessels in the SSA, hunting, and all large vessel main effects (Table C-9). The selected model only included a significant effect of group size, with all other effects not being statistically significant at the 0.05 level (Table C-10). It is likely that this result was driven by the limited data on cluster formation in the presence of large vessels within 15 km from the BSA (Figure 5-26). The odds of cluster group formation were estimated to increase by 35% for every 1 narwhal increase of group size, and be 54% higher at the presence of small vessels in the SSA (Table C-10, Figure C-11).

Overall, groups in linear formation were estimated to be most likely when large vessels were far from the BSA, whereas a parallel formation was most likely to be observed when large vessels were close to the BSA and when group sizes were small. Cluster formation was predicted to be most likely when group sizes were large.

Table C-9: Model selection for group formation modeling.

Formation	Model	Parameters	AIC	ΔAIC
Linear	1	Sightability + presence of small vessels in the SSA + group size + lack of hunting activity + time since last shooting + absence of large vessels within 15 km of BSA + distance from large vessel + approaching / departing the BSA	1191.4	7.0
	2	Removed presence of small vessels in the SSA	1184.3	0.0
	3	Removed presence of small vessels in the SSA and hunting effects	1184.4	0.1
Parallel	1	Sightability + presence of small vessels in the SSA + group size + lack of hunting activity + time since last shooting + absence of large vessels within 15 km of BSA + distance from	2133.4	5.0

Formation	Model	Parameters	AIC	ΔAIC
		large vessel + approaching / departing the BSA + entering / exiting Milne Inlet + vessel distance × approaching/departing + approaching / departing × entering / exiting + exiting / entering × vessel distance		
	2	Removed exiting / entering × vessel distance interaction	2131.5	3.1
	3	Removed exiting / entering × vessel distance and approaching / departing × entering / exiting interaction	2130.8	2.3
	4	Removed all three interactions	2130.2	1.7
	5	Removed presence of small vessels in the SSA	2131.9	3.4
	6	Removed presence of small vessels in the SSA and hunting activity	2128.5	0.0
Cluster	1	Sightability + presence of small vessels in the SSA + group size + lack of hunting activity + time since last shooting + absence of large vessels within 15 km of BSA + distance from large vessel + approaching / departing the BSA + entering / exiting Milne Inlet + vessel distance × approaching/departing + approaching / departing × entering / exiting + exiting / entering × vessel distance	1749.3	4.1
	2	Removed exiting / entering × vessel distance interaction	1748.4	3.2
	3	Removed exiting / entering × vessel distance and approaching / departing × entering / exiting interaction	1747.2	1.9
	4	Removed all three interactions	1745.2	0.0
	5	Removed presence of small vessels in the SSA	1750.3	5.1
	6	Removed presence of small vessels in the SSA and hunting activity	1747.7	2.4

Table C-10: Odds ratios and their lower (LCI) and upper (UCI) 95% confidence intervals from logistic regressions of group formation.

Formation	Parameter	Estimate	LCI	UCI	*P* value
Linear	Intercept (excellent sightability, a large vessel, exiting Milne Inlet and approaching the BSA is present)	0.04	0.01	0.13	<0.001
	Good sightability	1.27	0.91	1.79	0.158
	Medium sightability	1.00	0.58	1.65	0.995
	Poor sightability	1.72	0.57	4.25	0.283
	Group size	0.96	0.90	1.02	0.203
	Large vessel absence within 15 km from the BSA	2.84	0.98	9.67	0.072
	Large vessel distance from BSA	1.15	1.06	1.26	0.002
	Large vessel departing the BSA	0.81	0.39	1.71	0.569
	Large vessel entering Milne Inlet	0.40	0.17	0.85	0.023
Parallel	Intercept (excellent sightability, a large vessel, exiting Milne Inlet and approaching the BSA is present at 0 km from the BSA)	13.85	6.71	29.71	<0.001
	Good sightability	0.77	0.61	0.97	0.028
	Medium sightability	1.19	0.83	1.73	0.341

Formation	Parameter	Estimate	LCI	UCI	*P* value
	Poor sightability	0.71	0.34	1.59	0.385
	Group size	0.78	0.75	0.81	<0.001
	Presence of small vessels in the SSA	0.88	0.62	1.26	0.468
	Absence of hunting activity	1.06	0.82	1.38	0.650
	Time since last shot	1.00	1.00	1.00	0.955
	Large vessel absence within 15 km from the BSA	0.44	0.22	0.86	0.020
	Large vessel distance from BSA	0.92	0.87	0.97	0.004
	Large vessel departing the BSA	1.05	0.62	1.75	0.854
	Large vessel entering Milne Inlet	2.08	1.25	3.53	0.006
Cluster	Intercept (excellent sightability, a large vessel, exiting Milne Inlet and approaching the BSA is present at 0 km from the BSA)	0.04	0.02	0.09	<0.001
	Good sightability	1.23	0.94	1.59	0.125
	Medium sightability	0.82	0.52	1.24	0.351
	Poor sightability	1.14	0.41	2.73	0.782
	Group size	1.35	1.30	1.42	<0.001
	Presence of small vessels in the SSA	1.42	0.96	2.08	0.076
	Absence of hunting activity	0.93	0.69	1.25	0.630
	Time since last shot	1.00	1.00	1.01	0.652
	Large vessel absence within 15 km from the BSA	1.78	0.81	4.10	0.162
	Large vessel distance from BSA	1.03	0.96	1.10	0.397
	Large vessel departing the BSA	1.10	0.60	2.06	0.762
	Large vessel entering Milne Inlet	0.63	0.34	1.14	0.135

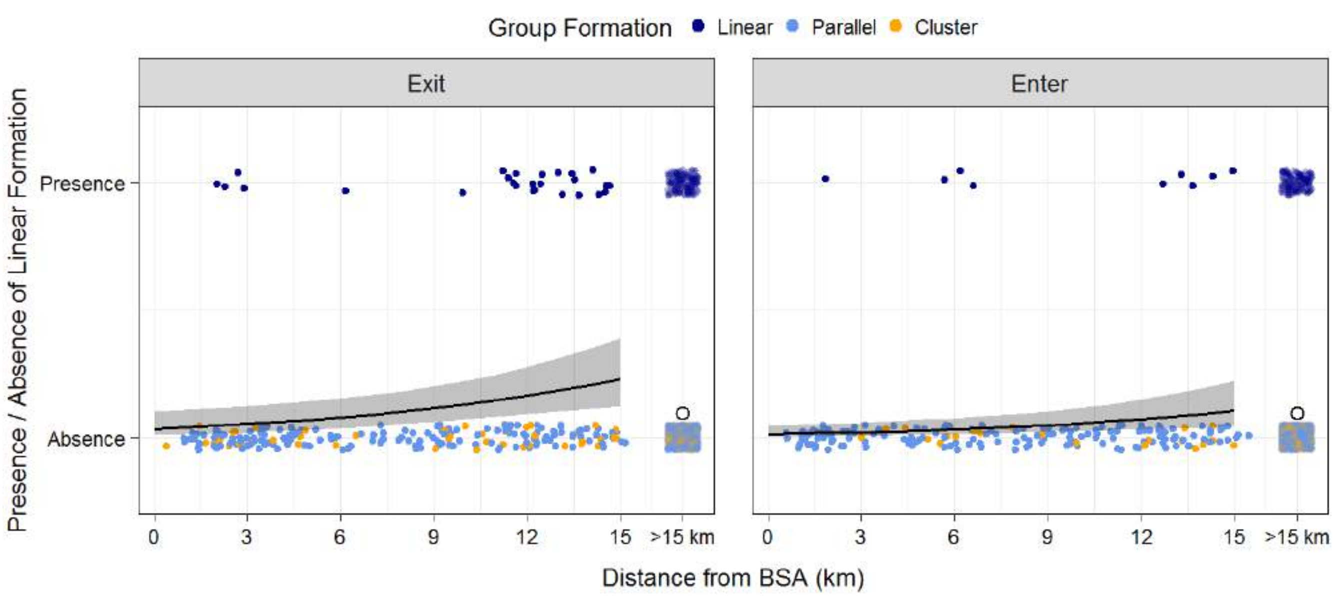

Figure C-9: Presence / absence of groups in a linear formation relative to large vessel distance from the BSA, and whether the vessel was exiting or entering Milne Inlet (as panels). Small points depict groups that were classified to one of the *three formations; lines and large points represent model predictions (as continuous probability between 0 – "absence" and 1 – "presence". Error bars and grey ribbons are 95% confidence intervals.*

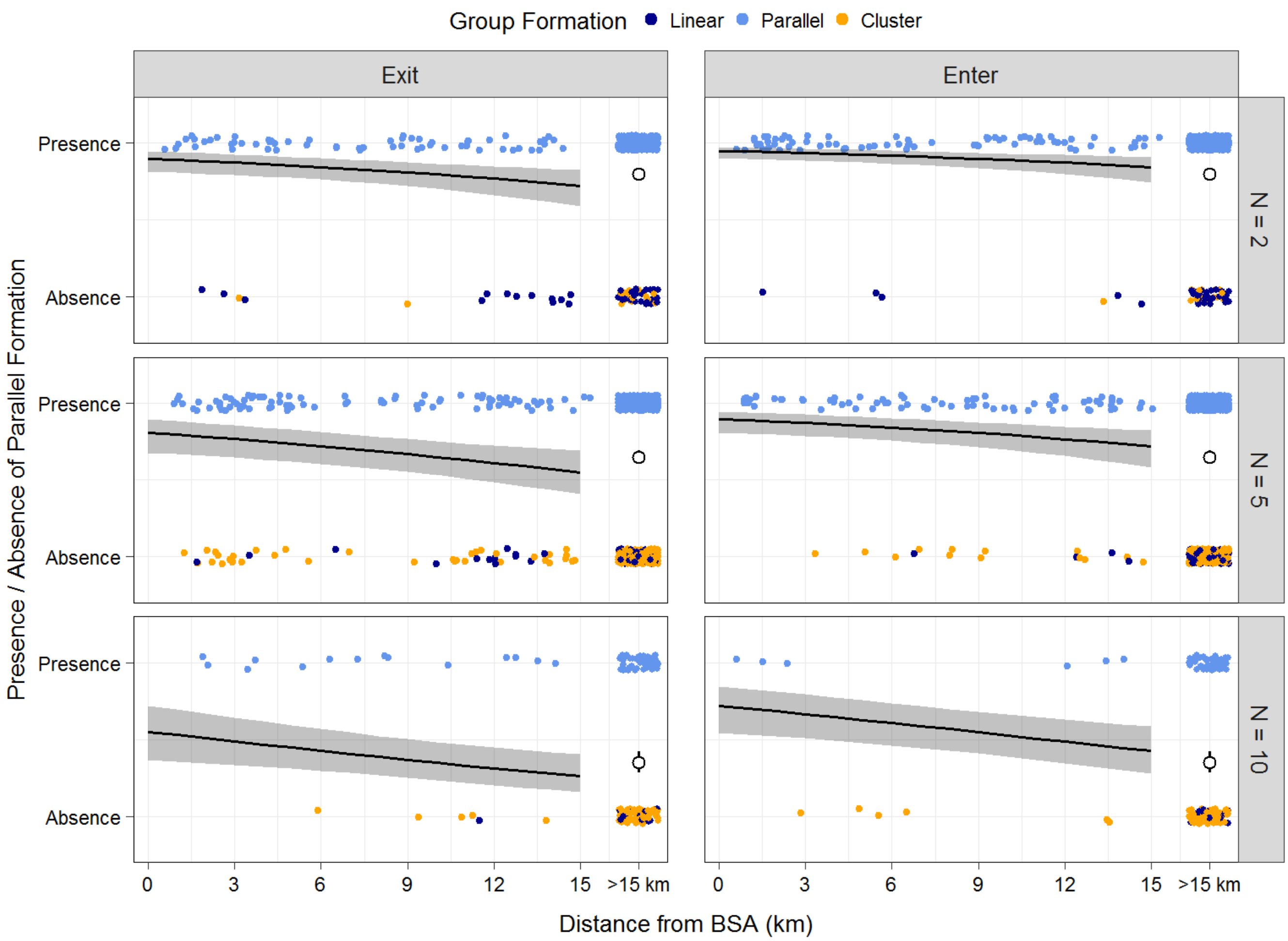

Figure C-10: Presence / absence of groups in a parallel formation relative to group size and large vessel scenario. Small points depict groups that were classified to one of the three formations, with group sizes rounded to the nearest value shown; lines and large points represent model predictions (as continuous probability between 0 – "Parallel" and 1 – "Cluster". Error bars and grey ribbons are 95% confidence intervals.

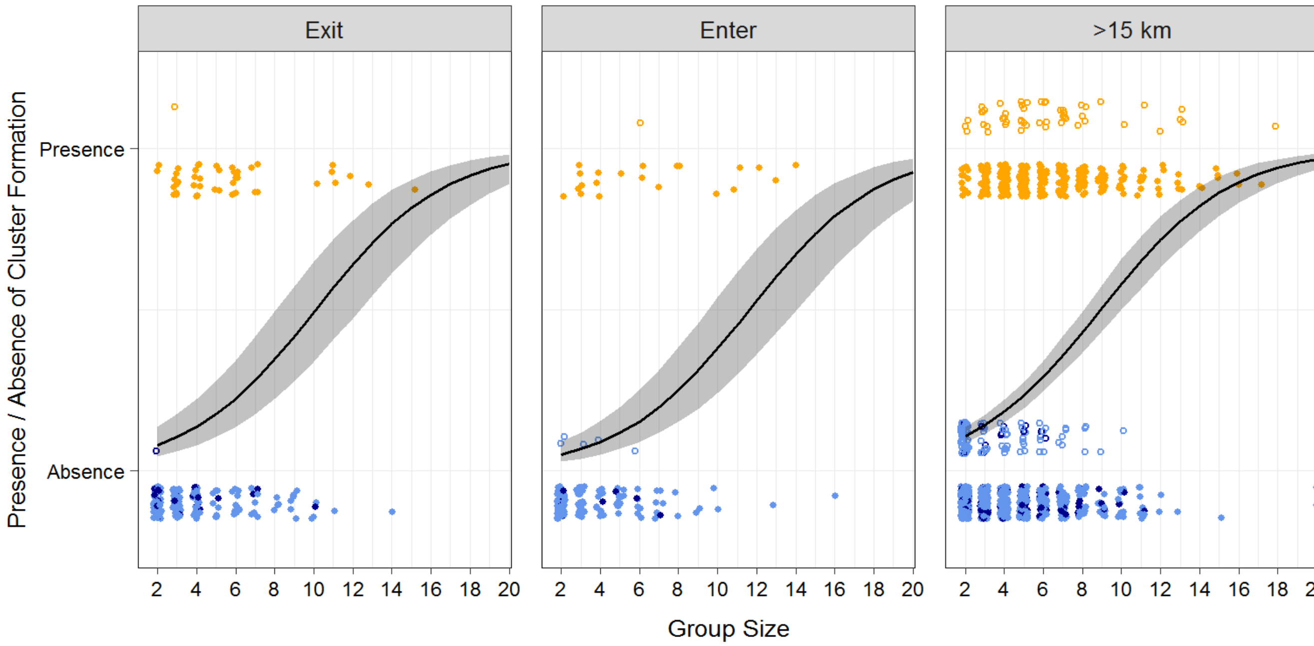

Figure C-11: Presence / absence of groups in a cluster formation relative to group size and large vessel scenario (as panels). Small points depict groups that were classified to one of the three formations; lines represent model predictions (as continuous probability between 0 – "absence" and 1 – "presence". Grey ribbons are 95% confidence intervals.

2.5 Group Direction

The full model of group travel direction included effects of group size, time since last shooting event, binomial variable for hunting activity, presence of small vessels in the SSA, categorical variable for absence of large vessels within 15 km from the BSA, distance between large vessel and the BSA, whether the vessel was approaching or departing the BSA, whether the vessel was entering or exiting Milne Inlet, and interactions between vessel distance and approaching/departing the BSA, between approaching/departing the BSA and entering/exiting Milne Inlet, and between vessel distance and entering/exiting Milne Inlet. The model selection process resulted in the removal of the vessel distance × entering/exiting interaction (Table C-11). The two interactions related to large vessel traffic and all non-vessel main effects were significant (Table C-12). The odds ratio for group size was 1.29, indicating that an addition of 1 narwhal to a group increased the odds of south travel by 29%. This is reflected in the lower prediction curves (i.e., closer to the "N" travel direction) at smaller group sizes (Figure C-12). The odds ratio for time since last shooting event was 0.98, indicating that for each minute that passed since the last shot was fired, the odds of travel south decreased by 2%, resulting in the decreasing trend of probability of traveling south as function of time since last shooting (Figure C-12). The low odds ratio for hunting activity (0.13) may be interpreted as strongly decreased odds of traveling south when no hunting occurred; however, it is more likely that hunting took place when animals predominantly traveled south, since south-traveling groups sizes were larger, therefore being more attractive to hunters.

When no large vessels were present within 15 km from the BSA, the odds of south travel were lower than when an exiting vessel was close to the BSA, and higher than when an entering vessel was within 15 km from the BSA (Table C-12). The odds ratio for distance between BSA and large vessel was 0.93, therefore the odds of traveling south were 7% lower with each added kilometer of distance between and approaching vessel and the BSA. Groups recorded when large vessels were entering the BSA were predicted to be considerably less likely to travel south, especially when the vessel was departing the BSA (Figure C-13). This result reflected the low incidence of south-traveling groups when a vessel was entering Milne Inlet and departing from the BSA. While significant, the odds ratio for this scenario was extremely high (31.1), with exceedingly wide 95% CIs (Table C-12), reflecting the high uncertainty in results due to the low occurrence of south-traveling groups.

Overall, narwhal were estimated to be most likely to travel south in large groups, and when large vessels exiting Milne Inlet were within approximately 12 km from the BSA. The probability of traveling south when large vessels were present within 15 km from the BSA was generally highest when the vessels were close. Travel north was more likely when groups were smaller and at larger distances from vessels, if large vessels were present, especially so when large vessels were entering Milne Inlet and departing the BSA.

Table C-11: Model selection for group direction modeling.

Model	Parameters	AIC	ΔAIC
1	Sightability + presence/absence of small vessels in the SSA + absence of large vessels within 15 km of BSA + distance from large vessel + approaching / departing the BSA + entering / exiting Milne Inlet + vessel distance × approaching/departing + approaching / departing × entering / exiting + exiting / entering × vessel distance	1846.2	0.1
2	Removed exiting / entering × vessel distance interaction	1846.2	0.0
3	Removed exiting / entering × vessel distance and approaching / departing × entering / exiting interaction	1878.2	32.1
4	Removed all three interactions	1877.1	30.9
5	Removed presence of small vessels in the SSA	1852.5	6.4
6	Removed presence of small vessels in the SSA and hunting effects	1976.1	129.9

Table C-12: Odds ratios and their lower (LCI) and upper (UCI) 95% confidence intervals from logistic regression of travel direction at the BSA.

Parameter	Odds ratio	LCI	UCI	*P* value
Intercept	26.61	9.32	83.24	<0.001
Group size	1.29	1.22	1.36	<0.001
Time since last shooting event	0.98	0.98	0.99	<0.001
No hunting activity	0.13	0.09	0.19	<0.001
Small vessel presence in the SSA	0.55	0.37	0.82	0.003
Large vessel absence	0.29	0.10	0.74	0.014
Distance between large vessel and BSA	0.93	0.85	1.00	0.058
Large vessel departing the BSA	31.10	4.55	290.12	0.001
Large vessel entering Milne Inlet	0.18	0.08	0.38	<0.001
Distance x Large vessel departing the BSA	0.77	0.64	0.90	0.002
Large vessel departing the BSA x Large vessel entering Milne Inlet	0.02	0.00	0.08	<0.001

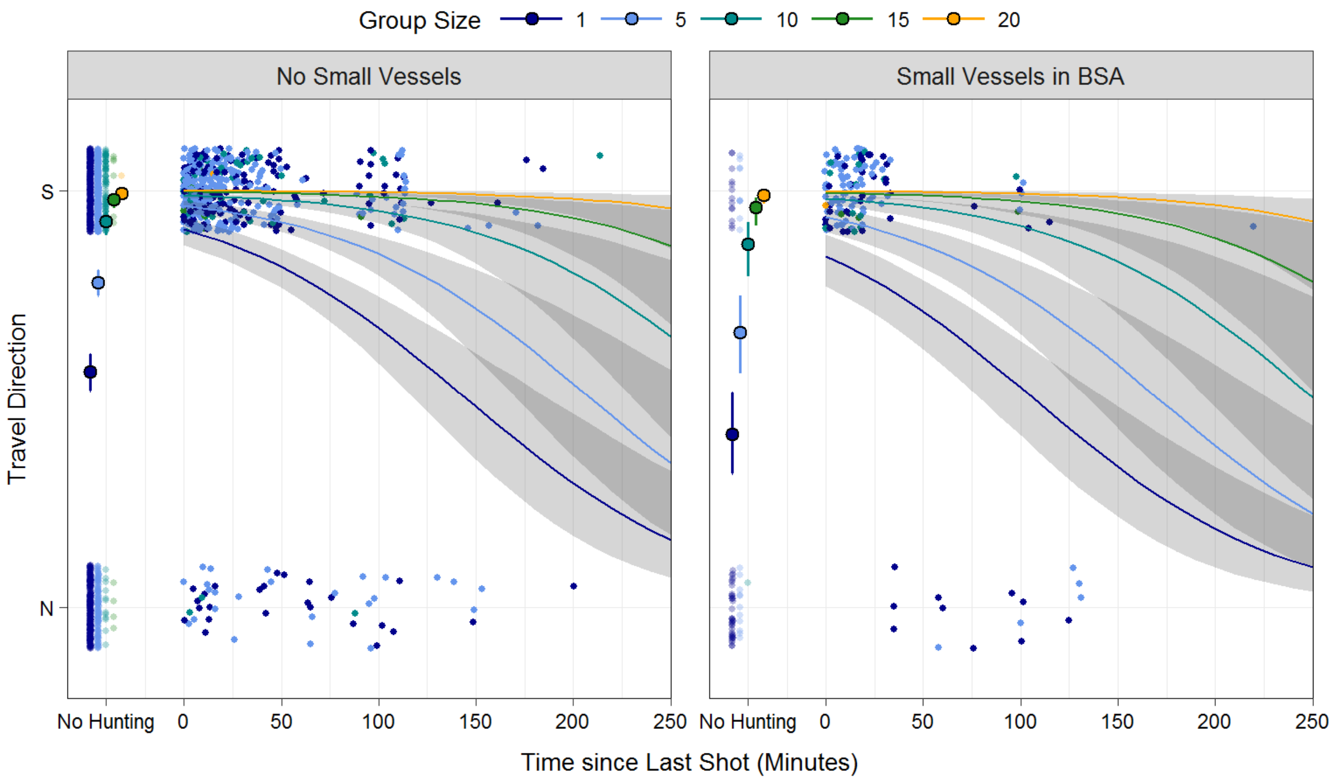

Figure C-12: Travel direction relative to anthropogenic activity when no vessels are within 15 km of SSA. Small points depict raw data, classified into N (north) and S (south) travel direction, with group sizes rounded to the nearest value shown; lines and large points represent model predictions (as continuous probability between 0 – north and 1 – south). Error bars and grey ribbons are 95% confidence intervals.

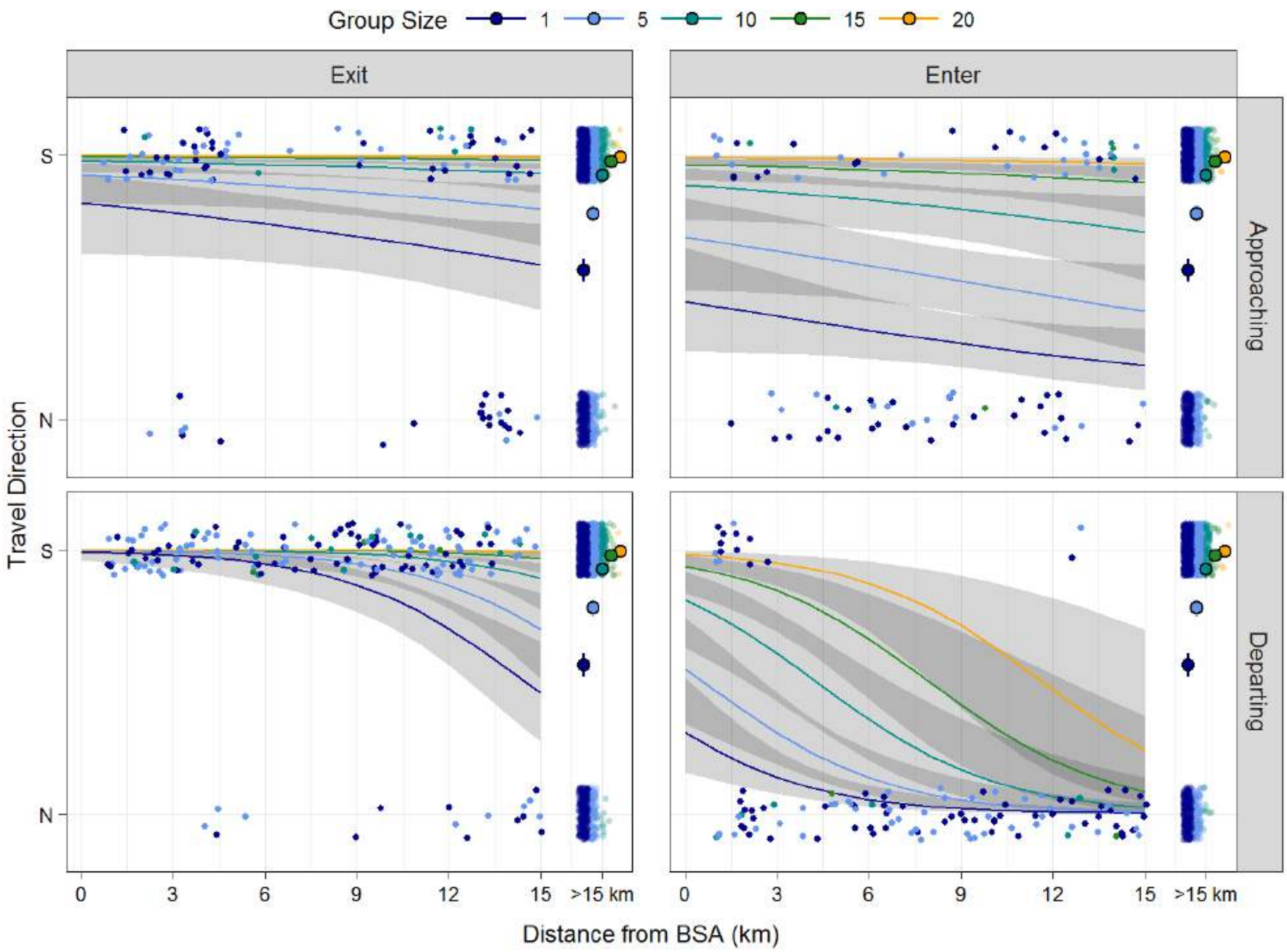

Figure C-13: Travel direction when large vessels are within 15 km of SSA. Small points depict raw data, classified into N (north) and S (south) travel direction, with group sizes rounded to the nearest value shown; lines and large points represent model predictions (as continuous probability between 0 – north and 1 – south). Error bars and grey ribbons are 95% confidence intervals.

2.6 Travel Speed

Movement speed data did not meet the ordinal regression assumption of proportional odds, and data were therefore modeled using three sets of logistic regressions, of presence/absence of slow, medium, and fast groups. Because very little data was available for fast-moving groups under the presence of large vessels, especially when vessels were exiting Milne Inlet and approaching the BSA (Figure 5-30), vessel-related variables were not added to the model of presence/absence of fast-moving groups.

The full logistic model of slow group presence/absence included effects of presence of small vessels in the SSA, group size, hunting activity, time since last shooting event, a categorical variable for no large vessels within 15 km from the BSA, distance between large vessel and BSA, whether the vessel was approaching or departing the BSA, whether the vessel was entering or exiting Milne Inlet, and interactions between vessel distance and approaching/departing the BSA, between approaching/departing the BSA and entering/exiting Milne Inlet, and between vessel distance and entering/exiting Milne Inlet. Of the examined five candidate models, model #4, which included none of the interactions, was the most parsimonious model within 2 AIC units from the lowest AIC value, and was therefore selected for interpretation (Table C-13).

The model results of slow travel speeds suggested that when small vessels were present, the odds for slow group presence were 2.1 times higher (Table C-14, Figure C-14). An increase of group size by 1 narwhal was estimated to decrease the odds of slow group presence by 17%, as reflected in Figure 5-30. In the absence of hunting activity, odds of slow traveling speed were 41% higher than immediately after a shooting event, and with every 1 min increase in time since last shooting events, the odds of a slow group presence increased by 1%. The modeled probability of slow group presence in relation to large vessel traffic depended on scenario (Figure C-15). However, since distance from vessel did not have a significant effect on slow group presence / absence, the results are likely spurious.

The full model of medium speed included effects of presence of small vessels in the SSA, group size, hunting activity, time since last shooting event, a categorical variable for absence of large vessels within 15 km of BSA, distance from large vessel, whether the vessel was approaching or departing the BSA, whether the vessel was entering or exiting Milne Inlet, and interactions between vessel distance and approaching/departing the BSA, between approaching/departing the BSA and entering/exiting Milne Inlet, and between vessel distance and entering/exiting Milne Inlet. The AIC values of the candidate models indicated that the full model had the best support (Table C-13).

The presence of small vessels in the SSA had a significant, 65% reduction on odds of travel at medium speed (Table C-14, Figure C-14). In the absence of hunting, the odds of observing a medium-moving group were not significantly different than immediately after a shooting event. However, time since last shooting event had a significant effect of the odds of medium travel, with the odds of medium traveling speed decreasing by 1% with every 1 min from the last shooting event. Since the effect of a rifle being fired should be largest immediately after the shot, the lack of significance of the “Absence of hunting” term suggests that hunting activity does not have an effect on medium travel speed probability based on the 2017 data. Larger groups were more likely to be observed traveling at a medium speed, with a 4% increase in odds for every 1 narwhal added to the group. The odds of medium traveling speed were 68% lower in the absence of large vessels within 15 km from the BSA (Table C-14, Figure C-16). The relationship with distance between vessel and BSA depended on scenario – when vessels were exiting Milne Inlet, the probability of medium-traveling groups was highest when vessels were close to the BSA, whereas when vessels were entering Milne Inlet, the probability was highest when they were far from the BSA (Figure C-16).

In the model selection of fast movement speed, the retained model was the full one, since the removal of small vessel presence or hunting effects increased the AIC values (Table C-13). The logistic model of presence of groups traveling at a fast speed indicated that the presence of small vessels in the SSA doubled the odds of fast travel (Table C-14, Figure C-14). In the absence of hunting activity, the odds of fast-traveling groups were 44% lower; however, time since shooting was not a significant in the analysis, likely due to the limited information available for fast-moving groups at long periods following shooting events (Figure C-14).

Overall, narwhal were more likely to travel at a slow speed in small groups, prior to a shooting event or approximately an hour after one, and in the presence of small vessels. Medium travel speed was more likely in groups of intermediate size and in the absence of small vessels. When large vessels were present within 15 km from the BSA, groups were more likely to travel at a medium speed when exiting vessels were near and entering vessels were far.

Table C-13: Model selection for travel speed modeling.

Speed	Model	Parameters	AIC	ΔAIC
Slow	1	Group size + presence/absence of small vessels in the SSA + absence of large vessels within 15 km of BSA + distance from large vessel + approaching / departing the BSA + entering / exiting Milne Inlet + vessel distance × approaching/departing + approaching / departing × entering / exiting + exiting / entering × vessel distance	2101.2	1.2
	2	Removed exiting / entering × vessel distance interaction	2100.0	0.0
	3	Removed exiting / entering × vessel distance and approaching / departing × entering / exiting interaction	2100.6	0.6
	4	Removed all three interactions	2101.4	1.4
	5	Removed presence of small vessels in the SSA	2118.2	18.2
	6	Removed presence of small vessels in the SSA and hunting effects	2131.5	31.5
Medium	1	Group size + presence/absence of small vessels in the SSA + absence of large vessels within 15 km of BSA + distance from large vessel + approaching / departing the BSA + entering / exiting Milne Inlet + vessel distance × approaching/departing + approaching / departing × entering / exiting + exiting / entering × vessel distance	2703.9	0.0
	2	Removed exiting / entering × vessel distance interaction	2712.2	8.2
	3	Removed exiting / entering × vessel distance and approaching / departing × entering / exiting interaction	2712.4	8.5
	4	Removed all three interactions	2715.0	11.0
	5	Removed presence of small vessels in the SSA	2748.4	44.5
	6	Removed presence of small vessels in the SSA and hunting effects	2778.4	74.4
Fast	1	Group size + presence/absence of small vessels in the SSA + absence of large vessels within 15 km of BSA + distance from large vessel + approaching / departing the BSA + entering / exiting Milne Inlet	1677.1	0.0
	2	Removed presence of small vessels in the SSA	1688.5	11.5
	3	Removed presence of small vessels in the SSA and hunting effects	1710.7	33.6

Table C-14: Odds ratios and their lower (LCI) and upper (UCI) 95% confidence intervals from logistic regressions of travel speed at the BSA.

Speed	Parameter	Estimate	LCI	UCI	*P* value
Slow	Intercept	0.45	0.23	0.85	0.016
	Small vessel presence in the SSA	2.14	1.53	2.98	<0.001
	Group size	0.83	0.79	0.87	<0.001
	Absence of hunting activity	1.41	1.05	1.90	0.025
	Time since last shooting event	1.01	1.01	1.01	<0.001
	Large vessel absence	0.71	0.39	1.31	0.264
	Large vessel distance from BSA	0.99	0.94	1.04	0.582
	Large vessel departing the BSA	0.48	0.30	0.76	0.002
	Large vessel entering Milne Inlet	1.55	0.98	2.47	0.060
Medium	Intercept	5.76	2.43	15.06	<0.001
	Small vessel presence in the SSA	0.35	0.26	0.48	<0.001
	Group size	1.04	1.01	1.08	0.022
	Absence of hunting activity	1.12	0.88	1.43	0.358
	Time since last shooting event	0.99	0.99	1.00	0.001
	Large vessel absence	0.32	0.12	0.76	0.014
	Large vessel distance from BSA	0.89	0.81	0.96	0.004
	Large vessel departing the BSA	0.35	0.13	0.91	0.036
	Large vessel entering Milne Inlet	0.15	0.05	0.41	<0.001
	Large vessel distance × Large vessel departing the BSA	1.11	1.01	1.21	0.025
	Large vessel distance × Large vessel entering the BSA	2.19	0.97	5.01	0.062
	Large vessel departing the BSA × Large vessel entering the BSA	1.15	1.06	1.26	0.002
Fast	Intercept	0.09	0.04	0.19	<0.001
	Small vessel presence in the SSA	2.01	1.39	2.87	<0.001
	Group size	1.11	1.06	1.15	<0.001
	Absence of hunting activity	0.56	0.41	0.76	<0.001
	Time since last shooting event	1.00	0.99	1.00	0.836
	Large vessel absence	1.52	0.71	3.49	0.302
	Large vessel distance from BSA	1.00	0.95	1.07	0.910
	Large vessel departing the BSA	2.34	1.28	4.55	0.008
	Large vessel entering Milne Inlet	1.00	0.57	1.71	0.987

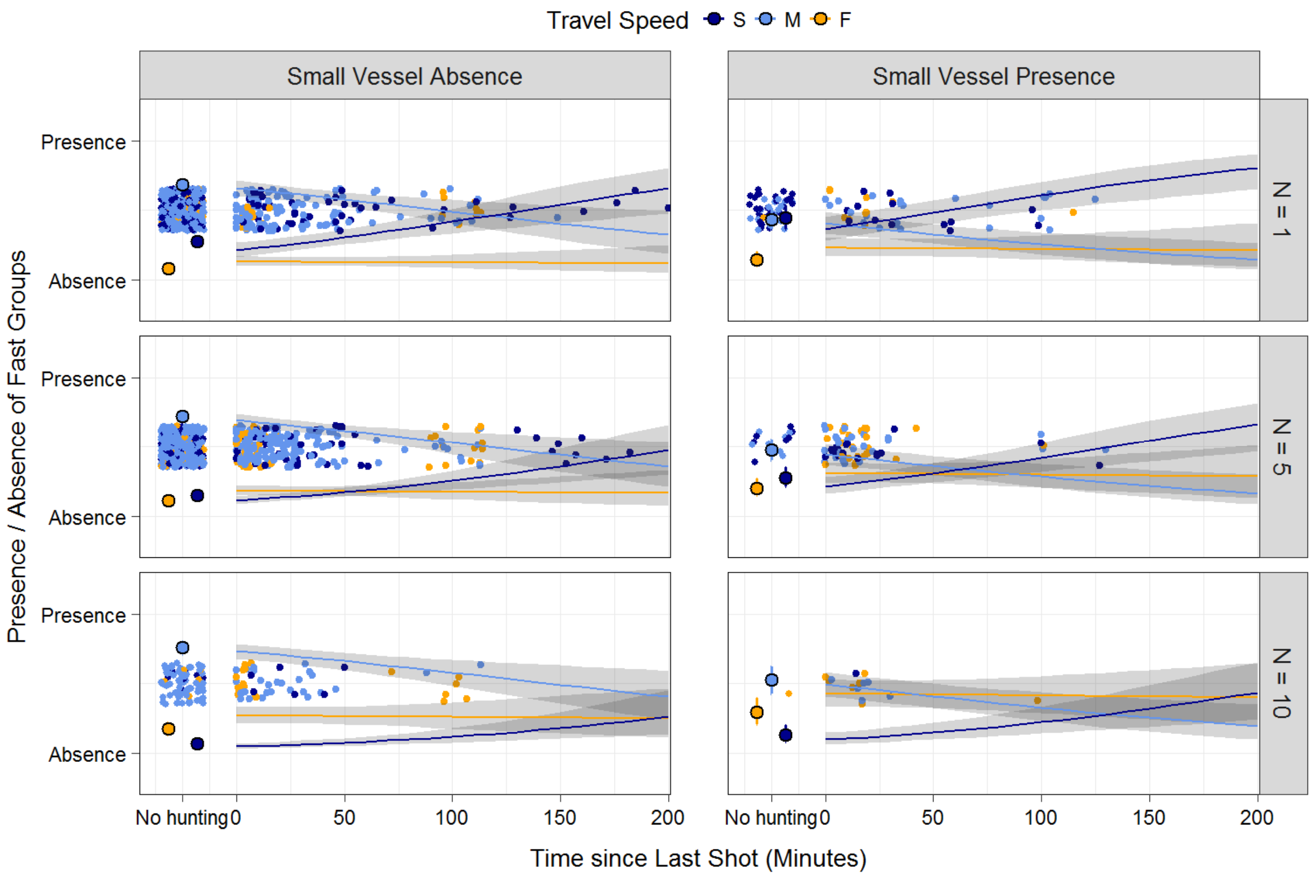

Figure C-14: Presence / absence of groups moving in a slow, medium, or fast speed relative to hunting activity, group size and presence/absence of small vessels in the SSA (as panels). Small points depict groups that were classified to one of the three travel speeds, with group size rounded to the nearest shown value; lines and large points represent model predictions (as continuous probability between 0 – "absence" and 1 – "presence". Error bars and grey ribbons are 95% confidence intervals.

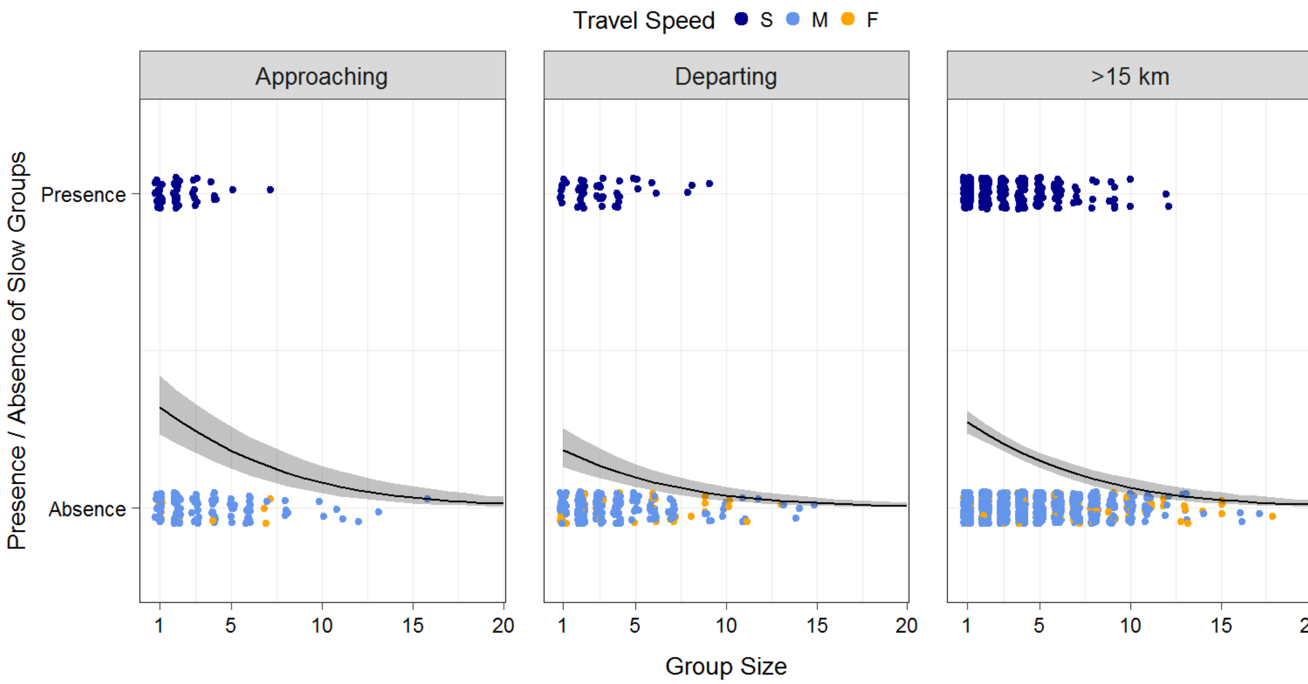

Figure C-15: Presence / absence of groups moving in a slow speed relative to group size and large vessel scenario (as panels). Small points depict groups that were classified to one of the three travel speeds; lines and large points represent model predictions (as continuous probability between 0 – "absence" and 1 – "presence". Error bars and grey ribbons are 95% confidence intervals.

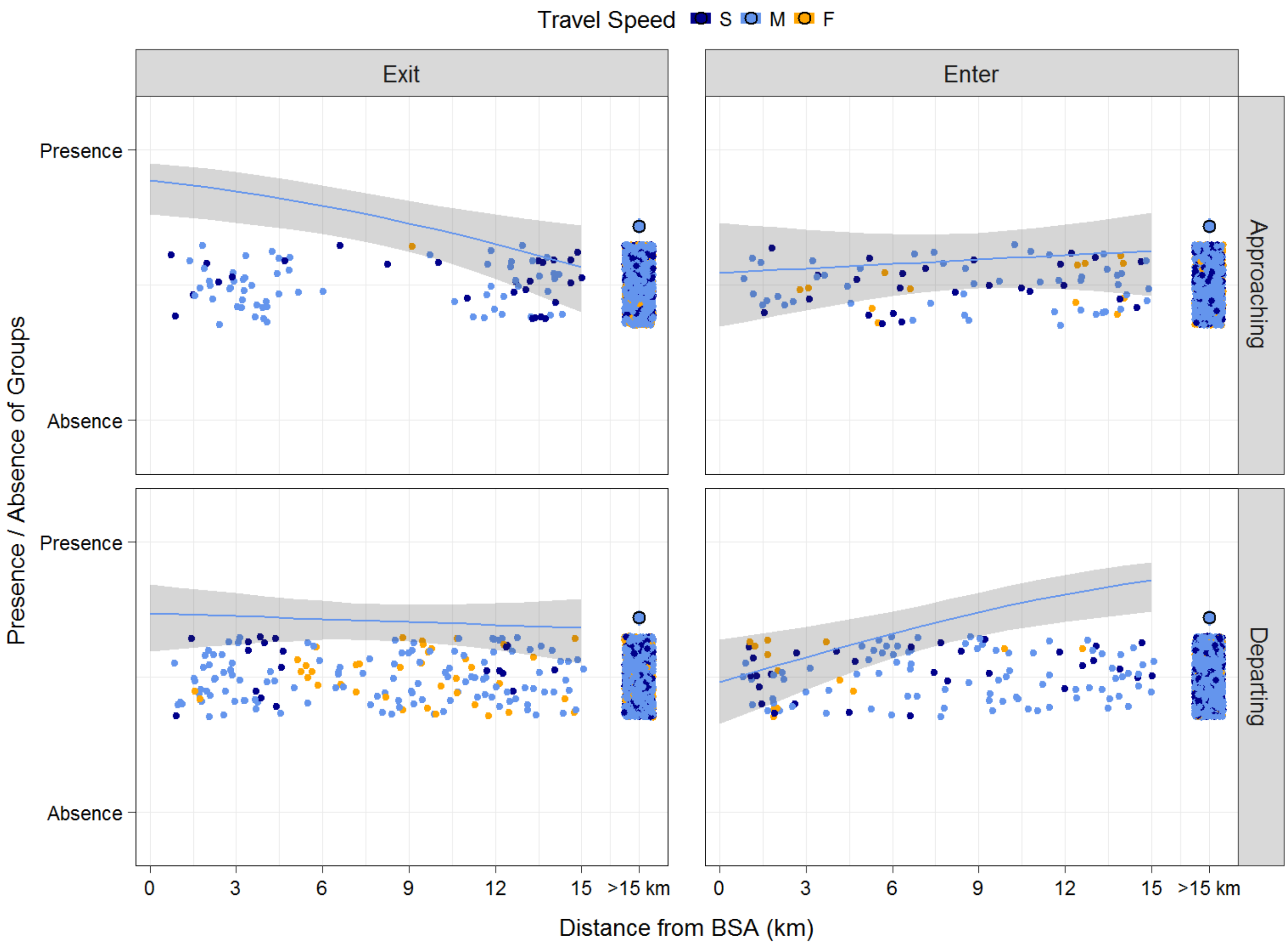

Figure C-16: Presence / absence of groups moving in a medium speed relative to group size and large vessel scenario (as panels). Small points depict groups that were classified to one of the three travel speeds; lines and large points represent model predictions (as continuous probability between 0 – "absence" and 1 – "presence". Error bars and grey ribbons are 95% confidence intervals. Note slow group predictions are shown in Figure C-15.

2.7 Distance from the Bruce Head Shore

The full model of distance from shore included effects of sightability, group size, presence/absence of small vessels in the SSA, categorical variable for absence of large vessels within 15 km of BSA, distance between large vessel and BSA, whether the vessel was approaching or departing the BSA, whether the vessel was entering or exiting Milne Inlet, and interactions between vessel distance and approaching/departing the BSA, between approaching/departing the BSA and entering/exiting Milne Inlet, and between vessel distance and entering/exiting Milne Inlet. Of the examined six candidate models, model #3, which included an interaction between vessel distance and whether the vessel was approaching or departing the BSA, was the simplest model within 2 AIC units from the lowest AIC value, and was therefore selected for interpretation (Table C-15).

The odds of offshore group presence significantly decreased with reduced sightability conditions (relative to excellent sightability) – by 30% at good sightability, 36% at medium sightability, and 52% at poor sightability

(Table C-16), indicating that observers were more likely to record groups closer to shore with reduced sightability (Figure C-17). The odds ratio for group size was 0.89, indicating that with every 1 narwhal increase in group size, the odds of offshore travel were 11% lower, as reflected in Figure 5-32. In the absence of hunting, the odds of offshore travel were 68% higher (since hunting is more likely to occur when groups are closer), and increased by 1% with every minute that passed from the last shooting event.

In the absence of large vessels, the odds of offshore travel were 72% lower than when a large vessel, exiting Milne Inlet and approaching the BSA, was at 0 lm from the BSA (Figure C-18). Narwhal were less likely to travel offshore when a vessel was entering Milne Inlet when compared to an exiting vessel, regardless of whether the vessel was approaching or departing the BSA. However, while the probability of being offshore decreased with vessel distance when vessels were approaching, it increased with distance when vessels were departing the BSA (Table C-16, Figure C-18). The reversal of predicted probabilities with distance when a vessel was approaching and departing is not likely. If large vessel presence affected travel from shore, it would be expected that the effect would be low when the vessel was far and high when the vessel was near. It is not likely that effect levels would reverse depending on whether vessel was approaching or departing the BSA. This result may therefore be spurious.

Overall, narwhal were more likely to remain inshore when groups were larger and when large vessels were entering Milne Inlet, rather than exiting. In addition, sightability significantly affected the observation of group distance from shore. While an effect of distance between vessels and the BSA on travel distance from shore was identified, the exact relationship may be spurious.

Table C-15: Model selection for distance from shore modeling

Model	Parameters	AIC	ΔAIC
1	Sightability + group size + presence/absence of small vessels in the SSA + absence of large vessels within 15 km of BSA + distance from large vessel + approaching / departing the BSA + entering / exiting Milne Inlet + vessel distance × approaching/departing + approaching / departing × entering / exiting + exiting / entering × vessel distance + group size × absence of large vessels within 15 km of BSA	2863.9	1.7
2	Removed exiting / entering × vessel distance interaction	2862.1	0.0
3	Removed exiting / entering × vessel distance and approaching / departing × entering / exiting interaction	2863.9	1.8
4	Removed all three interactions	2867.7	5.6
5	Removed presence of small vessels in the SSA	2863.4	1.3
6	Removed presence of small vessels in the SSA and hunting activity	2884.8	22.7

Table C-16: Odds ratios and their lower (LCI) and upper (UCI) 95% confidence intervals from logistic regression of group distance from shore.

Parameter	Estimate	LCI	UCI	*P* value
Intercept (Excellent sightability)	2.41	1.25	4.74	0.010
Good sightability	0.70	0.57	0.85	<0.001
Medium sightability	0.64	0.48	0.85	0.002
Poor sightability	0.48	0.25	0.90	0.027
Group size	0.89	0.85	0.92	0.000
Small vessel presence in the BSA	0.82	0.60	1.13	0.227
Absence of hunting activity	1.68	1.33	2.15	<0.001
Time since last shooting event	1.01	1.00	1.01	<0.001
Absence of large vessels in 15 km from the BSA	0.28	0.15	0.52	<0.001
Large vessel distance from the BSA	0.94	0.88	1.00	0.050
Large vessel departing the BSA	0.17	0.08	0.38	<0.001
Large vessel entering Milne Inlet	0.57	0.38	0.84	0.005
Distance x Large vessel departing the BSA	1.11	1.02	1.21	0.017

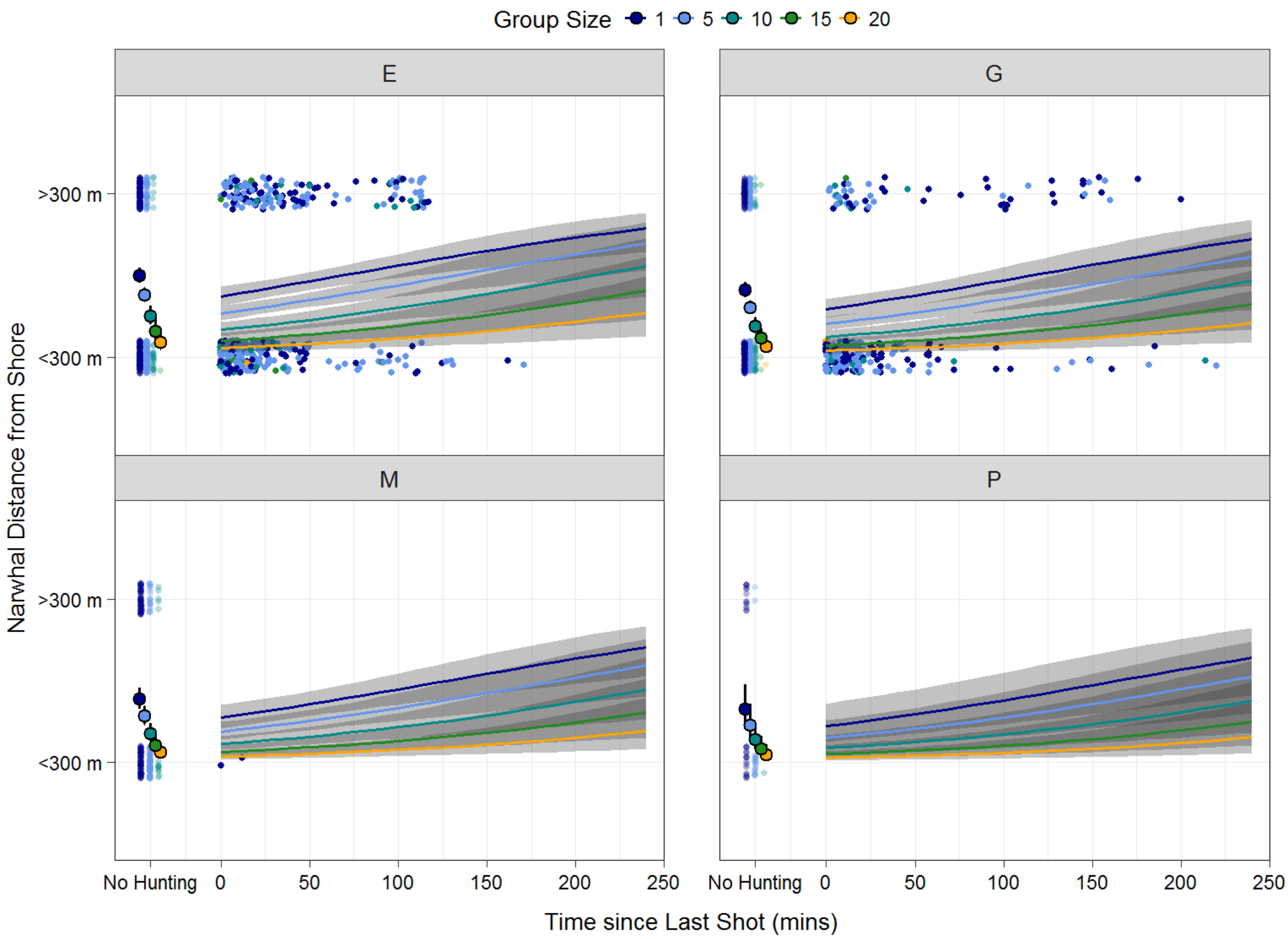

Figure C-17: Distance from shore relative to group size, hunting activity, and sightability conditions (as panels). Small points depict raw data, classified into "<300 m" and ">300" distances, with group sizes rounded to the nearest shown number; lines and large points represent model predictions (as continuous probability between 0 – "<300 m" and 1 – ">300 m"). Error bars and grey ribbons are 95% confidence intervals.

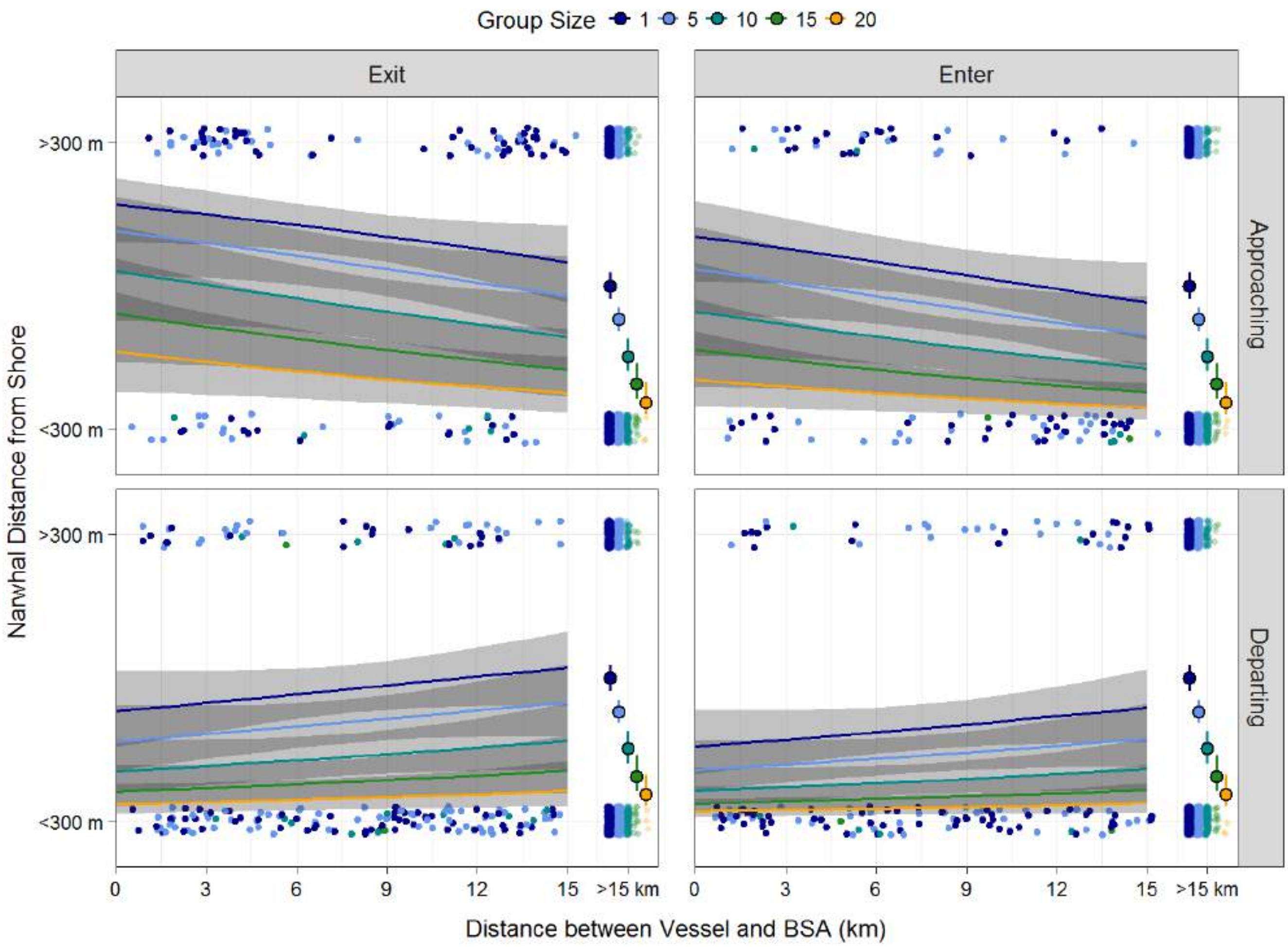

Figure C-18: Distance from shore relative to group size and large vessel scenario. Small points depict raw data, classified into "<300 m" and ">300" distances, with group sizes rounded to the nearest shown number; lines and large points represent model predictions (as continuous probability between 0 – "<300 m" and 1 – ">300 m"). Error bars and grey ribbons are 95% confidence intervals.

https://golderassociates.sharepoint.com/sites/11206g/deliverables/p7000 - bruce head monitoring/2017 annual report/v2_from megan/appendix c.docx

APPENDIX D

Vessel Track Information

Large Vessel traffic (>100 m) present in SSA during 2017 BH Field Program.
**Black text = vessels observed. Grey text = Vessels not observed.

Count	Date in SSA	Approximate Time in SSA (EDT)	Vessel Name	Vessel Class	Travel Direction	Vessel Speed (kt) in SSA
1	August 2, 2017	(05:30-06:30)	Nordic Olympic	Bulk (ore) carrier	South	under 9.0
2	August 2, 2017	(05:50 - 07:00)	Nordic Odin	Bulk (ore) carrier	South	under 9.0
3	August 2, 2017	(22:00 - 22:40)	BBC Volga	General cargo	South	up to 13.9
4	August 3, 2017	(03:40 - 04:50)	Sagar Samrat	Bulk (ore) carrier	South	under 9.0
5	August 3, 2017	(13:20 - 14:15)	MV Spleithoff (Dolfijngracht)	General cargo	South	up to 9.2
6	August 3, 2017	(15:05 - 16:00)	Nordic Olympic	Bulk (ore) carrier	North	under 9.0
7	August 4, 2017	(11:20 - 12:10)	Nordic Oshima	Bulk (ore) carrier	South	up to 9.4
8	August 4, 2017	(15:20 - 16:10)	Nordic Odin	Bulk (ore) carrier	North	up to 9.9
9	August 4, 2017	(18:40 - 19:40)	Nordic Orion	Bulk (ore) carrier	South	up to 9.0
10	August 5, 2017	(20:10 - 21:05)	Sagar Samrat	Bulk (ore) carrier	North	under 9.0
11	August 5, 2017	(22:30 - 23:30)	Rio Tamara	Bulk (ore) carrier	South	up to 9.1
12	August 7, 2017	(01:45 - 02:55)	Nordic Oshima	Bulk (ore) carrier	North	under 9.0
13	August 7, 2017	(05:15 - 06:10)	Nordic Oasis	Bulk (ore) carrier	South	up to 9.2
14	August 8, 2017	(12:10 - 13:00)	Nordic Orion	Bulk (ore) carrier	North	up to 9.4
15	August 8, 2017	(15:35 - 16:25)	NS Energy	Bulk (ore) carrier	South	under 9.0
16	August 8, 2017	(22:40 - 23:20)	BBC Volga	General cargo	North	up to 14.4
17	August 9, 2017	(07:20 - 08:05)	National Geographic Explorer	Passenger vessel	South	up to 13.4
18	August 9, 2017	(12:55 - 14:20)	National Geographic Explorer	Passenger vessel	North / South	up to 14.0
19	August 9, 2017	(22:35 - 23:30)	Rio Tamara	Bulk (ore) carrier	North	up to 9.0
20	August 10, 2017	(10:05 - 11:00)	Golden Ice	Bulk (ore) carrier	South	under 9.0
21	August 11, 2017	(16:30 - 17:20)	Dolfijngracht	General cargo	North	up to 9.2
22	August 12, 2017	(04:55 - 05:50)	Nordic Oasis	Bulk (ore) carrier	North	up to 9.7

Count	Date in SSA	Approximate Time in SSA (EDT)	Vessel Name	Vessel Class	Travel Direction	Vessel Speed (kt) in SSA
23	August 12, 2017	(12:30 - 13:30)	Golden Diamond	Bulk (ore) carrier	South	up to 10.4
24	August 13, 2017	(16:25 - 17:15)	NS Energy	Bulk (ore) carrier	North	up to 9.3
25	August 13, 2017	(19:45 - 20:50)	MV Golden Bull	Bulk (ore) carrier	South	up to 9.3
26	August 15, 2017	(17:30 - 18:30)	Golden Ice	Bulk (ore) carrier	North	under 9.0
27	August 16, 2017	(11:35 - 12:35)	Golden Opal	Bulk (ore) carrier	South	up to 10.2
28	August 17, 2017	(01:45 - 02:35)	Golden Diamond	Bulk (ore) carrier	North	up to 9.3
29	August 17, 2017	(07:40 - 08:35)	MV Golden Brilliant	Bulk (ore) carrier	South	under 9.0
30	August 18, 2017	(05:15 - 06:05)	MV Golden Bull	Bulk (ore) carrier	North	under 9.0
31	August 18, 2017	(09:05 - 10:00)	Nordic Odyssey	Bulk (ore) carrier	South	up to 9.3
32	August 18, 2017	(17:45 - 18:15)	Le Boreal	Passenger vessel	South	up to 15.9
33	August 19, 2017	(15:55 - 16:55)	Golden Opal	Bulk (ore) carrier	North	under 9.0
34	August 19, 2017	(18:35 - 19:30)	Golden Opportunity	Bulk (ore) carrier	South	up to 9.0
35	August 19, 2017	(21:50 - 22:40)	Nunalik	General cargo	South	up to 10.0
36	August 20, 2017	(14:40 - 15:15)	Sarah Desgagnes	Oil tanker	South	up to 13.1
37	August 20, 2017	(18:20 - 19:10)	MV Golden Brilliant	Bulk (ore) carrier	North	up to 9.5
38	August 20, 2017	(20:25 - 21:25)	NS Yakutia	Bulk (ore) carrier	South	under 9.0
39	August 23, 2017	(05:25 - 06:15)	Nordic Odyssey	Bulk (ore) carrier	North	up to 9.4
40	August 23, 2017	(07:40 - 08:30)	Arkadia	Bulk (ore) carrier	South	up to 9.7
41	August 24, 2017	(04:55 - 05:45)	Golden Opportunity	Bulk (ore) carrier	North	up to 9.0
42	August 24, 2017	(08:05 - 09:00)	Golden Strength	Bulk (ore) carrier	South	up to 9.1
43	August 24, 2017	(09:00-09:55)	Nunalik	General cargo	North	up to 9.6
44	August 25, 2017	(05:30 - 06:30)	NS Yakutia	Bulk (ore) carrier	North	up to 9.0
45	August 25, 2017	(09:15 - 10:10)	Golden Ruby	Bulk (ore) carrier	South	up to 9.2
46	August 25, 2017	(20:10 - 20:45)	Rosaire A. Desgagnes	General cargo	South	up to 13.7

Count	Date in SSA	Approximate Time in SSA (EDT)	Vessel Name	Vessel Class	Travel Direction	Vessel Speed (kt) in SSA
47	August 26, 2017	(06:50 - 07:25)	Claude A. Desgagnes	General cargo	South	up to 13.7
48	August 26, 2017	(07:50 - 08:40)	Arkadia	Bulk (ore) carrier	North	up to 9.6
49	August 26, 2017	(10:50 - 11:40)	Golden Pearl	Bulk (ore) carrier	South	up to 9.9
50	August 26, 2017	(12:40 - 13:10)	Rosaire A. Desgagnes	General cargo	North	up to 13.7
51	August 26, 2017	(18:20 - 19:10)	Mitiq	General cargo	South	up to 9.6
52	August 27, 2017	(05:40 - 06:35)	Golden Strength	Bulk (ore) carrier	North	up to 9.1
53	August 27, 2017	(10:45 - 11:40)	Golden Saguenay	Bulk (ore) carrier	South	under 9.0
54	August 27, 2017	(19:15 - 19:55)	Sarah Desgagnes	Oil Tanker	North	up to 12.0
55	August 28, 2017	(07:35 - 08:25)	Golden Ruby	Bulk (ore) carrier	North	up to 9.1
56	August 28, 2017	(11:40 - 12:35)	Golden Amber	Bulk (ore) carrier	South	up to 11.2
57	August 29, 2017	(14:30 - 15:25)	Golden Pearl	Bulk (ore) carrier	North	under 9.0
58	August 29, 2017	(16:50 - 17:50)	Nordic Odin	Bulk (ore) carrier	South	up to 9.2

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