REPORT

Mary River Project

2020 Bruce Head Shore-based Monitoring Program

Submitted to:

Baffinland Iron Mines Corporation

2275 Upper Middle Road East - Suite 300
Oakville, ON, L6H 0C3

Submitted by:

Golder Associates Ltd.

2nd floor, 3795 Carey Road, Victoria, British Columbia, V8Z 6T8, Canada

+1 250 881 7372

1663724-269-R-Rev0-33000

31 August 2021

Executive Summary

The Mary River Project (hereafter, “the Project”) is an operating open pit iron ore mine owned by Baffinland Iron Mines Corporation (Baffinland) and located in the Qikiqtani Region of North Baffin Island, Nunavut. To date, Baffinland has been operating in the Early Revenue Phase (ERP) of the Project and is currently authorized to transport 6.0 million tonnes per annum (Mtpa) of iron ore to global markets. The operating mine site is connected to Milne Port, located at the head of Milne Inlet, through which iron ore is transported to chartered ore carrier vessels for open water shipping along the Project’s Northern Shipping Route. During the first year of ERP operations in 2015, Baffinland shipped ~900,000 tonnes of iron ore from Milne Port involving 13 return ore carrier voyages. In 2016, the total volume of ore shipped out of Milne Port reached 2.6 million tonnes involving 37 return ore carrier voyages. In 2017, the total volume of ore shipped out of Milne Port reached ~4.2 million tonnes involving 56 return ore carrier voyages. A total of 5.44 Mtpa of iron ore was shipped via 71 return voyages in 2018 and 5.86 Mtpa of ore was shipped via 81 return voyages in 2019. In 2020, a total of 5.5 Mtpa was shipped via 72 return voyages.

The Project’s Northern Shipping Route encompasses Milne Inlet, Eclipse Sound, Pond Inlet, and adjacent water bodies. This coastal fjord system represents important summering grounds for narwhal (*Monodon monoceros*) in the Canadian Arctic. To investigate narwhal response to shipping activities along the Northern Shipping Route, the Bruce Head Shore-based Monitoring Program (“the Program”) has been conducted annually since 2014, following a pilot project in 2013. The Program was structured to specifically address Project Certificate (PC) conditions 99c, 101g, 109, and 111, related to evaluating potential disturbance of marine mammals from shipping activities that may result in changes in animal abundance, distribution, and migratory movements within the Project’s Regional Study Area (RSA). The 2020 shore-based Program represents the sixth year of environmental effects monitoring undertaken at Bruce Head in support of the Project.

This report presents the results of shore-based monitoring of narwhal and vessel traffic in Milne Inlet during the 2014-2017 and the 2019-2020 open-water seasons. Behavioural response of narwhal to Project-related ore carriers and other non-Project-related vessel traffic was investigated by collecting visual survey data from a cliff-based observation platform at Bruce Head, overlooking the Northern Shipping Route. As knowledge regarding the context and function (if any) of narwhal aggregations and space use patterns is generally incomplete, monitoring of narwhal relative abundance, distribution, and group composition is warranted to better understand potential responses to a perceived threat (i.e., a transiting vessel). Therefore, information was collected on relative abundance and distribution (RAD), group composition, and behaviour of narwhal near Bruce Head. Additional data were 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 that may also influence narwhal behaviour.

Based on analysis of data obtained during previous Bruce Head Shore-based Monitoring Programs, as well as consultation with the various stakeholder groups (i.e., the Marine Environment Working Group), it was determined that a more in-depth understanding of potential effects of shipping activities to narwhal could be obtained through the integration of an Unmanned Aerial Vehicle (UAV) and by correlating visual observations with concurrent acoustic data. As such, the use of an UAV was incorporated into the 2020 Program to enhance the collection of observational data on narwhal group composition and behaviour.

The following is a summary of key findings pertaining to narwhal behavioural response to vessel traffic based on six years of shore-based visual survey data collected at Bruce Head between 2014 and 2020:

Relative Abundance and Distribution

- Interannual variation: The overall relative abundance of narwhal in the SSA, inferred from sighting rate (no. of narwhal per hour - corrected for effort), was relatively constant between 2014 and 2019 despite a gradual increase in iron ore shipping along the Northern Shipping Route during this period. However, the relative abundance of narwhal in the SSA was lower in 2020 compared to all previous years. The lower relative abundance of narwhal observed in 2020 in the Bruce Head study area was consistent with findings from the 2020 aerial survey (i.e., a significant decrease in the 2020 Eclipse Sound abundance estimate). These results collectively suggest either potential displacement of a portion of the Eclipse Sound stock to the Admiralty Inlet summering ground during the summer of 2020, a potential displacement of these animals to another area (e.g., Eastern Baffin Bay or Somerset summering ground), or a potential decrease in the Eclipse Sound summer stock. The observed finding of a lower relative abundance of narwhal at Bruce Head in 2020, coincident with the 2020 aerial survey results demonstrating a significant decrease in the abundance of the Eclipse Sound narwhal stock in the RSA, has triggered further detailed investigation on the root cause of the observed finding along with implementation of precautionary based mitigation measures for application in 2021, as described in Section 7.1 and in Golder (2021b). **If found to be elicited by the Project, this finding is consistent with a high severity response, as defined by Finneran et al. (2017), and therefore has the potential to result in a significant alteration of natural behavioural patterns by narwhal in the RSA and/or a significant disruption to their daily routine. This finding would be contrary to impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Consistent with the definition of a significant effect used in the FEIS, large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses) could result in a population or stock-level consequence.**

Narwhal Density

- Vessel exposure effects: Within each study year, an effect of vessel exposure on narwhal density in the SSA was estimated. Specifically, vessel exposure was shown to result in a significant decrease in narwhal density in the SSA compared to when no vessels were present, but only when vessels were in close proximity (1-2 km from vessel for northbound vessels, and 3-4 km for southbound vessels). A 4-km maximum range of disturbance would be equivalent to a total exposure period of 29 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behavior following the exposure period (temporary effect). During the 2020 Bruce Head program (Aug 07 to Sept 01), there were approximately two transits per day in the SSA (56 one-way transits in SSA over a 26-day period). The daily vessel exposure period for narwhal was therefore equivalent to approximately one hour. On a heavy traffic day (assuming four transits per day), the daily vessel exposure period would be on the order of two hours. **These results suggest that narwhal density was influenced by vessel traffic at close distances (i.e., within 4 km), consistent with previous years' findings and similar to results from the 2017/2018 narwhal tagging study (Golder 2020a). Localized avoidance of the sound source (i.e., the vessel) by narwhal is indicative of a moderate severity response. As the observed response was of short duration (i.e., less than the duration of the vessel exposure), no significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine is anticipated. This is in line with impact predictions made in the FEIS for the ERP, in**

that the effects of ship noise on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., change in narwhal density), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

Group Composition and Behaviour

- Group Size: the effects of shipping (directional distance from vessel, vessel direction within Milne Inlet) on narwhal group size were not statistically significant (*P*>0.3 for all effects), with small effect sizes (-4% and +15% at 0 km from vessel). **These results suggest that narwhal neither congregate into larger groups nor fragment into smaller groups in response to vessel exposure. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., group size), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).**
- Group Composition:
  - All narwhal life stage categories (adults, juveniles, yearlings, and calves) were recorded in the BSA throughout the six sampling years. The mean daily proportion of calves recorded in the BSA (relative to the total number of narwhal observed per day) was higher in 2020 (annual mean of 11.3%) than three of previous years (2014=10.7%, 2016=10.5%, 2017=9.5%), and lower than 2019 (11.6%) and 2015 (12.9%). This suggests that calving rate (i.e., reproductive success) of the Eclipse Sound summering stock in 2020 was consistent with pre-shipping levels, despite a relatively steady increase in shipping throughout the RSA during this time.
  - The annual proportion of immatures (i.e., calves and yearlings) observed in 2020 was 14.3%, comparable to the annual proportion of immatures observed in previous years and above the identified Early Warning Indicator (EWI) threshold of 13.7%.
  - Vessel traffic was shown to have a possible, though uncertain, effect on group composition relative to the presence of immatures. Of note, despite a lack of statistical significance, observed data suggested that the proportion of groups with immatures was higher when vessels were in close proximity to the BSA. This finding is potentially due to groups without calves or yearlings being more capable of diving and moving away, thus inflating the probability of observing groups with calves or yearlings at the surface.
  - **Collectively, these results suggest that narwhal group composition, including proportion of immatures, did not significantly change between study years despite a relatively steady increase in shipping activity during this period. Furthermore, vessel traffic did not have a significant effect on the proportion of immatures observed. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to**

temporary, localized avoidance behaviour. Specific to this response variable (i.e., group composition), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

- Group Spread: Narwhal groups were more often observed in tight associations compared to loose associations under both vessel presence and vessel absence scenarios. In general, narwhal did not alter their spatial use patterns in the presence of vessels by associating in tighter groups or by dispersing widely. The effects of shipping (directional distance from vessel, vessel direction within Milne Inlet) on narwhal group spread were not statistically significant ($P>0.6$ for all effects), with small effect sizes (-1% and +14% at 0 km from vessel). **Similar to previous years' findings, these results suggest that narwhal group spread did not significantly change during vessel exposure events. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., group spread), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).**

- Group Formation: Narwhal groups were most often observed in parallel formation under both vessel presence and vessel absence scenarios. None of the shipping-related variables (i.e., distance from vessel, vessel direction within Milne Inlet, vessel direction relative to the BSA, or their interaction) were statistically significant in influencing narwhal group formation. **Similar to previous years' findings, these results suggest that narwhal group formation did not significantly change during vessel exposure events. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., group formation), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).**

- Group Direction: Narwhal groups were predominantly observed travelling south through the BSA. Southbound travel was least common when southbound vessels were headed away from the BSA, and most common when northbound vessels were headed away from the BSA. **Similar to previous years' findings, these findings suggest that narwhal groups may experience some level of avoidance behaviour in the wake of vessels transiting through Milne Inlet (i.e., narwhal groups appear to avoid "following" vessels) but that travel direction by narwhal groups is relatively less affected during the approach of vessels. These findings are consistent with a low severity response, as defined by Finneran et al. (2017), and are therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. This is in line with impact predictions made**

in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (group direction), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

- Travel Speed: The majority of the observed narwhal groups travelled at a medium speed, regardless of vessel exposure conditions. Despite a possible but uncertain effect of vessel distance on travel speed, this response variable is inherently subjective and findings may be influenced by data being recorded by multiple observers, providing low confidence in its usefulness for assessing behavioural response to vessel traffic. **Similar to previous years' findings, monitoring results do not suggest that narwhal alter their travel speed in the presence of transiting vessels. As defined by Finneran et al. (2017), a change in travel speed by narwhal is indicative of a moderate severity response. As no change in travel speed was observed in response to shipping, no significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine has been demonstrated. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., travel speed), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).**
- Distance from Bruce Head Shoreline: Narwhal groups were observed more often within 300 m of the Bruce Head shore under both vessel presence and vessel absence scenarios. Both south- and northbound vessel traffic was shown to result in a significant decrease in 'distance from shore', particularly evident when vessels were in close proximity to the BSA. **These findings suggest that narwhal may swim closer to shore when vessels are in close proximity to the BSA, indicating a moderate severity response but of short duration. As defined by Finneran et al. (2017), moderate severity responses lasting for a short duration (i.e., less than the duration of the vessel exposure) are unlikely to result in a significant alteration of an animal's natural behavioural patterns or disruption to their daily routine. This is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., distance from shore), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).**

UAV Focal Follow Surveys

- In 2020, a total of 84 narwhal focal follow surveys were successfully undertaken in the RSA (near Bruce Head and Koluktoo Bay) using a UAV-based video system (representing 7.3 h of recorded behaviour). This included 16 focal follows when ships were present (representing 1.3 h of recorded behaviour) and 68 focal follows when ships were absent (representing 6.0 h of recorded behaviour). Primary behaviors assessed included travelling (i.e., directional movement), milling (i.e., non-directional movement), resting (i.e., not moving/logging or moving slightly), and social behavior (i.e., clear interaction between individuals with physical contact). Of the followed groups, narwhal spent the majority of time travelling (65% of the time), followed by milling (20% of the time), resting (12% of the time) and social behaviours (3% of the time).

- The proportion of time groups spent travelling was similar when vessels were present compared to when vessels were absent (71% and 64%, respectively). Similarly, narwhal spent a similar proportion of time resting, milling and performing social behaviours when vessels were present (17%, 10% and 1%, respectively) compared to when vessels were absent (10%, 22% and 4%, respectively).
- While narwhal groups were shown to spend similar proportions of time in “loose” and “tight” group formation (i.e., 48% and 51%, respectively), the proportion of time that groups spent in tight formation was slightly higher when a vessel was present (57% of the time) compared to periods when no vessels were present (46% of the time).
- In terms of relative position of mother to offspring, immature narwhal were most commonly observed below their mother (compared to beside, behind or above their mother), in both presence and absence of shipping. The proportion of time immature narwhal maintained this position was slightly higher when vessels were present compared to when no vessels were present (69% and 53%, respectively). However, the proportion of time that mothers and their dependent young were tightly associated with one another was similar in the presence of vessels (79%) compared to periods when no vessels were present (76%).
- Additional monitoring is required to increase the sample size of focal follow surveys conducted in the presence of vessel traffic (given that the current sample size is limited to 1.3 h of observational data only).

ᓇᐃᓈᖅᓯᒪᔪᖅ

ᓄᓘᔾᓂᑦ ᐱᓕᕆᐊᖅ (ᑕᐃᔭᐅᔪᖅ ᑖᕝᕙᓂ, "ᐱᓕᕆᐊᖅ") ᐊᐅᓛᖅᑎᑦᑎᔪᖅ ᓄᓇᒥᑦ ᐅᒃᑯᐃᖓᔪᒥᑦ ᓴᕕᒃᓴᒥᑦ ᐅᔭᕋᒃᑕᕆᐊᕐᒥᑦ ᓇᖏᓂᕆᔭᐅᑉᓗᓂ ᐹᕖᓛᓐ ᓴᕕᒃᓴᓄᑦ ᐅᔭᕋᒃᑕᕆᓕᐊᕆᓐᑯᓐᓄᑦ (ᐹᕖᓛᓐᑯᑦ) ᕿᑭᖅᑖᓘᖏᑦ ᐅᐊᖕᓇᖕᒐᓂᑦ ᕿᑭᖅᑖᓘᑉ, ᓄᓇᕗᒻᒥᑦ. ᐅᑉᓗᒥᒧᑦ ᑎᑭᓪᓗᒍ ᐹᕖᓛᓐᑯᑦ ᐊᐅᓛᖅᑎᑦᑎᓯᒪᓕᖅᑐᑦ ᐱᓕᕆᐊᖅ ᐲᓇᐅᔾᔨᐅᕆᐊᖅᐸᓪᓕᐊᓕᓵᓂᕐᒥᑦ (ERP) ᐊᒻᒪᓗ ᒦᓈ ᐱᔪᖕᓇᖅᑎᑕᐅᓯᒪᔪᖅ ᐊᒡᔭᖅᑐᐃᓗᓂ 6.0 ᒥᓕᔭᓐ ᑖᓂᒃ ᐅᑭᐅᑖᒥᑦ (Mtpa) ᓴᕕᒃᓴᓂᒃ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᓂᒃ ᓄᓇᕐᔪᐊᕐᒥᑦ ᓂᐅᕕᕈᒪᔪᓄᑦ. ᐊᐅᓛᖅᑎᑕᐅᓂᖓ ᐅᔭᕋᒃᑕᕆᐊᑉ ᐃᓂᖓ ᑲᑎᓐᓂᖃᖅᑐᑦ ᕿᙵᐊᓂᑦ ᐃᒃᓴᕐᕕᖕᒧᑦ, ᓵᖓᓃᑦᑐᖅ ᕿᙵᐊᓂᑦ, ᓴᕕᒃᓴᐃᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᑦ ᐊᒡᔭᖅᑕᐅᖃᑦᑕᖅᓱᑎᒃ ᑦᓵᑐᑕᐅᔪᒃᑯᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᓂᒃ ᐅᓯᖃᖅᑕᖅᑐᑦ ᐅᒥᐊᕐᔪᐊᒃᑯᑦ ᐊᐅᔭᐅᑎᓪᓗᒍ ᐱᓕᕆᐊᑉ ᐅᐊᖕᓇᖕᒐᓂᑦ ᐊᑉᑯᑎᒋᔭᖕᒐᑦᑎᒍᑦ. ᓯᕗᓪᓕᖅᐹᖅ ᐅᑭᐅᕐᒥᑦ ᐲᓇᐅᔾᔨᐅᕆᐊᖅᐸᓪᓕᐊᓕᓵᓂᕐᒥᑦ (ERP) ᐊᐅᓛᖅᑎᑦᑎᓂᕐᓂᑦ 2015-ᒥᑦ, ᐹᕖᓛᓐᑯᑦ ᐊᐅᓪᓚᖅᑎᑦᑎᓚᐅᖅᑐᖅ ~900,000 ᑖᓂᒃ ᓴᕕᒃᓴᓂᒃ ᕿᙵᐊᓂᑦ ᐃᒃᓴᕐᕕᖕᒥᑦ 13-ᖏᖅᑕᖅᓱᑎᒃ ᐅᔭᕋᒃᑕᖅᑐᐃᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐅᑎᖅᑕᒃᑕᖅᓱᑎᒃ. 2016-ᒥᑦ, ᑲᑎᖅᓱᕆᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᑦ ᐊᐅᓪᓚᖅᑎᑕᐅᔪᑦ ᕿᙵᐊᓂᑦ ᐃᒃᓴᕐᕕᖕᒥᑦ ᑎᑭᐅᑎᓚᐅᖅᑐᖅ 2.6 ᒥᓕᔭᓐ ᑖᓄᑦ 37-ᖏᖅᑕᖅᓱᑎᒃ ᐅᔭᕋᒃᑕᖅᑐᐃᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐅᑎᖅᑕᒃᑕᖅᓱᑎᒃ. 2017-ᒥᑦ, ᑲᑎᖅᓱᕆᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᑦ ᐊᐅᓪᓚᖅᑎᑕᐅᔪᑦ ᕿᙵᐊᓂᑦ ᐃᒃᓴᕐᕕᖕᒥᑦ ᑎᑭᐅᑎᓚᐅᖅᑐᖅ ~4.2 ᒥᓕᔭᓐ ᑖᓄᑦ 56-ᖏᖅᑕᖅᓱᑎᒃ ᐅᔭᕋᒃᑕᖅᑐᐃᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐅᑎᖅᑕᒃᑕᖅᓱᑎᒃ. ᑲᑎᖅᓱᕆᑦ 5.44 Mtpa ᓴᕕᒃᓴᐃᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᑦ ᐊᐅᓪᓚᖅᑎᑕᐅᓚᐅᖅᑐᑦ 71-ᖏᖅᑕᖅᓱᑎᒃ ᐅᔭᕋᒃᑕᖅᑐᐃᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐅᑎᖅᑕᒃᑕᖅᓱᑎᒃ 2018-ᒥᑦ ᐊᒻᒪᓗ 5.86 Mtpa ᓴᕕᒃᓴᐃᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᑦ ᐊᐅᓪᓚᖅᑎᑕᐅᓚᐅᖅᑐᑦ 81-ᖏᖅᑕᖅᓱᑎᒃ ᐅᔭᕋᒃᑕᖅᑐᐃᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐅᑎᖅᑕᒃᑕᖅᓱᑎᒃ 2019-ᒥᑦ. 2020-ᒥᑦ, ᑲᑎᖅᓱᕆᑦ 5.5 Mtpa ᐊᐅᓪᓚᖅᑎᑕᐅᔪᑦ 72-ᖏᖅᑕᖅᓱᑎᒃ ᐅᔭᕋᒃᑕᖅᑐᐃᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐅᑎᖅᑕᒃᑕᖅᓱᑎᒃ.

ᐱᓕᕆᐊᑉ ᐅᐊᖕᓇᖅᐸᓯᖕᒥᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ ᐊᑉᖁᑎᖓᑦ ᐊᕙᓗᓯᒪᔪᖅ ᕿᙵᐊᓂᑦ, ᑕᓯᐅᔭᕐᒥᑦ, ᒥᑦᑎᒪᑕᓕᖕᒥᑦ, ᐊᒻᒪᓗ ᖃᓂᑕᖕᒋᑦ ᐃᒪᕐᓂᑦ. ᓯᒡᔭᖅᐸᓯᖕᒦᑦᑐᑦ ᐃᒪᐃᑦ ᐱᒻᒪᕆᐅᔪᒃᑯᑦ ᐊᐅᔾᑯᑦ ᐃᓂᒋᔭᐅᒃᑕᖅᑐᑦ ᑑᓚᓕᕐᓄᑦ ᑲᓇᑕᐅᑉ ᐅᑭᐅᖅᑕᖅᑐᓂᑦ. ᖃᐅᔨᓴᕐᓂᐊᕐᓱᒋᑦ ᑑᓚᓖᑦ ᖃᓄᐃᓕᐅᕐᓂᖏᑦ ᐅᒥᐊᕐᔪᐊᓂᑦ ᐃᖏᕐᕋᔾᑐᓄᑦ ᐅᐊᖕᓇᖅᐸᓯᖕᒥᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ ᐊᑉᖁᑎᖓᓂᑦ, ᐃᓗᕕᓕᖕᒥᑦ ᐃᒫᓂᑦ ᖃᐅᔨᓴᐃᓂᒃᑲᑦᑕᖅᑐᑦ ("ᖃᐅᔨᓴᐃᓂᕐᒧᑦ ᑐᕌᖓᔪᖅ") ᐊᕐᕎᒍᑕᒦᒃᑯᑦ ᑕᐃᒪᙵᓂᑦ 2014-ᒥᑦ, ᑭᖑᓂᐊᒍᑦ ᐆᒃᑐᕋᐃᓂᖃᓚᐅᖅᑎᓪᓗᒋᑦ 2013-ᒥᑦ. ᖃᐅᔨᓴᐃᓂᖅ ᐋᖅᑭᐅᒪᓚᐅᖅᑐᑦ ᐱᓕᕆᐊᕆᓂᐊᕐᓗᒋᑦ ᐱᓕᕆᐊᕐᒧᑦ ᓇᓗᓇᐃᒃᑯᑕᕐᒥᑦ (PC) ᖃᓄᐃᖓᔪᕆᐊᖃᕐᓂᐅᔪᑦ 99c, 101g, 109, ᐊᒻᒪᓗ 111, ᐱᔾᔪᑎᖃᖅᑐᖅ ᕿᒥᕈᓂᕐᒃ ᐃᓱᐃᓵᕆᔭᐅᑐᐃᓐᓇᕆᐊᖃᕐᓂᖏᓐᓄᑦ ᑕᕆᐅᕐᒥᐅᑕᓂᒃ ᐅᒥᐊᕐᔪᐊᑦ ᐱᓕᕆᓂᖏᓐᓂᑦ ᐱᔪᓂᒃ ᐊᓯᐊᙱᖅᑎᑦᑎᑐᐃᓐᓇᕆᐊᖃᖅᓱᑎᒃ ᓂᕐᔪᑏᑦ ᐊᒥᓲᓂᖏᓐᓄᑦ, ᓇᒨᕆᐅᖃᑦᑕᕐᓂᖏᓐᓄᑦ, ᐊᒻᒪᓗ ᐅᑎᖃᑦᑕᖅᑐᑦ ᐊᐅᓚᓂᖏᓐᓄᑦ ᐱᓕᕆᐊᕐᒧᑦ ᖃᓐᑐᒥᑦ ᖃᐅᔨᓴᐃᕝᕕᒋᔭᕆᓂᑦ (RSA). 2020 ᓯᒡᔭᖅᐸᓯᖕᒥᑦ ᑐᕌᖓᔪᕐᒥᑦ ᑕᑯᒃᓴᐅᔪᑦ ᐊᕐᕕᓂᓕᕆᓕᖅᑕᖓᓂᑦ ᐅᑭᐅᕐᒥᑦ ᐊᕙᑎᒥᒃ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᕐᒥᒃ ᖃᐅᔨᓴᐃᖃᓚᐅᖅᑐᑦ ᐃᓗᕕᓕᖕᒥᑦ ᐃᑲᔪᖅᓱᒍ ᐱᓕᕆᐊᖅ.

ᐅᓂᑉᑳᕆᑦᑐᑦ ᖃᓄᐃᖓᓂᐅᔪᑦ ᐃᒪᕐᒥᒃ ᖃᐅᔨᓴᐃᓂᐅᔪᑦ ᑑᓚᓕᕐᓄᑦ ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔾᔪᓐᓂᖏᓐᓂᑦ ᕿᙵᐊᓂᑦ 2014-2017 ᐊᒻᒪᓗ 2019-2020-ᒥᑦ ᐊᐅᔭᐅᑎᓪᓗᒍ. ᐱᖁᓯᕆᔭᕐᒋᑦ ᖃᓄᐃᓕᐅᕐᓂᖏᑦ ᑑᓚᓖᑦ ᐱᓕᕆᐊᕐᒥᑦ ᐅᔭᕋᒃᑕᖅᑕᐅᔪᓂᒃ ᐅᓯᒃᑲᖅᑐᓄᑦ ᐊᓯᕐᒋᓐᓄᓪᓗ ᐅᔭᕋᒃᑕᕆᐊᕐᒥᐅᕐᒋᑦᑐᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔾᔪᓐᓂᑦ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᑐᖅ ᑲᑎᖅᓯᐃᑉᓗᒋᑦ ᑕᑯᑉᓗᒋᑦ ᓈᓴᐅᑎᓂᒃ/ᑎᑎᖅᑲᓂᒃ ᐃᓐᓈᕈᕐᓃᕐᓱᒋᑦ ᖃᐅᔨᓴᐃᕙᖕᒥᑦ ᐃᓗᕕᓕᖕᒥᑦ, ᑕᐅᓄᙵ ᑕᑯᒃᓴᐅᓇᖅᑐᒥᑦ ᐅᐊᖕᓇᖅᐸᓯᖕᒐᓂᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐊᑉᖁᑎᖓᔪᖏᓐᓂᑦ. ᖃᐅᔨᒪᓂᕆᔭᐅᔪᑦ ᐱᔾᔪᑎᖃᖅᑐᓂᒃ (ᐱᑕᖃᖅᐸᑦ) ᑑᓚᓖᑦ ᑲᑎᕝᕕᖏᓐᓂᒃ ᐊᒻᒪᓗ ᐃᓂᐅᔪᓂᒃ ᐊᑐᖃᑦᑕᖅᑕᖏᓐᓂᑦ ᖃᓄᐃᓕᐅᕐᓂᐅᔪᑦ ᐱᐊᓂᒃᓯᒪᙵᓕᒪᑕ, ᖃᐅᔨᓴᐃᓂᖅ ᑑᓚᓖᑦ ᖃᑉᓯᐅᓂᖏᓐᓄᑦ, ᓇᒨᕆᐅᓂᖏᓐᓄᑦ, ᐊᒻᒪᓗ ᑲᑎᒪᔪᑦ ᖃᓄᐃᓕᐅᕐᓂᖏᓐᓄᑦ ᑐᑭᓯᐊᓂᖕᓴᐅᔭᕆᐊᖃᖅᑐᑦ ᖃᓄᐃᓕᐅᖃᑦᑕᕐᓂᖏᑦ ᐅᓗᕆᐊᓇᖅᑐᕆᔭᖏᓐᓄᑦ (ᓃᕐᓗ, ᑎᑭᓴᖅᑐᖅᑐᒥᑦ ᐅᒥᐊᕐᔪᐊᕐᒥᑦ). ᑕᐃᒪᓐᓇᒧᑦ, ᑐᑭᓯᐊᒪᔾᔨᖑᑦ ᑲᑎᑕᐅᓚᐅᖅᑐᑦ ᖃᔾᔨᐅᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ ᓇᒨᕆᐅᖃᑦᑕᕐᓂᖏᓐᓄᑦ, ᑲᑎᒪᔪᑦ ᐋᖅᑭᐅᒪᓂᖏᓐᓄᑦ, ᐊᒻᒪᓗ ᐱᖁᓯᕆᔭᕐᒋᑦ ᑑᓚᓖᑦ ᐃᓗᕕᓕᐅᑉ ᖃᓂᑕᕐᓂᑦ. ᓈᓴᐅᑎᓂᒃ/ᑎᑎᖅᑲᓂᒃ ᑲᑎᖅᓯᐃᓚᐅᕐᒥᔪᑦ ᐊᕙᑎᐅᑉ ᖃᓄᐃᓐᓂᕆᔭᖕᒐᓄᑦ ᐊᒻᒪᓗ ᐃᓄᐃᑦ ᖃᓄᐃᓕᐅᕐᓂᕆᔭᒃᑕᖅᑕᖏᓐᓂᑦ (ᓃᕐᓗ, ᐅᒥᐊᕐᔪᐊᑦ ᐊᒻᒪᓗ ᒪᖃᐃᓐᓃᑦ) ᓇᓗᓇᐃᕐᓂᐊᕐᓗᑎᑦ ᐊᑯᓐᓂᖏᓐᓂᑦ ᖃᓄᐃᓕᖅᑎᑦᑎᓂᐅᔪᓐᓇᖅᑐᓂᒃ ᐱᓕᕆᐊᕐᒧᑦ ᐅᒥᐊᕐᔪᐊᓕᕆᓃᑦ ᐊᒻᒪᓗ ᐱᔾᔪᑕᐅᔪᑦ ᐱᖁᓯᕆᔭᕐᒋᓐᓄᑦ ᑑᓚᓖᑦ.

ᒪᓕᒃᓱᕆᑦ ᖃᐅᔨᓴᐃᓂᐅᔪᑦ ᓈᓴᐅᑎᓂᒃ/ᑎᑎᖅᑲᓂᒃ ᐱᔭᐅᓚᐅᖅᑐᑦ ᓯᕗᓂᐊᒍᑦ ᐃᓄᕕᓕᐅᑉ ᖃᓂᑕᖓᓂᑦ ᖃᐅᔨᓴᐃᑎᓪᓗᑎᑦ, ᐊᒻᒪᓗ ᐅᖃᖅᑎᖅᓱᑎᒃ ᐊᔾᔨᓖᙱᑦᑐᓂᒃ ᑲᑎᕐᒪᔪᓂᑦ (ᓃᕐᓗ, ᑕᕆᐅᕐᒥᐅᑕᐃᑦ ᒥᒃᓵᓄᑦ ᐱᓕᕆᐊᓖᑦ), ᖃᐅᔨᓚᐅᖅᑐᑦ ᑐᑭᓯᐊᓕᒃᑲᓂᕐᓂᖅᓴᐅᓂᐊᕐᓗᓂ ᖃᓄᐃᓕᖅᑎᑦᑎᓂᐅᔪᖕᓇᖅᑐᓂᒃ ᑑᓚᓖᖕᓄᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔾᔪᓐᓂᖏᓐᓂᑦ ᐱᔪᓂᒃ ᐱᔭᐅᔪᖕᓇᖅᑐᑦ ᐃᓄᒃᑕᐅᓯᒪᙱᑦᑐᒃᑯᑦ ᖃᖓᑕᓲᒃᑯᑦ (UAV) ᐊᒻᒪᓗ ᐱᓕᕆᖃᑎᒌᒃᑎᓪᓗᒋᑦ ᑕᑯᔭᐅᑉᓗᑎᒃ ᐊᒻᒪᓗ ᒦᓇᐅᔪᖅ ᓂᐱᖃᕐᓂᕐᒧᑦ ᓈᓴᐅᑎᐅᔪᑦ/ᑎᑎᖅᑲᓂᑦ. ᑕᐃᒪᓐᓇᒧᑦ ᐊᑐᖅᑕᐅᓂᖏᑦ ᐃᓄᒃᑕᐅᓯᒪᙱᑦᑐᒃ ᖃᖓᑕᓲᑦ ᐃᓚᓕᐅᑎᔭᐅᓚᐅᖅᑐᑦ 2020 ᖃᐅᔨᓴᐃᓂᕐᒧᑦ ᐱᐅᓯᕆᐊᕐᓂᐊᕐᓗᒋᑦ ᑲᑎᑕᐅᔪᑦ ᖃᐅᔨᔭᐅᔪᓂᑦ ᑲᑎᕐᒪᔪᑦ ᖃᓄᐃᓐᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ ᐱᖁᓯᕆᔭᖏᓐᓄᑦ.

ᓇᐃᓈᖅᓯᒪᔪᖅ ᖃᐅᔨᓴᐅᔪᓂᒃ ᑑᒐᓖᑦ ᐱᖁᓯᕆᖃᑦᑕᖅᑕᖏᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕋᓱᒃᑐᓄᑦ ᐊᕐᕕᓂᓖᑦ ᐅᑭᐅᓂᑦ ᐃᒪᕐᒥᑦ ᑕᑯᓯᐅᔪᑉᓗᑎᒃ ᖃᐅᔨᓴᐃᓂᕐᒧᑦ ᓈᓴᐅᑏᑦ/ᑎᑎᖅᑲᐃᑦ ᑲᑎᑕᐅᔪᓂᒃ ᐃᓗᕙᓕᖕᒥᑦ ᐊᑯᓂᖕᓂᓐᓂᑦ 2014 ᐊᒻᒪᓗ 2020:

ᐊᒥᓲᑎᒋᓂᖕᒋᑦ ᐊᒻᒪᓗ ᓇᒧᒥᐅᖃᑦᑕᕐᓂᖕᒋᑦ

- ᐊᕐᕌᒍᓂᑦ ᐊᔾᔨᒌᙱᓐᓂᐅᖃᑦᑕᖅᑐᑦ: ᑕᒪᐃᓐᓃᖓᔪᒃᑯᑦ ᐊᒥᓲᑎᒋᓂᖕᒋᑦ ᑑᒐᓖᑦ SSA-ᒥᑦ, ᐱᔭᐅᓯᒪᔪᑦ ᑕᑯᔭᐅᖃᑦᑕᕋᔪᖕᓂᖕᒋᓐᓄᑦ (ᑑᒐᓖᑦ ᑕᑯᔭᐅᔪᑦ ᐃᑲᕐᕋᑕᒫᒥᑦ - ᐋᖅᑭᒃᑕᐅᔪᖅ ᐱᓇᓱᒃᑕᐅᓂᕐᒧᑦ), ᐊᔾᔨᐸᓗᓚᐅᖅᑕᖓ 2014-ᒥᑦ ᐊᒻᒪᓗ 2019-ᒥᑦ ᐊᒥᓱᙳᖅᐸᓪᓕᐊᓚᐅᓗᐊᖅᑎᓪᓗᒋᑦ ᓴᕕᒃᓴᓂᒃ ᐅᓯᖃᑦᑕᖅᑐᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐅᑎᖅᑕᖃᑦᑕᕋᓗᐊᖅᑎᓪᓗᒋᑦ ᐅᐊᖕᓇᖅᐸᓯᖕᓕᓂᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ ᐊᑉᕐᑯᑎᒋᔭᐅᔪᒥᑦ ᑖᑉᑯᓇᓂ ᐅᑭᐅᕐᓂᑦ. ᑭᓯᐊᓂ, ᐊᒥᓲᑎᒋᓂᖕᒋᑦ ᑑᒐᓖᑦ SSA-ᒥᑦ ᐊᑦᑎᖕᓂᖅᓴᐅᓚᐅᖅᑐᖅ 2020-ᒥᑦ ᑕᐅᑐᙳᖅᓱᒋᑦ ᐊᓯᓗᒃᑖᖕᒋᑦ ᓯᕗᓂᐊᒍᑦ ᐅᑭᐅᖑᔪᑦ. ᐊᑦᑎᖕᓂᖅᓴᐅᔪᑦ ᐊᒥᓲᑎᒋᓂᖕᒋᑦ ᑕᑯᔭᐅᓚᐅᖅᑐᑦ ᑑᒐᓖᑦ 2020-ᒥᑦ ᐃᓗᕙᓕᐅᑉ ᖃᓂᑕᖕᓕᓂᑦ ᖃᐅᔨᓴᐃᑦᕕᐅᔪᒥᑦ ᐊᔾᔨᒋᔭᖓ ᖃᐅᔨᓴᐅᓚᐅᖅᑐᓂᒃ 2020-ᒥᑦ ᖃᖓᑕᓲᒃᑯᑦ ᖃᐅᔨᓴᐃᑎᓪᓗᒋᑦ (ᓲᕐᓗ, ᐊᒥᓲᖕᓃᖅᐸᓪᓕᕐᔪᐊᖅᑐᑦ 2020-ᒥᑦ Eclipse Sound -ᒥᑦ ᐊᒥᓲᑎᒋᓂᖕᒋᓐᓄᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᔪᓂᑦ). ᖃᓄᐃᖕᒪᓂᐅᔪᑦ ᐊᑕᐅᑦᑎᒃᑯᑦ ᐅᖃᖅᑐᑦ 2020-ᒥᑦ ᐊᓯᐊᓄᐊᖅᓯᒪᑐᐃᓐᓇᐊᖃᕐᓂᖕᒋᑦ ᐃᓚᖕᒋᑦ ᑕᓯᐅᔨᒫᖃᑦᑕᖅᑐᑦ Admiralty Inlet-ᒧᑦ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᒃᓯᒪᖃᑦᑕᖅᑕᖕᒋᓄᑦ, ᐊᓯᐊᓄᑦ ᐃᓂᐅᔪᒧᐊᖅᓯᒪᑐᐃᓐᓇᐊᖃᕐᓂᖕᒋᑦ (ᓲᕐᓗ, ᑲᓇᖕᓇᖅᐸᓯᐊᓄᑦ ᕿᑭᖅᑖᓘᑉ ᐃᒪᖕᒪᓄᑦ ᐅᕙᓘᓐᓃᑦ Somerset-ᒥᑦ ᐊᐅᔭᖅᓯᐅᕝᕕᒋᖃᑦᑕᖅᑕᖕᒋᓐᓂᑦ), ᐅᕙᓘᓐᓃᑦ ᐊᒥᓲᖕᓃᑐᐃᓐᓇᐊᖃᖅᑐᑦ ᑕᓯᐅᔭᕐᒥᑦ ᐊᐅᔭᒃᑯᑦ ᑕᐃᑲᓃᖃᑦᑕᖅᑐᑦ. 2020-ᒥᑦ ᖃᐅᔨᓴᐅᔪᑦ ᐊᒥᓲᖕᓃᕐᓂᖅᓴᐅᓂᖕᒋᓐᓄᑦ ᑑᒐᓖᑦ ᐃᓗᕙᓕᖕᒥᑦ, 2020-ᒥᓗ ᖃᖓᑕᓲᒃᑯᑦ ᖃᐅᔨᓴᖅᑕᐅᔪᓄᑦ ᖃᓄᐃᖕᒪᓂᐅᔪᑦ ᑕᑯᒃᓴᐅᑎᑦᑎᖕᒥᔪᑦ ᐊᒥᓲᖕᓃᖅᐸᓪᓕᕐᔪᐊᖅᓯᒪᔪᓂᒃ ᑑᒐᓖᑦ ᑕᓯᐅᔭᕐᒥᑦ ᖃᓂᑦᑐᒥᑦ ᖃᐅᔨᓴᐃᕝᕕᐅᔪᒥᑦ (RSA), ᓇᓗᓇᐃᔭᖅᓯᒪᓂᖅᓴᐅᔪᓂᒃ ᖃᐅᔨᓴᐃᓂᖃᖅᑎᑦᑎᓂᐊᖅᑐᑦ ᐱᔾᔪᑕᐅᔪᒥᒃ ᖃᐅᔨᓴᐅᔪᓄᑦ ᐃᓚᐅᓗᑎᒃ ᐊᑐᓕᖅᑕᐅᓂᖓ ᐅᔾᔨᖅᑐᕐᓂᕐᒥᒃ ᐊᕐᕆᓗᐊᕐᕆᕆᐊᖅᑎᑦᑎᓂᒃᑯᑦ ᐊᑐᖅᑕᐅᓂᐊᕐᓗᑎᒃ 2021-ᒥᑦ, ᐅᖃᐅᓯᐅᓂᖓᑐᑦ ᐃᓚᕆᔭᐅᔪᖅ 7.1-ᒥᑦ ᐊᒻᒪᓗ ᐅᕙᓂ Golder (2021b).

- **ᖃᐅᔨᓴᐅᒃᐸᑦ ᐱᓕᕆᐊᖅ ᐱᔾᔪᑕᐅᖓᒪᑦ, ᖃᐅᔨᓴᐅᔪᖅ ᐊᔾᔨᒋᔭᖓ ᖁᑦᑎᒃᑑᔪᒥᑦ ᐊᖏᔪᒥᑦ ᐅᐸᓗᐊᑎᑦᑎᓂᐅᔪᖅ, ᑐᑭᓕᐅᖅᑕᐅᓯᒪᓂᖓᑐᑦ Finneran et al.-ᒥᑦ (2017), ᑕᐃᒪᓐᓇᒧᑦ ᐊᖏᔪᒥᒃ ᐊᓯᐊᙳᕐᓂᖃᕈᓐᓇᕐᓂᖓ ᐱᖁᓯᓇᔭᖏᑦ ᖃᓄᐃᓕᐅᕐᓂᖕᒋᓐᓄᑦ ᑑᒐᓖᑦ ᖃᓂᑦᑐᒥᑦ ᖃᐅᔨᓴᐃᕝᕕᐅᔪᒥᑦ (RSA) ᐊᒻᒪᓗ/ᐅᕙᓘᓐᓃᑦ ᐊᖏᔪᒥᒃ ᐃᓅᐃᓗᖅᑕᐅᓂᖕᒋᑦ ᖃᐅᑕᒫᒃᑯᑦ ᐊᑐᖃᑦᑕᖅᑕᖕᒋᓐᓄᑦ. ᖃᐅᔨᓴᐅᔪᖅ ᐊᔾᔨᙲᑕᖓ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᓯᒪᔪᑦ FEIS-ᒥᑦ ERP-ᒧᑦ, ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖃᕐᓂᖕᒋᑦ ᖃᓄᐃᙵᓕᖅᑎᑦᑎᓂᐅᔪᑦ ᑑᒐᓕᖕᓄᑦ ᓂᓚᐅᕆᔭᐅᔪᑦ ᑮᓕᖃᕐᓂᐊᖅᑐᖅ ᐊᒻᒪᓗ ᕿᓚᒥᐅᓗᓂ, ᖃᓂᑦᑑᓗᓂ ᑎᑭᐅᑎᑦᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᓯᓇᔭᐅᔪᖅ. ᐊᔾᔨᒋᔭᖓ ᑐᑭᐅᔫᑉ ᐊᖏᔪᒥᒃ ᖃᓄᐃᙵᓕᖅᑎᑦᑎᓂᐅᔪᒧᑦ ᐊᑐᖅᑕᐅᔪᒥᑦ FEIS-ᒥᑦ, ᐊᖏᔫᖓᔪᒥᑦ ᑎᑭᐅᑎᑦᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᓯᓇᔭᐅᔪᒧᑦ, ᐊᓯᐊᓄᐊᕐᓂᖕᒋᓐᓄᑦ ᖃᓄᐃᙵᓕᖅᑎᑦᑎᓂᕐᓄᑦ, ᐅᕙᓘᓐᓃᑦ ᕿᒪᐃᓂᖕᒋᓐᓂᒃ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᒃᓯᒪᖃᑦᑕᖅᑕᖕᒋᓐᓂᒃ (ᖁᑦᑎᒃᑐᒥᑦ ᐊᖏᓂᖓ ᖃᓄᐃᓕᐅᕐᓂᓇᔭᖏᑦ) ᑑᒐᓕᖕᓂᑦ ᐅᕙᓘᓐᓃᑦ ᑑᒐᓖᑦ ᑲᑎᕐᒪᔪᓐᓂᖓᔪᒥᒃ ᖃᓄᐃᓕᑎᑦᑎᔪᖕᓇᖅᑐᖅ.**

ᑑᒐᓖᑦ ᐱᑕᖃᐅᕐᓂᖕᒋᑦ

- ᐅᒥᐊᕐᔪᐊᓄᑦ ᖃᓄᐃᖕᒪᓕᖅᑎᑦᑎᓃᑦ: ᐊᑐᓂ ᐅᑭᐅᓂᑦ ᖃᐅᔨᓴᐃᕝᕕᐅᔪᓂᑦ, ᖃᓄᐃᖕᒪᓕᖅᑎᑦᑎᓂᖅ ᐅᒥᐊᕐᔪᐊᕐᒥᑦ ᐱᔪᒥᒃ ᑑᒐᓕᒃᑕᖃᐅᕐᓂᖕᒪᓄᑦ SSA-ᒥᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᓚᐅᖅᑐᖅ. ᐱᓗᐊᖅᑐᒥᑦ, ᐅᒥᐊᕐᔪᐊᕐᒧᑦ ᐱᔪᓂᒃ ᑕᑯᒃᓴᐅᑎᑦᑎᓚᐅᖅᑐᖅ ᐊᒥᓲᖕᓃᖅᑎᑦᑎᓂᖓ ᐱᑕᖃᐅᕐᓂᖕᒋᓐᓄᑦ SSA-ᒥᑦ ᑕᐅᑐᙳᖅᓱᒍ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ, ᑭᓯᐊᓂ ᐅᒥᐊᕐᔪᐊᑦ ᖃᓂᑎᕐᔭᕋᙵᑕᐅᐃᓐᓇᖅ (1-2 ᑭᓛᒥᑕᓂᒃ ᐅᒥᐊᕐᔪᐊᕐᒥᑦ ᐅᐊᖕᓇᖅᐸᓯᖕᒍᙱᓚᐅᑎᓪᓗᒋᑦ, ᐊᒻᒪᓗ 3-4 ᑭᓛᒥᑕᓂᒃ ᓂᕆᖅᐸᓯᖕᒍᙱᓚᐅᑎᓪᓗᒋᑦ).

- **ᖃᓄᐃᖕᒪᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒐᓖᑦ ᐱᑕᖃᐅᕐᓂᖕᒋᑦ ᐱᑎᑕᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕋᖃᑦᑕᕐᓂᖕᒋᓐᓄᑦ ᖃᓂᒍᕐᓗᑎᒃ (ᓲᕐᓗ, 4 ᑭᓛᒥᑕᓂᒃ). ᐊᔾᔨᒋᔭᖓ ᓯᕗᓂᐊᒍᑦ ᖃᐅᔨᓴᐅᓚᐅᖅᑐᓄᑦ ᐊᒻᒪᓗ ᐊᔾᔨᕐᓕᒋᔭᖕᒋᑦ ᖃᓄᐃᖕᒪᓂᐅᔪᓄᑦ 2017/2018-ᒥᑦ ᑑᒐᓖᑦ ᐃᓕᐅᖅᑲᐃᕝᕕᐅᓯᒪᓂᖕᒋᓐᓄᑦ ᑖᒡᓂᒃ ᖃᐅᔨᓴᐃᓂᕐᓄᑦ (Golder 2020a). ᖃᓂᑦᑐᒥᑦ ᓂᐱᖃᖅᑎᑦᑎᔪᒧᐊᖅᑕᐃᓕᓂᖕᒋᑦ (ᓲᕐᓗ, ᐅᒥᐊᕐᔪᐊᖅ) ᑑᒐᓖᑦ ᓇᓗᓇᐃᖅᓯᔪᖅ ᕿᑎᐊᓃᖕᒪᔪᒥᒃ ᐊᖏᓂᖓᔪᖕᒪᓄᑦ ᖃᓄᐃᓕᔾᔪᑕᐅᖃᑦᑕᕐᓂᖕᒪᓄᑦ. ᖃᐅᔨᓴᐅᔪᖅ ᓇᐃᑦᑑᓚᐅᕐᒪᑦ ᐊᑯᓂᐅᑎᒋᔭᖕᒪᑕ (ᓲᕐᓗ, ᑐᖕᓕᓂᐅᑉᓗᓂ ᐊᑯᓂᐅᑎᒋᔭᖕᒪᑕ ᐅᒥᐊᕐᔪᐊᕐᒧᑦ ᑎᑭᐅᑎᓯᒪᓂᐅᑉ), ᐊᖏᔪᒥᒃ ᐊᓯᐊᙳᖅᓯᓂᐅᔪᒥᒃ ᐱᖁᓯᓇᖃᑦᑕᖅᑕᖅᑕᖕᒋᓐᓄᑦ ᑑᒐᓖᑦ ᖃᓂᑦᑐᒥᑦ ᖃᐅᔨᓴᐃᓂᕐᒥᑦ (RSA) ᐅᕙᓘᓐᓃᑦ ᐃᓅᐃᓗᖅᑕᐅᓂᖕᒋᑦ ᖃᐅᑕᒫᒃᑯᑦ ᐊᑐᖃᑦᑕᖅᑕᖕᒋᓐᓄᑦ ᓂᖓᐅᕆᔭᐅᖕᒋᑦᑐᖅ. ᑕᒪᓐᓇ ᐊᔾᔨᒋᔭᖓ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᔪᓂᒃ FEIS-ᒥᑦ ERP-ᒧᑦ, ᖃᓄᐃᖕᒪᓕᖅᑎᑦᑎᓃᑦ ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖕᒋᓐᓂᒃ ᐱᔪᑦ ᑑᒐᓕᖕᓄᑦ ᓂᖓᐅᕆᔭᐅᔪᑦ ᑮᓕᖃᕐᓂᐊᕐᒪᑕ ᐊᒻᒪᓗ ᑕᐃᒪᐅᓚᐅᐱᓪᓚᒃᑐᑎᒃ, ᖃᓂᑦᑑᓕᓗᓂ ᑎᑭᐅᑎᑦᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᓯᓇᔭᖏᑦ. ᐱᔾᔪᑎᒋᐸᓗᒍ ᐊᔾᔨᒌᙱᓐᓂᖕᒋᑦ ᖃᓄᐃᓕᐅᖃᑦᑕᕐᓂᖕᒋᓐᓄᑦ (ᓲᕐᓗ, ᐊᓯᐊᙳᖅᑐᑦ ᑑᒐᓖᑦ ᐱᑕᖃᐅᕐᓂᖕᒋᑦ), ᖃᐅᔩᓇᐅᑎᑕᖅᒋᑦᑐᑦ ᐊᖏᔪᒥᒃ ᖃᓄᐃᓕᐅᕈᑎᖕᒋᓐᓄᑦ ᐱᖁᓯᓇᔭᖕᒋᓐᓄᑦ, ᐊᓯᐊᓄᐊᕐᓂᕐᓄᑦ, ᐅᕚᓘᓐᓃᑦ ᕿᒪᐃᐸᓗᑎᒃ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᒃᓯᒪᖃᑦᑕᖅᑕᖕᒋᓐᓂᒃ (ᖁᑦᑎᒃᑐᒥᑦ ᐊᖏᔪᒥᒃ ᖃᓄᐃᓕᓂᖃᑦᑕᖅᑕᖏᑦ), ᐊᒥᓲᓂᖕᒋᓐᓄᑦ ᐅᕙᓘᓐᓃᑦ ᑲᑎᕐᒪᓂᖕᒋᓐᓄᑦ ᐱᔾᔪᑎᖃᕈᓐᓇᖅᓱᓂ (ᐊᔾᔨᒋᔭᖓ ᑐᑭᐅᔪᖅ ᐊᖏᔪᒥᒃ ᖃᓄᐃᖕᒪᓕᖅᑎᑦᑎᓂᕐᒧᑦ ᐊᑐᖅᑕᐅᔪᖅ FEIS-ᒥᑦ).**

ᑲᑎᕐᒪᔪᑦ ᖃᓄᐃᖓᓂᖏᑦ ᐊᒻᒪᓗ ᐱᖁᓯᖏᑦ

- ᑲᑎᕐᒪᔪᑦ ᐊᖏᓂᕆᔭᖏᑦ: ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᑦ ᐅᒥᐊᕐᔪᐊᕐᓂᑦ ᐱᔪᓂᒃ (ᐅᖓᓯᒃᑎᒋᓂᖓ ᐅᕐᓂᒃᑕᖏᑦ ᐅᒥᐊᕐᔪᐊᕐᒥᑦ, ᐅᒥᐊᕐᔪᐊᖅ ᕿᙳᐅᓄᙵᐅᑎᓪᓗᒍ) ᑑᒐᓖᑦ ᑲᑎᕐᒪᓂᖏᑦᑕ ᐊᖏᓂᕆᖓᓄᑦ ᓈᓴᐅᓯᕆᓂᒃᑯᑦ ᐅᔾᔨᕐᓇᓚᐅᖏᑦᑐᑦ (*P*>0.3 ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᓗᒃᑖᓄᑦ), ᒥᑭᔫᒥᒃ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᑦ ᐊᖏᓂᖃᖅᓱᑎᒃ (-4% ᐊᒻᒪᓗ +15% 0 ᑭᓛᒥᑕᓂᒃ ᐅᖓᓯᒃᑎᑉᐸᓗᑎᒃ ᐅᒥᐊᕐᔪᐊᕐᒥᑦ).

- **ᖃᓄᐃᖓᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒐᓖᑦ ᑲᑎᒃᑕᙱᑦᑐᑦ ᑲᑎᕐᒪᓄᖏᑦ ᐊᖏᓂᖅᓴᐅᐸᓗᓂ ᐅᕙᓘᓐᓂᑦ ᒥᑭᓂᖅᓴᓄᑦ ᑲᑎᕐᒪᔪᑦ ᐊᕕᒃᑐᖅᓱᑎᒃ ᐅᒥᐊᕐᔪᐊᓄᑦ ᑎᑭᐅᑎᔭᕌᖓᑕ. ᖃᐅᔨᓴᐅᔪᖅ ᓇᓗᓇᐃᖅᓯᔪᖅ ᐊᑦᑎᖕᓂᖓᑕ ᐊᖏᑎᒋᓂᖓᓄᑦ ᑑᒐᓖᑦ ᖃᓄᐃᓕᔾᔪᑎᖏᑦ ᐱᒋᐊᖅᑎᑕᐅᖏᒻᒪᑦ, ᑐᑭᓕᐅᖅᑕᐅᓂᖓᑐᑦ Finneran et al.-ᒥᑦ (2017), ᑕᐃᒪᓐᓇᒎᑦ ᐊᖏᔫᒥᒃ ᐊᓯᐊᙳᖅᑎᑦᑎᓂᖃᕋᔭᖏᑦᑐᑦ ᐱᖁᓯᖏᑦᑕ ᖃᓄᐃᓕᐅᕐᓂᖏᑦ ᑑᒐᓖᑦ ᖃᓂᑦᑐᒥᑦ ᖃᐅᔨᓴᕝᕕᐅᔪᒥᑦ (RSA) ᐅᕙᓘᓐᓂᑦ ᐃᓱᐃᕌᕐᓱᖏᑦ ᖃᐅᑕᒫᑦ ᐊᑐᒃᑕᖅᑕᖏᑦ. ᐱᑕᖕᒋᓐᓂᖏᑦ ᖃᓄᐃᓕᐅᒃᑕᕐᓂᖏᓐᓄᑦ ᐃᑲᔪᐃᔪᖅ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᔭᓂᒃ ᓇᓚᐅᑦᑖᖅᑕᐅᔭᓂᒃ FEIS-ᒥᑦ ERP-ᒧᑦ, ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖏᓐᓄᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᕐᓄᑦ ᑑᒐᓕᖕᓂᑦ ᓂᕆᐅᒋᔭᐅᔪᖅ ᓂᕆᐅᒋᔭᐅᔪᑦ ᑮᓕᖃᕐᓂᐊᕐᒪᑕ ᐊᒻᒪᓗ ᑕᐃᒪᐅᓚᐅᐱᓪᓚᓪᓗᑎᒃ, ᖃᓂᑦᑑᒥᓗᓂ ᑎᑭᐅᑎᑦᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᓯᕆᔭᖏᑦ. ᐱᔾᔪᑎᒋᐸᓗᒍ ᐊᔾᔨᙱᓐᓂᖏᑦ ᖃᓄᐃᓕᐅᒃᑕᕐᓂᖏᓐᓄᑦ (ᓲᕐᓗ, ᑲᑎᕐᒪᔪᑦ ᐊᖏᑎᒋᓂᖓ), ᖃᐅᔾᔨᓇᐅᑎᑕᖕᒋᑦᑐᖅ ᐊᖏᔫᒥᑦ ᑎᑭᐅᑎᑦᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᓯᕆᔭᖏᓐᓂᒃ, ᐊᓯᐊᓄᐊᕐᓂᖏᓐᓄᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᕐᓂᑦ, ᐅᕚᓘᓐᓂᑦ ᕿᒪᐃᐸᓗᑎᒃ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᒃᓯᒪᒃᑕᖅᑕᖏᓐᓂᒃ (ᖁᑦᑎᒃᑐᒥᑦ ᐊᖏᔫᒥᒃ ᖃᓄᐃᓕᓂᕆᒃᑕᖅᑕᖏᑦ), ᐊᒥᒌᓂᖏᓐᓄᑦ ᐅᕚᓘᓐᓂᑦ ᑲᑎᕐᒪᓂᖏᓐᓄᑦ ᐱᔾᔪᑎᖃᕆᓐᓇᖅᓱᓂ (ᐊᔾᔨᒋᔭᖓ ᑐᑭᐅᔪᖅ ᐊᖏᔫᒥᒃ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᕐᒧᑦ ᐊᑐᖅᑕᐅᔪᖅ FEIS-ᒥᑦ).**

- ᑲᑎᕐᒪᔪᑦ ᐋᖅᑭᐅᒪᓂᖓ:
  - ᑑᒐᓘᒃᑖᓄᑦ ᐃᓂᓕᐊᖑᔪᑦ (ᐃᓇᐃᑦ, ᐃᓈᕋᐃᑦ, ᐅᑭᐅᓖᑦ, ᐊᒻᒪᓗ ᐱᐊᓛᑦ) ᑎᑎᕋᐅᓯᐅᓚᐅᖅᑐᑦ BSA-ᒥᑦᐊᕐᕕᓂᓖᑦ ᐅᑭᐅᓂᑦ ᐆᒃᑐᕋᐃᓂᐅᔪᓂᑦ. ᒥᑭᓖᙳᔪᖅ ᖃᐅᑕᒫᒃᑯᑦ ᑎᑎᕋᐅᓯᐅᓯᒪᔪᖅ BSA-ᒥᑦ (ᑲᑎᙵᓕᑦ ᖃᐸᓯᐅᓂᖏᑦ ᑑᒐᓖᑦ ᖃᐅᔨᓴᐅᒃᑕᖅᑐᑦ ᖃᐅᑕᒫᒃᑯᑦ) ᖁᑦᑎᖕᓂᖅᓴᐅᓚᐅᖅᑐᖅ 2020-ᒥᑦ (ᐊᕐᕌᒍᑕᒫᒃᑯᑦ ᒥᑭᓖᙳᔪᖅ 11.3%) ᐱᖓᓱᓂᑦ ᓯᕗᓂᐊᒍᑦ ᐅᑭᐅᖑᓚᐅᖅᑐᓂᐅᖓᓂᑦ (2014=10.7%, 2016=10.5%, 2017=9.5%), ᐊᒻᒪᓗ ᐊᑦᑎᖕᓂᖅᓴᐅᐸᓗᓂ 2019-ᒥᑦ (11.6%) ᐊᒻᒪᓗ 2015-ᒥᑦ (12.9%). ᑕᒪᓐᓇ ᐅᖃᖅᑐᖅ ᓄᕐᕋᐅᕐᓂᕐᒧᑦ ᓈᓴᐅᑎᐅᔪᖅ (ᓲᕐᓗ., ᓄᕐᕋᐅᒃᑕᕈᓐᓇᕐᓂᖅ) ᑕᓯᐅᔭᕐᒥᑦ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᒃᓯᒪᒃᑕᖅᑕᖓᓃᑎᓪᓗᒋᑦ ᑲᑎᕐᒪᔪᑦ 2020-ᒥᑦ ᐊᔾᔨᒋᓚᐅᖅᑕᖓ ᓯᕗᓂᐊᒎᑦ ᐅᒥᐊᕐᔪᐊᑦ ᓇᓃᓂᕆᔭᖏᓐᓄᑦ, ᐊᒥᓱᙳᖅᐸᓪᓕᐊᕌᕐᔪᒃᑲᓗᐊᖅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ ᖃᓂᑦᑐᒥᑦ ᖃᐅᔨᓴᐃᓂᓗᒃᑖᕐᒥᑦ (RSA).
  - ᐊᕐᕌᒍᑕᒫᑦ ᐃᓚᖏᑦ ᐃᓇᕈᙱᑦᑐᓄᑦ (ᓲᕐᓗ., ᐱᐊᓛᑦ ᐊᒻᒪᓗ ᓄᕋᐃᑦ) ᖃᐅᔨᔭᐅᓚᐅᖅᑐᖅ 2020-ᒥᑦ 14.3%-ᖑᓚᐅᖅᑐᖅ, ᖃᓄᐃᓐᓂᖅᓴᐅᓂᖓᓗᐊᖅᑐᖅ ᐊᕐᕌᒍᑕᒫᖅ ᐃᓚᖏᓐᓄᑦ ᐃᓇᕈᙱᑦᑐᓄᑦ ᖃᐅᔨᔭᐅᓯᒪᔪᓂᒃ ᓯᕗᓂᐊᒍᑦ ᐅᑭᐅᕐᓂᑦ ᐊᒻᒪᓗ ᖃᓖᓂᑦ ᖃᐅᔨᔭᐅᓯᒪᔪᑦ ᖃᐅᔨᑎᑦᑎᓵᓕᓂᕐᒧᑦ ᓇᓗᓇᐃᖅᓯᔾᔪᑎᒧᑦ (EWI) ᑎᑭᐅᑎᓃᑦ 13.7%-ᒥᑦ.
  - ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔭᒃᑐᑦ ᑕᑯᒃᓴᐅᓚᐅᖅᑐᖅ ᐱᔪᓐᓇᖅᑐᒥᒃ, ᓇᓗᓇᕋᓗᐊᖅᑯᓂ, ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᕐᒥᒃ ᑲᑎᕐᒪᔪᑦ ᖃᓄᐃᖓᓂᖏᓐᓄᑦ ᑕᐃᒪᑕᕐᖃᐅᖅᑐᓂᒃ ᐃᓇᕈᐊᓂᙱᑦᑐᓂᑦ. ᖃᐅᔨᓴᐅᔪᒥᑦ, ᓈᓴᐅᓯᕆᓂᕐᓂᒃ ᐱᑕᖅᑲᓐᖏᒃᑲᓗᐊᖅᑎᓗᒍ, ᖃᐅᔨᓴᐅᔪᑦ ᓈᓴᐅᑎᓂᑦ/ᑎᑎᖅᑲᓂᑦ ᐅᖃᖅᑐᑦ ᐃᓚᖏᑦ ᑲᑎᕐᒪᔪᐃᑦ ᐃᓇᕈᐊᓂᙱᑦᑐᓄᑦ ᖁᑦᑎᖕᓂᖅᓴᐅᓚᐅᖅᑐᑦ ᐅᒥᐊᕐᔪᐊᑦ ᖃᓂᑦᑕᕐᖂᖓᑕ BSA-ᒧᑦ. ᑕᒪᓐᓇ ᖃᐅᔨᓴᐅᔪᖅ ᐱᔾᔪᑎᖃᑐᐃᓐᓇᕆᐊᖃᖅᑐᖅ ᑲᑎᕐᒪᔪᑦ ᐱᐊᓛᖃᙱᑦᑐᑦ ᐅᕙᓘᓐᓂᑦ ᐅᑭᐅᓕᖕᓂᑦ ᐋᖃᐅᒪᔪᖕᓇᕐᓂᖅᓴᐅᐸᓗᑎᒃ ᐊᒻᒪᓗ ᐊᓯᐊᓄᙵᐅᓗᑎᒃ, ᑕᐃᒪᓐᓇᒎᑦ ᐱᐊᓛᓕᔭᖅᑐᑦ ᐅᑭᐅᓕᖕᓂᓗᓐᓂᑦ ᑕᑯᔭᐅᒃᑕᕐᓂᖅᓴᐅᐸᓗᑎᒃ.
  - **ᐊᑕᐅᑦᑎᒃᑯᑦ, ᖃᓄᐃᖓᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒐᓖᑦ ᑲᑎᕐᒪᔪᑦ ᖃᓄᐃᖓᓂᖏᑦ, ᐃᓚᐅᐸᓗᑎᒃ ᐃᓚᖏᑦ ᐃᓇᕈᐊᓂᒃᓯᒪᙱᑦᑐᑦ, ᐊᖏᔫᒥᒃ ᐊᓯᐊᙳᕐᓂᖃᓗᐊᖏᑦᑐᑦ ᐊᑯᓂᖏᓐᓂᑦ ᐅᑭᐅᓂᑦ ᖃᐅᔨᓴᕝᕕᐅᔪᓂᑦ ᐊᒥᓱᙳᖅᐸᓪᓕᐊᓂᖃᕋᓗᐊᖅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔭᒃᑯᑦ ᑖᕝᕗᓇᓂ ᐅᐸᓗᕐᓂᑦ. ᐊᒻᒪᓗᒃᑲᓂᖅ, ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔭᒃᑐᑦ ᐊᖏᔫᒥᒃ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᖃᙱᑦᑐᑦ ᐃᓚᖏᓐᓂᒃ ᐃᓇᕈᐊᓂᙱᑦᑐᓂᒃ ᖃᐅᔨᔭᐅᓯᒪᔪᓂᑦ. ᖃᐅᔨᓴᐅᔪᖅ ᓇᓗᓇᐃᖅᓯᔪᖅ ᐊᑦᑎᒃᑐᒥᑦ ᐊᖏᑎᒋᓂᖓ ᖃᓄᐃᓕᐅᕐᓂᖏᑦ ᑑᒐᓖᑦ ᐱᒋᐊᖅᑎᑕᐅᓯᒪᙱᑦᑐᖅ, ᑐᑭᓕᐅᖅᑕᐅᓯᒪᓂᖓᑐᑦ Finneran et al.-ᒥᑦ (2017), ᑕᐃᒪᓐᓇᒎᓗ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓇᔭᙱᑦᑐᖅ ᐊᖏᔫᒥᒃ ᐊᓯᐊᙳᖅᑐᓄᒃ ᐱᖁᓯᕆᔭᖏᑦᑕ ᖃᓄᐃᓕᐅᕐᓂᖏᓐᓄᑦ ᑑᒐᓖᑦ ᖃᓂᑦᑐᒥᑦ ᖃᐅᔨᓴᕝᕕᐅᔪᒥᑦ (RSA) ᐅᕙᓘᓐᓂᑦ ᐃᓱᐃᕌᕆᓗᑎᒃ ᖃᑕᐅᒪᑦ ᐊᑐᒃᑕᖅᑕᖏᓐᓂᑦ. ᖃᓄᐃᓕᐅᓂᖕᒋᓐᓂᖏᑦ ᐃᑲᔪᐃᔪᖅ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᔪᓂᑦ FEIS-ᒥᑦ ERP-ᒧᑦ, ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖏᓐᓄᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔪᑦ ᑑᒐᓕᖕᓄᑦ ᓂᕆᐅᒋᔭᐅᔪᖅ ᑮᓕᖅᑐᒥᑦ ᕿᓚᒥᐅᓂᐊᖅᑐᒧᑦ, ᖃᓂᑦᑑᒥᓗᓂ ᑎᑭᐅᑎᑦᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᓯᕆᔭᐅᔪᒥᒃ. ᐱᔾᔪᑎᒋᐸᓗᒍ ᖃᓄᐃᓕᐅᕈᑎᖃᕐᓂᖏᓐᓄᑦ ᐊᔾᔨᙱᓐᓂᖅ (ᓲᕐᓗ, ᑲᑎᕐᒪᔪᑦ ᖃᓄᐃᖓᓂᖓ), ᖃᐅᔨᓇᐅᑎᑕᖕᒋᑦᑐᖅ ᐊᖏᔫᒥᒃ ᖃᓄᐃᓕᐅᕈᑎᖃᑦᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᓯᕆᔭᐅᔪᒥᒃ, ᐊᓯᐊᓄᐊᕐᓂᖏᓐᓄᑦ, ᐅᕚᓘᓐᓂᑦ ᕿᒪᐃᓐᓂᖏᓐᓄᑦ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᒃᓯᒪᒃᑕᖅᑕᖏᓐᓂᑦ (ᖁᑦᑎᒃᑐᖅ ᐊᖏᓂᕆᔭᖓ ᖃᓄᐃᓕᐅᕐᓂᖏᓐᓄᑦ), ᐊᒥᒌᑎᕆᓂᖏᓐᓂᒃ ᑲᑎᒪᕐᔪᐃᓪᓗᒍᓐᓂᑦ ᖃᓄᐃᓕᑎᑦᑎᓂᕐᒧᑦ (ᐊᔾᔨᖓ ᑐᑭᐅᔪᒧᑦ ᐊᖏᔫᒥᒃ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᕐᒧᑦ ᐊᑐᖅᑕᐅᔪᖅ FEIS-ᒥᑦ).**

- ᑲᑎᖕᒪᔪᑦ ᓱᐊᒻᒪᒃᓯᒪᓂᖏᑦ: ᑑᒎᓕᑦ ᑲᑎᖕᒪᔪᑦ ᑕᑯᔭᐅᖃᑦᑕᕐᓂᖅᓴᐅᓚᐅᖅᑐᑦ ᑲᑎᖕᒪᐅᖅᓱᑎᒃ ᑲᑎᒪᙵᑎᓪᓗᒋᐅᖓᓂᑦ ᑕᒪᐃᑎᒎᑦ ᐅᒥᐊᕐᔪᐊᑦ ᑕᐃᒪᐅᑎᓪᓗᒋᑦ ᐊᒻᒪᓗ ᐅᒥᖃᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ. ᑑᒑᓕᑦ ᐊᓯᐊᙳᓚᐅᖏᑦᑐᑦ ᐃᓂᒥᒃ ᐊᑐᖃᑦᑕᕐᓂᖏᓐᓂᒃ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓪᓗᒎᑦ ᑲᑎᖕᒪᓂᖅᓴᐅᓂᖏᓐᓄᑦ ᐅᕙᓘᓐᓃᑦ ᐊᑉᑎᖅᑎᓪᓗᒋᑦ. ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓐᓂᑦ ᐅᒥᐊᕐᔪᐊᓂᒃ ᐱᔪᓂᒃ (ᓇᒎᙵᐅᑎᓪᓗᒋᑦ ᐅᖓᓯᒃᑎᒋᓂᖏᓐᓂᒃ ᐅᒥᐊᕐᔪᐊᕐᒥᑦ, ᐅᒥᐊᕐᔪᐊᖅ ᓇᒎᙵᐅᑎᓪᓗᒍ ᖃᓂᑕᖓᓂᑦ ᕿᙳᐊᓂᑦ) ᑑᒑᓕᑦ ᓱᐊᒻᒪᖕᓂᖏᓐᓄᑦ ᓈᓴᐅᓯᕆᓂᒃᑯᑦ ᐅᔾᔨᕆᓇᓚᐅᖏᑦᑐᖅ (*P*>0.6 ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᓗᒃᑖᓄᑦ), ᑲᑎᖕᒪᔪᑦ ᐊᖏᑎᒋᓂᖏᓐᓄᑦ ᖃᓄᐃᖓᔪᓂᖀᔮᕐᓗᓂ (-1% ᐊᒻᒪᓗ +14% ᐅᒥᐊᕐᔪᐊᕐᒥᑦ 0 ᑭᓛᒥᑕᓂᒃ ᐅᖓᓯᒃᑎᒋᐸᓗᓂ). **ᐊᔾᔨᕐᓚᒋᔭᖓ ᓯᕗᓂᐊᒍᑦ ᐅᑭᐅᓂᑦ ᖄᐅᔨᔮᐅᔪᓄᑦ, ᖃᓄᐃᖓᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒑᓕᑦ ᑲᑎᖕᒪᓂᖏᓂᑦ ᓱᐊᒻᒪᖓᓂᖏᑦ ᐊᓯᐊᙳᓗᐊᖅᓯᒪᙵᑦᑐᖅ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓪᓗᒍ. ᖄᐅᔨᔮᐅᔪᖅ ᓇᓗᓇᐃᖅᓯᔪᖅ ᐊᑦᑎᒃᑑᔪᖅ ᐊᖏᑎᒋᓂᖓ ᖃᓄᐃᓕᐅᖅᑎᑦᑎᓂᖅ ᑑᒑᓕᖓᓄᑦ ᐱᒋᐊᖅᑎᑕᐅᓯᒪᙵᑦᑐᖅ, ᑐᑭᓕᐅᖅᑕᐅᓯᒪᓂᖓᑐᑦ Finneran et al.-ᒥᑦ (2017), ᑕᐃᒪᓐᓇᒎᑦ ᐊᖏᔪᒥᒃ ᐊᓯᐊᙳᕋᔭᙵᑦᑐᖅ ᑑᒎᓕᑦ ᐱᖁᓯᖏᓐᓄᑦ ᖃᓂᑦᑐᒥᑦ ᖄᐅᔨᓴᐃᕝᕕᐅᔪᒥᑦ (RSA) ᐅᕙᓘᓐᓃᑦ ᐃᓗᐊᓈᖅᑕᐅᓂᖏᑦ ᖃᐅᑕᒫᑦ ᐊᑐᖃᑦᑕᖅᑕᖏᑦ. ᖃᓄᐃᓕᐅᓂᖃᙱᓐᓂᖏᑦ ᐃᑲᔪᐃᔪᖅ ᐊᑐᖅᓯᓂᕐᒧᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᔪᓂᑦ FEIS-ᒥᑦ ERP-ᒧᑦ, ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖏᓐᓄᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔪᑦ ᑑᒑᓕᖕᓄᑦ ᓂᕆᐅᒋᔭᐅᔪᖅ ᑭᓪᓕᖃᖅᑐᒥᑦ ᕿᓚᒥᐅᓂᐊᖅᑐᒧᑦ, ᖃᓂᑦᑑᒥᓪᓗᓂ ᑎᑭᐅᑎᑦᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᓯᓇᔭᐅᔪᒥᒃ. ᐱᔪᑎᒋᐸᓗᒍ ᖃᓄᐃᓕᐅᕈᑎᖃᕐᓂᖏᓐᓄᑦ ᐊᔾᔨᒌᙵᖏᓐᓂᖅ (ᐊᓯᖏᓗ, ᑲᑎᖕᒪᔪᑦ ᓱᐊᒻᒪᖓᓂᖏᑦ), ᖄᐅᔾᔨᓇᐅᑎᑕᙵᑦᑐᖅ ᐊᖏᔪᒥᒃ ᑎᑭᐅᑦᑎᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᓯᓇᔭᐅᔪᒥᒃ ᐊᓯᐊᓄᐊᕐᓂᖏᓐᓄᑦ, ᕿᒪᐃᓂᖏᓐᓄᓪᓘᓐᓃᑦ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᒃᓯᒪᑲᑦᑕᖅᑕᖏᓐᓂᑦ ᕿᒪᐃᓂᖏᓐᓄᓪᓘᓐᓃᑦ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᒃᓯᒪᑲᑦᑕᖅᑕᖏᓐᓂᑦ (ᖁᑦᑎᒃᑐᖅ ᖃᓄᐃᓕᑲᑦᑕᕐᓂᖏᓐᓄᑦ)), ᐊᒥᓲᑎᒋᓂᖏᓐᓄᑦ ᐅᕙᓘᓐᓃᑦ ᑲᑎᖕᒪᔪᓄᑦ ᐊᒃᑐᖅᓯᓂᖃᕈᓇᖅᓱᓂ (ᐊᔾᔨᖓ ᑐᑭᐅᔩᑉ ᐊᖏᔪᒥᒃ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᖅ ᐊᑐᖅᑕᐅᔪᖅ FEIS-ᒥᑦ).**
- ᑲᑎᖕᒪᔪᑦ ᐋᖅᑭᖓᓂᖏᑦ: ᑑᒑᓕᑦ ᑲᑎᖕᒪᔪᑦ ᑕᑯᔭᐅᓚᔪᕈᓘᓚᐅᖅᑐᑦ ᑲᑎᑉᐸᓕᐊᓂᖏᓐᓂᑦ ᑕᒪᐃᓐᓂᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓪᓗᒍ ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ. ᐅᒥᐊᕐᔪᐊᕐᒥᑦ ᐱᔪᓂᒃ ᐊᔾᔨᒌᙱᓂᖅᑕᖃᙱᑦᑐᖅ (ᐊᓯᖏᓗ, ᐅᖓᓯᒃᑎᒋᓐᓂᑦ ᐅᒥᐊᕐᔪᐊᕐᓂᑦ, ᐅᒥᐊᕐᔪᐊᑦ ᓇᒎᙵᐅᓂᖏᑦ ᕿᙳᐊᓂᑦ, ᐅᒥᐊᕐᔪᐊᑦ ᓇᒎᙵᐅᓂᖏᑦ BSA-ᒥᑦ, ᐅᕙᓘᓐᓃᑦ ᖃᓄᐃᓕᐅᖃᑎᒌᖕᓂᖏᑦ) ᓈᓴᐅᓯᕆᓂᒃᑯᑦ ᐅᔾᔨᕆᓚᙱᑦᑐᑦ ᐱᑎᑦᑎᓂᖃᖅᑐᓂᒃ ᑑᒑᓕᑦ ᑲᑎᑉᐸᓕᐊᓂᖏᓐᓄᑦ. **ᐊᔾᔨᕐᓚᒋᔭᖓ ᓯᕗᓂᐊᒍᑦ ᐅᑭᐅᓂᑦ ᖄᐅᔨᔮᐅᔪᓄᑦ, ᖃᓄᐃᖓᓂᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒑᓕᑦ ᑲᑎᖕᒪᓂᖏᓂᑦ ᑲᑎᑉᐸᓕᐊᓂᖏᑦ ᐊᓯᐊᙳᓗᐊᖅᓯᒪᙵᑦᑐᖅ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓪᓗᒍ. ᖄᐅᔨᔮᐅᔪᖅ ᓇᓗᓇᐃᖅᓯᔪᖅ ᐊᑦᑎᒃᑑᔪᖅ ᐊᖏᑎᒋᓂᖓ ᖃᓄᐃᓕᐅᖅᑎᑦᑎᓂᖅ ᑑᒑᓕᖓᓄᑦ ᐱᒋᐊᖅᑎᑕᐅᓯᒪᙵᑦᑐᖅ, ᑐᑭᓕᐅᖅᑕᐅᓯᒪᓂᖓᑐᑦ Finneran et al.-ᒥᑦ (2017), ᑕᐃᒪᓐᓇᒎᑦ ᐊᖏᔪᒥᒃ ᐊᓯᐊᙳᕋᔭᙵᑦᑐᖅ ᑑᒎᓕᑦ ᐱᖁᓯᖏᓐᓄᑦ ᖃᓂᑦᑐᒥᑦ ᖄᐅᔨᓴᐃᕝᕕᐅᔪᒥᑦ (RSA) ᐅᕙᓘᓐᓃᑦ ᐃᓗᐊᓈᖅᑕᐅᓂᖏᑦ ᖃᐅᑕᒫᑦ ᐊᑐᖃᑦᑕᖅᑕᖏᑦ. ᖃᓄᐃᓕᐅᓂᖃᙱᓐᓂᖏᑦ ᐃᑲᔪᐃᔪᖅ ᐊᑐᖅᓯᓂᕐᒧᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᔪᓂᑦ FEIS-ᒥᑦ ERP-ᒧᑦ, ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖏᓐᓄᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔪᑦ ᑑᒑᓕᖕᓄᑦ ᓂᕆᐅᒋᔭᐅᔪᖅ ᑭᓪᓕᖃᖅᑐᒥᑦ ᕿᓚᒥᐅᓂᐊᖅᑐᒧᑦ, ᖃᓂᑦᑑᒥᓪᓗᓂ ᑎᑭᐅᑎᑦᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᓯᓇᔭᐅᔪᒥᒃ. ᐱᔪᑎᒋᐸᓗᒍ ᖃᓄᐃᓕᐅᕈᑎᖃᕐᓂᖏᓐᓄᑦ ᐊᔾᔨᒌᙵᖏᓐᓂᖅ (ᐊᓯᖏᓗ, ᑲᑎᑉᐸᓕᐊᓂᖏᑦ), ᖄᐅᔾᔨᓇᐅᑎᑕᙵᑦᑐᖅ ᐊᖏᔪᒥᒃ ᑎᑭᐅᑦᑎᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᓯᓇᔭᐅᔪᒥᒃ ᐊᓯᐊᓄᐊᕐᓂᖏᓐᓄᑦ, ᕿᒪᐃᓂᖏᓐᓄᓪᓘᓐᓃᑦ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᒃᓯᒪᑲᑦᑕᖅᑕᖏᓐᓂᑦ (ᖁᑦᑎᒃᑐᖅ ᖃᓄᐃᓕᑲᑦᑕᕐᓂᖏᓐᓄᑦ), ᐊᒥᓲᑎᒋᓂᖏᓐᓄᑦ ᐅᕙᓘᓐᓃᑦ ᑲᑎᖕᒪᔪᓄᑦ ᐊᒃᑐᖅᓯᓂᖃᕈᓇᖅᓱᓂ (ᐊᔾᔨᖓ ᑐᑭᐅᔩᑉ ᐊᖏᔪᒥᒃ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᖅ ᐊᑐᖅᑕᐅᔪᖅ FEIS-ᒥᑦ).**
- ᑲᑎᖕᒪᔪᑦ ᓇᒎᙵᐅᓂᖏᑦ: ᑑᒑᓕᑦ ᑲᑎᖕᒪᔪᑦ ᑕᑯᔭᐅᓚᔪᕐᓂᖅᓴᐅᓚᐅᖅᑐᑦ ᓂᒋᕐᒎᙵᐅᔪᑦ BSA-ᑯᑦ. ᓂᒋᕐᒎᙵᐅᔪᑦ ᑕᑯᔭᐅᓚᔪᙱᓐᓂᖅᓴᐅᔪᑦ ᓂᒋᕐᒎᙵᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ BSA-ᒥᙹᖅᐸᓕᐊᑎᓪᓗᒋᑦ, ᐊᒻᒪᓗ ᑕᐃᒪᐅᓚᔪᕐᓘᑉᓗᑎᒃ ᐅᐊᖕᓇᕐᒎᙵᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ BSA-ᒥᙹᖅᑎᓪᓗᒋᑦ. **ᐊᔾᔨᕐᓚᖓ ᓯᕗᓂᐊᒍᑦ ᐅᑭᐅᓂᑦ ᖄᐅᔨᔮᐅᔪᓄᑦ, ᖄᐅᔨᔮᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒑᓕᑦ ᑲᑎᖕᒪᔪᑦ ᐱᑦᑕᐃᓕᓂᖃᕈᓐᓇᕐᓂᖏᓐᓄᑦ ᐅᒥᐊᕐᔪᐊᑦ ᕿᙳᐊᓄᙵᐅᑎᓪᓗᒋᑦ (ᐊᓯᖏᓗ, ᑑᒑᓕᑦ "ᒪᓕᒃᑕᐃᓕᖃᑦᑕᖅᑐᑦ" ᐅᒥᐊᕐᔪᐊᕐᓂᑦ) ᑭᓯᐊᓂ ᓇᒎᙵᐅᓂᖏᑦ ᑲᑎᖕᒪᔪᑦ ᑑᒑᓕᑦ ᐊᑐᖅᑕᐅᓯᒪᙵᓂᖅᓴᐅᑉᓗᑎᒃ ᐅᒥᐊᕐᔪᐊᓄᑦ ᑎᑭᓴᖅᑐᖅᑐᓄᑦ. ᖄᐅᔨᔮᐅᔪᑦ ᐊᔾᔨᒋᔭᖓ ᐊᑦᑎᒃᑐᒥᑦ ᐊᖏᓂᐅᔪᖅ ᖃᓄᐃᓕᔾᔪᑎᖏᓐᓄᑦ. ᑐᑭᓕᐅᖅᑕᐅᓯᒪᓂᖓᑐᑦ Finneran et al.-ᒥᑦ (2017), ᑕᐃᒪᓐᓇᒎᓗ ᐊᖏᔪᒥᒃ ᐊᓯᐊᙳᕐᓂᖃᙱᑦᑐᖅ ᐱᖁᓯᓇᖃᑦᑕᖅᑕᖏᓐᓄᑦ ᑑᒑᓕᑦ ᖃᓂᑦᑐᒥᑦ ᖄᐅᔨᓴᐃᓂᕐᒥᑦ (RSA) ᐃᓗᐃᓈᖅᑕᐅᓂᖏᓐᓄᓪᓘᓐᓃᑦ ᖃᐅᑕᒫᑦ ᐊᑐᖃᑦᑕᖅᑕᖏᓐᓄᑦ. ᐊᔾᔨᒋᔭᖓ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᓇᓚᐅᑦᑖᑕᐅᔪᑦ FEIS-ᒥᑦ ERP-ᒧᑦ, ᐅᒥᐊᕐᔪᐊᓂᒃ ᓂᐱᖃᕐᓂᖏᓐᓄᑦ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᐅᔪᑦ ᑑᒑᓕᖕᓄᑦ ᓂᕆᐅᒋᔭᐅᔪᖅ ᒥᑭᔫᓂᐊᕐᓂᖓᓄᑦ ᐊᒻᒪᓗ ᕿᓚᒥᐅᓗᓂ, ᖃᓂᑦᑑᒥᓪᓗᓂ ᖃᓄᐃᓕᐅᖅᑕᐃᓕᓂᖏᓐᓄᑦ. ᐱᔪᑎᒋᐸᓗᒍ ᖃᓄᐃᓕᐅᕈᑎᖃᕐᓂᖏᓐᓄᑦ ᐊᔾᔨᒌᙵᖏᓐᓂᖅ (ᑲᑎᖕᒪᔪᑦ ᓇᒎᙵᐅᓂᖏᑦ, ᖄᐅᔾᔨᓇᐅᑎᑕᙵᑦᑐᖅ ᐊᖏᔪᒥᒃ ᑎᑭᐅᑦᑎᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᓯᓇᔭᐅᔪᒥᒃ ᐊᓯᐊᓄᐊᕐᓂᖏᓐᓄᑦ, ᕿᒪᐃᓂᖏᓐᓄᓪᓘᓐᓃᑦ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᒃᓯᒪᑲᑦᑕᖅᑕᖏᓐᓂᑦ (ᖁᑦᑎᒃᑐᖅ ᖃᓄᐃᓕᑲᑦᑕᕐᓂᖏᓐᓄᑦ), ᐊᒥᓲᑎᒋᓂᖏᓐᓄᑦ ᐅᕙᓘᓐᓃᑦ ᑲᑎᖕᒪᔪᓄᑦ ᐊᒃᑐᖅᓯᓂᖃᕈᓇᖅᓱᓂ (ᐊᔾᔨᖓ ᑐᑭᐅᔩᑉ ᐊᖏᔪᒥᒃ ᖃᓄᐃᖓᓕᖅᑎᑦᑎᓂᖅ ᐊᑐᖅᑕᐅᔪᖅ FEIS-ᒥᑦ).**
- ᐃᖏᕐᕋᔭᒃᑎᓪᓗᒋᑦ ᓇᑭᕐᓂᖓ: ᑕᑯᔭᐅᔪᓗᒃᑖᕐᓚᐃᑦ ᑑᒑᓕᑦ ᑲᑎᖕᒪᔪᑦ ᐃᖏᕐᕋᑦᑕᓚᐅᖅᑐᑦ ᕿᑎᐊᓃᙶᕐᓗᓂ ᓇᑭᕐᓂᖏᒥᑦ, ᐅᒥᐊᕐᔪᐊᖅᑕᖃᓗᐊᖅᐸᑦ. ᑕᐃᒪᐅᔪᖕᓇᖃᓗᐊᖅᑎᓪᓗᒍ ᑭᓯᐊᓂ ᓇᓗᓇᖅᓗᓂ ᐅᒥᐊᕐᔪᐊᑦ ᐅᖓᓯᒃᑎᒋᓂᖏᑦ ᐃᖏᕐᕋᐸᓪᓗᑎᒃ ᓇᑭᖅᓱᕐᓂᕐᒧᑦ,

ᖃᓄᐃᓕᔾᔪᑎᐅᔪᖅ ᐊᔾᔨᒌᙱᑦᑐᖅ ᐱᔾᔪᑎᖃᕐᓂᖓᓄᑦ ᐊᒻᒪᓗ ᖃᐅᔨᔭᐅᔪᑦ ᐱᑎᑦᑎᔪᙶᖅᑐᑦ ᓈᓴᐅᑎᓄᑦ/ᑎᑎᖅᑲᓄᑦ ᑎᑎᕋᐅᓯᐅᔪᑦ ᐊᑕᐅᓯᐅᖏᑦᑐᓂᒃ ᑕᑯᔭᐅᔪᓄᑦ, ᐊᑦᑎᒃᑑᑉᓗᓂ ᓇᓗᓇᙱᓐᓂᐅᔪᖅ ᐋᑎᖃᕐᓂᖏᓐᓄᑦ ᖃᐅᔨᓴᖅᑕᐅᔪᑦ ᐱᖁᑎᕆᔭᐅᔪᑦ ᖃᓄᐃᓕᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᐅᒥᐊᖅᔪᐊᑦ ᐃᖏᕐᖓᔭᒃᑐᓄᑦ. **ᐊᔾᔨᒌᙱᖦᖢ ᓯᕗᓂᐊᒍᑦ ᐅᑭᐅᓂᑦ ᖃᐅᔨᓴᐅᔪᓄᑦ, ᖃᐅᔨᓴᐃᓂᕐᒧᑦ ᖃᓄᐃᖕᖓᓂᐅᔪᑦ ᑑᒑᓕᑦ ᐊᓯᐊᙳᕐᓂᖃᙱᑦᑐᑦ ᐃᖏᕐᖓᔭᒃᑎᓪᓗᒋᑦ ᓇᑭᕐᓂᖏᓐᓄᑦ ᐅᒥᐊᖅᔪᐊᓂᒃ ᐃᖏᕐᖓᔪᓂᒃ ᑕᐃᒪᑖᖅᑎᓪᓗᒍ. ᑐᑭᓕᐅᖅᑕᐅᓯᒪᓂᖓᑐᑦ Finneran et al.-ᒥᑦ (2017), ᐊᓯᐊᙳᕐᓂᐅᔪᖅ ᐃᖏᕐᖓᑉᓗᑎᒃ ᓇᑭᕐᓂᕐᒧᑦ ᑑᒑᓖᑦ ᓇᓗᓇᐃᖅᓯᐸᓗᓂ ᕿᑎᐊᓃᖓᔪᖅ ᐊᖏᑎᒥᓂᖓᓄᑦ ᖃᓄᐃᓕᐅᕈᑎᒥᒃᑕᖅᑕᖏᓐᓄᑦ. ᐊᓯᐊᙳᕐᓂᖅᑕᖏᒻᒪᑦ ᐃᖏᕐᖓᐅᓗᑎᒃ ᓇᑭᕐᓂᕐᒧᑦ ᖃᐅᔨᓴᐅᔪᓂᒃ ᐊᐅᒥᐊᖅᔪᐊᑦ ᐃᖏᕐᖓᔭᒃᑕᖅᑕᕐᓂᖏᓐᓄᑦ, ᐊᖏᔪᒥᒃ ᐊᓯᐊᙳᖅᑐᓂᒃ ᐱᖁᑎᕆᔭᐅᔪᑦ ᖃᓄᐃᓕᐅᕐᓂᖏᓐᓄᑦ ᑑᒑᓖᑦ ᖃᓂᑦᑐᒥᑦ ᖃᐅᔨᓴᐃᕝᕕᐅᔪᒥᑦ (RSA) ᐅᕝᕙᓘᓐᓃᑦ ᐃᓱᐃᓵᖅᑕᐅᓂᖏᑦ ᖃᐅᑕᒫᑦ ᐊᑐᖃᑦᑕᖅᑕᖏᓐᓄᑦ ᑕᑯᒃᓴᐅᔪᖃᙱᑦᑐᖅ. ᖃᓄᐃᓕᐅᓂᖃᙱᓐᓂᖏᑦ ᐃᑲᔪᐃᔪᖅ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᔪᓂᑦ FEIS-ᒥᑦ ERP-ᒧᑦ, ᐅᒥᐊᖅᔪᐊᑦ ᓂᐱᖏᓐᓄᑦ ᖃᓄᐃᖕᒪᖅᑎᑦᑎᓂᐅᔪᑦ ᑑᒑᓖᓐᓄᑦ ᓂᕆᐅᒋᔭᐅᔪᖅ ᑭᒡᓕᖃᖅᑐᒥᑦ ᕿᓚᒥᐅᓂᐊᖅᑐᒧᑦ, ᖃᓂᑦᑑᓕᖓᓂ ᑎᑭᐅᑎᑦᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᑎᕆᔭᐅᔪᒥᒃ. ᐱᔾᔪᑎᒋᐸᒍ ᖃᓄᐃᓕᐅᕈᑎᖃᕐᓂᖏᓐᓄᑦ ᐊᔾᔨᒌᙱᖏᓐᓂᖅ (ᐊᓯᐊᓗ, ᐃᖏᕐᖓᐸᓗᑎᒃ ᓇᑭᖅᓴᕐᓂᕐᒧᑦ), ᖃᐅᔾᔭᐅᓇᐅᑎᑕᖅᑲᖏᑦᑐᖅ ᐊᖏᔪᒥᒃ ᑎᑭᐅᑎᑦᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᑎᕆᔭᐅᔪᒥᒃ ᐊᓯᐊᓄᐊᕐᓂᖏᓐᓄᑦ, ᕿᒪᐃᓂᖏᓐᓄᓪᓗᓐᓃᑦ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᒃᓯᒪᖃᑦᑕᖅᑕᖏᓐᓂᑦ (ᖁᑦᑎᒃᑐᖅ ᖃᓄᐃᓕᔾᔪᑎᒋᖃᑦᑕᖅᑕᖏᓐᓄᑦ), ᐊᒥᖕᖏᑎᓂᖏᓐᓄᑦ ᐅᕝᕙᓘᓐᓃᑦ ᑲᑎᕐᒪᔪᓄᑦ ᐊᒃᑐᖅᓯᓂᖃᕈᓐᓇᖅᖢᓂ (ᐊᔾᔨᖓ ᑐᑭᐅᔫᑉ ᐊᖏᔪᒥᒃ ᖃᓄᐃᖕᒪᖅᑎᑦᑎᓂᖅ ᐊᑐᖅᑕᐅᔪᖅ FEIS-ᒥᑦ).**

- ᐅᖓᓯᒃᑎᒋᓂᖓ ᐃᓗᕕᓕᖏᑦ: ᑑᒑᓕᑦ ᑲᑎᖅᓱᐃᔪᑦ ᑕᑯᔭᐅᒐᔭᖕᓂᖅᓴᐅᓚᐅᖅᑐᑦ 300 ᒦᑕᓂᒃ ᐅᖓᓯᒃᑎᒋᐊᓗᑎᒃ ᐃᓗᕕᓕᖏᑦ ᑕᒪᐃᓐᓂᑦ ᐅᒥᐊᖅᔪᐊᖅᑕᖅᑎᓪᓗᒍ ᐊᒻᒪᓗ ᐱᑕᖃᙱᑎᓪᓗᒋᑦ. ᑕᒪᕐᒥᒃ ᓂᒋᖅᒧᙵᐅᔪᑦ ᐊᒻᒪᓗ ᐅᐊᖕᓇᒧᙵᐅᔪᑦ ᐅᒥᐊᖅᔪᐊᑦ ᐃᖏᕐᖓᔭᒃᑐᑦ ᑕᑯᓴᐅᑎᑦᑎᔪᑦ ᒥᒃᓵᓕᖅᔪᐊᖅᓯᒪᓂᖏᑦ 'ᐅᖓᓯᒃᑎᒋᓂᖓᑦ', ᐱᓗᐊᖅᑐᒥᑦ ᐅᒥᐊᖅᔪᐊᑦ ᖃᓂᑦᑕᕋᖓᑕ BSA-ᒧᑦ. **ᖃᐅᔨᓴᐅᔪᑦ ᐅᖃᖅᑐᑦ ᑑᒑᓕᑦ ᖃᓕᒋᐊᕋᔭᖅᑐᑦ ᐅᒥᐊᖅᔪᐊᑦ ᖃᓂᓐᓂᖅᓴᐅᑎᓪᓗᒋᑦ BSA-ᒧᑦ, ᓇᓗᓇᐃᖅᓯᔪᖅ ᕿᑎᐊᓃᖔᓕᖅᑐᖅ ᐊᖏᓂᕆᔭᖓ ᖃᓄᐃᓕᐅᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᑭᓯᐊᓂ ᓇᐃᑦᑑᓗᓂ. ᑐᑭᓕᐅᖅᑕᐅᓯᒪᓂᖓᑐᑦ Finneran et al.-ᒥᑦ (2017), ᕿᑎᐊᓃᖓᔪᒥᒃ ᐊᖏᑎᒋᓗᓂ ᖃᓄᐃᓕᐅᕈᑎᒃᑕᖅᑕᖏᑦ ᓇᐃᑦᑑᓗᓂ ᐊᑯᓂᐅᑎᒋᓂᖓ (ᐊᓯᐊᓗ, ᑐᓕᒫᓂᑦ ᐊᑯᓂᐅᑎᒋᓂᖓ ᐅᒥᐊᖅᔪᐊᒧᑦ ᑎᑭᐅᑎᓯᒪᓂᖏᓐᓂᑦ) ᐊᓯᐊᙳᖅᓯᓂᖃᕈᓐᓇᖅᑐᖅ ᑑᒑᓕᐅᑉ ᐱᖁᑎᕆᔭᖅᑕᖅᑕᖏᓐᓂᒃ ᐅᕝᕙᓘᓐᓃᑦ ᐃᓱᐃᓵᖅᑕᐅᓗᑎᒃ ᖃᐅᑕᒫᒃᑯᑦ ᐊᑐᖃᑦᑕᖅᑕᖏᑦ. ᐊᔾᔨᒋᔭᖓ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᔪᓂᒃ FEIS-ᒥᑦ ERP-ᒧᑦ, ᐅᒥᐊᖅᔪᐊᕐᒥᑦ ᓂᐱᖃᕐᓂᕐᒥᒃ ᖃᓄᐃᖕᒪᖅᑎᑦᑎᓂᕐᓄᑦ ᑑᒑᓕᖕᓄᑦ ᓂᕆᐅᒋᔭᐅᔪᖅ ᒥᑭᕗᓂᐊᖅᑐᖅ ᐊᒻᒪᓗ ᕿᓚᒥᐅᓗᓂ, ᖃᓂᑦᑑᓕᖓᓂ ᑎᑭᐅᑎᑦᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᑎᕆᔭᐅᔪᒥᒃ. ᐱᔾᔪᑎᒋᐸᒍ ᖃᓄᐃᓕᐅᕈᑎᖃᕐᓂᖏᓐᓄᑦ ᐊᔾᔨᒌᙱᖏᓐᓂᖅ (ᐆᒃᑑᑎᒋᓗᒍ, ᐅᖓᓯᒃᑎᒋᓂᖓ), ᖃᐅᔾᔭᐅᓇᐅᑎᑕᖅᑲᖏᑦᑐᖅ ᐊᖏᔪᒥᒃ ᑎᑭᐅᑦᑎᑕᐃᓕᓂᕐᒧᑦ ᐱᖁᑎᕆᔭᐅᔪᒥᒃ ᐊᓯᐊᓄᐊᕐᓂᖏᓐᓄᑦ, ᕿᒪᐃᓂᖏᓐᓄᓪᓗᓐᓃᑦ ᐊᐅᔭᒃᑯᑦ ᐅᕐᓂᒃᓯᒪᖃᑦᑕᖅᑕᖏᓐᓂᑦ (ᐊᖏᔪᒥᒃ ᖃᓄᐃᓕᔾᔪᑎᒋᖃᑦᑕᖅᑕᖏᑦ), ᑕᐃᒪᓐᓇ ᖃᓄᐃᖕᒪᖅᑎᑦᑎᔪᙶᖅᑐᖅ ᐊᒥᖕᖏᑎᓂᖏᓐᓂᒃ ᐅᕝᕙᓘᓐᓃᑦ ᑲᑎᕐᒪᔪᓄᑦ (ᐊᔾᔨᖓ ᑐᑭᐅᔫᑉ ᐊᖏᔪᒥᒃ ᖃᓄᐃᖕᒪᖅᑎᑦᑎᓂᖅ ᐊᑐᖅᑕᐅᔪᖅ FEIS-ᒥᑦ).**

UAV-ᑯᑦ ᑕᑯᔭᐅᔪᑦ ᒪᓕᒃᑕᐅᑉᓗᑎᒃ ᖃᐅᔨᓴᐃᓃᑦ

- 2020-ᒥᑦ, ᑲᑎᖕᒍᒥᑦ 84 ᑑᒑᓕᑦ ᑕᑯᔭᐅᔪᑦ ᒪᓕᒃᑕᐅᑉᓗᑎᒃ ᖃᐅᔨᓴᐃᓂᖃᓚᐅᖅᑐᑦ ᖃᓂᑦᑐᒥᑦ ᖃᐅᔨᓴᐃᕝᕕᐅᔪᒥᑦ (RSA) (ᖃᓂᑕᖓᓂᑦ ᐃᓗᕕᓕᐅᑉ ᐊᒻᒪᓗ ᖁᖅ) ᐊᑐᖅᓗᑎᒃ UAV-ᑯᑦ ᐊᐅᓚᔪᓂᒃ ᐊᔾᔨᓕᐅᕈᑎᒃᑯᑦ (7.3 ᐃᑲᔪᕋᓂᒃ ᐊᔾᔨᓕᐅᕆᓚᐅᑉᓗᑎᒃ ᐱᖁᑎᕆᔭᐅᔪᓂᒃ). ᐃᓚᐅᑉᓗᑎᒃ 16 ᑕᑯᔭᐅᔪᑦ ᒪᓕᒃᑕᐅᑉᓗᑎᒃ ᐅᒥᐊᖅᔪᐊᑦ ᑕᐃᒪᐅᔮᕐᖓᑕ (1.3 ᐃᑲᔪᕋᓂᒃ ᐊᔾᔨᓕᐅᕆᓚᐅᑉᓗᑎᒃ ᐱᖁᑎᕆᔭᐅᔪᓂᒃ) ᐊᒻᒪᓗ 68 ᑕᑯᔭᐅᔪᑦ ᒪᓕᒃᑕᐅᑉᓗᑎᒃ ᐅᒥᐊᖅᔪᐊᖅᑕᖃᖅᑎᓪᓗᒍ (6.0 ᑕᑯᔭᐅᔪᑦ ᒪᓕᒃᑕᐅᑉᓗᑎᒃ). ᐱᕐᑯᓯᕆᔭᐅᔪᓂᒃ ᖃᐅᔨᓴᖅᑕᐅᓗᐊᓚᐅᖅᑐᓂᑦ ᐃᓚᐅᔪᑦ ᐃᖏᕐᖓᔭᖕᓂᖅ (ᐊᓯᐊᓗ, ᓇᒧᙵᐅᓂᖏᑦ), ᓇᒧᙵᐅᖏᓐᓂᖅᑎᓪᓗᒋᑦ (ᐊᓯᐊᓗ, ᓄᒧᙵᐅᖏᓐᓗᑎᒃ ᐊᐅᓚᓐᓂᖏᑦ), ᓄᖅᑲᖓᓂᖅᑎᓪᓗᒋᑦ (ᐊᓯᐊᓗ, ᐊᐅᓚᙱᑦᑐᑦ/ᐊᐅᓚᓂᖃᙱᖦᖢᑦ), ᐊᒻᒪᓗ ᐃᖏᕐᖓᓄᑦ ᑑᒑᓕᖃᑎᒌᓄᑦ ᐱᖁᑎᕆᔭᐅᔪᖅ (ᐊᓯᐊᓗ, ᓇᒡᓇᙱᑦᑐᖅ ᖃᓄᐃᓕᐅᖃᑎᒌᖕᓂᖏᑦ ᐊᑐᕈᑎᖃᑦᑕᖅᓯᒪᙱᑦ). ᒪᓕᒃᑕᐅᔪᓂᑦ ᑲᑎᖦᖢᓂᒃ, ᑑᒑᓕᑦ ᐃᖏᕐᖓᔪᓗᐊᖃᑦᑕᓚᐅᖅᑐᑦ (65%-ᖑᔪᒥᑦ), ᑭᖑᓂᐊᒍᑦ ᓇᒧᙵᐅᖏᖕᒍᑎᒃ (20%-ᖑᔪᒥᑦ), ᓄᖅᑲᖓᔪᑦ (12%-ᖑᔪᒥᑦ) ᐊᒻᒪᓗ ᐃᖏᕐᖓᓄᑦ ᑑᒑᓕᑦ ᖃᓄᐃᓕᐅᖃᑎᒌᑦᑐᑦ (3%-ᖑᔪᒥᑦ).

- ᐃᓚᖏᑦ ᑲᑎᖅᓱᐃᔪᑦ ᐃᖏᕐᖓᔭᖃᑕᓚᐅᖅᑐᑦ ᐊᔾᔨᒋᔭᖓᒍᑦ ᐅᒥᐊᖅᔪᐊᑦ ᑕᐃᒪᐅᑎᓪᓗᒋᑦ ᑕᐅᑐᙳᖅᖢᒋᑦ ᐅᒥᐊᖅᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ (71% ᐊᒻᒪᓗ 64%-ᓂᒃ). ᐊᔾᔨᒌᙱᖦᖢ, ᑑᒑᓕᑦ ᐃᓚᖏᑦ ᓄᖅᑲᖓᖅᑕᖅᖢᒋᑦ, ᓇᒧᙵᐅᖏᖕᒍᑎᒃ ᐊᒻᒪᓗ ᐃᖏᕐᖓᓄᑦ ᑑᒑᓕᐅᖃᑎᖏᓐᓄᑦ ᖃᓄᐃᓕᐅᕈᑎᓂᖃᖕᒍᑎᒃ (17%, 10% ᐊᒻᒪᓗ 1%-ᖏᑦ) ᑕᐅᑐᙳᖅᖢᒋᑦ ᐅᒥᐊᖅᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ (10%, 22% ᐊᒻᒪᓗ 4%-ᖏᑦ).

- ᑑᒑᓕᑦ ᑲᑎᖅᓱᐃᔪᑦ ᑕᑯᓴᐅᑎᑦᑎᓚᐅᑉᓗᑎᒃ ᐊᔾᔨᒌᙱᑦᑐᓂᑦ ᐃᓚᖏᑦ "ᑲᑎᖅᓱᐊᖅᑐᑦ" ᐊᒻᒪᓗ "ᑲᑎᖅᓱᐃᔪᑦ" (ᐊᓯᐊᓗ, 48% ᐊᒻᒪᓗ 51%-ᖏᑦ), ᐃᓚᖏᑦ ᑲᑎᖅᓱᐃᔪᑦ ᑲᑎᖅᓱᖃᑦᑕᓚᐅᖅᑐᑦ ᖁᑦᑎᖕᓂᖅᓴᐅᕗᔪᓚᐅᖅᑐᑦ ᐅᒥᐊᖅᔪᐊᖅᑕᖃᖅᑎᓪᓗᒍ (57%-ᖓᓂᑦ) ᑕᐅᑐᙳᖅᖢᒋᑦ ᐅᒥᐊᖅᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ (46%-ᖓᓂᑦ).

- ᐊᓈᓇᖓᓃᖃᑦᑕᖅᑐᓄᑦ ᐱᐊᓛᕆᔭᐅᔪᑦ, ᐃᓐᓇᕈᐊᓂᖏᑦᑐᑦ ᑑᒑᓖᑦ ᑕᑯᔭᐅᒐᔪᓛᖑᓚᐅᖅᑐᑦ ᐊᑖᓃᕐᔪᑎᒃ ᐊᓈᓇᖏᓐᓂᑦ (ᑕᐅᑐᙳᖅᔪᒋᑦ ᓴᓂᐊᓃᑦᑐᑦ, ᑐᓄᐊᓂᑦ ᖁᓛᓂᓘᓐᓃᑦ ᐊᓈᓇᖓᓐᓂᑦ), ᑕᒪᐃᓐᓂᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓪᓗᒍ ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ. ᐃᓚᖏᑦ ᐃᓐᓇᕈᐊᓂᖏᑦᑐᑦ ᑑᒑᓖᑦ ᑕᐃᒪᓐᓇᐃᑦᑐᑦ ᖁᑦᑎᖕᓂᖅᓴᐅᕖᕐᔪᓚᐅᖅᑐᑦ ᐅᒥᐊᕐᔪᐊᑦ ᑕᐃᒪᐅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒨᖓᓂᑦ (69% ᐊᒻᒪᓗ 53%-ᖏᑦ). ᑭᓯᐊᓂ, ᐃᓚᖏᑦ ᐊᓈᓇᐅᔪᑦ ᐊᒻᒪᓗ ᐱᐊᓛᖏᑦ ᐱᖃᑎᒌᒃᑯᑦ ᐊᔾᔨᒋᓚᐅᖅᑕᖓ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓪᓗᒍ (79%) ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒨᖓᓂᑦ (76%).

- ᖃᐅᔨᓴᐃᓂᖅᑕᖃᒃᑲᓐᓂᕆᐊᖃᖅᑐᖅ ᐆᒃᑐᕋᐅᑕᐅᔪᑦ ᐊᖏᒡᓕᒥᐊᕐᓂᐊᕐᓗᒋᑦ ᑕᑯᔭᐅᔪᑦ ᒪᓕᒃᑕᐅᓗᑎᒃ ᖃᐅᔨᓴᐃᓂᐅᔪᓂᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔭᒃᑎᓪᓗᒋᑦ (ᒫᓐᓇᐅᔪᖅ ᐆᒃᑐᕋᐅᑕᐅᔪᑦ 1.3 ᐃᑲᕐᕋᐅᖓᑕ ᑕᑯᔭᐅᓗᑎᒃ ᓈᓴᐅᑎᑐᐃᓐᓇᐅᖓᑕ).

Study Limitations

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, has been prepared by Golder for the sole benefit of Baffinland Iron Mines Corporation (Baffinland). The Executive Summary was translated into Inuktitut and provided by Baffinland to Golder. In the event of discrepancies in information or interpretation, the English version shall prevail. This report represents Golder's professional judgement based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations, and opinions expressed in this document pertain to the specific project, station conditions, design objective, development and purpose described to Golder by Baffinland, and are not applicable to any other project or station location. In order to properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder. Baffinland may make copies of the document in such quantities as are reasonably necessary for those parties conducting business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration, and incompatibility and therefore no party can rely solely on the electronic media versions of this document.

Acronyms / Abbreviations

AIS	Automatic Identification System
Baffinland	Baffinland Iron Mines Corporation
BSA	Behavioural Study Area
DFO	Fisheries and Oceans Canada
ERP	Early Revenue Phase
EWI	Early Warning Indicator
FEIS	Final Environmental Impact Statement
Golder	Golder Associates Ltd.
GPS	Global Positioning System
h	Hour
Hz	Hertz
ICI	Inter click interval
IQ	Inuit Qaujimajatuqangit
JASCO	JASCO Applied Sciences
kHz	Kilohertz
km	Kilometres
LDA	Linear Discriminant Analysis
LOESS	locally estimated scatterplot smoothing
m	Metres
m/s	metres per second
MHTO	Mittimatalik Hunters and Trappers Organization
MMOs	Marine Mammal Observers
MMP	Marine Monitoring Program
Mtpa	million tonnes per annum
PAM	passive acoustic monitoring
PC	Project Certificate
PCoD	Population Consequences of Disturbance
RAD	relative abundance and distribution
RSA	Regional Study Area
SARA	Species at Risk Act
SEL	sound exposure level
SFOC	Special Flight Operations Certificate
SPL_{rms}	sound pressure level (root mean square)
SSA	Stratified Study Area
Steenbsy Port	port at Steensby Inlet
the Program	Bruce Head Shore-based Monitoring Program
the Project	Mary River Project
UAV	Unmanned Aerial Vehicle

Table of Contents

TABLES

FIGURES

APPENDICES

APPENDIX A
Training Manual

APPENDIX B
Power Analysis

APPENDIX C
Vessel Track Information

APPENDIX D
Test Statistics and Coefficients

APPENDIX E
Model Diagnostics

APPENDIX F
Focal Follow Survey Tracks Relative to Vessel Tracks

APPENDIX G
Information Requests

1.0 INTRODUCTION

This report presents the integrated results of a six-year shore-based monitoring study of narwhal (*Monodon monoceros*) conducted near Bruce Head on North Baffin Island, Nunavut. During the open-water seasons of 2014-2017 and 2019-2020, visual survey data were collected from a cliff-based observation platform overlooking an established shipping corridor to investigate potential narwhal response to shipping activities, with information collected on relative abundance and distribution (RAD), group composition, and behaviour of narwhal. Additional data were 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 potential confounding factors that may also influence narwhal behaviour.

1.1 Project Background

The Mary River Project (hereafter, "the Project") is an operating open pit iron ore mine owned by Baffinland Iron Mines Corporation (Baffinland) and located in the Qikiqtani Region of North Baffin Island, Nunavut (Figure 1-1). The operating mine site is connected to Milne Port, located at the head of Milne Inlet, via the 100 km long Milne Inlet Tote Road. An approved but yet-undeveloped component of the Project includes a South Railway connecting the Mine Site to an undeveloped port at Steensby Inlet (Steensby Port).

To date, Baffinland has been operating in the Early Revenue Phase (ERP) of the Project and is authorized to transport 4.2 Mtpa of ore by truck to Milne Port for shipping through the Northern Shipping Route using chartered ore carrier vessels. A production increase to ship 6.0 Mtpa from Milne Port was approved for 2018-2021 and shipping 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 of iron ore from Milne Port involving 13 return ore carrier voyages. In 2016, the total volume of ore shipped out of Milne Port reached 2.6 million tonnes involving 37 return ore carrier voyages. In 2017, the total volume of ore shipped out of Milne Port reached 4.2 million tonnes involving 56 return ore carrier voyages. Following approval to increase production to 6.0 Mtpa, a total of 5.4 Mtpa of ore was shipped via 71 return voyages in 2018 and 5.9 Mtpa of ore was shipped via 81 return voyages in 2019. A total of 5.5 Mtpa was shipped via 72 return voyages in 2020.

LEGEND

- PROJECT SITE
- COMMUNITY
- FUTURE SOUTH RAILWAY
- MILNE INLET TOTE ROAD
- NUNAVUT SETTLEMENT AREA
- SHIPPING ROUTE
- MARINE MAMMAL REGIONAL STUDY AREA
- 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.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
PROJECT LOCATION

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-21
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-05	0	1-1

PATH: I:\2016\1663724\Mapping\MXD\33000_UAV_Program\1663724_33000_05_Fig1_1_Project_Location_Rev0.mxd PRINTED ON: 2021-04-21 AT: 3:26:21 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25mm
0

1.2 Program Objective

The Bruce Head Shore-based Monitoring Program (the Program) represents one of several environmental effects monitoring (EEM) programs for marine mammals. The Program 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 to animal distribution, relative abundance, and migratory movements in the Project's Regional Study Area (RSA; Figure 1-1). Specifically, the Program contributes to the following PC conditions:

- Condition No. 99c and 101g – "Shore-based observations of pre-Project narwhal and bowhead whale behaviour 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. 110 – "The Proponent shall immediately develop a monitoring protocol that includes, but is not limited to, acoustical monitoring, to facilitate assessment of the potential short term, long term, and cumulative effects of vessel noise on marine mammals and marine mammal populations. The Proponent is expected to work with the Marine Environment Working Group to determine appropriate early warning indicator(s) that will ensure rapid identification of negative impacts along the southern and northern shipping routes."
- Condition No. 111 – "The Proponent shall develop clear thresholds for determining if negative impacts as a result of vessel noise are occurring.
- Condition No. 112 – "Prior to commercial shipping of iron ore, the Proponent, in conjunction with the Marine Environment Working Group, shall develop a monitoring protocol that includes, but is not limited to, acoustical monitoring that provides an assessment of the negative effects (short and long term cumulative) of vessel noise on marine mammals. Monitoring protocols will need to carefully consider the early warning indicator(s) that will be best examined to ensure rapid identification of negative impacts. Thresholds shall be developed to determine if negative impacts as a result of vessel noise are occurring. Mitigation and adaptive management practices shall be developed to restrict negative impacts as a result of vessel noise."

Through the Program, narwhal responses to shipping activities are investigated along the Northern Shipping Route in Milne Inlet, with data collected on relative abundance and distribution (RAD), and group composition and behaviour. Additionally, data are 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 that may also influence narwhal behaviour.

1.2.1 Applicable Early Warning Indicators (EWIs)

Through the development of appropriate EWIs, negative impacts to narwhal along the Northern Shipping Route may be promptly identified and mitigated. Therefore, in accordance with requirements outlined in PC Condition No. 110 and 112, Baffinland has collaborated with the Marine Environment Working Group (MEWG) to develop an early warning indicator (EWI) that is most appropriately addressed through the Bruce Head Shore-based Monitoring Program. The indicator in question was proposed by Fisheries and Oceans Canada (DFO) as part of Baffinland's initial MEWG engagement in the EWI framework and was identified as being of high importance by the Mittimatalik Hunters and Trappers Organization (MHTO).

The identified EWI used to monitor whether narwhal are being adversely affected by vessel traffic and associated noise is a 10% decrease in the proportion of immatures in the population. While it is acknowledged that juvenile individuals are not considered fully mature, the definition of immature individuals in this context includes calves and yearlings exclusively. Therefore, the specific indicator threshold is a 10% decrease in the proportion of calves and yearlings observed at Bruce Head relative to the lowest available baseline value (i.e., 0.152 recorded in 2014). If the proportion of immature narwhal recorded at Bruce Head drops below the EWI threshold of 0.137 (i.e., a 10% decrease from 0.152), adaptive management practices may be triggered.

1.3 Study Area

The Bruce Head Shore-based Monitoring Program is 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, renovated in 2019, is located on a cliff at Bruce Head, approximately 215 m above sea level (N 72° 4' 17.76", W 80° 32'35.52") and approximately 40 km from Milne Port. From the observation platform, Marine Mammal Observers (MMOs) are provided with a mostly unobstructed view of Milne Inlet from the southern tip of Stephens Island to the north, to the embayment south of Agglerojaq Ridge to the south, with the mouth of Koluktoo Bay visible to the south of the peninsula, and Poirier Island visible to the east (directly offshore of the survey platform).

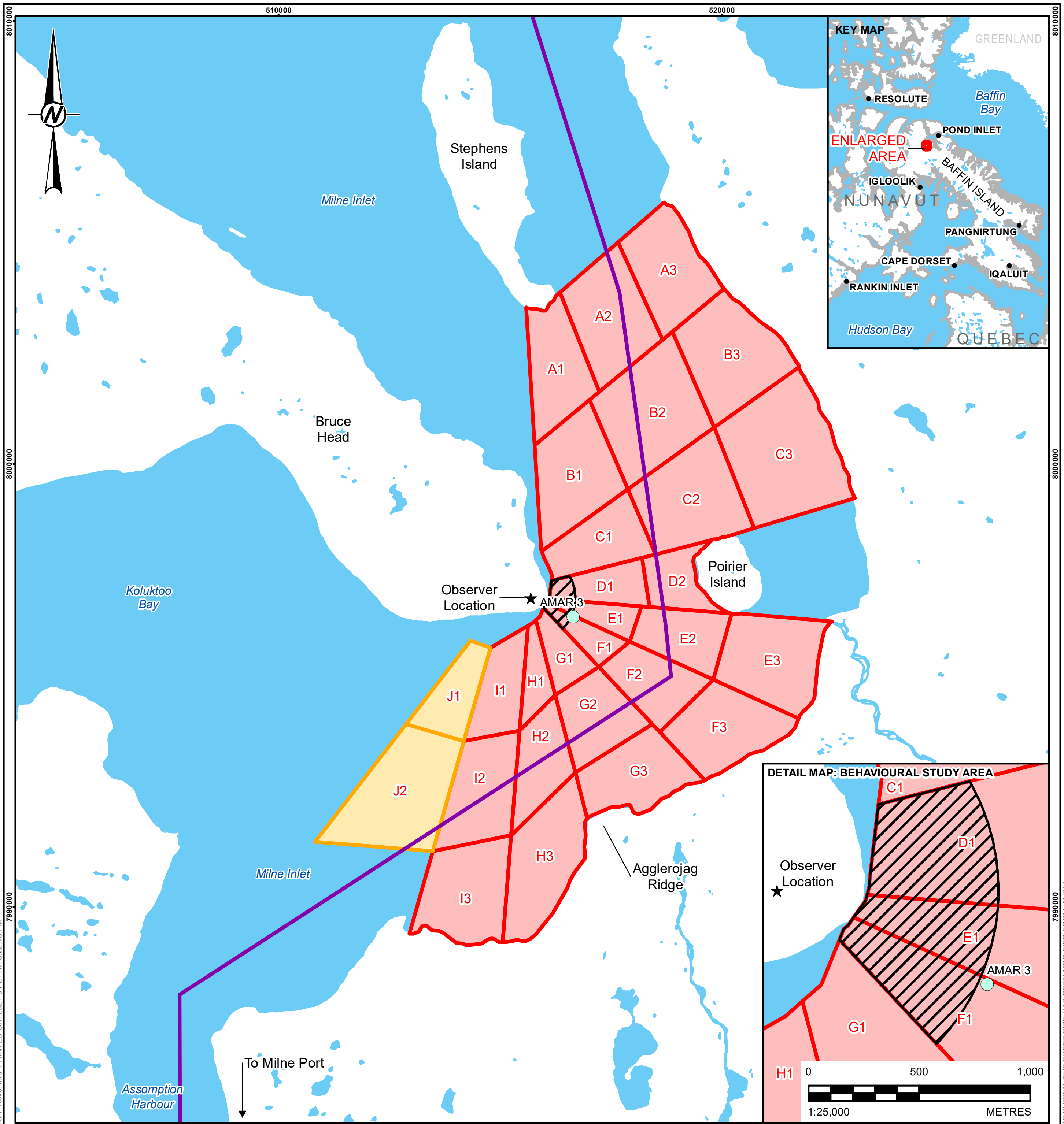
Consistent with previous years, two study areas were used for the 2020 shore-based study depending on the applicable data collection protocol. These areas included a broader Stratified Study Area (SSA) and a smaller Behavioural Study Area (BSA) nested within the SSA (Figure 1-2).

1.3.1 Stratified Study Area (SSA)

The stratified study area (SSA) covers a total area of 90.5 km^2 and was designed to collect narwhal relative abundance and distribution data (RAD). The SSA is stratified into strata A (northernmost stratum) through J (southernmost stratum; added in 2019) 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 28 substrata within the SSA as stratum D and J are comprised of only 2 substrata, 1 and 2. These substrata boundaries are visually defined in the field using definitive landmarks on the far shore of Milne inlet and nearby islands.

1.3.2 Behavioural Study Area (BSA)

The behavioural study area (BSA) covers portions of strata D, E, and F that extends 600 m from the shoreline below the Bruce Head observation platform. The BSA spatial boundary was designed to collect narwhal group composition and behaviour data. The shoreline adjacent to the BSA is a common narwhal hunting camp for local Inuit.



LEGEND

- AMAR LOCATION
- COMMUNITY
- OBSERVER LOCATION
- APPROXIMATE SHIPPING ROUTE
- BEHAVIOURAL STUDY AREA (BSA)
- WATERBODY

STRATIFIED STUDY AREA (SSA) SUBSTRATA

- PREVIOUS SUBSTRATA
- NEW SUBSTRATA

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 CLIENT, JULY 14, 2020. 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
MEMBER OF WSP

YYYY-MM-DD	2021-04-21
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-05	0	1-2

PATH: I:\2016\1663724\Mapping\MXD\33000_UAV_Program\1663724_33000_05_Fig1_2_SSA_BSA_Rev0.mxd PRINTED ON: 2021-04-21 AT: 3:22:43 PM

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

25mm

2.0 SPECIES BACKGROUND

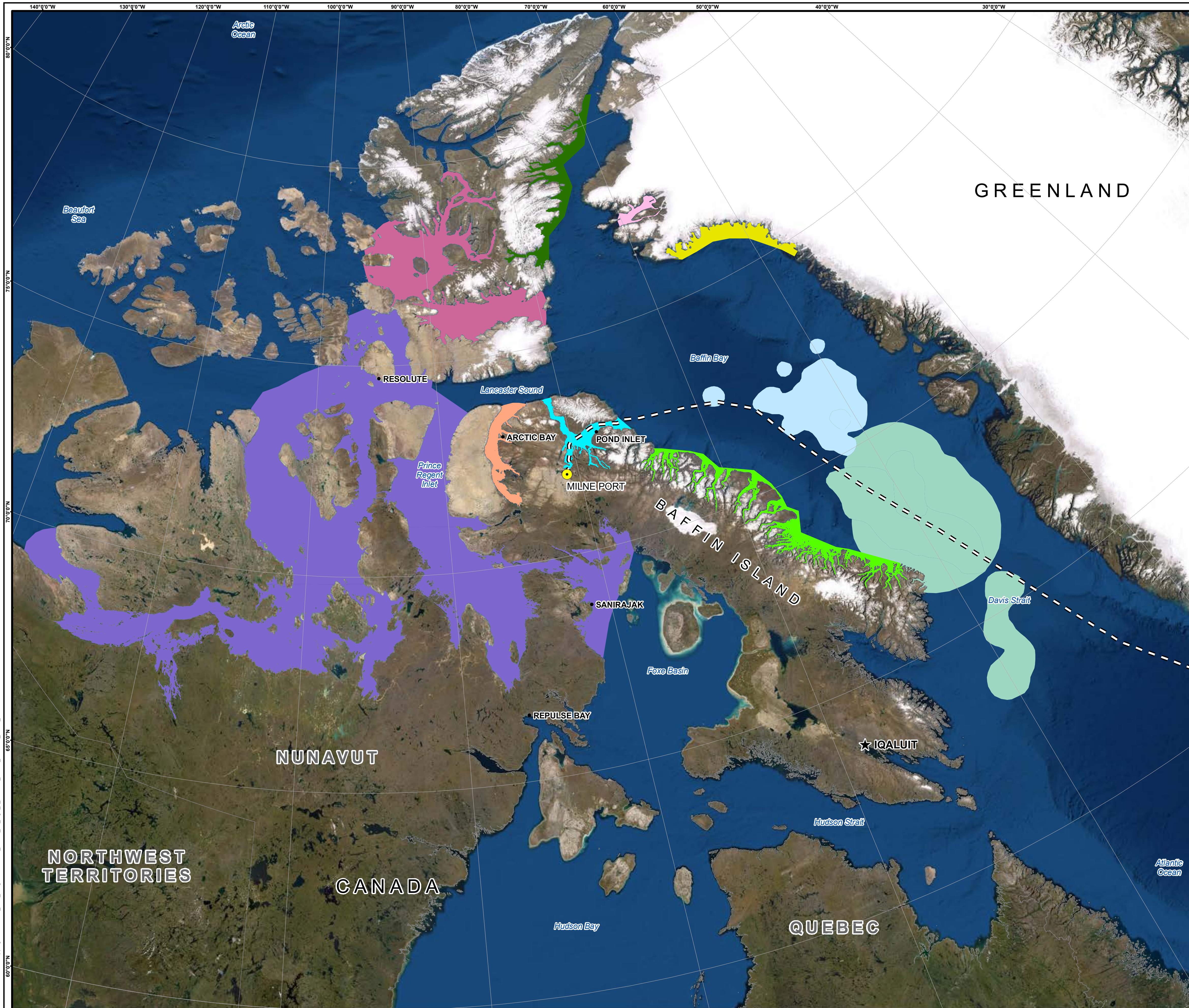
2.1 Population Status and Abundance

Narwhal are endemic to the Arctic, occurring 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 (BB) population and the northern Hudson Bay (NHB) population (Watt et al. 2017). Of these, only the Baffin Bay population occurs seasonally along the Northern Shipping Route for the Project (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).

For management purposes, DFO has defined seven narwhal stocks (i.e., resource units subject to hunting) in Nunavut: Jones Sound, Smith Sound, Somerset Island, Admiralty Inlet, Eclipse Sound, East Baffin Island, and Northern Hudson Bay (Doniol-Valcroze et al. 2015) (Figure 2-1). These stocks were selected based on satellite 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). While the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) considers narwhal a species of special concern, narwhal populations in Canada are not presently listed under the federal *Species at Risk Act* (*SARA*).

The Canadian High Arctic Cetacean Survey conducted by DFO in August 2013 represents the most complete survey conducted to date of six major narwhal summering aggregations in the Canadian Arctic (Doniol-Valcroze et al. 2015). The current abundance estimate for the Baffin Bay population, corrected for diving and observer bias, is 141,909 individuals (Doniol-Valcroze et al. 2015). Although narwhal stocks tend to segregate in the summer months, annual variation in stock estimates between Eclipse Sound and Admiralty Inlet suggests that there is movement between these two summering ground locations (Thomas et al. 2015; DFO 2020a). The corrected estimate for the Eclipse Sound stock is 12,039 narwhal (CV = 0.23; DFO 2020a) while the corrected estimate for the Admiralty Inlet stock is 35,043 narwhal (CV = 0.42) (Doniol-Valcroze et al. 2015; Doniol-Valcroze et al. 2020).

Results from aerial surveys conducted by Golder in 2020 indicated an abundance estimate of 28,301 narwhal for the combined Eclipse Sound and Admiralty Inlet stocks (Coefficient of Variation (CV) = 0.10, 95% confidence interval CI = 23,426– 34,190; Golder 2021a), which falls within the 95% CI of DFO's 2013 abundance estimate of the combined stock (45,532 narwhals, CV=0.33, CI = 22,440–92,384; Doniol-Valcroze et al. 2015). For the Eclipse Sound stock alone, the 2020 abundance estimate was 4,266 narwhal (CV = 0.02, 95% CI = 4,088–4,451; Golder 2021a) which falls below the 95% confidence interval of all previous DFO abundance estimates for the Eclipse Sound stock, including the last aerial survey undertaken in 2016 (12,093 narwhal, CV = 0.23, CI = 7,768–18,660; Marcoux et al. 2019).



LEGEND

- ★ TERRITORY CAPITAL
- • COMMUNITY
- MILNE PORT
- SHIPPING ROUTE (APPROXIMATE)

SUMMER AGGREGATION AREA

- ADMIRALTY INLET
- EAST BAFFIN ISLAND
- ECLIPSE SOUND
- INGLEFIELD BREDNING
- JONES SOUND
- MELVILLE BAY
- SMITH SOUND
- SOMERSET ISLAND

WINTER AGGREGATION AREA

- NORTHERN WINTERING AREA
- SOUTHERN WINTERING AREA

0 200 400

1:10,000,000 KILOMETRES

REFERENCE(S)

NARWHAL POPULATION RANGES DIGITIZED FROM DFO FIGURE 1 'MAP OF HIGH ARCTIC NARWHAL SUMMER AGGREGATIONS' (SOURCE: AMMCO/SC/21-JCNB/SWG/14-05). NARWHAL WINTERING AREAS DIGITIZED FROM RICHARD ET AL. (2014) FIGURE 3 PUBLISHED WINTER HOME RANGES OF TRACKED BAFFIN BAY NARWHAL. SHYDROGRAPHY, 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. SOURCE: ESRI, MAXAR, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
PROJECTION: CANADA ALBERS EQUAL AREA CONIC DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
NARWHAL SUMMERING AND WINTERING AREAS – BAFFIN BAY POPULATION

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-04-21
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-05	0	2-1

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

2.2 Geographic and Seasonal Distribution

Narwhal show high levels of site fidelity, annually returning to well-defined summering and wintering areas (Laidre et al. 2004; Richard et al. 2010). During summer, narwhal tend to remain in inlet 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-water offshore areas and the continental slope where water depths are 1,000 to 1,500 m, and where upwelling increases biological productivity and supports abundant prey species (Dietz and Heide-Jørgensen 1995; Dietz et al. 2001; Richard et al. 2010).

Between April and June, narwhal migrate from their Baffin Bay wintering areas to the Pond Inlet floe edge, northern coast of Bylot Island, Navy Board Inlet floe edge, and eastern Lancaster Sound (JPCS 2017). As ice conditions permit (usually late June and July), narwhal move into 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). According to Inuit Qaujimajatuqangit (IQ), narwhal first enter into Eclipse Sound in July through leads in the ice, with large males typically entering ahead of females and calves (JPCS 2017). Throughout the summer months, narwhal remain in western Eclipse Sound and associated inlets during which time calves are born and reared (Koski and Davis 1994; Dietz and Heide-Jørgensen 1995; Dietz et al. 2001; Doniol-Valcroze et al. 2015). The distribution of narwhal in Eclipse Sound, Milne Inlet, Koluktoo Bay, and Tremblay Sound during summer is thought to be influenced 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 toward overwintering areas in Baffin Bay and Davis Strait (Dietz et al. 2001; Watt 2012; JPCS 2017). Depending on ice conditions, specific migratory routes may change from year to year (JPCS 2017). Individuals summering near Somerset Island typically 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. Narwhal tracking data have identified two distinct wintering areas for the Baffin Bay population (Richard et al. 2010, Laidre and Heide-Jørgensen 2005). One wintering area is located in northern Davis Strait / southern Baffin Bay (referred to as the southern wintering area) and is frequented by Canadian narwhal summering stocks from Admiralty Inlet and Eclipse Sound, and the Greenland narwhal stock from Melville Bay. The second wintering area is located in central Baffin Bay (referred to as the northern wintering area) and is used by narwhal from the Somerset Island summering stock (Laidre and Heide-Jørgensen 2005).

2.3 Reproduction

Female narwhal are believed to mature at 8 to 9 years of age and produce their first young at 9 to 10 years of age while males mature at 12 to 20 years of age (Garde et al. 2015). Pond Inlet hunters reported that narwhal mating activity occurs in areas off the north coast of Bylot Island and at the floe edge east of Pond Inlet and at the north end of Navy Board Inlet. Eclipse Sound, Tremblay Sound, Milne Inlet, and Koluktoo Bay have also been reported as mating areas (Remnant and Thomas 1992). Conception typically occurs between late March and late May, although mating has been observed in June at the Admiralty Inlet floe edge and in August in western Admiralty Inlet (Stewart 2001). 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). Calving has been reported in Pond Inlet, Eclipse Sound, Navy Board Inlet, Milne Inlet, and Koluktoo Bay (Remnant and Thomas 1992; JPCS 2017); which is consistent with IQ information indicating that calving has been observed in all areas of North Baffin Island (Furgal and Laing 2012). The birth of a narwhal calf near Bruce Head was also observed in August 2016, which supports IQ and previous suggestions from other research that Milne Inlet is used for calving in addition to calf-rearing (Smith et al. 2017). On average, females are thought to produce a single calf approximately once every two to three years and have a generation time of approximately 30 years (Garde et al. 2015). However, 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) with IQ suggesting 15 months based on fetuses observed (Furgal and Laing 2012). Newborn calves are primarily born between May and August each year and measure 140 to 170 cm in length, approximately 1/3 to 1/2 the body length of an adult female (Charry et al. 2018). Typically, newborn calves travel less than one body length away from their mother and in larger group sizes while in Eclipse Sound (mean group size = 5) compared to smaller group sizes along the east coast of Baffin Island (mean group size = 2; Charry et al. 2018). Calves are generally weaned at 1–2 years of age (COSEWIC 2004).

2.4 Diet

Current understanding of narwhal diet is based on studies focusing on stomach content analysis (Finley and Gibb 1982; Laidre and Heide Jørgensen 2005), satellite-based tagging studies (Watt et al. 2015; 2017) and fatty acid and stable isotope analysis (Watt et al. 2013; Watt and Ferguson 2015). Finley and Gibb (1982) analyzed the diet of 73 narwhal near Pond Inlet from June through September (1978-1979) through stomach content analysis and reported food in 92% of the stomachs analyzed. Feeding was found to be most intensive during spring when narwhal occurred near the floe edge and within open leads (Finley and Gibb 1982). Diet consisted of pelagic and benthic species including Arctic cod (*Boreogadus saida*) (identified in 88% of analyzed stomachs), Greenland halibut (*Reinhardtius hippoglossoides*), squid (*Gonatus fabricii*), redfish (*Sebastes marinus*), and polar cod (*Arctogadus glacialis*), with foraging occurring at depths greater than 500 m (Finley and Gibb 1982; Watt et al. 2017).

Studies using dietary biomarkers have found some evidence for sexual segregation in the feeding ecology of narwhal in Pond Inlet (Kelly 2014) and Greenland (Louis et al. 2021). In Kelly (2014), tissue samples were collected from narwhal hunted in Pond Inlet between 2004 and 2006 and tested to compare dietary biomarkers ($\delta^{13}C$ and $\delta^{15}N$) between males, females, and immature whales. Significant differences in the fatty acids and carbon isotope enrichment of females, males and immature whales were found, suggesting that each group was consuming different prey. Females and immature narwhal were suggested to be feeding pelagically and nearer to the sea-ice while males were proposed to be feeding benthically (Kelly 2014). In another study by Louis et al. (2021), bone powder from the skulls of 40 narwhal from West Greenland and 39 narwhal from East Greenland was collected during subsistence hunts from 1990 and 2007. The same biomarkers used by Kelly (2014) were tested and used to compare differences in diet, over several years (vs shorter term data from skin tissue), between males and females. The results of this study also suggested differences in the foraging ecology of males and females. Of note, males from East Greenland had significantly higher levels of $\delta^{15}N$ and larger ecological niches than females (Watt et al. 2013). It was suggested that the differences in foraging ecology are driven by sexual size dimorphism, maternal investment, and deep-diving lifestyles. However, no sex-specific differences in depth were found in West Greenland narwhal which suggests that differences in foraging ecology are population specific (Louis et al. 2021).

Deep diving is energetically costly to marine mammals and requires lipid-rich prey or abundant food sources to support this activity (Bluhm and Gradinger 2008; Davis 2014; Watt et al. 2017). Narwhal are well adapted to deep diving and are known to prey on deep-water fish species (Finley and Gibb 1982; Watt et al. 2015) to meet their dietary requirements. Early studies reported that narwhal spend limited time feeding while present on their summering grounds, compared to winter or spring (Mansfield et al. 1975; Finley and Gibb 1982; Laidre et al. 2004; Laidre and Heide-Jørgensen 2005). However, recent studies that have analyzed the spatial and seasonal patterns in narwhal dive behaviour (using targeted deep dives as a proxy for benthic foraging) suggest that, although the majority of dives recorded in Eclipse Sound during the summer occurred near the surface, deep-water dives were also frequently observed, suggesting the occurrence of important benthic foraging areas (Watt et al. 2015; 2017; Golder 2020a). This finding is supported by stable isotope analysis conducted for the Baffin Bay population, in which Greenland halibut and Northern shrimp (*Pandalus borealis*) were identified as the major constituents (>50%) of their summer diet (Watt et al. 2013).

2.5 Locomotive Behaviour

Like many cetacean species that inhabit patchy and/or dynamic environments (Laidre et al. 2003), narwhal surface movement and dive behaviour varies depending on where they are distributed on their summering grounds (Watt et al. 2017; Golder 2020a). The following sections (Section 2.5.1 and 2.5.1) provide context regarding the current understanding of narwhal locomotive behaviour while summering throughout Milne Inlet and adjacent water bodies. Detailed analyses of narwhal surface and dive movements throughout the RSA are presented in the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a).

2.5.1 Surface Movements

Narwhal are a migratory species, travelling large distances between high Arctic summering grounds and low Arctic wintering grounds annually (Laidre and Heide-Jørgensen 2005). Ice conditions permitting, narwhal typically move into summering grounds in Eclipse Sound and adjacent inlets (e.g., Milne Inlet) during late June/July (Remnant and Thomas 1992; Kingsley et al. 1994; Koski and Davis 1994; Richard et al. 1994). Once at their summering grounds, narwhal are widely distributed throughout the open-water fjord complexes and bays (Laidre et al. 2003; Golder 2020a) and rely on the region for important mating and calving activities (Mansfield et al. 1975; Remnant and Thomas 1992; Marcoux et al. 2009; Smith et al. 2017). Following a summer spent in Milne Inlet and adjacent water bodies, narwhal then begin their migration eastward out of Eclipse Sound during mid- to late September (Koski and Davis 1994), where they make their way from Pond Inlet, down the east coast of Baffin Island (Dietz et al. 2001; Golder 2020a), toward winter feeding areas in Baffin Bay (Koski and Davis 1994; Heide-Jørgensen et al. 2002; Laidre et al. 2004; Dietz et al. 2008).

IQ information and telemetry data have suggested that there is some mixing of narwhal between Admiralty Inlet and Eclipse Sound summering areas (DFO 2020b). Satellite tagging data obtained from 1999 (Heide-Jorgensen et al. 2002), 2009 to 2011 (Watt 2012), 2017 to 2018 (Golder 2020a), and 2016 to 2018 (Marcoux and Watt 2020) provide additional evidence of narwhal use of both areas. While tagging data provides evidence of overlap in narwhal use of Admiralty Inlet and Eclipse Sound, overall site fidelity to specific summering areas is thought to be high (Laidre et al. 2004; Richard et al. 2010; DFO 2020b).

Narwhal are highly gregarious and are closely associated with one another by nature (Marcoux et al. 2009). Although knowledge regarding the context and function (if any) of narwhal aggregations is incomplete (Marcoux et al. 2009), they have been observed throughout Milne Inlet and Koluktoo Bay in small groups or clusters[1] averaging 3.5 individuals (range: 1 to 25), and in herds[2] of up to hundreds of clusters (Marcoux et al. 2009; Golder 2020c). According to Marcoux et al. (2009), herds observed from the Bruce Head Peninsula were composed of 1 to 642 clusters, with a mean of 22.4 clusters/herd. Observations from the Bruce Head Peninsula also reveal that narwhal generally enter Milne Inlet and Koluktoo Bay in larger clusters than when they exit and show strong site fidelity to Koluktoo Bay specifically (Marcoux et al. 2009; Smith et al. 2017; Golder 2019; Golder 2020c).

Understanding confounding effects such as the presence of predators in a system is important when assessing movement behaviour of cetaceans in relation to vessel traffic. Killer whales (*Orcinus orca*), for example, are well known to prey on narwhal and may affect narwhal space use patterns (Campbell et al. 1988; Cosens and Dueck 1991; Golder 2021a). In one report by Laidre et al. (2006), an attack was observed in which multiple narwhal were killed by a pod of killer whales over six hours. In the immediate presence of killer whales, narwhal moved slowly, travelling in very shallow water close to shore, and in tight groups at the surface (Laidre et al. 2006). Once the attack commenced, narwhal dispersed widely (approximately doubling their normal spatial distribution), beached themselves in sandy areas, and shifted their distribution away from the attack site. Normal (pre-exposure) behaviour was said to resume shortly (< 1 hour) after the killer whales departed the area (Laidre et al. 2006). This observation is supported by Breed et al. (2017), who suggested that behavioural changes in narwhal extend beyond discrete predation/attack events, with space use patterns being highly influenced by the mere presence of killer whales in an area. Of note, simultaneous satellite tracking of narwhal and killer whales revealed that narwhal constrained themselves to a narrow band close to shore (≤500 m) when killer whales were present within approximately 100 km (Breed et al. 2017). Narwhal were also observed swimming in tight groups near shore as a large group of killer whales herded ~150-200 individuals into Fairweather Bay near Milne Inlet during aerial surveys in 2021 (Golder 2021a).

Based on findings from the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a), narwhal were shown to alter their surface behaviour in response to vessel traffic by turning back on their own track at distances up to 4 km of a transiting vessel, corresponding to a total exposure period of 29 min per vessel transit (based on a 9 knot travel speed). Tagged narwhal were also shown to change their travel orientation relative to transiting vessels at distances up to 5 km of an approaching vessel and up to 10 km of a departing vessel, corresponding to a total exposure period of 54 min per vessel transit (based on a 9 knot travel speed). For both response variables, animals returned to their pre-response behaviour following the vessel exposure period (i.e., a temporary effect). Given that vessels were within 4 to 10 km of a tagged narwhal for <2% to <7% of the GPS datapoints collected in the RSA respectively, the frequency of occurrence of these effects was considered intermittent. Finally, a gap in narwhal distribution evident in close proximity to transiting vessels (0.5 km of a vessel's port and starboard and 1 km of a vessel's bow and stern) suggested movement away from the vessel by narwhal (i.e., avoidance), however this finding may have also been a function of low-resolution data available in close proximity to vessels.

[1] Cluster = a group with no individual more than 10 body lengths apart from any other (Marcoux et al. 2009).

[2] Herd = an aggregation of clusters.

2.5.2 Dive Behaviour

Narwhal are specially adapted for sustained, deep submergence (Martin et al. 1994, Watt et al. 2017). It is generally accepted that depth and duration of narwhal dives are positively correlated given the longer travel time required to reach deeper depths (Laidre et al. 2002; Golder 2020a). Dive data collected in Tremblay Sound revealed a maximum recorded dive duration of 26.2 minutes for one narwhal tagged during August 1999 (mean = 4.9 min; Laidre et al. 2002). Despite this event being presented as one of the longest dives recorded for narwhal at the time, the maximum depth to which this animal dove was only 256 m (mean = 50.8 m; Laidre et al. 2002), likely a result of the dive being limited by bathymetry. Similarly, the longest dive during a tagging study in East Greenland was 23.6 min performed by a female narwhal (Tervo et al. 2021). Narwhal tagged in Tremblay Sound during August 2010 and August 2011 made the majority of dives to between 400 and 800 m depths (Watt et al. 2017), indicating that these dives took place in adjacent water bodies that offered deeper bathymetry (i.e., Milne Inlet/Eclipse Sound). Similar depths were recorded from a narwhal tagged in East Greenland in 2013 (Ngô et al. 2019) and narwhal (n=13) tagged in East Greenland from 2013 to 2017 and 2019 (Tervo et al. 2021). The majority of the 8,609 dives recorded from one tagged male narwhal were less than 200 m or between 400 and 600 m (Ngô et al. 2019), while the majority of dives recorded from the 13 narwhal were less than 100 m in depth followed by dives between 300 and 500 m depths with a maximum dive depth of 890 m (Tervo et al. 2021). Most recently, one narwhal tagged during the 2017 Narwhal Tagging Program was recorded undertaking a dive for 30.1 minutes to a depth of 332.5 m in southern Milne Inlet (Golder 2020a).

During the summer months, narwhal spend a large proportion of time near the surface, milling and socially interacting with one another (Pilleri 1983; Heide-Jørgensen et al. 2001). Narwhal (n = 23) tagged near Baffin Island between 2009 and 2012 were estimated to spend approximately 31.4% of their time within 2 m of the surface during the month of August (Watt et al. 2015). Innes et al. (2002) reported a similar value of 38% of time that narwhal spend within 2 m of the surface based on aerial surveys. The proportion of time that narwhal spend within 5 m of the surface is slightly greater; Heide-Jørgensen et al. (2001) reported narwhal (n = 21) spend approximately 45.6% of time within the top five metres of the water column, while Laidre et al. (2002) reported a range of 30-53% of time that narwhal (n = 4) spend within this upper depth. Additionally, Tervo et al (2021) reported narwhal (n=13) spent 54% of their time in the upper 20 m of the water column. Although mother-calf pairs have been predicted to spend a greater proportion of time at the surface given the limited diving ability of calves (Watt et al. 2015), no obvious pattern between surface time and body length, sex, and/or presence/absence of calves was observed in a study conducted by Heide-Jørgensen et al. (2001).

Heide-Jørgensen et al. (2001) evaluated dive rate (number of dives per hour) of 25 narwhal tagged in Tremblay Sound between 1997 and 1999 and in Melville Bay, West Greenland between 1993 and 1994. According to this study, mean dive rate of all narwhal outfitted with tags during the month of August was 7.4 dives/hour below 8 m depth, with narwhal from Tremblay Sound having a significantly lower dive rate overall (7.2 dives/hour) compared to animals tagged in Melville Bay (8.6 dives/hour). No diurnal difference was found in narwhal dive rate from either tagging site (Heide-Jørgensen et al. 2001). Furthermore, increasing number of dives (dive rate) had no effect on narwhal surfacing times (0-5 m). Laidre et al. (2002) reported similar dive rates for two narwhal tagged in Tremblay Sound, ranging from 6.0 dives/hour to 10.9 dives/hour.

In regard to descent and ascent speeds, one study conducted by Laidre et al. (2002) determined that a typical dive profile for two narwhal tagged in Tremblay Sound consisted of a steep descent, followed by a short bottom interval, a gradual ascent, and a relatively slow approach to the surface. The two narwhal in this study exhibited mean descent rates of 0.8 m/s and 1.3 m/s and mean ascent rates of 0.7 m/s and 1.5 m/s, respectively (Laidre et al. 2002). According to an older study that tracked the dive behaviour of three narwhal tagged in Tremblay Sound

(Martin et al. 1994), the maximum rates of ascent and descent for each dive ≥20 m depth were positively correlated to the depth and duration of the dive. This finding was supported by the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a) in which mean descent rates were strongly correlated with destination depth. A recent study reported dive profiles similar to those reported by Laidre et al. (2002) where tagged narwhal (n=13) had steeper descents than ascents. Dives were described as either V- or U-dives and narwhal were recorded spending more time on V-dives. V-dives were on average, longer lasting (8.7 min vs 6.9 min respectively), deeper (257 m vs 123 m) and had shorter bottom times (4.1 min vs 5.0 min) than U-dives (Tervo et al. 2021). The tagged narwhal also utilised prolonged gliding during descent, active fluke stroking during ascent, and demonstrated spinning behaviour (rolling along their longitudinal axis) typically during descents and during the bottom phase of a dive, particularly during presumed foraging (Tervo et al. 2021).

It is important to note that narwhal dive behaviour is variable based on parameters such as sex, life stage, location, season, and activity state (Heide-Jørgensen et al. 2001). For example, differences in dive rates (number of dives per hour) and dive depth have been found to vary between size and sex of narwhal tagged, with female narwhal generally diving shallower and having lower dive rates than males (Heide-Jørgensen and Dietz 1995). Surprisingly, female narwhal have also been found to spend more time at depth compared to males (Watt et al. 2015; Golder 2020a), despite hypotheses that those with larger body size (i.e., males) would have enhanced ability to dive deeper and for greater periods of time. Whether a female is with or without a calf may also influence dive behaviour, given the aerobic limitations of the young (Watt et al. 2015), though studies conducted by Heide-Jørgensen and Dietz (1995) found no difference in dive behaviour between female narwhal with and without calves. The depths to which narwhal dive are also known to vary with season (Watt et al. 2015; Watt et al. 2017). In general, narwhal make relatively short, shallow dives while on their summering grounds (with depths often limited by the seabed bathymetry), increasing their dive depth and duration in the fall months (Heide-Jørgensen et al. 2002), and making the deepest dives while over-wintering in the pack ice in Baffin Bay (Laidre et al. 2003). Tidal and circadian cycles are not thought to influence narwhal movement patterns (Martin et al. 1994; Born 1986; Dietz and Heide-Jørgensen 1995; Marcoux et al. 2009) and predation by killer whales is not a significant predictor of narwhal dive behaviour but, as discussed in the Section 2.5.1, does influence narwhal spatial distribution at the surface (Watt et al. 2017).

Based on findings from the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a), narwhal were shown to alter their dive behaviour in response to vessel traffic by decreasing their surface time and their total dive duration at distances up to 1 km of a vessel, suggesting that individuals within this exposure zone undertook a greater number of relatively shorter duration dives. For narwhal that were presumed to be engaged in foraging (i.e., performing bottom dives to >75% available bathymetry), individuals were shown to reduce the number of subsequent bottom dives when they were within 5 km of a transiting vessel. No significant effects of vessel traffic on narwhal dive behaviour were observed for dive rate, time at depth (i.e., time within the deepest 20% of dive), descent speed, or bottom dives for narwhal not actively engaged in bottom diving at the initial time of exposure. The distance at which significant changes were observed in dive behaviour (i.e., 1 to 5 km) corresponded with an exposure period ranging from 7 to 36 min per vessel transit (based on a 9 knot travel speed), with animals returning to their pre-response behaviour following the vessel exposure period (i.e., a temporary effect). The frequency of this effect was considered intermittent given that vessels were within 5 km of a tagged narwhal for <1% of the GPS datapoints collected in the RSA during 2017 and 2018.

2.6 Acoustic Behaviour

Like all cetaceans, narwhal depend on the transmission and reception of sound in order to carry out the majority of critical life functions (i.e., communication, reproduction, navigation, detection of prey, and avoidance of predators; Holt et al. 2013). For Arctic cetaceans that are closely associated with sea ice (e.g., narwhal), they are also likely dependent on sound for locating leads and polynyas in the ice for breathing (Richardson et al. 1995; Heide-Jørgensen et al. 2013b; Hauser et al. 2018).

2.6.1 Vocalizations

Narwhal are a highly vocal species that produce a combination of pulsed calls, clicks, and whistles (Ford and Fisher 1978; Marcoux et al. 2011a). Pulsed calls are the predominant form of narwhal vocalization and are comprised of pulsed tones and click series (Ford and Fisher 1978). Pulsed tones emitted by narwhal possess pulsed repetition rates that have distinct tonal properties and are generally concentrated between 500 Hz and 5 kHz (Ford and Fisher 1978; Shapiro 2006). Click series are broadband and are concentrated between 12 and 24 kHz, though many click series with low repetition rates are concentrated at lower frequencies between 500 Hz and 5 kHz (Ford and Fisher 1978). High frequency broadband echolocation clicks emitted by narwhal extend up to and beyond 150 kHz (Miller et al. 1995; Rasmussen et al. 2015). Finally, whistles are typically emitted between 300 Hz and 10 kHz, though some whistles have been found to reach frequencies as high as 18 kHz (Ford and Fisher 1978; Marcoux et al. 2011a). More recent studies that include recordings at higher sampling rates or that have incorporated novel techniques of data collection/analysis have allowed for more complete descriptions of narwhal vocalizations (Rasmussen et al. 2015; Koblitz et al. 2016; Walmsley et al. 2020; Podolskiy and Sugiyama 2020).

2.6.2 Hearing

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; Southall et al. 2019). According to updated marine mammal noise exposure criteria by Southall et al. (2019), narwhal, like several other toothed whales previously considered mid-frequency cetaceans, are now considered high-frequency cetaceans whose functional hearing range likely occurs between 150 Hz and 160 kHz (Southall et al. 2007; Southall et al. 2019). Although no behavioural or electrophysiological audiograms are currently available for narwhal specifically (Rasmussen et al. 2015), auditory response curves for this grouping of cetaceans suggest maximum hearing sensitivity in frequencies between 1 kHz and 20 kHz (corresponding to social sound signals) and between 10 kHz and 100 kHz (corresponding to echolocation signals) (Tougaard et al. 2014; Veirs et al. 2016; Southall et al. 2019).

2.6.3 Narwhal and Vessel Noise

Behavioural responses of marine mammals exposed to vessel traffic and associated noise have been documented for several species, however limited information is available for cetaceans inhabiting Arctic waters and for narwhal specifically. Vessel disturbance may elicit several different behavioural responses in cetaceans, including a shift in travel speed or dive rate, freeze or flight (avoidance) response, and short- or long-term displacement from optimal habitat, all of which have the potential to affect subpopulation viability. Of note, narwhal have been shown to react at relatively low received sound levels to distant icebreaking vessels actively breaking ice (Finley et al. 1990; Cosens and Dueck 1993).

In comparing the proposed hearing range of narwhal to the sound output of transiting vessels, the majority of underwater sound generated by vessel traffic is concentrated in the lower frequencies between 20 and 200 Hz (Veirs et al. 2016). Propeller cavitation accounts for peak spectral power between 50-150 Hz while propulsion noise (from engines, gears, and other machinery) generates noise below 50 Hz (Veirs et al. 2016). Broadband noise generated by propeller cavitation has, however, been found to radiate into the higher frequencies up to 100 kHz (Arveson and Vendittis 2000; Veirs et al. 2016), overlapping with the range of maximum hearing sensitivity of narwhal. Therefore, while vessels associated with the Project would generate some broadband noise in the proposed hearing range of narwhal and other high-frequency cetaceans, the majority of sound energy produced is likely concentrated below the peak hearing sensitivity of narwhal (>1 kHz).

Sound level (or 'intensity') must also be considered when assessing the behavioural response of narwhal to vessel-generated noise. Of note, two metrics commonly used to describe and evaluate the effects of non-impulsive sound on marine mammals are sound pressure level (SPL_{rms}; dB re: 1µPa) and sound exposure level (SEL; dB re: $1µPa^2 \cdot s$). Sound pressure level (SPL_{rms}) refers to the average of the squared sound pressure over some duration, while sound exposure level (SEL) is a cumulative measure of sound energy that takes into account the duration of exposure (Southall et al. 2007; NMFS 2018; Southall et al. 2019). It is generally accepted that cetaceans exposed to received sound levels above 120 dB re: 1µPa (SPL_{rms}) will begin to demonstrate behavioural disturbance, though the specific behavioural responses exhibited are highly variable depending on the context of the exposure, the receiving environment, the familiarity of the animal with the sound, and the behaviour of the animal during the exposure event (Southall et al. 2007; Ellison et al. 2012; Williams et al. 2013; NMFS 2018; Southall et al. 2019).

Acoustic modelling of ore carriers transiting at 9 knots along the Northern Shipping Route was undertaken by JASCO Applied Sciences (JASCO) in 2018 that considered the spectral content for vessel operations up to 25 kHz (Quijano et al. 2017). Modelling results predicted that ore carriers transiting at 9 knots through Milne Inlet would not reach the SEL_{24h} injury threshold[3] at ranges beyond 20 m from the center of the vessel and that the 120 dB re 1µPa (SPL_{rms}) disturbance threshold[4] may be exceeded at distances between 5.9 and 11.2 km (R95%) from the vessel. However, following a review of passive acoustic monitoring data collected during the 2018 and 2019 shipping seasons (Frouin-Mouy et al. 2019, 2020), it was determined that acoustic modelling estimates were overly conservative by a factor of approximately two to three times when compared to measured sound levels.

[3] Injury thresholds reported have auditory weighting functions applied, meaning that the frequencies in which the animal hears well are emphasized and the frequencies that the animal hears less well or not at all are de-emphasized, based on the animal's audiogram (NMFS 2018; Southall et al. 2019).

[4] The disturbance threshold is broadband, meaning that the total sound pressure level (SPL) is measured over the specified frequency range (i.e. 25 kHz).

3.0 SEVERITY SCORE RANKING AND SELECTION OF BEHAVIORAL RESPONSE VARIABLES

Current scientific practice (Southall et al. 2007; Finneran et al. 2017) involves categorizing marine mammal behavioural responses to anthropogenic sound sources based on a severity scale described as low, moderate, or high. Low severity responses are within an animal's range of typical (baseline) behaviours and are unlikely to disrupt an individual to a point where natural behaviour patterns are significantly altered or abandoned.

Low severity responses would include:

- Orientation response (e.g., change in group direction)
- Startle response
- Change in respiration
- Change in heart rate
- Change in group spacing or synchrony (e.g., change in group spread, group formation, and/or group size)

Moderate severity responses would not be considered significant behavioural responses if they lasted for a short duration and the animal immediately returned to their pre-response behaviour. Moderate severity responses would be considered significant behavioural responses if they were sustained for a long duration. What constitutes a long-duration response is different for each situation and species, although it is likely dependent upon the magnitude of the response and species characteristics such as body size, feeding strategy, and behavioural state at the time of the exposure. In general, a response would be considered 'long-duration' if it lasted up to several hours, or enough time to significantly disrupt an animal's daily routine. For the derivation of behavioural criteria in this study, a long duration was defined as a response that lasted for the full duration of vessel exposure or longer. This assumption was made because examination of behavioural response data suggests that had the vessel exposure continued, the behavioural responses would have continued as well.

Moderate severity responses would include:

- Altering migration path, locomotion (e.g., change in group travel speed, group direction, and/or distance from shore), dive profiles
- Stopping/altering nursing, breeding, feeding/foraging, sheltering/resting, vocal behaviour
- Avoiding area near sound source (e.g., vessel sound)
- Displays of aggression or annoyance (e.g., tail slapping)

High severity responses include those with immediate consequences to growth, survival, or growth, and those affecting animals in vulnerable life stages (i.e., calf, yearling). High severity responses are therefore always considered to be significant.

High severity responses would include:

- Long-term or permanent abandonment of area
- Prolonged separation of females and dependent offspring (e.g. change in group composition)

- Panic, flight, or stampede[5]
- Stranding

Narwhal behavioural response variables evaluated in the Bruce Head Monitoring Program include group size, group composition, group spread, group formation, group travel direction, travel speed, and distance from shore. Depending on the nature and duration of behavioral responses observed, the response variables assessed herein are considered in relation to the severity score ranking outlined previously. Of note, any significant changes in narwhal group spread, group formation, and/or group size would be classified as a low severity response given that they simply indicate a change in group spacing or synchrony that are within an animal's range of natural (baseline) behaviors (Finneran et al. 2017). Significant changes in narwhal group direction, travel speed, and/or distance from shore would indicate a change in locomotion or orientation and therefore be classified as low to moderate severity responses, depending on the duration that they are sustained. Finally, a significant change in group composition may suggest a moderate to high severity response if, for example, the proportion of immatures (i.e., calves and yearlings) are shown to be negatively impacted. That is, the presence of significantly less immatures in a group may suggest that some critical life function (e.g., nursing, breeding) has been interrupted (i.e., a moderate severity response) and/or that females and dependent offspring have been separated (i.e., a high severity response). This latter component is currently being assessed through the Unmanned Aerial Vehicle (UAV) Program (see section 4.1).

While one of the driving factors in carrying forward the response variables defined by LGL (2014-2016) was to maintain consistency among sampling years, it is acknowledged that an explanation of each response variable's relevance for assessing behavioural response of narwhal to vessel traffic is important for interpretation of results. Therefore, the following subsections provide the rationale for including the response variables of interest based on relevant literature describing cetacean behavioural response to shipping and to other natural and anthropogenic threats.

3.1 Group Size

Cetaceans have been shown to change group size in response to predators (Mattson et al. 2005; de Stephanis 2014; Visser et al. 2016) and anthropogenic disturbance such as vessels and navy sonar (Curé et al. 2012; Curé et al. 2016). For example, in the presence of tourism and shipping vessels, bottlenose dolphins (*Tursiops truncatus*) have been found to reduce group size (Arcangeli and Crosti, 2009; Pennacchi 2013). According to Arcangeli and Crosti (2009), the presence of tour boats resulted in bottlenose dolphins spreading out into more groups, each containing fewer individuals, with mean group sizes reduced by 12%. Another study assessed the behaviour of resident bottlenose dolphins in the presence of industrial and non-industrial vessels in the Galveston Ship Channel (Pennacchi 2013), finding that dolphins associated in smaller groups when in the presence of industrial vessels compared to non-industrial vessels.

Conversely, cetacean groups have also been shown to increase group size in the presence of potential threats (Mattson et al. 2005; de Stephanis 2014; Visser et al. 2016). In one study by Mattson et al. (2005), the effects of boat activity on bottlenose dolphin behaviour was assessed along Hilton Head, South Carolina, USA, where it

[5] For the purpose of the present study, 'panic, flight and stampede' are considered one in the same behavioural responses, collectively defined as a 'sudden, overt and directed high-speed movement away from a particular threat or disturbance source'.

was determined that dolphins had a larger mean group size in the presence of all vessel types (dolphin tour boats, motorboats, shrimp boats). Additionally, as long-finned pilot whales (*Globicephala melas*) are known to use social defence strategies when detecting and responding to a threat (Curé et al. 2012; de Stephanis 2014), the behaviour of whales in response to three types of disturbance (killer whale sound playbacks, tagging, and naval sonar) was investigated (Visser et al. (2016). Pilot whales were shown to form larger groups during exposure to all sources, with the most significant increase in group size occurring during and after sonar playback exposure, followed by during satellite tagging and killer whale sound playbacks. The pilot whales also appeared to be attracted to the source and actively approached it, a behaviour suggested to be a form of social defence through mobbing (Visser et al. 2016). These results represent a different response to findings of dolphin groups responding to stimuli but decreasing group size (Arcangeli and Crosti, 2009; Pennacchi 2013) and avoiding the perceived threat, such as vessels (Au and Perryman 1982; Finley et al. 1990; Ribiero et al. 2005; Christiansen et al. 2010; Krasnova et al. 2020; Lusseau 2003; Ribiero et al. 2005; Williams et al. 2002) or predators (Shane et al. 1986; Breed et al. 2017; Laidre et al. 2006). Finley et al. (1990) found similar differences in species-specific responses to altering group size when they compared the responses of narwhal and beluga to ice-breaking ships in the Eastern Canadian Arctic over a three-year period. Of note, beluga were observed forming larger herds and fleeing while narwhal did not form larger herds and tended to freeze (Finley et al. 1990).

3.2 Group Composition

Changes in the group composition of cetaceans in response to disturbance occur over the short-term, as group membership changes in the immediate presence of a disturbance (Bejder et al. 2006a), and over the long-term because of reduced reproductive success (Mann et al. 2000; Bejder 2005), resulting in changes in population structure. In a study by Bejder et al. (2006a) in which the behavioural responses of Indo-Pacific bottlenose dolphins to experimental vessel approaches in Shark Bay, Western Australia were tested, dolphin groups had higher rates of change in group membership during vessel approaches, compared to before and after vessel approaches. To our knowledge, effects of disturbance on group composition were not previously described for cetaceans prior to this work (Bejder et al. 2006). However, change in group composition was previously reported as a disturbance response by a variety of terrestrial animals (e.g., mountain goats: Foster & Rahs 1983, Côté 1996; and Sulawesi black macaques, *Macaca nigra* Kinnaird & O'Brien 1996) with some studies reporting that group separation enabled predators to prey on unprotected offspring (e.g., Dall sheep, *Ovis dalli dalli*: Nette et al. 1984; mountain goats: Côté & Beaudoin 1997; numerous species of water birds: Carney & Sydeman 1999). Social interdependence is considered important in reducing the vulnerability of cetaceans to predation and a primary determinant in the evolution of cetacean grouping behaviour (Norris & Dohl 1980; Wells et al. 1980; Norris et al. 1994). For the Shark Bay dolphin population, Bejder et al. (2006a) suggested strong social interdependence may be important in reducing vulnerability to predation from sharks, and disruptions in grouping behaviour, even in the short term, may have long term repercussions. Frequent group changes in response to vessel activity, especially if mutually reliant group members are separated, may escalate predation risk (Bejder et al. (2006a) and increase individual stress levels.

Cetacean response to potential threats or disturbance also depends on group composition. Bottlenose dolphin groups with calves were found to be particularly sensitive to tour boats during a study in Doubtful Sound, New Zealand from 2011-2012 (Guerra et al. 2014). Of note, mother-calf pairs were observed moving away from approaching boats, increasing their distance from the rest of the group. It is noted by Guerra et al. (2014) that the sensitivity of mother-calf groups to vessels has important implications for management, especially for small or endangered populations, that could result in demographic changes in the long-term. Cumulative effects of short-term responses to disturbance have been shown to result in long-term changes in population structure, including number of bottlenose dolphin calves. In studying the survival rates of bottlenose dolphin adults and calves in Doubtful Sound, New Zealand from 1990 to 2008, Currey et al. (2009) detected a significant reduction in calf survival in the population after 2002. Using age-structured population models, reduced calf survival was found to be a key factor in the population decline (Currey et al. 2009), with calf survival rate being 0.86 prior to 2002, dropping to 0.375 post-2002. The authors of this study found evidence that the decline coincided with the opening of a hydroelectrical power station in 2002 which resulted in significant ecological changes such as changes in prey availability and reduced water temperatures, likely increasing physiological stress to mother and calves.

It is acknowledged that the demographic characteristics of a population are strongly correlated with the population's status and may therefore be used as EWI of future changes in abundance (Booth et al. 2020). In Booth et al. (2020), the sensitivity of two vital rates were assessed, including the ratio of calves/pups to mature females and the proportion of immature animals in a population. Both characteristics were shown to be sensitive to changes in fertility and calf survival. Based on PCod (population consequences of disturbance) models, Booth et al. (2020) also confirmed that demographic characteristics, especially the proportion of immature animals in a population, can be used as EWI of population decline. This conclusion has been supported by other studies that investigated the potential effects of disturbance on reproductive success where disturbance resulted in a large reduction in the proportion of calves reaching weaning age in North Atlantic long-finned pilot whales (Hin et al. 2019) and Blaineville's beaked whales (*Mesoplodon densirostris*) (Moretti et al. 2019). These studies confirm that the EWI selected to be monitored through this Program (i.e., a decline in the proportion of immatures) is appropriate for identifying potential adverse impacts on narwhal that may arise from exposure to vessel traffic and associated vessel noise along the Northern Shipping Route.

3.3 Group Spread

Cetaceans have been shown to form tight groups in situations of perceived threat or when surprised (Johnson and Norris 1986; Cosens and Dueck 1988, 1991, 1993; Finley et al. 1990; Nowacek et al. 2001; Visser et al. 2016; Golder 2021a), potentially as a mechanism to provide increased protection for individuals within the group. Cetaceans have also been shown to form tight pods in the presence of vessels (Irvine et al. 1981; Au and Perryman 1982; Finley et al. 1990; Blane and Jaakson 1994; Bejder et al. 1999, 2006a; Nowacek et al. 2001) and when exposed to navy sonar activity (Visser et al. 2016). In one study, Nowacek et al. (2001) assessed the behavioural responses of bottlenose dolphins to vessel traffic by collecting focal animal data, including group spread, using an overhead video observation system during opportunistic and experimental boat approaches in Sarasota Bay, Florida. Significant reductions in the inter-animal distance of subsurface groups was found 77% of the time when vessels were present (Nowacek et al. 2001). Another study based in Porpoise Bay, New Zealand quantified the behaviour of Hector's dolphins (*Cephalorhynchus hectori*) in the presence of tour boats and swimmers over two austral summers (Bejder et al. 1999). When the tour boats were in the bay, dolphins were shown to form significantly tighter groups. Conversely, Arcangeli and Crosti (2009) demonstrated a response to vessel activity in which bottlenose dolphins exposed to tour boats spread out into more groups containing fewer animals in each.

There is evidence that cetacean response to perceived threats such as vessel noise, predation, and hunting, may depend on whether calves are present. Dolphin groups containing calves have been found to alter their space use patterns by forming tighter groups (Johnson and Norris 1986) or by forming looser groups (Arcangeli and Crosti 2009; Guerra et al. 2014). For example, spinner dolphins (*Stenella longirostris*) in Hawaii were observed forming tight-knit groups, in which mother-calf pairs were centrally located, at the first sign of a threat (Johnson and Norris

1982). Conversely, Guerra et al. (2014) studied the effects of tour boats on group structure of bottlenose dolphins in Doubtful Sound, New Zealand and found that dolphin groups containing mother-calf pairs were especially sensitive to vessel presence and associated noise, with mother-calf pairs increasing their distance from the rest of the group in the presence of tour boats. Though these accounts are not considered avoidance responses directly, it is acknowledged that disruptions to normal behaviour can lead to increased energetic challenges with the potential for population level consequences, particularly to small or vulnerable populations (Lusseau and Bejdger 2007).

In the Eastern Canadian High Arctic, narwhal have been observed forming tight groups in response to killer whales (Steltner et al. 1984; Laidre et al. 2006; Breed et al. 2017, Golder 2021a) and vessel traffic (Cosens and Dueck 1988, 1993; Finley et al. 1990). These results fit with the majority of findings that suggest cetaceans form tighter groups in situations of perceived threat (e.g., as an anti-predator response). Finley et al. (1990) conducted aerial surveys of beluga and narwhal behaviour and distribution prior to the arrival of an icebreaker and accompanying Canadian Coast Guard icebreakers, during icebreaking activity and after icebreaking activity ceased. The two species were found to react very differently during icebreaking activities; beluga demonstrated herd formation and a loss of pod integrity while narwhal huddled together often engaging in physical contact. These differences in responses fit with Inuit descriptions of “ardlinayuk”, fear of killer whales, the specific behaviours beluga and narwhal demonstrate in response to killer whales. During aerial surveys in 2020, a large group of killer whales was observed herding 150-200 narwhal into Fairweather Bay near Milne Inlet (Golder 2021a). The killer whales travelled quickly into the bay swimming abreast of each other in two lines as the narwhal swam in tight groups and clustered near the shoreline. As the killer whales neared the narwhal, the killer whales dispersed into smaller groups and were observed killing two narwhal calves and two adults, including an adult male observed floating motionless near shore and one probable adult female, potentially the mother to one of the killed calves (Golder 2021a).

3.4 Group Formation

Previous studies have shown that cetaceans react to disturbances by changing group formation (Irvine et al. 1981; Au and Perryman 1982). In one study, 47 bottlenose dolphins were captured, tagged, and released ninety times as part of a study on the behavioural ecology of Atlantic bottlenose dolphins near Sarasota, Florida from 1975-1976. During capture events, some of the previously caught bottlenose dolphins recognised the capture boat and fled in a tight group, often in a line-abreast formation (Irvine et al. 1981).

In another study, data on the behavioural response to a survey ship was collected on eight separate schools of spotted dolphin (*Stenella attenuata*), spinner dolphin, and striped dolphin (*Stenella coeruleoalba*) from a helicopter ahead of the ship (Au and Perryman 1982). Dolphin group formations were often observed changing as the vessel approached, with groups scattering, orienting in lines abreast, and forming arcs, oval-shaped groups, or compact ranks. During one observation, a group of spotted dolphins was observed scattering when the vessel approached within 3.0 miles, then congregated to form a large arc (with some animals scattered on the sides when the vessel was 2.5 miles away, and finally scattering again when the vessel was 1.6 miles away. During another observation, a group of spotted and spinner dolphins formed compact ranks at the rear of the group when the vessel was 3.3 miles away, then swam in various directions in an oval-shaped group when the vessel was 2.2 miles away. The dolphin groups were described swimming “in an almost amoeboid” fashion in the presence of the vessel and, when the vessel was within 2 miles of the dolphins, the groups were increasingly oriented in lines abreast (Au and Perryman 1982).

3.5 Group Direction

Cetaceans are known to change direction in the presence of vessels (Au & Perryman 1982; Finley et al. 1990; Golder 2020a; Krasnova et al. 2020; Mattson et al. 2005; Nowacek et al. 2001). For example, during a study of bottlenose dolphin responses to experimental vessel approaches in Shark Bay, Western Australia, Bejder et al. (2006a) found that dolphin groups were more erratic in their direction of travel when in the presence of vessels. Mattson et al. (2005) also studied behavioural responses of bottlenose dolphins to a variety of vessel types and found that dolphin groups frequently changed direction in the presence of all vessel types in the study (i.e., motorboats, jet skis, shrimp boats), except in the presence of larger ships. In a study by Krasnova et al. (2020), shore-based data was collected to assess changes in beluga behaviour in the presence of tour boats in the White Sea, Russia over a 16-year period. The authors assessed three periods of tourism development based on vessel type and intensity of vessel traffic and found that beluga exhibited avoidance behaviour, including directional changes, 90% of the time during the initial tourism development (Krasnova et al. 2020). During subsequent periods, when tour boats were visiting the area more frequently (i.e., between one to five times per day), beluga did not move away as readily. The authors concluded that the lack of response in the later phase of the study suggests that beluga became habituated to vessels after the initial arrival of tour boats.

Aerial surveys flown in Lancaster Sound and Admiralty Inlet, Nunavut from 1982-1984 prior to the arrival of an icebreaker, during active icebreaking, and following icebreaking activity, assessed the behavioural responses of beluga and narwhal to icebreaking activity (Finley et al 1990). In all years of the study, narwhal and beluga were reported to react very differently to icebreaking activities, with beluga demonstrating a distinct ‘flee’ response while narwhal generally exhibited a ‘freeze’ response. Of note, narwhal were observed to move slowly in the presence of the icebreaker, frequently resting motionless at the surface even after the icebreaker first struck the ice (Finley et al. 1990). Conversely, data presented in the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a) demonstrated that narwhal turn back on their own track when within 4 km of a transiting vessel and change their travel orientation relative to a transiting vessel when within 5 km of an approaching ore carrier.

3.6 Travel Speed

Many studies have demonstrated changes in travel speed of cetacean groups in response to vessel disturbance (e.g., Nowacek et al. 2001; Williams et al., 2002; Bejder et al. 2006a; Laidre et al. 2006; Matsuda et al., 2011; Erbe et al. 2019). For example, Bejder et al. (2006a) reported bottlenose dolphin groups travelling at more erratic travel speeds during experimental vessel approaches in Shark Bay, Western Australia. Bottlenose dolphins have also been found to increase travel speeds when in the vicinity of power boats and personal watercraft in Sarasota Bay, Florida (Nowacek et al. 2001), personal watercraft in the Mississippi Sound, USA (Miller et al. 2008) and dolphin watching boats off Amakusa-Shimoshima Island, Japan (Matsuda et al. 2011). Other cetacean species have demonstrated increased swimming speed in the presence of vessels, including killer whales in British Columbia (Kruse 1991) and Chilean dolphins (*Cephalorhynchus eutropia*) in Yaldad Bay, southern Chile (Ribeiro et al. 2005). Conversely, despite Finley et al. (1990) documenting a flee response by beluga to icebreaking vessels, the authors reported no increase in travel speed for narwhal in the presence of ice-breaking vessels, but rather documented a “freeze” response. Based on movement data obtained through the narwhal tagging study (Golder 2020a), no significant change in travel speed has been detected for narwhal in the presence of vessels compared to periods when no vessels were present.

3.7 Distance from Shore

Various studies conducted in the Eastern Canadian Arctic have documented narwhal moving closer to shore in the presence of killer whales (Steltner et al. 1984 in Marcoux 2011b; Laidre et al. 2006; Ferguson et al. 2012; Breed et al. 2017; Golder 2021a). For example, satellite tagging data collected in Admiralty Inlet in August 2005 revealed that narwhal travelled closer to shore over the two days that killer whales were in the area compared to the five days prior to killer whale arrival and then shortly after the killer whales left the area (Laidre et al. 2006). Breed et al. (2017) reported similar observations of narwhal behaviour when killer whales were present in Admiralty Inlet in August 2009. In the study by Breed et al. (2017), one killer whale and seven narwhal were tagged to assess narwhal movements in the presence of killer whales. With the narwhal and a group of 12-20 killer whales both occupying the Inlet over a ten-day period, the authors were able to assess narwhal habitat use in both the presence and absence of killer whales. Narwhal habitat use was shown to differ between the two periods significantly, with narwhal remaining within 500 m of the shore when in the presence of killer whales until killer whales left the area at which point narwhal moved further offshore (i.e., 4-10 km from shore). Marcoux (2011b) also reported observing narwhal swimming very close to shore a few hours after killer whales departed Koluktoo Bay. Unlike the other studies, where narwhal resumed normal distances from shore not long after killer whales left the area, the narwhal remained closer to shore for many hours after the killer whales departed (Marcoux et al. 2011b). Narwhal were also observed swimming in tight groups near shore when a large group of killer whales was observed herding ~150-200 narwhal into Fairweather Bay, Milne Inlet during aerial surveys in 2021 (Golder 2021a).

4.0 MODIFICATIONS TO 2020 PROGRAM DESIGN

Based on data collected to date as part of the Program (2014-2017, 2019), and through consultation with the various stakeholder groups (i.e., the Marine Environment Working Group), it was determined that a more in-depth understanding of potential effects of Project-related shipping activities to narwhal could be obtained through certain additions to the Program. Of note, the 2020 study design included integration of visual observations via an Unmanned Aerial Vehicle (UAV; section 4.1).

4.1 Integration of Unmanned Aerial Vehicle (UAV) Surveys

In collaboration with InDro Robotics Inc., visual surveys of narwhal in the vicinity of Bruce Head were conducted using a drone (i.e., UAV) to further investigate the response of narwhal to shipping activities. The drone operations team used several different UAV systems to conduct surveys in coordination with shore-based visual observers with the following objectives:

1) Assess behavioural changes (e.g., change in travel direction) in relation to shipping events under a different behavioural context (e.g., resting/milling, socializing) than what is typically observed of animals in the BSA (i.e., travelling) via focal follow surveys.
2) Confirm sightings information (e.g., group composition, group size, behaviour) during narwhal herding events through the BSA.
3) Evaluate detection performance of marine mammal observers (i.e., ability to effectively detect narwhal) throughout the SSA.

Focal follow survey results (i.e., objective 1) are presented in this report. Unfortunately, mechanical issues with the drone system assigned to confirm sightings information (i.e., objective 2) and evaluate observer detection performance (i.e., objective 3) precluded the successful completion of these surveys. Therefore, further discussion relating to the UAV survey design and results relates specifically to the focal follow survey component.

5.0 METHODS

5.1 Study Team and Training

The 2020 field program took place between 7 August 2020 and 1 September 2020 and consisted of 16 hours of daily monitoring effort (weather permitting), undertaken by two teams comprised of five individuals each, alternating at 4 h observation intervals. Study teams consisted of Golder biologists with previous arctic marine mammal survey experience, graduate students, and qualified Marine Mammal Observer (MMO) subcontractors (**Photograph 5.1**). The drone operations team, comprised of three individuals from InDro Robotics, worked closely with Golder biologists to plan and execute the aerial surveys of narwhal. Unfortunately, due to restrictions related to the global COVID-19 pandemic, local Inuit MMOs were not able to participate in the 2020 Program.

Upon arrival to the Bruce Head camp on 6 August 2020, the field team participated in an on-site orientation led by the Camp Manager, Shea Pollard, and Site Supervisor, Ben Widdowson. Topics covered during the orientation included general camp etiquette expectations, 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. All relevant health and safety policies and regulations by Golder and Baffinland were reviewed and discussed.

The study team also participated in a comprehensive training session led by the Technical Lead, Ainsley Allen, with support from Mitch Firman. This practical training session included 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 session, all study team members were provided with a Training Manual (APPENDIX A). Topics covered during the training session included the following study components:

- Spatial boundaries of the Stratified Study Area (SSA) and Behavioural Study Area (BSA)
- Methodology for recording narwhal sightings (i.e., number of individuals, group size, direction of travel)
- Methodology for identifying group formation and group composition
- Methodology for differentiating types of narwhal behaviour
- Methodology for recording weather conditions and sightability conditions
- Methodology for recording vessel presence
- Overview of UAV survey design

Photograph 5.1: 2020 Bruce Head Shore-based Monitoring Field Team.

5.2 Data Collection

Understanding the context and function (if any) of narwhal aggregations and spatial use patterns is important in assessing behavioural response to a potential perceived threat (e.g., vessel traffic). Narwhal are a highly gregarious species (Marcoux et al. 2009; Smith et al. 2015; Smith et al. 2016; Smith et al. 2017; Golder 2019; Golder 2020c) and are known to alter their spatial use patterns in the presence of predators (Campbell et al. 1988; Cosens and Dueck 1991; Laidre et al. 2006; Breed et al. 2017). In drawing from accounts of predator-induced behavioural responses by narwhal, the following metrics were selected to be examined to assess behavioural response to other potential perceived threats such as vessel traffic: relative abundance and distribution, group size, group composition, group spread, group formation, group direction, travel speed, and distance from shore.

Visual survey data collected during the 2014-2017 and 2019-2020 Programs included information on (1) narwhal relative abundance and distribution (RAD); (2) narwhal group composition and behaviour; and (3) other anthropogenic activities, such as hunting activity. During each monitoring shift, the study team was split into two separate survey groups. The first group, composed of two MMOs, was exclusively responsible for collecting RAD data in the SSA. The second group, composed of three to four MMOs, was responsible for collecting data on group composition and behaviour in the BSA, as well as tracking vessels and recording anthropogenic activities in the SSA. Both teams also collected data on environmental conditions during their respective survey efforts. To minimize potential observer fatigue, study team members rotated between observer and recorder roles throughout each monitoring shift. During the 2020 Program, the drone operations team coordinated survey effort with the MMOs, though worked primarily independently (see section 5.2.6). Detailed descriptions of data collection and survey methods employed during the 2014–2017 and 2019 programs are provided in the respective annual reports (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020c).

5.2.1 Relative Abundance and Distribution

Consistent with previous years' data collection techniques (2014-2017 and 2019), RAD surveys were conducted throughout the SSA in 2020. Observations were made using survey and scan observation (Mann 1999), where the observer surveyed each stratum for a minimum of three minutes to identify narwhal groups, group size (solitary narwhal were considered a group of one), and travel direction. Once all narwhal present within each substratum were counted and their direction of travel was 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) to minimize the potential of double-counting groups. RAD surveys were conducted in the SSA throughout the daily monitoring period, every hour, on the hour. In addition, RAD surveys were conducted continuously as a vessel approached the SSA, throughout the time that a vessel transited through the SSA, and once again after the vessel had exited the SSA. During vessel transits through the SSA, counting commenced in the stratum closest to the incoming vessel.

5.2.2 Group Composition and Behaviour of Narwhal

Group composition and nearshore behavioural data were collected for all narwhal observed within the BSA (<1 km from shore). Survey and scan sampling protocols (Mann 1999) were used to record group-specific data (Table 5-1, Table 5-2, Table 5-3). 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 conducting a RAD count, the RAD team assisted in collecting group composition data in the BSA. The data collection protocols were similar across all years of sampling (2014-2017, 2019-2020). A detailed description of group composition and behavioural data collected is provided in the Training Manual (APPENDIX A).

Table 5-1: Group composition and behavioural data collected in the BSA

Recorded Data	Description
Time of sighting	Time of initial observation within the BSA
Sighting number	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[1]	Number of narwhal within one body length of one another
Number of narwhal by tusk classification	■ Number of narwhal with tusks ■ Number of narwhal without tusks ■ Number of narwhal with unknown tusks (i.e., head not visible)
Number of narwhal by age category	Adult, juvenile, yearling, calf, unknown life stage (Table 5-2)
Spread of group	■ Tight: narwhal ≤ 1 body width apart ■ Loose: narwhal >1 body width apart
Group formation	Linear, parallel, cluster, non-directional line, no formation (Table 5-3)
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 8 (Behavioural Data) in the Training Manual (APPENDIX A) for lists of primary and secondary behaviours recorded

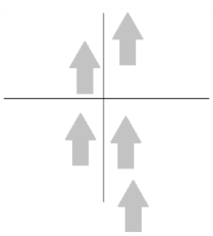
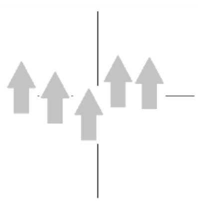
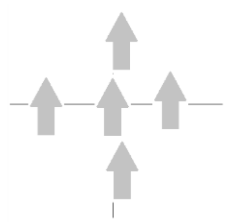
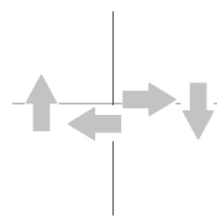
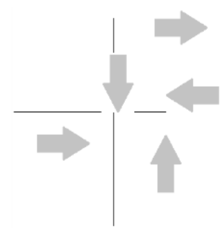
Notes:

[1] This included a group size of n = 1.

Table 5-2: Life stages of narwhal

	Adult	Juvenile	Yearling	Calf
Length	4.2 – 4.7 m	80-85% the length of adult	2/3 the length of accompanying female	1/3 to 1/2 the length of accompanying female, usually in “baby” or “echelon” position close to mother.
Coloration	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 5-3: Group formation categories

Linear	Parallel	Cluster	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
				

5.2.3 Vessel Transits

Vessel transits in the SSA were tracked and recorded using a combination of shore-based and satellite AIS data to provide accurate real-time data on all medium (50-100 m in length) and large (>100 m in length) vessel passages through Milne Inlet. AIS transponders are mandatory on all commercial vessels >300 gross tonnage and on all passenger ships. Information provided by the AIS includes vessel name and unique identification number, vessel size and class, position and heading, course, and speed of travel, and destination port. The shore-based and satellite AIS datasets were used to complement one another as the AIS shore-based station at Bruce Head provided higher resolution positional data, but only provided line-of sight spatial coverage, while the satellite-based AIS data had lower resolution but provided coverage of the entire Northern Shipping Route.

The study teams also visually recorded vessel traffic in the SSA during each survey period. 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. In previous years of analysis (Golder 2019; Golder 2020c), small vessels were modelled as either total count present during each RAD count or as present/absent. In the current analysis, only medium and large vessels were included, while small vessel presence was omitted from analysis due to concerns of small vessels being detected disproportionately between different substrata and between different levels of narwhal activity in the BSA.

5.2.4 Non-vessel Anthropogenic Activity

The rocky shoreline below the Bruce Head observation platform serves intermittently as a hunting camp for local Inuit. Over the course of the 2014-2017 and 2019-2020 field programs, active shooting events associated with hunting have been regularly observed by the study team both visually and acoustically from the observation platform. All hunting (i.e., shooting) events were recorded during each daily monitoring period, including the time of occurrence, duration of the event, number of shots fired, and target species. In addition, a pair of Wildlife Acoustic SM4 recorders were set up approximately 50 m from the hunting camp to record hunting events during times that the study team was not actively monitoring (Photograph 4.3). Both recorders recorded continuously using the built in omni-directional microphones, with one recorder sampling at a rate of 24 kHz and the other at 48 kHz.

Photograph 4.3: Two SM4 acoustic recorders mounted back-to-back on a fiberglass pole. The shoreline location of the Inuit hunting camp is visible in the background.

5.2.5 Environmental Conditions

Environmental conditions were recorded at the start of the monitoring period, every hour, and whenever conditions changed. For the entire SSA, cloud cover (percent [%]), precipitation, and ice cover (%) were recorded. Beaufort scale, sun glare, and an overall assessment of sightability were recorded for each substratum within the SSA and also in the BSA. In all years, modelled tidal data for Bruce Head were obtained from WebTide Tidal Prediction Model (v 0.7.1). These tidal data were provided as tide height (m) relative to chart datum. A derivative variable of elevation change (as cm/5 min) was calculated by subtracting each data point from the previous recorded tide height point.

5.2.6 Focal Follow (UAV) Surveys

InDro Robotics was contracted to complete aerial photography of the SSA and surrounding area for the duration of the Program. The Drone Operations team worked closely with Golder biologists to carry out focal follow surveys of narwhal using a selection of UAV units, primarily the EVO 2 by Autel Robotics. The EVO 2 is a compact UAV unit that includes a powerful camera on a 3-axis stabilized gimbal, capable of recording video at 8k resolution up to 25 frames per second and capturing 48 megapixel stills. All survey footage was recorded at 4k or higher. To conduct this work, a Special Flight Operations Certificate (SFOC) was obtained from Transport Canada to perform Beyond Visual Line of Sight (BVLOS) operations (SFOC #930030).

A team of three individuals was present for all focal follow surveys conducted, including the primary Beyond Visual Line of Sight (BVLOS) Pilot in Command, a Ground Supervisor/Visual Observer from InDro Robotics, and a Golder biologist. For each survey, the drone was flown to a predetermined, randomized starting point either within the SSA or slightly to the south, toward Koluktoo Bay. Once at the starting point, the drone was oriented north (to facilitate data entry later) and flown along a predetermined grid until the first group of narwhal was encountered. The UAV team followed the focal group for as long as it was visible and terminated the survey only once the group dove deeply out of sight, dispersed widely, or other logistical factors such as low battery levels or inclement weather necessitated survey end. In instances when groups dispersed widely, the Pilot increased the altitude of the drone, attempting to stay with the focal group for as long as possible.

Effort was made to conduct consecutive focal follow surveys during active vessel transits through the SSA, regardless of whether narwhal were visible to marine mammal observers at the time. These surveys were considered “searches” and did not always result in focal groups being followed. While this component of the UAV survey design was intended to maximize potential focal follows in the presence of ships, it also informed observer detection performance by validating animal presence/absence in the distal portions of the SSA and near the mouth of Koluktoo Bay.

5.3 Data Management

For the RAD data collection, data recorders entered observations directly into a tablet-based Microsoft Access© database. In addition to the tablet, a laptop-based Microsoft Access© database was used by the BSA team for entry of environmental and anthropogenic data. Of all data collected, only group composition and behavioural data were entered manually on field data sheets, as in previous years. This exception was made to allow for more efficient data entry during data-rich events when a large number of observations needed to be recorded quickly, such as during herding events.

At the end of each daily monitoring period, study team members reviewed the BSA field data sheets and the Access databases (for RAD, environmental, and anthropogenic data) as a means for quality control. Any discrepancies/omissions in the data were addressed immediately while the study team 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. Every day, the group composition and behaviour data were entered into an Access database, and the full data suite (RAD, group composition and behaviour, environmental, and anthropogenic data) was reviewed and quality checked a second time. Any missing and/or incorrectly entered fields, as well as discrepancies, were corrected by cross referencing with field notes taken during each monitoring period.

5.4 Data Analysis

5.4.1 Data Preparation for Analysis

5.4.1.1 Data Integration between Sampling Years

In 2014 and 2015, sightability categories included Excellent (E), Good (G), Poor (P), and Impossible (X). In 2016 and 2017, an additional category was added: Moderate (M). Due to inconsistencies in how sightability was assessed between survey years (particularly in substrata 3), sightability was instead assessed using a combination of Beaufort scale, level of glare, and substratum (as a measure of distance).

For the 2014 RAD surveys, the time stamp associated with each substratum survey was identical (i.e., only the timing of start of the overall RAD count was recorded, not the timing of each stratum or substratum survey). Since vessel passage and anthropogenic activity are tied to RAD data via time stamps, it was required to provide substratum-specific start times. To calculate these, it was assumed that a full RAD survey required 27 min (three minutes per stratum × nine strata). Each stratum was then allocated three minutes (one minute per substratum), and time stamps were allocated to each substratum.

The 2014 and 2015 satellite-based AIS data did not include information on ‘vessel heading’; and in 2014, there was no information on ‘vessel speed’. In these cases, missing variables were reconstructed based on consecutive vessel relocations.

For BSA surveys conducted in 2014, 2015, and 2016, sightings data were limited to substrata E1 and F1 (within 1 km from shore). For BSA surveys conducted in 2017, sightings data also included substratum D1 (within 1 km from shore). This change in the extent of the BSA resulted in a shift in the centroid of the BSA from a longitude of -80.52394° to a longitude of -80.52319°. The latitude value shifted from 72.06899° to a latitude of 72.07098°. The expanded 2017 BSA study area was not expected to influence the main response variables of interest (group size, composition, spread, formation, direction, speed, and distance from shore), although it could introduce bias to the number of narwhal groups observed, due to the larger survey area. To account for this discrepancy and other potential inter-annual effects, the year of sampling was included as a covariate in the BSA models.

5.4.1.2 Automatic Identification System (AIS) Data

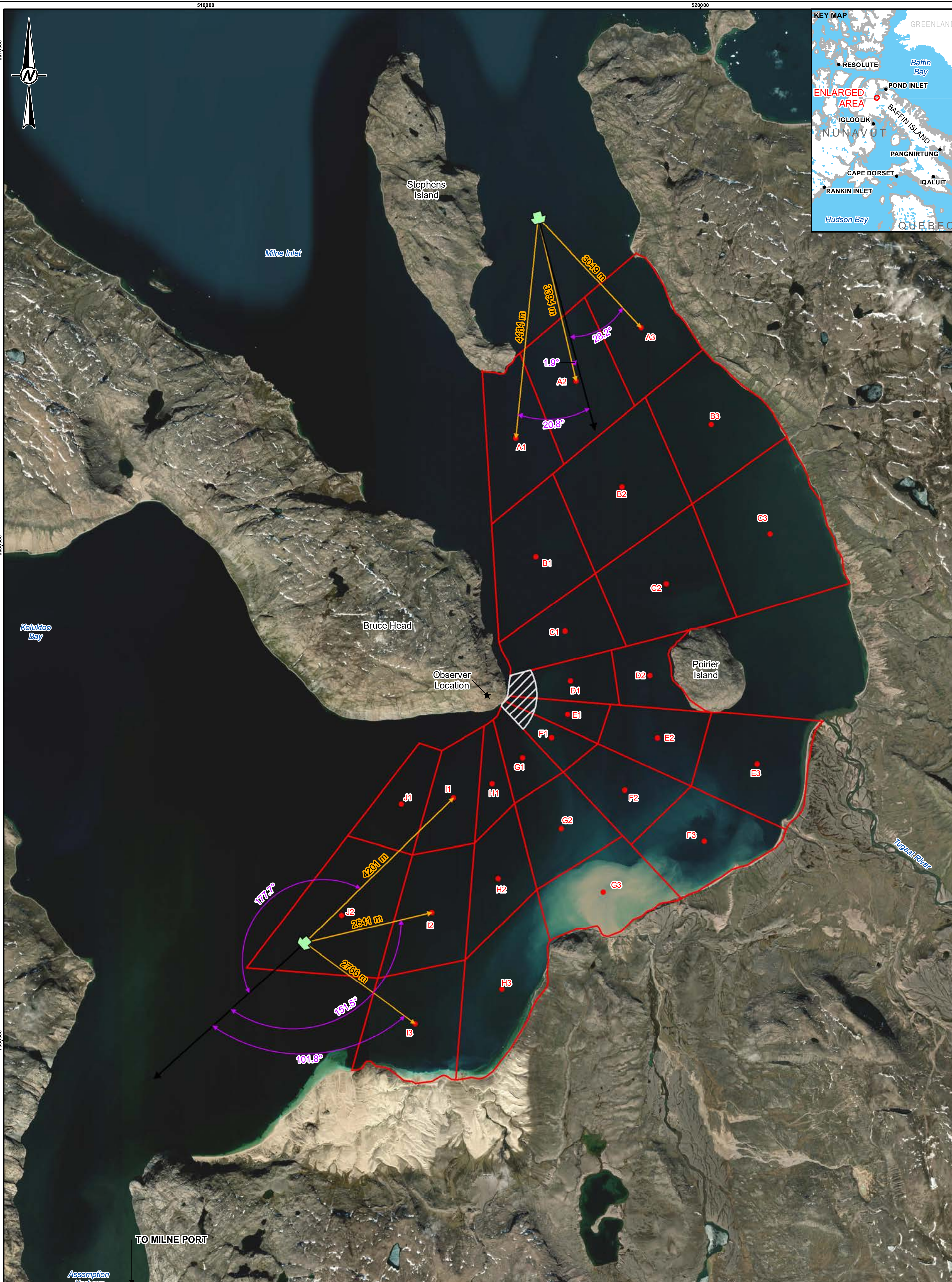
Satellite-based AIS data were merged with the AIS base station data. The full AIS dataset was clipped to only include ship track data collected in the Bruce Head study area (between Stephens Island and Milne Port). The full positioning dataset obtained in 2020 from the shore-based AIS station at Bruce Head had a mean of 0.2 minutes between positions (range of 0.02-403.00 minutes, median of 0.20 minutes, SD of 1.70 minutes). The distances between positions ranged from 0.0 km to 0.70 km (mean of 0.04 km, median of 0.04 km, and SD of 0.02 km). Positioning data from the AIS satellite only (i.e., with removed Bruce Head antenna data) had a mean of 0.6 minutes between positions (range of 0-106.00 minutes, median of 0.30 minutes, SD of 1.60 minutes). The distances between positions ranged from 0.0 km to 0.8 km (mean of 0.10 km, median of 0.08 km, and SD of 0.14 km).

AIS data were subsequently filtered to only include data collected during active RAD/BSA survey periods at the platform. In AIS positioning data filtered to the temporal extent of RAD/BSA sampling, only 2.5% of the AIS data were contributed by satellite data. The combined shore-based and satellite-based AIS dataset had a mean of 0.2 minutes between positions (range of 0-2.4 minutes, median of 0.2 minutes, SD of 0.14 minutes). The distances between positions ranged from 0.0 km to 0.7 km (mean of 0.05 km, median of 0.04 km, and SD of 0.04 km). The resulting dataset was used to interpolate the AIS data to 1 min resolution, to create a high temporal resolution, necessary to relate vessel positions to narwhal sightings and behaviour.

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 28 SSA substrata (Figure 5-1). 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 (angles >270º and <90º) were classified as "Toward the substratum", whereas vessels that were moving away from the substrata (90º< angles <270º) were classified as "Away from the substratum". The interpretation of a vessel moving toward or moving away 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 facing the stern of a departing vessel where the majority of radiated noise is generated. The AIS data preparation was repeated in an identical way for the behavioural and composition dataset, using the BSA centroid as the reference point.

The potential effects of the vessel were assessed up to 15 km from the SSA substrata or from the centroid of the BSA following the collection of data in 2017 (Golder 2019) and up to 10 km following the collection of data in 2019 (Golder 2020c). However, based on narwhal movement data collected as part of the 2017-2018 narwhal tagging study (Golder 2020a), narwhal behavioural responses to shipping were generally limited to distances up to 5 km from the vessel. That is, narwhal behaviour was generally found to return to non-exposure levels once vessels were 5 km or farther from the narwhal. In addition, shipping sound levels recorded as part of JASCO's passive acoustic monitoring program indicated that vessel noise was generally below 120 dB re: 1µPa beyond 7 km from the vessel (Austin and Dofher 2021). Therefore, the study design was modified in 2020 to reduce the 10 km exposure zone to 7 km, such to more accurately capture the predicted zone of disturbance for narwhal. This reduction in spatial extent aimed to reduce potential noise in the data noise at farther distances, which would allow to better quantify the effects at closer distances, where effects are likely to be stronger.

PATH: I:\2016\1663724\Mapping\MXD\33000_UAV_Program\1663724_33000_05_Fig5_1_AnglesDistancesAISData_Rev0.mxd PRINTED ON: 2021-04-21 AT: 3:27:34 PM



LEGEND

- OBSERVER LOCATION
- SAMPLE AIS VESSEL LOCATION
- STRATIFIED STUDY AREA (SSA) SUBSTRATA CENTROID
- ANGLE BETWEEN HEADING AND SUBSTRATA
- DIRECTION TO SUBSTRATA
- SAMPLE AIS VESSEL HEADING
- WATERCOURSE
- BEHAVIOURAL STUDY AREA (BSA)
- 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, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
VESSEL DISTANCE AND TRANSITING ANGLE RELATIVE TO SURVEY SUBSTRATA

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-04-21
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-05	0	5-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
25mm 0

5.4.1.3 Relative Abundance and Distribution (RAD) Data

For each RAD count within a given substratum, AIS data were retrieved for each vessel present in the study area, including information on course, heading, and distance, and whether the vessel was moving toward or away from the substratum's centroid (recorded to the nearest time stamp). The data were then filtered using a temporal criterion: vessels with GPS positions recorded more than 15 minutes either before or after each substratum's count were removed from the analysis, leaving only relevant AIS data for inclusion in the model. In addition, a spatial criterion was added – vessels that were more than 7 km away from a centroid were not considered to affect relative abundance, distribution, or behaviour of narwhal. This spatial filter corresponds to the farthest distance at which vessel noise levels were at or above 120 dB re: 1µPa (Austin and Dofher 2021). Data filtration was performed similarly for the behavioural and composition data. All data collected during conditions of impossible sightability were removed from the analyses.

5.4.1.4 Group Composition and Behavioural Data

Similar to the process described above to calculate vessel distance and angle relative to SSA centroids, group composition and behavioural data were also allocated vessel distance and angle, using the centroid of the BSA instead of the SSA centroids. Note that the BSA centroid used for 2014-2016 data differed from the centroid used for 2017 and 2019-2020 data, as detailed in Section 5.4.1.1.

5.4.1.5 Anthropogenic Data

In addition to the anthropogenic effects of vessel traffic, other anthropogenic activities considered in the multi-year analysis were 'small vessel traffic' and 'hunting activity'. Hunting activity included discrete shooting events recorded by observers at the observation platform throughout 2014-2017 and 2019-2020 sampling. In addition, starting in 2019, shooting events as recorded using Wildlife Acoustics SM4 recorders were added to the dataset. For each RAD survey and group composition and behaviour sighting, the time since last shooting (in minutes) was calculated.

In previous analyses, the effects of hunting were assessed up to 12.5 h from the last shooting event (Smith et al 2017; Golder 2019) and up to 3 h post-shooting (Golder 2020c). As part of the analysis of the combined 2014-2019 dataset (Golder 2020c), the temporal extent of the effects of hunting on number of narwhal per substratum were assessed. The results indicated that the number of narwhal recorded up to 50 minutes following a shooting event were significantly different from number of narwhal recorded during no hunting activity (P values of <0.009 for all) and that narwhal group sizes were significantly different up to 70 minutes following a shooting event when compared to group sizes when no hunting occurred (Golder 2020c). Significant differences in other response variables between hunting and no-hunting periods were not found (Golder 2020c). To encompass the temporal extent of hunting effect on both RAD and group size, the period of "potential hunting effects" in the present analyses was defined as 70 minutes, and narwhal recorded more than 70 minutes following a shooting events were considered as "no hunting" observations.

5.4.1.6 Environmental Data

Following the approach used by Smith et al. (2017), continuous tide elevation estimates were used to calculate the change in water elevation between consecutive intervals. The tide values were categorized into four levels - low slack, flood, high slack, and ebb. If the change in water elevation within a 5 min interval was ≤0.01 m on either side of the lowest elevation level for a given cycle, the tide was considered to be “low slack”. An increasing change in water elevation >0.01 m was considered to be a “flood” tide. If the change in water elevation within a 5 min interval was ≤0.01 m on either side of the highest elevation level for a given cycle, the tide was considered to be “high slack”. A decreasing change in water elevation >0.01 m was considered to be an “ebb” tide.

5.4.1.7 Data Filtering

Data omitted from the multi-year analysis of RAD data included the following:

- Data collected during periods of ‘impossible’ sightability and cases with Beaufort scale value of 6 or higher (1,347 cases representing 3.1% of total individual substratum surveys). These accounted for a combination of high sea state, glare, fog, or ice cover, and therefore had to be removed from the modelling dataset.
- Data collected on days when killer whales were known to be present within southern Milne Inlet (1,386 cases, representing 3.3% of total individual substratum surveys). Killer whales were present on four days of the combined 2014-2020 dataset: 12 August 2015, 18 August 2019, and 26-27 August 2020. These cases were removed, since narwhal behaviour and distribution are strongly affected by the presence of killer whales.
- Cases with narwhal density of ≥200 narwhal/km² (2 cases, <0.01% of total individual substratum surveys) – these were removed to resolve model convergence issues.

Note that some of these cases overlapped. For example, in 34 substratum surveys, sightability was “impossible” and Beaufort scale value was 6 or higher.

Data omitted from the multi-year analysis of group composition and behaviour data included the following:

- Observations collected during periods of ‘impossible’ sightability (27 observations representing <0.5% of total observations).
- Cases where group size was >20 narwhal (20 cases overall representing 0.3% of total observations). Group sizes of >20 narwhal were very rare, observed only twenty times since the start of the Program. Group size was used as a continuous covariate in the analysis of group composition, spread, formation, direction, speed, and distance from shore. These large group sizes resulted in there being influential cases, skewing model results. Therefore, the 20 cases associated with group sizes > 20 narwhal were removed from the analysis to better capture patterns of the overall dataset.
- Sightings collected on days when killer whales were present in southern Milne Inlet (155 cases, representing 2.5% of the data). Killer whales were recorded in the study area on four days of the combined 2014-2020 dataset: 12 August 2015, 18 August 2019, and 26-27 August 2020. The 155 cases associated with killer whale occurrences were removed from the analysis, since narwhal behaviour is known to be strongly influenced by the presence of killer whales.

5.4.2 Statistical Models

5.4.2.1 Updates to Analytical Approach

The following changes were made to the analytical approach used in 2019 (Golder 2020c) and were applied to the entire six-year dataset to not affect the ability to assess differences between sampling years:

- Narwhal RAD data were analyzed as density, as opposed to number of narwhal (‘counts’) per substratum. This allowed for drawing conclusions on changes in density (i.e., accounting for the areas of different substrata), which is more biologically meaningful.
- The effect of distance from a vessel was updated from a positive, non-directional distance, which was used in combination with relative position of vessel (i.e., vessel moving toward or away from centroid), to a directional distance. In the updated variable, a negative value represents distance from a vessel that is heading toward a centroid, while a positive value represents distance from a vessel that is moving away from a centroid. This allows for simplification of the model (since the categorical variable of relative position of the vessel is no longer required), as well as for continuity in the response variable when a vessel is modelled to be at 0 km from a centroid. When presenting the results, negative distance values were shown as absolute values, and a note describing when the vessel is moving toward or away from the centroid was added.
- Vessel effects were considered when vessels were within 7 km from SSA and BSA centroids (i.e., 7 km exposure zone), as opposed to the 10 km spatial extent that was used previously, as detailed in Section 5.4.1.1.
- Presence of multiple vessels within the spatial extent of effect (7 km) was incorporated into the model. While in previous analyses, cases with multiple vessels in the spatial extent of effect were removed from analysis, the analyses presented in this report were applied to the full dataset. To accommodate this change, specific vessel-related variables such as vessel distance, relative position, and vessel travel direction within Milne Inlet, were set to describe the vessel that was nearest to the SSA / BSA. With a spatial extent reduced to 7 km, only 62 sightings of RAD data with more than one vessel present were recorded in the clean data (in comparison to 3,742 sightings of RAD data with a single vessel and 36,560 cases with no vessels present within 7 km). For BSA data, only one sighting was recorded in the presence of more than one vessel within 7 km from the BSA. Therefore, data available in the presence of multiple vessels are not sufficient to estimate whether the presence of multiple vessels differs significantly from the effect of a single vessel, and the analysis was performed without accounting for the potential effect of the presence of additional vessels.
- In the previous analysis (Golder 2020c), the effects of hunting were assessed up to 3 h from the last shooting event. In the current analysis, the temporal effects of hunting were only considered up to 70 minutes, as detailed in Section 5.4.1.5.
- Small vessel effects – in previous analysis, presence of small vessels within the SSA was included as a predictor variable in the models (Golder 2019, 2020c). With the relocation of the observation platform in 2019, it became more challenging to detect small vessels passing through the study area directly below the cliff (out of visual range), and likely leading to an underrepresentation of small vessel presence. With the focus of the observers on recording numbers of narwhal, group composition and behavioral data, as well as hunting activity, the records of small vessels were found to be disproportionate between different substrata and between different levels of narwhal activity in the BSA. The small vessel effects variable was therefore removed from the analysis.

5.4.2.2 Fixed Effect Predictors

For the RAD analysis, a plot showing the response variable (i.e., narwhal count per substratum) in response to distance from vessels was constructed using the raw data. For this plot, narwhal density (narwhal/km²) was summarized for each combination of southbound or northbound vessel, vessel moving toward or away from the substratum, and 0.5 km distance bins. For behavioural and group composition data, a similar plot was constructed, however the response variable was not summarized, and was instead shown as is. The plot provided a visual tool to identify potential trends in the response variable in relation to vessel predictor variables.

The analyses detailed in this report included two components: 1) RAD analysis; and 2) group composition and behavioural data analyses. Both RAD and group composition/behavioural data were analyzed using the same host of fixed-effect predictors. While evaluating the effect of vessel traffic (i.e., shipping) was the focus of the analysis, it was important to include other potential explanatory variables in the model to account for spatial and temporal trends. The list of predictor variables used for all analyses included the following:

1) Glare (within SSA strata or BSA, as applicable) — categorical variable with the following categories: None (N), Low (L), Moderate (M), and Severe (S).
2) Beaufort scale (within SSA strata or BSA, as applicable) — for the RAD, it was used as categorical variable, with categories ranging from 0 to 5. For the BSA, Beaufort scale values of 4 of greater were combined into a single bin of “4+”. These accounted for 559 cases in the dataset following removal of impossible sightability and days when killer whales were present in southern Milne Inlet (9.5%).
3) Tide – categorical variable with the following categories: "low slack", "flood", "high slack", and "ebb", as detailed in Section 5.4.1.6.
4) Directional distance from vessel — continuous variable (in km) calculated between vessel location and each of the SSA substratum (and BSA) centroids. The values are negative when the vessel is heading toward the centroid and positive when the vessel is heading away from centroid.
5) Vessel direction within Milne Inlet — categorical variable with two categories: ‘northbound’ and ‘southbound’.
6) Interaction between vessel distance and vessel direction.
7) Vessel presence within 7 km of the substratum/BSA centroid — categorical variable with two categories: ‘no vessel present within 7 km’, and ‘at least one vessel present within 7 km’.
8) Whether hunting occurred within a pre-defined window prior to a sighting — categorical variable with two categories: ‘hunting occurred’ and ‘no hunting occurred’. For both RAD and behaviour and composition analyses, 70 minutes was selected as the pre-sighting cut-off limit for a hunting activity, as detailed in Section 5.4.1.5.
9) Year — categorical variable with six categories: 2014, 2015, 2016, 2017, 2019, and 2020.
10) Day of year — continuous variable, where January 1 of each year is assigned a value of 1. Only used for RAD analysis, since preliminary visual data assessments did not identify relationships between group composition and behaviour response variables and day of year.
11) Stratum – categorical variable (A to J), only used for RAD analysis.

12) Substratum – categorical variable (1, 2, or 3), only used for RAD analysis. Note that substratum was not nested within stratum, since substratum was treated as a proxy for distance between observer and each sampled substratum.

The effects of day of year, time since last shooting event, and distance between vessels and centroids were expressed as polynomials whenever necessary, as determined by visual examination of the data and preliminary modelling. All polynomial terms were modelled as orthogonal, rather than raw polynomials, to assist with numerical stability; hence, the coefficients reported for polynomial model effects are not directly interpretable. The list of fixed effects and their degrees of freedom are provided in the results of each component for transparency. All continuous variables were standardized by subtracting the mean and dividing by the standard deviation of the variable.

5.4.2.3 Narwhal Density Modelling

Narwhal RAD data collected in the SSA were analyzed as the total density of narwhal observed in each substratum during each RAD survey completed across six years of sampling. The generalized mixed linear model with a zero-inflation component evaluated how the density of narwhal (accounting for the areas of individual substrata) was affected by the various predictor variables; the model contained an offset term of natural log-transformed substratum area, which allowed for the analysis of RAD data as a density, rather than simply analyzing numbers of narwhal per substratum. Predictor variables used for this analysis are listed in Section 5.4.2.2. The interaction between directional distance from vessel and whether the vessel was north- or southbound was not included in the model, due to problematic predictions observed during preliminary modelling. The effect of north- versus southbound vessel was still included in the model as a main effect, to assess whether vessel direction within Milne Inlet affects density of narwhal.

The selected modelling framework was a zero-inflated mixed effect negative binomial model with a random effect of day (where each sampling day within the six-year period had a unique value) and a spatial autocorrelation within each sampling day. The spatial autocorrelation approach used the built-in spatial autocorrelation structure provided by the glmmTMB package (Brooks et al. 2017), which used substratum centroid UTM positions to estimate the spatial autocorrelation between data points. The zero-inflation portion of the model was modelled to depend on stratum, substratum, sampling year, and Beaufort scale, thus reflecting the unequal distribution of zero counts of narwhal between different categories of these variables.

The selected analytical approach allowed for analysis of count data with a high occurrence of zeroes, while accounting for differences in sampling areas (i.e., areas of substrata) and specifying an explicit spatial autocorrelation — i.e., accounting for the fact that narwhal were not randomly distributed and that numbers of narwhal in adjacent substrata were likely more similar than numbers of narwhal in spatially segregated substrata. The model was used for inference of statistical significance based on *P* values of effects. Variable significance was assessed using type II *P* values (Langsrud 2003). Type III *P* values, which are commonly used in statistical analysis, allow for testing the statistical significance of main effects in the presence of significant interactions. However, when the interactions are significant, the effect sizes associated with the effects are of more interest than the *P* values of the main effects (e.g., Matthews and Altman 1996). In contrast, when the interactions are not significant, the type II tests have more power than type III tests (Lewsey et al. 2001). That is, a model with type II *P* values provides a more powerful test for main effects in the absence of a significant interaction, and no loss of information in the presence of a significant interaction, since the *P* values of the main effects are of no interest. In addition to testing of model effects using Type II *P* values, model coefficients were also reported (using treatment contrasts), which allows assessment of each slope relative to the intercept.

For effects that were found to be statistically significant, population-level model predictions (i.e., model prediction for a typical survey day) were plotted against observed data to visualize the estimated relationships between narwhal counts and the various explanatory variables. Since the model contained multiple predictor variables, the visualization of predictions relative to specific variables of interest required setting the other predictor variables to a constant value. These predictor values were selected based on observed numbers of narwhal (so that narwhal counts were close to the overall mean of narwhal/substratum values), frequency of occurrence (e.g., the majority of the data were collected in the absence of vessels or shooting events), or, when possible, their average values. The following predictor values were used to visualize model predictions: stratum F, substratum 2, Beaufort scale of 2, survey year 2017, day of year 227 (15 August), tide level 'flood', and glare value 'N'.

If significant effects of distance from vessel were found, multiple comparisons (with Dunnett-adjusted *P* values) were performed to estimate at which distance the estimated response values became significantly different from values predicted when no vessels were present within 7 km. All comparisons were made using the package emmeans (Lenth 2020) in R v. 4.0.3 (R 2020).

All analyses were performed using the package glmmTMB (Brooks et al. 2017) in the statistical package R v. 4.0.3 (R 2020). Model fit was assessed via diagnostic and residual plots using the DHARMa package (Hartig 2019) in R v. 4.0.3 (R Core Team 2020).

5.4.2.4 Group Composition and Behaviour

The following sections describe the models used for group composition and behaviour data. For each group composition and behavioural response variable, if effects were found to be statistically significant, population-level model predictions (i.e., model prediction for a typical survey day) were plotted against observed data to visualize the estimated relationships between narwhal group composition and behaviour and the various explanatory variables. In cases where shipping effects were not statistically significant but effect sizes were large (and statistical power was low), predictions were still produced and plotted and results discussed. Since each model contained multiple predictor variables, the visualization of predictions relative to specific variables of interest required setting the other predictor variables to a constant value. Similar to RAD analysis, the following predictor values were used to visualize model predictions: Beaufort scale of 1, survey year 2017, tide level 'flood', glare value 'N', and a group size of 3 (mean value).

5.4.2.4.1 Group Size

The analysis of group size included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship, and since this relationship would not generally be expected). A generalized mixed linear model was used to estimate the effect of the various fixed variables on group size. Group size was assumed to have a truncated Poisson distribution (where truncation was necessary, since no zeroes were possible in the data), and a random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019-2020) was used to account for the inter-day variability in group sizes.

5.4.2.4.2 Group Composition

5.4.2.4.2.1 Presence of Calves or Yearlings

The analysis of presence of calves or yearlings in observed groups included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Group size was used as a covariate in the model. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on presence of calves or yearlings in the observed groups. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019-2020) was used to account for the inter-day variability in presence of calves or yearlings.

5.4.2.4.3 Group Spread

The analysis of group spread (loose vs tight groups) included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Group size was also used as a covariate, however it was changed from a continuous variable (number of individuals in a group) to a categorical variable – whether the group size was 2 individuals or >2 individuals. This change was made because groups of two individuals were often mom-calf pairs that were in a tight spread, and an increase from a group size of two individuals to a group size of three individuals resulted in a marked increase in the proportion of loose groups. On the other hand, further increases in group size did not have an effect on the proportion of groups in a loose formation. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group spread. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019-2020) was used to account for the inter-day variability in group spread.

5.4.2.4.4 Group Formation

The analysis of group formation was simplified to a logistic regression by analysing whether the observed group formation was parallel or not (instead of analysing each individual observed formation). Since parallel formation was by far the most common (63% of all data), the parallel formation was assumed to be the baseline formation. Therefore, the logistic analysis will provide insight into the effect of the predictor variables and deviations from the baseline parallel formation.

The analysis of group formation included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Group size was also used as a covariate. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group formation. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019-2020) was used to account for the inter-day variability in group formation.

5.4.2.4.5 Group Direction

The analysis of group direction was simplified to a logistic regression by removing cases of west- or east-travelling groups (a total of 177 groups representing 3% of the data). The resulting dataset contained only north- or south-travelling groups. The analysis of group direction included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship), as well as effects of glare and Beaufort. The inclusion of glare and Beaufort in previous analyses (Golder 2020c) did not indicate a meaningful relationship, and the variables were found to increase uncertainty in predictions. In addition, it was not deemed likely that glare and sea state would consistently affect the observers' ability to record group direction. Group size was also used as a covariate. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group direction. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019-2020) was used to account for the inter-day variability in group direction.

5.4.2.4.6 Travel Speed

The analysis of travel speed was performed using a logistic model of slow vs medium speeds. Medium travel speeds were assumed to be the baseline values since medium travel speeds were the most common (57% of the data). A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group travel speed. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019-2020) was used to account for the inter-day variability in speed. The analysis of travel speed included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship), in addition to group size that was used as a covariate.

5.4.2.4.7 Distance from Bruce Head Shore

The analysis of whether narwhal groups were close to shore (<300 m) or far from shore (>300 m) included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Group size was also used as a covariate. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group distance from shore. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017 and 2019-2020) was used to account for the inter-day variability in distance from shore.

5.4.2.5 Power Analysis

To assess the statistical power of the analyses performed in this report, a separate power analysis was performed for each model. The power analysis was performed using simulations that quantified the relevant model's statistical power to detect various effect sizes. The resulting power curves were presented for each model. Refer to APPENDIX B for detailed methods and results of the power analysis.

5.4.3 Focal Follow (UAV) Analysis

Group composition and behavioural data collected for each focal follow survey was entered into a database in 30 second segments. Similar to the group composition and behavioural data collected by shore-based observers in the BSA, response variables considered in the focal follow analysis included group composition, group spread, group formation, and primary behaviour (i.e., travelling, milling, etc.). In addition, the orientation of the focal group was documented, as well as the relative and distal position of all calves and yearlings in relation to the adult female (i.e., presumed mother) with which they were associated. One of the motivating factors in assessing position of immatures relative to the adult female was to assess whether certain positions may be utilized more readily in response to a perceived threat. Unique behaviours such as nursing, scanning, rubbing, and rolling (either vertically in the water column or horizontally) were also documented in 30 second segments.

The sample size of focal follows in the presence of shipping (16 out of a total of 84 focal follows) was insufficient for a meaningful statistical analysis of behavioural response to vessel traffic. Therefore, analysis of the focal follow data was qualitative only. The data were summarized using visual plots and summary statistics for each focal follow. Vessel presence (i.e., vessels visible from the observation platform) is shown on each plot. The track of each focal follow conducted in the presence of a vessel was also mapped individually, detailing the location of the vessel relative to the focal group, as well as distance at the closest point of approach (CPA). Should the sample size be increased through additional UAV surveys in future monitoring years, focal follow data will be analysed similarly to shore-based data, using linear and generalized mixed linear models.

6.0 RESULTS

6.1 Observational Effort and Environmental Conditions

Each yearly monitoring program at Bruce Head (2014–2017 and 2019-2020) was timed to extend over an approximate four-week period, coinciding with the open-water season (Table 6-1; Figure 6-1). In general, the study area was ice-free during each annual program, with occasional presence of drifting ice floes in the SSA. Survey effort varied between years (Table 6-1), largely due to changing weather conditions and the number of monitoring shifts used each year. For example, survey effort was lower in 2017 than in previous years due to only having a single 10-h monitoring shift per day, while previous years consisted of two daily rotating 8-h shifts. In 2019, two daily shifts were resumed, with each team monitoring for 8 h (16 hours total).

Table 6-1: Number of narwhal and vessel transits recorded during RAD survey effort (2014–2017 and 2019-2020)

Statistic	Survey year						Total
	2014	2015	2016	2017	2019	2020	
Shipping season extent	08 Aug–03 Sep	03 Aug–04 Sep	28 Jul–03 Sep	02 Aug–17 Oct	18 Jul– 30 Oct	05 Jul– 15 Oct	-
Survey dates	03 Aug–05 Sep	29 July–05 Sep	30 July–30 Aug	31 July–29 Aug	06 Aug–01 Sep	07 Aug–01 Sep	-
No. of active survey days	23	29	27	26	26	26	131
No. of survey days lost to weather	14	9	11	2	3	0	36
No. of observer hours (total)	103.2	148.7	159.3	97.3	151.5	193.0	853.0
Average daily survey effort (h)	7.8	10.8	11.9	6.2	11.1	13.6	9.3
No. of attempted RAD surveys	179	314	321	160(1)	288	353	1,327
No. of complete RAD surveys	166	313	311	109	169	206	1,274
Number of RAD surveys with 0 narwhal counts(2)	74	164	127	35	71	236	471
No. of narwhal (total)	10,463	14,599	28,309	11,862	19,210	9,047	93,490
No. of narwhal excluding 'impossible' sightability	10,463	14,599	28,309	11,831	19,200	9,047	93,449
No. of narwhal excluding 'impossible' sightability, standardized by effort (total narwhal / total h)	101.4	98.2	178.0	121.8	126.7	47.5	128.3[4]
No. of vessel transits during RAD effort	7	11(3)	21(3)	22	32(3)	42	135
No. of RAD surveys with >1 vessel transiting	2	0	3	4	11	3	23

(1) = one survey out of the total 160 surveys was omitted from all other counts and analyses due to high chance of double-counting animals. All other values shown for 2017 in this table and elsewhere exclude this survey.

(2) = non-complete surveys were included in this calculation

(3) = counts of vessel transits differ from those presented in Table 6-2 due to transits occurring outside of a RAD count or the vessel being farther than 7 km from relevant substrata during the RAD count.

(4) Total number of observed narwhal, divided by total effort

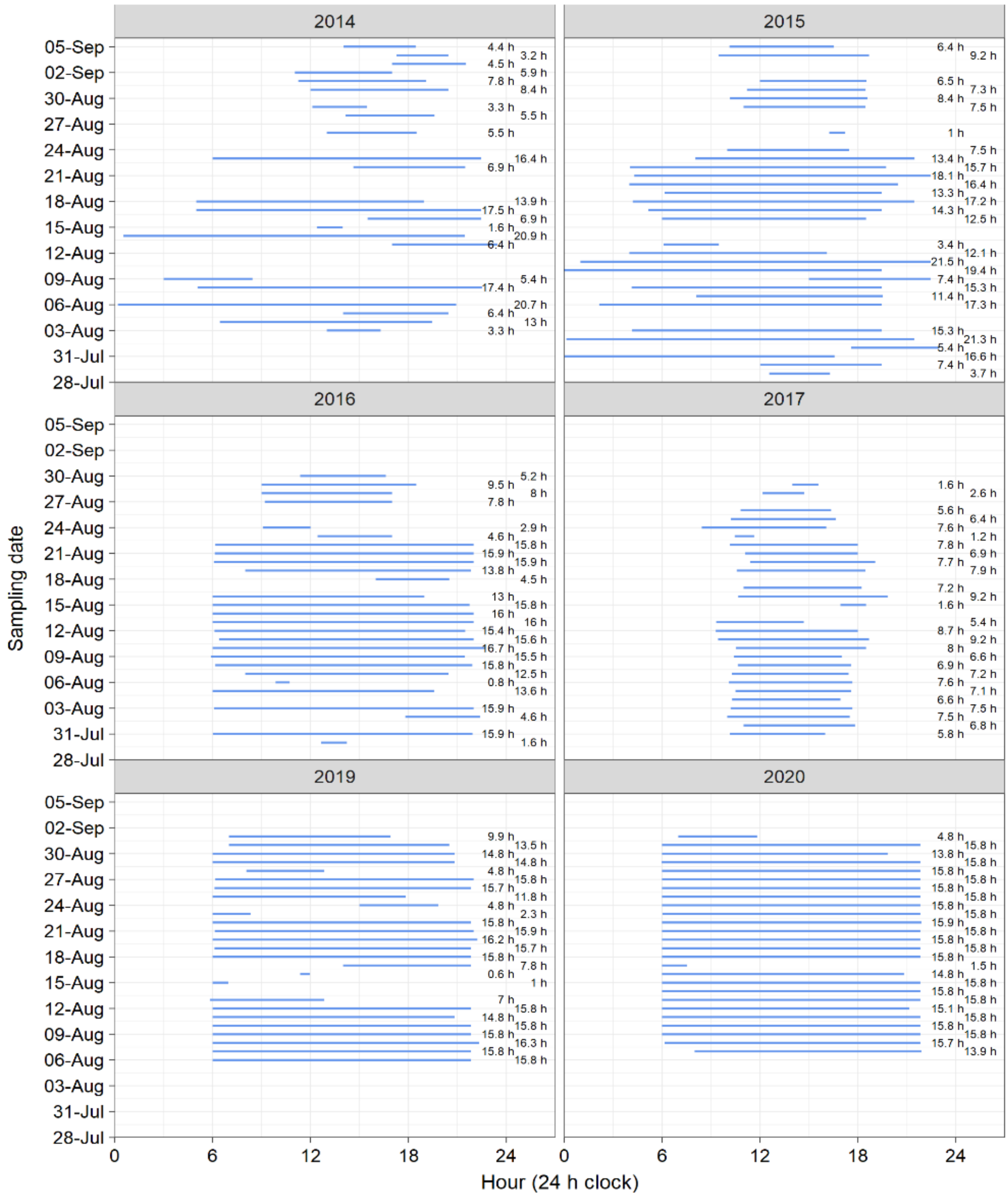


Figure 6-1: Observer effort (h) by survey day (2014–2017, 2019-2020); lines extend from first to last observations made within each day.

Across the six years of data collection, sightability was shown to decrease with increasing wind levels, and with increasing stratum distance relative to the observation platform (e.g., substratum 3 was generally associated with reduced sightability compared to substratum 1; Figure 6-2). All sightings made during ‘impossible’ sighting conditions or during wind conditions of Beaufort value 6 or higher were removed from the multi-year analysis, equivalent to 1,347 rows of RAD data (3.1% of the total 2014–2017 and 2019-2020 dataset).

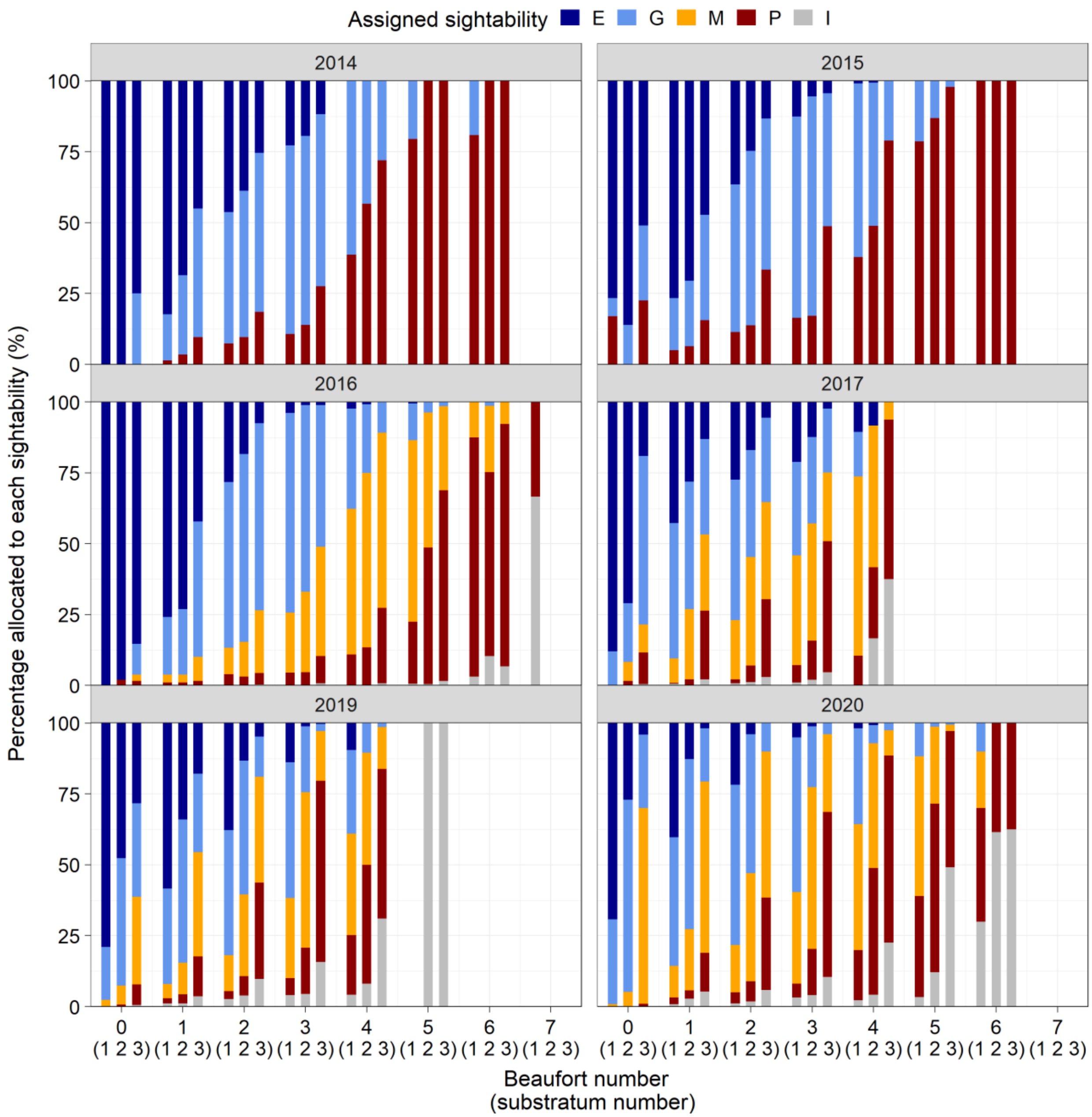


Figure 6-2: Sightability conditions during the 2014–2017 and 2019-2020 RAD surveys in the SSA based on Beaufort Wind Scale and substratum location (plotted by year): Excellent, Good, Moderate, Poor, Impossible

6.2 Vessel Transits and Other Anthropogenic Activity

6.2.1 Baffinland Vessels and Other Large/Medium-Sized Vessels

The total number of one-way vessel transits that entered the SSA during the full shipping season and during the Bruce Head study period each year is summarized in Table 6-2 and Figure 6-3. In 2020, sighting data were recorded during 75% of all vessel transits that occurred during the study period and consisted primarily of Project-related bulk (ore) carriers (25 unique vessels, 42 one-way transits; Table 6-2; APPENDIX C). Ore carriers accounted for 59%, 77%, 73%, 83%, and 80% of total one-way transits in 2015, 2016, 2017, 2019, and 2020, respectively (no ore carriers were present in 2014). Other large Project-related vessels included general cargo vessels and fuel tankers. No passenger vessels were recorded in the SSA in 2020.

Recorded tracklines of all vessel transits through the SSA during the full extent of the shipping seasons (2014 – 2017 and 2019-2020) are presented in Figure 6-4. Recorded track lines of vessel transits during the 2020 survey period specifically are presented in (Figure 6-5).

Table 6-2: Number of vessel transits in SSA per survey year

Survey Year	No. of 1-way Transits in SSA (No. of Project-related Transits)		No. and (%) of 1-way Transits Recorded by Observers during Bruce Head Survey Period
	Full Shipping Season	During Bruce Head Survey Period	
2014	13 (5)	13 (5)	7 (54%)
2015	22 (20)	22 (20)	13 (59%)
2016	56 (49)	47 (40)	24 (51%)
2017	154 (150)	59 (55)	22 (37%)
2019	240 (238)	75 (73)	41 (55%)
2020	188 (188)	56 (56)	42 (75%)
Total	485 (462)	216 (193)	149 (69%)

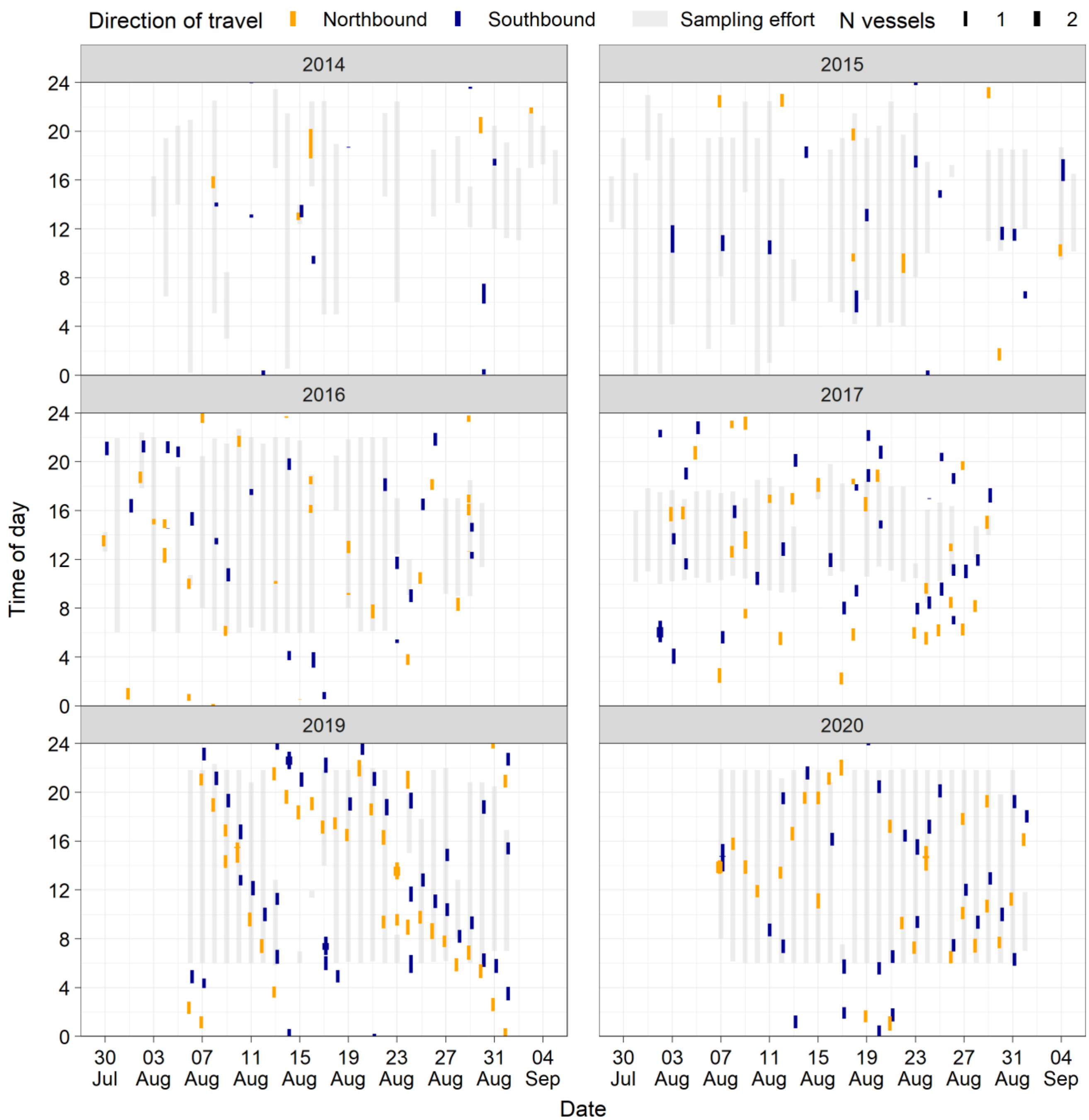
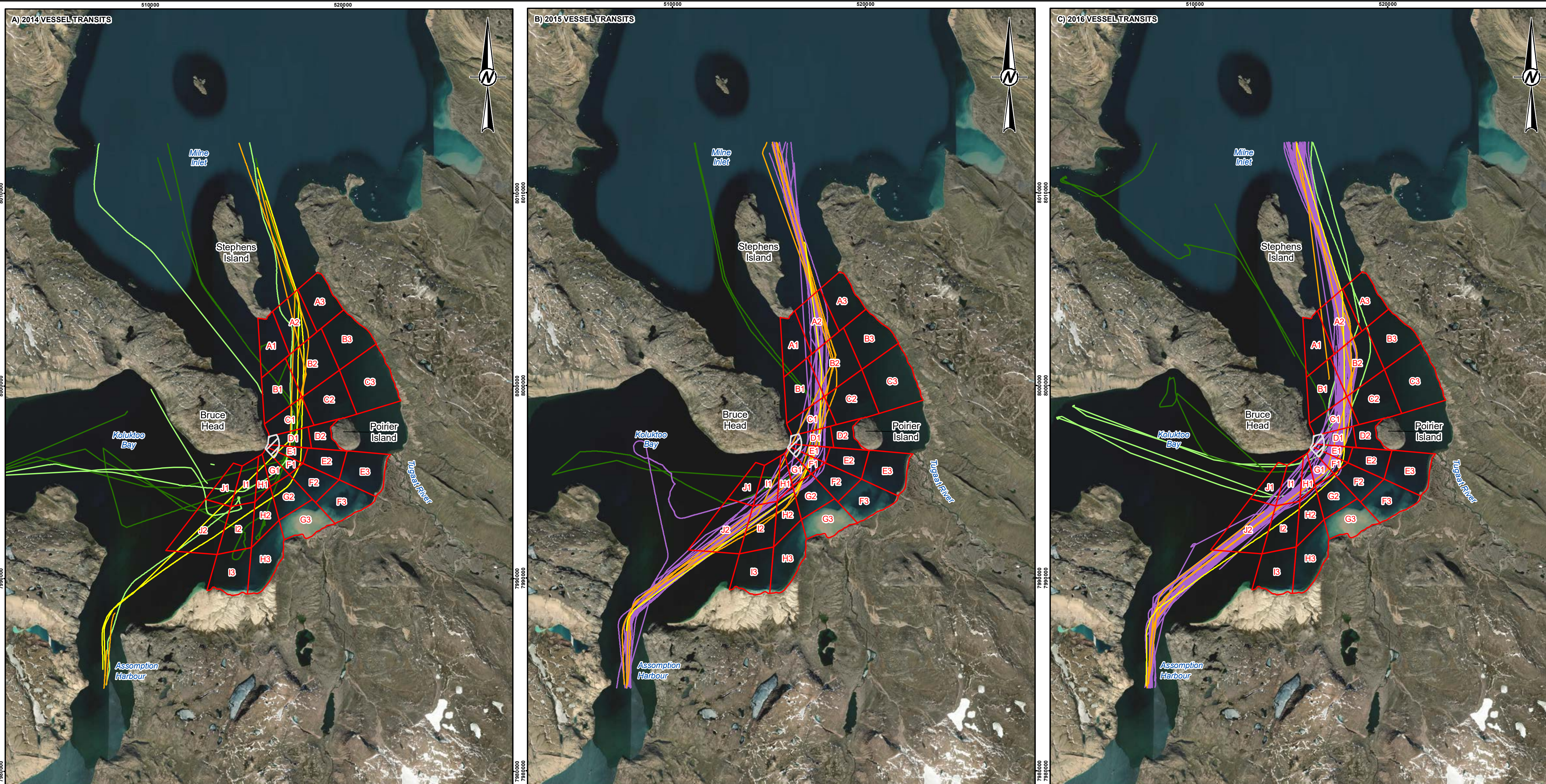


Figure 6-3: Daily summary of vessel transits in SSA with associated survey effort. Grey boxes indicate daily monitoring periods and correspond to observer survey effort shown in Figure 6-1; grey boxed extend from first to last observations made within each day.



LEGEND

WATERCOURSE

VESSEL TRANSIT ROUTES BY LENGTH AND CLASS

LARGE VESSELS

- BULK (ORE) CARRIER
- CARGO CARRIER
- FUEL TANKER
- ICE BREAKER
- OTHER (NON-PROJECT RELATED)

MEDIUM VESSELS

- CARGO CARRIER
- ICE BREAKER
- OTHER (NON-PROJECT RELATED)

BEHAVIOURAL STUDY AREA (BSA)

STRATIFIED STUDY AREA (SSA) SUBSTRATA

WATERBODY

0 5 10

1:200,000 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. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

MARY RIVER PROJECT

CONSULTANT

GOLDER

MEMBER OF WSP

YYYY-MM-DD	2021-04-21
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

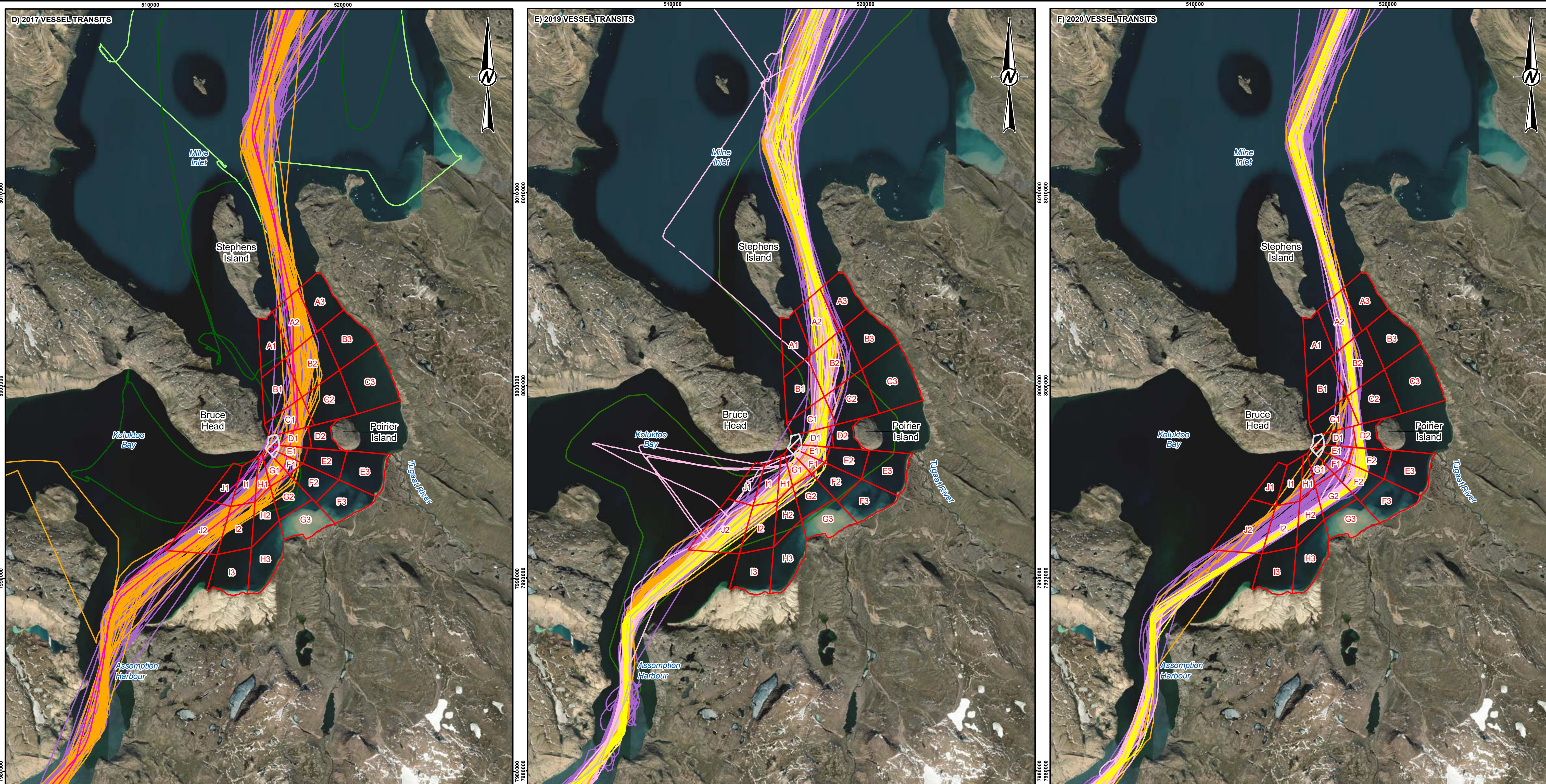
TITLE

TRACKLINES OF LARGE AND MEDIUM VESSEL TRANSITS IN SSA (2014-2017, 2019 AND 2020) DURING FULL SEASON SHIPPING

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-05	0	6-4A

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

25mm



LEGEND

WATERCOURSE

VESSEL TRANSIT ROUTES BY LENGTH AND CLASS

LARGE VESSELS

- BULK (ORE) CARRIER
- CARGO CARRIER
- FUEL TANKER
- ICE BREAKER
- OTHER (NON-PROJECT RELATED)

MEDIUM VESSELS

- CARGO CARRIER
- ICE BREAKER
- OTHER (NON-PROJECT RELATED)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA
- WATERBODY

0 5 10

1:200,000 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. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

MARY RIVER PROJECT

CONSULTANT

GOLDER

MEMBER OF WSP

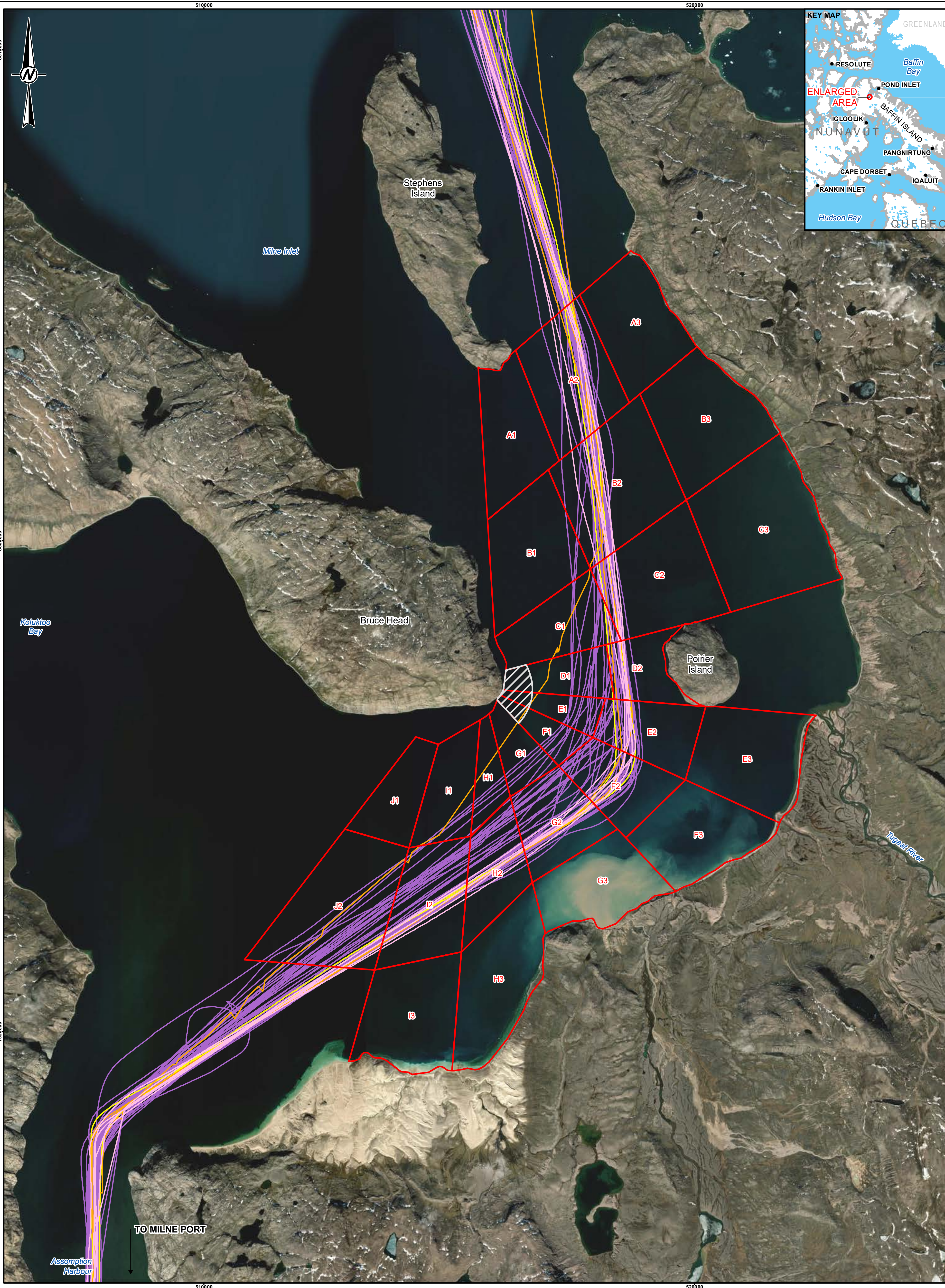
YYYY-MM-DD	2021-04-21
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

TITLE

TRACKLINES OF LARGE AND MEDIUM VESSEL TRANSITS IN SSA (2014-2017, 2019 AND 2020) DURING FULL SEASON SHIPPING

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-05	0	6-4B

PATH: I:\2016\1663724\Mapping\MXD\33000_UAV_Program\1663724_33000_05_Fig6_05_2020Vessels_SamplingPeriod_Rev0.mxd PRINTED ON: 2021-04-21 AT: 3:27:10 PM



LEGEND

WATERCOURSE

LARGE VESSELS

BULK (ORE) CARRIER

CARGO CARRIER

FUEL TANKER

MEDIUM VESSELS

ICE BREAKER

BEHAVIOURAL STUDY AREA (BSA)

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, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

MARY RIVER PROJECT

TITLE

TRACKLINES OF LARGE AND MEDIUM VESSEL TRANSITS IN SSA DURING 2020 SURVEY (6-31 AUG 2020)

CONSULTANT

GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-04-21
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-05	0	6-5

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

25mm

Vessel speeds were plotted by vessel type for each year (Figure 6-6). As part of Baffinland's vessel management practices, a maximum vessel speed limit of nine knots along the Northern Shipping Route is enforced. Of the 45 ore carrier transits recorded in the SSA during the 2020 survey period, only 4 ore carriers (9%) transited at speeds ≥9 knots and only one ore carrier transit (2.2%) exceeded 10 knots.

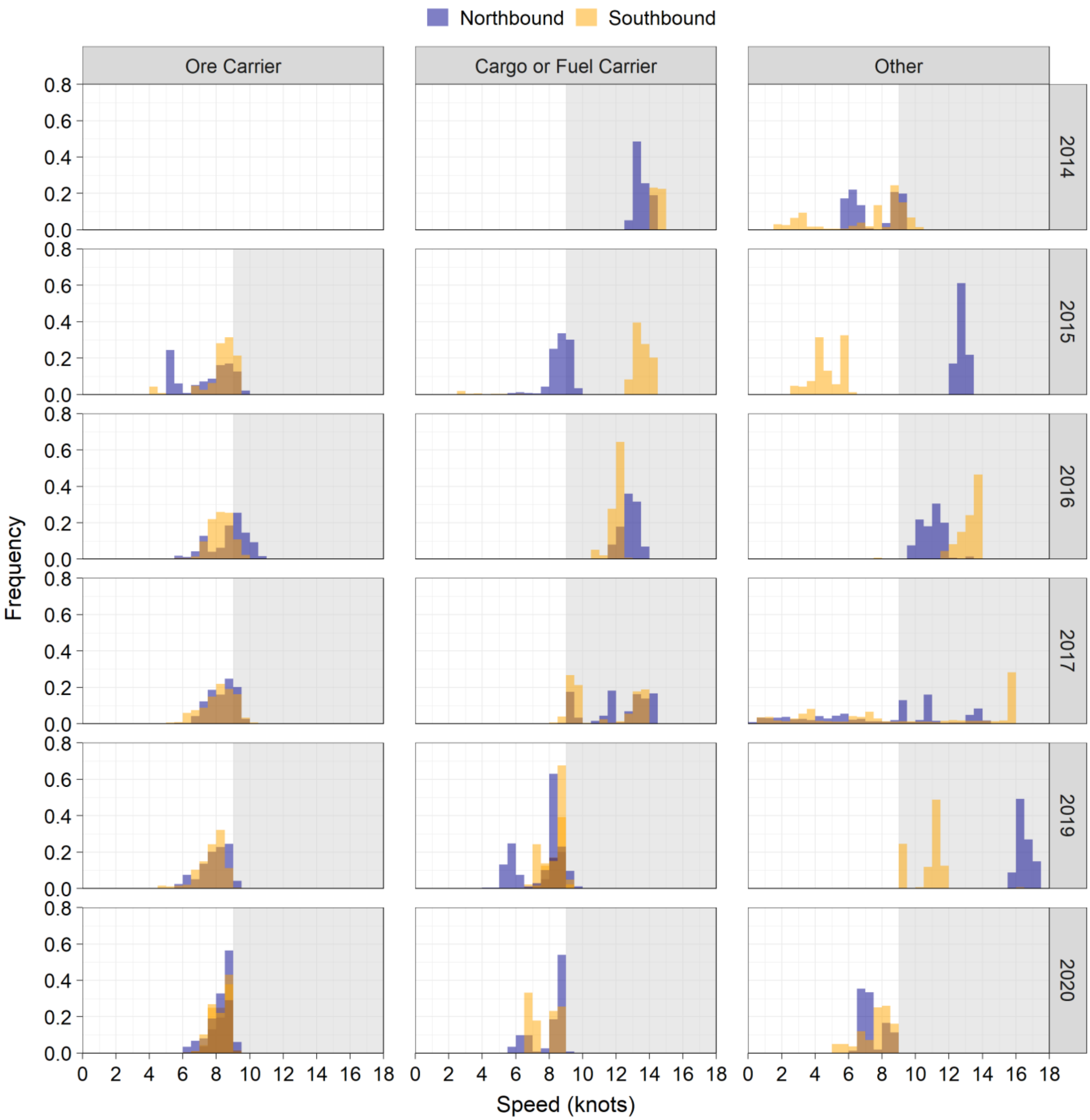


Figure 6-6: Travel speed (knots) of all vessels in the SSA during the 2014–2020 survey periods. Shaded area represents speeds >9 knots

6.2.2 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. During the 2020 field program specifically, the hunting camp was visited or occupied by local hunters for the majority of the study period.

The majority of RAD surveys were performed more than 70 minutes after the last shooting event (81-96% of surveys; Figure 6-7). Where hunting occurred within 70 minutes prior to surveys, 2-16% of the surveys were performed within 10 minutes after a shooting event, depending on year. Important to note, however, is that monitoring of hunting activity for the full extent of the day (i.e., 24 h) only occurred in 2019 and 2020, with the introduction of in-air acoustic recorders set up above the hunting camp for the purpose of continuously recording all shots fired over the course of the study period.

Generally, shooting events targeted either narwhal or seal. However, hunters were often observed firing rounds straight over the water (with rounds landing on the opposite side of transiting narwhal), with the intent of displacing animals inshore so they would approach closer to the hunters along the Bruce Head shoreline.

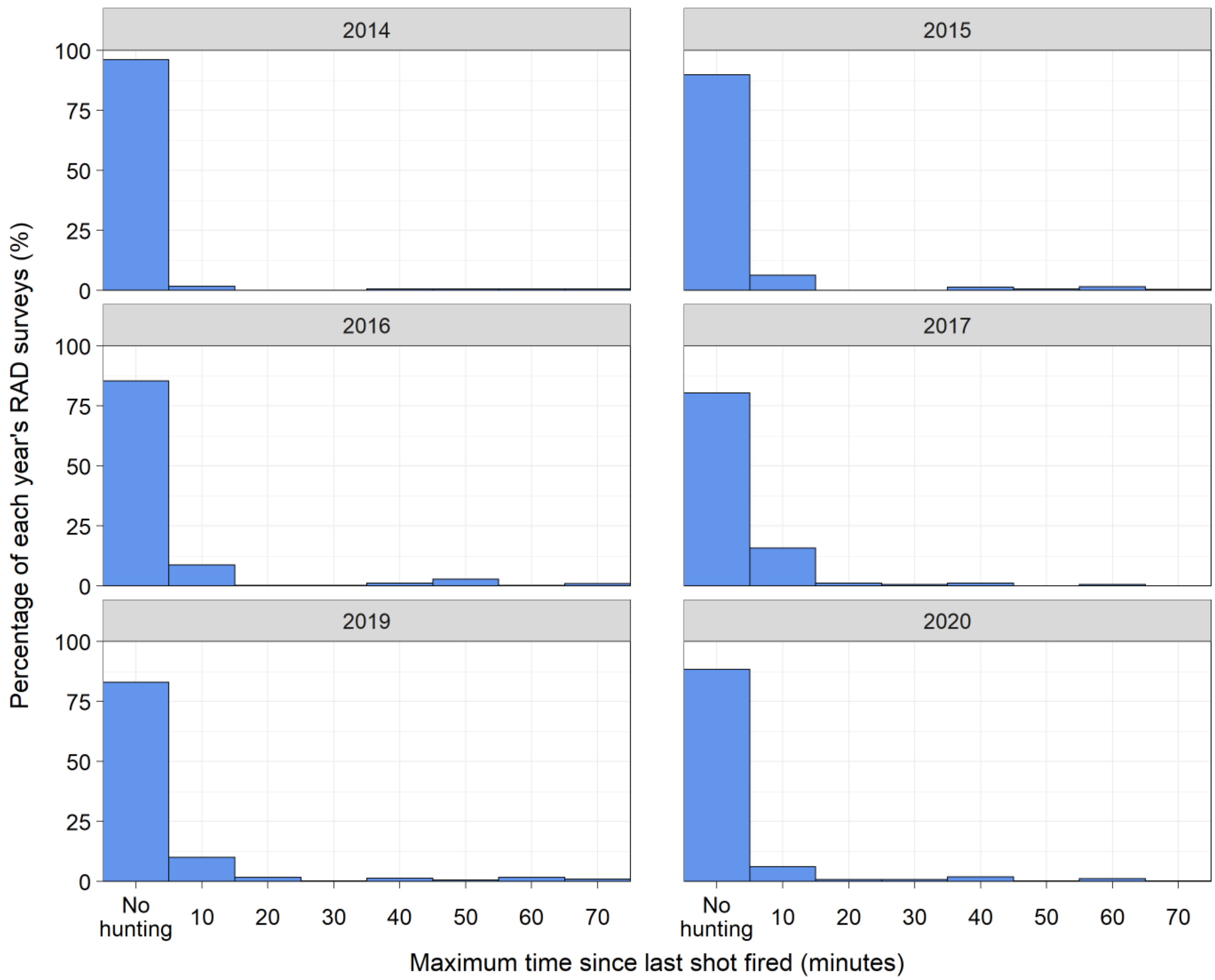


Figure 6-7: Distribution of each year's minimum time since shooting occurred, calculated for each RAD survey.

6.3 Relative Abundance and Distribution

A total of 353 RAD surveys were completed over the course of 26 days between 7 August and 1 September 2020. A summary of the 2020 RAD data, compared to that collected from 2014 to 2020, is included in Table 6-1. Similar to previous years, narwhal were the most common cetacean species recorded at Bruce Head in 2020. Less common cetacean sightings recorded during 2020 included killer whale (multiple sightings), bowhead whale (n=3), and beluga (n=1). The total number of narwhal recorded (corrected for effort) in 2020 was much lower than that reported in previous survey years (Table 6-1; Golder 2019).

Over the six years of data collection, the number of RAD surveys completed per year ranged from 160 in 2017 to 353 in 2020 (Table 6-1). Where surveys were incomplete (e.g., at least one of the substrata had an impossible sightability or some of the substrata were not surveyed due to inclement weather), only the affected substrata were removed from analysis. That is, all substrata that were successfully surveyed, excluding those associated with impossible sightability, were included in the analysis. The average daily effort for RAD surveys ranged from 6.2 h in 2017 to 13.6 h in 2020. The lower number of RAD surveys in 2017 reflected a reduction in survey effort that year (one observation shift vs. two rotating observation shifts). Analysis of the RAD data excluded sightings made during ‘impossible’ sightability conditions and excluded an entire RAD survey conducted on 11 August 2017 in which observations were recorded in the same direction as a herding event and therefore had high potential of double-counting animals.

A total of 93,449 narwhal were recorded in the SSA over six years of data collection (Table 6-1). Annual numbers of narwhal recorded ranged from 9,047 (2020) to 28,309 (2016), reflecting both narwhal density and level of survey effort. When standardized by effort (i.e., number of narwhal observed per RAD survey divided by length of survey [h]), the annual mean ranged from 43.1 narwhal/h in 2020 to 156.4 narwhal/h in 2016 (Figure 6-8). Since mean values were strongly influenced by both surveys with zero narwhal observed and with very high numbers of narwhal observed (as recorded in 2016; Figure 6-8), median values were also calculated. Median values of standardized counts ranged from 12.6 narwhal/h in 2020 to 106 narwhal/h in 2017.

Daily standardized number of narwhal (narwhal/h) were bimodal in 2014, with an initial peak (503 narwhal/h) observed on 16 August and a second peak (272 narwhal/h) observed on 31 August (Figure 6-8). In 2015, daily standardized numbers of narwhal were generally low (20 out of 29 survey days with values <70 narwhal/h). However, there were multiple days in 2015 (six days in August and one day in September) with relatively high standardized numbers of narwhal (>150 narwhal/h). In 2016, daily standardized numbers of narwhal observed were similar to 2014, with multiple days having high numbers of narwhal observed (>150 narwhal/h), with an initial peak in mid-August (205-406 narwhal/h) and a second peak in late August (150-820 narwhal/h). In both 2017 and 2019, no counts >400 narwhal/h were recorded. In 2020, three peaks in numbers of narwhal were recorded: 9 August (142 narwhal/h), 22 August (183 narwhal/h), and 29 August (153 narwhal/h). Daily numbers of narwhal in 2020 were the lowest observed since sampling began in 2014 (Figure 6-8).

In all monitoring years, numerous RAD surveys were conducted in which no narwhal were observed (see Table 6-1). The proportion of zero-count RAD surveys varied from 41% of RAD surveys in 2014 to 52% in 2015, 41% in 2016, 22% in 2017, 25% in 2019, and 67% in 2020. This variation strongly affected annual median values. Median daily standardized numbers of narwhal ranged from 12.6 narwhal/h in 2020 to 106.0 narwhal/h in 2017 (Figure 6-8).

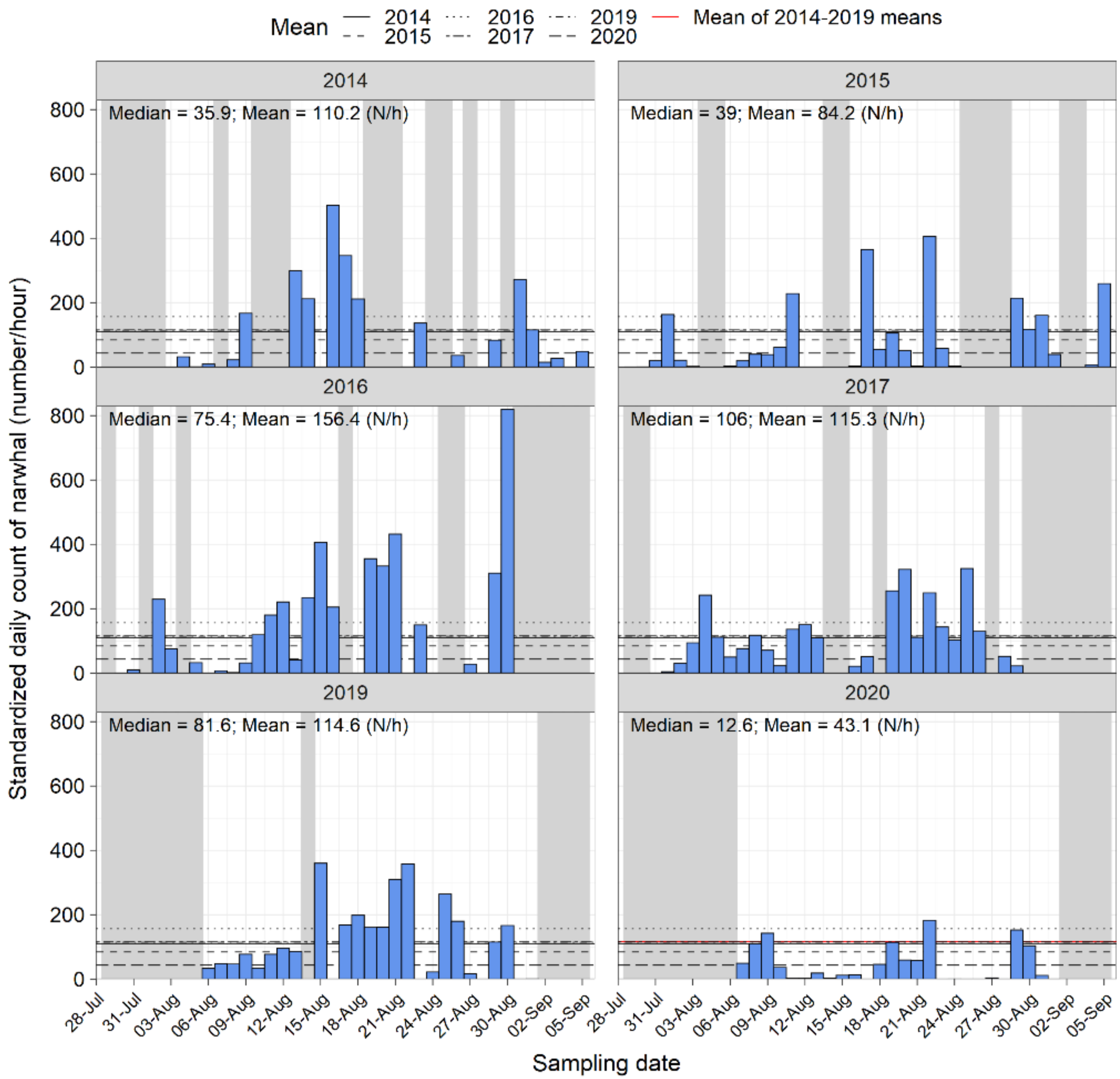


Figure 6-8: Standardized daily numbers of narwhal recorded in the SSA from 2014–2020. Shaded area represents days where no data was collected.

In general, higher numbers of narwhal were recorded in the southern strata (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020c). In each survey year, strata G, H, and I possessed the highest proportion of narwhal (Figure 6-9), accounting for 62–72% of total narwhal recorded in 2014–2017, 57% of total narwhal recoded in 2019 and 47% of total narwhal recorded in 2020 (influenced by the introduction of new stratum J in 2019). Stratum J accounted for 23% of the total narwhal recorded in both 2019 and 2020. In comparison, strata A, B, and C only accounted for 5–11% of total narwhal recorded in 2014-2020. Number of narwhal recorded also varied with substratum distance from the observation platform (Figure 6-9). Each year, substratum ‘2’ had the highest proportion of total narwhal recorded, accounting for 48–56% of total annual narwhal observations.

In addition to stratum and substratum, sightability also affected number of narwhal recorded (Figure 6-9). Number of narwhal recorded per RAD survey were considerably higher during periods when sightability was considered ‘excellent’ and ‘good’, with number of narwhal recorded during ‘excellent’ sightability ranging between 5 narwhal/survey in 2020 and 63 narwhal/survey in 2016 and number of narwhal recorded during ‘good’ sightability ranging from 16 narwhal/survey in 2020 to 42 narwhal/survey in 2016. In comparison, number of narwhal recorded during ‘moderate’ sightability ranged from 8 narwhal/survey in 2020 to 23 narwhal/survey in 2017 (‘moderate’ sightability was not recorded before 2016) and, during ‘poor’ sightability conditions, from 1 narwhal/survey in 2020 to 19 narwhal/survey in 2014 (before ‘moderate’ sightability was used and thus when ‘poor’ sightability also likely included some ‘moderate’ conditions).

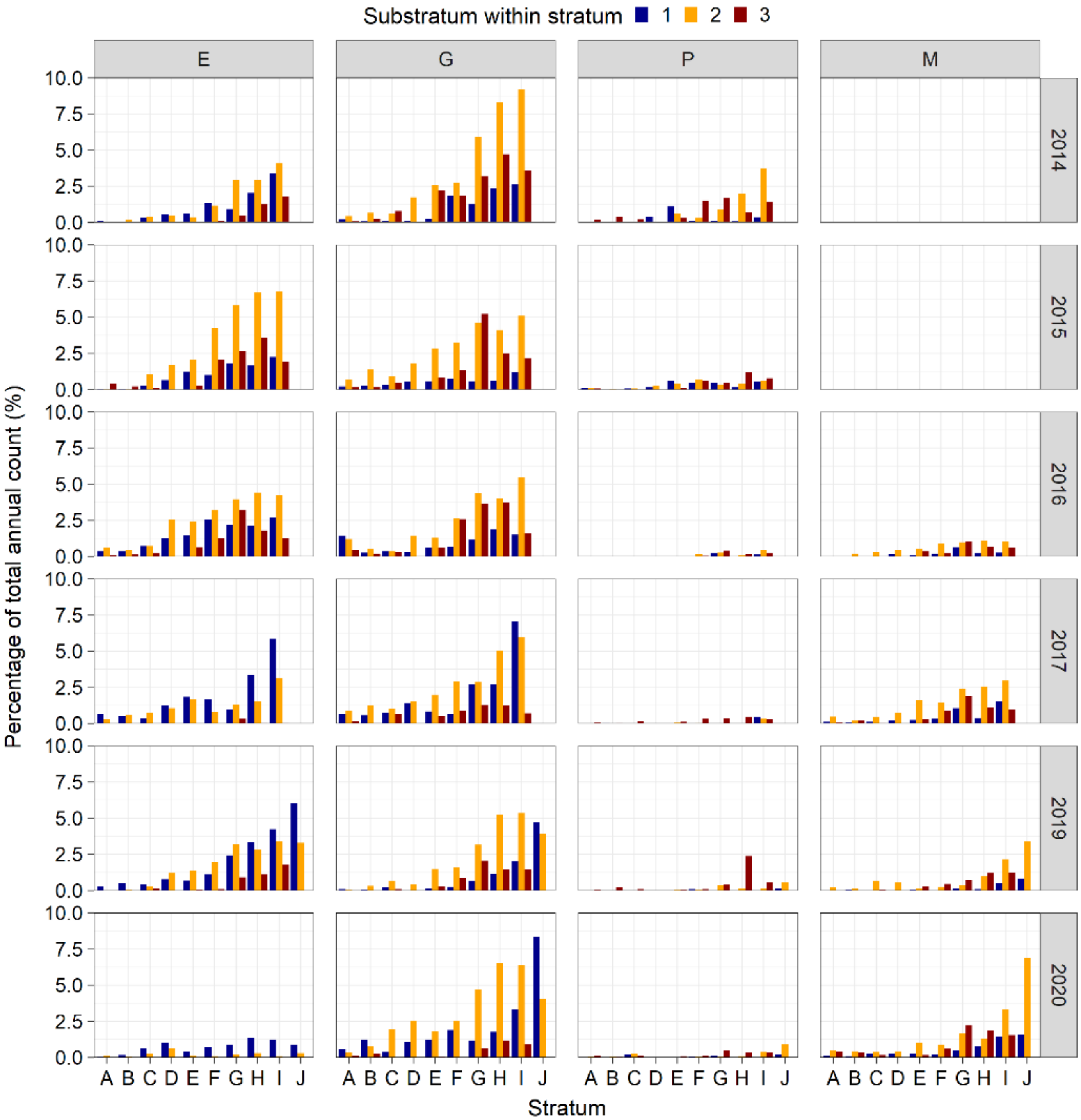


Figure 6-9: Percentage of narwhal counted in each substratum and sightability out of total narwhal counted in 2014-2017, 2019-2020 (sightability categories were: E = excellent, G = good, M = moderate, P = poor).

The proportion of narwhal observed in the presence of at least one vessel (i.e., within 7 km of the substratum centroids) increased from 2.9% in 2014 to 5.1% in 2015, 6.4% in 2016, 12.4% in 2017, 15.4% in 2019, and 13.5% in 2020. Of the narwhal recorded during periods when a single vessel was within 7 km, the majority were recorded when vessels were northbound (97.9%, 61.2%, 84.0%, 60.1%, and 59.0% in 2014–2017 and 2020, respectively), with the exception of 2019, in which 41.7% of narwhal were recorded when vessels were northbound.

In the combined multi-year RAD dataset, the majority of narwhal were recorded when no vessels were present (n = 36,558 surveys of individual substrata, with 82,407 individuals counted), with a mean of 2.3 narwhal per substratum and a mean density of 0.9 narwhal/km² (Figure 6-10). During periods of single vessel exposure (single vessel ≤7 km), a total of 3,742 surveys of individual substrata were recorded, with 8,283 individuals (mean of 2.2 narwhal per substratum and a mean density of 1 narwhal/km²). In 2020, the mean number of narwhal per substratum during periods of single vessel exposure was 0.6 individuals, with a mean density of 0.2 narwhal/km².

During periods of multiple vessel exposure (two or more vessels ≤7 km), a total of 62 surveys of individual substrata, with 99 narwhal counted were recorded in the SSA throughout the six-year monitoring program (mean of 1.6 narwhal per substratum and a mean density of 0.4 narwhal/km²). In 2020, the mean number of narwhal per substratum during periods of multiple vessel exposure was 0.5 individuals, with a mean density of 0.1 narwhal/km².

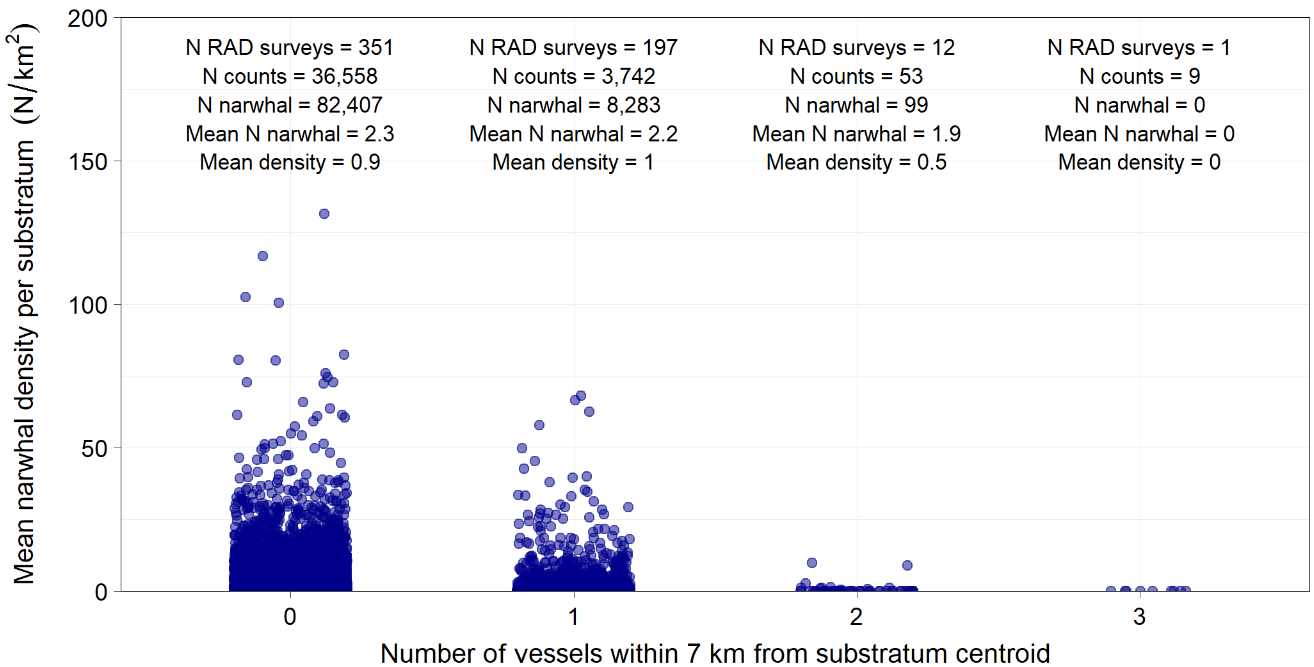


Figure 6-10: Summary of surveys conducted in the SSA relative to vessel exposure level (no exposure, single vessel, and multiple vessels within 7 km).

In summary, the overall relative abundance of narwhal in the SSA, inferred from sighting rate (no. of narwhal per hour - corrected for effort), has remained relatively constant between 2014 and 2019 despite a gradual increase in iron ore shipping along the Northern Shipping Route during this period. However, the relative abundance of narwhal in 2020 was lower than in previous years, although not significantly (at the 0.05 significance level). The observed finding of a lower relative abundance of narwhal at Bruce Head in 2020, coincident with the 2020 aerial survey results demonstrating a significant decrease in the abundance of the Eclipse Sound narwhal stock in the RSA, has triggered further detailed investigation into the root cause of this finding, and development of precautionary based mitigation measures for application in 2021, as described in Section 7.1 and in Golder (2021b). If found to be elicited by the Project, this finding is consistent with a high severity response, as defined by Finneran et al. (2017), and therefore has the potential to result in a significant alteration or abandonment of natural behavioural patterns by narwhal in the RSA. This finding would be contrary to impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Consistent with the definition of a significant effect used in the FEIS, large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses) could result in a population or stock-level consequence.

6.3.1 Narwhal Density Modelling

Of the total 40,362 surveys of individual substrata (excluding “impossible” sightability conditions and days when killer whales were present in south Milne Inlet), a total of 3,742 (9.3%) were associated with a single vessel exposure event, and a total of 62 cases (0.2%) were associated with a multiple vessel exposure event.

Based on the smoothing trend curve (i.e., not accounting for any other pertinent variables), an increase in narwhal density was often observed at vessel distances of 5-6 km (relative to the substratum), regardless of whether the vessel was moving toward the substratum or moving away from it (Figure 6-11). In the presence of southbound vessels, this effect was less pronounced, especially when the vessel was moving toward a substratum. Overall, the data suggest that narwhal density within the SSA was influenced by both ‘vessel travel direction’ (northbound vs. southbound) and ‘vessel orientation relative to substratum’ (moving towards vs. moving away), particularly for southbound vessels.

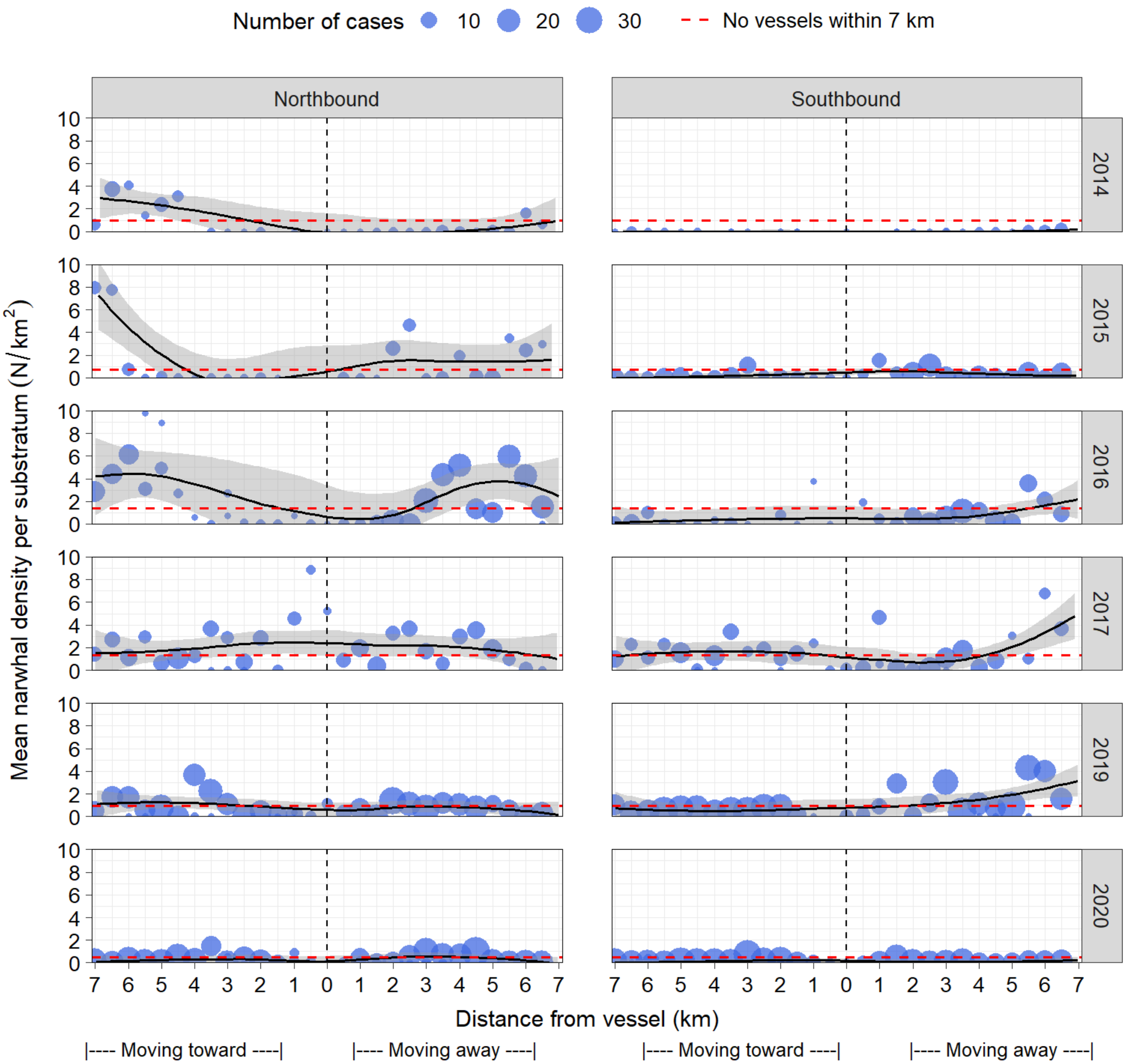


Figure 6-11: Mean narwhal density per substratum as a function of distance from vessel (rounded to 1 km), vessel travel direction, vessel orientation relative to substratum, and sampling year. Size of circle represents relative sample size. Horizontal lines depict mean density of narwhal per substratum during vessel non-exposure periods. Curve and confidence band represent a LOESS (locally estimated scatterplot smoothing) trend curve.

Test statistics and coefficient estimates for the narwhal density model are provided in APPENDIX D. Residual diagnostic plots are provided in APPENDIX E.

The full model had a zero-inflation component that depended on stratum, substratum, sampling year, and Beaufort scale. All four variables were significant predictors in the zero-inflation component of the model (P<0.001; APPENDIX D, Table D-1). This indicates that these three fixed effect predictors affect not only narwhal density, but also the probability of recording narwhal presence – whether due to sighting conditions (Beaufort scale effect and distance of the substratum), inter-annual variability (year effect) or spatial (stratum) distribution within the SSA.

Summary of observed data and model predictions for statistically significant variables are shown in Figure 6-12 and Figure 6-13. Note that probability values detailed below and shown as orange lines in Figure 6-12 and Figure 6-13 were estimated for a specific set of predictor values (Section 5.4.2.3), whereas the blue bars in Figure 6-12 and Figure 6-13 summarize the entirety of the collected data. This leads to some visual discrepancies between the observed and estimated values.

In the model of narwhal density, the effects of day of year, stratum, substratum, glare, Beaufort scale, tide, and hunting were statistically significant (P<0.001 for all; APPENDIX D, Table D-1). The effect of year was marginally significant (P=0.058). The effects of vessel were statistically significant – both the directional distance from vessel (P=0.019) and whether the vessel was north- or southbound (P=0.043). The model had sufficient power (>0.8) to detect a -65% or +85% effect size in the test of the overall effect of distance from vessel (APPENDIX B). Despite the low power to detect the effect sizes observed at 0 km, the analysis found a significant effect of vessel distance.

Mean narwhal density was estimated to increase throughout the strata, from the lowest estimate at stratum A to the highest estimate in strata I and J, as well as throughout the substrata, with the lowest estimate at substratum ‘3’ and the highest at substratum ‘2’ (Figure 6-12, panel A). For example, at the predictor levels used for visualization of model results (year = 2017, date = 15 August, Beaufort value of 2, glare = ‘none’, no vessels present within 7 km, and no hunting activity), narwhal predictions increased from 0.10 narwhal/km² in substratum A2 to 1.5 narwhal/km² in substratum I2. Similarly, for the same predictor values and for stratum F, narwhal density predictions increased from 0.35 narwhal/km² in substratum ‘3’ to 1.05 narwhal/km² in substratum ‘2’, and to 1.26 narwhal/km² in substratum ‘1’.

Mean narwhal density was estimated to decrease from 1.50 narwhal/km² and 1.48 narwhal/km² at Beaufort levels of 0 and 1, respectively, to 1.05 narwhal/km² and 0.70 narwhal/km² at Beaufort levels of 2 and 3, respectively, and to 0.53 narwhal/km² and 0.46 narwhal/km² at Beaufort levels of 4 and 5, respectively. Multiple comparisons between Beaufort scale levels indicated that narwhal density estimates were significantly higher at Beaufort levels of 0 and 1 than at increasing values of Beaufort scale (Figure 6-12). At Beaufort levels of 3, 4 and 5, recorded narwhal densities were lowest (and not significantly different from each other). These results indicate that Beaufort levels above 1 significantly affect the observers’ ability to sight narwhal, and that observations made at Beaufort levels of 3 or higher may strongly underestimate true numbers of narwhal in the SSA. Mean narwhal densities estimated under no glare, low glare, and severe glare were estimated to all be significantly different from each other, with densities under severe glare estimated to be the lowest (0.67 narwhal/km²) and densities under low glare estimated to be the highest (1.2 narwhal/km²; Figure 6-12).

Multiple comparisons between predictions at different tide levels suggested that mean narwhal densities were significantly different between high slack (0.97 narwhal/km²), ebb (1.2 narwhal/km²), and low slack (1.4 narwhal/km²) conditions, but not between high slack and flood conditions (Figure 6-12). The highest density of narwhal in the SSA occurred under low slack conditions. This differs from the results from previous monitoring years, where narwhal counts were reported to be highest during ebb conditions, and the remaining three conditions were not found to be significantly different from each other (Smith et al. 2017).

The effect of day of year (presented as date in Figure 6-12) was dome-shaped, with lower narwhal densities observed and predicted in the early and late season (mean predicted values of 0.07 narwhal/km² on 29 July and 0.25 narwhal/km² on 05 September of 2017), and higher mid-season (mean predicted value of 1.11 narwhal/km² on 21 August 2017). The effect of year was marginally significant (P=0.058) and observed data and predicted density values relative to sampling year were included in the RAD model plots (Figure 6-13). Prior to 2020, mean annual density ranged from 0.43 narwhal/km² in 2014 to 1.05 narwhal/km² in 2017. In 2020, mean annual density decreased to 0.14 narwhal/km², although this decrease was not significantly different from other sampling years (Figure 6-13).

Mean narwhal density was higher during hunting events (1.27 narwhal/km²) than during periods when no hunting occurred (1.05 narwhal/km²; Figure 6-13). Higher densities of narwhal observed following hunting activity were likely the cause, rather than the effect, of hunting.

Mean narwhal densities were lowest when a vessel was at close proximity to the substratum, with 0.74 narwhal/km² when a northbound vessel was at 0 km from the substratum and 0.62 narwhal/km² when a southbound vessel was at 0 km from the substratum (Figure 6-13). Mean narwhal densities were generally lower in the presence of a southbound vessel, compared to a northbound vessel. During vessel non-exposure periods, mean narwhal density was estimated to be 1.05 narwhal/km². With increasing distance from vessel (for both vessel moving toward and away from a substratum), narwhal density increased, peaking at 5.5 to 7.0 km from a vessel. Mean narwhal densities were significantly lower when a northbound vessel was at 0 km, or the vessel was at 2 km and moving away from the substratum, compared to non-exposure periods (Table 6-3). For southbound vessels, mean narwhal densities were significantly lower when a vessel was within 3 km and moving toward the substratum and when a vessel was within 4 km and moving away from the substratum. At farther distances, mean narwhal densities were not different from the vessel non-exposure period.

In summary, vessel exposure was shown to result in a significant decrease in narwhal density in the SSA compared to when no vessels were present, but only when narwhal were exposed to vessels at distances up to 4 km. This would be equivalent to a total exposure period of 29 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behavior following the exposure period (temporary effect). During the 2020 Bruce Head program (Aug 07 to Sept 01), there were approximately 2 transits per day in the SSA (56 one-way transits in SSA over a 26-day period). The daily vessel exposure period for narwhal was therefore equivalent to approximately 1 hour. On a heavy vessel day (assuming 4 transits per day), the daily vessel exposure period would be on the order of 2 hours.

These findings are consistent with previous years' findings and with behavioural results from the narwhal tagging study (Golder 2020a), indicating that narwhal density in the SSA is influenced by vessel traffic at close distances (i.e., within 4 km of a vessel). Localized avoidance of the sound source (i.e., the vessel) by narwhal is indicative of a moderate severity response. As the observed response was of short duration (i.e., less than the duration of the vessel exposure), no significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine is anticipated. This is in line with impact predictions made in the FEIS for the ERP, in that the effects of ship noise on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., change in narwhal density), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

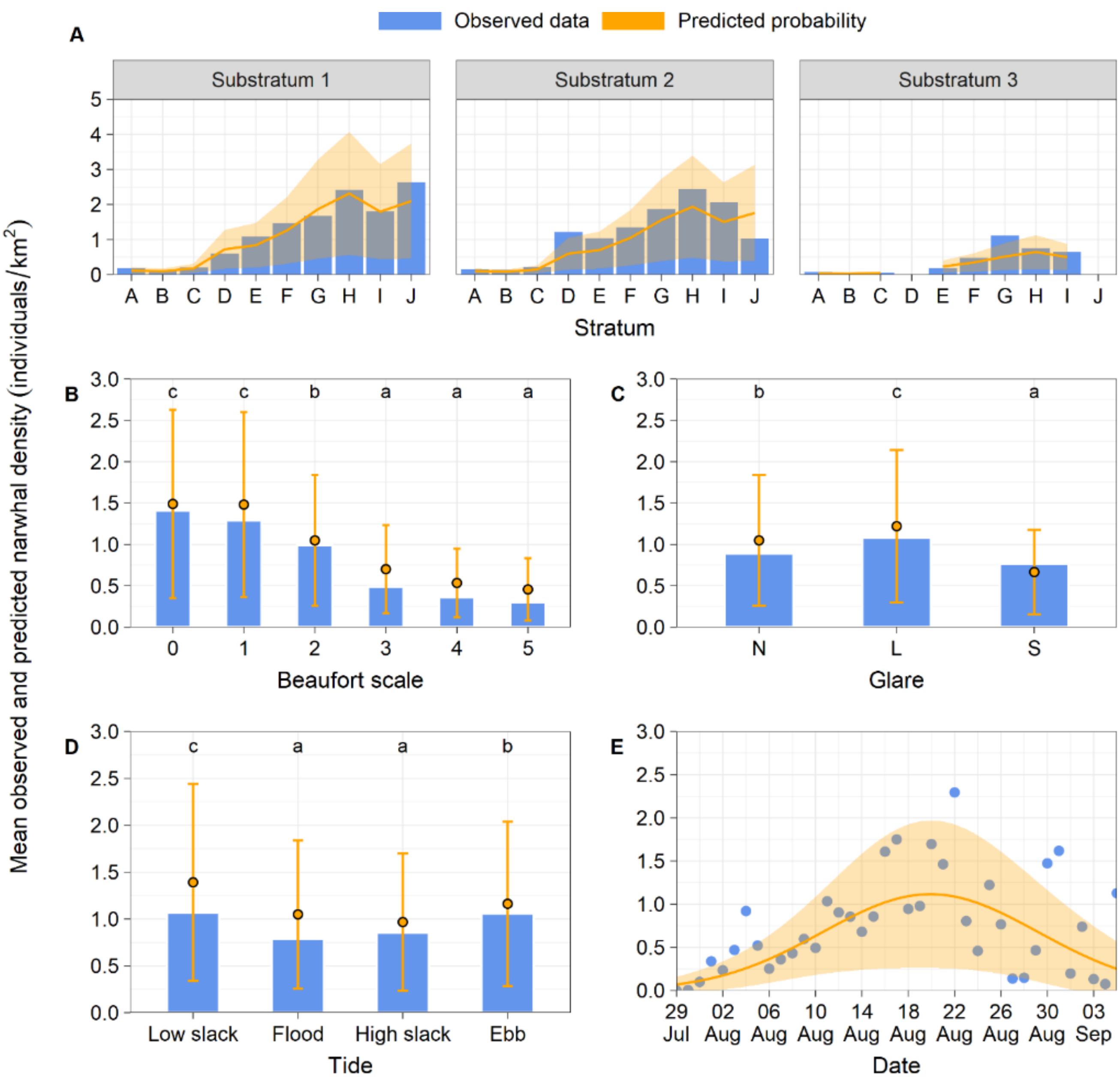


Figure 6-12: Mean observed and predicted narwhal density (individuals/km²) as a function of stratum and substratum (panel A), Beaufort scale (panel B), glare (panel C), tide (panel D), and date (panel E).

Notes: observed data depict mean substratum-level density of narwhal at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panels B, C, and D), different letters indicate significant difference between groups.

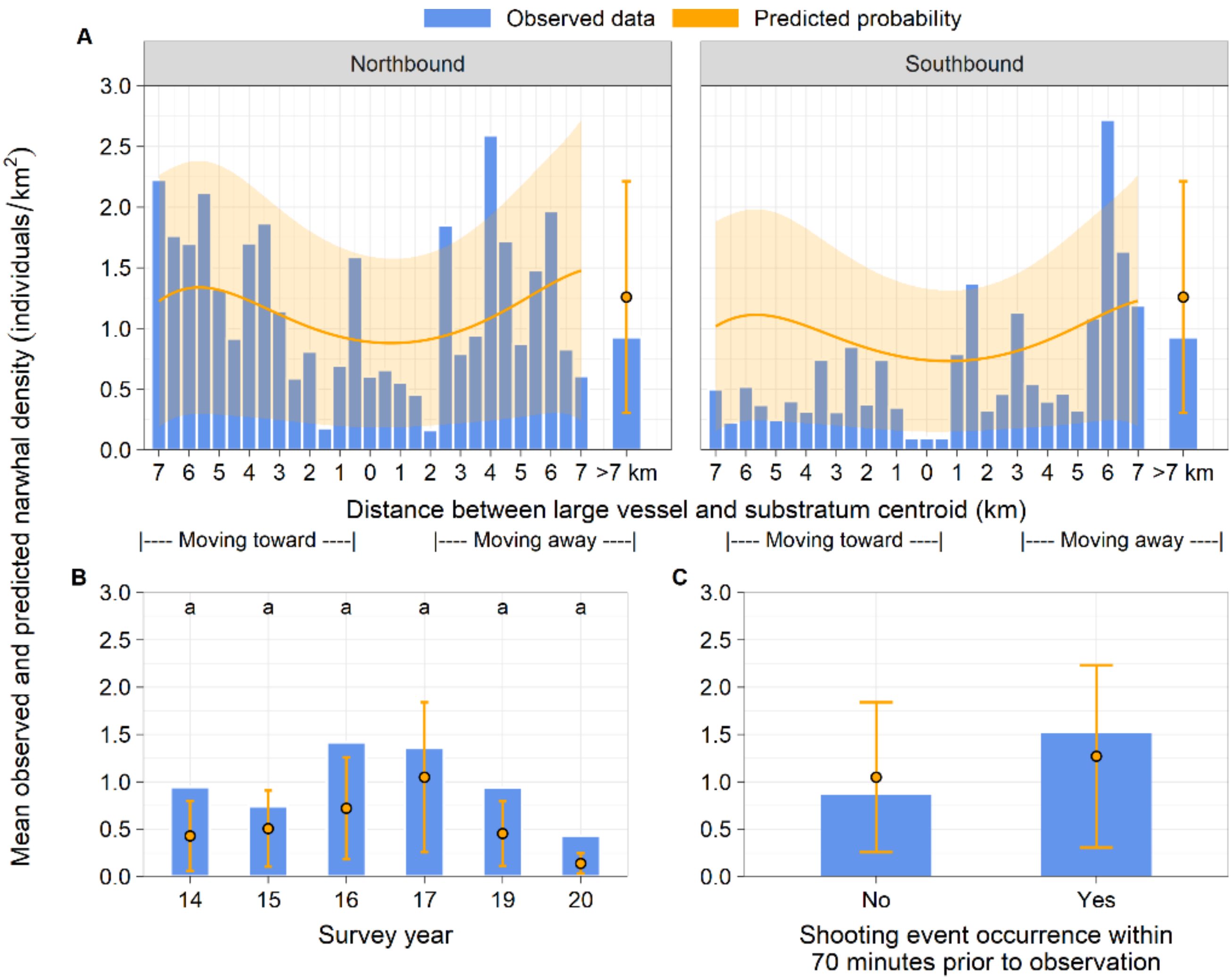


Figure 6-13: Mean observed and predicted narwhal density (individual/km²) as a function of distance from vessel, vessel travel direction, vessel orientation relative to substratum (2014–2020; panel A), survey year (panel B), and hunting activity (panel C).

Notes: observed data depict mean substratum-level density of narwhal at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

Table 6-3: Multiple comparisons of narwhal density predictions between vessel exposure (1 to 7 km distances) and non-exposure periods (> 7 km). Statistically significant values shown in bold.

Distance from Vessel (km)	Multiple Comparisons to No-exposure – Least-squares Means with *P* values in Brackets			
	Northbound vessel, toward substratum	Northbound vessel, away from substratum	Southbound vessel, toward substratum	Southbound vessel, away from substratum
0	**0.9 (0.039)**	**0.9 (0.039)**	**0.7 (<0.001)**	**0.7 (<0.001)**
1	0.9 (0.092)	**0.9 (0.017)**	**0.8 (0.001)**	**0.7 (<0.001)**
2	1.0 (0.278)	**0.9 (0.012)**	**0.8 (0.003)**	**0.8 (<0.001)**
3	1.1 (0.817)	1.0 (0.062)	**0.9 (0.039)**	**0.8 (<0.001)**
4	1.2 (1.000)	1.1 (0.626)	1.0 (0.361)	**0.9 (0.021)**
5	1.3 (0.997)	1.2 (1.000)	1.1 (0.773)	1.0 (0.343)
6	1.3 (0.993)	1.4 (0.951)	1.1 (0.833)	1.1 (0.928)
7	1.2 (1.000)	1.5 (0.951)	1.1 (0.892)	1.2 (1.000)

6.4 Group Composition and Behaviour of Narwhal

The total number of sampling days in which data on narwhal group composition and behaviour were collected in the BSA ranged from 11 days in 2014 to 27 days in 2016. In 2020, data were collected in the BSA on 24 days (Table 6-4). The number of narwhal groups observed in the BSA ranged from 250 groups (total of 1,086 narwhal) in 2014 to 2,416 groups (total of 8,913 narwhal) in 2017. In 2020, 878 groups were observed (total of 2,847 narwhal; Table 6-4).

A total of 27 groups were recorded under 'impossible' sightability conditions (8 and 19 groups in 2017 and 2020, respectively) and were excluded from further analyses. The proportion of narwhal groups recorded in the BSA during periods of 'no anthropogenic activity[6]' decreased from 100% in 2014 to 55% in 2019, followed by an increase to 80% in 2020 (71% in 2015, 84% in 2016, 64% in 2017), generally consistent with the increase in vessel traffic over time.

Table 6-4: Number of narwhal groups and individuals recorded in BSA (2014–2017 and 2019-2020)

Survey Year	# Sampling Days	# Narwhal Groups	# Narwhal
2014	11	250	1,086
2015	16	268	1,479
2016	27	761	2,476
2017	27	2,416	8,913
2019	25	1,301	4,986
2020	24	878	2,847

Note: data collected under 'impossible' sightability conditions and when killer whales were present in southern Milne Inlet were omitted from this table and the multi-year analysis.

[6] large and medium vessel transits, active shooting events

In the combined multi-year dataset, when data associated with “impossible” sightability and killer whale presence were removed, most narwhal sightings in the BSA occurred during vessel non-exposure periods (n = 5,249 cases; 89.65%). A total of 605 sightings occurred during single vessel exposure periods (10.33%). Only one sighting occurred during multiple vessel exposure periods (0.02%). Annually, the percentage of sightings that occurred when no vessels were present within the BSA ranged from 80% (in 2015) to 100% (in 2014). In 2020, 88% of the sightings occurred when no vessels were present. The percentage of observations when a single vessel was present (within 7 km of BSA) ranged from 7% (in 2016) to 20% (in 2015). In 2020, 12% of the sightings were recorded when a single vessel was present. Over the six-year study, only a single observation was made when two or more vessels were present within 7 km from the BSA – on 7 August 2020.

The majority of narwhal groups in the BSA were recorded during ‘excellent’ sightability conditions in all sampling years except for 2016 and 2020, and during ‘good’ sightability conditions in 2016 and 2020 (Figure 6-14). The proportion of narwhal groups recorded during ‘poor’ sightability conditions was relatively high in 2015 (21%). This was an artefact of the ‘moderate’ sightability category not being used during the first two years of the program, therefore inflating the number of sightings assigned to ‘poor’ by default. In 2020, a high proportion of narwhal was recorded within the BSA under ‘moderate’ sightability conditions (35%) compared to previous years (Figure 6-14).

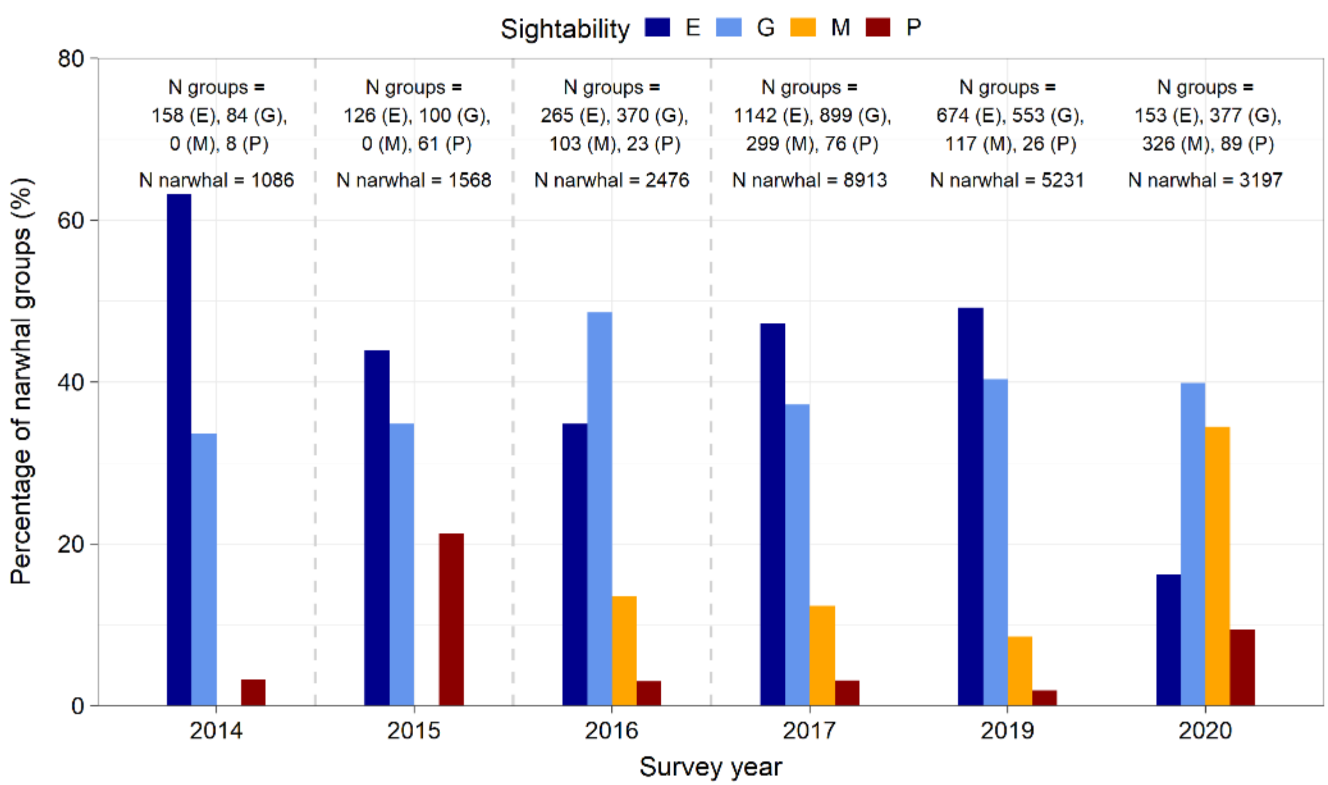


Figure 6-14: Percentage of narwhal groups in the BSA as a function of sightability and sampling year.

Note: Annual group counts and total number of narwhals observed by sightability are provided for each year.

6.4.1 Group Size

Throughout the six-year study, the number of narwhal observed per group was relatively low, generally between one and five individuals (Figure 6-15). Mean group size in the BSA was 4.3 in 2014, 5.5 in 2015, 3.3 in 2016, 3.7 in 2017, 3.8 in 2019, and 3.4 in 2020. Groups larger than 25 individuals were only recorded once in 2014, three times in 2015 (with group sizes up to 45 individuals), and five times in 2019 (with group sizes up to 35 individuals). The largest group recorded in 2020 comprised 22 individuals.

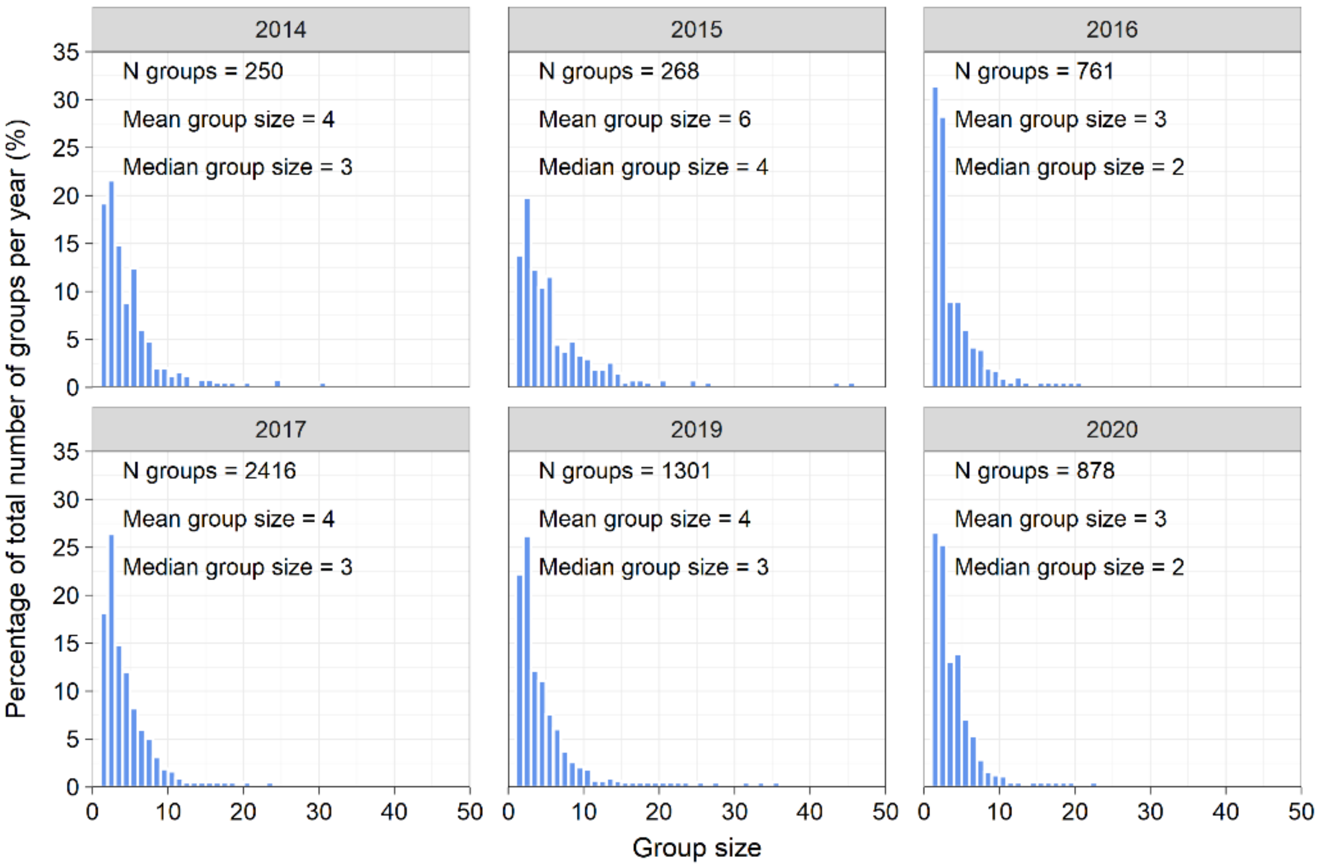


Figure 6-15: Distribution of group size observed in BSA by sampling year.

During vessel non-exposure periods, mean group size was 3.6 individuals (SD = 2.9 individuals; Figure 6-16). During vessel exposure periods, a total of 606 narwhal groups were sighted with a mean group size of 3.6 individuals (SD = 2.8 individuals). Of the 606 observations when vessels were present, 164 and 199 groups were recorded when a northbound vessel was heading toward or away from the BSA, respectively; and 113 and 130 cases were recorded when a southbound vessel was heading toward or away from the BSA, respectively. Mean group size of narwhal observed under these four vessel passage scenarios ranged from 1.9 (northbound vessel heading toward the BSA) to 3.4 individuals (southbound vessel heading toward the BSA).

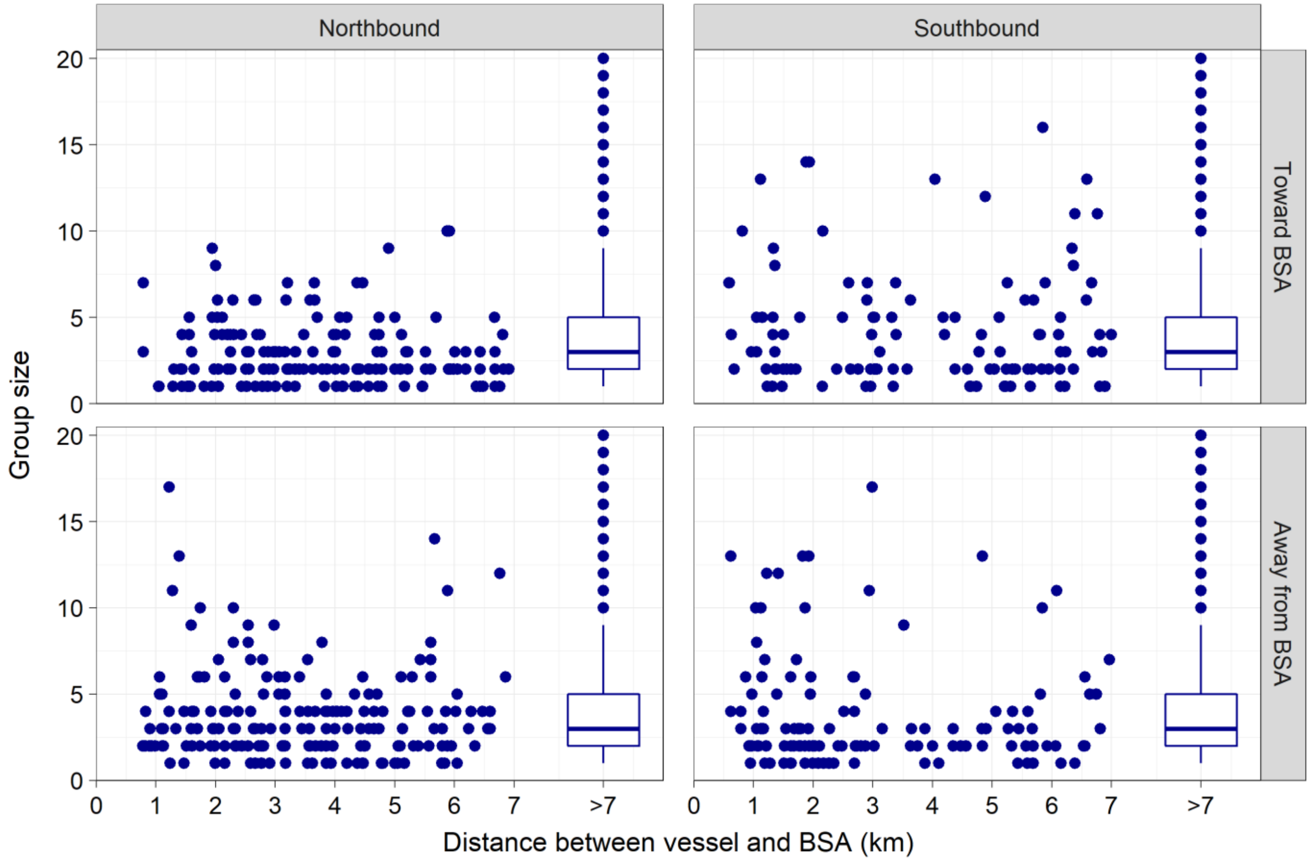


Figure 6-16: Narwhal group size observed in BSA relative to distance from vessels transiting through the SSA (2014–2017, 2019-2020).

Test statistics and coefficient estimates for the model are provided in APPENDIX D. Residual diagnostic plots are provided in APPENDIX E.

Summary of observed data and model predictions for statistically significant variables are shown in Figure 6-17. Note that mean group size values detailed below and shown as orange lines in Figure 6-17 were estimated for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars in Figure 6-17 summarize the entirety of the collected data. This leads to some visual discrepancies between the observed and estimated values.

The effects of survey year and hunting activity were statistically significant in the model of group size ($P<0.001$ for both; APPENDIX D, Table D-3). Multiple comparisons of survey years indicated that group sizes recorded in 2016 (1.9 individuals) were significantly smaller than group sizes in 2014, 2015, and 2017 (2.6, 3.4, and 2.3 individuals; Figure 6-17). Group sizes in 2020 (2.0 individuals) were not significantly different from most sampling years, except for 2015, when group sizes were significantly larger. Group sizes were significantly larger during hunting events compared to when no hunting took place (3.1 individuals and 2.3 individuals, respectively; Figure 6-17). The effects of shipping (directional distance from vessel and vessel direction within Milne Inlet) were not statistically significant ($P>0.3$ for all effects). The estimated effect sizes at 0 km from a vessel were small: -4% (for a northbound vessel) and +15% (for a southbound vessel). The model had sufficient power (>0.8) to detect a -57% or a +95% effect size in the test of the overall effect of distance from vessel (APPENDIX B).

In summary, findings based on the combined multi-year dataset did not suggest that narwhal alter their group size in response to vessel traffic. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (group size), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

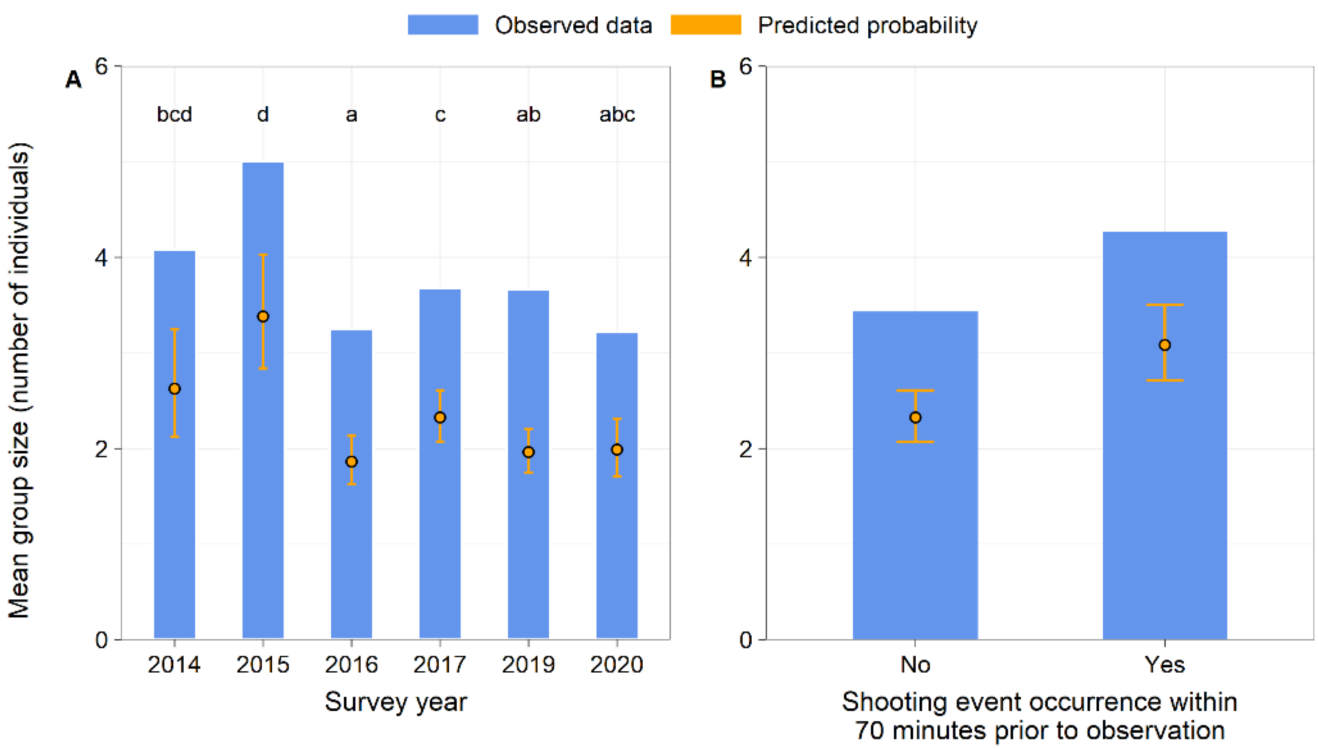


Figure 6-17: Mean narwhal group size relative to survey year (Panel A) and hunting activity in the BSA (2014–2020; panel B).

Notes: observed data depict mean narwhal group size at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panels A and B), different letters indicate significant difference between groups.

6.4.2 Group Composition

A qualitative assessment of group composition by life stage recorded in 2020 indicated an overall similar group composition to previous years, with the majority of the sightings consisting of adult whales, followed by juveniles, calves, and yearlings (Figure 6-18). Note that yearlings were not categorized on their own prior to 2016 but were grouped together with calves. Similar to previous years, calves were observed during most sampling days, with only four days (11, 14, 15, and 29 August 2020) when no calves were recorded. On those days, only 10, 19, 1, and 18 narwhal were recorded in the BSA, respectively. In 2020, the daily proportion of calves (relative to total narwhal counts) ranged between 0% (on 11, 14, 15, and 29 August) and 40% (on 24 August 2020, when only five narwhal were recorded within the BSA). The life stage of 137 narwhal (4.8% of all narwhal recorded in the BSA in 2020) was not recorded, due to either visibility restrictions or logistical challenges of accurately documenting all individuals during periods of high activity.

In previous years, daily percentages of calves ranged between 0% (in all years) and 23-50% (23% in 2014 and 50% in 2017). Mean values of daily proportion of calves in 2020 (11.3%) were higher than three of the previously estimated annual means (2014=10.7%, 2016=10.5%, 2017=9.5%), and lower than mean values in 2019 (11.6%) and 2015 (12.9%). Note that yearlings were not categorized on their own prior to 2016 but were grouped together with calves. The mean daily proportion of calves recorded in 2020 suggests that the calving rate (i.e., reproductive success) of the Eclipse Sound summering stock is consistent with pre-shipping conditions, despite a relatively steady increase in shipping throughout the RSA during this time.

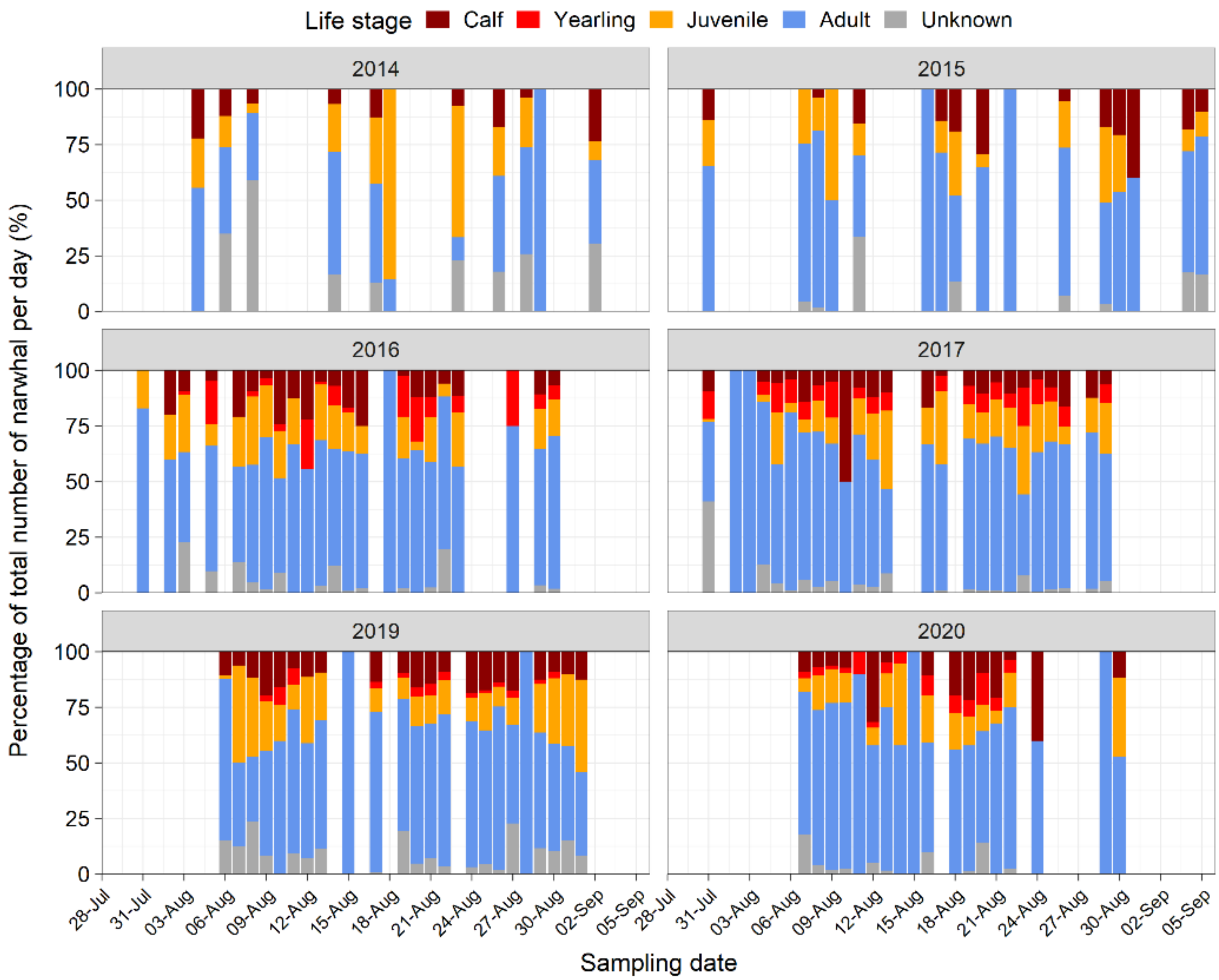


Figure 6-18: Daily summary of narwhal sightings in BSA presented by life stage (2014-2017, 2019-2020).

Based on the group composition classification used in Smith et al. (2017) and as outlined in Section 5.2.2, the most common group composition observed throughout the six year study were groups with ‘no observed tusks’, whether with or without calves or yearlings (Figure 6-19), accounting for a total of 72% of all narwhal groups observed during the full study period (not including groups of unknown composition). Groups with ‘no calves or yearlings’ accounted for 60% of all observed groups with known composition. Group composition of 49 groups (6% of all groups recorded in the BSA in 2020) was not recorded (i.e., “Other” groups), due to either visibility restrictions or logistical challenges of accurately documenting all individuals during periods of high activity.

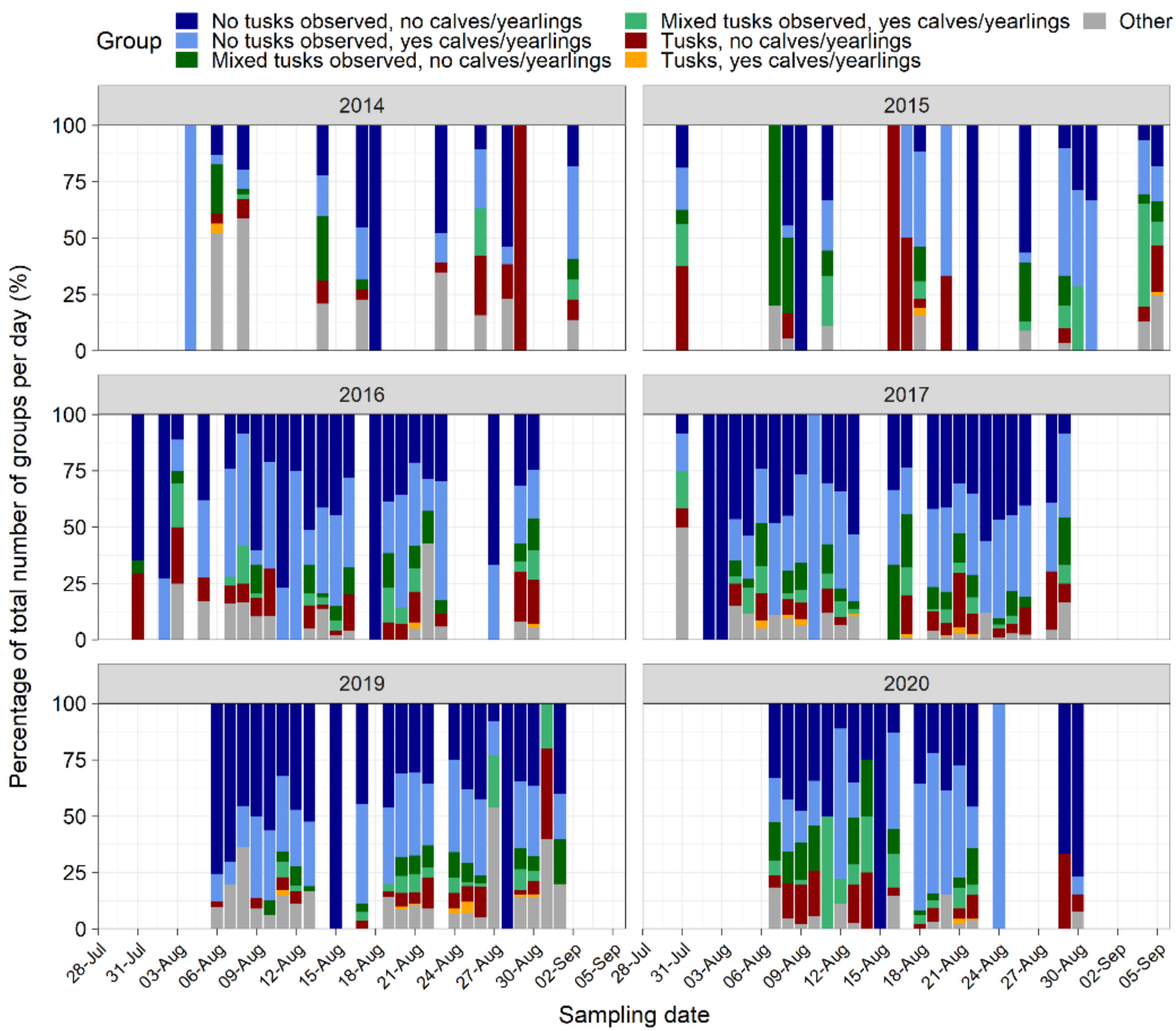


Figure 6-19: Daily distribution of narwhal group composition in BSA (2014–2017, 2019-2020)

6.4.2.1 Presence of Calves or Yearlings

To inform the identified EWI, an analysis of groups with immatures (i.e., calves or yearlings) was conducted. In the analysis of the presence of immatures, groups that consisted of a single narwhal were removed to avoid skewing the analysis as lone calves or yearlings are not typically observed. In the combined multi-year dataset, the majority of observations associated with a group size of ≥2 individuals (with a known group composition) were recorded during vessel non-exposure periods (n = 3,703), of which 51% had calves or yearlings (yearly proportion ranged from 37% in 2014 to 58% in 2019). After the removal of single narwhal observations, mean narwhal group size was similar for groups with and without calves or yearlings (4.3 individuals for both; Figure 6-20).

During the 2020 survey period, a total of 3012 narwhal of known life stage were observed, of which 284 were identified as calves and 148 were identified as yearlings. The annual proportion of immatures (i.e., calves and yearlings) observed in 2020 was 0.143, comparable to the annual proportion of immatures observed in previous years and above the identified EWI threshold of 0.137 (Table 6-5). The mean and standard deviation values of daily proportion of calves and yearlings combined are also presented for transparency, but do not inform the EWI threshold directly. It should be noted that the mean value of combined calves and yearlings in 2020 was the third highest since 2014.

Table 6-5: Annual proportion and mean daily proportion of immatures (i.e., calves and yearlings) observed at Bruce Head (2014-2020)

Year	Annual Proportion of Immatures Observed	Daily Proportion of Immatures Observed	
		Mean	Standard Deviation
2014	0.152	0.102	0.081
2015	0.163	0.129	0.115
2016	0.164	0.173	0.103
2017	0.163	0.168	0.093
2018	N/A	N/A	N/A
2019	0.156	0.137	0.063
2020	0.143	0.159	0.116

During vessel exposure periods, a total of 451 groups with and without calves or yearlings were recorded. The percentage of groups with calves or yearlings ranged from 39% when northbound vessels were moving toward the BSA to 51-58% in the remaining three shipping scenarios (i.e., northbound vessels moving away, southbound vessels moving toward, southbound vessels moving away). Similar to vessel non-exposure periods, groups sizes were comparable for groups with and without observed calves or yearlings (mean of 4.1 individuals for both).

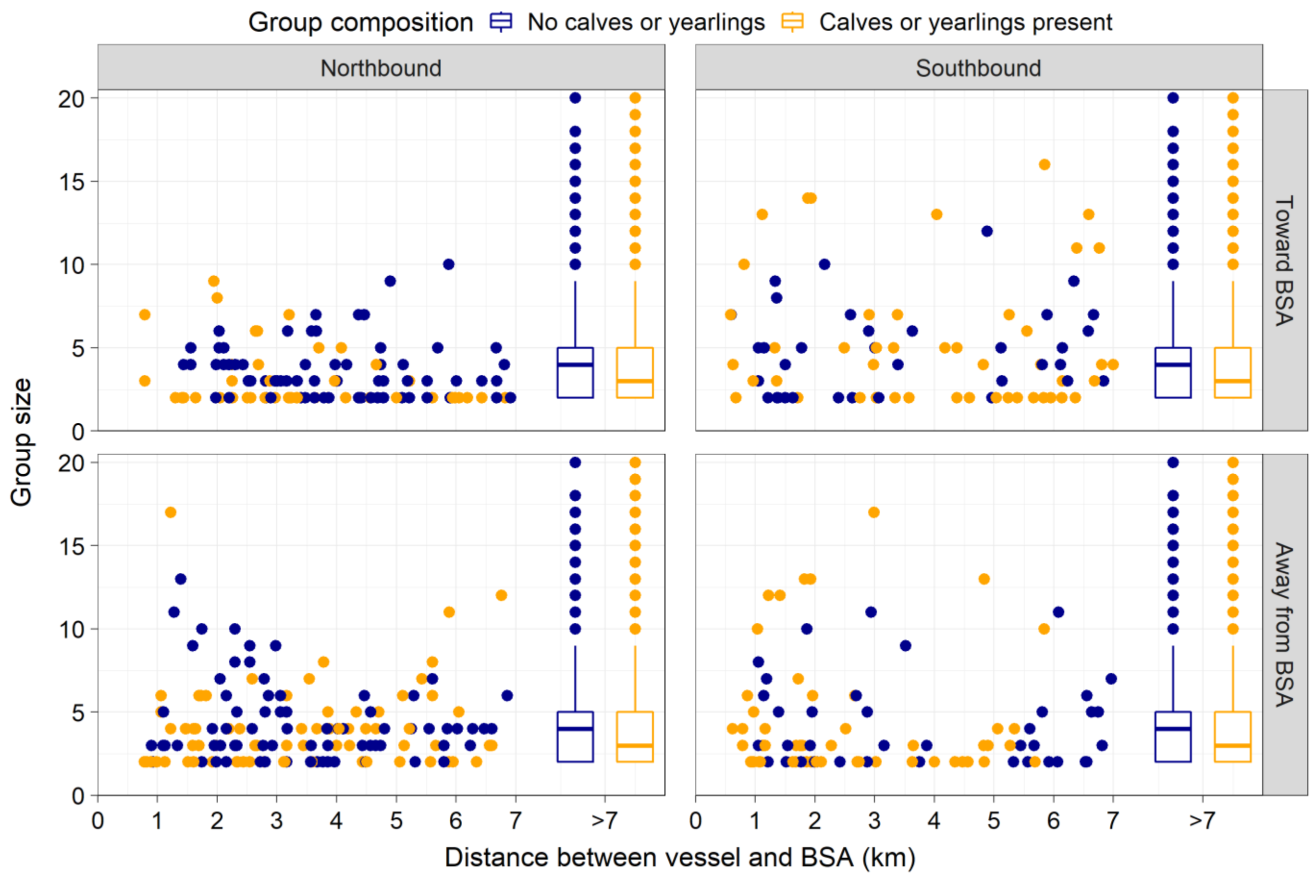


Figure 6-20: Presence/absence of calves or yearlings in narwhal groups comprised of ≥ 2 narwhal recorded in BSA relative to distance from vessels transiting through the SSA (2014–2017, 2019-2020)

Test statistics and coefficient estimates for the model are provided in APPENDIX D. Residual diagnostic plots are provided in APPENDIX E.

Summary of observed data and model predictions for statistically significant variables are shown in Figure 6-21. Note that probability values detailed below and shown as orange lines in Figure 6-21 were estimated for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars in Figure 6-21 summarize the entirety of the collected data. This leads to some visual discrepancies between the observed and estimated values.

In the model for presence of calves or yearlings in groups, the effects of group size and glare were statistically significant (P<0.001 and P=0.013, respectively), while no other variables (including the three shipping scenarios) were not statistically significant (all P values >0.1; APPENDIX D, Table D-5). Estimated effect sizes for a vessel at 0 km from the BSA were +21% (for a northbound vessel) and +45% (for a southbound vessel). The model had low power, and effect sizes of -80% or +350% would be required to detect a significant effect of vessel distance (APPENDIX B).

The estimated probability to observe calves or yearlings in a group was higher (0.52) for groups comprised of two individuals than for groups of 3-11 individuals (probabilities ranging between 0.42 and 0.49), because many of the groups comprised of two individuals were mother-calf pairs. With further increase in group size, the probability of observing calves or yearlings increased to 0.67 (group size of 15) and 0.92 (group size of 20).

The effect of glare was statistically significant in the model of observing calves or yearlings. Multiple comparisons of glare levels indicated that the probability of observing calves or yearlings was significantly lower under severe glare than under no or low glare (0.34 vs 0.49 and 0.48, respectively, Figure 6-21). There was no significant difference in the probability of observing calves or yearlings between no glare and low glare.

Due to the large effect sizes and the importance of this analysis informing the identified EWI, estimated effects of vessel distance and direction on the presence of calves or yearlings were plotted despite the lack of statistical significance (Figure 6-22). When vessels were at close proximity, the model estimated an elevated chance of observing groups with calves or yearlings than when vessels were farther away or not present. This effect may be due to groups without dependent young being able to dive more than groups with calves or yearlings, resulting in a larger proportion of groups with calves or yearlings observed when vessels were in close proximity. However, the effect was uncertain and not pronounced enough to be statistically significant. From examination of the observed data, it is possible that the effects of vessel on presence of calves or yearlings had a shorter spatial extent than the 7 km extent used in the models.

In summary, the analysis of presence of calves and yearlings using the 2014–2017 and 2019-2020 integrated Bruce Head data suggested a possible but uncertain effect of vessel distance on presence of calves or yearlings. The lack of a significant response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., group composition), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a non-significant effect used in the FEIS).

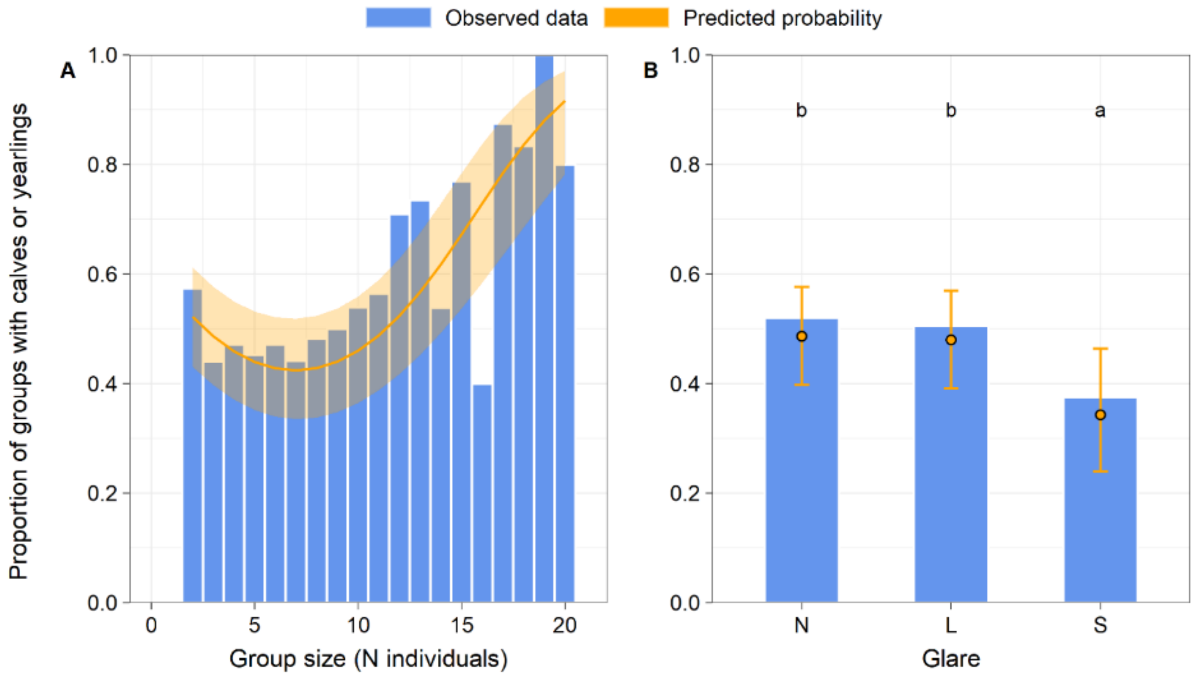


Figure 6-21: Proportion of narwhal groups with calves or yearlings relative to group size (panel A) and glare (panel B).
Notes: observed data depict total proportion of groups observed with calves or yearlings at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panel B), different letters indicate significant difference between groups.

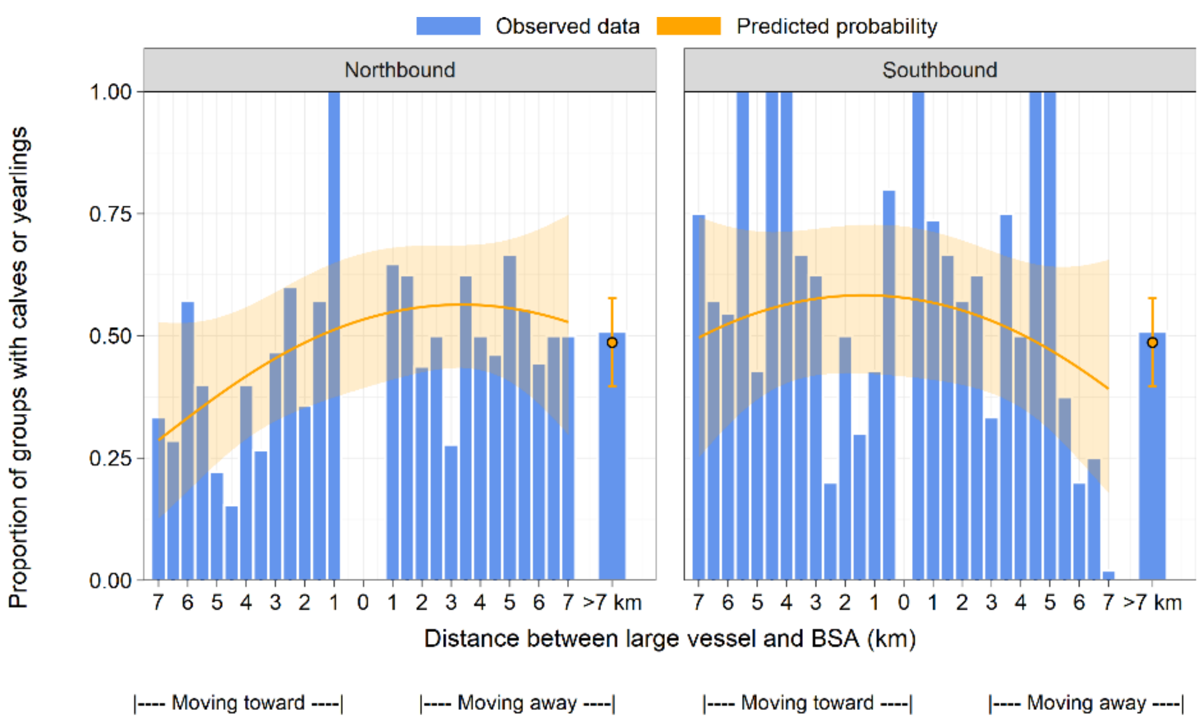


Figure 6-22: Proportion of narwhal groups with calves or yearlings relative to distance from vessels in transit, vessel travel direction, and vessel orientation relative to the BSA (2014–2017, 2019-2020).
Notes: observed data depict total proportion of groups observed with calves or yearlings at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

6.4.3 Group Spread

Based on reports suggesting that narwhal form tight groups as an anti-predator response to killer whale presence (Steltner et al.1984; Laidre et al. 2006; Breed et al. 2017), it was predicted that narwhal may form tight groups in response to other potential perceived threats such as vessel traffic. Therefore, narwhal groups of two or more individuals 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. In 26 cases (4.0% of the 2020 data), group spread was not recorded due to either visibility restrictions or logistical challenges of accurately documenting individuals during periods of high activity. Throughout the six years of sampling, narwhal were more often observed in tight groups than in loose groups (Figure 6-23), regardless of whether individuals were exposed to anthropogenic activity or not (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020).

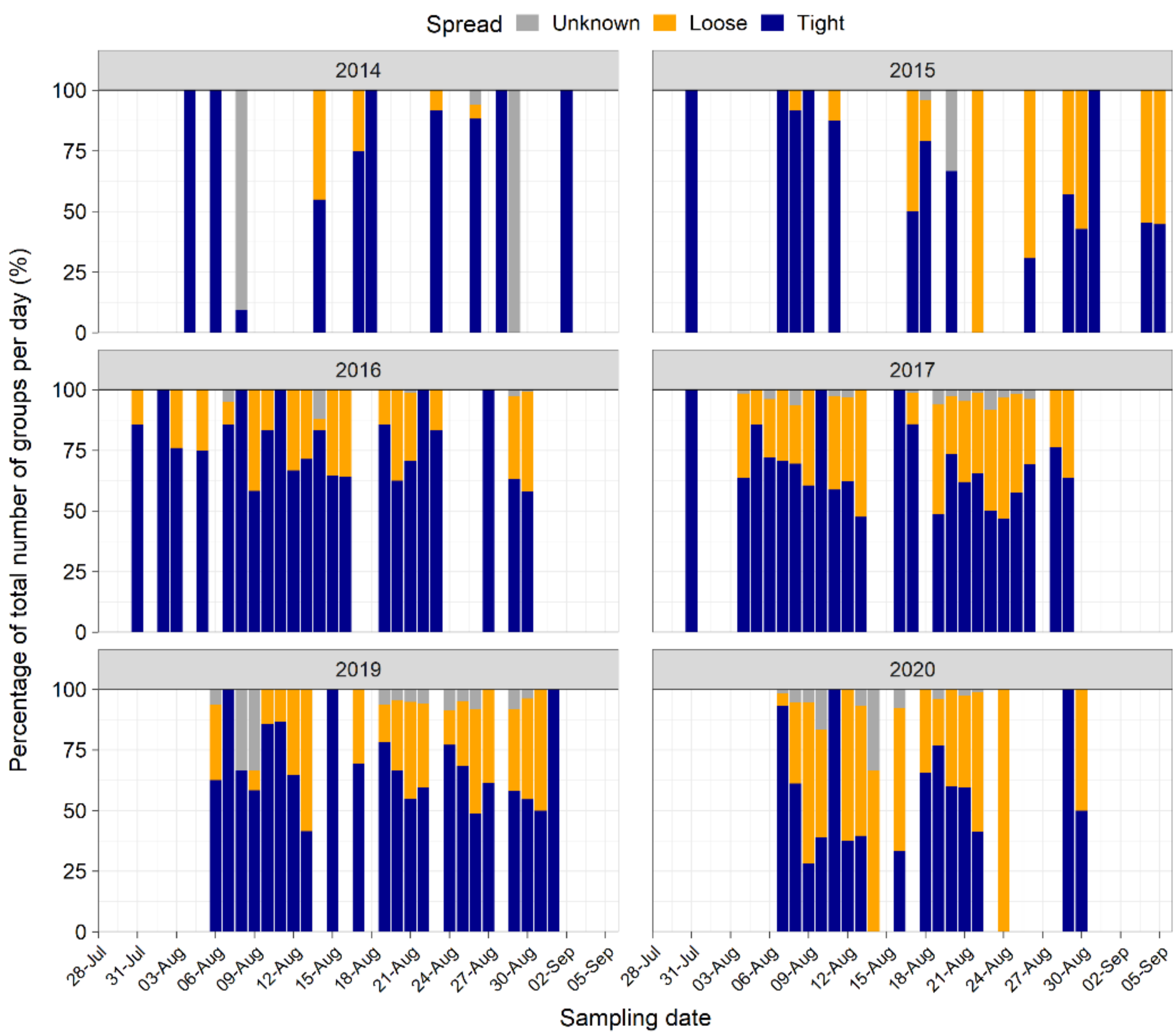


Figure 6-23: Daily distribution of groupings of narwhal group spread (2014–2017, 2019-2020)

In the combined multi-year dataset, the majority of observations of narwhal group spread were recorded during vessel non-exposure periods (n = 3,917), of which 36% were in loose spread (annual percentage ranging from 23% in 2014 to 47% in 2020). Mean group size was larger for loose spread groups than for tight groups (4.8 and 4.2 individuals, respectively; Figure 6-24).

During vessel exposure periods, 472 groups with a known spread were recorded. Groups in loose spread were less common during southbound vessel passage (30% when vessel heading toward BSA and 32% when vessel heading away from BSA) than during northbound vessel passage (41% when vessel heading toward BSA and 39% when vessel heading away from BSA). Similar to the non-exposure periods, loose groups were on average larger (mean of 4.8 individuals) than tight groups (mean of 3.9 individuals).

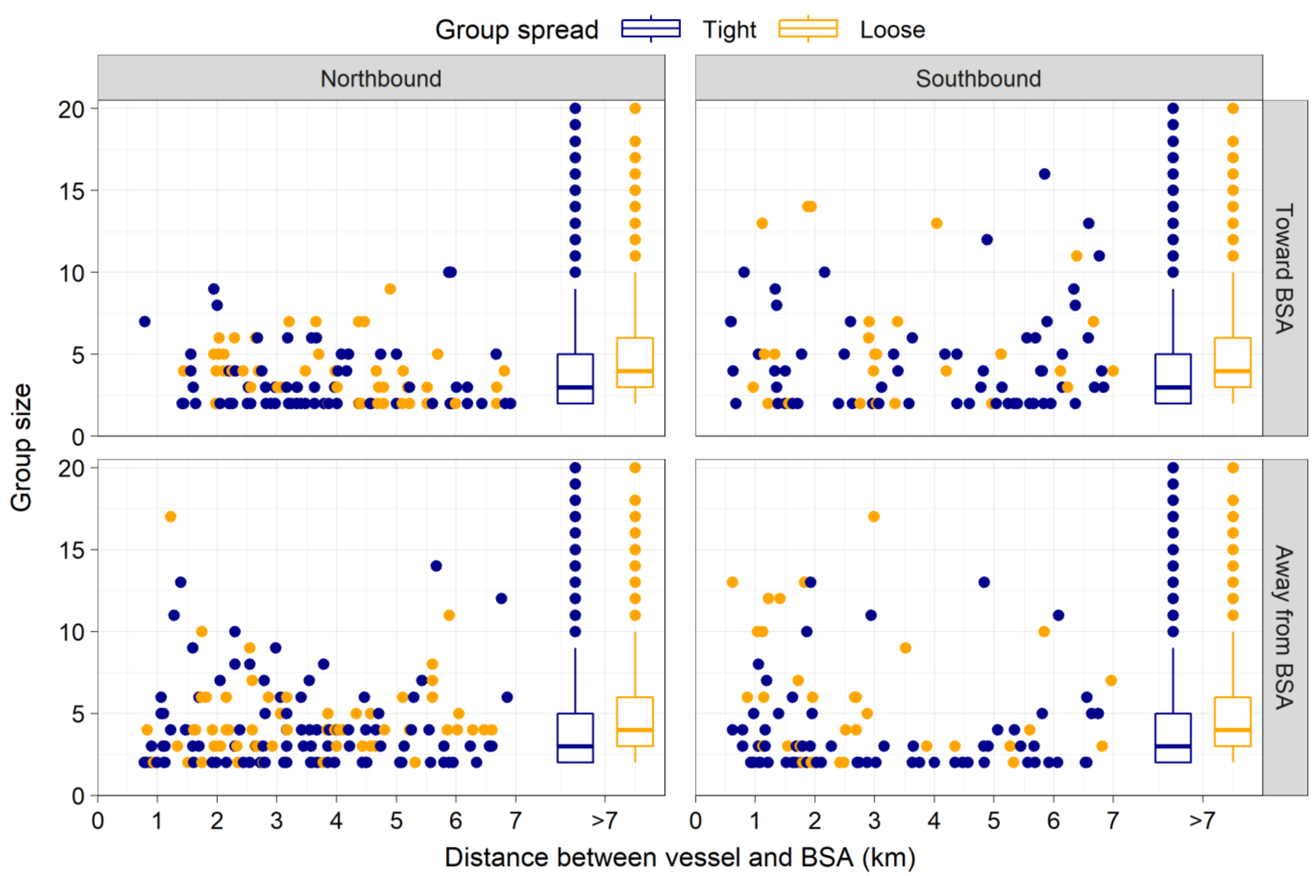


Figure 6-24: Group spread of narwhal groups observed in BSA relative to distance from vessels transiting through the SSA (2014–2017, 2019-2020)

Test statistics and coefficient estimates for the model are provided in APPENDIX D. Residual diagnostic plots are provided in APPENDIX E.

Summary of observed data and model predictions for statistically significant variables are shown in Figure 6-17. Note that probability values detailed below and shown as orange lines in Figure 6-17 were estimated for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars in Figure 6-17 summarize the entirety of the collected data. This leads to some visual discrepancies between the observed and estimated values.

In the model of group spread, none of the shipping-related variables (directional distance from vessel, vessel direction within Milne Inlet, and their interaction) were statistically significant (P>0.6 for all; APPENDIX D, Table D-7). The estimated effect size for vessels at 0 km from the BSA centroid were small: -1% for a northbound vessel and +14% for a southbound vessel. The effects of survey year (P<0.001), categorical group size (P<0.001), and hunting activity (P=0.013) were statistically significant in the model of group spread. Multiple comparisons of survey years indicated that the probability of groups in loose spread was not significantly different in 2020 (probability = 0.54) than in 2015 (0.37), 2017 (0.40), or 2019 (0.38), but was significantly greater than in 2014 (0.10) and 2016 (0.28; Figure 6-17). The model had low power, and effect sizes of -90% or +350% would be required to detect a significant effect of vessel distance (APPENDIX B).

The population-level estimate of the probability of observing groups in loose spread increased for groups of more than 2 individuals – from 0.18 for a group size of 2 to 0.40 for a group size of >2 individuals (Figure 6-17). This reflected the occurrence of mother-calf pairs, which are usually found in a tight spread, therefore decreasing the probability of groups of 2 individuals to be in a loose spread. The estimated population-level probability of observing groups in loose spread immediately following hunting was slightly lower when hunting event occurred within 70 minutes prior to the observation (probability of 0.40) than when no hunting occurred (probability of 0.32).

In summary, findings based on the combined multi-year dataset did not suggest that narwhal either congregate into tight groups or disperse into loose groups as a potential response to vessel traffic. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., group spread), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

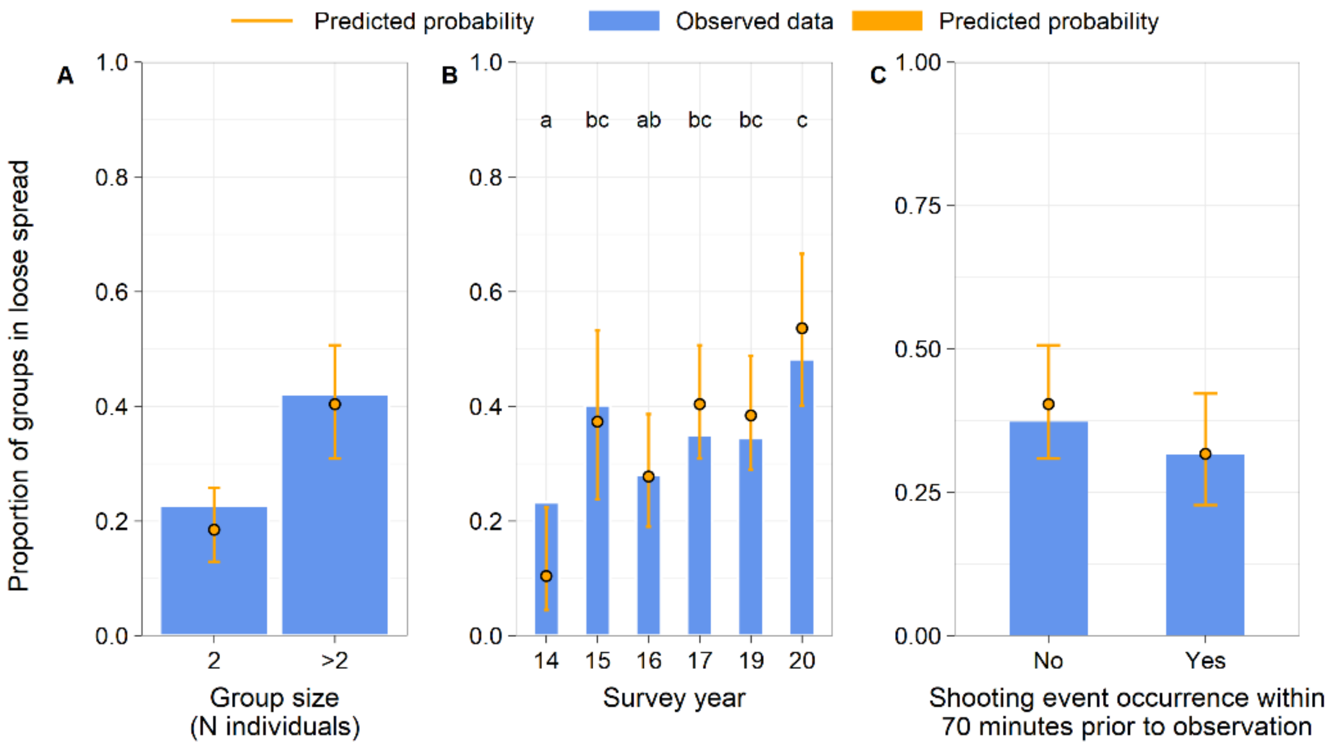


Figure 6-25: Proportion of narwhal groups observed in a loose spread (rather than tight spread) relative to group size (panel A), survey year (panel B), and hunting activity (panel C), (2014–2017, 2019-2020).

Notes: observed data depict total proportion of groups observed a loose spread (rather than at tight spread) at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panel B), different letters indicate significant difference between groups.

6.4.4 Group Formation

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). The formation of narwhal groups of two or more individuals observed in the BSA during 2014–2017 and 2019-2020 sampling years was classified as linear, parallel, cluster, non-directional line, or no formation. The majority of recorded groups in the six years of sampling were in the parallel formation, followed by cluster formation (Figure 6-26), regardless of whether individuals were exposed to anthropogenic activity or not (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020c). In 25 cases (3.9% of the 2020 data), group formation was not recorded, due to either visibility restrictions or logistical challenges of accurately documenting individuals during periods of high activity. Parallel groups comprised a minimum of 12%, 34%, 33%, 49%, 23%, and 22% of all daily recorded groups of two or more individuals in 2014–2017 and 2019-2020, respectively. Cluster groups comprised a minimum of 7%–19% of all daily groups, depending on year. Conversely, linear groups comprised only a minimum of 1%–6% of all groups recorded within the year, and only up to 10%, 33%, 17%, 38%, and 10% of all daily groups in 2014, 2016, 2017, 2019, and 2020 (with a single day in 2015 with 100% linear formation, where only one group of narwhal with two or more individuals was recorded in the BSA).

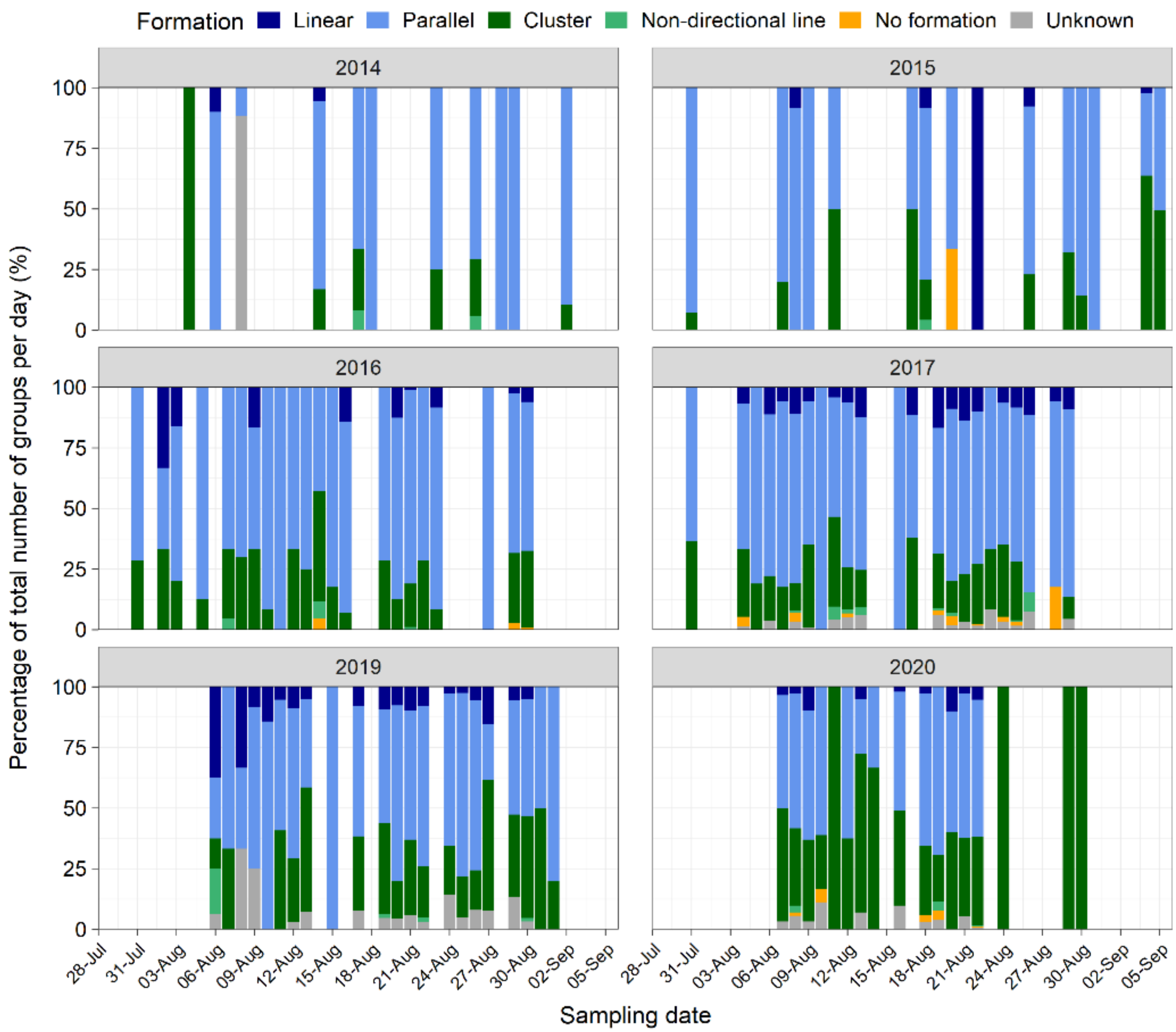


Figure 6-26: Daily distribution of groupings of narwhal group formation (2014–2017, 2019-2020)

In the combined multi-year dataset, the majority of narwhal group formation observations were recorded during non-exposure periods (n = 3,921), of which 38% were in non-parallel formation (annual percentage ranging from 19% in 2014 to 47% in 2020). Mean narwhal group size was larger for non-parallel groups than for groups in parallel formation (5.7 and 3.6 individuals, respectively; Figure 6-27).

During vessel exposure periods, 471 groups with a known formation were recorded. The lowest proportion of groups in non-parallel formation was recorded during the passage of southbound vessels, when vessels were heading away from BSA (26%). The highest proportion was recorded during the passage of northbound vessels when vessels were heading away from the BSA (36%). The proportion of groups travelling in non-parallel formation were similar between northbound and southbound vessels that were heading toward the BSA (31% and 33%, respectively). Similar to non-exposure periods, non-parallel groups were on average larger (mean of 5.9 individuals) than groups in parallel formation (mean of 3.4 individuals).

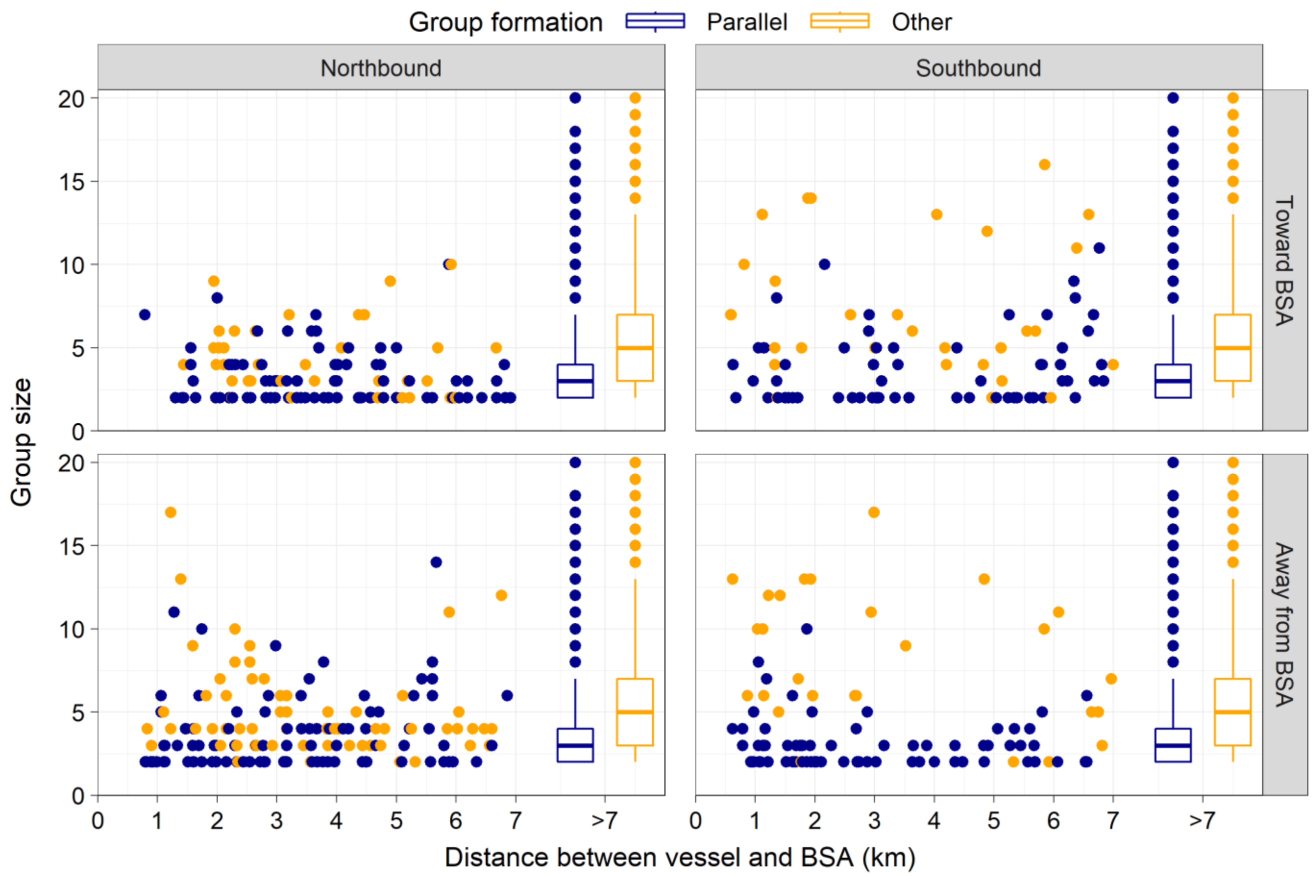


Figure 6-27: Group formation of narwhal recorded in BSA relative to group size and distance from vessels transiting through the SSA (2014–2017, 2019-2020)

Test statistics and coefficient estimates for the model are provided in APPENDIX D. Residual diagnostic plots are provided in APPENDIX E.

Summary of observed data and model predictions for statistically significant variables are shown in Figure 6-28. Note that probability values detailed below and shown as orange lines in Figure 6-28 were estimated for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars in Figure 6-28 summarize the entirety of the collected data. This leads to some visual discrepancies between the observed and estimated values.

In the model of group formation, none of the shipping-related variables (distance from vessel, vessel direction within Milne Inlet, vessel direction relative to the BSA, or their interaction) were statistically significant (P>0.1 for all effects; APPENDIX D, Table D-7). Hunting was not a statistically significant predictor of group formation. The effects of survey year (P<0.001), group size (P<0.001), and glare (P=0.003) were statistically significant in the model of group formation. The model had low power, and effect sizes of -95% or +300% would be required to detect a significant effect of vessel distance (APPENDIX B). Estimated effect sizes for vessels at 0 km from the BSA were -26% (for a northbound vessel) and -49% (for a southbound vessel).

Multiple comparisons of survey years indicated that the proportion of groups in non-parallel formation increased over the years (Figure 6-28); estimates from 2014 (probability of 0.07) were significantly lower than those from

2016-2020 (0.20, 0.23, 0.27, and 0.32, respectively). The 2020 estimate was not significantly different than the 2016-2019 estimates but was significantly higher than those of 2014 and 2015 (Figure 6-28). The proportion of groups in non-parallel formation was significantly greater during “severe glare” (probability of 0.37 for non-parallel formation) than during “low glare” or “no glare” (probability of 0.23 for both). There was a strong effect of group size on the proportion of groups in non-parallel formation, with population-level estimates of the probability of a non-parallel group increasing from 0.17 at two individuals to 0.93 at 15 individuals, and 0.99 at 20 individuals.

Due to the large effect sizes, estimated effects of vessel distance and direction on proportion of groups in non-parallel formation were plotted despite the lack of statistical significance (Figure 6-29). When vessels were at close proximity, the model estimated a reduced chance of observing groups in non-parallel formation than when vessels were farther away or not present, however the effect was not statistically significant.

In summary, findings based on the combined multi-year dataset do not suggest an effect of vessel distance on group formation. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., group formation), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

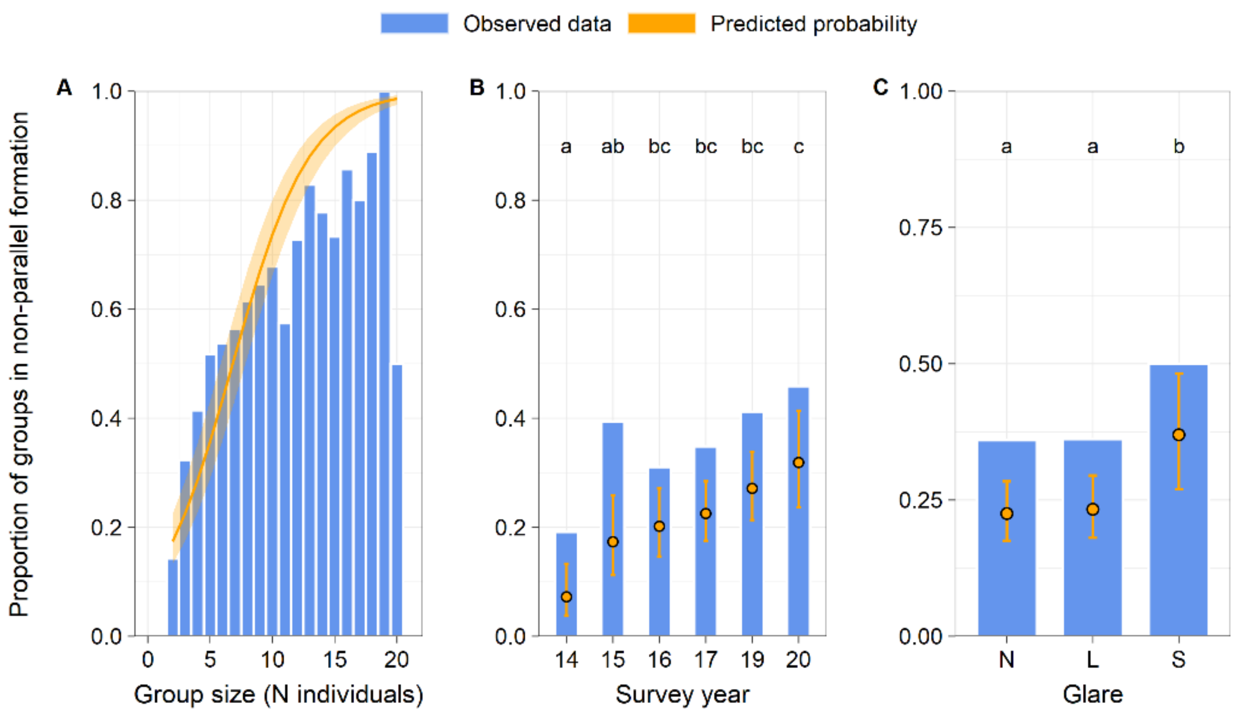


Figure 6-28: Proportion of narwhal groups observed in a non-parallel formation relative to group size (panel A), survey year (panel B), and glare (panel C).

Notes: observed data depict total proportion of groups observed in non-parallel formation at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panels B and C), different letters indicate significant difference between groups.

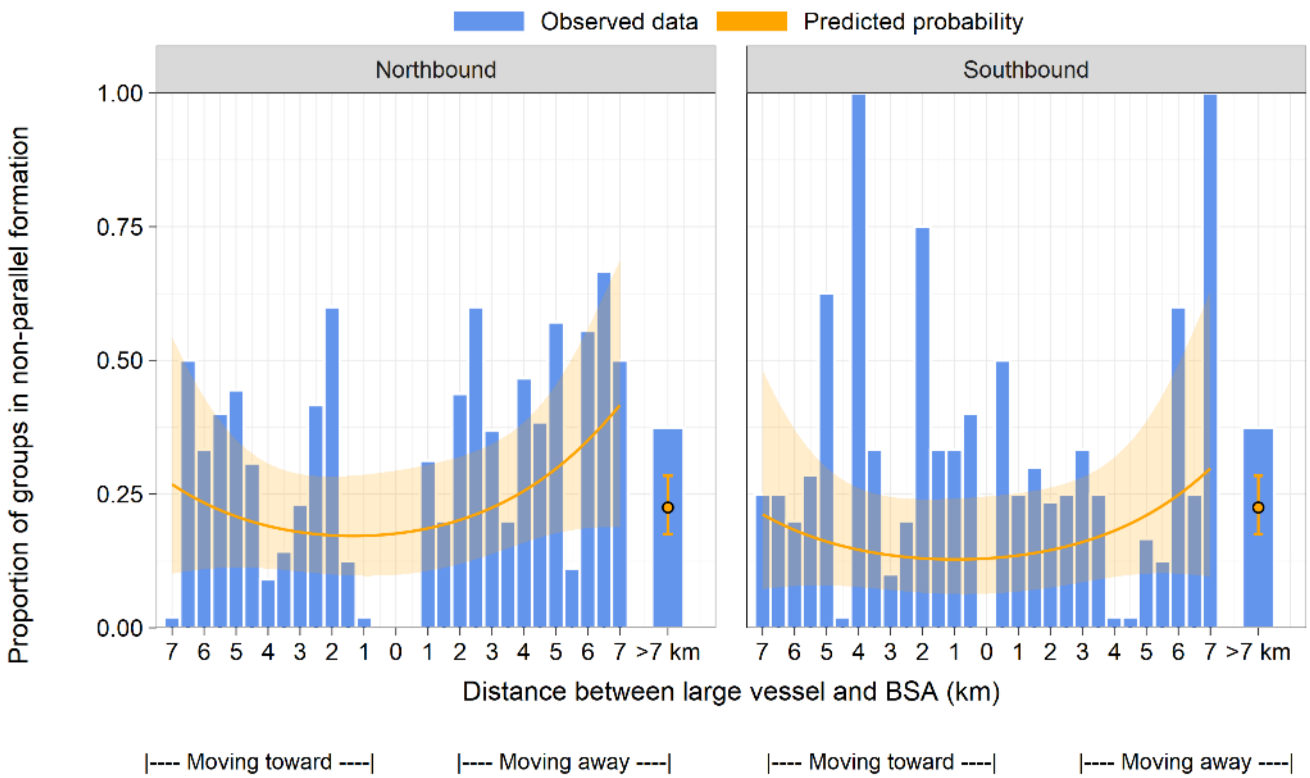


Figure 6-29: Proportion of narwhal groups observed in a non-parallel formation relative to distance from vessel, vessel travel direction, and vessel orientation relative to the BSA (2014–2017, 2019-2020).

Notes: observed data depict total proportion of groups observed in a non-parallel formation relative at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

6.4.5 Group Direction

The majority of narwhal groups observed in the BSA during the six-year study were shown to travel in a southerly direction (Figure 6-30) toward Koluktoo Bay and Milne Port, with annual averages of daily percentages of south-travelling groups ranging between 55% (in 2020) and 91% (in 2015). Annual averages of daily percentages of north-travelling groups ranged between 40% (in 2017) and 59% (in 2014). In 2020, the annual average of daily percentages of north-travelling groups was 53%. In 41 cases (4.7% of the 2020 data), group direction was not recorded due to either visibility restrictions or logistical challenges of accurately documenting individuals during periods of high activity. Both east and west travel directions were rare, with annual averages of daily percentages between 2% and 15%, depending on direction and sampling year.

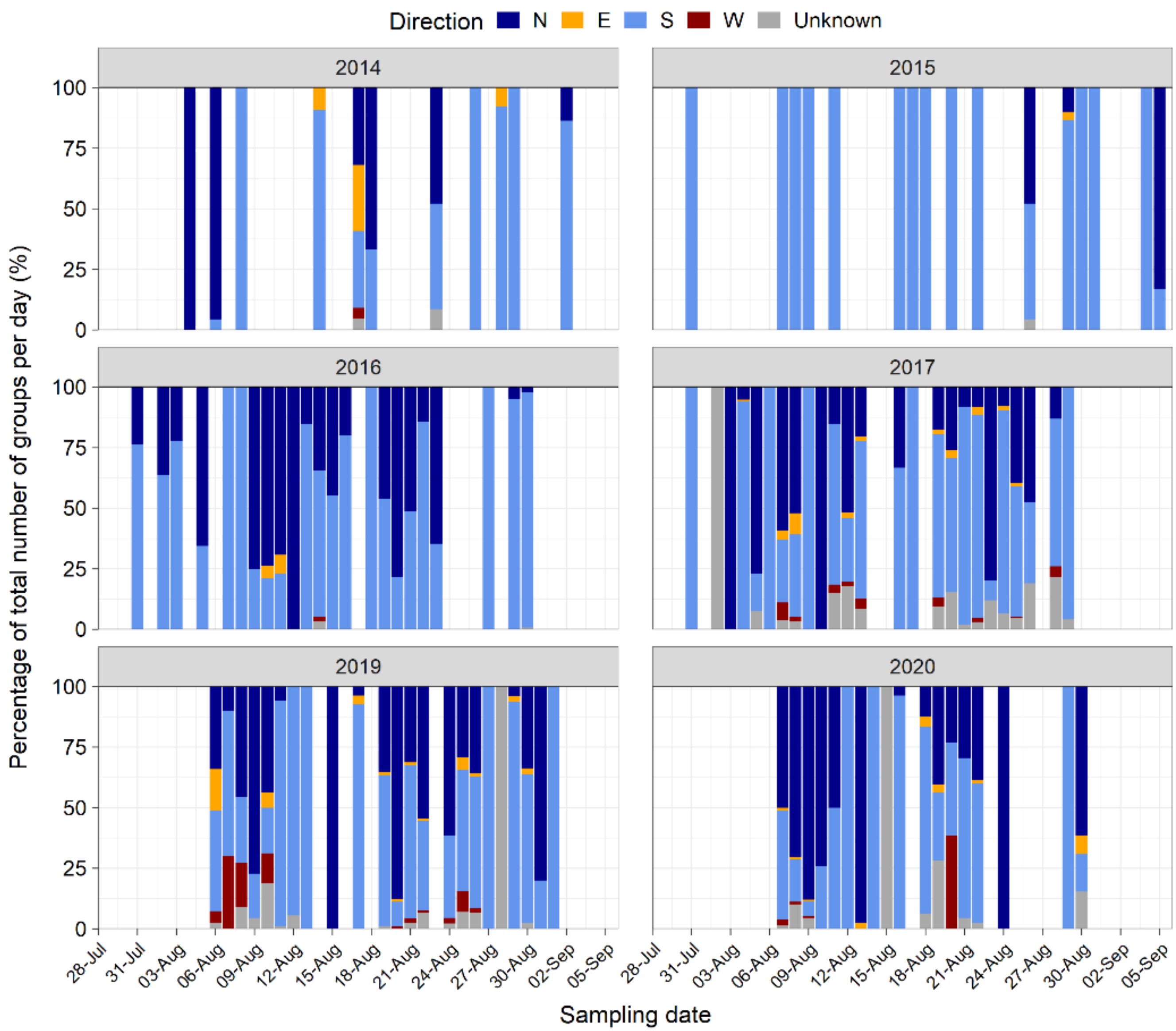


Figure 6-30: Daily distribution of narwhal group travel direction in BSA (2014–2017, 2019-2020)

The direction that narwhal groups are observed travelling through the BSA in relation to vessel traffic may inform whether animals actively move away from, or potentially avoid, vessels transiting along the Northern Shipping Route. In the combined dataset, the majority of group travel direction observations (filtered to north/south travel only) were recorded during vessel non-exposure periods (n = 4,863; 89%), of which 64% travelled south and 36% travelled north. Annual percentage of south-travelling groups ranged from 63% in 2015 and 2019 to 80% in 2014. Mean narwhal group size was larger for south-travelling groups than for north-travelling groups (4.3 and 2.7 individuals, respectively; Figure 6-31).

During vessel exposure periods, 555 groups with a known travel direction were recorded. South-travelling groups were least common when southbound vessels were headed away from BSA (46%) than when vessels were moving toward BSA (77% and 83% for southbound and northbound vessels, respectively). South-travelling groups were most prevalent when northbound vessels were moving away from the BSA (96%). Similar to vessel non-exposure periods, south-travelling groups were on average larger (mean of 3.8 individuals) than north-travelling groups (mean of 3.2 individuals).

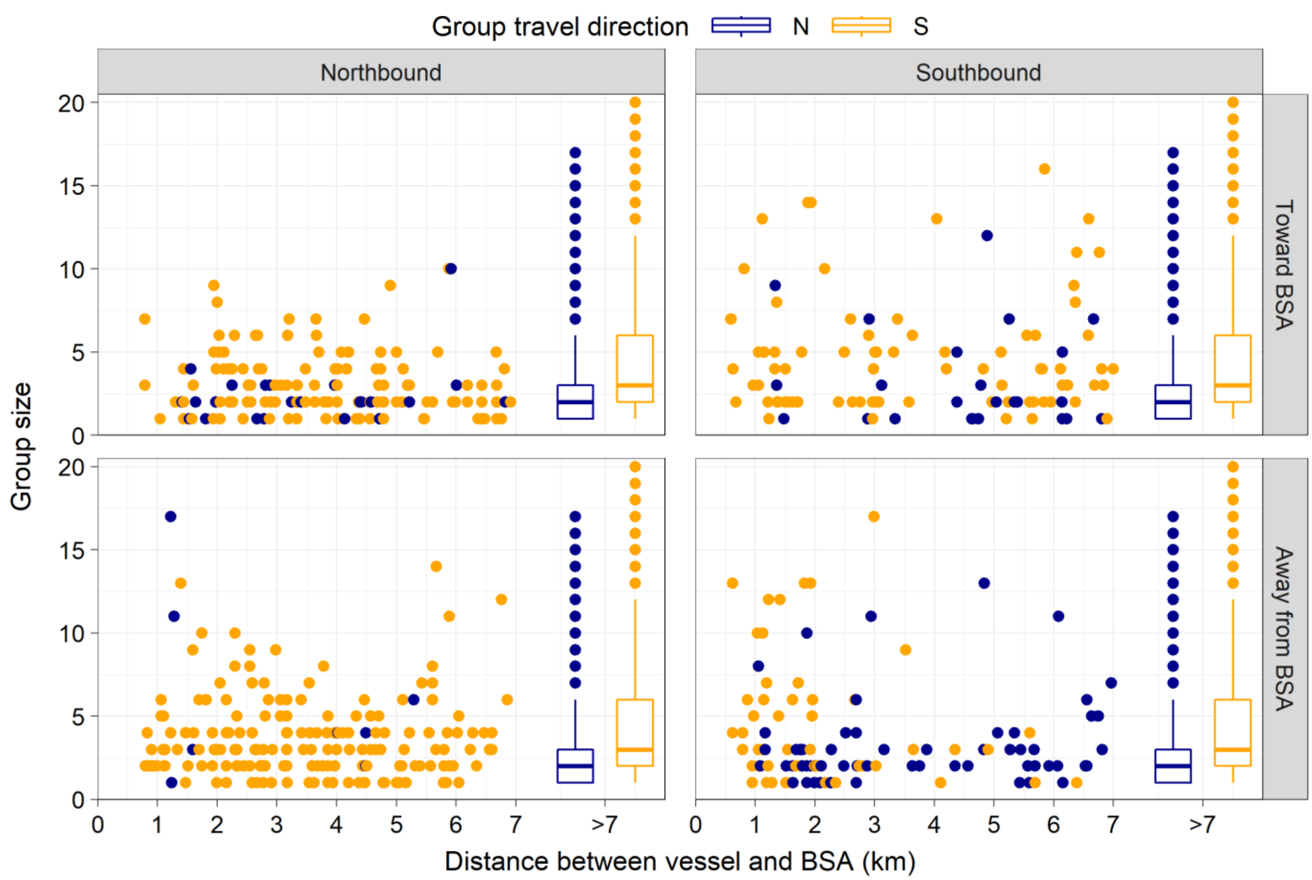


Figure 6-31: Group travel direction of narwhal groups observed in BSA relative to distance from vessels transiting through the SSA (2014–2017, 2019-2020)

The effect of directional distance on group travel direction was modelled as a linear broken stick relationship, with a break at 0 km distance from vessel, to account for the different trends in the relationship when vessels were approaching or moving away from the BSA. Test statistics and coefficient estimates for the model are provided in APPENDIX D. Residual diagnostic plots are provided in APPENDIX E.

Summary of observed data and model predictions for statistically significant variables are shown in Figure 6-32. Note that probability values detailed below and shown as orange lines in Figure 6-32 were estimated for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars in Figure 6-32 summarize the entirety of the collected data. This leads to some visual discrepancies between the observed and estimated values.

In the model of group direction, sampling year was the only significant variable (P=0.02). None of the variables related to vessels were significant (P>0.08), and none of the other variables were statistically significant predictors of group direction (APPENDIX D, Table D-11). Estimated effect sizes for a vessel at 0 km from the BSA were large, +1,126% (for a northbound vessel) and 6,116% (for a southbound vessel). The estimated effect sizes were very large due to the nonlinear nature of the logit transformation used in analysis of binomial data. On the probability scale (which extends from 0 to 1), the probability of a group to travel south increased from 0.970 when no vessels were present to 0.998 when a northbound vessel was at 0 km, and to 0.999 when a southbound vessel was at 0 km. The model had low power to detect the observed effect sizes or any of the examined effect sizes (Appendix B).

Multiple comparisons between years indicated a greater probability of observing groups travelling south in 2015 compared to 2020, with no other significant differences between years (Figure 6-32). Due to the large effect sizes, estimated effects of vessel distance and direction on the group direction were plotted despite the lack of statistical significance (Figure 6-33). When vessels were northbound, the probability to observe groups travelling south was very high (>0.99) for the entire 7-km spatial extent. This was similar to southbound vessels moving toward the BSA. In contrast, when a southbound vessel was moving away from the BSA, the probability to observe groups travelling south decreased from 0.99 at 0 km to 0.88 at 5 km, 0.71 at 6 km, and 0.43 at 7 km. However, the uncertainty associated with the effect was too high for the variable to be a statistically significant predictor in the model. This uncertainty was the result of the inclusion of a temporal autocorrelation term in the model – since travel direction can be highly autocorrelated (such as during herding events, when the vast majority of animals move in the same direction), not accounting for autocorrelation results in a model with highly autocorrelated residuals and strongly underestimated uncertainty. The inclusion of an autocorrelation term, however, results in high uncertainty, leading to lack of significance.

In summary, findings based on the combined multi-year dataset suggest a possible but uncertain effect of vessel distance on narwhal group direction. These findings are consistent with a low severity response, as defined by Finneran et al. (2017), and are therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. This is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (group direction), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

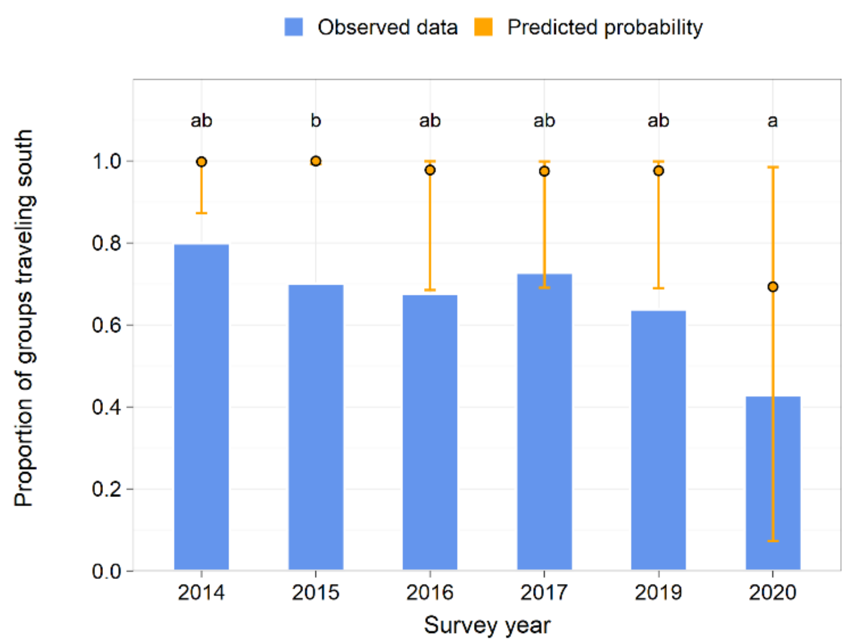


Figure 6-32: Proportion of narwhal groups travelling south relative to sampling year.

Notes: observed data depict total proportion of groups observed travelling south at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Different letters indicate significant difference between groups.

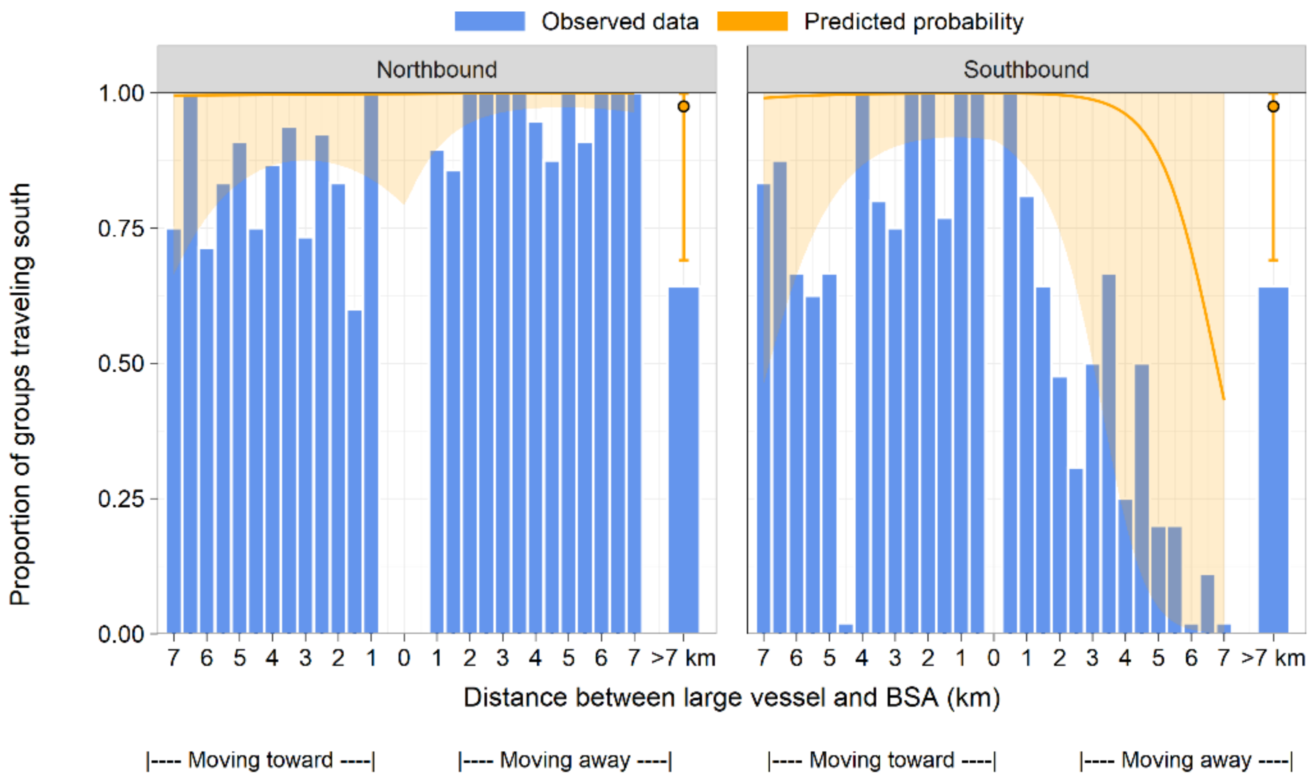


Figure 6-33: Proportion of narwhal groups travelling south relative to distance from vessel in transit, vessel travel direction and vessel orientation relative to BSA.

Notes: observed data depict total proportion of groups observed travelling south at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

6.4.6 Travel Speed

In assessing the effect of vessel exposure on narwhal travel speed, it was predicted that slow travel speed may be indicative of narwhal exhibiting a “freeze response” while fast travel speed may indicate an avoidance or flee response. The majority of narwhal groups observed in the BSA during 2014-2017 and 2019-2020 sampling years travelled at a medium speed, and slow speeds was the next most common travel speed (Figure 6-34). The mean annual proportion of narwhal groups travelling at a medium speed in the BSA ranged from 40% (in 2019) to 81% (in 2014), with a mean proportion of 53% observed in 2020. The mean annual proportion of narwhal groups travelling at a slow speed ranged from 30% (in 2017) to 52% (in 2015); with a mean proportion of 37% in 2020. Fast-travelling groups were relatively rare, with mean annual proportions of 9%, 57%, 26%, 17%, 21%, and 22% in 2014-2017 and 2019-2020, respectively. In 47 cases (5.4% of the 2020 data), travel speed was not recorded due to either visibility restrictions or logistical challenges of accurately documenting individuals during periods of high activity.

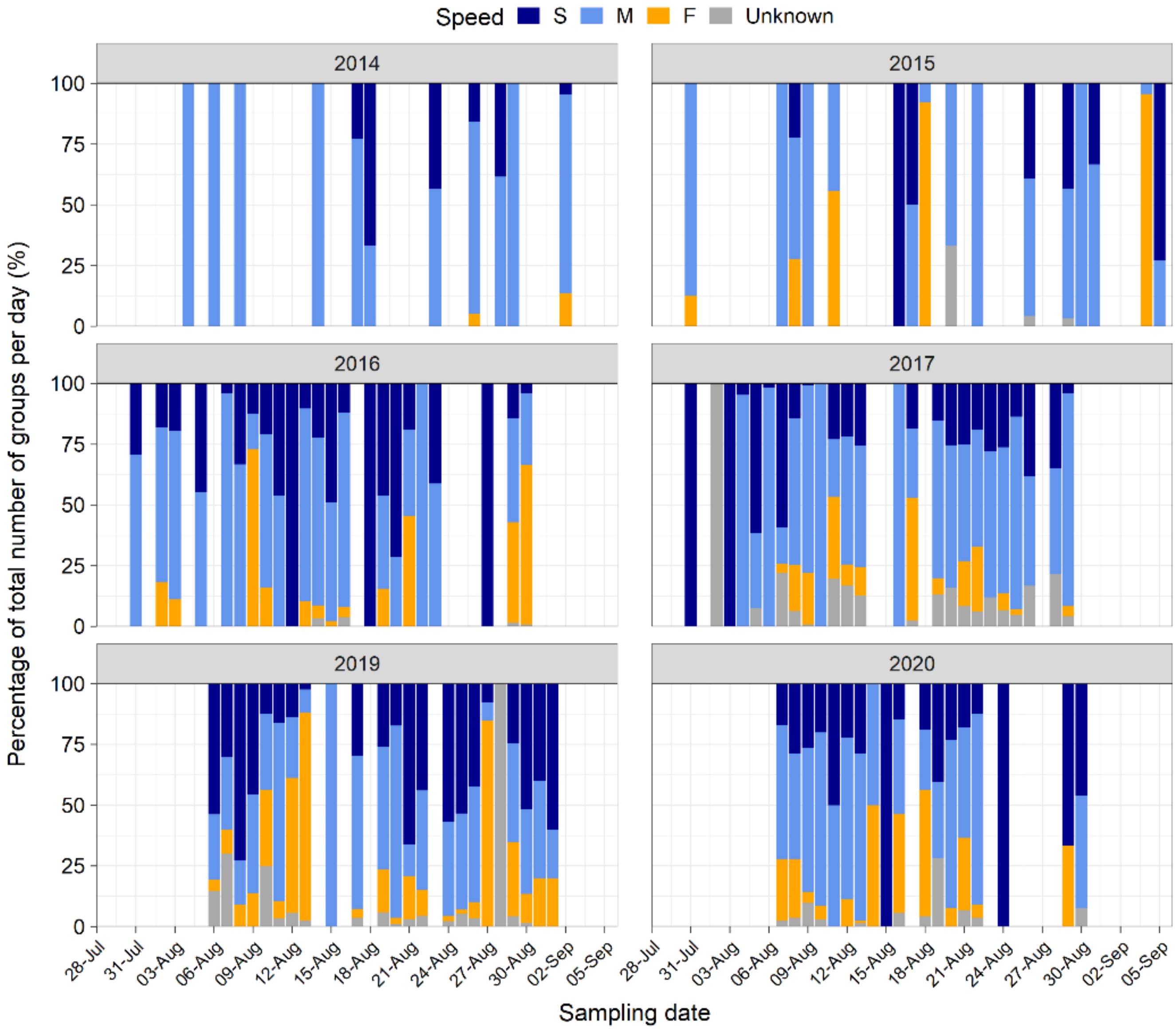


Figure 6-34: Daily distribution of narwhal group travel speed in BSA (2014–2017, 2019-2020)

The travel speed of narwhal groups in the BSA was analysed in relation to the proximity and orientation of transiting vessels (Figure 6-35). In the combined multi-year dataset, the majority of group travel speed observations were recorded during vessel non-exposure periods (n = 4,951), of which 27% of the groups were travelling slowly, 57% were travelling at a medium speed, and 17% were travelling fast. Mean narwhal group size was smallest for slow groups (2.8 individuals), intermediate for medium speed groups (3.8 individuals), and largest for fast groups (4.7 individuals).

During vessel exposure periods, a total of 580 groups with a known travel speed were recorded. The proportion of groups travelling slowly varied with vessel travel direction and orientation relative to the BSA, ranging from 16% for northbound vessels heading away from the BSA to 27% for southbound vessels heading away from the BSA. The proportion of groups travelling at a fast speed ranged from 8% for northbound vessels heading toward the

BSA to 36% for southbound vessels heading toward the BSA. Similar to vessel non-exposure periods, travel speed and group size were positively related, with mean group size increasing from 3.0 individuals for slow groups to 3.4 individuals for medium speed groups to 4.8 individuals for fast groups.

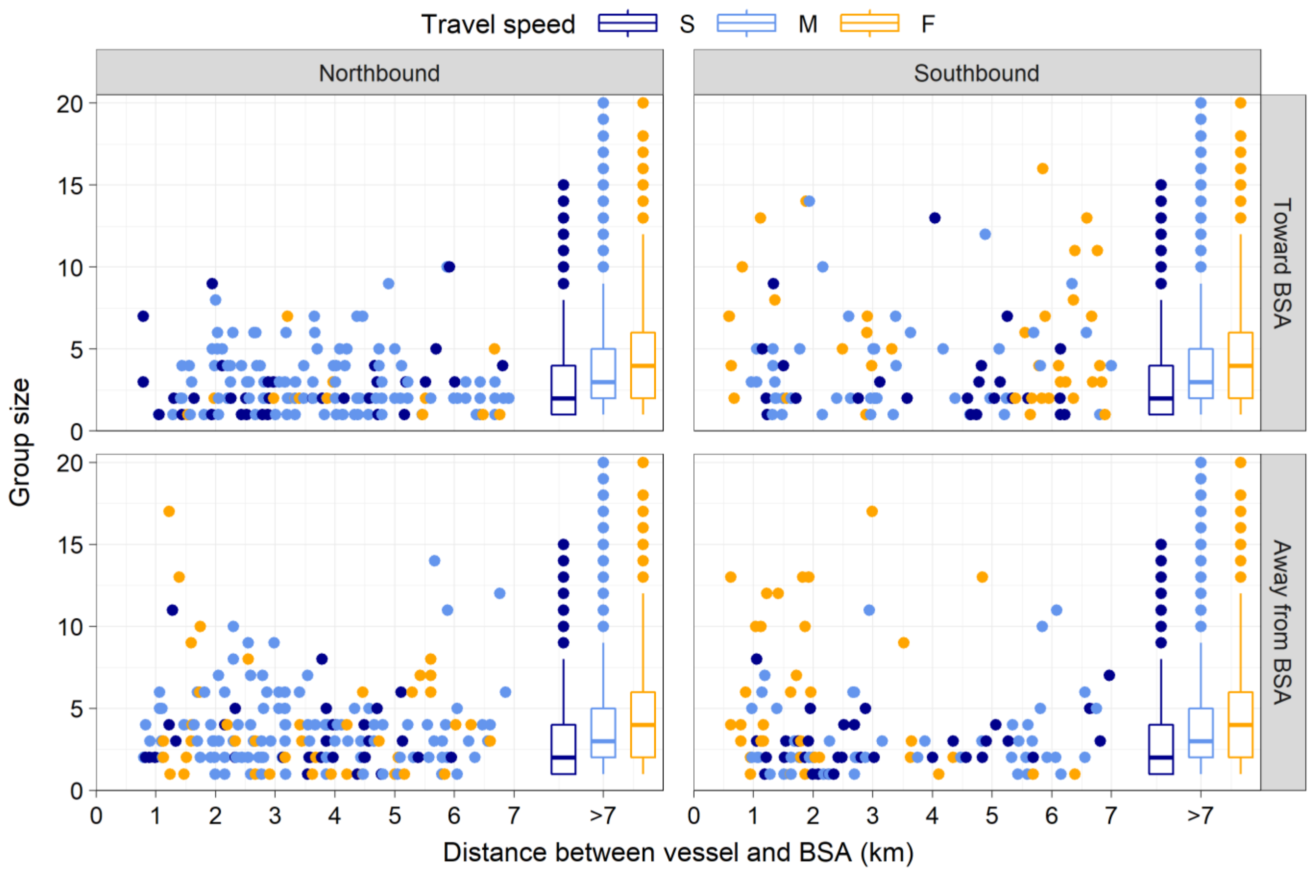


Figure 6-35: Travel speed of narwhal groups recorded in BSA relative to distance from vessels transiting through the SSA (2014–2017, 2019-2020)

Test statistics and coefficient estimates for the model are provided in APPENDIX D. Residual diagnostic plots are provided in APPENDIX E.

Summary of observed data and model predictions for statistically significant variables are shown in Figure 6-36. Note that probability values detailed below and shown as orange lines in Figure 6-36 were estimated for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars in Figure 6-36 summarize the entirety of the collected data. This leads to some visual discrepancies between the observed and estimated values.

In the model predicting the proportion of groups travelling slow (out of groups travelling at slow and medium speed), the effects of group size (P<0.001), survey year (P=0.001), and Beaufort level (P=0.007) were statistically significant. None of the other variables were statistically significant predictors of the proportion of groups travelling slow (all vessel-related P values >0.4; APPENDIX D, Table D-13). Estimated effect sizes for a vessel at 0 km from the BSA were +3% (for a northbound vessel) and -43% (for a southbound vessel). The model had low power to detect the observed effect sizes or any of the examined effect sizes (APPENDIX B).

There was a strong negative effect of group size on travel speed (Figure 6-36), with the population-level estimate of the probability of groups to be travelling slowly decreasing from 0.47 at a group size of one individual to 0.06 at a group size of 15 individuals. Multiple comparisons between years indicated a significantly greater probability of slow travel in 2019 (probability of 0.68) than in 2014, 2016, and 2017 (probability of 0.13, 0.40, and 0.384, respectively; Figure 6-36). The estimated probability of observing a slow-moving group in 2020 was not significantly different from the probabilities estimated for all previous sampling years. Beaufort level had a significant effect on the probability of observing a slow-moving group – the probability was highest (0.57) at a Beaufort level 0, intermediate at a Beaufort level 1 (0.38), and low at higher Beaufort levels (0.23-0.26 at Beaufort levels of 2, 3, and 4 or higher; Figure 6-36). Multiple comparisons of the probability of slow-moving groups between levels of the Beaufort scale indicated a significant difference between Beaufort level 2 and Beaufort levels 0 and 1, but no other significant differences were observed. These results suggest that it is more difficult to detect slow moving narwhal at higher sea states.

The model did not identify a significant effect of vessel traffic on the proportion of groups travelling slow, based on the observed data. However, statistical power was low. Due to the observed effect sizes, estimated effects of vessel distance and direction on the group direction were plotted despite the lack of statistical significance (Figure 6-37). When vessels were northbound, the probability to observe groups travelling at a slow speed increased from 0.32 (vessel moving toward the BSA, at 7 km) to 0.39 (vessel at 0 km), and decreased to 0.15 (vessel moving away, at 7 km). In contrast, in the presence of a southbound vessel, the probability to observe groups travelling at a slow speed decreased from 0.70 (vessel moving toward BSA, 7 km) to 0.260 (vessel at 0 km), and increased up to 0.41 (vessel moving away from BSA, at 7 km). In comparison, the probability of observing groups travelling at a slow speed was 0.38 during vessel non-exposure periods. From examination of the observed data, it is possible that the effects of vessel on group travel speed were associated with a smaller spatial extent. For example, in the presence of northbound vessels, the probability of groups to travel at a slow speed was lowest when vessels were at 3-4 km distances, increasing to levels similar to no-vessel values at farther distances (Figure 6-37). This is not captured in the current model which is based on a larger spatial extent (7 km). The high uncertainty associated with the model estimates was the result of the inclusion of a temporal autocorrelation term in the model – since travel speed can be highly autocorrelated (such as during herding events, when groups travel at similar speeds), not accounting for autocorrelation results in a model with highly autocorrelated residuals and strongly underestimated uncertainty. The inclusion of an autocorrelation term, however, results in high uncertainty, leading to lack of significance.

In summary, findings based on the combined multi-year dataset suggest a possible but uncertain effect of vessel distance on narwhal travel speed, though the direction of the response was not consistent. That is, compared to when no vessels were present within 7 km, narwhal were more likely to travel at slow speed when exposed to a northbound vessel and less likely to travel at slow speed when exposed to southbound vessel, likely suggesting a spurious effect.

As defined by Finneran et al. (2017), a change in travel speed by narwhal is indicative of a moderate severity response. As no significant change in travel speed was observed in response to shipping, no significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine has been demonstrated. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., travel speed), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

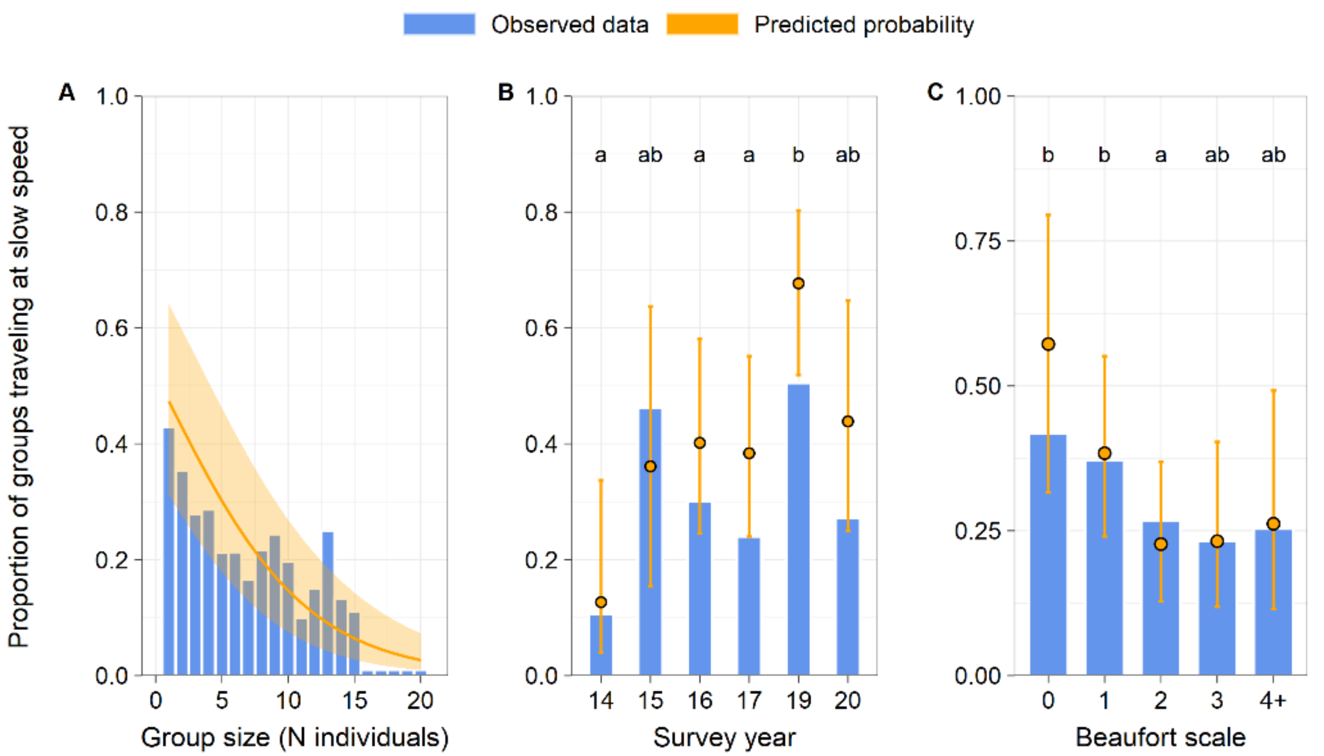


Figure 6-36: Proportion of narwhal groups travelling slowly relative to group size (panel A), survey year (panel B), and Beaufort scale (panel C).

Notes: observed data depict total proportion of groups observed travelling slowly (rather than at medium speed) at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panels B and C), different letters indicate significant difference between groups.

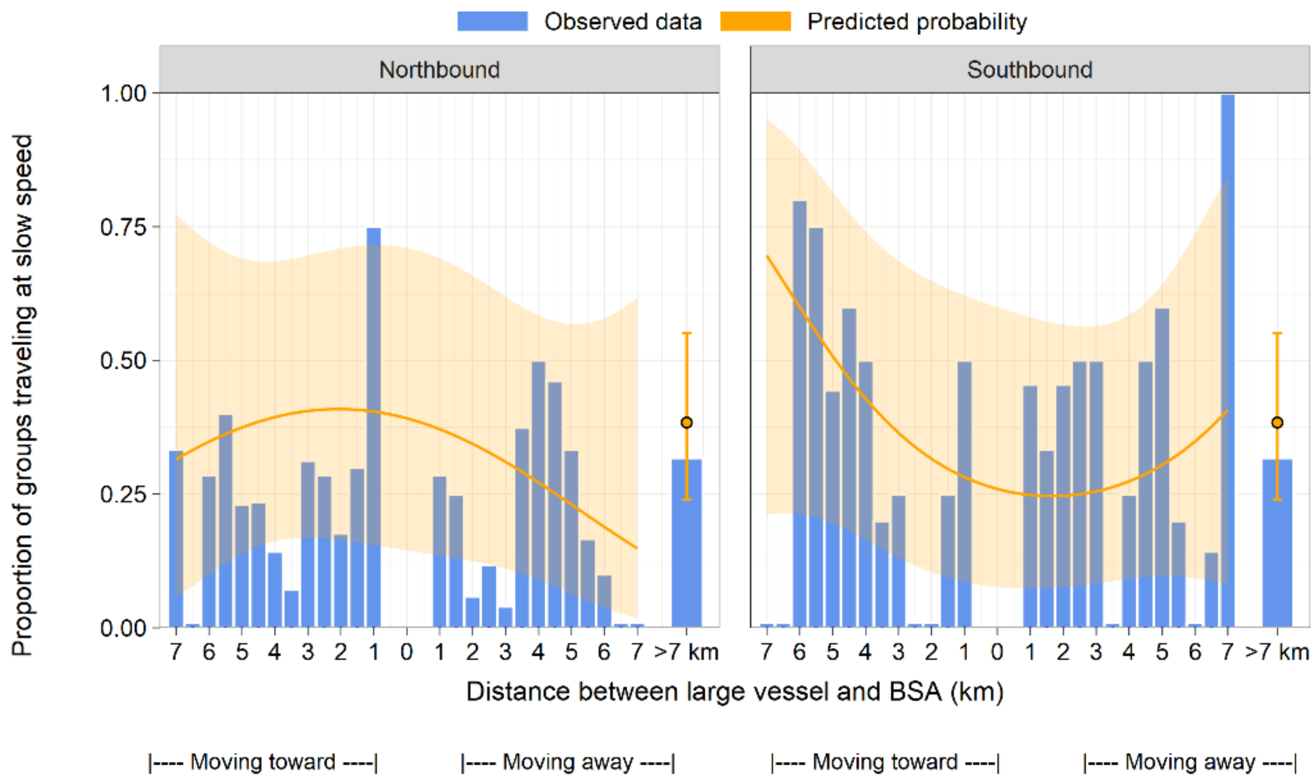


Figure 6-37: Proportion of narwhal groups travelling slowly relative to distance from vessels in transit, vessel travel direction, and vessel orientation relative to BSA.

Notes: observed data depict total proportion of groups observed travelling slowly (rather than at medium speed) at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals, holding all other variables constant.

6.4.7 Distance from Bruce Head Shoreline

Based on reports suggesting that narwhal move close to shore when attempting to escape predation by killer whales (Steltner et al.1984; Laidre et al. 2006; Marcoux et al. 2009; Breed et al. 2017), it was predicted that narwhal moving close to shore when exposed to vessel traffic may indicate an avoidance response to a perceived threat (i.e., vessel traffic). The majority of narwhal groups observed in the BSA during the six-year study were recorded close to shore (<300 m distance classification; Figure 6-38). In 23 cases (2.6% of the 2020 data), distance from shore was not recorded due to either visibility restrictions or logistical challenges of accurately documenting individuals during periods of high activity. The mean annual proportion of groups close to shore ranged from 68% (in 2017 and 2019) to 89% (in 2015). In 2020, the mean annual proportion was 70%. In comparison, the mean annual proportion of groups far from shore ranged from 22% (in 2015) and 50% (in 2014); with a mean proportion of 43% recorded in 2020.

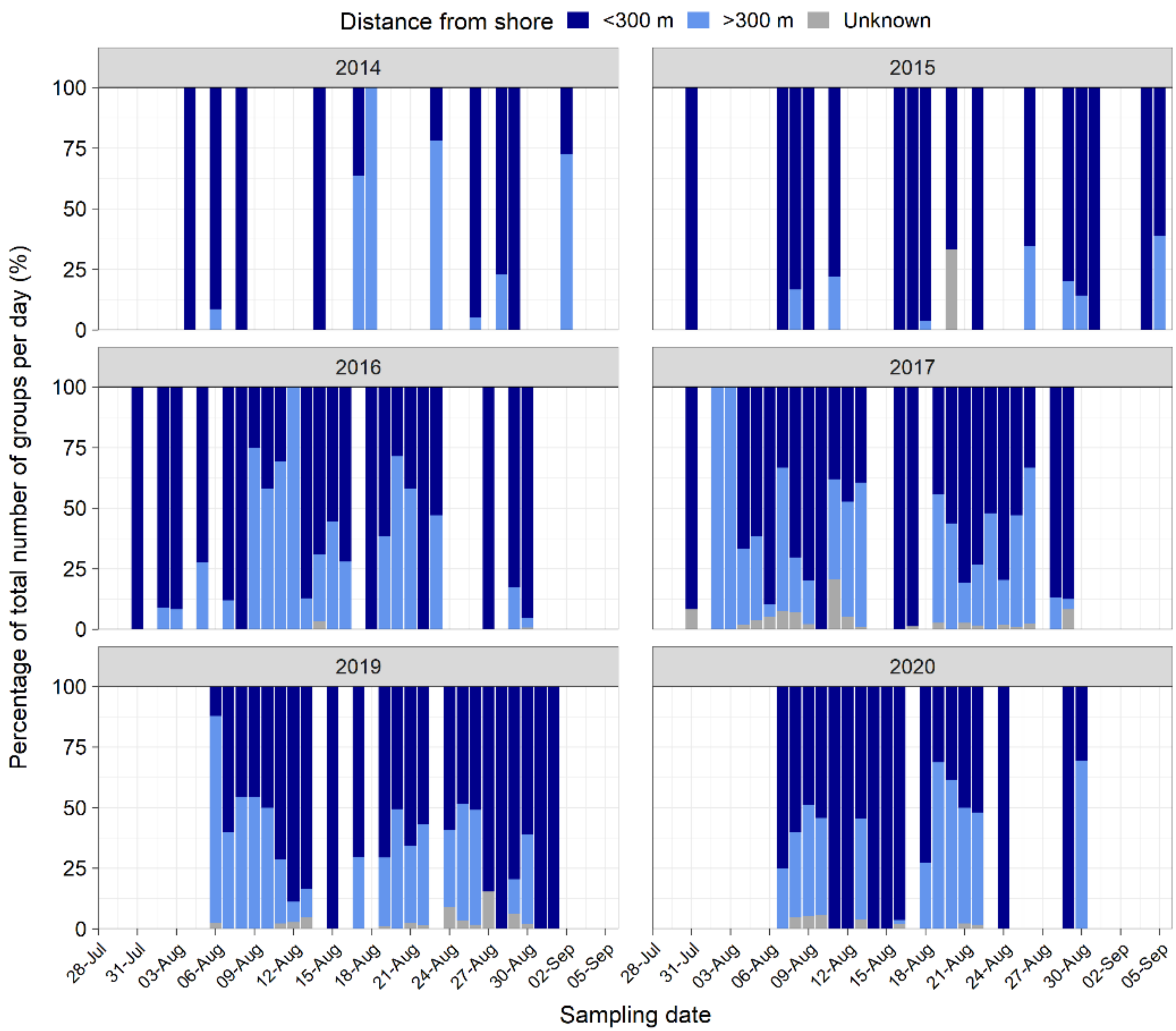


Figure 6-38: Daily distribution of narwhal groups in BSA relative to distance from shore (2014 – 2017, 2019-2020)

Distance from shore was analysed for narwhal groups in the BSA in relation to the proximity and orientation of transiting vessels (Figure 6-39). In the combined multi-year dataset, the majority of 'distance from shore' observations were recorded during vessel non-exposure periods (n = 5,119), of which 35% were >300 m from shore (mean annual proportion ranging from 23% in 2014 to 40% in 2020). Mean narwhal group size was larger for groups found closer to shore than for groups >300 m from shore (4.0 and 2.9 individuals, respectively; Figure 6-39).

During vessel exposure periods, 592 groups with a known distance from shore were recorded. The proportion of narwhal groups occurring far from shore (>300m) was influenced by vessel travel direction and vessel orientation relative to the BSA. The proportion of groups occurring far from shore was lowest when vessels were heading away from the BSA (22% for southbound vessels), intermediate for southbound vessels heading toward the BSA and northbound vessels heading away from the BSA (29% for both), and highest for northbound vessels heading toward the BSA (43%).

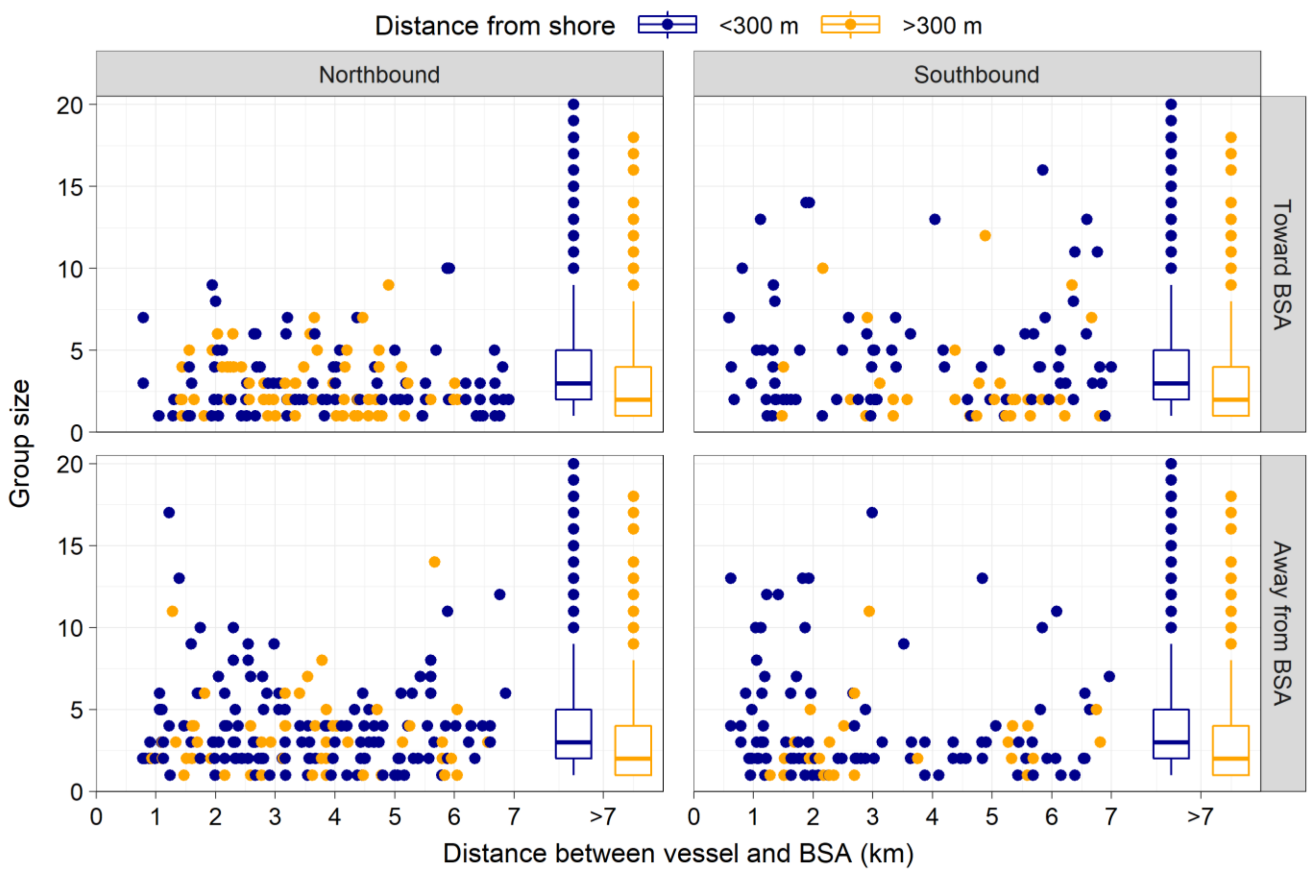


Figure 6-39: Distance from shore for narwhal groups recorded in BSA relative to distance from vessels transiting through the SSA (2014–2017, 2019)

Test statistics and coefficient estimates for the model are provided in APPENDIX D. Residual diagnostic plots are provided in APPENDIX E. The model did not have sufficient power to detect the observed effect sizes, and effect sizes of +275% were required for sufficient power (APPENDIX B).

Summary of observed data and model predictions for statistically significant variables are shown in Figure 6-40. Note that probability values detailed below and shown as orange lines in Figure 6-40 were estimated for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars in Figure 6-40 summarize the entirety of the collected data. This leads to some visual discrepancies between the observed and estimated values.

The effect of directional distance was significant (*P*=0.006), whereas the effect of whether the vessel was northbound or southbound was not significant (*P*=0.7), and neither was the interaction between the two variables (*P*=0.5). This suggests an effect of shipping on group distance from shore, but the effect of vessel on group distance from shore does not depend on whether the vessel is northbound or southbound. Estimated effect sizes for a vessel at 0 km from the BSA were large, -59% (for a northbound vessel) and -65% (for a southbound vessel). Other variables that were statistically significant predictors of the proportion of groups >300 m from shore were group size (*P*<0.001), survey year (*P*=0.007), and Beaufort scale (*P*=0.006). None of the other predictor variables in the model were statistically significant (APPENDIX D, Table D-15).

During vessel non-exposure periods, the probability of observing a group of narwhal away from shore was estimated to be 0.34 (95% confidence interval of 0.20-0.51). When vessels were travelling toward the BSA, population-level estimates suggested a dome-shaped relationship (Figure 6-40), with the predicted probability of observing groups away from shore peaking at a value of 0.53 and 0.63 (for northbound and southbound vessels, respectively) when a vessel was 4-6 km away and heading toward the BSA. When a vessel was in the immediate vicinity of the BSA (distance of 0 km from centroid), groups were less likely to be away from shore (probabilities of 0.17 and 0.15 for northbound and southbound vessels, respectively). Once the vessel moved past the BSA, groups moved away from shore again (probability peaking at 0.26-0.27 at 4-5 km distance for both vessel directions).

In the multiple comparison analysis of ‘narwhal group distance from shore’ between vessel exposure (0–7 km) and non-exposure (>7 km) periods, none of the comparisons were shown to be statistically significant (Table 6-6), which reflected uncertainty in the effects of vessel distance on the response variable for all vessel directions. These predicted values suggest effect sizes that are large enough to be potentially meaningful, but lack of statistical significance and large 95% confidence intervals in the predictions indicate large uncertainty in the relationship between vessel direction and distance, and group distance from shore.

Modelled population-level estimates of the probability to observe groups >300 m from shore indicated a negative effect of group size, with predictions decreasing from 0.37 at a group size of 1 individual to 0.18 at a group size of 15 individuals (Figure 6-40). For the median group size in the combined data (3 individuals), the probability of observing narwhal groups >300 m from shore was 0.34. Multiple comparisons between years indicated a significantly lower probability of groups to be >300 m from shore in 2015 (0.08) than in 2019 and 2020 (0.37 and 0.52, respectively) but no other significant differences between years was observed. The predicted probability to observe >300 m from shore was generally lower at Beaufort levels 3 and 4+ (0.12–0.15) than at levels 0 to 2 (0.25–0.34), which suggests that detection of groups farther from shore was more difficult in higher sea states, although most of the pairwise multiple comparisons between Beaufort levels were not statistically significant.

In summary, findings based on the combined multi-year dataset suggest an effect of vessel distance on group distance from shore that was similar for both north- and southbound vessels. Results suggest that narwhal may swim closer to shore as a potential response to vessel traffic when vessels are in close proximity to the BSA. These findings suggest that narwhal may swim closer to shore when vessels are in close proximity to the BSA, indicating a moderate severity response but of short duration. As defined by Finneran et al. (2017), moderate severity responses lasting for a short duration (i.e., less than the duration of the vessel exposure) are unlikely to result in a significant alteration of an animal’s natural behavioural patterns or disruption to their daily routine. This is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., distance from shore), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

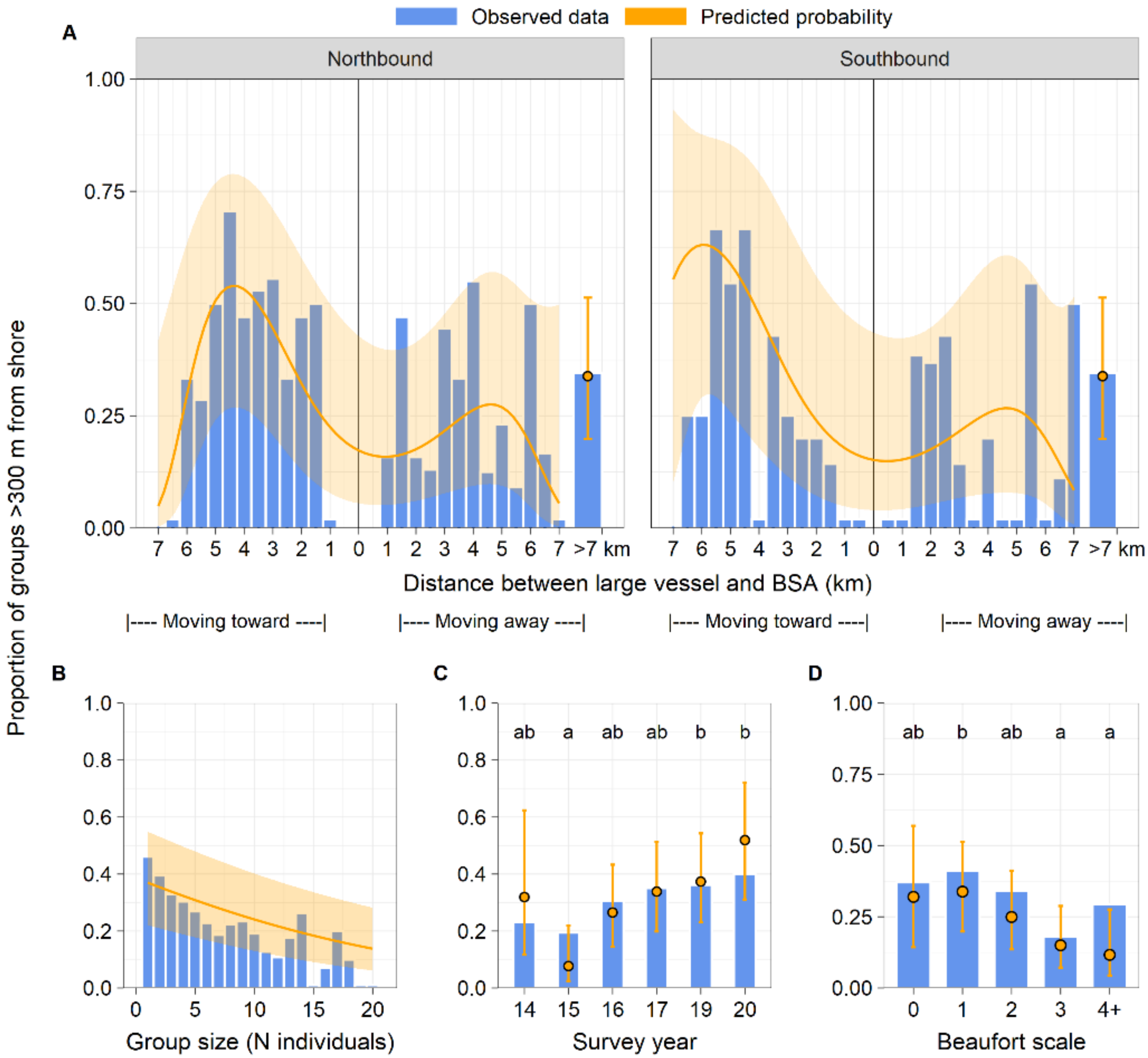


Figure 6-40: Proportion of narwhal groups observed >300 m from shore relative to distance from vessels in transit, vessel travel direction, and vessel orientation relative to the BSA (panel A), group size (panel B), survey year (panel C), and Beaufort scale (panel D).

Notes: observed data depict total proportion of groups observed >300 m from shore at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Where multiple comparisons were performed (panels C and D), different letters indicate significant difference between groups.

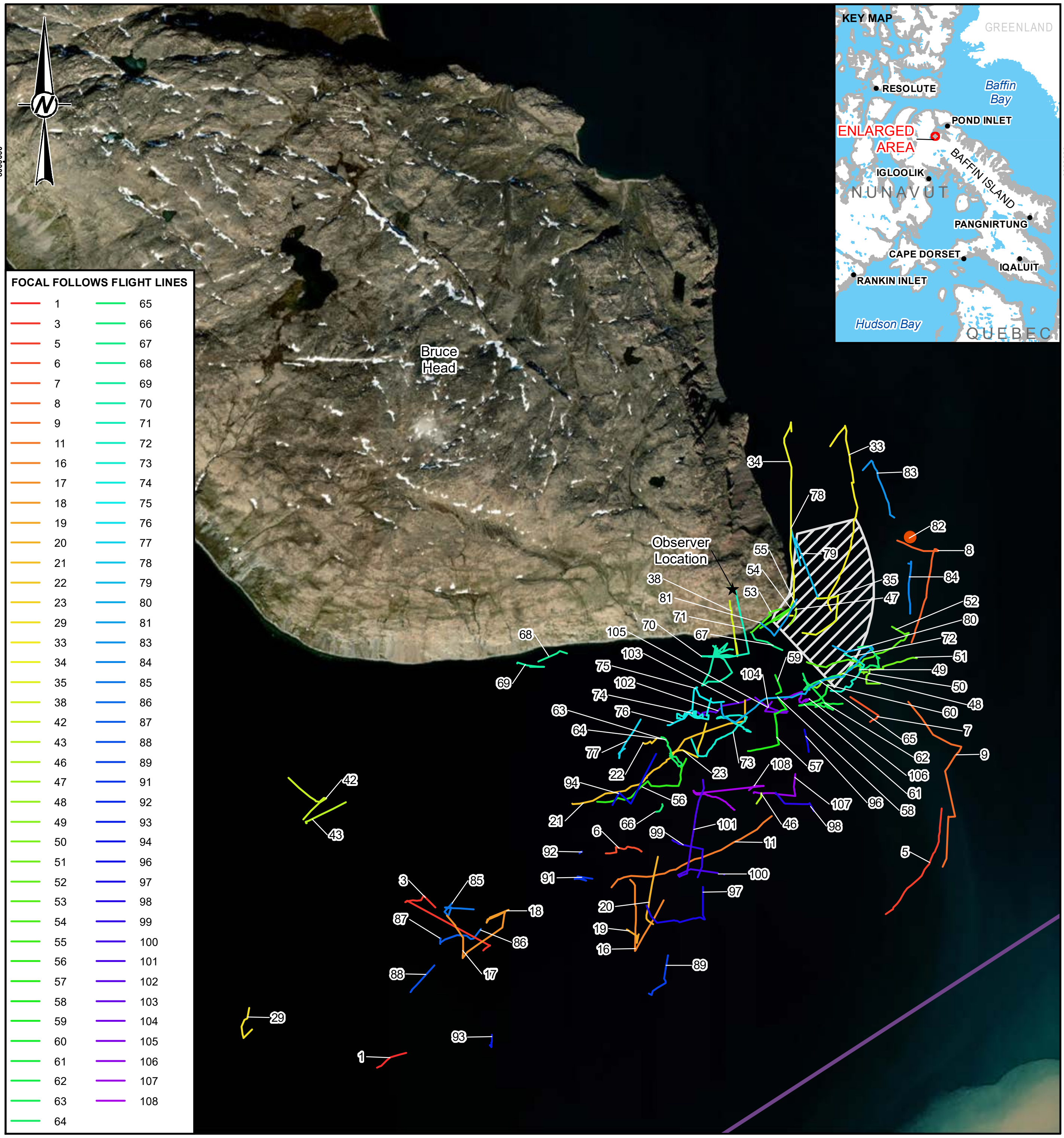
Table 6-6: Distance of narwhal group from shore - multiple comparison analysis between vessel exposure (0 to 7 km distances) and non-exposure (> 7 km) periods. Statistically significant values shown in bold.

Distance from Vessel (km)	Multiple Comparisons to No-exposure – Least-squares Means with *P* values in Brackets			
	Northbound vessel, toward BSA	Northbound vessel, away from BSA	Southbound vessel, toward BSA	Southbound vessel, away from BSA
0	0.2 (0.612)	0.2 (0.612)	0.2 (0.624)	0.2 (0.624)
1	0.2 (0.901)	0.1 (0.642)	0.2 (0.789)	0.1 (0.719)
2	0.3 (1.000)	0.2 (0.858)	0.2 (0.973)	0.2 (0.894)
3	0.4 (0.929)	0.3 (0.992)	0.3 (1.000)	0.3 (0.994)
4	0.5 (0.547)	0.3 (0.986)	0.5 (0.949)	0.3 (0.990)
5	0.5 (0.715)	0.2 (0.848)	0.6 (0.579)	0.2 (0.908)
6	0.3 (1.000)	0.2 (0.548)	0.6 (0.406)	0.2 (0.687)
7	0.05 (0.497)	0.2 (0.462)	0.6 (0.976)	0.2 (0.576)

6.5 Focal Follows (UAV) Surveys

A total of 108[7] focal follow UAV surveys were attempted during the 2020 season at Bruce Head (Figure 6-41), though not every survey search resulted in a successful focal follow. Narwhal were successfully located and followed in 84 of the UAV surveys conducted, providing 7.3 hours of total observational data. Sixteen of the 84 focal follow surveys conducted coincided with a vessel transit (19%), providing 1.3 hours of observational data in the presence of vessels, with closest point of approach (CPA) distances ranging from 1.03 km to 11.77 km (Table 6-7). Sixty-eight focal follow surveys were conducted in the absence of vessels, representing a total of 6.0 hours of observational data. Survey tracklines of the 16 focal follows involving a vessel transit are presented in APPENDIX F, with one survey figure (Focal Follow No. 11) included below as an example (Figure 6-42). For illustrative purposes, photos associated with focal follow surveys 102, 104,106, and 107 are presented in Figure 6-43 to Figure 6-46.

[7] While only 84 of the 108 UAV surveys resulted in successful follows of focal groups, unique focal follow I.D.s are numbered according to the total number of surveys carried out (i.e., 108), including successful focal follow surveys and survey searches in which narwhal were not successfully located.



LEGEND

- • COMMUNITY
- FOCAL FOLLOWS FLIGHT 82 - NOT ENOUGH POINTS IN TABLE TO CONSTRUCT A LINE
- ★ OBSERVER LOCATION
- APPROXIMATE SHIPPING ROUTE
- BEHAVIOURAL STUDY AREA (BSA)

0 1,000 2,000

1:40,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED. PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW SURVEYS CONDUCTED DURING THE 2020 FIELD SEASON AT BRUCE HEAD

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-21
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

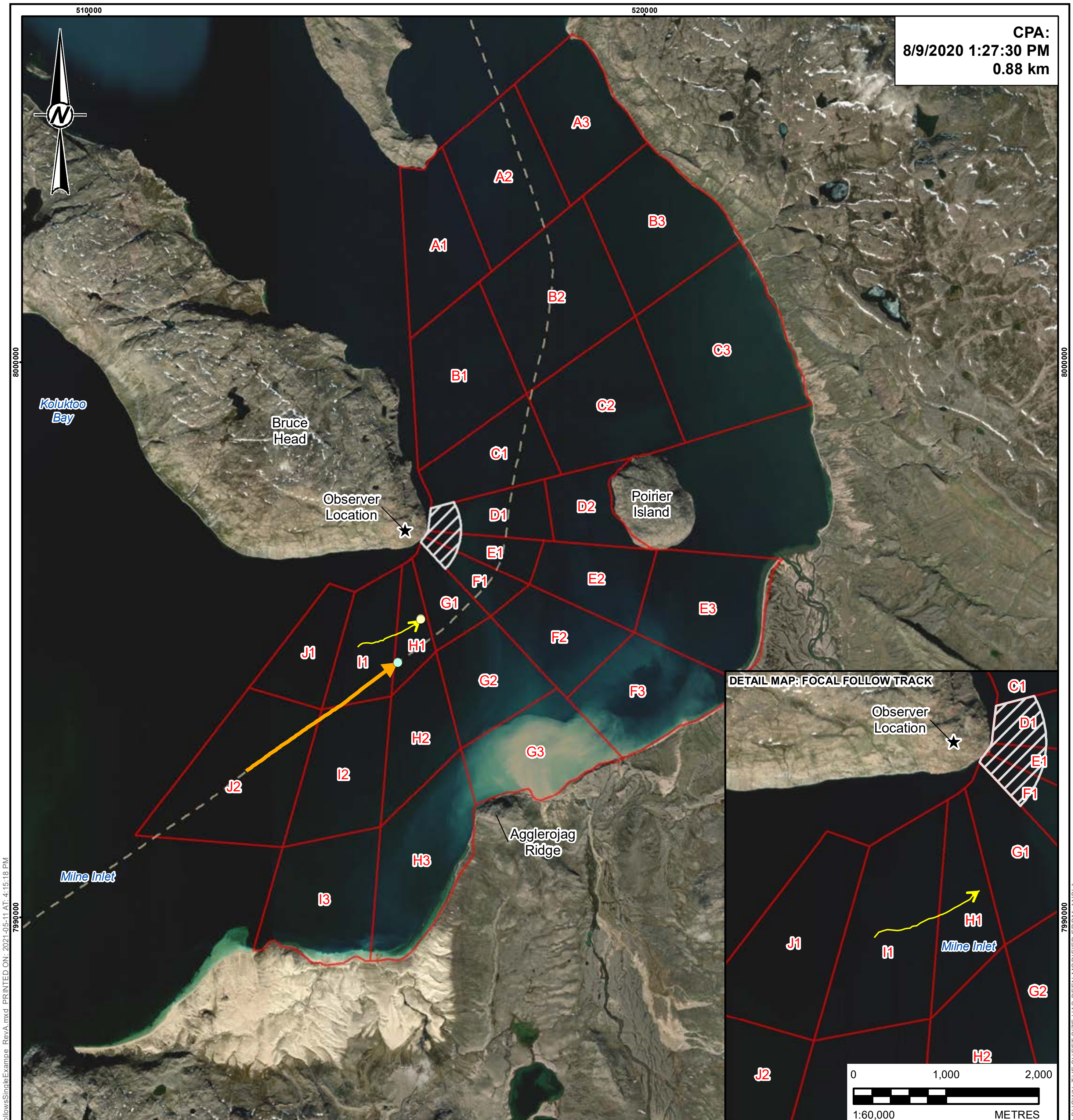
PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	6-41

PATH: I:\2016\1663724\Mapping\MXD\33000_UAV_Program\1663724_33000_05_Fig6_41_AllFocalFollows_Rev0.mxd PRINTED ON: 2021-04-21 AT: 3:26:03 PM

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

25mm

0



LEGEND

- COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 11 (2020-08-09 1:14 PM, 12 m 5 s)
- ACTIVE VESSEL TRANSIT (GOLDEN OPPORTUNITY)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN OPPORTUNITY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

DRAFT

0 2,500 5,000

1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 11 AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-05-11
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	A	6-42

PATH: I:\2016\1663724\Mapping\MXD\33000_UAV_Program\1663724_33000_05_Fig6_42_FocalFollowsSingleExampe_RevA.mxd PRINTED ON: 2021-05-11 AT: 4:15:18 PM

25mm

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

0

Table 6-7: Summary of observations - narwhal focal follow surveys conducted during active vessel transits through the study area (2020)

Survey #	Date / Start Time (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
11	9 August / 13:14	12 m 5 s	1.03	3x adults (tusked)	Group observed travelling NE as Golden Opportunity transited northbound through the southern portion of the SSA. Primarily parallel formation, mixed loose and tight spread throughout. Some scanning and horizontal rolling observed throughout survey. Shallow and deep dives throughout. Sudden change in orientation at approximately 1 m 0 s and again at 5 m 30 s into survey, all scanning and spaced tightly, then continued NE travel. Survey ended due to battery.
69	20 August / 20:27	1 m 20 s	5.27	4x adults (no tusk); 1x juvenile (no tusk)	Group observed travelling westward relatively quickly as Georg Oldendorff transited southbound through stratum B. Inuit at Bruce Head hunting camp actively hunting directly prior to the survey start. Group primarily clustered and loosely spread. Juvenile positioned to the left and rear of one of the adult individuals. Survey ended due to group diving deeply and not resurfacing.
78	22 August / 9:11	1 m 59 s	2.29	3x adults (tusked); 1x adults (no tusk); 2x juveniles (tusked); 1x juvenile (no tusk)	Group observed travelling southward as Georg Oldendorff transited northbound through stratum C. Group primarily clustered and tightly spread. Tusked adult positioned at the front of the group observed scanning. Survey ended due to high winds.
79	22 August / 9:15	4 m 6 s	2.82	3x adults (tusked)	Group observed travelling southward/SE relatively slowly. Some milling behaviour observed momentarily. Group primarily in parallel formation and loosely spread. Individuals switch between shallow diving and travelling at surface. Georg Oldendorff transiting northbound through stratum B. Survey ended due to high winds.
85	29 August / 13:21	1 m 21 s	3.49	1x adult (no tusk); 1x calf	Mother and calf pair observed travelling NE, closely associated with one another and calf predominantly below mother. Tusked male observed trailing behind the pair but far away (i.e., >20 body lengths) and not considered part of the focal group. Nordic Olympic transiting southbound through stratum G. Survey ended due to pair diving deeply and not resurfacing.

Survey #	Date / Start Time (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
86	29 August / 13:25	1 m 10 s	2.62	1x adult (no tusk)	Adult (no tusk) observed travelling NE and scanning. Nordic Olympic transiting southbound through stratum H. Survey ended due to individual diving deeply and not resurfacing.
87	29 August / 13:27	1 m 30 s	2.44	1x adult (no tusk); 1x calf	Mother and calf pair observed milling and slowly travelling NE, closely associated with one another and calf predominantly below mother. Nordic Olympic transiting southbound through stratum H. Survey ended due to pair diving deeply and not resurfacing.
88	29 August / 13:41	3 m 55 s	2.80	1x adult (no tusk); 1x yearling	Adult (no tusk) observed resting while oriented NE/E at start of survey. Individual joined by a yearling at 3 m 0 s into survey, with yearling approaching from behind and then remaining closely associated with the underside of the adult (potentially its mother). Nordic Olympic transiting southbound through southern SSA. Survey ended due to pair diving deeply and not resurfacing.
89	29 August / 13:37	3 m 47 s	7.88	1x adult (no tusk)	Non-tusked adult observed milling and travelling, frequently altering its course while also scanning and rolling horizontally. Individual’s behavior (i.e., increased scanning and horizontal rolling) appears to commence once drone is lower in elevation, suggesting that it may be aware of the drone overhead. Nordic Olympic transiting southbound through stratum J. Survey ended due to individual diving deeply and not resurfacing.
102	30 August / 9:20	6 m 18 s	11.77	1x adult (tusked)	Tusked adult with a potential flesh wound on its underside observed resting throughout survey. Orientation of individual changes throughout the survey. Observed undertaking shallow dives, scanning, and rolling horizontally from approximately 2 m 0 s onward. Individual’s behavior (i.e., increased scanning and horizontal rolling) appears to commence once drone is lower in elevation, suggesting that it may be aware of the drone overhead. Bulk Destiny transiting southbound, north of SSA. Survey ended due to individual diving deeply and not resurfacing.

Survey #	Date / Start Time (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
103	30 August / 9:28	4 m 15 s	10.26	1x adult (no tusk)	Adult (no tusk) observed milling and rolling vertically at start of survey and then engaged in shallow and deep dives, though still visible throughout. Oriented primarily eastward (slightly NE). Bulk Destiny transiting southbound, entering northern portion of SSA. Survey ended due to individual diving deeply and not resurfacing.
104	30 August / 9:35	3 m 21 s	9.08	1x adult (no tusk); 1x calf	Mother with small calf observed resting in close association with one another, with both individuals oriented NE and the calf nursing from its mother for much of the survey. Mother appears to be aware of the drone overhead and begins slow travel, then dives deeply while leaving the calf at the surface. Bulk Destiny transiting southbound, entering northern portion of SSA. Survey ended due to battery.
105	30 August / 9:46	2 m 40 s	6.80	1x juvenile (no tusk) Also: 1x adult (no tusk); 1x yearling	Juvenile (no tusk) observed travelling in loose association with a mother/yearling pair. The mother/yearling pair dives deeply immediately and does not resurface. Direction of travel changes throughout survey. An adult (no tusk) approaches focal individual but the two do not remain together. Bulk Destiny transiting southbound through stratum A. Survey ended due to focal individual (i.e., juvenile, no tusk) diving deeply and not resurfacing.
106	30 August / 9:50	10 m 0 s	4.25	1x adult (no tusk) 1x calf Later joined by: 1x adult (no tusk)	Mother and calf pair observed oriented westward, with mother making deep dives at start of the survey while calf waits at surface, periodically attempting to dive down deeply. Orientation changes throughout but primarily moving N/NW. Mother resurfaces at 1 m 30 s and the pair observed resting in close association with one another, oriented N/NE, with the calf nursing from its mother. Pair begins slow travel while the mother is observed scanning at approximately 6 m onward. Joined by another adult (no tusk) at 7 m 30 s, at which point the mother dives down deeply and leaves her calf with the new individual. Calf begins travelling westward with the new adult, positioned above and to the side of the individual. New adult swimming closely with the calf but making erratic movements as if looking around and scanning. Bulk Destiny transiting southbound through stratum B. Survey ended due to pair diving deeply and not resurfacing.

Survey #	Date / Start Time (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
107	30 August / 10:13	4 m 45 s	2.62	2x adults (no tusk); 2x juveniles (tusked); 1x juvenile (no tusk); 1x calf	Group observed travelling westward, loosely associated with one another and in parallel formation. The mother and calf are in close association with one another throughout the survey, with the calf primarily underneath of its mother. The two juveniles (tusked) dive deeply at 30 s and then resurface, re-joining the group, at 2 m 30 s. At 3 m 0 s, the juvenile (no tusk) is observed swimming ahead of the group, at which point all abruptly change direction, now moving eastward and then milling while the tusked juveniles dive deeply and then resurface. Three of the immatures are then observed rolling vertically as they again change direction, now moving NE, and the tusked juvenile is observed briefly resting its tusk on the juvenile (no tusk) before the two are seen belly to belly. Bulk Destiny transiting southbound through stratum E. Survey ended due to the group diving deeply and not resurfacing.
108	30 August / 10:20	12 m 49 s	1.86	1x adult (no tusk) Later joins: 2x adults (no tusk); 1x calf	Single adult (no tusk) observed travelling westward, with momentary change in travel eastward at 30 s, before resuming westward travel. Individual observed just below the surface for much of the survey. Another abrupt change in travel direction observed at 5 m 30 s, with individual now travelling NE, SE, and then E, all while continually scanning and rolling horizontally. Toward the last minute of the survey, focal individual joins a group of two adults (no tusk) with calf. Formation of group changing every few seconds (linear to parallel to cluster). Bulk Destiny transiting southbound through stratum F → H. Survey ended due to battery.

Figure 6-43: Screen capture from focal follow UAV video survey #102: Single adult (tusked) observed within 11.77 km of a southbound vessel (Bulk Destiny), 8 August 2020 (9:20 A.M.).

Figure 6-44: Screen capture from focal follow UAV video survey #104: Mother and calf pair observed within 9.08 km of a southbound vessel (Bulk Destiny), 8 August 2020 (9:35 A.M.).

Figure 6-45: Screen capture from focal follow UAV video survey #106: Mother and calf pair observed throughout focal follow, later joined by another adult (no tusk). Focal group observed within 4.25 km of a southbound vessel (Bulk Destiny), 8 August 2020 (9:50 A.M.).

Figure 6-46: Screen capture from focal follow UAV video survey #107: Two adults (no tusk), three juveniles (two tusked, one no tusk), and calf observed within 2.62 km of a southbound vessel (Bulk Destiny), 8 August 2020 (10:13 A.M.).

Focal follow surveys were conducted throughout the 2020 field season, though the ability to conduct surveys was highly dependent on weather conditions and external factors such as helicopter traffic in the area and hunting activity. On days when UAV surveys were flown, the number of surveys completed per day ranged from 2 (8 August) to 17 (29 August; Figure 6-47). The daily number of focal follow surveys conducted in the presence of vessels ranged from 1 (15 and 20 August) to 7 (30 August). The total daily amount of time spent following groups (i.e., not searching) ranged from <5 minutes (11, 14, and 15 August) to >50 minutes (9 and 21 August; Figure 6-48). Of that time, the daily amount of time spent following groups when a vessel was present ranged from 1.5 minutes (20 August) to 44 minutes (30 August).

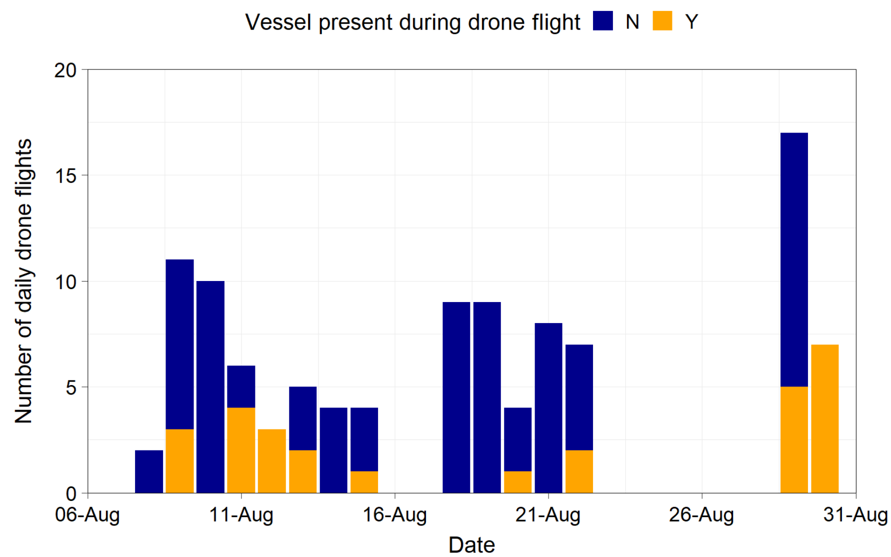


Figure 6-47: Time series of UAV surveys conducted near Bruce Head in 2020.

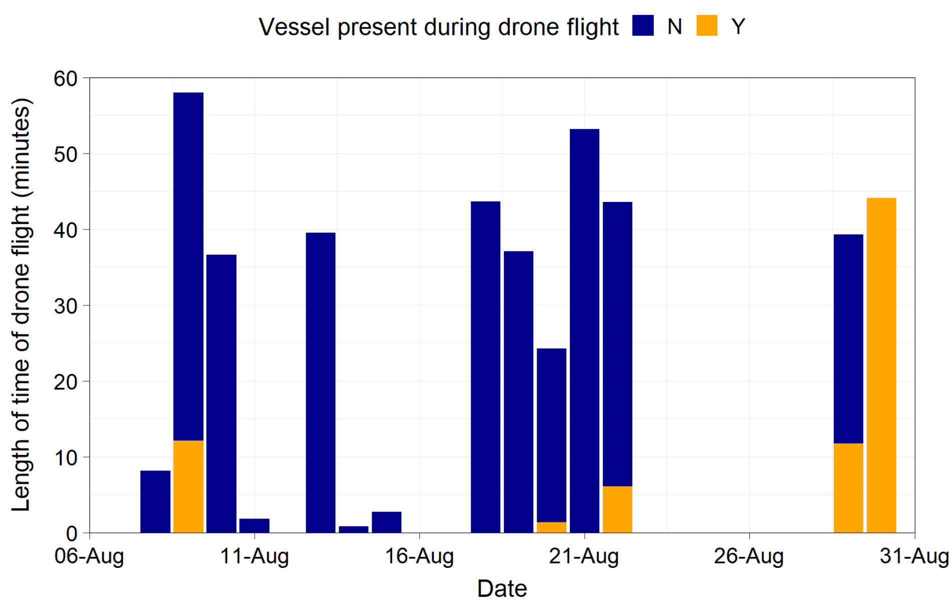


Figure 6-48: Time series of total daily time spent with focal groups.

The majority of the focal follow surveys consisted of small group sizes (Figure 6-49). Focal groups comprised of two or less individuals accounted for 40 of the 80 surveys undertaken when no vessels were present, and 8 of the 28 surveys when a vessel was present, representing 58% of all successful follows (i.e., surveys in which a group was located and followed). Groups larger than 10 narwhal were only recorded during four of the focal follow surveys; on 18 August (maximum groups size of 11 narwhal), 13 August (maximum group size of 13 narwhal), and 22 August (two groups – with 11 and 13 narwhal each). In the absence of vessels, the median value of maximal group size was two narwhal, and the mean group size was 3.3 narwhal (SD of 3.0 narwhal). When vessels were present, the median value of maximal group size was 2.5 narwhal, and the mean group size was 2.9 narwhal (SD of 1.8 narwhal).

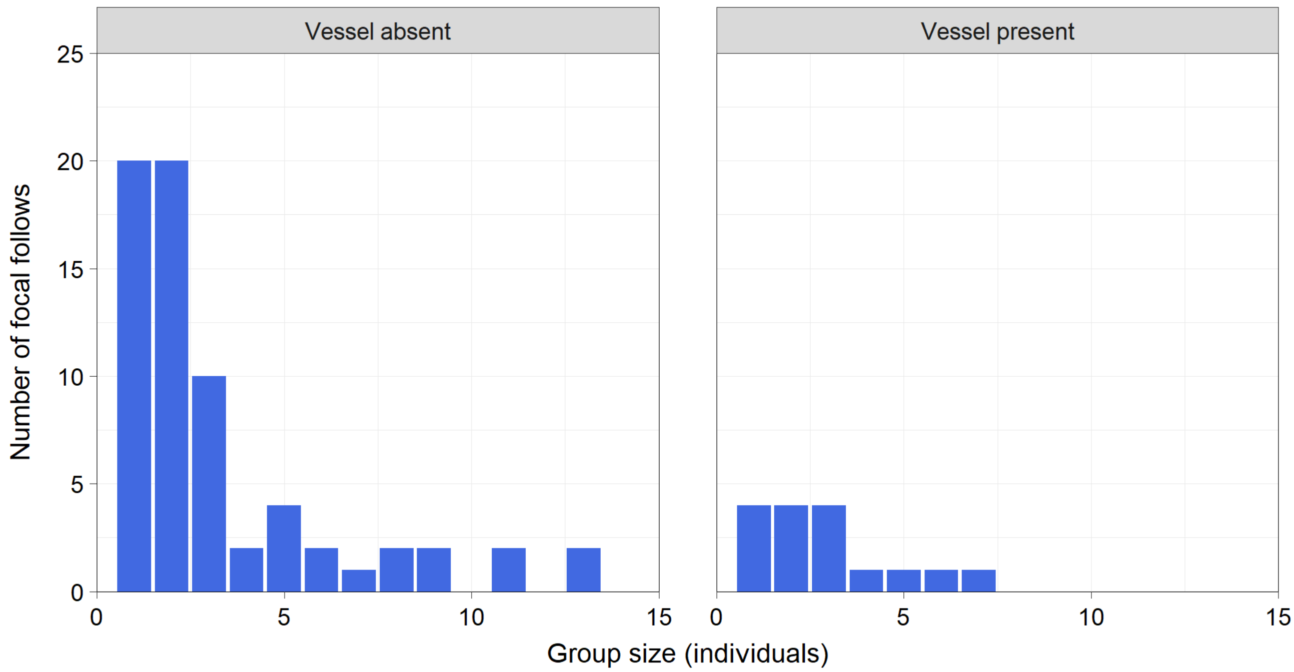


Figure 6-49: Narwhal maximum group size during focal follow surveys relative to vessel presence.

Of the focal groups, adult narwhal were observed most frequently (66% of all narwhal), followed by juveniles (13%), calves (12%) and yearlings (4%) (Figure 6-50). Group composition recorded during the surveys did not vary with vessel presence. When vessels were present, group composition was comprised of 65% adults, 17% juveniles, 4% yearlings, and 13% calves. When no vessels were present, group composition was comprised of 71% adults, 13% juveniles, 4% yearlings, and 13% calves. A total of 37 of the focal groups surveyed were comprised of one or more mothers with dependent young, of which eight coincided with vessel passages.

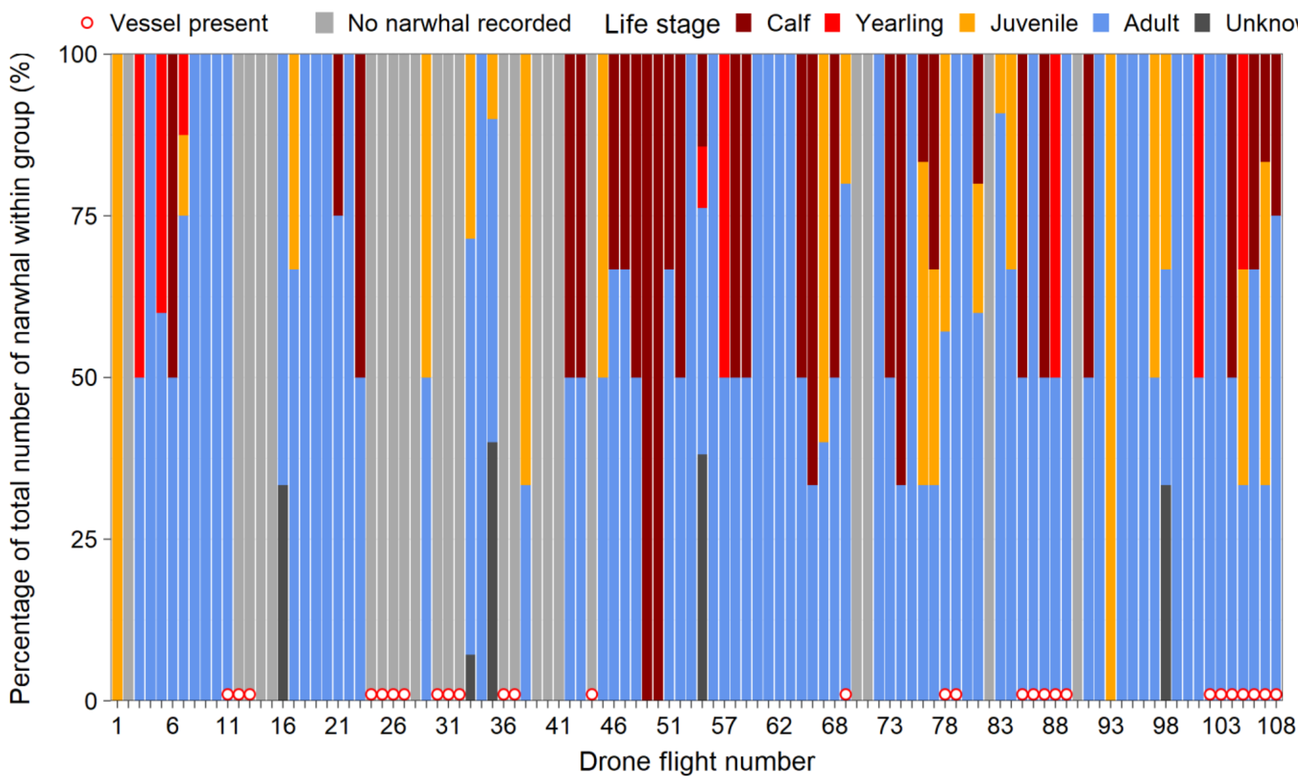


Figure 6-50: Group composition recorded during focal follow surveys.

Of the followed groups, the most frequently observed formation was parallel (40% of time), similar to the predominant formation observed by MMOs in the BSA, followed by linear formation (28% of the time), and cluster formation (27% of the time). When a vessel was present, the proportion of groups in parallel formation was higher than when no vessel was present (59% and 36%, respectively). In contrast, the proportion of groups in linear and cluster formations was lower when a vessel was present (19% and 14%, respectively) relative to when no vessels were present (30% for both).

Of the followed groups, narwhal spent similar amounts of time in “loose” and “tight” spread (48% and 51% of the time, respectively; Figure 6-52). When a vessel was present, the proportion of time that narwhal groups spent in tight formation was slightly higher (57%) compared to periods when no vessels were present (46% of the time).

Primary behaviors assessed included travelling (i.e., directional movement), milling (i.e., non-directional movement), resting (i.e., not moving/logging or moving slightly), and social behavior (i.e., clear interaction between individuals with physical contact). Of the followed groups, narwhal spent the majority of time travelling (65% of the time), followed by milling (20 % of the time), resting (12% of the time), and social behaviours (3% of the time; Figure 6-53). The proportion of time groups spent travelling was similar when vessels were present compared to when no vessels were present (71% and 64%, respectively). Similarly, the proportions of time that narwhal spent resting, milling, and performing social behaviours were similar when a vessel was present (17%, 10%, and 1%, respectively) compared to when no vessels were present (10%, 22%, and 4%, respectively).

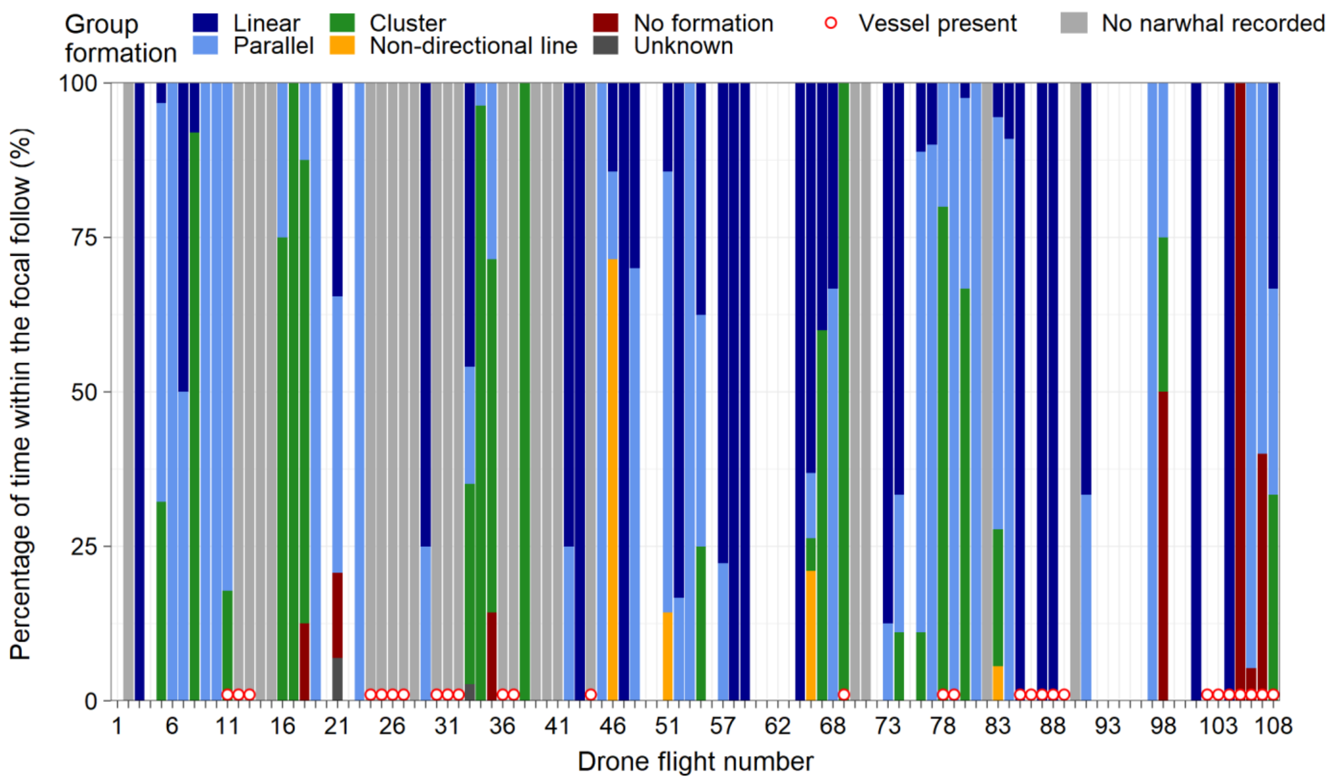


Figure 6-51: Group formation recorded during focal follow surveys.

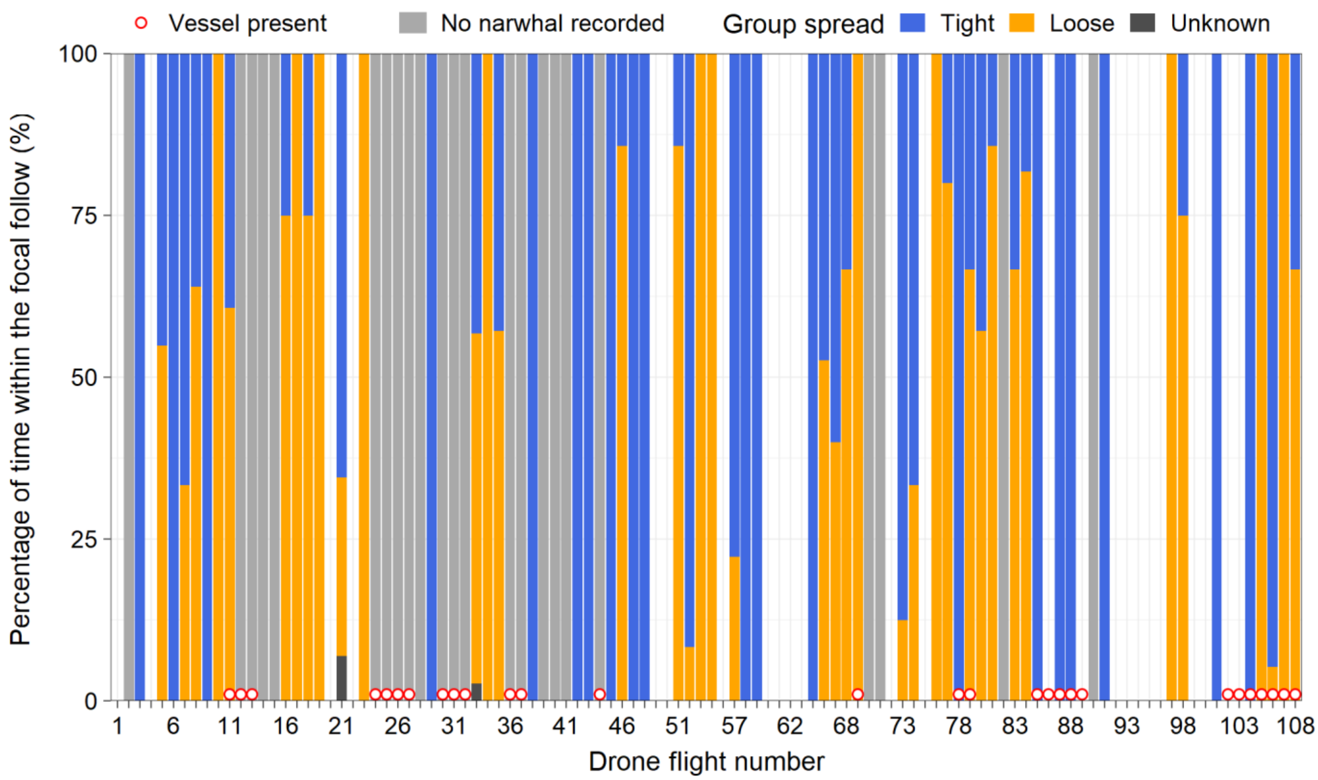


Figure 6-52: Group spread recorded during focal follow surveys.

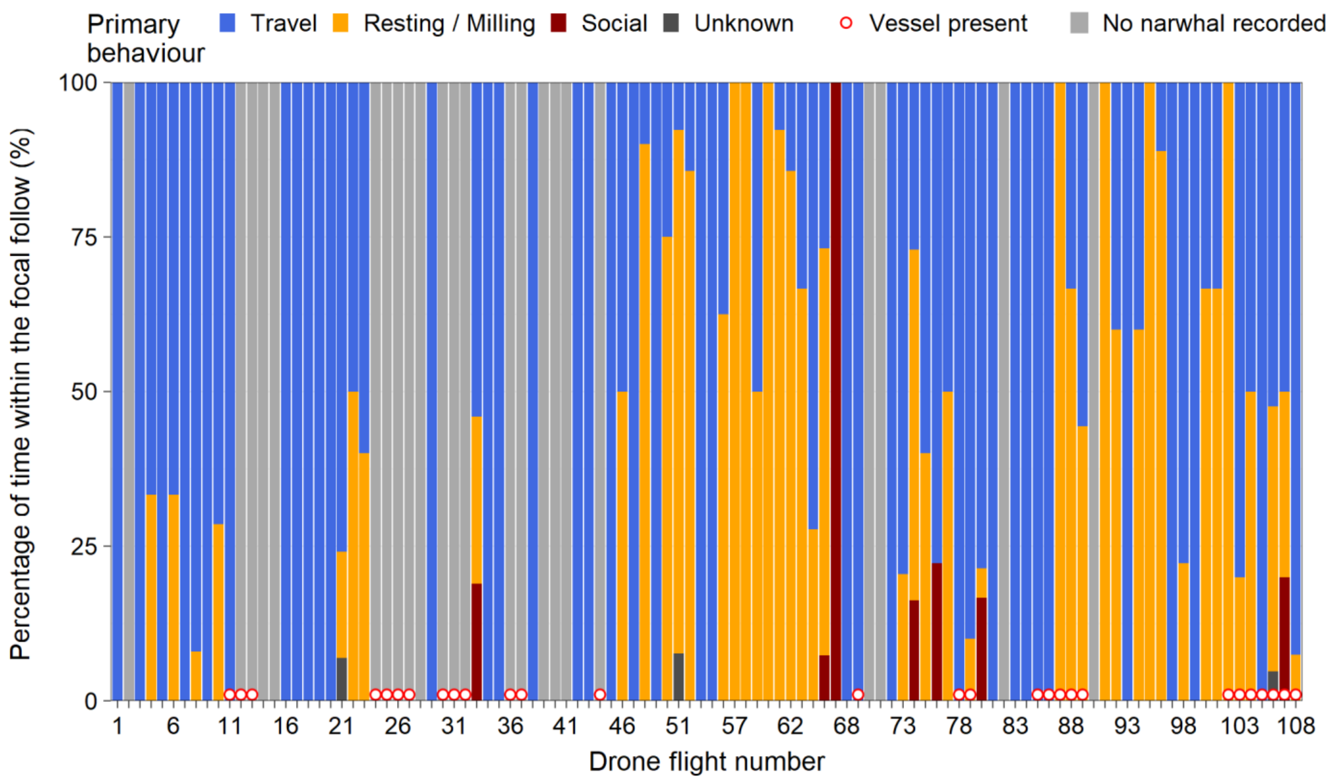


Figure 6-53: Primary behaviour recorded during focal follows.

Of the followed groups, nursing was recorded for 13 of the groups (19% of all groups), horizontal and vertical rolling were recorded for 33 and 13 of the groups (47% and 19% of all groups), respectively, and rubbing, tusking, and "jousting" (i.e., directed movement of one tusked individual toward another) were recorded in 8, 1, and 2 groups, respectively (11%, 1%, and 3% of all groups; Figure 6-54). In groups where nursing was recorded, time spent nursing ranged between 6% and 70% of the focal follow (mean value of 40% of the time, SD of 24% of the time). In the two groups where nursing was recorded while a vessel was present within the SSA, the proportion of time nursing was high (63% of the time in FF104 and 52% of the time in FF106), resulting in a higher mean value for time nursing (57%) relative to when no vessels were present (34% of the time).

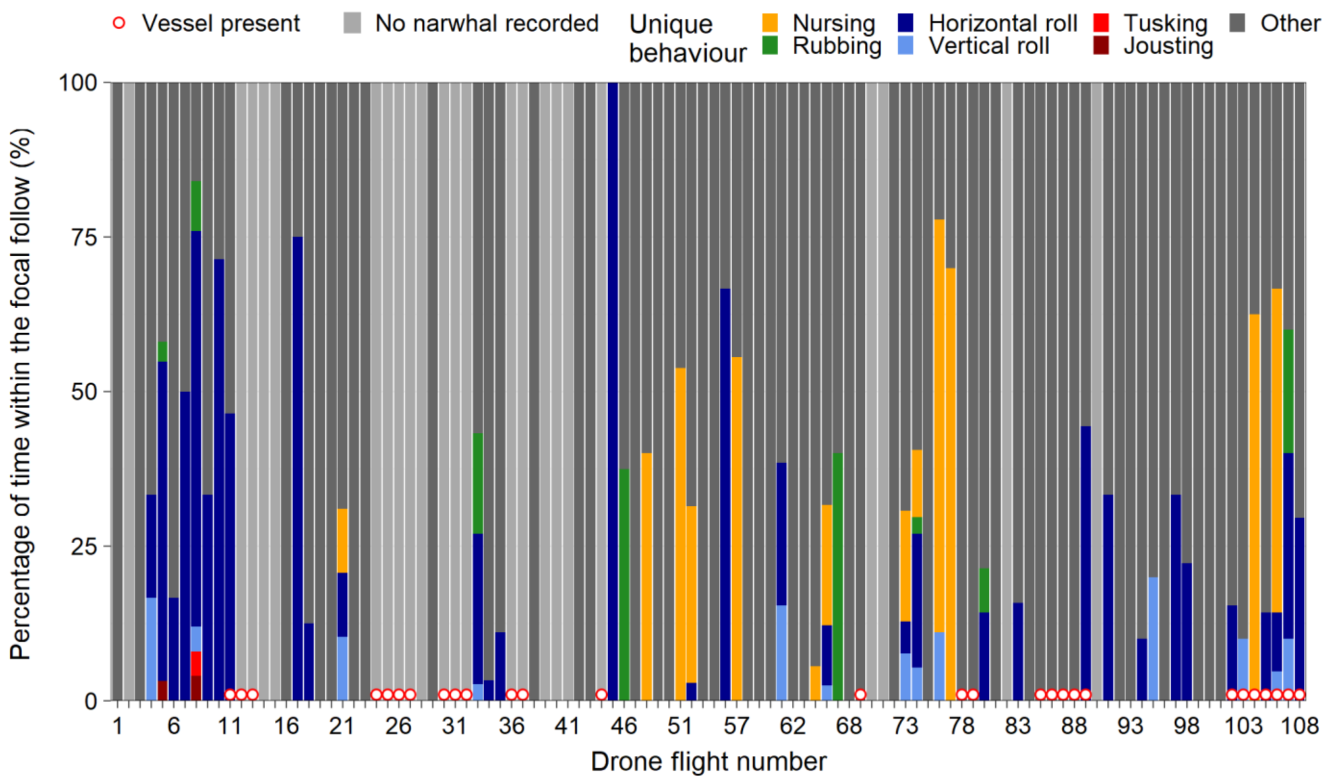


Figure 6-54: Unique behaviours recorded during focal follows.

Of the followed groups, immatures (i.e., calves and yearlings) were most often recorded underneath of their presumed mother (55% of time - compared to beside, behind or above their mother) in both presence and absence of shipping. Although calf and yearling positions often changed, with up to four relative positions recorded for a single immature within a given survey (Figure 6-55). Calves positioned to the left or the right side of the adult were the second and third most common relative positions (20% and 11% of the time, respectively). When a vessel was present, the proportion of time that immatures were recorded underneath of the presumed mother was slightly higher compared to when no vessels were present (69% and 53%, respectively). In contrast, the proportion of time immature narwhal were recorded to the left or right of an adult was lower (i.e., 6% and 8%, respectively) when vessels were present compared to when no vessels were present (i.e., 22% and 12%, respectively).

When a calf or yearling was underneath of the presumed mother, it was tightly associated with the adult 91% of the time (Figure 6-56). In comparison, immature narwhal were tightly associated with the presumed mother only 70% of time when positioned above the adult, 57% and 50% of the time when they were positioned to the left or to the right of the adult, respectively, 50% of the time when they were in front of the adult, and only 33% of the time when they were behind the adult.

Additional monitoring is required to increase the sample size of focal follow surveys conducted in the presence of vessel traffic (given that the current sample size is limited to 1.3 h of observational data only).

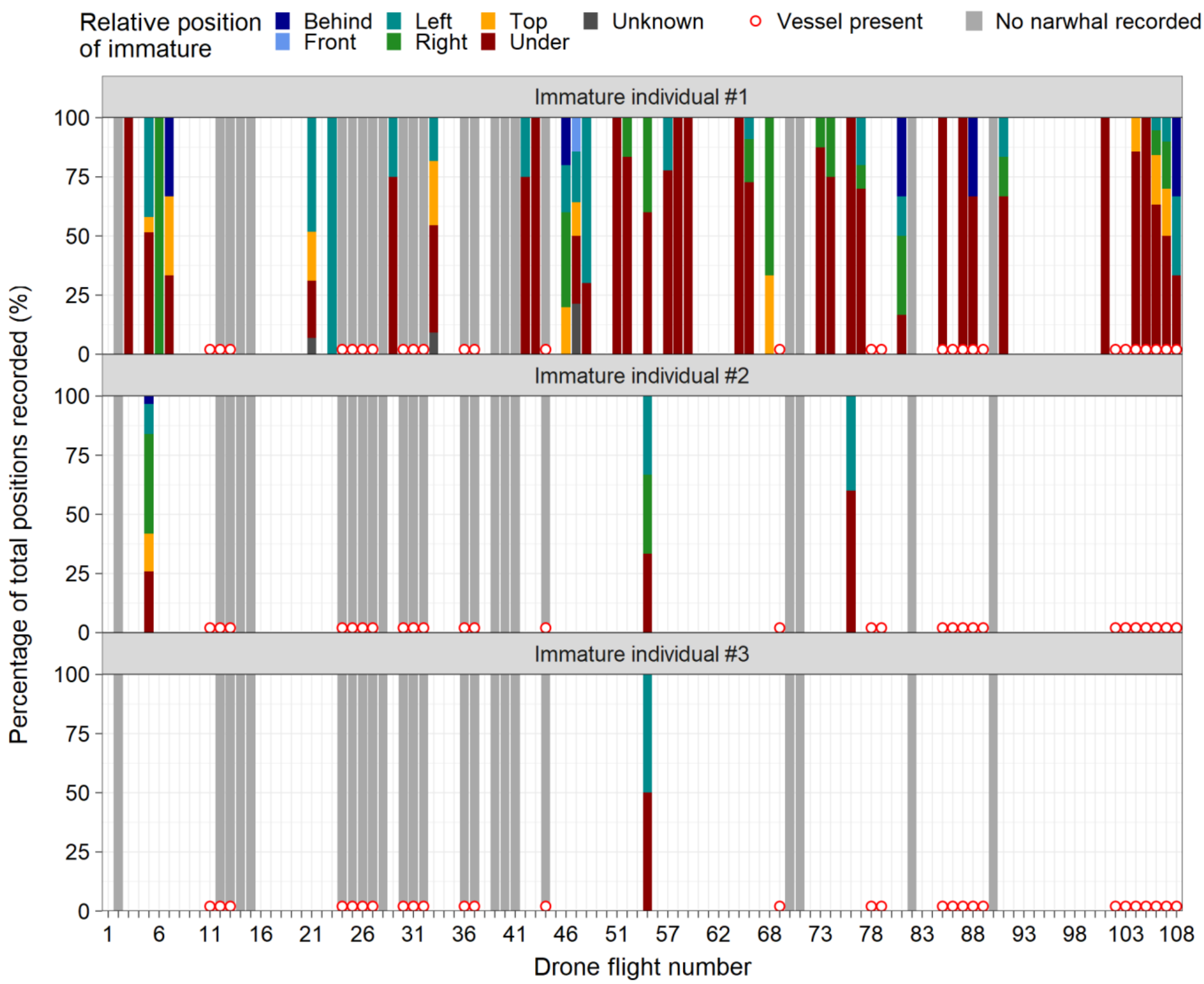


Figure 6-55: Relative position of immatures recorded during focal follow surveys. A separate plot is presented for each individual calf or yearling in a given group.

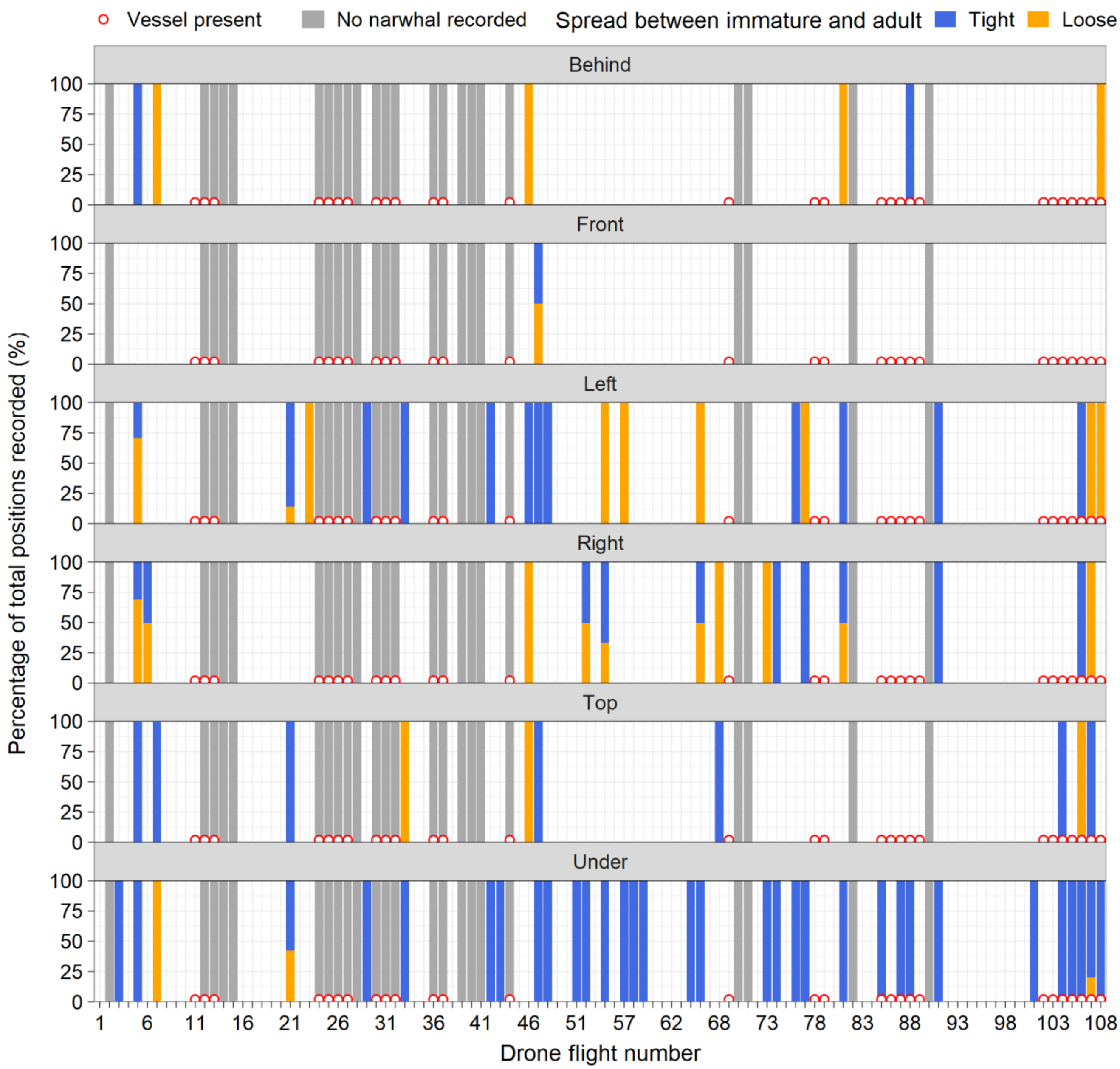


Figure 6-56: Position and spread of immatures relative to the presumed mother recorded during focal follow surveys. A separate plot is presented for each relative position.

6.6 General Observations

Narwhal were frequently observed south of the SSA in the general vicinity of Koluktoo Bay and near the entrance to Assomption Harbour. Similar distribution of narwhal in this area has been reported during aerial surveys (Thomas et al. 2015, 2016; Golder 2018b; Golder 2020b) affirming the importance of Koluktoo Bay as a summering ground for narwhal during the open-water season.

The majority of narwhal recorded in the BSA over the six years of data collection were engaged in travelling behaviour. Other behaviours observed in the BSA included nursing, rubbing, tusking, foraging, socializing and mating. In all years of the program, narwhal calves have been commonly observed, with evidence of nursing behaviour recorded in 2015 (two occasions), 2016 (four occasions), 2017 (two occasions), 2019 (seven occasions), and 2020 (8 occasions). On 11 August 2016, the birth of a narwhal calf off Bruce Head was observed. Collectively, these qualitative observations lend further support to the importance of southern Milne Inlet as an important area for calf rearing.

Ad lib observations made throughout the multi-year program suggest that the response of narwhals to ore carrier traffic is variable, ranging from 'no obvious response' in which animals remain in close proximity to ore carriers as they transit through the SSA, to temporary and localized displacement and related changes in behaviour.

Throughout all survey years, narwhal have been observed responding to shooting events by diving abruptly and increasing their swim speed. Despite repeatedly being targeted from the hunting camp at the shore by Bruce Head, narwhal continue to return to the area shortly thereafter, though the time following a hunting event that individuals return has been variable.

During the 2020 field season, a group of six narwhal were observed engaged in prolonged social (and potentially sexual) behaviour in the southern portion of the BSA (Figure 6-57), rolling both horizontally and vertically in the water column, and in close association with one another. The group included a single individual possessing two tusks, four additional tusked adults, and a juvenile (no tusk). This event was captured on video by the UAV team.

Figure 6-57: Group of six narwhal engaged in social behaviour in the BSA, including a single narwhal possessing two tusks, 8 August 2020.

6.6.1 Other Cetacean Species

Several other cetacean species were observed in the SSA during the 2020 field season at Bruce Head (Table 6-8). On 26 August 2020, a large pod of killer whales (*Orcinus orca*) was observed entering the SSA from the north and travelling southward through substrata A1, A2, B2, C2, D2, E2, F1 and G1. At approximately 18:24, a total of 67 killer whales were observed at one time throughout the SSA and one individual was later observed making a kill in substratum A2 (thought to be a narwhal though distance and marginal sighting conditions prevented confirmation). Multiple pods of killer whales were again observed throughout the SSA during 27 August 2020 (i.e., up to 18 individuals at one time) between 10:00 and 14:04, before they travelled northward and exited the SSA. A total of three RAD surveys conducted on 26 August and seven RAD surveys conducted on 27 August included killer whale sightings. A single beluga whale (*Delphinapterus leucas*) was observed within the BSA on the evening of 18 August 2020. A single bowhead whale (*Balaena mysticetes*) was also recorded in the BSA on 6 August, 7 August, and 22 August 2020.

Table 6-8: Other cetacean species observed in the SSA during the 2020 Bruce Head Program

Species	Date of Record	Number of Individuals
Killer whale (*Orcinus orca*)	2020-08-26	67 (maximum observed at one time)
	2020-08-27	18 (maximum observed at one time)
Beluga whale (*Delphinapterus leucas*)	2020-08-09	1
Bowhead whale (*Balaena mysticetes*)	2020-08-06	1
	2020-08-07	1
	2020-08-22	1

7.0 DISCUSSION

7.1 Relative Abundance and Distribution

Overall, the relative abundance of narwhal (total number narwhal corrected for effort) in 2020 was shown to be lower than previous survey years, including prior to the start of shipping operations in the RSA. The lower relative abundance of narwhal observed in 2020 in the Bruce Head study area is consistent with findings from the 2020 aerial survey (significant decrease in 2020 Eclipse Sound abundance estimate). These results collectively suggest either potential displacement of a portion of the Eclipse Sound stock to the Admiralty Inlet summering ground during the summer of 2020, a potential displacement of these animals to another area (e.g., Eastern Baffin Bay or Somerset summering ground), or a potential decrease in the Eclipse Sound summer stock. The potential driver(s) of low narwhal numbers in 2020 is presently unknown. Potential contributing factors under current investigation include acoustic disturbance effects from icebreaking, acoustic disturbance effects from impact pile driving in Pond Inlet, and increased killer whale presence in the RSA. A more detailed discussion is provided in Golder (2021b).

If found to be elicited by the Project, this finding is consistent with a high severity response, as defined by Finneran et al. (2017), and therefore has the potential to result in a significant alteration of natural behavioural patterns by narwhal in the RSA and/or a significant disruption to their daily routine. This finding would be contrary to impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Consistent with the definition of a significant effect used in the FEIS, large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses) could result in a population or stock-level consequence.

As preliminary 2020 monitoring suggests a ‘High Risk’ threshold has potentially been triggered, one of the identified response actions is implementation of precautionary Project-based operational mitigation measures, as presented in Golder (2021b). New mitigation measures being implemented by Baffinland for the 2021 shipping season include a delay in shipping during the early shoulder season until there is a continuous path between the entrance of Eclipse Sound and Milne Port of less than 9/10ths ice concentrations. This requirement will avoid impacting narwhal that concentrate in leads, as the leads are unlikely to exist in less than 9/10 ice concentrations. This will also minimize icebreaking noise, as it eliminates breaking of the thickest ice over a continuous period. Based on historical ice conditions, the average date less than 9/10ths ice has been continuous along the entire shipping route is July 27th, which is 8 days later than the average date landfast ice is completely broken (July 19th) and shipping would regularly be able to commence. The exact date the 2021 shipping season will commence will continue to be subject to variability in ice conditions. These newly proposed management measures will be communicated to the MEWG and the community of Pond Inlet as they are further developed.

The proposed additional mitigation being put forward aim to avoid and/or further minimize cumulative impacts on narwhal from Project icebreaking, even if the underlying causal factor(s) for the observed decrease in narwhal abundance in Eclipse Sound is unconfirmed. This precautionary approach will allow for a simultaneous investigation of potential causal factors of the observed change while adjusting current shipping operations to reliably manage impacts from icebreaking on narwhal in the RSA.

7.2 Narwhal Density

Based on statistical analyses of the RAD data, the effects of ‘distance from vessel’ and ‘vessel travel direction’ were shown to be statistically significant, which means that both these predictor variables had a significant effect on narwhal density. The model predicted reduced narwhal densities in the SSA when either a south or northbound vessel was in close proximity to a given substrata (0-2 km for a northbound vessel, and 0-4 km for a southbound vessel).

Once a northbound vessel passed through the SSA, heading away from the strata, narwhal density was shown to gradually increase until the vessel was 5 to 7 km away. The same pattern was observed for a southbound vessel moving away from the substrata. This pattern could represent a refractory period during which narwhal reoccupy the SSA after their initial displacement. These findings are consistent with previous years' findings and with behavioural results from the narwhal tagging study (Golder 2020a), indicating that narwhal density in the SSA is influenced by vessel traffic at close distances (i.e., within 4 km of a vessel). Localized avoidance of the sound source (i.e., the vessel) by narwhal is indicative of a moderate severity response. As the observed response was of short duration (i.e., less than the duration of the vessel exposure), no significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine is anticipated. This is in line with impact predictions made in the FEIS for the ERP, in that the effects of ship noise on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., change in narwhal density), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

When comparing the current integrated results (2014-2020) to the results reported in the 2019 Bruce Head Monitoring Report (2014-2019 integrated results; Golder 2020c), the main difference is that in the current analysis, significant reductions in narwhal density were observed when vessels were in relatively close proximity. In comparison, the 2019 report indicated a likely, but uncertain effect of vessel distance on relative narwhal abundance in the SSA (Golder 2020c). This change is likely not representative of an actual change in behaviour from past years, but rather due to the use of density in the 2020 model, distance as a directional variable (i.e., accounting for both distance and whether the vessel was moving toward or away from the substratum), and the reduction of the spatial extent of vessel exposure from 10 km (as used in Golder 2020c) to 7 km in the present analysis. The reduced spatial extent for vessel exposure has allowed for better estimation of vessel effects at closer distances and appears justified based on behavioural response results available from the narwhal tagging study (Golder 2020a).

7.3 Group Composition and Behaviour

Understanding the context and function (if any) of narwhal aggregations and spatial use patterns is important in assessing narwhal behavioural responses to a potential perceived threat (i.e., vessel traffic). For example, narwhal are known to alter their spatial use patterns in the presence of predators by moving slowly, travelling close to shore, and in tight groups at the surface (Campbell et al. 1988; Cosens and Dueck 1991; Laidre et al. 2006; Breed et al. 2017). In one report detailing an attack by killer whales, it was documented that once the attack commenced, narwhal further altered their spatial use by dispersing widely (approximately doubling their normal spatial distribution), beaching themselves in sandy areas, and quickly shifting their distribution away from the attack site (Laidre et al. 2006). In drawing from accounts of predator-induced behavioural responses by narwhal, the following response variables were evaluated for narwhal in the BSA as a function of vessel exposure, assuming narwhal respond to vessel traffic in a similar manner as they do with predators.

7.3.1 Group Size

As none of the effects of shipping on narwhal group size were shown to be statistically significant, the results suggest that narwhal neither congregate into larger groups nor fragment into smaller groups in response to vessel exposure. Estimated effect sizes for a vessel at 0 km from the BSA were only -4% and +15% (for northbound and southbound vessels, respectively). That is, group size changed very little following vessel exposure in the collected 2016-2020 data. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (group size), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

7.3.2 Group Composition

Depending on the composition of individuals that make up a group, narwhal groups may possess different strategies and/or capabilities for temporarily avoiding the potential disturbance of a transiting vessel. For example, adult groups may perceive vessel traffic and associated noise as a potential threat and attempt to move away from it by changing course or altering their travel/dive behaviour, while mother/dependent offspring groups may not be able to respond in a similar manner given physiological limitations of the dependent (i.e., slower swimming speed, reduced dive capability; Marcoux et al. 2009).

Narwhal groups with immatures (i.e., calves/yearlings) have been present in the BSA throughout the six years of data collection. The mean proportion of immatures recorded in 2020 suggests that calving success at Bruce Head is still similar to that observed during the pre-shipping period, despite a relatively steady increase in shipping throughout the RSA during this time. The presence of calves or yearlings in the BSA may, however, be affected by vessel distance and vessel travel direction, although effects were not statistically significant. That is, while the probability of observing groups possessing calves or yearlings in the BSA did not change between years despite an increase in vessel traffic, the probability of observing groups possessing calves or yearlings in the BSA was shown to increase during close vessel encounters. This finding may reflect a lower ability for calves or yearlings to actively avoid close vessel encounters by engaging in a dive, thus inflating the probability of observing a higher number of calves or yearlings at the surface.

Overall, the results suggest the current level of shipping in the RSA has not resulted in any discernible changes in the proportion of calves/yearlings present over the six years of data collection. Furthermore, the proportion of immature narwhal recorded in 2020 (i.e., 0.143) was above the identified EWI threshold value of 0.137. The mean proportion of calves reported in 2020 suggests that the calving rate (i.e., reproductive success) of the Eclipse Sound summering stock is consistent with pre-shipping conditions. These findings indicate that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., group composition), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

7.3.3 Group Spread

Consistent with observations from previous years, narwhal groups were more often observed in tight associations compared to loose associations under both vessel presence and vessel absence scenarios. Narwhal group spread did not significantly change during vessel-exposure events. Based on reports suggesting that narwhal alter their spatial use patterns in the presence of a perceived threat (e.g., killers whales) by associating in tighter groups (Laidre et al. 2006), these results do not indicate that such an anti-predator response is elicited when narwhal are exposed to vessel traffic as individuals neither congregated into tighter groups nor dispersed widely. That is, model results did not suggest that narwhal congregate into tight groups in response to vessels. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., group spread), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

7.3.4 Group Formation

Consistent with observations from previous years, narwhal groups were most often observed in parallel formation under both vessel presence and vessel absence scenarios, both by shore-based monitoring and by the UAV-based focal follow surveys. Despite none of the shipping-related variables being statistically significant, further monitoring of narwhal group formation is warranted to better understand the context and function (if any) of narwhal aggregations and whether a given formation is indicative of a potential response to a perceived threat (i.e., a transiting vessel). This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., group formation), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

7.3.5 Group Direction

Consistent with observations from previous years, narwhal groups were predominantly observed travelling south through the BSA in 2020 and tended to travel south in large groups and north in relatively smaller groups. Despite none of the shipping-related variables being statistically significant, a likely but uncertain effect of vessel distance on narwhal group direction was evident. Of note, south-travelling groups were observed least frequently (i.e., 46% of the time) when southbound vessels transited away from the BSA. This finding may suggest that some narwhal groups tend to avoid travelling south (i.e., toward Milne Port) in the wake of vessels also transiting south. A similar trend was observed by the very low proportion of narwhal groups travelling north (i.e., 4% of groups) in the wake of vessels also transiting north. These findings suggest that narwhal groups may experience some level of localized avoidance behaviour in the wake of vessels transiting through Milne Inlet (i.e., narwhal groups appear to avoid “following” vessels) but that travel direction by narwhal groups is relatively less affected during the approach of vessels, consistent with findings from the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a). These findings are consistent with a low severity response, as defined by Finneran et al. (2017), and are therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. This is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (group direction), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

7.3.6 Travel Speed

Similar to the anti-predator response elicited in narwhal when interacting with killer whales (i.e., their top predator; Breed et al. 2017), a change in swimming speed in the presence of vessel traffic may signify avoidance of a perceived threat by narwhal (Williams et al. 2002). Similar to previous years’ findings, monitoring results do not suggest that narwhal alter their travel speed in the presence of transiting vessels (noting however that statistical power for this response variable was low). As defined by Finneran et al. (2017), a change in travel speed by narwhal is indicative of a moderate severity response. As no significant change in travel speed was observed in response to shipping, no significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine has been demonstrated. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., travel speed), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

7.3.7 Distance from Bruce Head Shoreline

The distance that narwhal groups were observed from shore was shown to change with distance from a vessel and depended on the relative position of vessels, with the most consistent effect suggested for vessels moving toward the BSA. Of note, narwhal were observed swimming closer to shore in response to vessels in close proximity to the BSA. As the literature suggests that narwhal move close to shore when attempting to escape predation by killer whales (Steltner et al.1984; Laidre et al. 2006; Marcoux et al. 2009; Breed et al. 2017), it is conceivable that narwhal moving closer to shore when exposed to vessel traffic indicates an avoidance response to a perceived threat (i.e., vessel traffic). Based on the marine mammal severity score ranking by Finneran et al. (2017), the finding that narwhal swam close to shore in close proximity to vessel traffic may constitute a moderate severity response (Finneran et al. 2017). However, as the behavioral response lasted for only a short duration (i.e., in close proximity to vessels) and narwhal returned to their pre-response behavior following the exposure, the response is not considered a significant effect (i.e., an effect with potential implications on survival, growth or reproduction). Furthermore, consistent with observations from previous years, narwhal groups were regularly observed at a distance <300 m of the Bruce Head shore under both vessel presence and vessel absence scenarios. 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 is dependent on anthropogenic activity.

These findings suggest that narwhal may swim closer to shore when vessels are in close proximity to the BSA, indicating a moderate severity response but of short duration. As defined by Finneran et al. (2017), moderate severity responses lasting for a short duration (i.e., less than the duration of the vessel exposure) are unlikely to result in a significant alteration of an animal's natural behavioural patterns or disruption to their daily routine. This is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., distance from shore), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

7.4 Focal Follows (UAV)

A total of 84 narwhal focal follow surveys were successfully undertaken in the RSA in 2020, representing 7.3 h of recorded behaviour. This included 16 focal follows when ships were present (representing 1.3 h of recorded behaviour) and 68 focal follows when ships were absent (representing 6.0 h of recorded behaviour). Primary behaviors assessed included travelling (i.e., directional movement), milling (i.e., non-directional movement), resting (i.e., not moving/logging or moving slightly), and social behavior (i.e., clear interaction between individuals with physical contact).

Of the followed groups, narwhal spent the majority of time travelling (65% of the time), followed by milling (20% of the time), resting (12% of the time) and social behaviours (3% of the time). The proportion of time groups spent travelling was similar when vessels were present compared to when vessels were absent (71% and 64%, respectively). Similarly, narwhal spent a similar proportion of time resting, milling and performing social behaviours when vessels were present (17%, 10% and 1%, respectively) compared to when vessels were absent (10%, 22% and 4%, respectively). While narwhal groups were shown to spend similar proportions of time in "loose" and "tight" group formation (i.e., 48% and 51%, respectively), the proportion of time that groups spent in tight formation was slightly higher when a vessel was present (57% of the time) compared to periods when no vessels were present (46% of the time).

Through the focal follow surveys, special attention was paid to assessing behavioural changes of mothers (presumed) with dependent young (i.e., calves and yearlings) in relation to shipping activities. While serving to inform the identified EWI, the UAV surveys of mother and dependent young also provided an enhanced ability to monitor for moderate severity responses such as changes in nursing behavior in the presence of vessels. Furthermore, the relative and distal position of immatures to their mother was assessed to inform whether certain positions by dependent young are favored in the presence of vessels.

In terms of relative position of mother to offspring, immature narwhal were most commonly observed below their mother (compared to beside, behind or above their mother), in both presence and absence of shipping. The proportion of time immature narwhal maintained this position was slightly higher when vessels were present compared to when no vessels were present (69% and 53%, respectively). However, the proportion of time that mothers and their dependent young were tightly associated with one another was similar in the presence of vessels (79%) compared to periods when no vessels were present (76%). Findings also suggest that when immatures are positioned underneath of their mother, they are almost always tightly associated (i.e., 91% of the time), compared to other relative positions (i.e., left, right, above, behind) in which they are relatively more loosely associated. Collectively, these findings may have implications for the broader shore-based monitoring program at Bruce Head, suggesting that calves and yearlings passing through the BSA may be disproportionally underrepresented given the reduced ability to sight an animal that is underneath of another.

Nursing by a calf or yearling was recorded during 13 of the 37 focal follow surveys that comprised mothers with dependent young (35%); two of which coincided with a vessel transit. For the two focal follow surveys where nursing was recorded in the presence of a vessel, the proportion of time spent nursing was high (i.e., 63% of the time in FF104 and 52% of the time in FF106), resulting in a higher mean time nursing (57%) relative to when no vessels were present (34% of the time). Although this represents a small sample size, this finding does suggest that mother and dependent young continue to carry out such critical life functions in the presence of vessel traffic. However, the CPA associated with FF106 and FF104 was 4.25 km and 9.08 km, respectively. It is possible that nursing activities could be affected in closer proximity to vessels. Additional monitoring is required to increase the sample size of focal follow surveys conducted in the presence of vessel traffic (give the current sample size is limited to 1.3 h of observational data only).

Incorporating UAV surveys into the shore-based monitoring program at Bruce Head has provided new insights into narwhal group composition and finer scale behaviour. Of note, focal follow surveys conducted during the 2020 field season revealed multiple instances of nursing between mother and dependent young, and documented unique behaviours such as potential territorial or aggressive displays between tusked individuals (referred to as “jousting” in this study; e.g., FF5, FF8). New insights into the dive behaviour between mother and dependent young were also obtained, as mothers were observed in multiple surveys diving deeply out of sight of their young, either leaving their young alone at the surface (e.g., FF6, FF23, FF52, FF64, FF65, FF73) or with another non-tusked adult (e.g., FF106). In one survey (i.e., FF21), a calf was observed in what appeared to be attempted deep dive as it undertook consecutive short, erratic dives below the surface while the mother and another non-tusked adult observed from the surface. Together, these findings are noteworthy in that the prior understanding was that a calf or yearling would typically be observed in close association with a mature individual, though multiple examples were observed during focal follow surveys in which immatures were on their own, either temporarily or for extended periods. How the presence of vessel traffic may influence these finer scale behaviours can be further assessed using the UAV survey approach.

As the sample size of focal follow surveys conducted in the presence of vessels is currently too small to allow statistical analyses, it is recommended that focal follow surveys be continued in future monitoring campaigns at Bruce Head in order to increase the sample size and allow for a quantitative assessment. Once sufficient data are collected, the quantitative analysis is expected to be similar to the generalized linear mixed models performed for the 2017-2018 narwhal tagging data (Golder 2020a), where various response variables were defined based on the collected behavioural data, and vessel distance was used as a predictor to assess shipping effects on narwhal behaviour.

8.0 SUMMARY OF KEY FINDINGS

Relative Abundance and Distribution

- Interannual variation: The overall relative abundance of narwhal in the SSA, inferred from sighting rate (no. of narwhal per hour - corrected for effort), was relatively constant between 2014 and 2019 despite a gradual increase in iron ore shipping along the Northern Shipping Route during this period. However, the relative abundance of narwhal in the SSA was lower in 2020 compared to all previous years. The lower relative abundance of narwhal observed in 2020 in the Bruce Head study area is consistent with findings from the 2020 aerial survey (i.e., a significant decrease in the 2020 Eclipse Sound abundance estimate). These results collectively suggest either potential displacement of a portion of the Eclipse Sound stock to the Admiralty Inlet summering ground during the summer of 2020, a potential displacement of these animals to another area (e.g., Eastern Baffin Bay or Somerset summering ground), or a potential decrease in the Eclipse Sound summer stock. The observed finding of a lower relative abundance of narwhal at Bruce Head in 2020, coincident with the 2020 aerial survey results demonstrating a significant decrease in the abundance of the Eclipse Sound narwhal stock in the RSA, has triggered further detailed investigation on the root cause of the observed finding along with implementation of precautionary based mitigation measures for application in 2021, as described in Section 7.1 and in Golder (2021b). **If found to be elicited by the Project, this finding is consistent with a high severity response, as defined by Finneran et al. (2017), and therefore has the potential to result in a significant alteration of natural behavioural patterns by narwhal in the RSA and/or a significant disruption to their daily routine. This finding would be contrary to impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Consistent with the definition of a significant effect used in the FEIS, large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses) could result in a population or stock-level consequence.**

Narwhal Density

- Vessel exposure effects: Within each study year, an effect of vessel exposure on narwhal density in the SSA was estimated. Specifically, vessel exposure was shown to result in a significant decrease in narwhal density in the SSA compared to when no vessels were present, but only when vessels were in close proximity (1-2 km from vessel for northbound vessels, and 3-4 km for southbound vessels). A 4-km maximum range of disturbance would be equivalent to a total exposure period of 29 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behavior following the exposure period (temporary effect). During the 2020 Bruce Head program (Aug 07 to Sept 01), there were approximately two transits per day in the SSA (56 one-way transits in SSA over a 26-day period). The daily vessel exposure period for narwhal was therefore equivalent to approximately one hour. On a heavy traffic day (assuming four transits per day), the daily vessel exposure period would be on the order of two hours. **These results suggest that narwhal density was influenced by vessel traffic at close distances (i.e., within 4 km), consistent with previous years' findings and similar to results from the 2017/2018 narwhal tagging study (Golder 2020a). Localized avoidance of the sound source (i.e., the vessel) by narwhal is indicative of a moderate severity response. As the observed response was of short duration (i.e., less than the duration of the vessel exposure), no significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine is anticipated. This is in line with impact predictions made in the FEIS for the ERP, in**

that the effects of ship noise on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., change in narwhal density), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

Group Composition and Behaviour

- Group Size: the effects of shipping (directional distance from vessel, vessel direction within Milne Inlet) on narwhal group size were not statistically significant (*P*>0.3 for all effects), with small effect sizes (-4% and +15% at 0 km from vessel). **These results suggest that narwhal neither congregate into larger groups nor fragment into smaller groups in response to vessel exposure. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., group size), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).**
- Group Composition:
  - All narwhal life stage categories (adults, juveniles, yearlings, and calves) were recorded in the BSA throughout the six sampling years. The mean daily proportion of calves recorded in the BSA (relative to the total number of narwhal observed per day) was higher in 2020 (annual mean of 11.3%) than three of previous years (2014=10.7%, 2016=10.5%, 2017=9.5%), and lower than 2019 (11.6%) and 2015 (12.9%). This suggests that calving rate (i.e., reproductive success) of the Eclipse Sound summering stock in 2020 was consistent with pre-shipping levels, despite a relatively steady increase in shipping throughout the RSA during this time.
  - The annual proportion of immatures (i.e., calves and yearlings) observed in 2020 was 14.3%, comparable to the annual proportion of immatures observed in previous years and above the identified Early Warning Indicator (EWI) threshold of 13.7%.
  - Vessel traffic was shown to have a possible, though uncertain, effect on group composition relative to the presence of immatures. Of note, despite a lack of statistical significance, observed data suggested that the proportion of groups with immatures was higher when vessels were in close proximity to the BSA. This finding is potentially due to groups without calves or yearlings being more capable of diving and moving away, thus inflating the probability of observing groups with calves or yearlings at the surface.
  - **Collectively, these results suggest that narwhal group composition, including proportion of immatures, did not significantly change between study years despite a relatively steady increase in shipping activity during this period. Furthermore, vessel traffic did not have a significant effect on the proportion of immatures observed. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to**

temporary, localized avoidance behaviour. Specific to this response variable (i.e., group composition), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

- Group Spread: Narwhal groups were more often observed in tight associations compared to loose associations under both vessel presence and vessel absence scenarios. In general, narwhal did not alter their spatial use patterns in the presence of vessels by associating in tighter groups or by dispersing widely. The effects of shipping (directional distance from vessel, vessel direction within Milne Inlet) on narwhal group spread were not statistically significant (P>0.6 for all effects), with small effect sizes (-1% and +14% at 0 km from vessel). **Similar to previous years' findings, these results suggest that narwhal group spread did not significantly change during vessel exposure events. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., group spread), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).**
- Group Formation: Narwhal groups were most often observed in parallel formation under both vessel presence and vessel absence scenarios. None of the shipping-related variables (i.e., distance from vessel, vessel direction within Milne Inlet, vessel direction relative to the BSA, or their interaction) were statistically significant in influencing narwhal group formation. **Similar to previous years' findings, these results suggest that narwhal group formation did not significantly change during vessel exposure events. This finding indicates that a low severity response by narwhal has not been triggered, as defined by Finneran et al. (2017), and is therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., group formation), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).**
- Group Direction: Narwhal groups were predominantly observed travelling south through the BSA. Southbound travel was least common when southbound vessels were headed away from the BSA, and most common when northbound vessels were headed away from the BSA. **Similar to previous years' findings, these findings suggest that narwhal groups may experience some level of avoidance behaviour in the wake of vessels transiting through Milne Inlet (i.e., narwhal groups appear to avoid "following" vessels) but that travel direction by narwhal groups is relatively less affected during the approach of vessels. These findings are consistent with a low severity response, as defined by Finneran et al. (2017), and are therefore unlikely to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. This is in line with impact predictions made**

in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (group direction), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).

- Travel Speed: The majority of the observed narwhal groups travelled at a medium speed, regardless of vessel exposure conditions. Despite a possible but uncertain effect of vessel distance on travel speed, this response variable is inherently subjective and findings may be influenced by data being recorded by multiple observers, providing low confidence in its usefulness for assessing behavioural response to vessel traffic. **Similar to previous years' findings, monitoring results do not suggest that narwhal alter their travel speed in the presence of transiting vessels. As defined by Finneran et al. (2017), a change in travel speed by narwhal is indicative of a moderate severity response. As no change in travel speed was observed in response to shipping, no significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine has been demonstrated. The lack of a response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., travel speed), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).**

- Distance from Bruce Head Shoreline: Narwhal groups were observed more often within 300 m of the Bruce Head shore under both vessel presence and vessel absence scenarios. Both south- and northbound vessel traffic was shown to result in a significant decrease in 'distance from shore', particularly evident when vessels were in close proximity to the BSA. **These findings suggest that narwhal may swim closer to shore when vessels are in close proximity to the BSA, indicating a moderate severity response but of short duration. As defined by Finneran et al. (2017), moderate severity responses lasting for a short duration (i.e., less than the duration of the vessel exposure) are unlikely to result in a significant alteration of an animal's natural behavioural patterns or disruption to their daily routine. This is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour. Specific to this response variable (i.e., distance from shore), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).**

UAV Focal Follow Surveys

- In 2020, a total of 84 narwhal focal follow surveys were successfully undertaken in the RSA (near Bruce Head and Koluktoo Bay) using a UAV-based video system (representing 7.3 h of recorded behaviour). This included 16 focal follows when ships were present (representing 1.3 h of recorded behaviour) and 68 focal follows when ships were absent (representing 6.0 h of recorded behaviour). Primary behaviors assessed included travelling (i.e., directional movement), milling (i.e., non-directional movement), resting (i.e., not moving/logging or moving slightly), and social behavior (i.e., clear interaction between individuals with physical contact). Of the followed groups, narwhal spent the majority of time travelling (65% of the time), followed by milling (20% of the time), resting (12% of the time) and social behaviours (3% of the time).

- The proportion of time groups spent travelling was similar when vessels were present compared to when vessels were absent (71% and 64%, respectively). Similarly, narwhal spent a similar proportion of time resting, milling and performing social behaviours when vessels were present (17%, 10% and 1%, respectively) compared to when vessels were absent (10%, 22% and 4%, respectively).
- While narwhal groups were shown to spend similar proportions of time in “loose” and “tight” group formation (i.e., 48% and 51%, respectively), the proportion of time that groups spent in tight formation was slightly higher when a vessel was present (57% of the time) compared to periods when no vessels were present (46% of the time).
- In terms of relative position of mother to offspring, immature narwhal were most commonly observed below their mother (compared to beside, behind or above their mother), in both presence and absence of shipping. The proportion of time immature narwhal maintained this position was slightly higher when vessels were present compared to when no vessels were present (69% and 53%, respectively). However, the proportion of time that mothers and their dependent young were tightly associated with one another was similar in the presence of vessels (79%) compared to periods when no vessels were present (76%).
- Additional monitoring is required to increase the sample size of focal follow surveys conducted in the presence of vessel traffic (given that the current sample size is limited to 1.3 h of observational data only).

9.0 RECOMMENDATIONS

Golder recommends the following with respect to future monitoring at Bruce Head:

- Increase emphasis on the UAV survey component of the program, given the valuable insight this tool provides with respect to monitoring changes in group composition and fine scale behaviours in the presence of shipping. UAV surveys provide a detailed and permanent record of key narwhal behaviours (i.e., nursing, resting, territorial behaviour) that may not otherwise be quantifiable by shore-based visual methods. For example, one of the benefits of the focal follow surveys is an enhanced ability to monitor for moderate severity responses such as change in nursing or signs of annoyance or aggression. While the sample size of surveys conducted when ships were ‘present’ is currently insufficient to allow for a meaningful statistical analysis based on the 2020 dataset alone, increasing the sample size through future UAV surveys would have the potential to quantitatively evaluate changes in key narwhal behaviours in response to shipping.

- The current spatial extent (i.e., 7 km) of the ‘vessel exposure’ zone be further restricted to 5 km to better estimate vessel effects on narwhal at close distances. This recommendation is supported by results of the narwhal tagging study (Golder 2020a) which demonstrated that narwhal behavioral responses to shipping occurred at distances up to 5 km from a vessel. By further restricting the exposure zone to the spatial extent where narwhal have been shown to respond to vessel traffic, the statistical power for detecting shipping effects is likely to increase, due to reduction of variability in the dataset at the farther distances where responses have not been evident based on results of the narwhal tagging study (Golder 2020a).

- All other survey components of the Program (i.e., RAD survey, group composition and behavior survey) should be continued in future survey campaigns. Each component offers value in being able to identify, assess, and ultimately mitigate effects to narwhal resulting from Project shipping activities. For example, low numbers of narwhal observed through the 2020 RAD survey were consistent with aerial survey results, suggesting that the RAD survey alone may be valuable in identifying fluctuations in narwhal abundance during years that aerial surveys are not conducted. With respect to the EWI, collecting data on group composition and behavior in the BSA is instrumental for assessing changes in the annual proportion of immatures in the population. Finally, the effects of shipping on critical life functions such as nursing behavior may only be assessable by means of UAV surveys. Collectively, each component of the Program provides information that is critical to understanding how narwhal may respond to vessel traffic and vessel noise.

- Results from the 2020 shore-based monitoring at Bruce Head indicated fewer narwhal than previous years and this aligned with aerial survey results indicating a lower abundance of the Eclipse Sound summer stock in 2020. Based on these findings, further detailed investigation is recommended to identify the root cause of the observed decline, including consideration of potential contributing factors identified in Section 7.1 and summarized in Golder (2021b). New precautionary-based mitigation being implemented by Baffinland for 2021 shipping operations includes no icebreaking during the 2021 early shoulder season. This requirement will avoid impacting narwhal that concentrate in leads and/or areas of consolidated ice in the RSA, and will eliminate icebreaking noise altogether during the in-migration period. This enhanced mitigation aims to avoid and/or minimize potential cumulative impacts on narwhal from Project icebreaking in combination with other potential factors, even if the underlying causal factor(s) for the observed decrease in narwhal abundance in Eclipse Sound is unconfirmed. This precautionary approach will allow for a simultaneous investigation of potential causal factors of the observed change while adjusting current shipping operations to reliably manage impacts from icebreaking on narwhal in the RSA. As narwhal behavioural responses to open-water shipping are shown to be consistent with impact predictions (limited to temporary, localized disturbance), no additional adaptive management measures are considered necessary at this stage to mitigate for open-water shipping impacts on narwhal in the RSA.

10.0 CLOSURE

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

The draft version of this report was distributed to MEWG members for review and comment on 13 May 2021. Responses to information requests received by MEWG members are provided in Appendix G of this report and, where appropriate, the final version has been updated accordingly.

Golder Associates Ltd.

Ainsley Allen, MSc, RPBio
Marine Biologist

Sima Usvyatsov, PhD
Biological Scientist

Kyla Graham, BSc, MRes
Marine Biologist

Phil Rouget, MSc, RPBio
Senior Marine Biologist

Bart DeFreitas, MSc, RPBio
Associate, Senior Biologist

AA/SU/KG/PR/BDF/asd

https://golderassociates.sharepoint.com/sites/11206g/deliverables (do not use)/issued to client_for wp/200-299/1663724-269-r-rev0-33000/1663724-269-r-rev0-33000-2020 bruce head monitoring rpt_31aug_21.docx

11.0 REFERENCES

Arcangeli, A., and R. Crosti. 2009. The short-term impact of dolphin watching on the behaviour of bottlenose dolphins (*Tursiops truncatus*) in Western Australia. Journal of Marine Mammals and Their Ecology. 2(1):7 pp.

Arveson, R.T., and D.J. Vendittis. 2000. Radiated noise characteristics of a modern cargo ship. Acoustical Society of America 107(1): 118-129.

Au, D., and W. Perryman. Movement and speed of dolphin schools responding to an approaching ship. Fishery Bulletin, U.S. 80:371-379.

Austin, M and T. Dofher. 2021. Technical Memorandum – Vessel Source Level Estimates for the 2018 and 2019 Shipping Seasons: Baffinland Mary River Project. Document 02235, Version 2.0. Technical Memorandum by JASCO Applied Sciences for Golder Associates Ltd

Bejder, L., S.M., Dawson, and J.A. Harraway. 1999. Responses by Hector’s dolphins to boats and swimmers in Porpoise Bay, New Zealand. Marine Mammal Science. 15(3):738-750.

Bejder, L. 2005. Linking short and long-term effects of nature-based tourism on cetaceans. [Doctor of Philosophy thesis]. Halifax: Dalhousie University. 157 p.

Bejder, L., A., Samuels, H., Whitehead, and N. Gales. 2006a. Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. Animal Behaviour. 15:1-10.

Bejder, L., A., Samuels, H., Whitehead, N. Gales, J., Mann, R., Connor, M., Heithaus, J., Watson-Capps, C., Flaherty, and M. Kruntzen. 2006b. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conservation Biology. 20:1791-1798.

Blane, J.M., and R. Jaakson. 1994. The impact of ecotourism boats on the St. Lawrence beluga whales. Environmental Conservation. 21: 267-269.

Bluhm, B.A. and R. Gradinger. 2008. Regional variability in food availability for Arctic marine mammals. Ecological Applications 18: S77‑S96.

Born, E.W. 1986. Observations of narwhals (Monodon monoceros) in the Thule area (NW Greenland). August 1984. Rep. Int. Whaling Comm. 36: 387-392.

Booth, C.G., R.R. Sinclair, and J. Harwood. 2020. Methods for monitoring for the population consequences of disturbance in marine mammals: a review. Frontiers in Marine Science. 7: 15.

Breed, G.A., C.J.D. Matthews, M. Marcoux, J.W. Higdon, B. LeBlanc, S.D. Petersen, J. Orr, N.R. Reinhart and S. Ferguson. 2017. Sustained disruption of narwhal habitat use and behaviour in the presence of Arctic killer whales. PNAS. 114(10): 2628-2633.

Brooks M.E., K. Kristensen, K.J. van Benthem, A. Magnusson, C.W. Berg, A. Nielsen, H.J. Skaug, M. Maechler, and B.M. Bolker. 2017. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. The R Journal. 9(2): 378-400.

Campbell, R.R., D.B. Yurick and N.B. Snow. 1988. Predation on narwhals, *Monodon monoceros*, by killer whales, *Orcinus orca*, in the eastern Canadian Arctic. Can. Field-Nat. 102: 689-696.

Carney, K. M. and Sydeman, W. J. 1999. A review of human disturbance effects on nesting colonial waterbirds. Waterbirds: The International Journal Of Waterbird Biology. 22(1):68-79.

Charry, B. 2018. The distribution of narwhal (*Monodon monoceros*) males, females, and newborns in the Canadian Arctic Archipelago [MSc thesis]. Montreal: McGill University. 101 p.

Christiansen, F., D., Lusseau, E., Stensland, and P. Berggren. 2010. Effects of tourist boats on the behaviour of Indo-Pacific bottlenose dolphins off the south coast of Zanzibar. Endangered Species Research. 11:91-99.

Cosens, S.E. and L.P. Dueck. 1988. Responses of migrating narwhal and beluga to icebreaker traffic at the Admiralty Inlet ice-edge, N.W.T. in 1986. pp 39-54 *In* W.M. Sackinger and M.O. Jeffries (eds.). Port and ocean engineering under Arctic conditions, Vol. 2. University of Alaska Fairbanks, Fairbanks, AK.

Cosens, S.E. and L.P. Dueck. 1991. Group size and activity patterns of belugas (Delphinapterus leucas) and narwhals (*Monodon monoceros*) during spring migration in Lancaster Sound. Canadian Journal of Fisheries and Aquatic Sciences. 69: 1630-1635.

Cosens, S.E. and L.P. Dueck. 1993. Icebreaker noise in Lancaster Sound, N.W.T., Canada: Implications for marine mammal behaviour. Marine Mammal Science, 9: 285-300. https://doi.org/10.1111/j.1748-7692.1993.tb00456.x.

COSEWIC. 2004. COSEWIC assessment and update status report on the narwhal *Monodon monoceros* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 50 pp. (www.sararegistry.gc.ca/status/status_e.cfm)

Côté, S.D. 1996. Mountain goat responses to helicopter disturbance. Wildlife Society Bulletin. 24: 681-685.

Côté, S. D. and Beaudoin, C. 1997. Grizzly bear (Ursus arctos) attacks and nanny-kid separation on mountain goats (Oreamnos americanus). Mammalia. 61:614-617.

Curé, C., Antunes, R., Samarra, F., Alves, A.C., Visser, F., Kvadsheim, P.H., and P.J.O. Miller. 2012. Pilot whales attracted to killer whale sounds: acoustically-mediated interspecific interactions in cetaceans. PLoS ONE 7(12): e52201. doi:10.1371/journal.pone.0052201.

Curé, C., Isojuuno, S., Visser, F., Wensveen, P.J., Lise, D.S., Kvadsheim, P.H., Lam, F.A. and P.J.O. Miller. 2016. Biological significance of sperm whale responses to sonar: comparison with anti-predator responses. PLoS ONE 7(12): e52201. doi:10.1371/journal.pone.0052201.

Currey, R.J. C., S.M., Dawson, E., Slooten, K., Schneider, D., Lusseau, O.J., Boisseau, P., Haase, and J.A. Williams. 2009. Survival rates for a declining population of bottlenose dolphins in Doubtful Sound, New Zealand: an information theoretic approach to assessing the role of human impacts. Aquatic Conservation: Marine and Freshwater Ecosystems. 19:658-670 e52201.

Davis, R.W. 2014. A review of the multi-level adaptations for maximizing dive duration in marine mammals: from biochemistry to behaviour. Journal of Comparative Physiology. 184(1): 23‑53.

De Stephanis, R., Giménez, J., Esteban, R., Gauffier, P., García-Tiscar, S., Sinding, M-H.S., and P. Verborgh. 2014. Mobbing-like behaviour by pilot whales towards killer whales: a response to resource competition or perceived predation risk?. acta ethologica. 10.1007/s10211-014-0189-1.

Dietz, R. and M.R. Heide-Jorgensen. 1995. Movements and swimming speed of narwhals, *Monodon monoceros*, equipped with satellite transmitters in Melville Bay, northwest Greenland. Canadian Journal of Zoology, 73: 2106-2119.

Dietz, R., M.P. Heide-Jørgensen, P. Richard, and M. Acquarone. 2001. Summer and fall movements of Narwhal (*Monodon monoceros*) from Northeastern Baffin Island towards Northern Davis Strait. Arctic. 54:244-261.

Dietz, R., M.P. Heide-Jørgensen, P. Richard, J. Orr, K. Laidre, and and H.C. Schmidt. 2008. Movement of Narwhals (*Monodon monoceros*) from Admiralty Inlet monitored by satellite telemetry. Polar Biology. 31:1295-1306.

Doniol-Valcroze, T., J.F. Gosselin, D. Pike, J. Lawson, N. Asselin, K. Hedges and S. Ferguson. 2015. Abundance estimates of narwhal stocks in the Canadian High Arctic in 2013. DFO Canadian Science Advisory Secretariat Science Advisory Report 2015/060. v + 36 pp.

Doniol-Valcroze, T., J.F. Gosselin, D.G. Pike, J.W. Lawson, N.C. Asselin, K. Hedges and S.H. Ferguson. 2020. Narwhal abundance in the Eastern Canadian High Arctic in 2013. NAMMCO Scientific publications. 11. https://doi.org/10.7557/3.5100.

Ellison, W., B. Southall, C. Clark and A. Frankel. 2012. A new context-based approach to assess marine mammal behavioural responses to anthropogenic sounds. Conservation Biology 26(1): 21-28.

Erbe, C. S.A. Marley, R.P. Schoeman, J.N. Smith, L.E. Trigg and C.B. Embling. 2019. The effects of ship noise on marine mammals – a review. Frontiers in Marine Science. 6:606.

Ferguson, S.H., J.W., Higdon, and K.H. Westdal. 2012. Prey items and predation behaviour of killer whales (Orcinus orca) in Nunavut, Canada, based on Inuit hunter interviews. Aquatic Biosystems. 8(3):1-16.

Finley, K.J. and E.J. Gibb. 1982. Summer diet of the narwhal (*Monodon Monoceros*) in Pond Inlet, northern Baffin Island. Canadian Journal of Zoology. 60: 3353-3363

Finley, K.J., G.W. Miller, R.A. Davis and C.R. Greene. 1990. Reactions of belugas, *Delphinapterus leucas*, and narwhal, *Monodon monoceros*, to ice-breaking ships in the Canadian high arctic. Canadian Journal of Fisheries and Aquatic Science. 224: 97-117.

Finneran, J.J. and A.K. Jenkins. 2012. Criteria and thresholds for U.S. Navy acoustic and explosive effects analysis. SPAWAR Systems Center Pacific, San Diego, California.

Finneran, J., E. Henderson, D. Houser, K. Jenkins, S. Kotecki, and J. Mulsow. 2017. Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III). Technical report by Space and Naval Warfare Systems Center Pacific (SSC Pacific). June 2017. 194 pp.

Fisheries and Oceans Canada (DFO). 2011. Advice regarding the genetic structure of Canadian narwhal (*Monodon monoceros*). DFO Canadian Science Advisory Secretariat Science Advisory Report 2011/021. 5 p.

Fisheries and Oceans Canada (DFO). 2020a. Estimated abundance and total allowable landed catch for the Eclipse Sound narwhal stock. DFO Canadian Science Advisory Secretariat Science Advisory Report 2020/051. 8 p.

Fisheries and Oceans Canada (DFO). 2020b. Information related to the delineation of the Eclipse Sound and Admiralty Inlet narwhal stocks. DFO Canadian Science Advisory Secretariat Science Advisory Report 2020/048. 7 p.

Ford, J.K.B. and H.D. Fisher. 1978. Underwater acoustic signals of the narwhal (*Monodon monoceros*). Canadian Journal of Zoology. 56: 552-560.

Foster, B.R., and E.Y. Rahs. 1983. Mountain goat response to hydroelectric exploration in northwestern British Columbia. Environmental Management. 7:189-197.

Frouin-Mouy, H., E.E. Maxner, M.E. Austin, and S.B. Martin. 2019. Baffinland Iron Mines Corporation – Mary River Project. 2018 Passive Acoustic Monitoring Program. Document 10720. Version 3.0. Technical Report by Jasco Applied Sciences for Golder Associates Ltd.

Frouin-Mouy, H. and X. Mouy 2021. Analysis of narwhal calls recorded off Bruce Head (2019), Nunavut: Exploratory analysis of mother-calf contact calls based on visual and passive acoustic data. Document 02245, Version 3.0. Technical report by JASCO Applied Sciences for Golder Associates Ltd.

Frouin-Mouy, H., C.C. Wilson, K.A. Kowarski, and M.E. Austin. 2020. Baffinland Iron Mines Corporation – Mary River Project. 2019 Passive Acoustic Monitoring Program – Draft Report. Document 02007. Version 2.2. Technical Report by Jasco Applied Sciences for Golder Associates Ltd.

Furgal, C., and R. Laing. 2012. A synthesis and critical review of the Traditional Ecological Knowledge literature on narwhal (*Monodon monoceros*) in the eastern Canadian Arctic. DFO Canadian Science Advisory Secretariat Science Advisory Report 2011/131 iv + 47 p.

Garde, E., S. H. Hansen, S. Ditlevsen, K. B.Tvermosegaard, J. Hansen, K. C. Harding and M. P. Heide-Jørgensen. 2015. Life history parameters of narwhals (*Monodon monoceros*) from Greenland. Journal of Mammalogy. 96(4): 866-879.

Golder Associates Ltd. (Golder). 2018a. 2017 Bruce Head shore-based monitoring program. Final Golder Report No. 1663724-041-R-Rev0. Prepared by Golder Associates Ltd., Victoria, BC for Baffinland Iron Mines Corporation, Oakville, Ontario. 87 p. + appendices.

Golder. 2019. Bruce Head shore-based monitoring program. Final 2014-2017 Integrated Report No. 1663724-081-R-Rev0. Prepared by Golder Associates Ltd., Victoria BC for Baffinland Iron Mines Corporation, Oakville, Ontario. 119 p. + appendices.

Golder. 2020a. 2017 – 2018 Integrated narwhal tagging study. Technical Data Report. Prepared by Golder Associates Ltd., Victoria BC for Baffinland Iron Mines Corporation, Oakville, Ontario.

Golder. 2020b. 2019 Marine mammal aerial survey. Report No. 1663724-XX-R-RevB. Prepared by Golder Associates Ltd., Victoria BC for Baffinland Iron Mines Corporation, Oakville, Ontario. 118 p. + appendices.

Golder. 2020c. 2019 Bruce Head shore-based monitoring program. Final Golder Report No. 1663724-199-R-Rev0. Prepared by Golder Associates Ltd., Victoria, BC for Baffinland Iron Mines Corporation, Oakville, Ontario. 117 p. + appendices.

Golder. 2021a. 2020 Marine mammal aerial survey. Report No. 1663724-XX-R-RevB. Prepared by Golder Associates Ltd., Victoria BC for Baffinland Iron Mines Corporation, Oakville, Ontario. 118 p. + appendices.

Golder. 2021b. Preliminary Summary of 2020 Narwhal Monitoring Programs. Technical Memorandum No. 1663724-285-TM-Rev1-48000. 07 April 2021.

Guerra, M., S.M., Dawson, T.E., Brough, and W.J. Rayment. 2014. Effects of boats on the surface and acoustic behaviour of an endangered population of bottlenose dolphins. Endangered Species Research. 24:221-236.

Hauser, D.D.W, K.L. Laidre and H.L. Stern. 2018. Vulnerability of Arctic marine mammals to vessel traffic in the increasingly ice-free Northwest Passage and Northern Sea Route. Proceedings of the National Academy of Science of the USA 115: 7617–7622.

Heide-Jørgensen, M.P., R. Dietz, K.L. Laidre and P. Richard. 2002. Autumn movements, home ranges, and winter density of narwhals (*Monodon monoceros*) tagged in Tremblay Sound, Baffin Island. Polar Biology. 25: 331-341.

Heide-Jørgensen M.P. and R. Dietz. 1995. Some characteristics of narwhal, *Monodon monoceros*, diving behaviour in Baffin Bay. Canadian Journal of Zoology. 73: 2120–2132.

Heide-Jørgensen, M.P., N. Hammeken, R. Dietz, J. Orr and P.R. Richard. 2001. Surfacing times and dive rates for narwhals (*Monodon monoceros*) and belugas (*Delphinapterus leucas*). Arctic. 54: 284–298.

Heide-Jørgensen, M.P., R.G. Hansen, K. Westdal, R.R. Reeves and A. Mosbech. 2013a. Narwhals and seismic exploration: Is seismic noise increasing the risk of ice entrapments? Biological Conservation. 158: 50-54.

Heide-Jørgensen, M.P., K.L. Laidre, N.H. Nielsen, R.G. Hansen and A. Rostad. 2013b. Winter and spring diving behaviour of bowhead whales relative to prey. Animal Biotelemetry. 1:15.

Heide-Jørgensen, M.P., K.L. Laidre, Ø. Wiig, M.V. Jensen, L. Dueck, L.D. Maiers, H.C. Schmidt and R.C. Hobbs. 2003. From Greenland to Canada in ten days: Tracks of bowhead whales, *Balaena mysticetus*, across Baffin Bay. Arctic. 56(1): 21-31.

Heiler, J., S.H., Elwen, H.J., Kriessel, and T. Gridley. 2016. Changes in dolphin whistle parameters related to vessel presence, surface behaviour and group composition. Animal Behaviour. 117:167-177.

Hin, V., J., Harwood, and A.M. de Roos. 2019. Bio-energetic modelling of medium-sized cetaceans shows high sensitivity to disturbance in seasons of low resource supply. Ecological Applications. 29(5): e01903. 10.1002/eap.1903.

Holt, M.M., D.P. Noren and C.K. Emmons. 2013. An investigation of sound use and behaviour in a killer whale (*Orcinus orca*) population to inform passive acoustic monitoring studies. Marine Mammal Science, 29(2): E193-E202.Huntington, H.P. 2009. A preliminary assessment of threats to arctic marine mammals and their conservation in the coming decades. Marine Policy. 33(1): 77-82.

Innes, S., M.P. Heide-Jørgensen, J.L. Laake, K.L. Laidre, H.J. Cleator, P. Richard and R.E.A. Stewart. 2002. Surveys of belugas and narwhals in the Canadian High Arctic in 1996. NAMMCO Sci. Publication. 4: 169–190.

Irvine, A.B., M.D., Scott, R.S., Wells, and J.H. Kaufman. 1981. Movements and activities of the Atlantic bottlenose dolphin, Tursiops truncatus, near Sarasota, Florida. Fishery Bulletin, US. 79:671-688.

Jason Prno Consulting Services Ltd. (JPCS). 2017. Results of Community Workshops Conducted for Baffinland Iron Mines Corporation's Phase 2 Proposal. Report prepared for Baffinland Iron Mines Corporation. January 2017.

Johnson, C.M., and K.S. Norris. 1986. Delphinid social organisation and social behaviour. Pages 335-346 in R. J. Schusterman, J.A. Thomas, and F.G. Wood, eds. Dolphin cognition and behaviour. Lawrence Erlbaum Associates, Hillsdale, NJ.

Kelly, T.C. 2014. Linking feeding and reproductive ecology in beluga (*Delphinapterus leucas*) and narwhal (*Mondon monoceros*). [Doctor of Philosophy thesis]. Winnipeg: University of Manitobia. 235 p.

Kinnaird, M.F., and T.G. O'Brien. 1996. Ecotourism in the Tangkoko DuaSudara Nature Reserve: opening Pandora's Box?. Oryx. 30:65-73.

Kingsley, M.C.S., H.J. Cleator and M.A. Ramsay. 1994. Summer distribution and movements of narwhals (*Monodon monoceros*) in Eclipse Sound and adjacent waters, North Baffin Island, N.W.T. Meddelelser om Grønland, Bioscience. 39: 163–174.

Koblitz, J.S., P. Stilz, M.H. Rasmussen and K.L. Laidre. 2016. Highly directional sonar beam of narwhals (*Monodon monoceros*) measured with a vertical 16 hydrophone array. PLoS ONE 11(11): e0162069. 17 pp.

Koski, W.R. and R.A. Davis. 1994. Distribution and numbers of narwhal (*Monodon monoceros*) in Baffin Bay and Davis Strait. Medd Grøn Biosci. 39:15–40.

Krasnova, V.V., E.A., Prasolova, R.A., Belikov, A.D., Chernetsky, and E.M. Panova. 2014. Influence of boat tourism on the behaviour of Solovetskiy beluga whales (*Delphinapterus leucas*) in Onega Bay, the White Sea. Aquatic Conservation: Marine Freshwater Ecosystems. 2020:1–12.

Kruse, S. 1991. The interactions between killer whales and boats in Johnstone Strait, B.C. In K. Pryoe, and K. S. Norris (Eds.), Dolphin societies: discoveries and puzzles. Berkeley, CA: University of California Press. In Bejdger et al. 1999.

Laidre, K.L. and M.P. Heide-Jørgensen. 2005. Winter feeding intensity of narwhal (*Monodon monoceros*). Marine Mammal Science. 21(1): 45-57.

Laidre, K.L., M.P. Heide-Jørgensen and R. Dietz. 2002. Diving behaviour of narwhals (*Monodon monoceros*) at two coastal localities in the Canadian High Arctic. Canadian Journal of Zoology. 80: 624–635.

Laidre, K.L., M.P. Heide-Jørgensen, R. Dietz, R.C. Hobbs and O.A. Jørgensen. 2003. Deep-diving by narwhals, *Monodon monoceros*: differences in foraging behaviour between wintering areas? Marine Ecology Progress Series. 261: 269–281.

Laidre, K.L., M.P. Heide-Jørgensen, M.L. Logsdon, R.C. Hobbs, P. Heagerty, R. Dietz, O.A. Jørgensen and M.A. Trebel. 2004. Seasonal narwhal habitat associations in the high Arctic. Marine Biology. 145: 821–831.

Laidre, K.L., M.P. Heide-Jørgensen and J. Orr. 2006. Reactions of narwhals, *Monodon monoceros*, to killer whale, *Orcinus orca*, attacks in the eastern Canadian Arctic. Canadian Field-Naturalist. 120: 457-465.

Langsrud Ø. 2003. ANOVA for unbalanced data: use type II instead of type III sums of squares. Statistics and Computing. 13 (2): 163-167.

Length, R. 2020. emmeans: Estimated Marginal Means, aka Least-Squares Means. R package version 1.4.5.009003. https://github.com/rvlenth/emmeans

Lewsey, J.D., W.P. Gardiner, and G. Gettinby. 2001. A study of type II and type III power for testing hypotheses from unbalanced factorial designs. Communication in Statistics - Simulation and Computation 30(3): 597-609.

Louis M., M. Skovrind, E. Garde, M.P. Heide-Jørgensen, P. Szpak, and E.D. Lorenzen. 2021. Population-specific sex and size variation in long term foraging ecology of belugas and narwhals. Royal Society Open Science. 8(2). https://doi.org/10.1098/rsos.202226.

Lusseau, D. 2003. Male and female bottlenose dolphins Tursiops spp. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. Marine Ecology Progress Series. 257:267-274.

Lusseau, D. 2006. Short-term behavioural reactions of bottlenose dolphins to interactions with boats in Doubtful Sound, New Zealand. Marine Mammal Science. 22(4):802-818.

Lusseau, D., and L. Bejdger. 2007. The long-term consequences of short-term responses to disturbance experiences from whale watching impact assessment. International Journal of Comparative Psychology. 20:228-236.

Mann, J., R.C., Connor, L.M. Barre, and M.R. Heithaus. 2000. Female reproductive success in bottlenose dolphins (Tursiops sp.): life history, habitat, provisioning, and group size effects. Behavioural Ecology. 11:210-219.

Mansfield, A.W., T.G. Smith and B. Beck. 1975. The narwhal, *Monodon monoceros*, in eastern Canadian waters. Journal of the Fisheries Research Board of Canada. 32: 1041-1046.

Marcoux, M. 2011b. Narwhal communication and grouping behaviour: a case study in social research and monitoring [Doctor of Philosophy thesis]. Montreal: McGill University. 168 p.

Marcoux, M., M. Auger-Methe and M.M. Humphries. 2009. Encounter frequencies and grouping patterns of narwhal in Koluktoo Bay, Baffin Island. Polar Biology. 32:1705-1716.

Marcoux, M., M. Auger-Methe, E.G. Chmelnitsky, S.H. Ferguson and M.M. Humphries. 2011a. Local passive acoustic monitoring of narwhal presence in the Canadian Arctic: A pilot project. Arctic. 64(3): 307-316.

Marcoux, M., and C.A. Watt. 2020. Eclipse Sound narwhal (Monodon monoceros) movement and hunt composition and its relevance to stock delineation. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/067. In press.

Matsuda, N., M. Shirakihara, and K. Shirakihara. 2011. Effects of dolphin-watching boats on the behaviour of Indo-Pacific bottlenose dolphins off Amakusa-Shimoshima Island, Japan. Nippon Suisan Gakkaishi.

Matthews, J.N.S., and D.G. Altman. 1996. Interaction 2: Compare effect sizes not *P* values. BMJ 313: 808.

Mattson, M, C., Thomas, J.A., and D.St. Aubin. 2005. Effects of boat activity on the behaviour of bottlenose dolphins (Tursiops truncatus) in waters surrounding Hilton Head Island, South Carolina. Aquatic Mammals. 31(1):133-140.

Miller, L.A., J. Pristed, B. Mohl and A. Surlykke. 1995. The click sounds of narwhals (*Monodon monoceros*) in Inglefield Bay, Northwest Greenland. Marine Mammal Science. 11: 491-502.

Miller, L., M., Solangi, and S. Kuczaj. 2008. Immediate response of Atlantic bottlenose dolphins to high-speed personal watercraft in the Mississippi Sound. Journal of the Marine Biological Association of the UK. 88(06):1139-1143.

Moretti, D. 2019. Determining the effect of Mid-Frequency Active (MFA) sonar on fitness of Blainville's beaked whales (*Mesoplodon densirostris*) in the Tongue of the Ocean. PhD Thesis, University of St. Andrews, St. Andrews. 246 p.

National Marine Fisheries Service (NMFS). 2018. 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 pp.

Nette, T., D. Burles, and M. Hoefs. 1984. Observations of golden eagle, Aguila chrysaetos, predation on Dall sheep, Ovis dalli dalli, lambs. Canadian Field-Naturalist, 98, 252e255.

Ngô, M.C., M.P. Heide-Jørgensen, and S. Ditlevsen. 2019. Understanding narwhal diving behaviour using Hiddent Markov Models with dependent state distributions and long range depenedence. PLOS Computational Biology 15(3):1-21. https://doi.org/10.1371/journal.pcbi.1006425.

Norris, K.S., and T.P. Dohl. 1980. Behaviour of the Hawaiian spinner dolphin *Stenella loôirostris*. Fishery Bulleting: 77(4): 821-849.

Norris, K. S., B., Würsig, R. S. Wells, & M., Würsig. 1994. The Hawaiian Spinner Dolphin. Berkeley: University of California Press.

Nowacek, S.M., Wells, R.S., and R.S. Solow. 2001. Short-term effects of boat traffic on bottlenose dolphins, Tursiops truncatus, in Sarasota Bay, Florida. Marine Mammal Science. 17(5):673-688.

Ootova, A. 2017. Marine Mammal Observer, Pond Inlet Hunting and Trapping Organization, Nunavut. Personal communication with A. Allen, documented in Ad Lib 2017 Field Notebook. 4 August 2017.

Pennacchi, A.M. 2013. Behaviour of bottlenose dolphins (*Tursiops truncatus*) relative to boat traffic in the Galveston ship channel, Texas [Undergraduate Research Scholar thesis]. Houston: Texas A&M University. 50 p.

Pilleri, G. 1983. Remarks on the ecology and behaviour of the narwhal (*Monodon monoceros*), with particular reference to the savssat. Investigations on Cetacea. 15: 123-142.

Podolskiy, E.A., and S. Sugiyama. 2020. Soundscape of a narwhal summering ground in a glacier fjord (Inglefield Bredning, Greenland). Journal of Geophysical Research: Oceans. 125: 1-21.

Quijano, J.E., C. O'Neill and M. Austin. 2017. Underwater Noise Assessment for the Mary River Phase 2 Expansion Project: Construction and operation activities in Milne Port and along the proposed northern shipping corridor. Document 01372, Version 1.0. Technical report by JASCO Applied Sciences for Golder Associates Ltd.

R Core Team. 2020. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL www.R-project.org

Rasmussen, M.H., J.C. Koblitz and K.L. Laidre. 2015. Buzzes and high-frequency clicks recorded from narwhals (*Monodon monoceros*) at their wintering ground. Aquatic Mammals. 41(3): 256-264.

Reeves, R., C. Rosa, J.C. George, G. Sheffield and M. Moore. 2012. Implications of Arctic industrial growth and strategies to mitigate future vessel and fishing gear impacts on bowhead whales. Marine Policy 36:454-62.

Remnant, R.A. and M.L. Thomas. 1992. Inuit traditional knowledge of the distribution and biology of High Arctic narwhal and beluga. Unpublished report by North/South Consultants Inc. Winnipeg, Manitoba. vii + 96 p.

Ribeiro, S., F.A., Viddi, and T.R.O., Freitas. 2005. Behavioural responses of Chilean dolphins (*Cephalorhynchus eutropia*) to boats in Yaldad Bay, Southern Chile. Aquatic Mammals. 31(2):234-242.

Richard, P.R., J.L. Laake, R.C. Hobbs, M.P. Heide-Jørgensen, N.C. Asselin and H. Cleator. 2010. Baffin Bay narwhal population and distribution and numbers: Aerial surveys in the Canadian High Arctic, 2002-2004. Arctic. 63:85-99.

Richard, P.R., P. Weaver, L. Dueck and D. Barber. 1994. Distribution and numbers of Canadian High Arctic narwhals (*Monodon monoceros*) in August 1984. Meddelelser om Gronland Bioscience. 39: 41-50.

Richardson, W.J., D.H. Thomson, C.R. Green Jr. and C.I. Malme. 1995. Marine mammals and noise. Academic Press, Inc., San Diego, CA.

Shane, S.H., R.S., Wells, and B. Wursig. 1986. Ecology, behaviour, and social organisation of the bottlenose dolphin; a review. Marine Mammal Science. 2(1):34-63.

Shapiro, A. D. 2006. Preliminary evidence for signature vocalizations among free-ranging narwhals (*Monodon monoceros*). The Journal of the Acoustical Society of America. 120(3):1695-1705.

Smith, H.R., J.R. Brandon, P. Abgrall, M. Fitzgerald, R.E. Elliott and V.D. Moulton. 2015. Shore-based monitoring of narwhal and vessels at Bruce Head, Milne Inlet, 30 July - 8 September 2014. Final LGL Report No. FA0013-2. Prepared by LGL Limited, King City, Ontario for Baffinland Iron Mines Corporation, Oakville, Ontario. 73 p. + appendices.

Smith, H.R., S. Raborn, M. Fitzgerald and V.D. Moulton. 2016. Shore-based monitoring of narwhal and vessels at Bruce Head, Milne Inlet, 29 July – 5 September 2015. LGL Report No. FA0044-1. Prepared by LGL Limited, King City, Ontario for Baffinland Iron Mines Corporation, Oakville, Ontario. 73 p. + appendices.

Smith, H.R., V.D. Moulton, S. Raborn, P. Abgrall, R.E. Elliott and M. Fitzgerald. 2017. Shore-based monitoring of narwhal and vessels at Bruce Head, Milne Inlet, 2016. LGL Report No. FA0089-1. Prepared by LGL Limited, King City, Ontario for Baffinland Iron Mines Corporation, Oakville, Ontario. 87 p. + appendices.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R., Jr., Kastak, D., Ketten, D. R., Miller, J. H., Nachtigall, P. E., Richardson, W. J., Thomas, J. A. and Tyack, P. L. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. Aquatic Mammals. 33 (4).

Southall, B. L., J.J. Finneran, C. Reichmuth, P.E. Nachtigall, D.R. Ketten., A.E. Bowles, W.T. Ellison, D.P. Nowacek and P.L. Tyack. 2019. Marine mammal noise exposure criteria: Updated scientific recommendations for residual hearing effects. Aquatic Mammals. 45(2): 125-232.

Steltner, H., S. Steltner, and D.E. Sergeant. 1984. Killer whales, Orcinus orca, prey on narwhals, Monodon monoceros: an eyewitness account. Canadian Field Naturalist. 98: 458-462.

Stewart, D.B. 2001. Inuit knowledge of belugas and narwhals in the Canadian Eastern Arctic. Report for the Department of Fisheries and Oceans Canada. Arctic Biological Consultants. Winnipeg, Manitoba. 32 p.

Tervo, O.M., S. Ditlevsen, M.C. Ngô, N.H. Nielsen, S.B. Blackwell, T.M. Williams and M.P. Heide-Jørgensen. 2021. Hunting by the Stroke: How foraging drives diving behaviour and locomotion of East-Greenland Narwhals (*Monodon monoceros*). Frontiers in Marine Science. 7:596469. doi: 10.3389/fmars.2020.596469.

Thomas, T.A., S. Raborn, R.E. Elliott and V.D. Moulton. 2015. Marine mammal aerial surveys in Eclipse Sound, Milne Inlet, Navy Board Inlet, and Pond Inlet, 1 August – 22 October 2014. Final LGL Report No. FA0024-2. Prepared by LGL Limited, King City, ON for Baffinland Iron Mines Corporation, Oakville, ON. 70 p.

Thomas, T.A., S. Raborn, R.E. Elliott and V.D. Moulton. 2016. Marine mammal aerial surveys in Eclipse Sound, Milne Inlet and Pond Inlet, 1 August – 17 September 2015. LGL Report No. FA0059-3. Prepared by LGL Limited, King City, ON for Baffinland Iron Mines Corporation, Oakville, ON. 76 p. + appendices.

Veirs, S., V. Veirs and J.D. Wood. 2016. Ship noise extends to frequencies used for echolocation by endangered killer whales. Peer J. 35 pp.

Visser, F., C., Curé, P.H., Kvadsheim, F.A., Lam., P.L., Tyack, and P.O. Miller. 2016. Disturbance-specific social responses in long-finned pilot whales, *Globicephala melas*. Scientific Reports. 6, 28641; doi: 10.1038/srep28641.

Walmsley, S.F., L., Rendell, N.E., Hussey and M. Marcoux. 2020. Vocal sequence in narwhals (*Monodon monoceros*). The Journal of the Acoustical Society of America. 147(2):1078-1091.

Watt, C.A., J. Orr, B. LeBlanc, P. Richard, and S. Ferguson. 2012. Satellite tracking of narwhals (*Monodon monoceros)* from Admiralty Inlet (2009) and Eclipse Sound (2010-2011). DFO Canadian Science Advisory Secretariat Science Advisory Report 2012/046 iii + 17 p.

Watt, C.A. and S.H. Ferguson. 2015. Fatty acids and stable isotopes (δ13C and δ15N) reveal temporal changes in narwhal (*Monodon monoceros*) diet linked to migration patterns. Marine Mammal Science. 31(1): 21-44.

Watt, C.A., M.P. Heide-Jørgensen and S.H. Ferguson. 2013. How adaptable are narwhal? A comparison of foraging patterns among the world's three narwhal populations. Ecosphere. 4(6): 71. 15 pp.

Watt, C.A., J.R. Orr, M.P. Heide-Jorgensen, N.H. Nielsen and S.H. Ferguson. 2015. Differences in dive behaviour among the world's three narwhal *Monodon monoceros* populations correspond with dietary differences. Marine Ecology Progress Series. 525: 273-285.

Watt, C.A., J.R. Orr and S.H. Ferguson. 2017. Spatial distribution of narwhal (*Monodon Monoceros*) diving for Canadian populations helps identify important seasonal foraging areas. Canadian Journal of Zoology. 95: 41-50.

Watt, C.A., J. Simoniee, V. L'Herault, R. Zhou, S.H. Ferguson, M. Marcoux and S. Black. 2021. Cortisol levels in narwhal (*Monodon monoceros*) blubber from 2000-2019. Arctic Science. 10: 1139.

Wells, R.S., A.B., Irvine, and M.D. Scott. 1980.The social ecology of inshore odontocetes. Pages 263-318 In L.M. Herman (ed). Cetacean Behaviour: Mechanisms and Functions. J. Wiley, New York.

Williams, R., C. Erbe, E. Ashe, A. Beerman, and J. Smith. 2013. Severity of killer whale behavioural responses to ship noise: A dose-response study. Marine Pollution Bulletin. 79: 254-260.

Williams, R., A.W. Trites, and D.E. Bain. 2002. Behavioural response of killer whaes (Orcinus orca) to whale-watching boats: opportunistic observations and experimental approaches. Journal of Zoology. 256: 255-270.

Zuur A.F., Ieno E.N., Walker N., Saveliev A.A. and Smith G.M. 2009. Mixed effects models and extensions in ecology with R. (2009). Springer.

APPENDIX A

Training Manual

REPORT

2020 Bruce Head Shore-based Monitoring Program

Training Manual

Submitted to:

Baffinland Iron Mines Corporation

2275 Upper Middle Road East - Suite 300
Oakville, ON L6H 0C3

Attention: Megan Lord-Hoyle

Submitted by:

Golder Associates Ltd.

2nd floor, 3795 Carey Road, Victoria, British Columbia, V8Z 6T8, Canada

+1 250 881 7372

1663724-224-R-Rev0

23 July 2020

Distribution List

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

Golder will undertake and manage the 2020 Bruce Head shore-based monitoring program (the Program) to investigate the behavioural response of marine mammals to vessel traffic serving Milne Port as part of Baffinland Iron Mines Corporation's Mary River Project (the Project). The Program is based at Bruce Head, a high rocky peninsula (215 m above sea level) on the western shore of Milne Inlet, Nunavut, overlooking the Project's Northern Shipping Route (Photograph 1 to Photograph 3) and providing 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 primary objective of the Program is to evaluate potential disturbance of narwhal from shipping activities along the Northern Shipping Route that may result in changes in animal distribution, abundance, and migratory movements throughout Milne Inlet.

The 2020 Program represents the eighth consecutive year of environmental effects monitoring undertaken at Bruce Head in support of the Project. Previously developed by LGL Limited (LGL) in 2013 and implemented until 2016, the Program was assumed by Golder Associates beginning in 2017. Due to safety concerns associated with the distance that the team was required to travel between the Bruce Head camp and the observation platform each day, as well as concerns raised about the integrity of the previous observation platform, the Program was temporarily moved to a vessel-based platform in 2018 while plans to relocate and renovate the camp and observation platform were being drafted. Following the relocation of camp adjacent to the observation platform in 2019, data collection from the shore-based observation platform resumed. A new observation platform consisting of a modified seacan securely anchored to the ground will be utilized during the 2020 field season.

The 2020 study design is similar to that applied in previous survey years (2014-2019), with data collected on narwhal relative abundance and distribution (RAD) within a defined Stratified Study Area (SSA); on group composition and behaviour within a 1-km Behavioural Study Area (BSA); and 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 behaviour. The 2020 study design includes integration of data collection via an Unmanned Aerial Vehicle (UAV) that will be correlated with concurrently collected visual and acoustic data.

The 2020 Program will be led by Ainsley Allen (Program Technical Lead), with support from Mitch Firman and Ben Widdowson (Site Supervisors). The Program's Data Analyst, Sima Usvyatsov, will also be present in camp for the duration of the field program. Shea Pollard will be returning as Camp Manager.

Photograph 1: Camp at Bruce Head, overlooking Poirier Island and Milne Inlet.

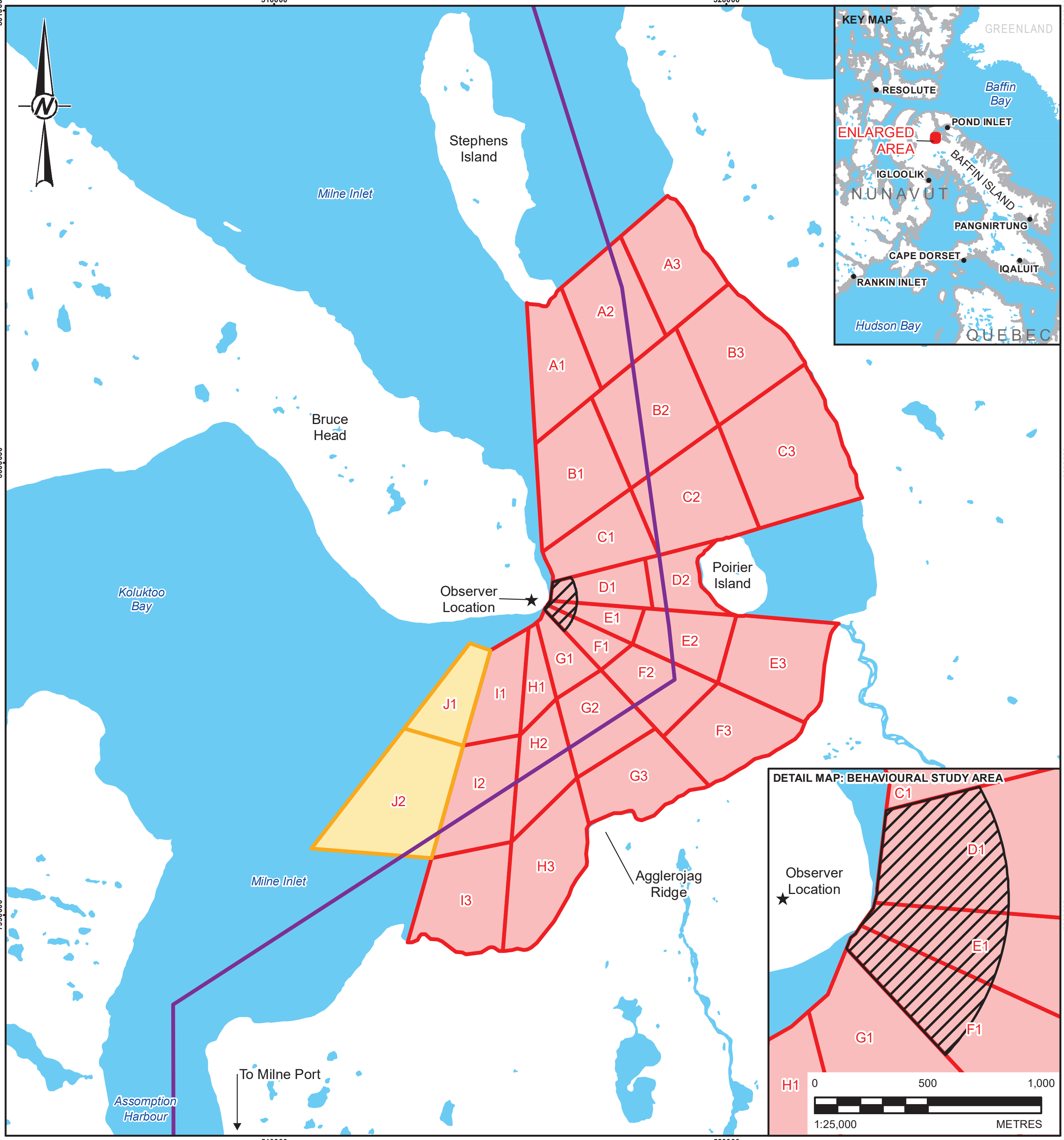
Photograph 2: Camp at Bruce Head, overlooking Milne Inlet.

Photograph 3: Camp at Bruce Head, with southern Milne Inlet in the background.

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 Behavioural Study Area (BSA) (Figure 1.1). The SSA is stratified into strata A (northernmost stratum) through J (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 28 substrata within the SSA as strata D, and J are comprised of only 2 substrata each. 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.

Beginning in 2019, the SSA was expanded westward to include substrata J. The objective of including additional substrata was to systematically capture the “pulsing” of narwhal in and out of Koluktoo Bay that has been observed anecdotally in past monitoring programs (Golder 2018, Golder 2020, Smith et al. 2015, Smith et al. 2016, Smith et al. 2017).



LEGEND

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

STRATIFIED STUDY AREA (SSA) SUBSTRATA

- EXISTING SUBSTRATA
- STRATA ADDED IN 2019

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 BIM, JULY 14, 2020. 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

YYYY-MM-DD	2020-07-21
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	1.1

2.0 CHANGES TO STUDY DESIGN

Based on collection and analysis of data obtained during previous Bruce Head Shore-based monitoring Programs, as well as consultation with the various stakeholder groups, the existing study design (2014 – 2017) has continued to evolve to provide for a more comprehensive picture of potential effects to narwhal resulting from Project-related shipping activities. Of note, changes to the 2019 study design included expansion of the SSA boundary to the south to include the mouth of Koluktoo Bay, and integration of acoustic data collection. Further modifications to the study design to be carried out during the 2020 field season include integration of a robust UAV Survey component and correlation with acoustic data, as outlined in section 4.2.

2.1 Amendment of Stratified Study Area (SSA) Boundary

The existing SSA was expanded in 2019 to include substrata J, for the purpose of evaluating narwhal movements at the mouth of Koluktoo Bay in relation to vessel traffic (Figure 1.1). Of particular interest is the apparent ‘pulsing’ of narwhal groups in and out of Koluktoo Bay that has been observed anecdotally in past years (Golder 2018, Golder 2020, Smith et al. 2015, Smith et al. 2016, Smith et al. 2017), and whether these movements are related to vessel disturbance or simply to variation in their natural habitat (e.g. tidal cycles, prey availability, etc).

2.2 Integration of UAV Survey

In collaboration with InDro Robotics Inc., Golder will conduct surveys of narwhal in the vicinity of Bruce Head using an UAV (Unmanned Aerial Vehicle), as outlined in section 4.2. The integration of this component of the study is contingent on obtaining a BVLOS (Beyond Visual Line of Sight) permit from Transport Canada.

2.3 Integration of Acoustic Data Collection

During the 2018 and 2019 field seasons, three Autonomous Multichannel Acoustic Recorders (AMARs) were deployed in the vicinity of Bruce Head and Koluktoo Bay (Figure 1.1). During the 2020 field season, visual observations of narwhal will be correlated with concurrently collected acoustic data via a survey new to this Program, termed the Visual Acoustic Correlation (VAC) Survey (Section 4.2.3).

3.0 MONITORING SCHEDULE

The 2020 Bruce Head Shore-based Monitoring Program will consist of 16 hours of daily monitoring effort (weather permitting), undertaken by two teams comprised of 5 core individuals each (‘Early shift’ and ‘Late shift’), alternating at 4 hr observation intervals (Table 1). Individuals will work with their respective teams throughout the duration of their time at Bruce Head and will alternate working the ‘Early’ or ‘Late’ shift according to a 3-day rotation schedule (Table 2). Individuals will also assist with 1-2 hours of data entry each day, depending on the duration of daily monitoring shifts. The team that is not monitoring narwhal during their 4-hr shift will have the opportunity to rest and prepare/eat meals during this time.

Three individuals from InDro Robotics will also conduct 10 hours of UAV surveying effort each day and will work closely with Golder co-pilots, Mitch Firman and Ainsley Allen, to plan and execute daily flight operations. Golder co-pilots will work between the observation platform, data entry and analysis at the computer, and with Indro Robotics during flight operations. Golder co-pilots will also assist the Field Data Analyst, Sima Usvyatsov, with management and QA/QC of data collected by visual observers and by the UAV survey team.

Table 1: Daily monitoring schedule and time available for meals.

Time (EDT)	Monitoring Narwhal	Meals
Before 06:00	N/A	Breakfast (Early shift)
06:00 – 10:00 (4 hrs)	Early shift	Breakfast (Late shift)
10:00 – 14:00 (4 hrs)	Late shift	Lunch (Early shift)
14:00 – 18:00 (4 hrs)	Early shift	Lunch / Dinner (Late shift)
18:00 – 22:00 (4 hrs)	Late shift	Dinner (Early shift)

Table 2: 2020 Monitoring Schedule[1]

Date (2020)	Early Shift	Late Shift
August 4	N/A: Travel	
August 5, 6	N/A: Training / set-up camp (everyone)	
August 7, 8, 9	**BW***, AJ, IS, MH, SS, AA	**AR**, FG*, DB, JG, TG, MF, (SU)
August 10, 11, 12	**AR**, FG*, DB, JG, TG, MF, (SU)	**BW***, AJ, IS, MH, SS, AA
August 13, 14, 15	**BW***, AJ, IS, MH, SS, AA	**AR**, FG*, DB, JG, TG, MF, (SU)
August 16, 17, 18	**AR**, FG*, DB, JG, TG, MF, (SU)	**BW***, AJ, IS, MH, SS, AA
August 19, 20, 21	**BW***, AJ, IS, MH, SS, SU	**AR**, DB, JG, TG, KW, MF
August 22, 23, 24	**AR**, DB, JG, TG, KW, MF	**BW***, AJ, IS, MH, SS, SU
August 25, 26, 27	**BW***, AJ, IS, MH, SS, SU	**AR**, DB, JG, TG, KW, MF
August 28, 29, 30	**AR**, DB, JG, TG, KW, MF	**BW***, AJ, IS, MH, SS, SU
August 31, Sept 1	N/A: Camp de-mobilization / travel	

[1] Ainsley Allen (AA), Alec Johnston (AJ), Andrew Rippington (AR), Ben Widdowson (BW), Dan Beaudry (DB), Ian Snider (IS), Francoise Gervaise (FG)*, Jake Glaspy (JG), Kristin Westman (KW), Mike Hann (MH), Sam Sweeney (SS), Sima Usvyatsov (SU), Tyler Grom (TG)

(* denotes Polar Bear Monitor, _ denotes UAV Co-pilot, bold font denotes Crew Lead, brackets denote Data Analyst)

4.0 PROGRAM OVERVIEW

4.1 Visual Survey by MMOs

During each 4-hr monitoring shift, three complementary surveys will be undertaken by Marine Mammal Observers (MMOs); 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 Behaviour surveys will be conducted within the BSA.

3) Anthropogenic activity and environmental conditions will be documented 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 anthropogenic activity (Team 1 will note whether a vessel is entering/exiting Milne Inlet and approaching/departing individual substrata; Team 2 will note any hunting activity within and beyond the SSA and document vessels within the BSA). 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/activities considered noteworthy within the SSA. Conversely, when narwhal are not present in the BSA, Team 2 may assist in collecting anecdotal information within the broader SSA.

4.1.1 Team 1 - Relative Abundance and Distribution (RAD)

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

S*urvey* and *scan* sampling protocols will be used (Mann, 1999[2]) whereby the observer surveys each stratum for a minimum of 3 minutes to identify narwhal groups[3] (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.
- 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.
- Vessel presence and direction of travel.
- Beaufort scale, glare and a subjective assessment of sightability (see section 4.1.1.3).

---

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

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

4.1.1.1 Roles and Responsibilities – Team 1

Table 3: Team 1 roles, responsibilities, and monitoring equipment employed.

Team Role	Responsibility	Equipment
Person 1 – Marine Mammal Observer (MMO)	■ Count all visible narwhal within each substratum and note direction of travel (N, S, E, W) whenever possible. ■ Note other marine mammal species observed in each substratum. All other cetaceans (whales) observed are to be documented as a separate sighting while any pinnipeds (seals) and walrus observed are to be documented anecdotally in the comments section. ■ Report beaufort scale, glare and sightability within each substratum. ■ Document vessel presence in relation to 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 MMO using the RAD data sheet. All times should be recorded in local time (EDT) using the 24-hr clock (e.g. 2 pm is recorded as 14:00).	Data sheet[4]

4.1.1.2 Survey Protocol - RAD

- 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 J, respectively (**Appendix B**).
- 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.
  - 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 (i.e. 1 minute per substratum).
  - 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.

[4] Data Sheets: Relative Abundance and Distribution

4.1.1.3 *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 behaviour (as possible). Always prioritize whale sightings.
- Vessel presence, vessel class[5], 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 C**)
  - 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.

4.1.2 Team 2 - Group Composition and Behaviour

A team of three individuals (Team 2) will collect group composition and nearshore behavioural data on all narwhal that swim within 1 km from the shore where the observation platform is located (i.e. the BSA). Surveys will consist of 50-minute observation periods, abbreviated by 10-minute rest periods. S*urvey* and *scan* sampling protocols will be used (Mann, 1999). For each sighting[6], the team will collect data as per the survey protocol outlined below, after which the observer will move on to the next sighting.

Data to be recorded for the BSA:

- Narwhal group composition.
- Narwhal group primary and secondary behaviour.
- Beaufort scale, glare, and an assessment of sightability (as per definitions in Section 4.1.2.4).

Team 2 will also collect data on the following for the entire SSA:

- Vessel presence, class (e.g., large, medium, and small), and direction of travel.
- Any hunting/shooting events, the associated time, and target species whenever possible.
- Environmental data (i.e. ice cover, precipitation, cloud cover).

---

[5] Vessel class: Small = 0-50m; medium = 50m-100m; large = $\geq$100m
[6] Sighting: Observation of a group of animals (including groups of 1).

Additionally, Team 2 will be responsible for documenting narwhal distance and orientation in relation to the Autonomous Multichannel Acoustic Recorder (AMAR) so that visual and acoustic observations of narwhal can be correlated as part of the Visual Acoustic Correlation (VAC) Survey.

4.1.2.1 Roles and Responsibilities – Team 2

Table 4: 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 behaviour of all narwhal within the BSA. Specific behaviour (e.g. tusking) within each of the seven behavioural categories should be documented whenever possible. ■ Note any other marine mammal species (and behaviour) observed in the BSA ■ Report glare and sightability within the BSA every hour. ■ Communicate all observations to the Recorder (Person 2).	Big eye binoculars
Person 2 – Recorder (Visual Observations of Narwhal)	■ Record all information received on the data sheet from the MMO. ■ Observe environmental conditions and complete the associated data sheet every hour and whenever conditions change. ■ Document which sightings are included by Person 3 in the VAC Survey. For sightings documented by Person 3, Include a check mark (√) in the final column of the Group Composition and Behaviour Survey datasheet. ■ 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 in local time (EDT) using the 24-hr clock (e.g. 2 pm is recorded as 14:00).	HD camera, 10 x 42 binoculars, Datasheets[7]
Person 3 – Recorder / Observer (Anthropogenic and Acoustic Observations)	■ Complete the Visual-Acoustic Correlation (VAC) survey whenever a lone narwhal group is sighted within 900 m from AMAR 3. This should be a “snapshot” of narwhal location and orientation in relation to AMAR 3 so should be documented with a single timestamp. If more time is required to accurately document all narwhal, a timestamp range should be included on the datasheet (e.g. 12:34 – 12:37). ■ For narwhal within the BSA, communicate to Person 2 which sightings are included in the VAC Survey. ■ Communicate to the Golder co-pilot whenever a group of interest (see Section 4.1.2.3) is present within the VAC survey grid. ■ Communicate to the Golder co-pilot whenever a herding event begins through the BSA. ■ For vessels present within the SSA, document vessel class and specify whether entering/exiting Milne Inlet and approaching/departing the BSA. ■ Record all hunting activity throughout each 4-hr observation period, the associated time, and the target species whenever possible. ■ Once datasheets have been completed, assist Person 1 with marine mammal observing.	10 x 42 binoculars, Datasheets[8],

[7] Datasheets: Group Composition and Behaviour; Environmental Conditions

[8] Datasheets: Vessel Passages and other Anthropogenic Activity; Visual-Acoustic Correlation (VAC) Survey

4.1.2.2 Survey Protocol – Group Composition and Behaviour

- Observations of narwhal group composition and behaviour will be made by the **Team 2 MMO** who will communicate findings to the **Team 2 Recorder.**
- The **Team 2 Recorder** will also be responsible for documenting environmental conditions for the entire SSA every hour and whenever conditions change,
- The third individual from Team 2, the **Recorder of Anthropogenic and Acoustic Observations**, will be responsible for collecting vessel traffic and anthropogenic data for both the BSA and the broader SSA and will assist the MMO with observations once completing the VAC Survey (Section 4.1.2.3).
- 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[9] (1) and secondary[10] (2) behavioural data are to be recorded for every sighting whenever possible, based on seven behavioural categories[11] (Table 8).
  - Unique behaviours[12] 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[13]: If multiple groups pass through the BSA too quickly such that group composition and behaviour 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 5 and associated tables) and the behavioural data (Table 8) that is to be recorded for each sighting[14] within each 50-minute survey.

---

[9] Primary behaviour = the behaviour displayed by the majority of animals; the predominant behaviour.

[10] Secondary behaviour = the second most commonly observed behaviour of a group of animals.

[11] Behavioral categories (see Table 8) = travelling, resting, milling, foraging, socializing, reproductive, other.

[12] Unique behaviours (see Table 8) = 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).

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

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

Table 5: Group composition and behaviour 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 narwhal with tusks	■ Present ■ Absent ■ Unknown (i.e. head not visible).
Number of narwhal in age categories adult, juvenile, yearling, and calf.	See Table 6 (Life stages).
Spread	■ Tight: narwhal ≤ body width apart ■ Loose: narwhal >1 body width apart
Group Formation	See Table 7 (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 8 (Behavioural Data).
Associated photo range	■ For each sighting where photos are taken, the numeric photo range should be recorded.

Table 6: 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 7: Group formation categories.

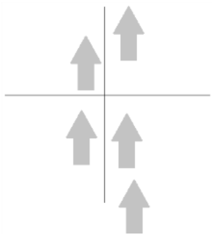
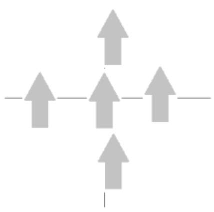
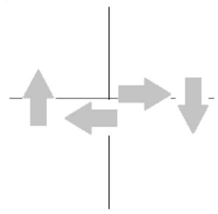
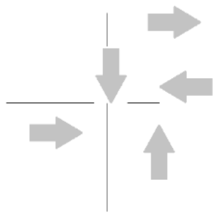
Linear	Parallel	Cluster/ circular	Non-directional line	No formation
Directional line	Directional line	Directional line	Non-directional line	Non-directional line
Stretched longitudinal	Stretched laterally	Stretched longitudinal + lateral	Linear formation	Non-linear
One animal after another in a straight 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 8: Behavioural data (primary and secondary) to be recorded.

Behaviour	Description of behaviour	Unique behaviour 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)

4.1.2.3 Survey Protocol – Visual Acoustic Correlation (VAC)

- Whenever a lone group of narwhal is sighted within 900 m from AMAR 3, the third individual from Team 2, the **Recorder of Anthropogenic and Acoustic Observations**, will be responsible for documenting narwhal distance and orientation relative to AMAR 3 by filling out the Visual Acoustic Correlation (VAC) Survey datasheet. This individual will also be responsible for coordinating with the UAV team by communicating narwhal activity within the VAC survey grid to the Golder co-pilot.
- General Rules:
  - The location and orientation of narwhal groups within 900 m from AMAR 3 will be recorded on the datasheet in 300 m increments using the following notation:
    - Circle encasing the number of animals in the group <u>with arrow</u> for groups showing clear direction/ orientation relative to the AMAR.
    - Circle encasing the number of animals in the group <u>with no arrow</u> for groups showing none or mixed orientation relative to the AMAR.
  - To the best extent possible, provide a “snapshot” of narwhal groups in the vicinity of AMAR 3 by recording all observations within one minute. Where more time is required due to challenging sighting conditions, document the time needed to collect the “snapshot” (e.g. 12:41 – 12:44).
  - The VAC Survey datasheet is to be filled out whenever a lone group of narwhal is sighted within 900 m of AMAR 3 and no other narwhal are visible within the VAC survey area, with the objective of attributing specific vocalizations to groups of known composition. Groups of interest include mother-calf pairs and exclusive adult groups (i.e. no immatures present).
  - Noteworthy events (e.g. presence of other marine mammals, icebergs calving, etc.) should also be documented on the VAC Survey datasheet whenever possible.
  - Communicate to the **Team 2 Recorder** (Person 2) which narwhal groups observed are included in the VAC Survey and ensure that this is recorded by the **Team 2 Recorder** (Person 2) in the final column of the Group Composition and Behaviour datasheet if within the BSA.
  - Survey # recorded on the VAC Survey datasheet should correspond with the survey # on the Group Composition and Behaviour Survey datasheet.
  - For documenting narwhal presence, circle “Y” (Yes) if narwhal are clearly present within/beyond the 900 m radius, “N” (No) if no narwhal are clearly present within the 900 m radius, and “U” (Unknown) if no narwhal are clearly present beyond the 900 m radius. As the VAC is intended to be a “snapshot” in time, it is not possible to comprehensively survey the entire SSA within a one-minute period and confirm narwhal absence. Therefore, narwhal absence beyond the 900 m radius will be later assessed by reviewing RAD data collected concurrently.

4.1.2.4 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 <u>for the entire SSA</u> 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 C**)
- 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.

All vessels present and hunting activity observed within the SSA (including the BSA) will be documented by the **Team 2 Recorder of Anthropogenic and Acoustic Observations**. The following will be recorded:

- Vessel class[15] for all vessel traffic present within the SSA.
- The time, duration, and general location of all hunting activity observed (visually or aurally) during each 50-minute survey, noting the target species whenever possible.
- Fixed-wing aircraft and helicopters are to be noted in the 'comments' section of the data sheet if present, including aircraft travel direction.

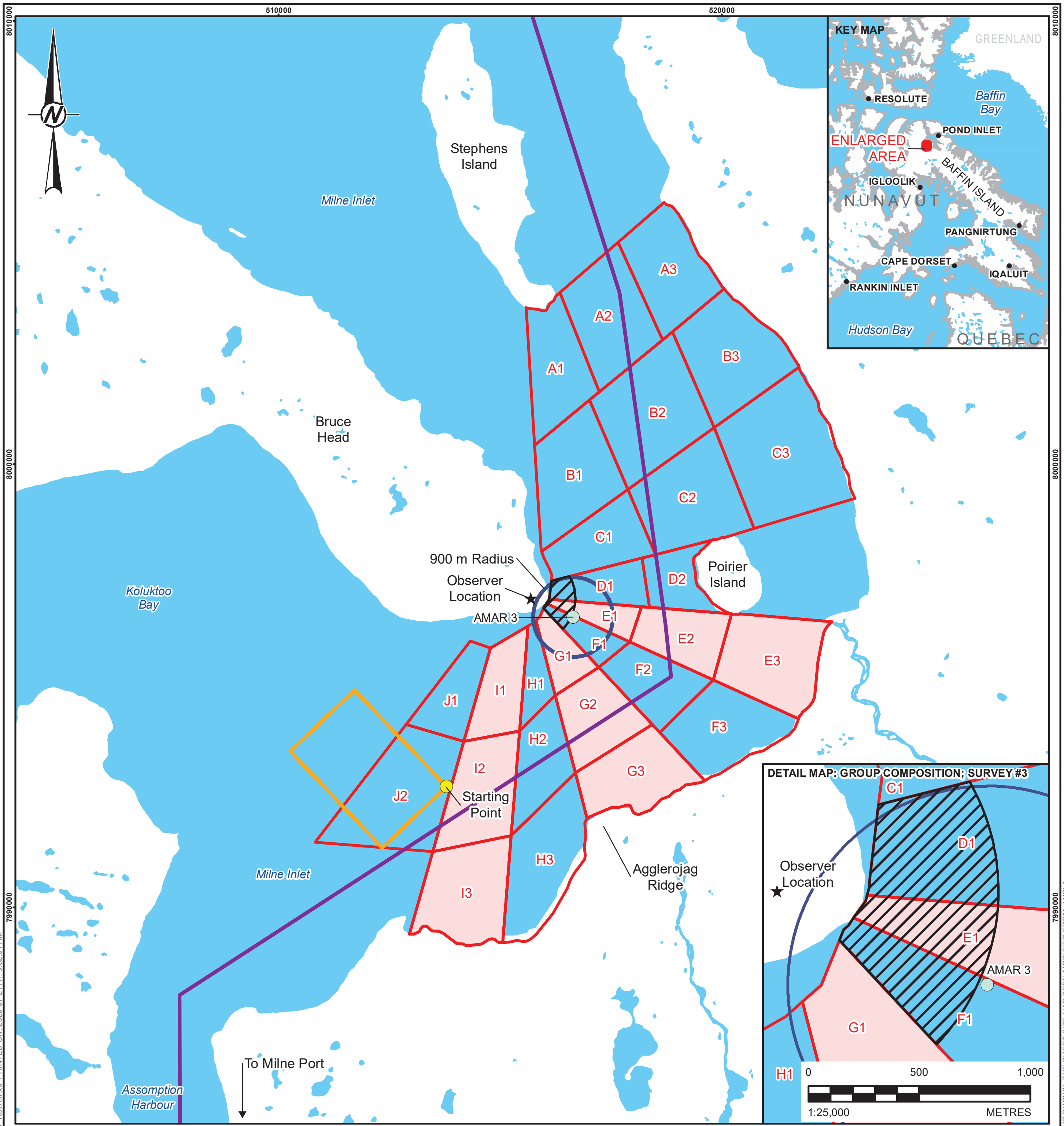
4.2 UAV Survey by InDro Robotics Inc.

An Unmanned Aerial Vehicle (UAV) survey will be undertaken in conjunction with the 2020 Bruce Head Shore-based monitoring program to further investigate the response of narwhal to shipping activities. The UAV units, including the Freefly Alta X (https://freeflysystems.com/alta-x), will conduct surveys of defined study grids (Figure 4.1) in coordination with shore-based visual observers with the following objectives:

1) Confirm sightings information (e.g., group composition, group size, behaviour) during narwhal herding events through the BSA;
2) Assess behavioral changes (e.g. change in orientation) in relation to shipping events under a different behavioral context (i.e. resting/milling) than what is typically observed of animals in the BSA (i.e. travelling) via focal follow surveys;
3) Correlate visual observations of narwhal with those detected aurally via an Autonomous Multichannel Acoustic Recorder (AMAR) deployed near Bruce Head (AMAR 3); and
4) Evaluate observer detection performance (i.e., ability to effectively detect animals) throughout the SSA.

A decision tree (section 4.2.5) will be used as a tool to determine which UAV surveys will be prioritized on a daily basis based on weather conditions, narwhal presence, and shipping activities.

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



LEGEND

- AMAR LOCATION
- FOCAL FOLLOW; SURVEY #2 STARTING POINT
- COMMUNITY
- OBSERVER LOCATION
- APPROXIMATE SHIPPING ROUTE
- GROUP COMPOSITION; SURVEY #1
- FOCAL FOLLOW; SURVEY #2
- VAC SURVEY; SURVEY #3
- STRATIFIED STUDY AREA (SSA) SUBSTRATA
- SYSTEMATIC SURVEY OF SSA; SURVEY #4
- 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
UAV STUDY DESIGN

CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-21
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	4.1

4.2.1 UAV Survey 1: Confirmation of Group Composition

Below is a summary of pertinent information relating to UAV Survey 1.

- Survey location: BSA (Figure 4.1).
- The objective of this component of the survey is to confirm sightings information during narwhal herding events through the BSA, with special attention paid to proportion of immature animals present (i.e. calves, yearlings, juveniles). Results of this survey will inform the proportion of immatures in the Eclipse Sound summering stock.
- Flight schedule: Daily, opportunistically as narwhal herding events occur.
- Flight details: The UAV will hover and hold over individual groups in BSA until composition of group determined and will then move onto the next until all groups in herding event are surveyed. Should the herding event go on for a period of time that exceeds the flight capabilities of an individual UAV (e.g. due to battery limitations, etc), multiple UAVs will be "hot-swapped" to capture the full duration of the event.
- Data entry / analytical approach: UAV footage will be correlated to sightings data at the end of each survey. It is predicted that composition of individual groups may not be feasible due to the large number of animals present during herding events. Therefore, the proportion of different life stages (i.e. adults, juveniles, yearlings, calves) observed via the UAV will be compared against proportion observed by MMOs during corresponding time periods. Should it be determined that numbers observed via the different survey methods are comparable (i.e. UAV confirms that data collected by MMOs is accurate), this survey will be terminated.
- Considerations: Narwhal herding events have typically been observed in the north→south direction, with animals moving through the BSA into Koluktoo Bay, though herding events have also been observed moving northward.

4.2.2 UAV Survey 2: Focal follows, Koluktoo Bay

Below is a summary of pertinent information relating to UAV Survey 2.

- Survey location: 2km x 3 km grid extending from the shipping lane into Koluktoo Bay (Figure 4.1).
- The objective of the focal follow surveys at the mouth of Koluktoo Bay is to assess behavioral changes (e.g. change in orientation) of narwhal in relation to shipping events under a different behavioral context (i.e. resting/milling) than what is typically observed of animals in the BSA (i.e. travelling).
- Flight schedule: Daily, opportunistically.
- Flight details: The UAV will be flown to a designated "starting position" at the NE corner of the survey grid, adjacent to the shipping lane, and will then begin transiting the flight path until encountering the first group. It will then stay with the group until the group disappears or disperses widely. If the group disperses, the UAV will increase altitude in an attempt to remain with the group for as long as possible. Once the group has disappeared, the UAV will go back to the starting point if outside of the survey grid or will carry on along the flight path if still within the grid.
- Data entry / Analytical approach: UAV footage will be reviewed at the end of each survey and the following response variables will be documented: group composition, group spread, travel speed, orientation relative to shipping lane (i.e. toward/away), and position of immatures relative to vessel if present (i.e. sheltered from vessel, or not).

4.2.3 UAV Survey 3: Correlation of Visual and Acoustic Observations

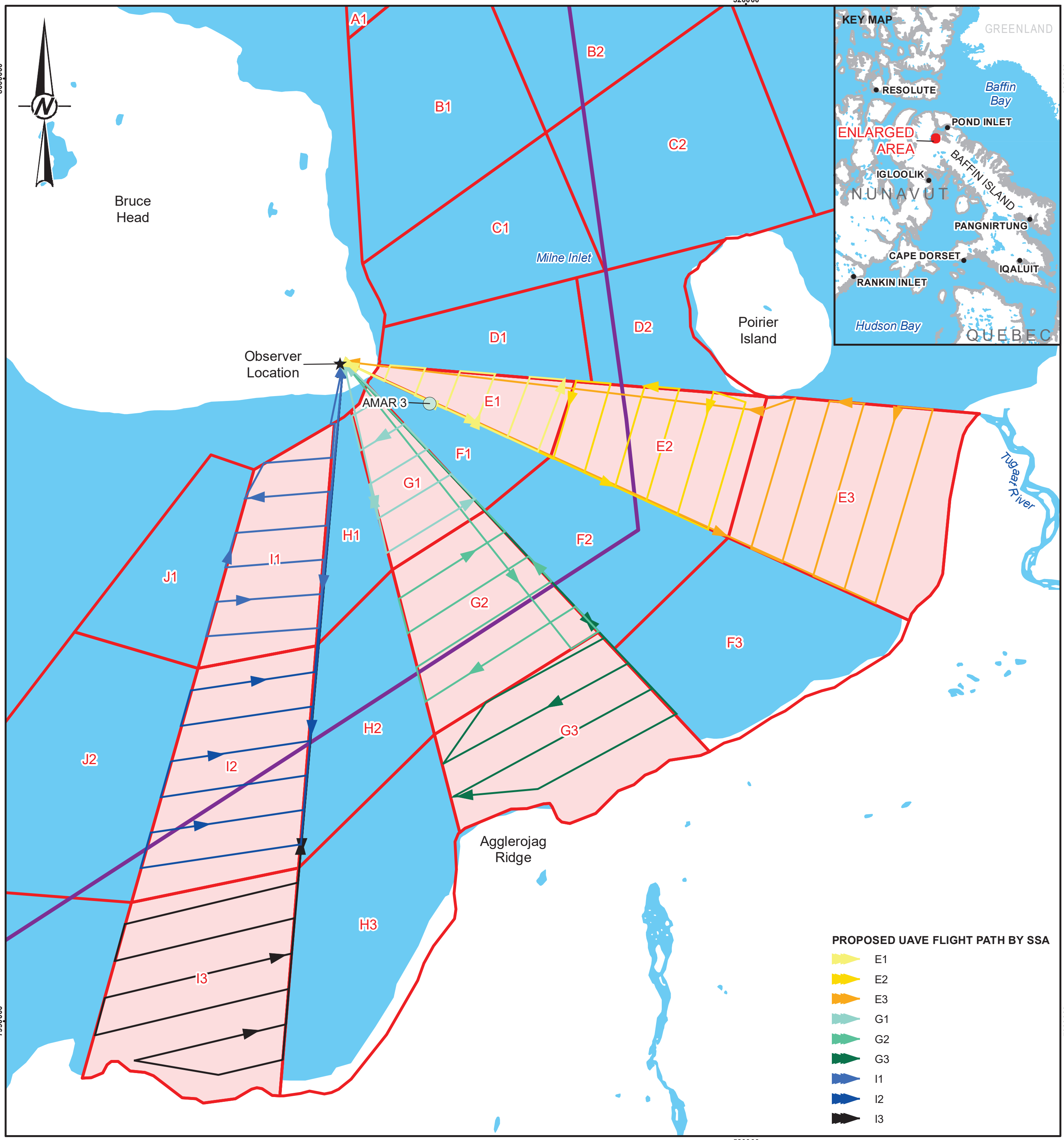
Comparison of visual observations of marine mammals with concurrently collected acoustic and Automatic Identification System (AIS) datasets is an effective way to assess the potential effects of shipping on animal behaviour. As such, data obtained via UAV Survey 3 will be incorporated into a study new to the Bruce Head Program, termed the Visual Acoustic Correlation (VAC) Study. Below is a summary of pertinent information relating to UAV Survey 3 (i.e. the VAC survey).

- Survey location: 2km x 2km grid surrounding AMAR 3 (Figure 4.1).
- The objective of the VAC survey is to assess narwhal group-specific vocal behaviour in relation to shipping activities. Narwhal sightings and UAV data will be correlated with acoustic data collected in the vicinity of Bruce Head via AMAR 3 in order to attribute vocalizations to groups of specific composition.
- Flight schedule: Daily, opportunistically as lone groups are sighted within a 1 km radius from AMAR 3.
- Flight details: Once a lone group is sighted in the vicinity of AMAR 3 (and no other groups appear to be within the 1 km radius), the UAV will be flown directly overhead of the group to take a fix of the group's location and confirm composition and orientation relative to the AMAR. If only one UAV is available to conduct survey, it will then increase altitude to confirm absence of other groups within the survey area and remain with the focal group until it disappears. If two UAVs are available, UAV #1 will remain with the focal group for as long as it is visible while UAV #2 will conduct the sweep of the full survey area at higher altitude to confirm absence of other groups.
- Data entry / Analytical approach: UAV footage will be reviewed at the end of each survey and a detailed account of the group's behavior during the survey will be documented, including group composition, distance relative to the AMAR, orientation relative to the AMAR, and other noteworthy observations.
- Considerations: Special attention will be paid to mother-calf pairs for the purpose of assessing contact calls relative to shipping activities.

4.2.4 UAV Survey 4: Systematic Survey of SSA

Below is a summary of pertinent information relating to UAV Survey 4.

- Survey location: SSA (Figure 4.1 and Figure 4.2).
- The objective of this component of the survey is to evaluate observer detection performance (i.e. ability to effectively detect narwhal) throughout the SSA.
- Flight schedule: Daily, opportunistically as weather permits.
- Flight details: Systematic transects of strata E, G, and I will be conducted in coordination with MMOs collecting sightings data.
- Considerations: This survey will be contingent on weather conditions being suitable. For each stratum surveyed, it is predicted that two back-to-back flights will be required based on battery limitations (i.e. survey of substrata 1 and 2, battery swap, continued survey of substratum 3).



LEGEND

- AMAR LOCATION
- ★ OBSERVER LOCATION
- APPROXIMATE SHIPPING ROUTE
- STRATIFIED STUDY AREA (SSA) SUBSTRATA
- SYSTEMATIC SURVEY OF SSA; SURVEY #4
- WATERBODY

0 1 2

1:60,000 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
UAV STUDY DESIGN - SYSTEMATIC SURVEY OF SSA; SURVEY #4

CONSULTANT

GOLDER

YYYY-MM-DD	2020-07-21
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	4.2

4.2.5 Prioritizing UAV Surveys

UAV surveys will be carried out in accordance with the priority objectives listed in section 4.2. A decision tree will serve as a tool to guide the UAV survey plan, which will be determined at the start of each day by Golder co-pilots in consultation with InDro Robotics personnel (Figure 4.3).

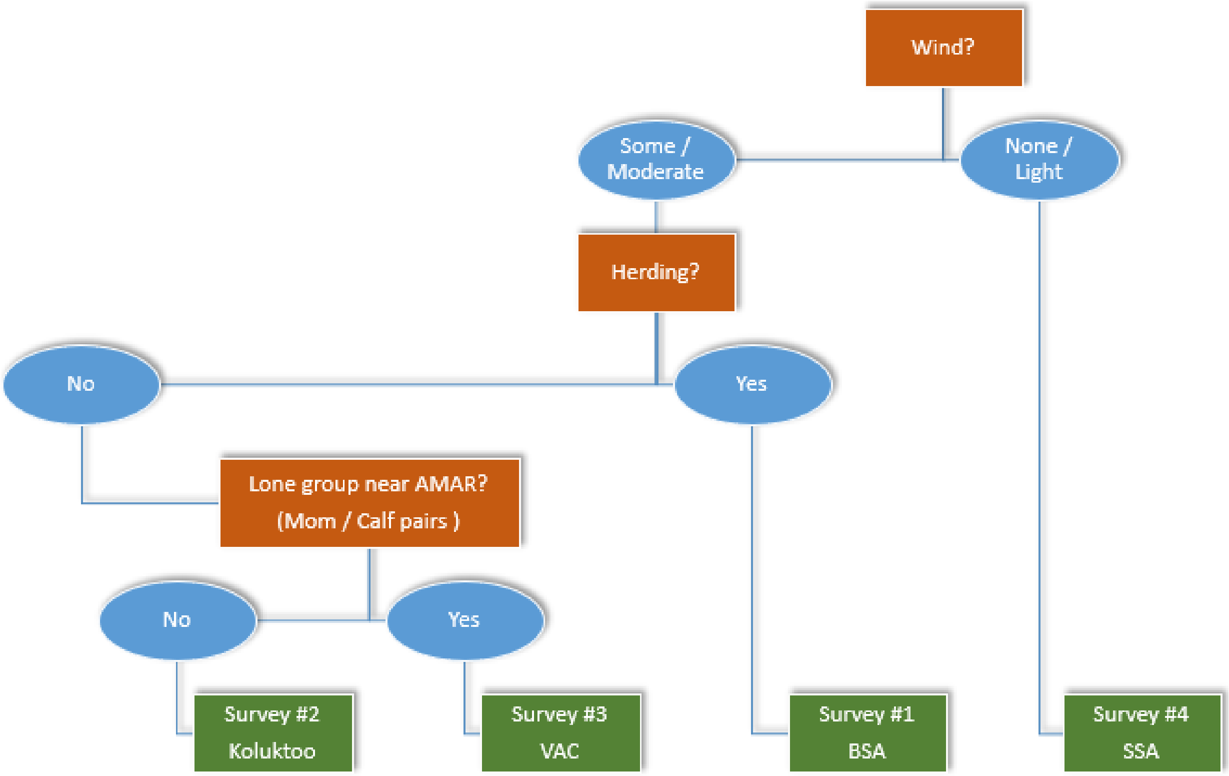


Figure 4.3: Decision tree for prioritizing respective UAV surveys.

5.0 LITERATURE CITED

Golder Associates Ltd. (Golder). 2020. 2019 Bruce Head Shore-based Monitoring Program. Draft Report prepared for Baffinland Iron Mines Corporation, Oakville, Ontario. Report No. 1663724-199-RevB-23000. 228 pp.

Golder Associates Ltd. (Golder). 2018. 2017 Bruce Head Shore-based Monitoring Program. 2014-2017 Integrated Report. Report No. 1663724-081-R-Rev0-12000. 27 November 2018. Report prepared for Baffinland Iron Mines Corporation, Oakville, Ontario. 111 pp.

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

Smith, H.R., J.R. Brandon, P. Abgrall, M. Fitzgerald, R.E. Elliott, and V.D. Moulton. 2015. Shore-based monitoring of narwhal and vessels at Bruce Head, Milne Inlet, 30 July - 8 September 2014. Final LGL Report No. FA0013-2. Prepared by LGL Limited, King City, Ontario for Baffinland Iron Mines Corporation, Oakville, Ontario. 73 p. + appendices.

Smith, H.R., V.D. Moulton, S. Raborn, P. Abgrall, R.E. Elliott, and M. Fitzgerald. 2017. Shore-based monitoring of narwhal and vessels at Bruce Head, Milne Inlet, 2016. LGL Report No. FA0089-1. Prepared by LGL Limited, King City, Ontario for Baffinland Iron Mines Corporation, Oakville, Ontario. 87 p. + appendices.

Smith, H.R., S. Raborn, M. Fitzgerald, and V.D. Moulton. 2016. Shore-based monitoring of narwhal and vessels at Bruce Head, Milne Inlet, 29 July – 5 September 2015. LGL Report No. FA0044-1. Prepared by LGL Limited, King City, Ontario for Baffinland Iron Mines Corporation, Oakville, Ontario. 73 p. + appendices.

Signature Page

Golder Associates Ltd.

Ainsley Allen
Marine Biologist

Phil Rouget
Senior Marine Biologist

AA/PR/lih

o:\final\2016\3 proj\1663724 baff_marinemammalsurvey_ont\16637724-224-r-rev0\1663724-224-r-rev0-bruce head2020 training manual 23jul_20.docx

APPENDIX A

Glossary

Beaufort Scale – an empirical measure of wind speed based on a visual estimation of the effect on the sea or land, from Beaufort force 1 (calm) to Beaufort force 12 (hurricane). See Appendix C for the Beaufort Scale.

Behaviour –

Table 1: Behavioral data (primary and secondary) to be recorded

Behavior	Unique Behaviours to be recorded	Description of behavior
Travelling		Directed movement; moving steadily in a constant direction
Resting	Logging (LO)	Not moving
Milling		Non-directional movement; moving about haphazardly within a limited area
Foraging	Chase prey (CH) Catch prey (CA)	
Socializing	Rubbing or petting (RU) Rolling (RO) Tusk displays or tusk contact (TU) Tail slap (TS)	Animals in physical contact with one another
Reproductive	Nursing (NU) Mounting (MO) Sexual display (SX)	
Other	Bubble rings (BU) Spyhopping (SP) Breaching (BR)	Behaviors not known to be context-related. Description of behavior observed to be included in comments.

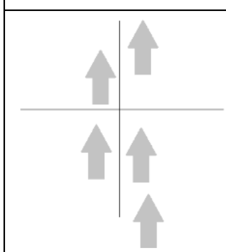
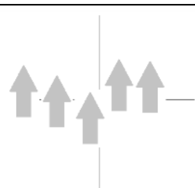
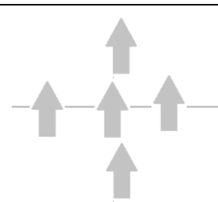
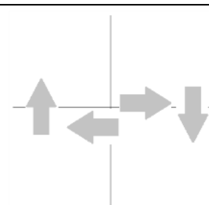
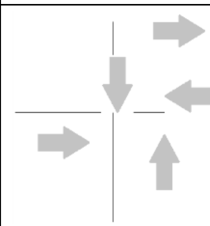
BSA – Behavioural Study Area covers portions of strata D, E and F that are within 1 km of the Bruce Head shore where the observation platform is located.

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

Group – Narwhal within one adult body length of each other.

Group Formation – The configuration of the shape that narwhal within a group swim together, categorized as in the table below.

Table 2: 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
				

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

Life Stages – The different phases of life that individuals pass through in a typical lifetime, categorized for narwhal as in the table below.

Table 3: Life stages of narwhal

	Adult	Juvenile	Yearling	Calf
Length	4.2 – 4.7 m	80-85% length of adult	2/3 length of accompanying female	1/3 to 1/2 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
Photo				

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

RAD counts – Relative Abundance and Distribution counts of narwhal and any other marine mammals observed 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.

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

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

Tight spread – narwhal ≤ body width apart

Loose spread - narwhal >1 body width apart

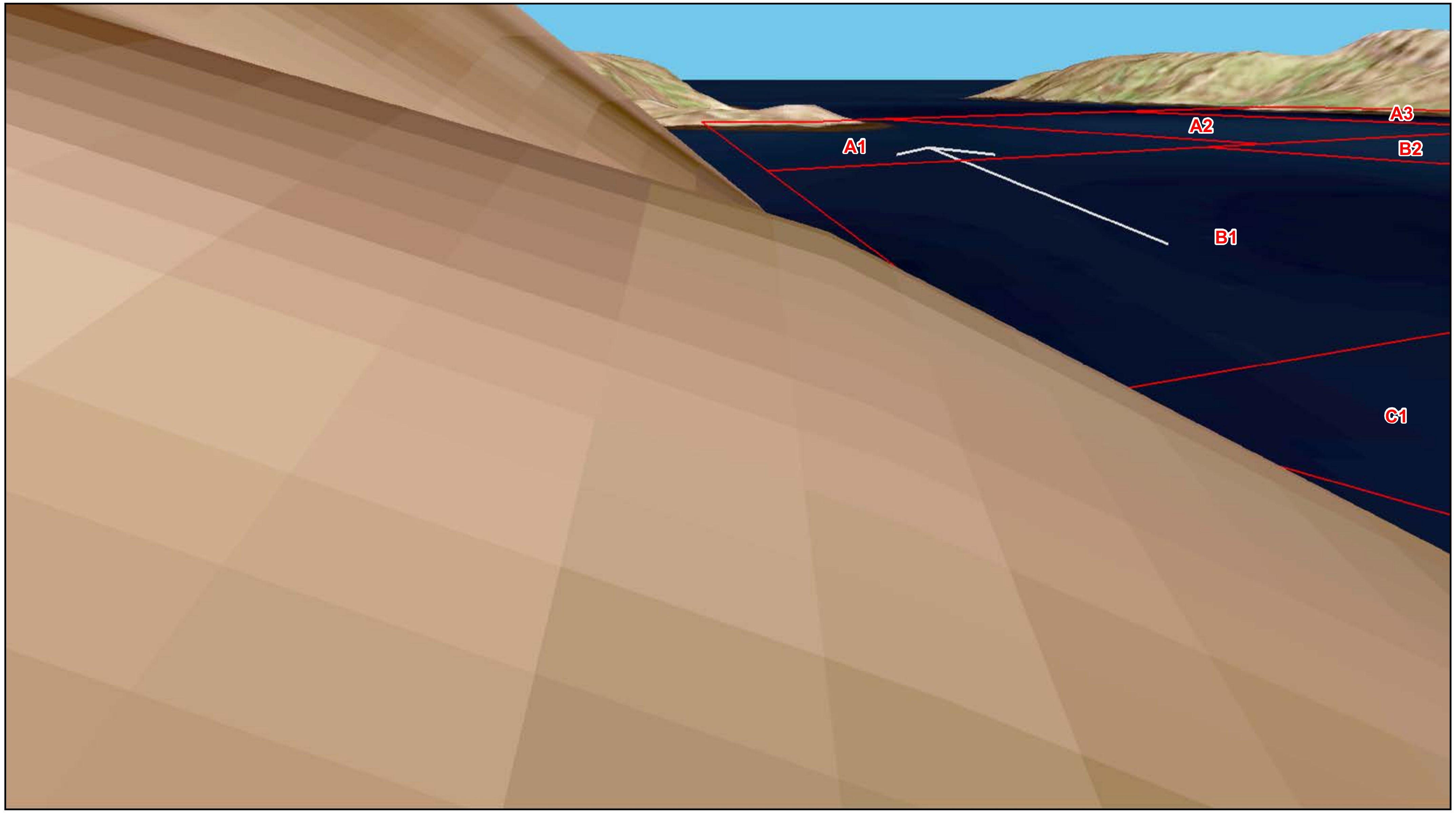
SSA – Stratified Study Area, the larger study area of the Program.

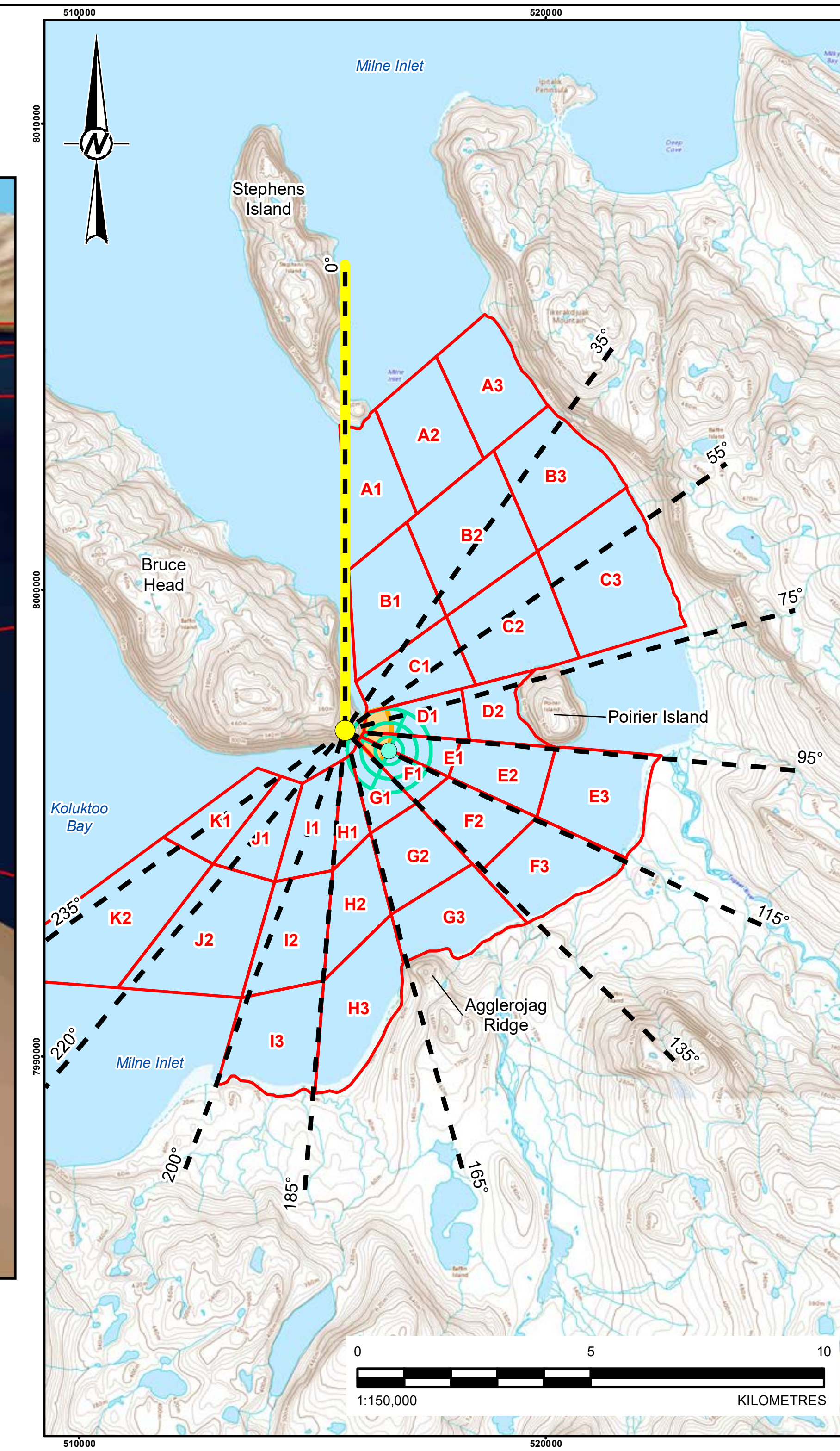
Stratum – Sections A through J of the SSA.

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

APPENDIX B

Perspective Images of Substrata





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- ACOUSTIC DETECTION RADII
- BEHAVIOURAL STUDY AREA (BSA)
- SUBSTRATA

DRAFT

REFERENCE(S)
SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

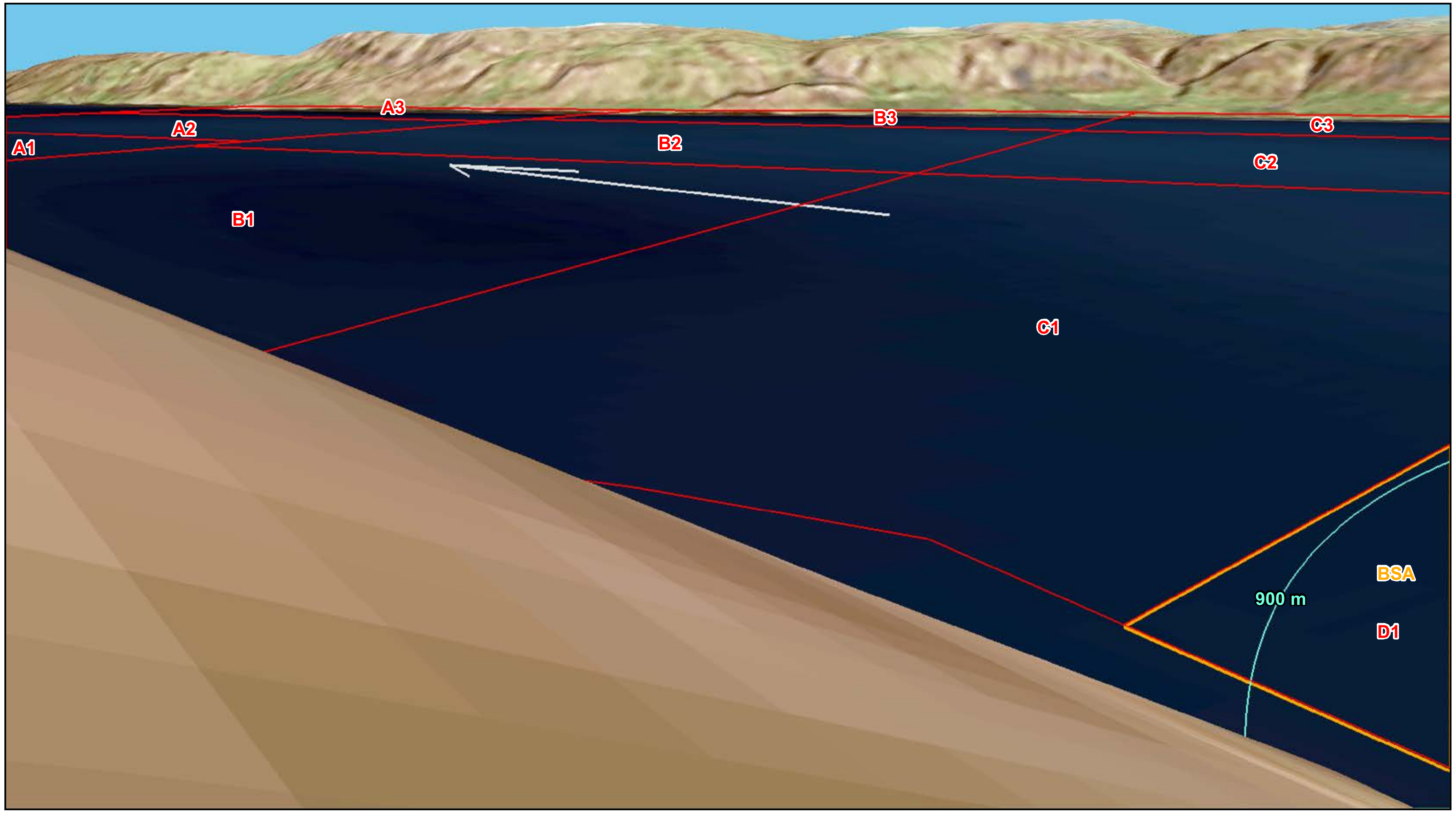
PROJECT
MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2020

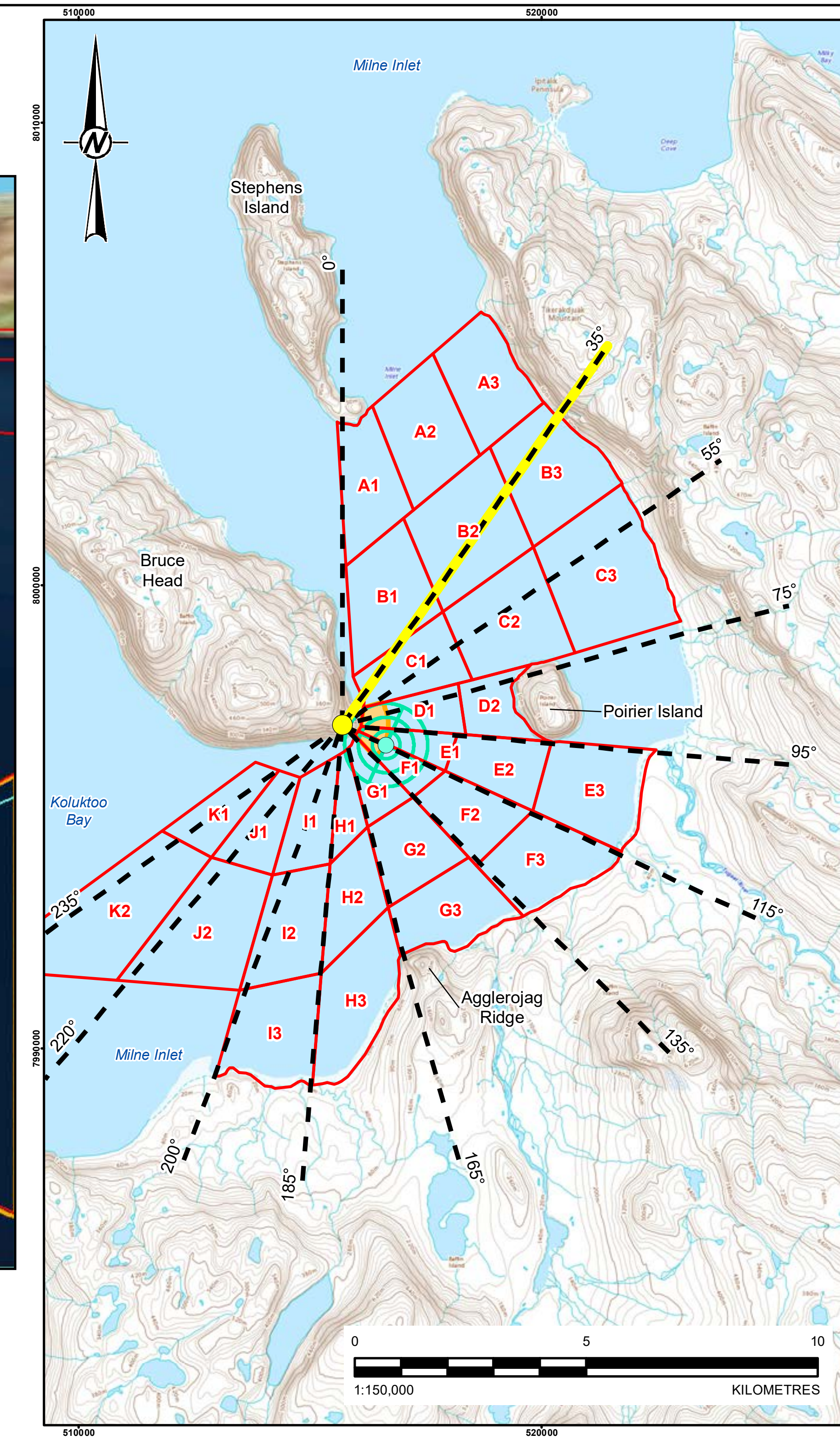
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-23
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2020 - OBSERVATION PERSPECTIVE AT 0°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-01	A	B-1





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- ACOUSTIC DETECTION RADII
- BEHAVIOURAL STUDY AREA (BSA)
- SUBSTRATA

DRAFT

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

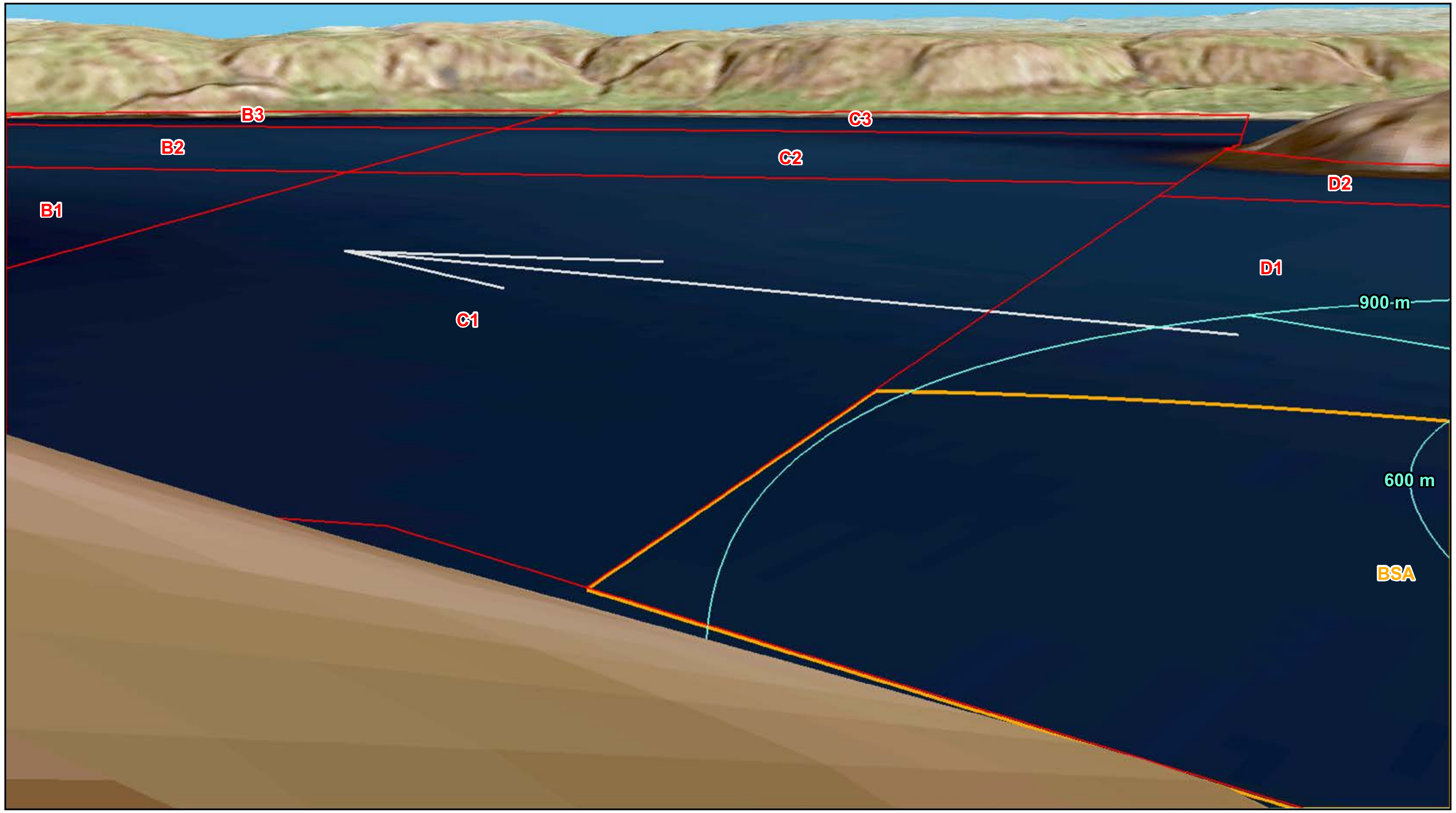
PROJECT
MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2020

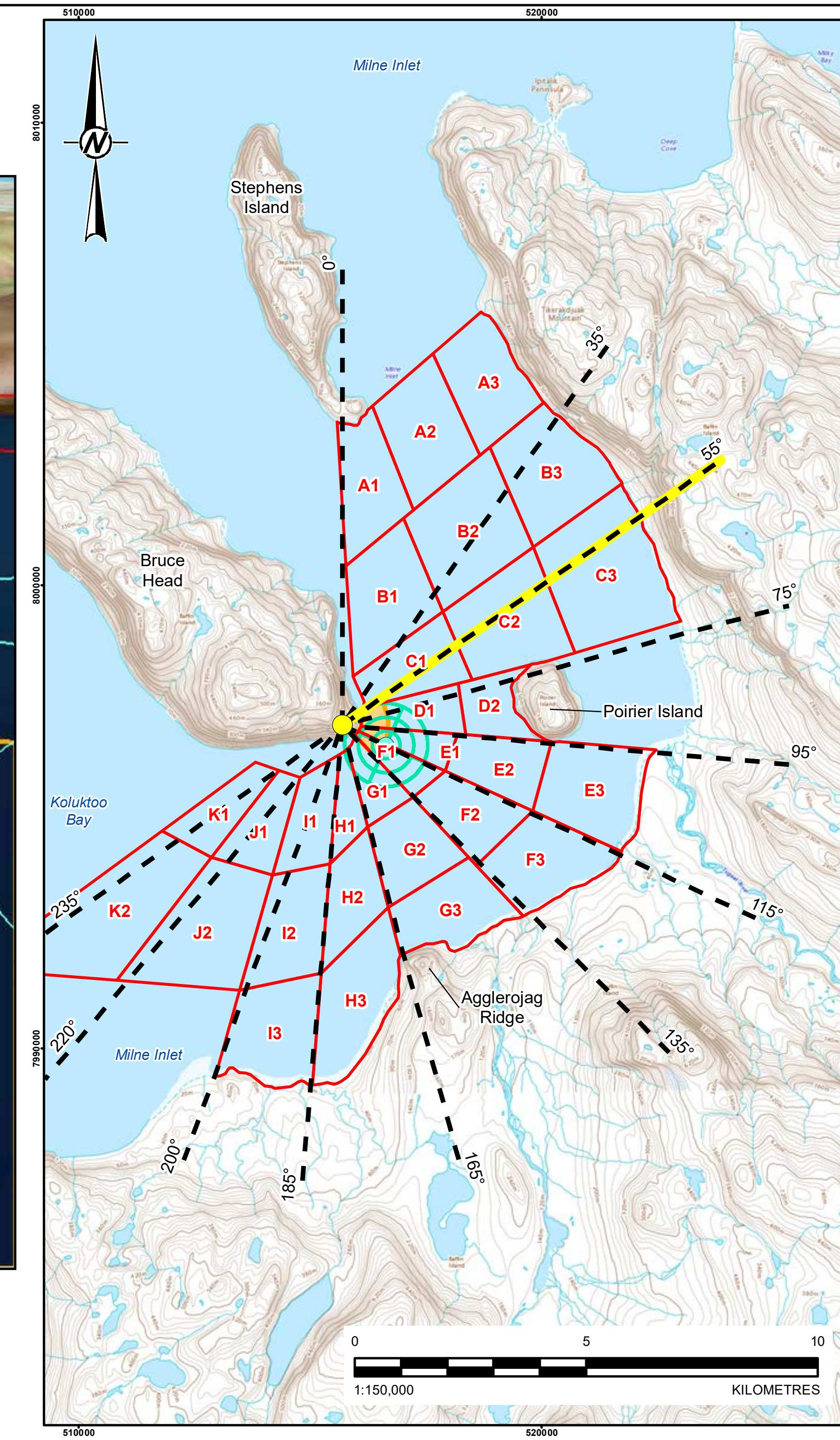
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-23
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2020 - OBSERVATION PERSPECTIVE AT 35°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-01	A	B-2





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- ACOUSTIC DETECTION RADII
- BEHAVIOURAL STUDY AREA (BSA)
- SUBSTRATA

DRAFT

REFERENCE(S)
SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

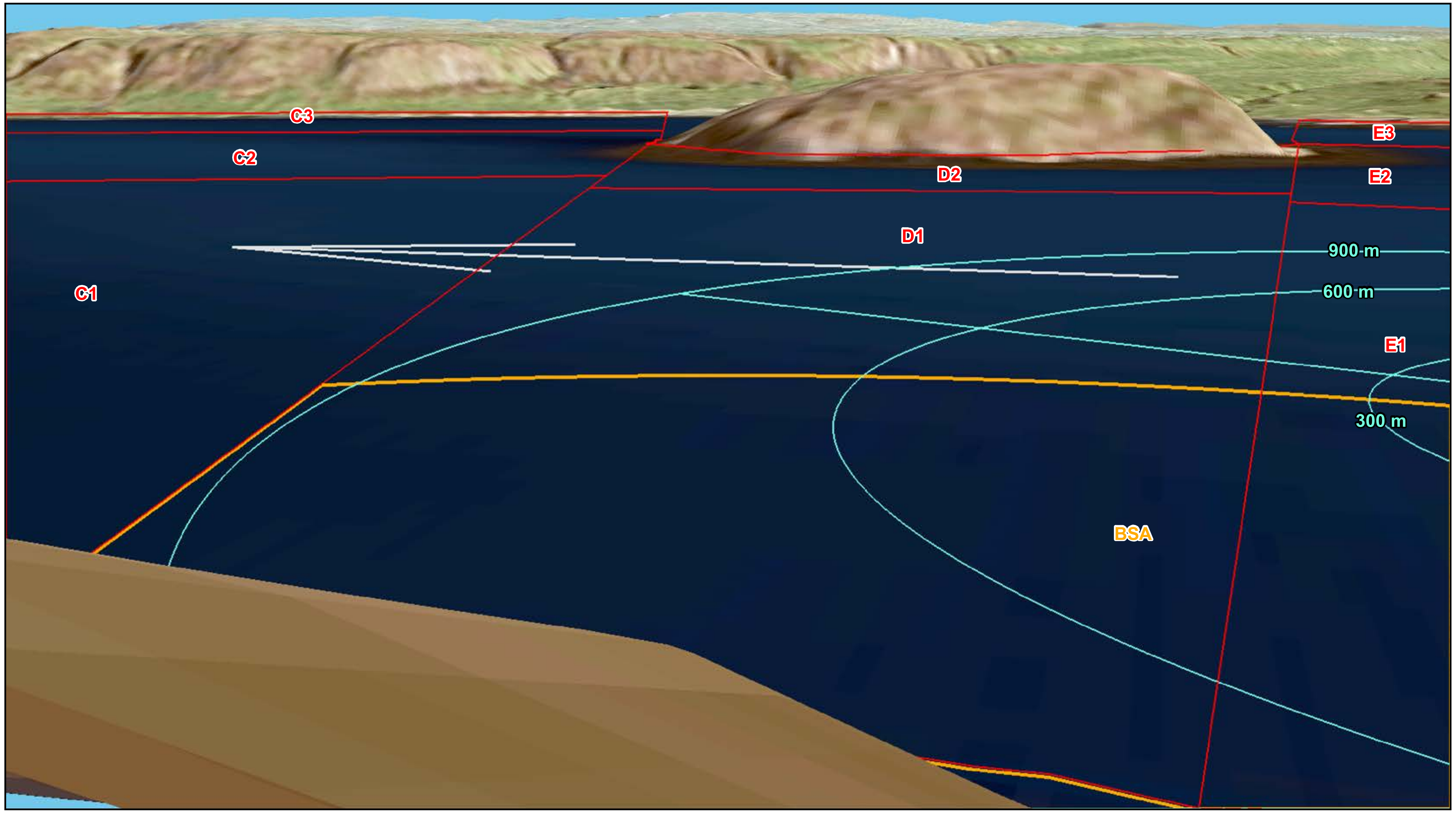
PROJECT
MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2020

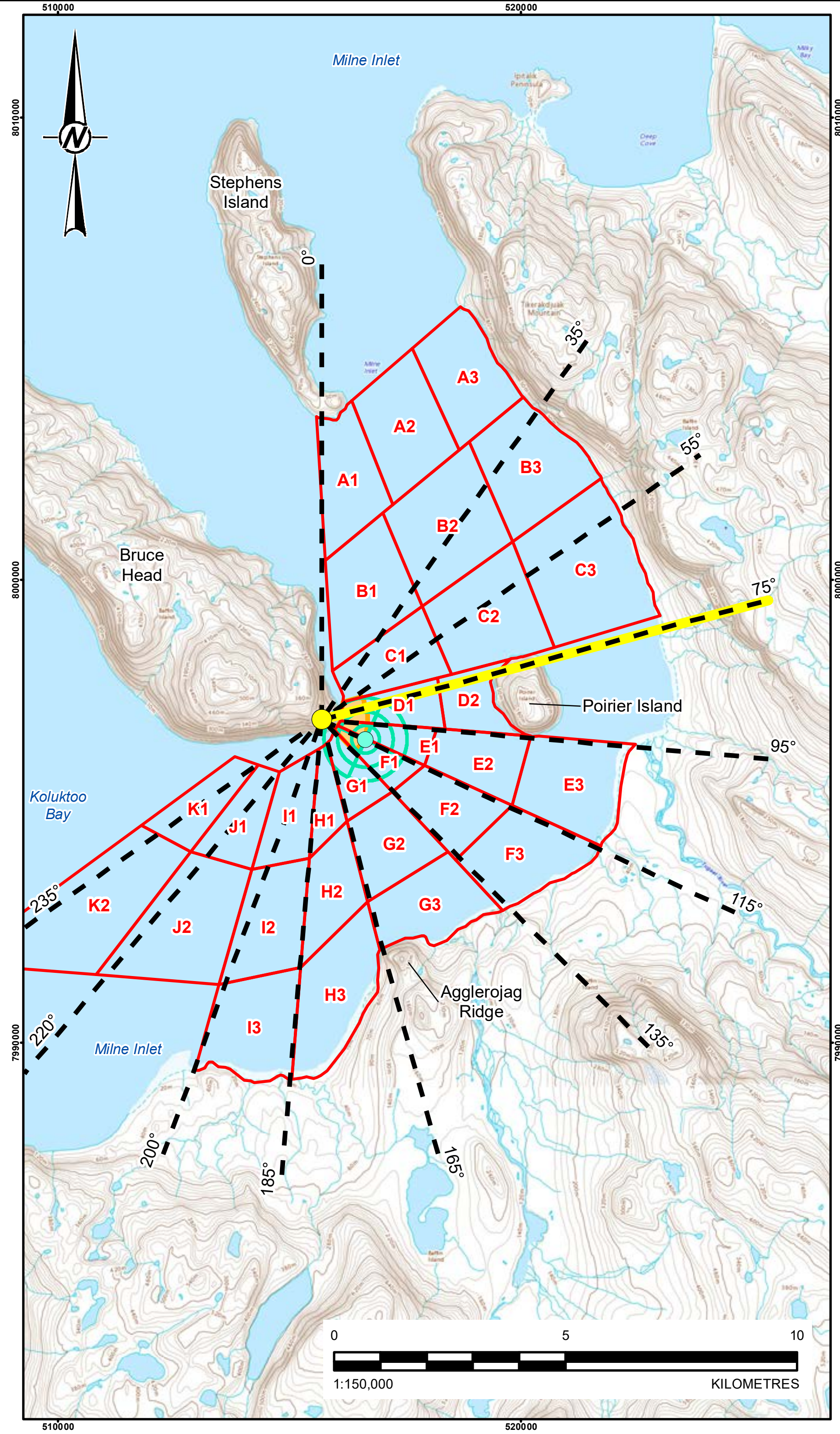
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-23
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2020 - OBSERVATION PERSPECTIVE AT 55°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-01	A	B-3





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- ACOUSTIC DETECTION RADII
- BEHAVIOURAL STUDY AREA (BSA)
- SUBSTRATA

DRAFT

REFERENCE(S)
SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS 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 PROGRAM 2020

CONSULTANT
GOLDER

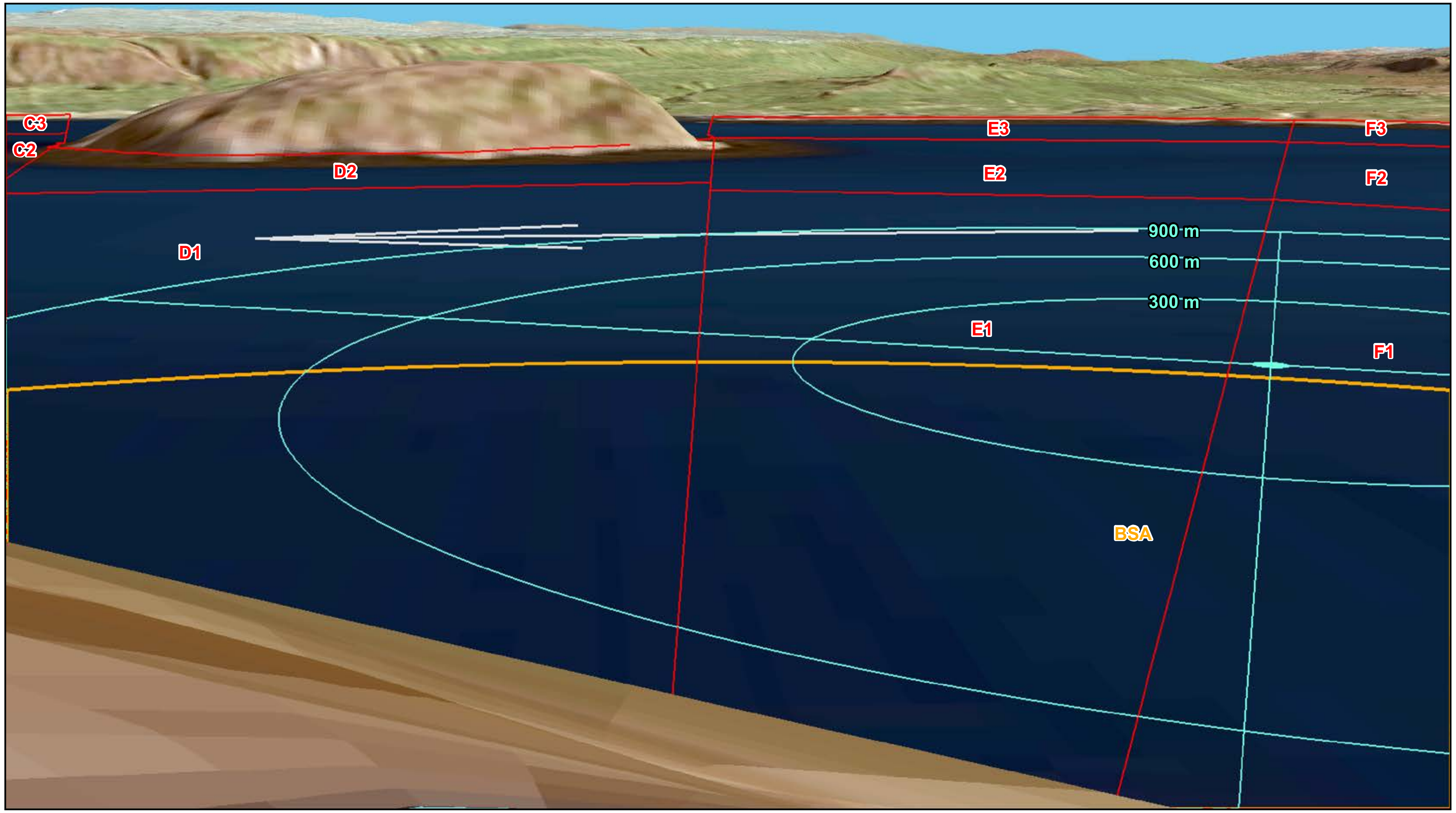
YYYY-MM-DD	2020-07-23
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

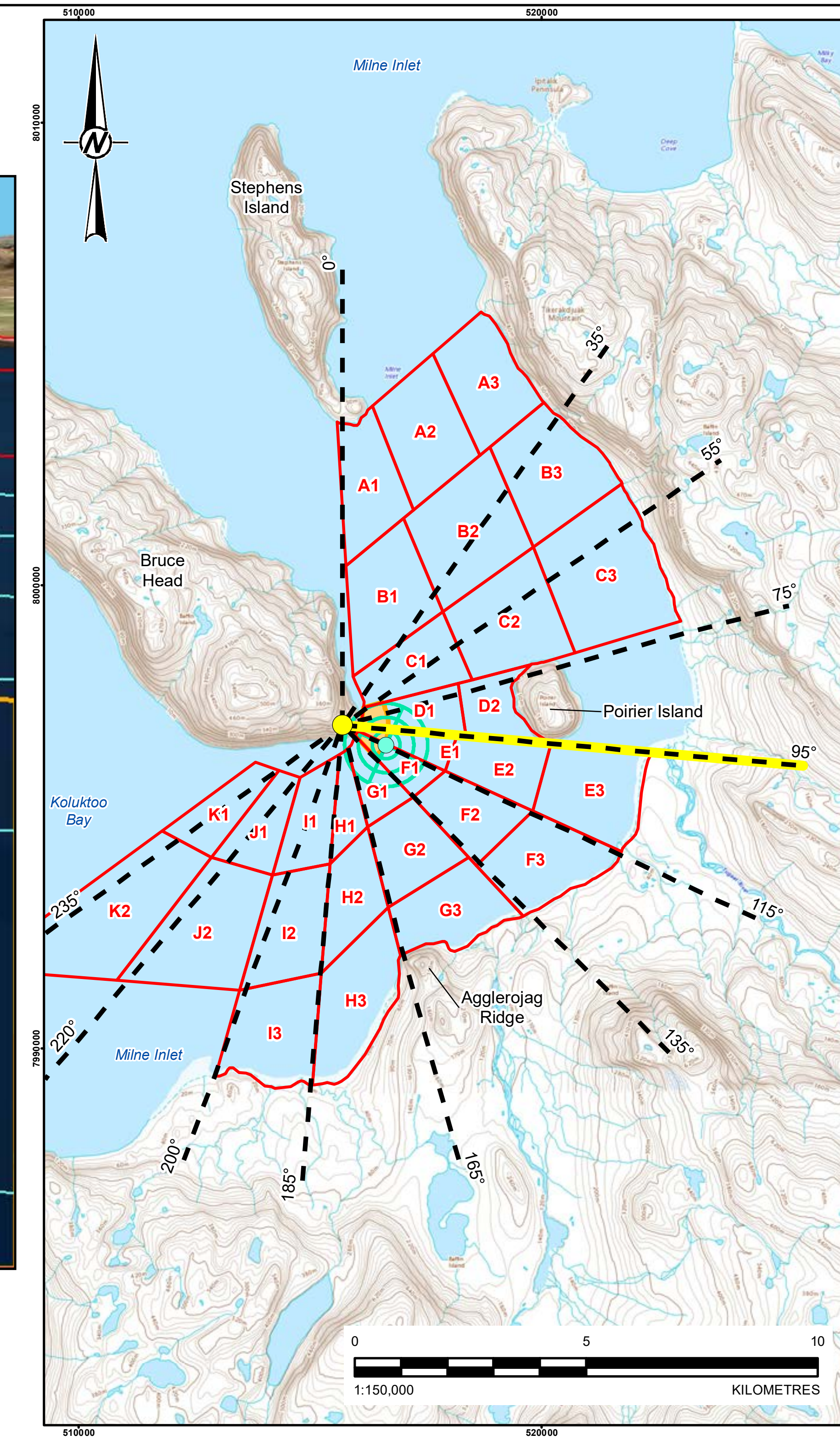
TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2020 - OBSERVATION PERSPECTIVE AT 75°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-01	A	B-4

25mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

PATH: I:\2016\1663724\Mapping\MXD\33000_UAV_Program\20200723_Perspectives_BSA_with_BSA_and_AMAR\1663724_33000_FigB04_2020BruceHead_75Deg_RevA.mxd PRINTED ON: 2020-07-23 AT: 12:13:34 PM





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- ACOUSTIC DETECTION RADII
- BEHAVIOURAL STUDY AREA (BSA)
- SUBSTRATA

DRAFT

REFERENCE(S)
SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

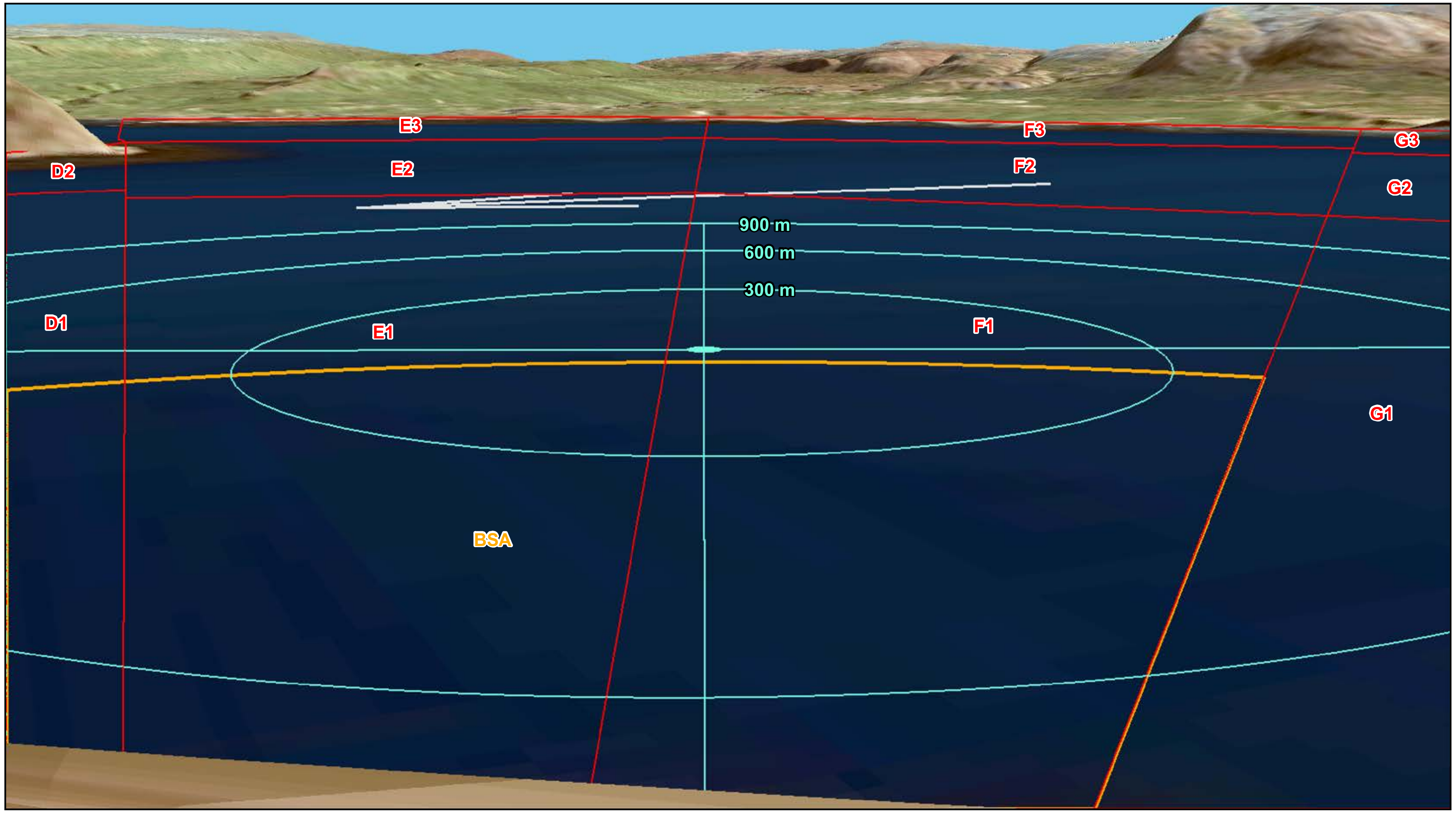
PROJECT
MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2020

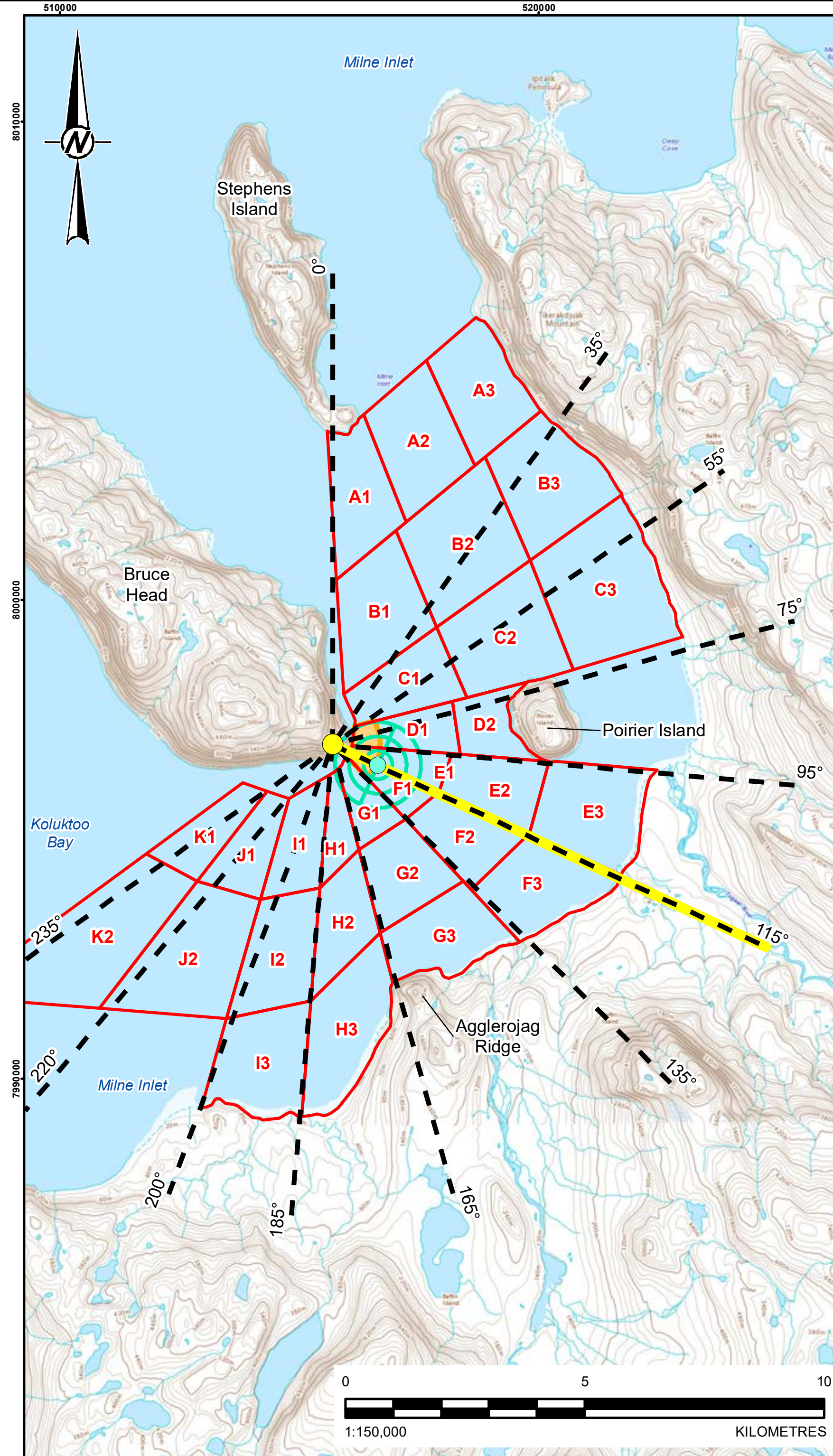
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-23
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2020 - OBSERVATION PERSPECTIVE AT 95°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-01	A	B-5





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- ACOUSTIC DETECTION RADII
- BEHAVIOURAL STUDY AREA (BSA)
- SUBSTRATA

DRAFT

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

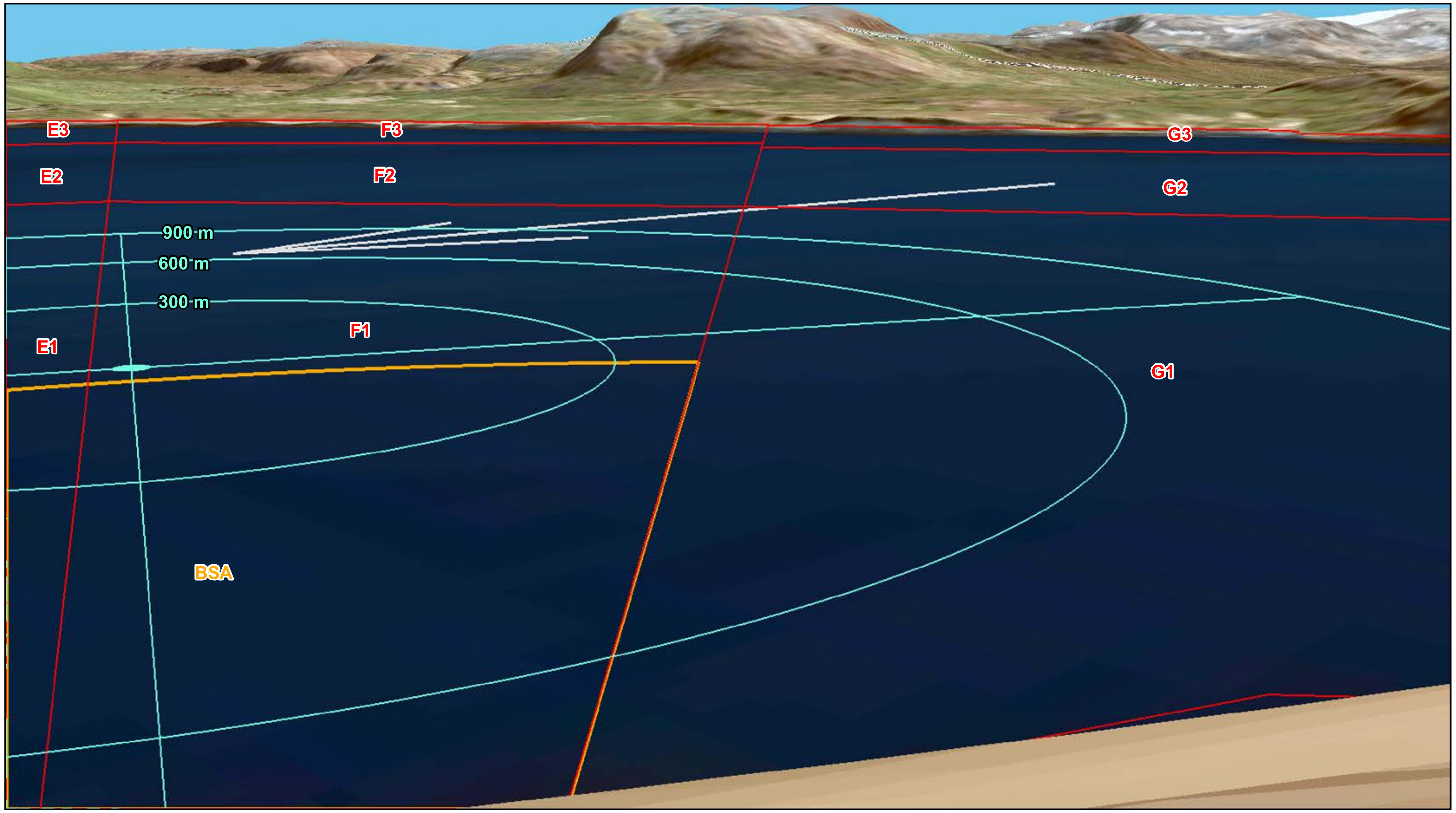
PROJECT
MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2020

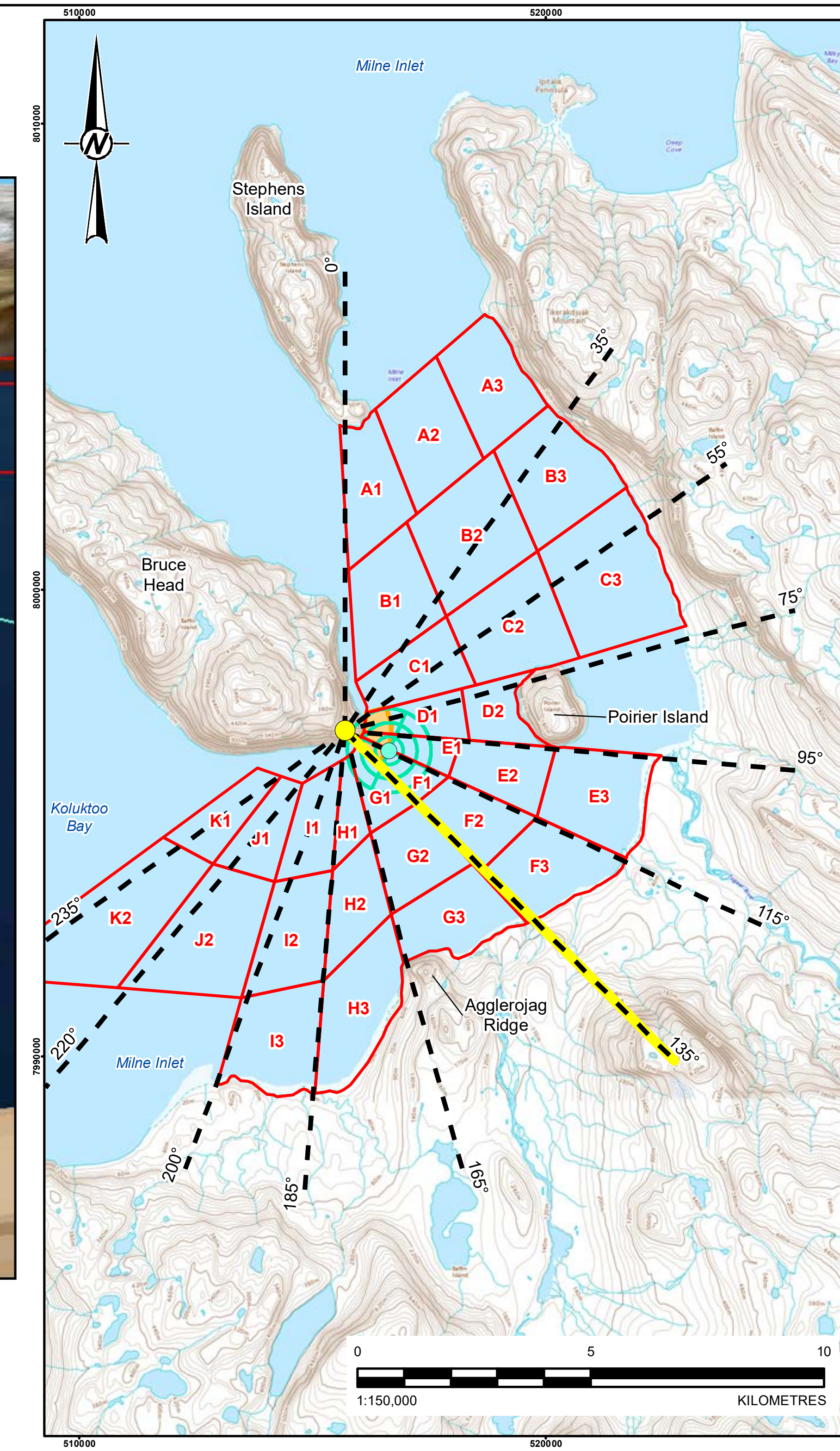
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-23
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2020 - OBSERVATION PERSPECTIVE AT 115°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-01	A	B-6





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- ACOUSTIC DETECTION RADII
- BEHAVIOURAL STUDY AREA (BSA)
- SUBSTRATA

DRAFT

REFERENCE(S)
SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

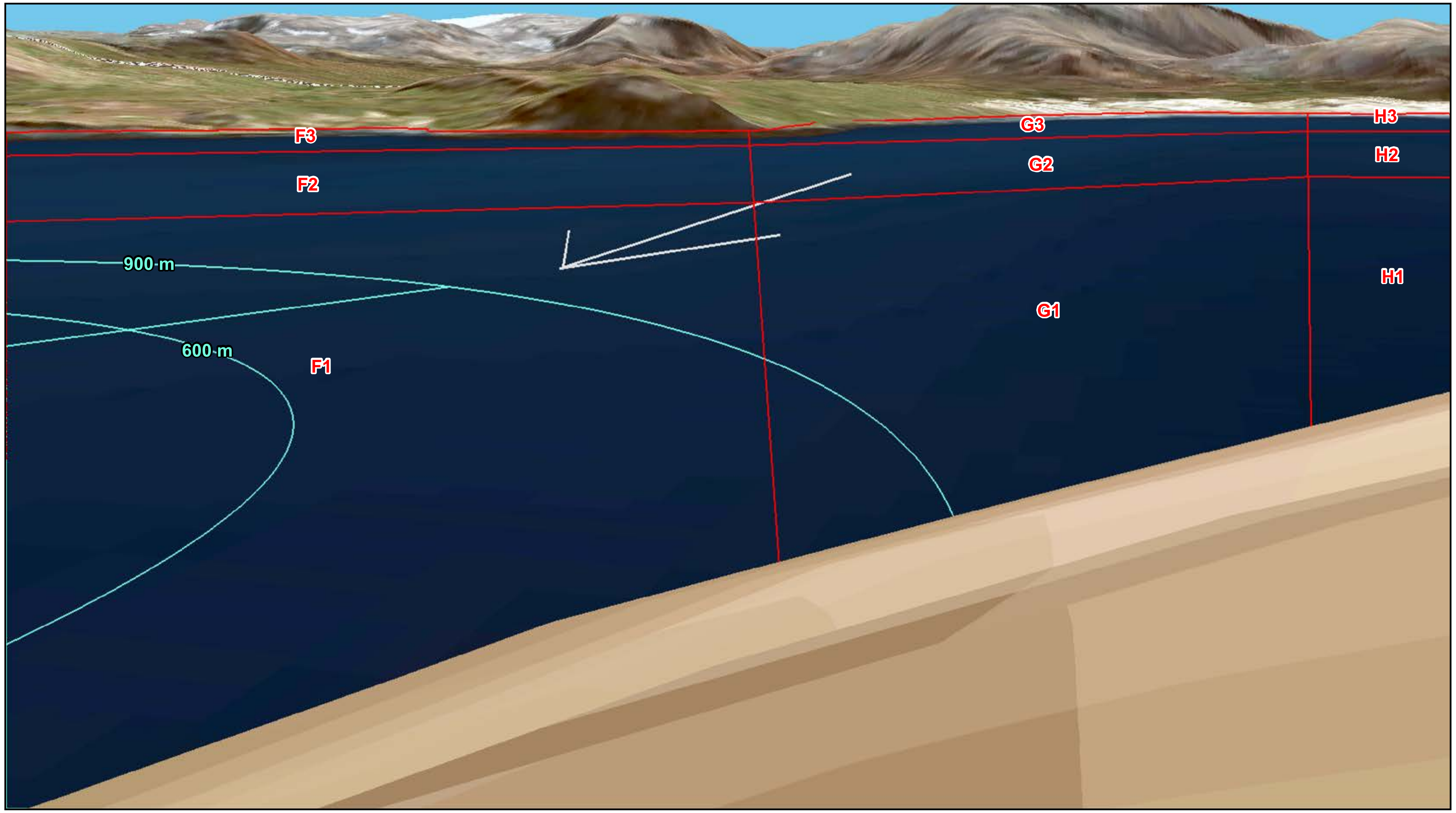
PROJECT
MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2020

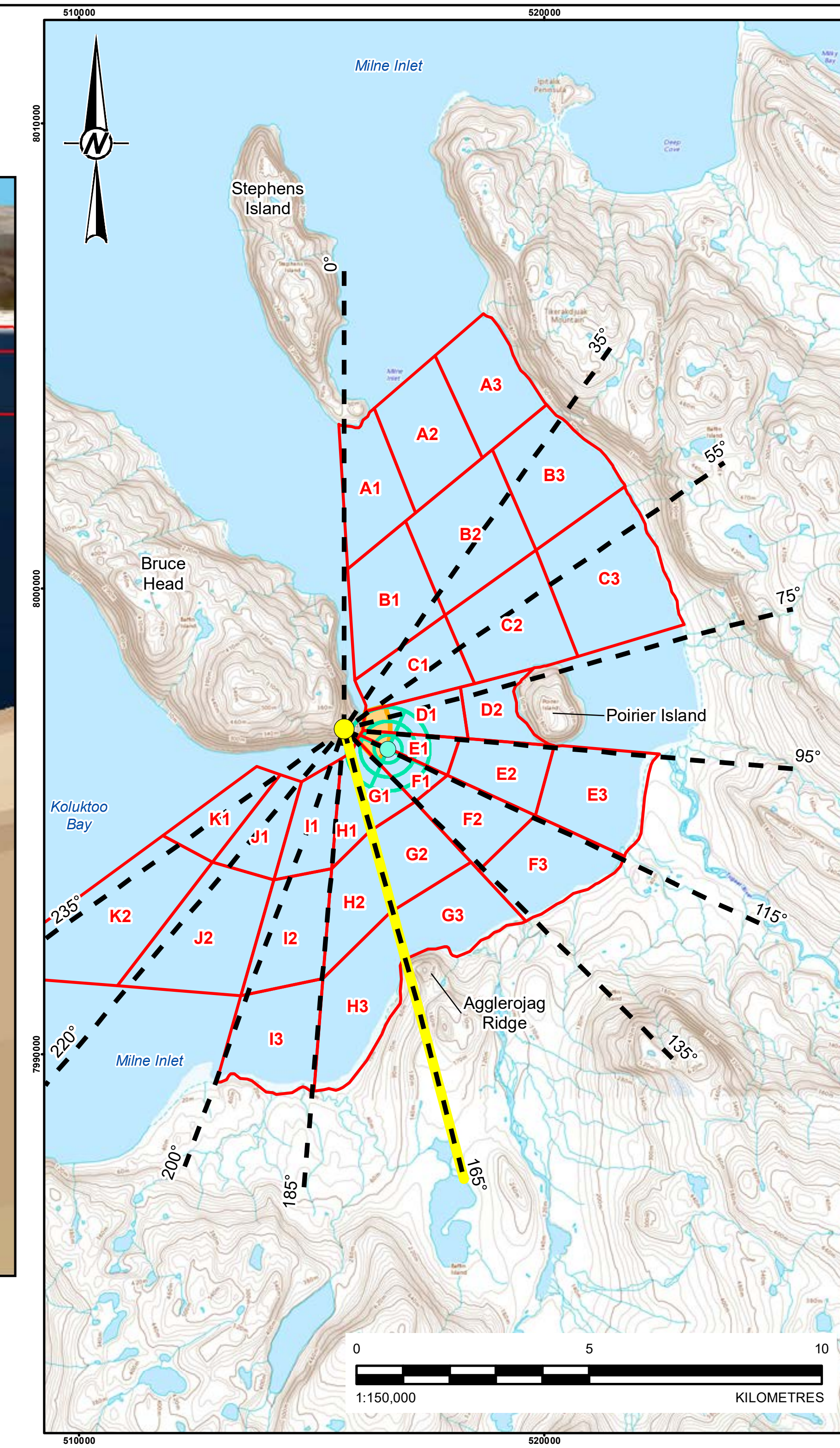
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-23
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2020 - OBSERVATION PERSPECTIVE AT 135°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-01	A	B-7





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- ACOUSTIC DETECTION RADII
- BEHAVIOURAL STUDY AREA (BSA)
- SUBSTRATA

DRAFT

REFERENCE(S)
SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

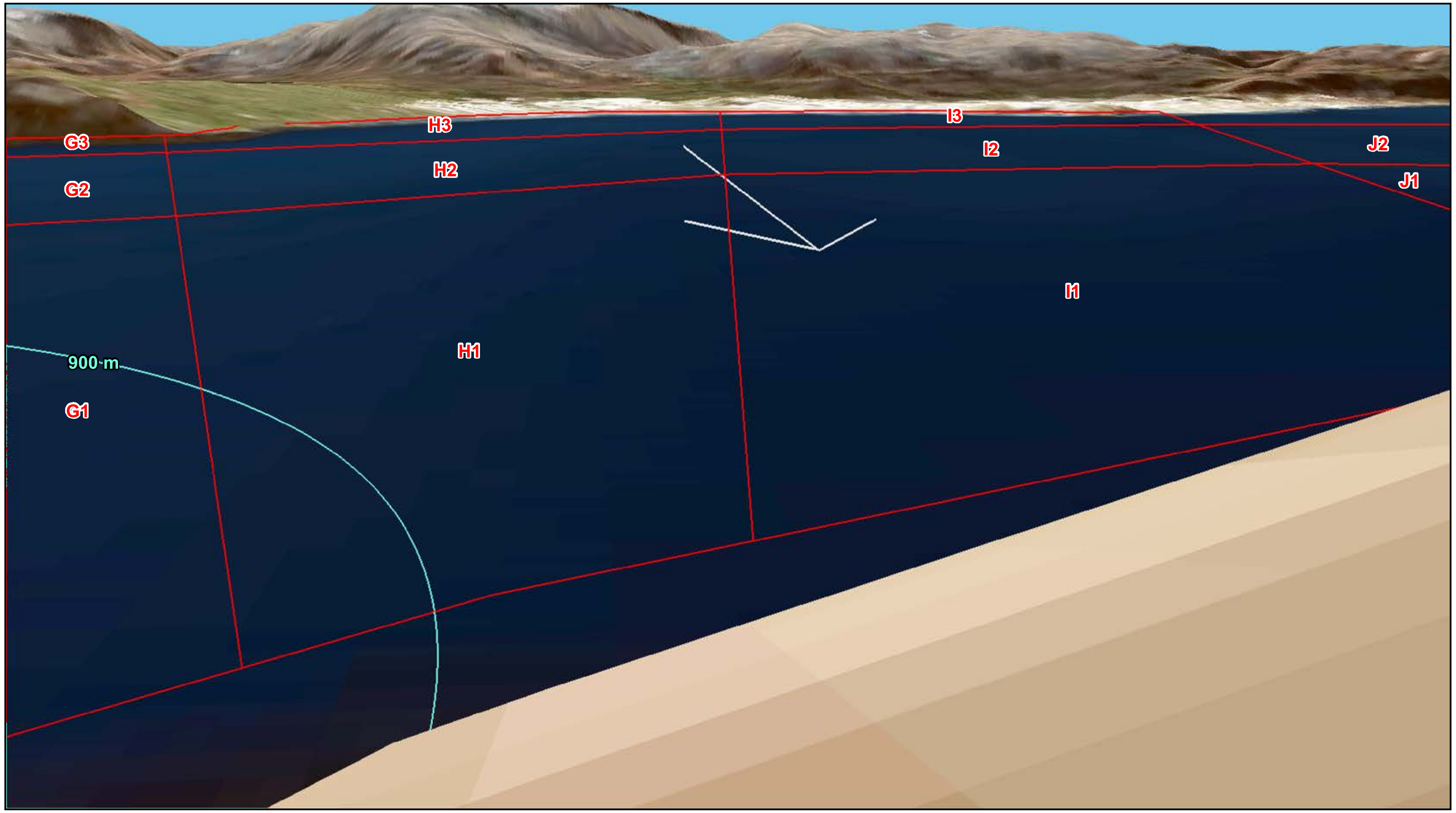
PROJECT
MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2020

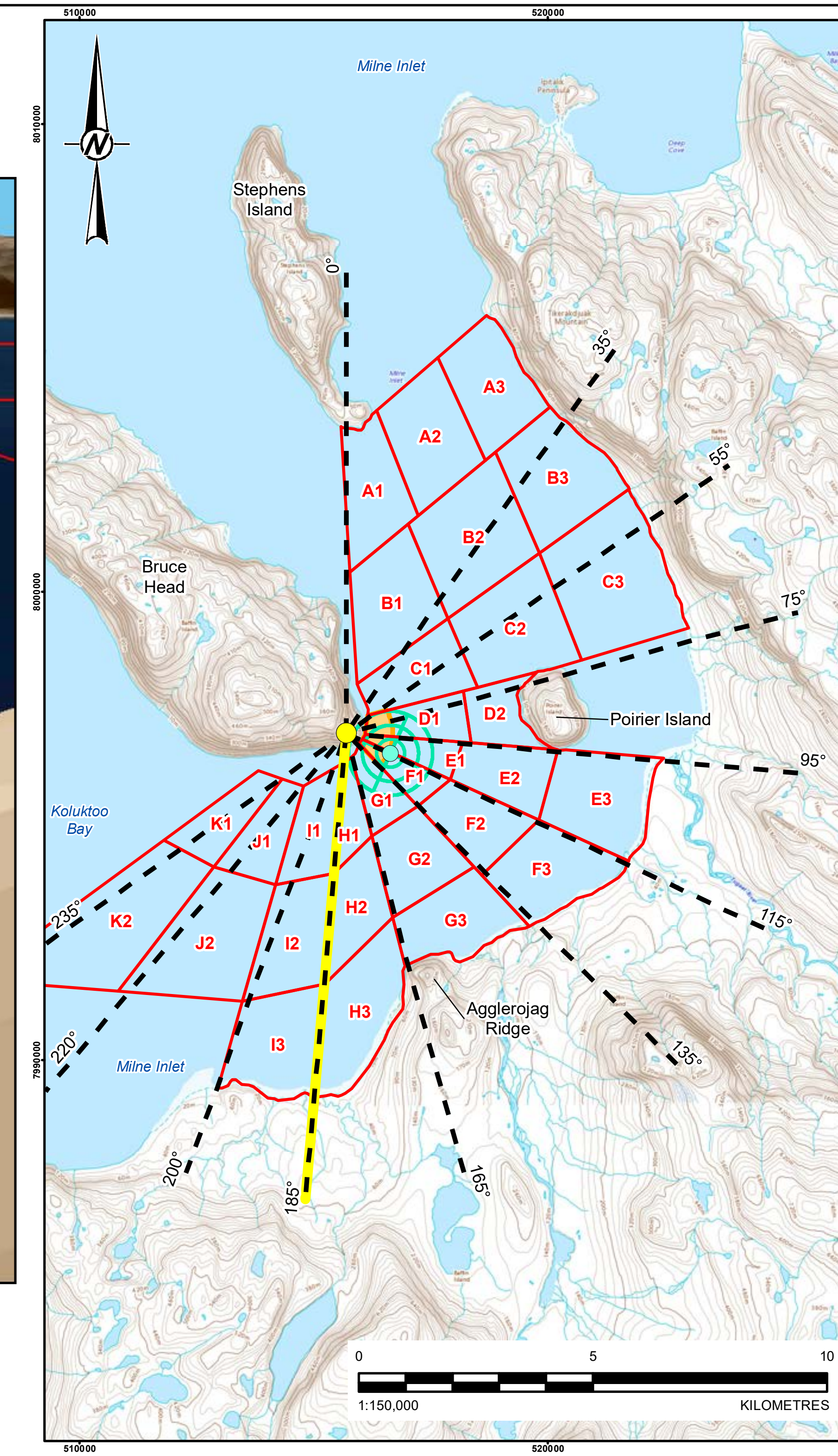
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-23
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2020 - OBSERVATION PERSPECTIVE AT 165°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-01	A	B-8





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- ACOUSTIC DETECTION RADII
- BEHAVIOURAL STUDY AREA (BSA)
- SUBSTRATA

DRAFT

REFERENCE(S)
SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

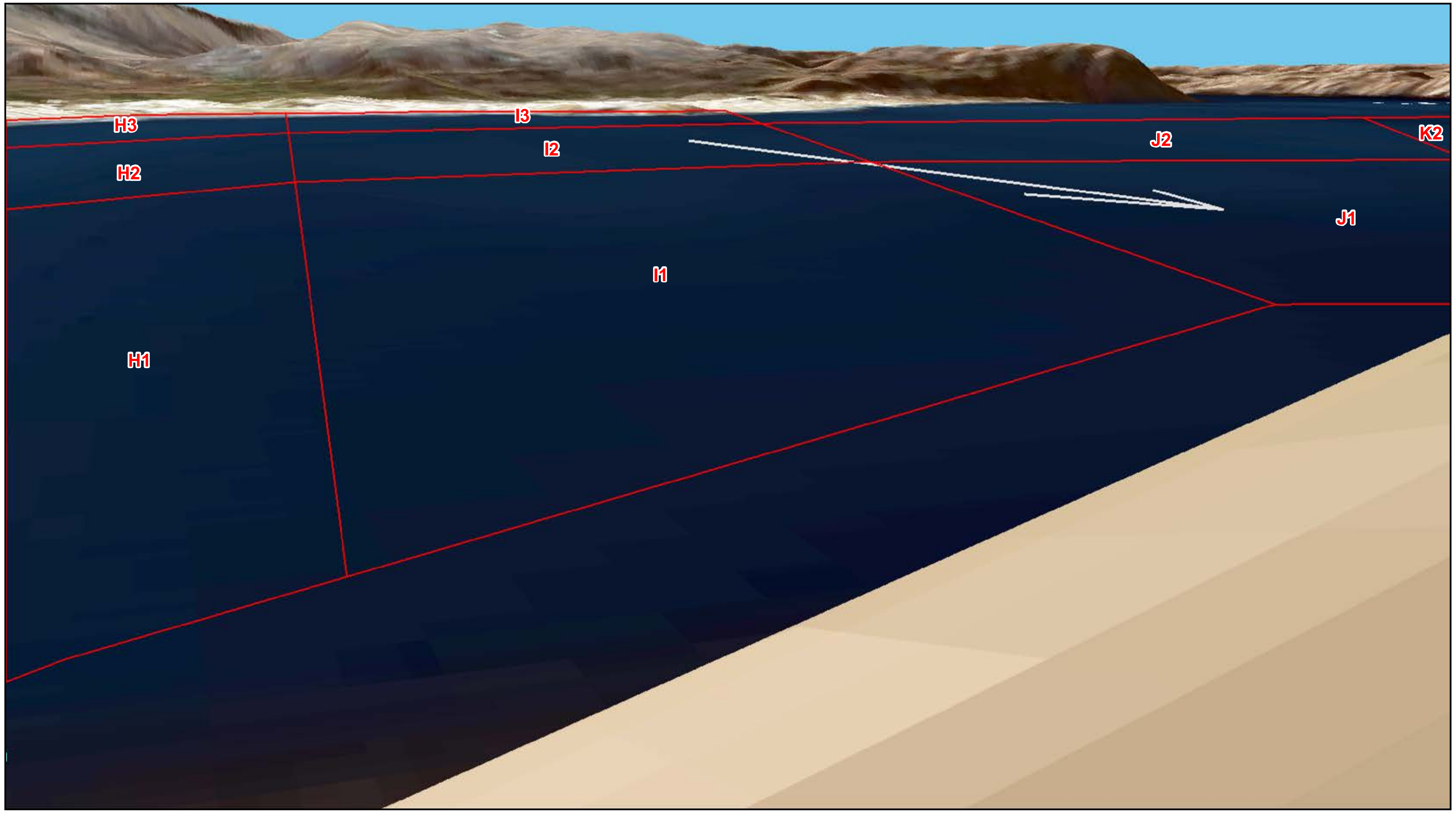
PROJECT
MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2020

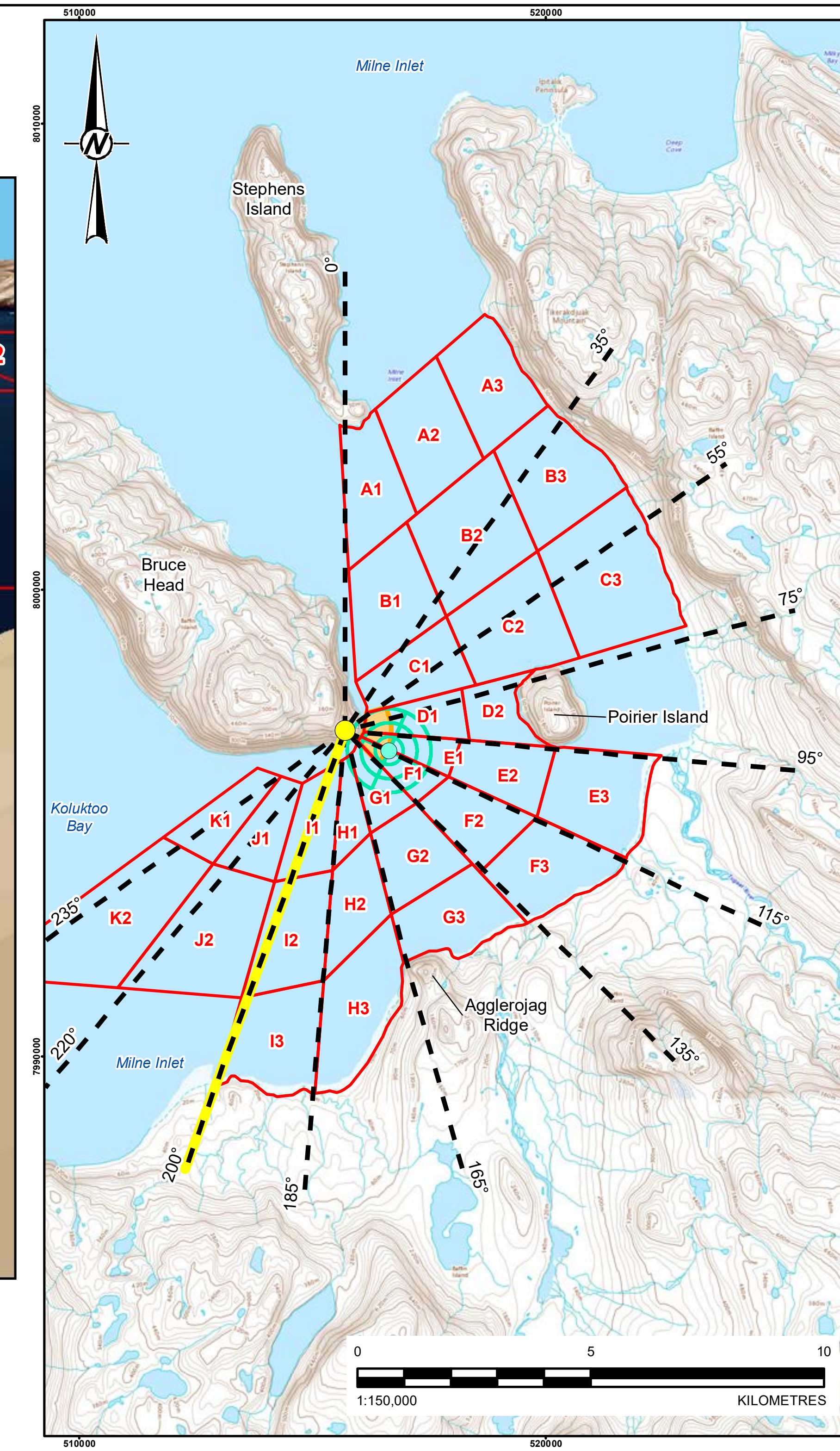
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-23
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2020 - OBSERVATION PERSPECTIVE AT 185°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-01	A	B-9





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- ACOUSTIC DETECTION RADII
- BEHAVIOURAL STUDY AREA (BSA)
- SUBSTRATA

DRAFT

REFERENCE(S)
SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT	PROJECT
BAFFINLAND IRON MINES CORPORATION	MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2020

CONSULTANT

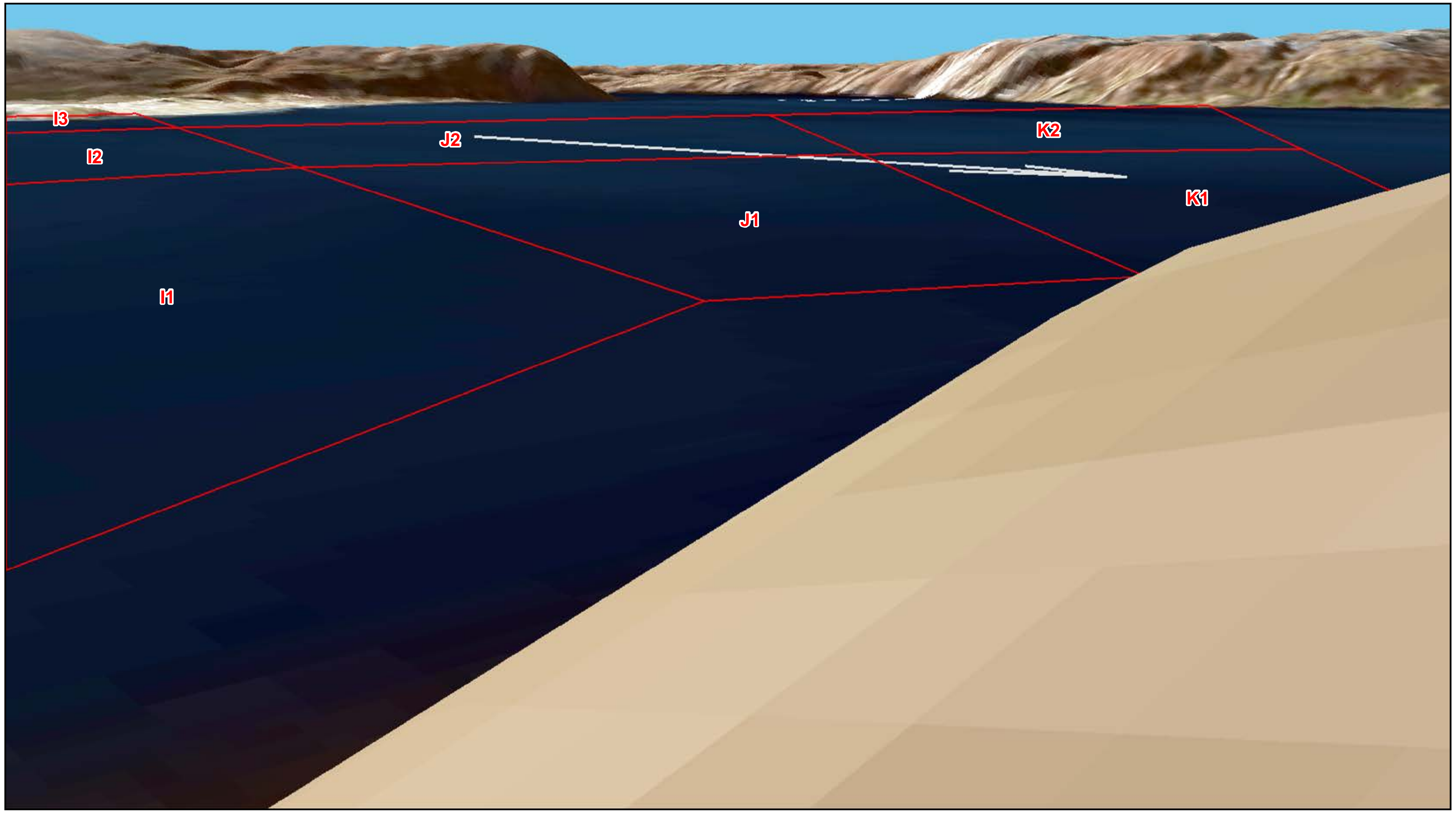
GOLDER

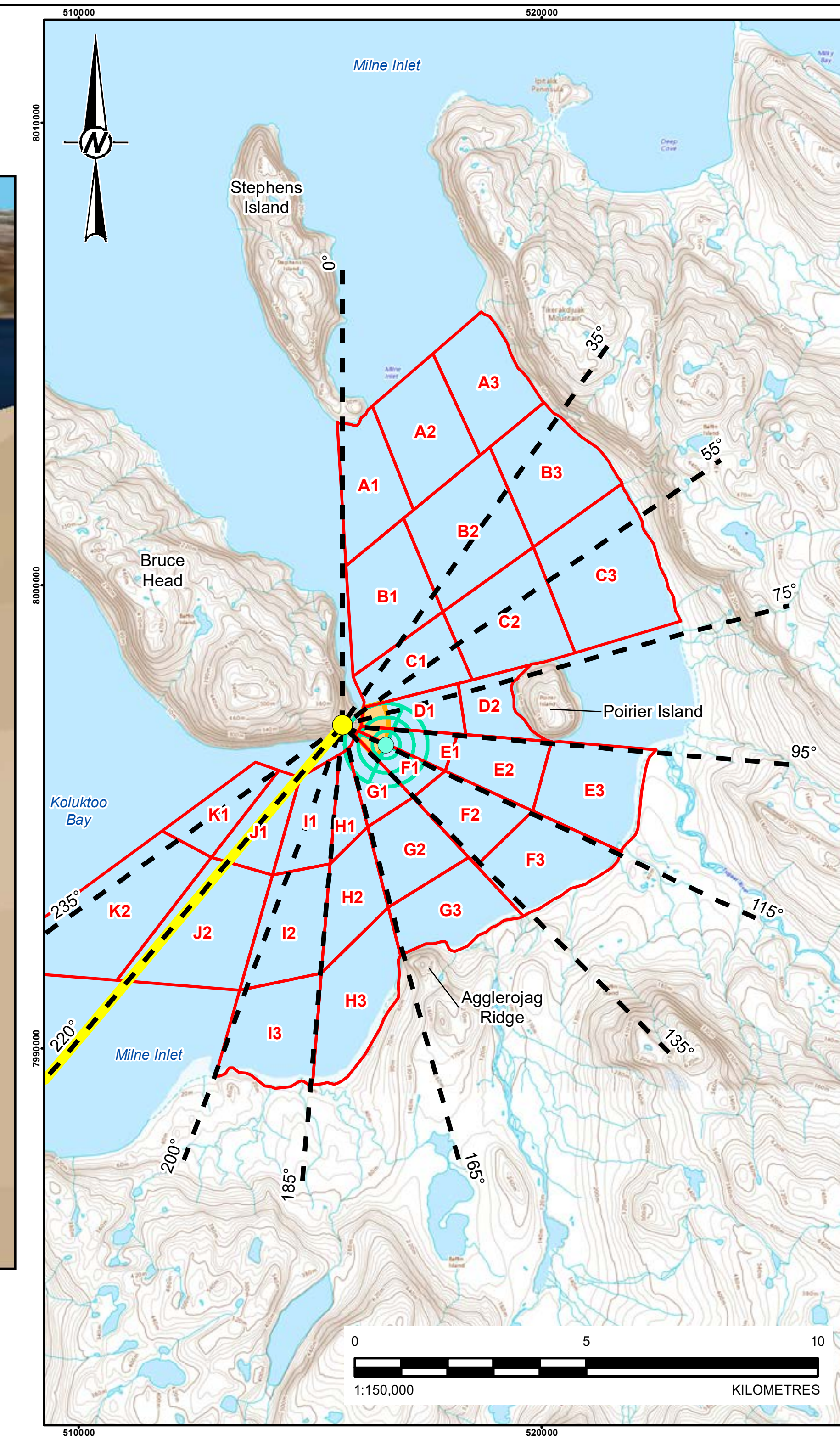
YYYY-MM-DD	2020-07-23
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2020 - OBSERVATION PERSPECTIVE AT 200°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-01	A	B-10

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





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- ACOUSTIC DETECTION RADII
- BEHAVIOURAL STUDY AREA (BSA)
- SUBSTRATA

DRAFT

REFERENCE(S)
SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

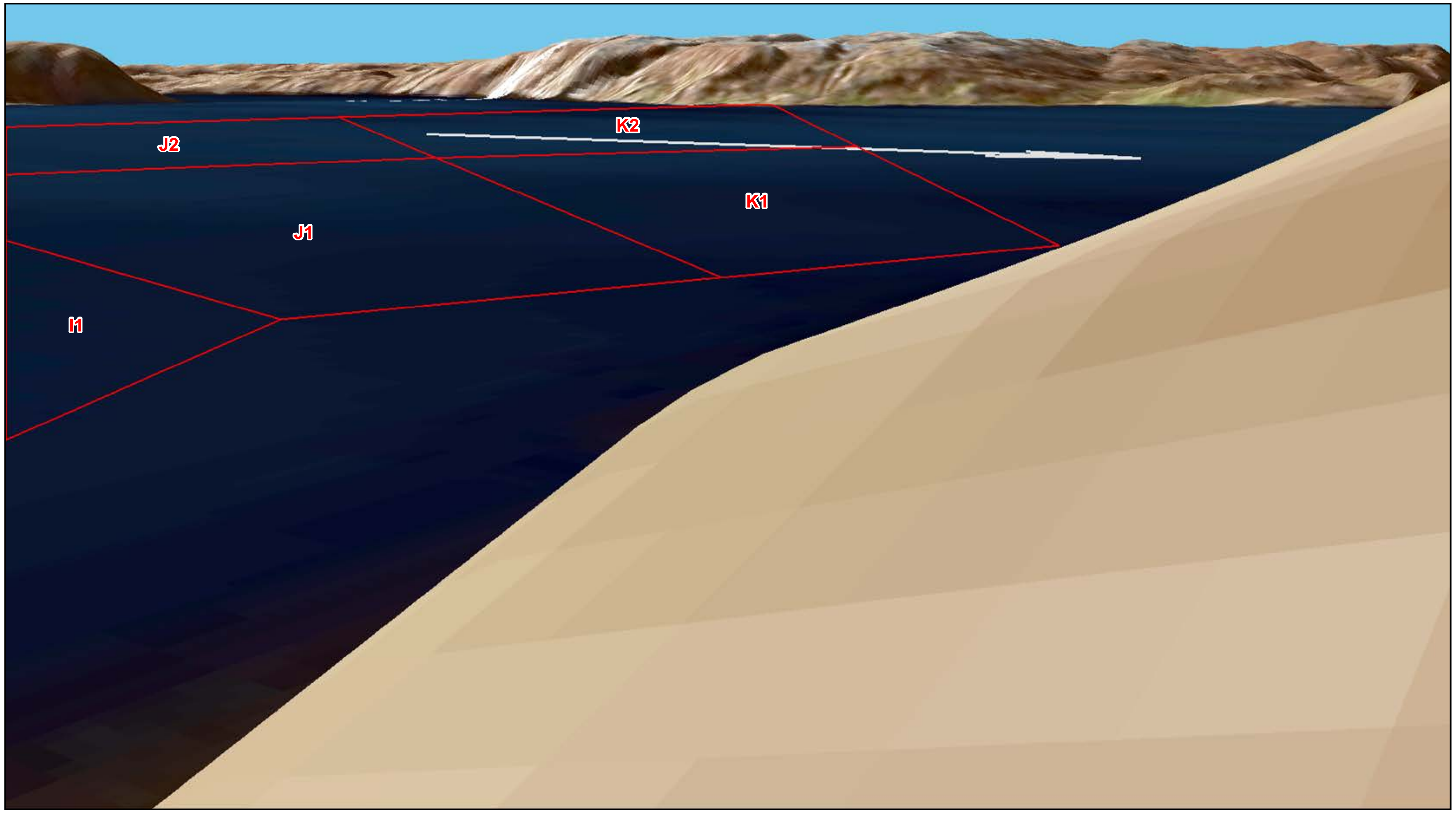
PROJECT
MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2020

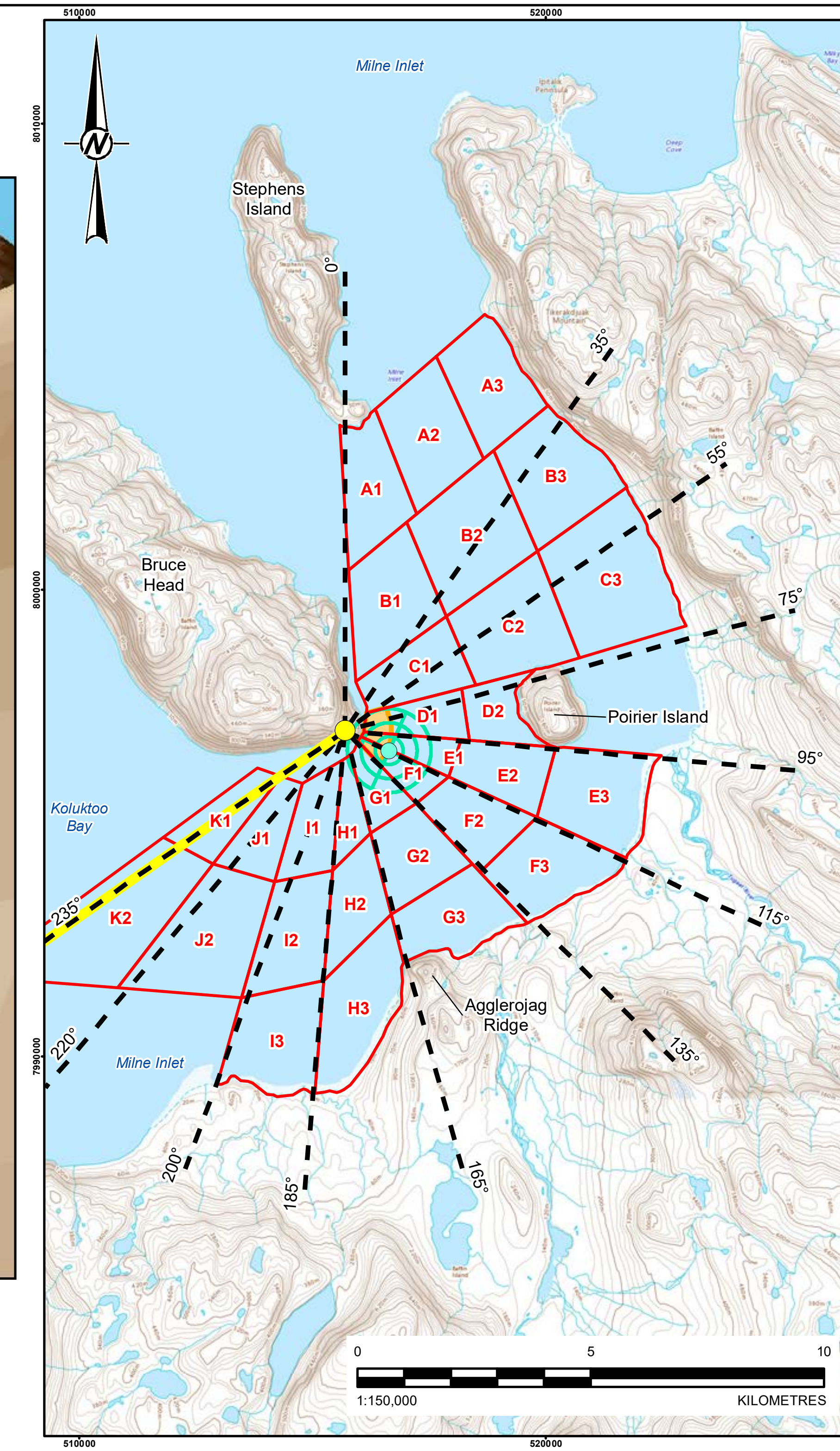
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-23
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2020 - OBSERVATION PERSPECTIVE AT 220°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-01	A	B-11





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- ACOUSTIC DETECTION RADII
- BEHAVIOURAL STUDY AREA (BSA)
- SUBSTRATA

DRAFT

REFERENCE(S)
SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS 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 PROGRAM 2020

CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-23
DESIGNED	AA
PREPARED	AJA
REVIEWED	
APPROVED	

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2020 - OBSERVATION PERSPECTIVE AT 235°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000-01	A	B-12

APPENDIX C

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

APPENDIX D

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.

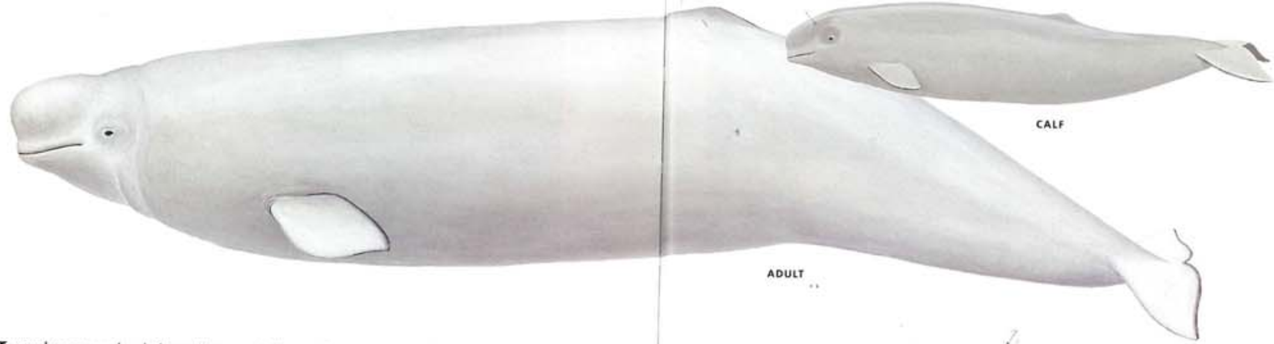
APPENDIX E

Marine Mammal Identification

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

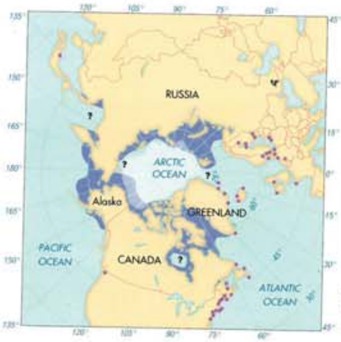


Known by some early whalers as "sea canaries" because of their loquacious natures, these whales are abundant and widespread in the Arctic and Subarctic. For many centuries, Belugas, also known as White Whales, have been a staple of arctic societies, providing food, fuel oil, and even soft durable leather. 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



- RANGE
- ? POSSIBLE RANGE
- EXTRALIMITAL RECORDS

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

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.

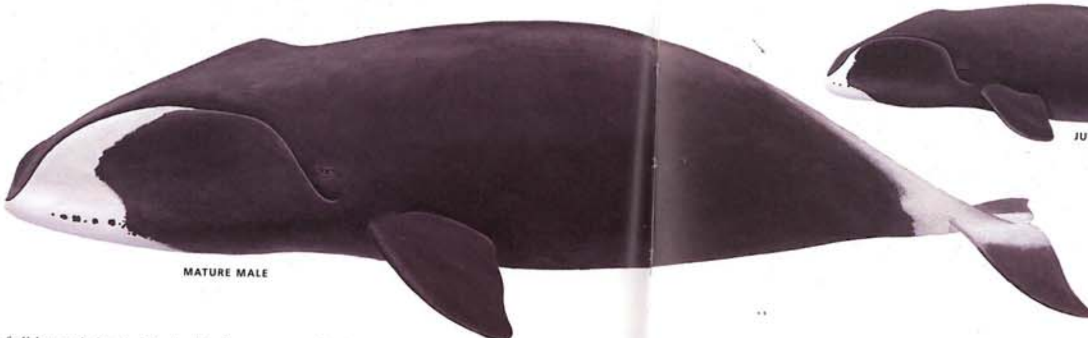
FOOD AND FORAGING The diets of Belugas vary according to regional and seasonal prey availability. Stomach contents of individuals from various regions demonstrate that the species' overall diet includes a great variety of organisms: fish (from salmon to arctic cod to herring and capelin), cephalopods (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


MATURE MALE


JUVENILE

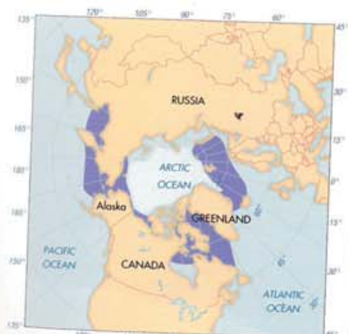
Of all large whales, the Bowhead is the most adapted to life in cold water, with a layer of blubber up to 1½ feet (50 cm) thick and a huge head that it uses to break through thick ice. Closely associated with sea ice through much of the year, the Bowhead Whale is found throughout arctic and subarctic 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 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.

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.*

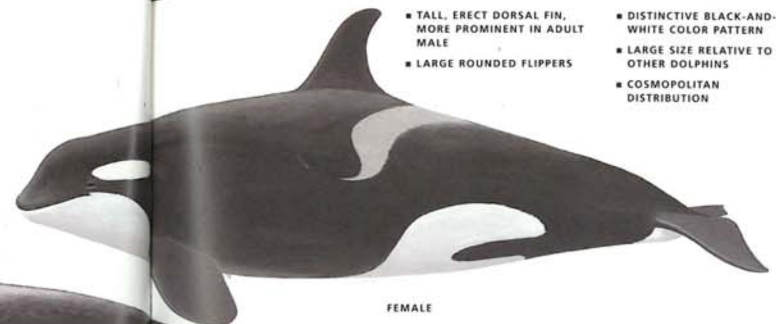
FOOD AND FORAGING Like right whales, Bowhead Whales are skim feeders; however, their diet is much more varied. Their primary prey are copepods and krill, and they also eat a wide variety of other invertebrates. More than 60 prey species have been identified in the stomachs of Bowheads killed by the Inuit 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 spikelike 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.*

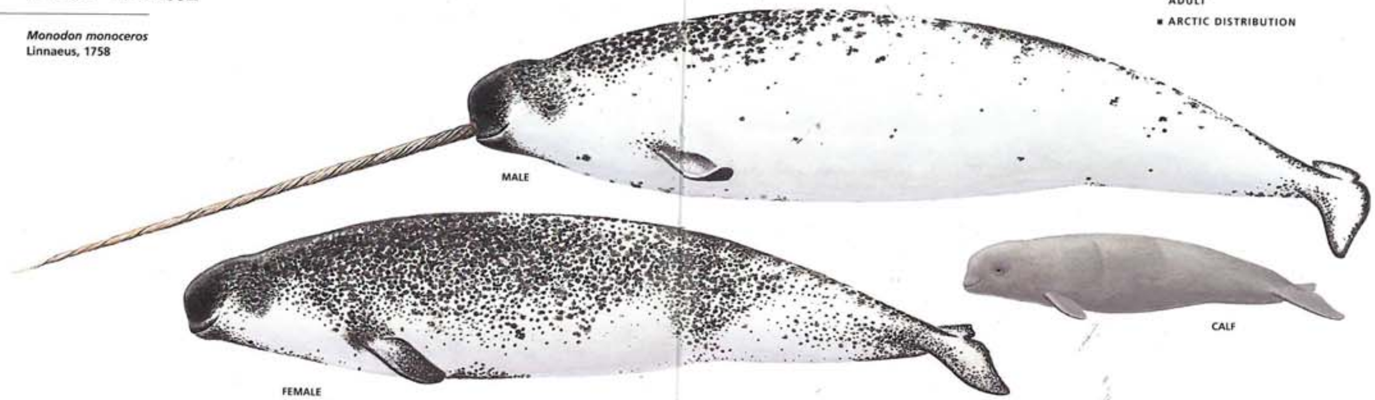
FOOD AND FORAGING Killer Whales eat a diet ranging from small schooling fish and squid to large baleen and sperm whales. Their prey items include sea turtles, otters, sirenians, sharks, rays, and even deer or moose, which they catch swimming across channels. Pods tend to specialize. For example, some 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 long-lines, 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)

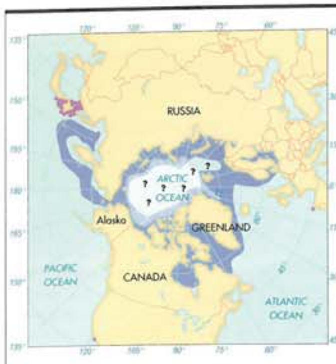
- DARK DORSAL PELAGE WITH SCATTERED, IRREGULAR LIGHT RINGS AND DARK BACKGROUND
- SMALLEST TRUE SEAL NEXT TO BAIKAL SEAL
- EXCAVATES BIRTH LAIRS BENEATH ICE SURFACE
- DISTRIBUTION CLOSELY ASSOCIATED WITH LANDFAST AND PACK ICE
- WIDELY DISPERSED IN ARCTIC BASIN AND BERING, OKHOTSK, JAPAN, AND BALTIC SEAS

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.*

APPENDIX B

Power Analysis

POWER ANALYSIS - METHODS

A Type I error is concluding there is a significant effect when none exists (i.e., a false positive). Alpha (α) is the probability of committing a Type I error. A Type II error is the probability of concluding there is no significant effect when there is a real effect of some specified magnitude (i.e., a false negative). Beta (β) is the probability of committing a Type II error. Effect sizes are the magnitude of the change or difference in the response variables, which in this report were the metrics of diving behaviour of narwhal. The power of a statistical test (1 - β) is the probability of detecting a real effect. The power of a statistical test depends on the alpha level, the effect size, the sample size, and the variability in the data. In this analysis, the Type I error-rate (α), also referred to as the significance level, was set to 0.05. The desired minimum statistical power was 80%, which corresponds to a Type II error-rate of 0.2.

Power analyses were conducted to assess the power of statistical tests of the effect of vessel traffic on each of the analyzed response variables for relative abundance and narwhal behaviour data across a range of effect sizes, assuming the same sample size and variability as the observed data. For each model, a range of effect sizes were created. The power of detecting either an increase or a decrease in each response variable was assessed by using both negative and positive effect sizes. The results show the range of effect sizes (e.g., -50% to +50% change, depending on the response variable variable) that are required for the study to detect statistically significant effects of vessel traffic.

Data Simulation following Effect Size Application

The power to detect statistically significant effects was estimated using residual bootstrapping in R v. 4.0.2 (R 2020), following the approach of Fox and Weisberg (2018). The general approach was to simulate data based on the model selected for interpretation, the observed sample size, and the residuals, and re-run the models that were used for the original analysis using the simulated data. The data simulation and analysis were repeated 1000 times for group behaviour and composition and 200 times for RAD models (due to the more intensive computing time). The proportion of repetitions where the *P*-values of interest were significant ($P<0.05$) was interpreted as the statistical power of the test.

To produce simulated data, the original model was used to predict values of the response variable. The predicted values were then adjusted according to the effect size, depending on the analysis (see below for details). The simulated data were then analyzed using the same model structure as the original analysis. Effect sizes and statistical tests were applied differently to different models and datasets, as detailed below.

Effects of a Distance from a Vessel

In the analysis of the effect of distance from a vessel (either a single vessel or the nearest vessel if multiple vessels were present within 7 km), the effect size was calculated as percent reduction or increase relative to data when no vessels were present within 7 km of the narwhal. Where effects of directional distance were modeled as a fourth-degree polynomial, the effect was only applied up to 5 km, and narwhal at >5 km from a vessel were simulated to have no effect (while still modelled as being within the exposure zone, for consistency with the original models). This distance was selected based on the results of narwhal tagging, where the majority of statistically significant results in the analyses were obtained within 5 km of a vessel. It was imposed to respect the non-linearity of the estimated effect, whereas applying the effect up to 7 km (the full exposure zone) would result in a linear simulated effect, which would not represent the observed relationship. Where effects of directional distance were modeled as a second-degree polynomial, the effect was applied to the full 7 km extent. Overall, an increasing effect size resulted in a steeper trend, whereas a decreasing effect size resulted in a flatter trend, and an effect size of zero resulted in a flat line (Figure 1).

The simulated data were analyzed using the same model as the original analysis described in the main report, and the *P*-values for the effects of distance on each response variable were retained, which included both the main effect of distance from vessel and any interactions with distance from a vessel. If any of these *P*-values were less than 0.05, it was considered a significant overall effect of distance from a vessel. The proportion of repetitions with at least one *P*-value less than 0.05 was interpreted as the statistical power of the overall regression for that effect size.

Effect Sizes and Data Simulation in Models with a Numeric Response Variable

For models with a numeric response variable (i.e., group size and narwhal count in the RAD dataset), the effect size was applied to the incidence rate, i.e., to the exponentiated difference in predicted values between a case where a vessel was within 7 km from narwhal and a “reference” case (where no vessel was present within 7 km from narwhal) on log-scale, rather than to the predicted values themselves. Overall, an increasing effect size resulted in a steeper trend, whereas a decreasing effect size resulted in a flatter trend, and an effect size of zero resulted in a flat line. For each iteration of the simulation, the predictions on the log-scale were estimated. Then, a truncated Poisson (for group size) or a negative binomial (for RAD data) distribution was used to generate a random value using the predictions calculated above. The generation of a random value was done to create random variability in the simulated data. For cases within the dataset that did not have an effect size applied to them (i.e., cases with no vessels within 7 km and cases where vessels were present within 7 km, but farther than 5 km from the narwhal – if the model used a fourth-degree polynomial), predictions were still used to generate a random value, resulting in simulated data that differed from the originally collected data.

To produce simulated data for these models, the original dataset was duplicated, and in the duplicate dataset, all data were treated as reference (i.e., no vessels within 7 km from narwhal). The original model was used to predict response values for this duplicate dataset, creating a “reference” dataset of predictor values and predicted responses. The effect size was then applied to the predicted “reference” values. For all data cases that were “impact” cases in the original data, the predicted “reference” response was multiplied by the effect size, to produce a range of responses as the various effect sizes. For Poisson and negative binomial models, the effect size was applied to the incidence rates – that is, the exponentiated difference between the log-scale predictions of “reference” and “impact” cases.

The simulated data were then analyzed using the same model structure as the original analysis.

Effect Sizes and Data Simulation in Logistic Models

For models with a binary response variable (e.g., presence/absence of tusks or calves), the effect size was applied to the odds ratio, i.e., to the exponentiated difference in predicted values between a case where a vessel was within 7 km from narwhal and a “reference” case (where no vessel was present within 7 km from narwhal) on logit-scale, rather than to the predicted values themselves. Overall, an increasing effect size resulted in a steeper trend, whereas a decreasing effect size resulted in a flatter trend, and an effect size of zero resulted in a flat line.

However, due to the nonlinearity of probabilities, a negative and a positive effect size of the same magnitude may result in asymmetrical magnitudes of change on the probability scale (Figure 2). For each iteration of the simulation, the predictions on the logit scale were used to calculate the probability of the outcome. Then, a binomial distribution was used to generate a random value using the probability of the outcome calculated above. The generation of a random probability was done to create random variability in the simulated data. For cases within the dataset that did not have an effect size applied to them (i.e., cases with no vessels within 7 km and cases where vessels were present within 7 km, but farther than 5 km from the narwhal – if the model used a fourth-degree polynomial), predictions were still used to generate a random value, resulting in simulated data that differed from the originally collected data.

To produce simulated data for logistic models, the original dataset was duplicated, and in the duplicate dataset, all data were treated as reference (i.e., no vessels within 7 km from narwhal). The original model was used to predict response values for this duplicate dataset, creating a “reference” dataset of predictor values and predicted responses. The effect size was then applied to the predicted “reference” values. For all data cases that were “impact” cases in the original data, the predicted “reference” response was multiplied by the effect size, to produce a range of responses as the various effect sizes. For logistic models, the effect size was applied to the odds ratio – that is, the exponentiated difference between the logit-scale predictions of “reference” and “impact” cases.

Effect Sizes and Data Simulation in Models with a Second-Degree Polynomial Effect of Directional Distance

For models with a second-degree polynomial relationship between directional distance from vessel and the response variable, the effect size was applied to the full 7 km distance from vessel, so that the simulation did not create a nonlinearity in the effect before or after distance from vessel was 0 km. Multiple comparisons were performed as detailed above, comparing the effects of vessels at various distances from narwhal to cases when no vessels were presence.

Power Analysis – Reporting of Results

To summarize the results of the power analyses, power curves were produced. Power curves show statistical power, which is the probability of detecting a significant effect, as a function of effect size, which is shown as a percentage change of the response variable. Separate curves were produced for overall effects and for multiple comparisons (for effects of distance only). Horizontal lines were added to visualize statistical power values of 0.8 (hereafter sufficient power) and 0.9 (hereafter high power). A vertical line was added to visualize the magnitude of difference that was observed in the original data.

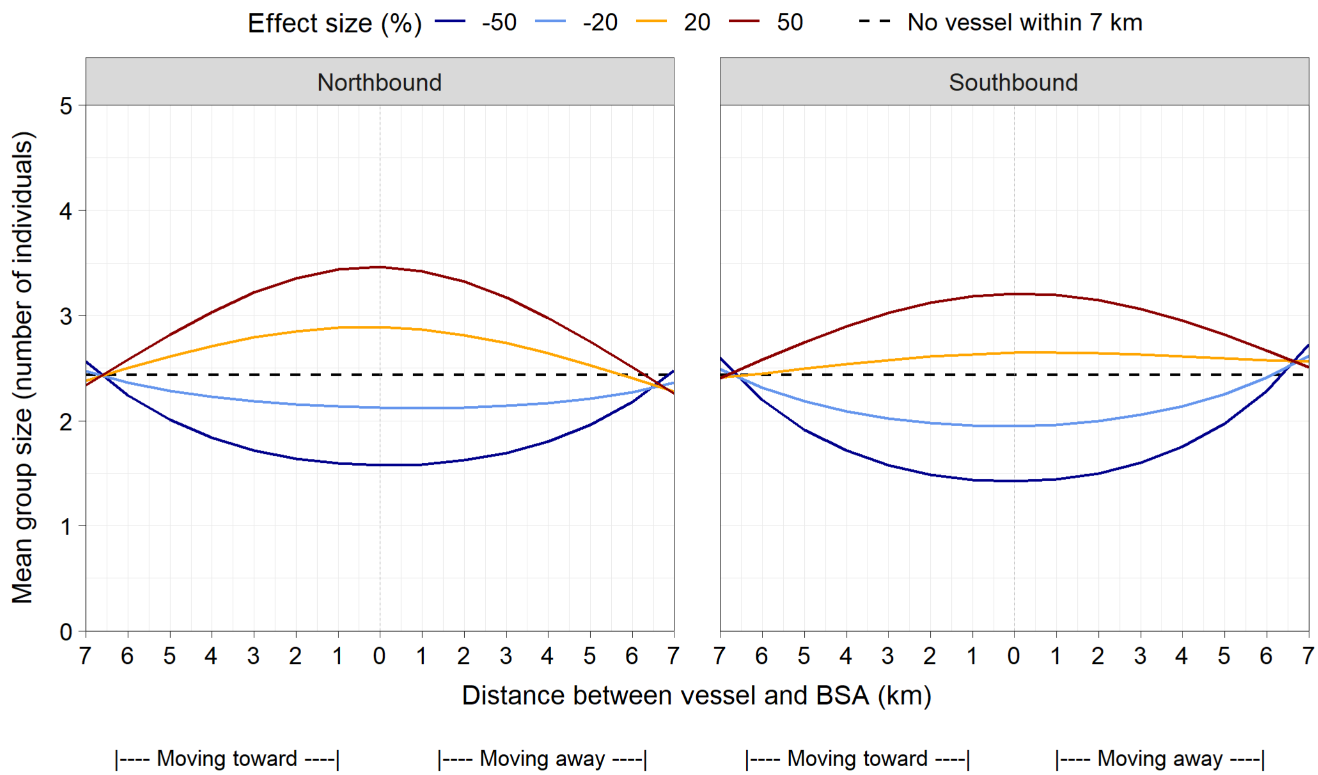


Figure 1: Application of effect sizes to a model with a numeric response variable (group size; effect applied to the full 7 km extent).

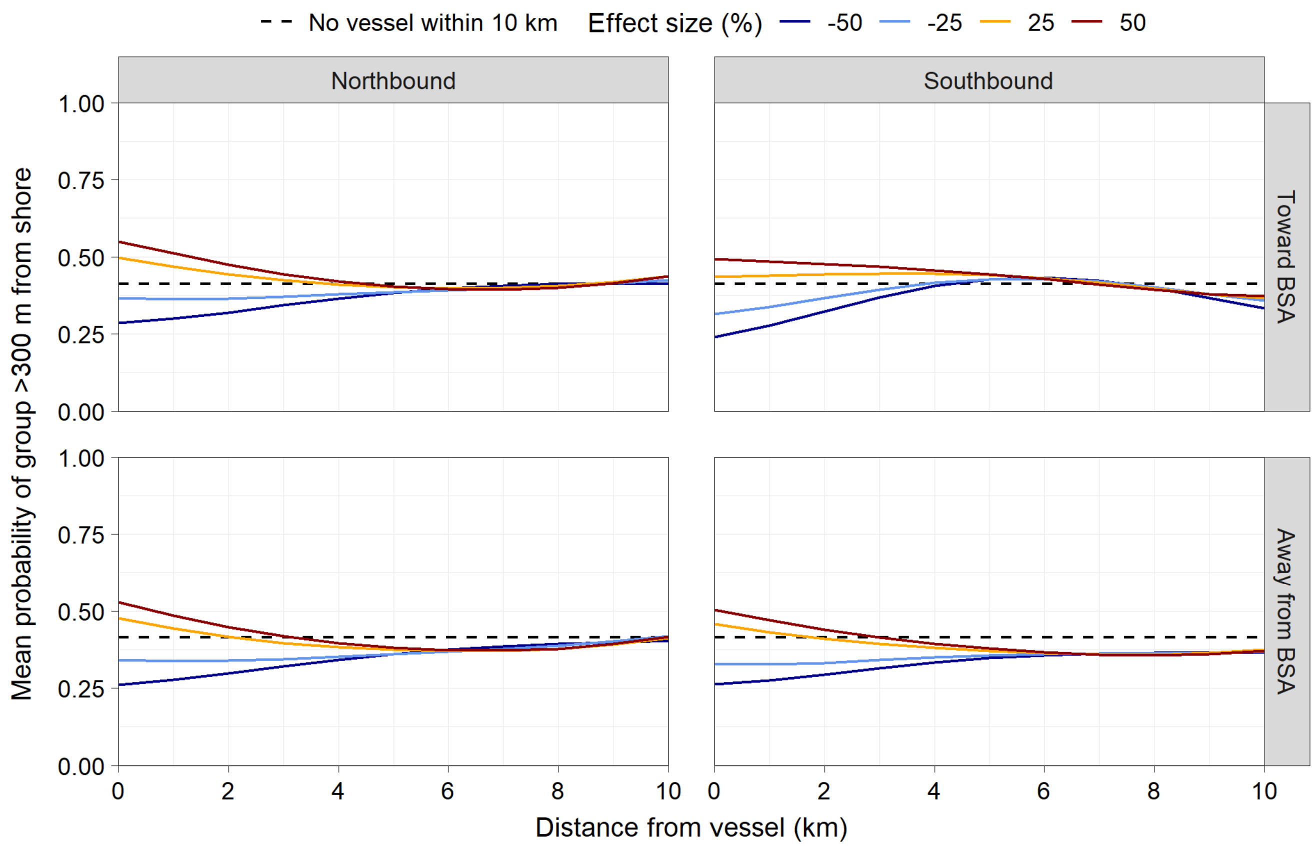


Figure 2: Application of effect sizes to a model with a binary response variable (group distance from shore)

POWER ANALYSIS – RESULTS

RAD

There was sufficient power (>0.8) to detect an effect of distance from vessel on relative abundance at effect sizes of approximately -65% or +85% (Figure 3). In comparison, observed effect sizes at a distance of 0 km from vessels were -29% (for a northbound vessel) and -41% (for a southbound vessel). Statistical power to estimate the observed effects was <0.4. That is, the analysis had sufficient power to detect effect sizes of -65% or +85%, and the original analysis found a significant effect of vessel distance on relative abundance, despite effect sizes at 0 km being less than those required for power of 0.8.

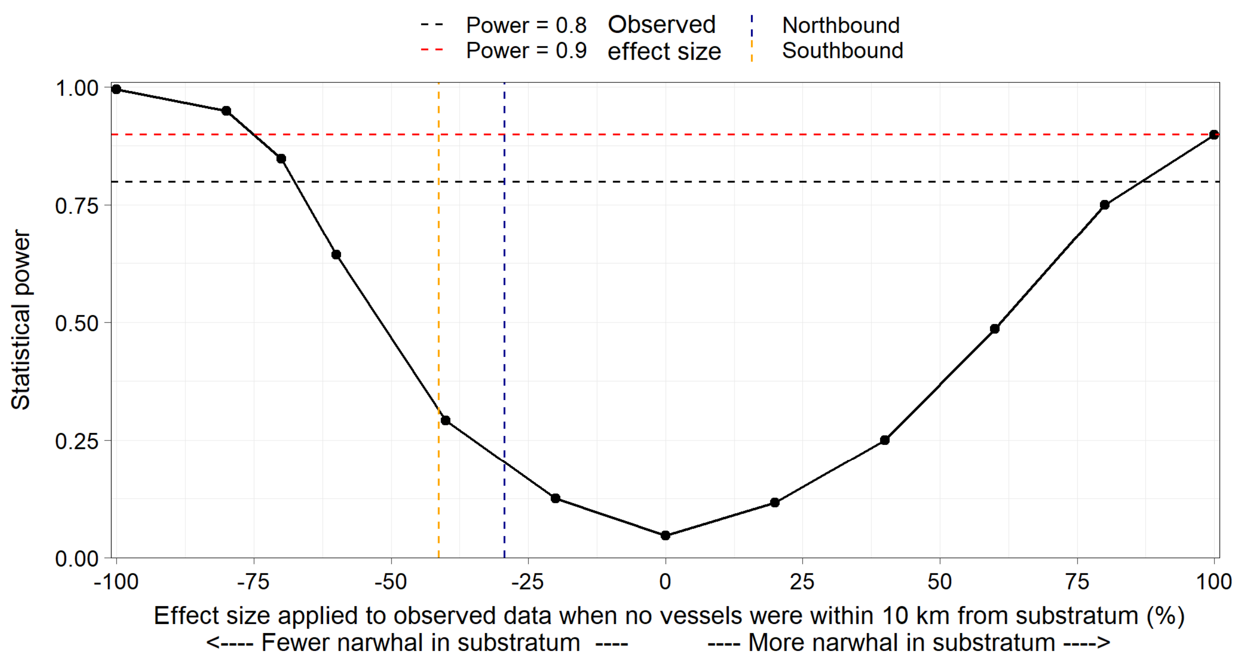


Figure 3: Statistical power of the overall model of RAD to detect a significant effect of distance from vessel, showing observed effect sizes for north- and southbound vessels.

Group size

There was sufficient power (>0.8) to detect an effect of directional distance from vessel on group size at effect sizes of approximately -57% or +95% (Figure 4). In comparison, observed effect sizes at a distance of 0 km from vessels were -4% (for a northbound vessel) and +15% (for a southbound vessel). Statistical power to estimate the observed effects was <0.2. That is, while the analysis only had sufficient power to detect effect sizes of -57% or +95%, the absolute magnitude of observed effect sizes was small. Due to the small effect size, the original analysis did not find a significant effect of vessel distance on group size (Section 6.4.1 in main report).

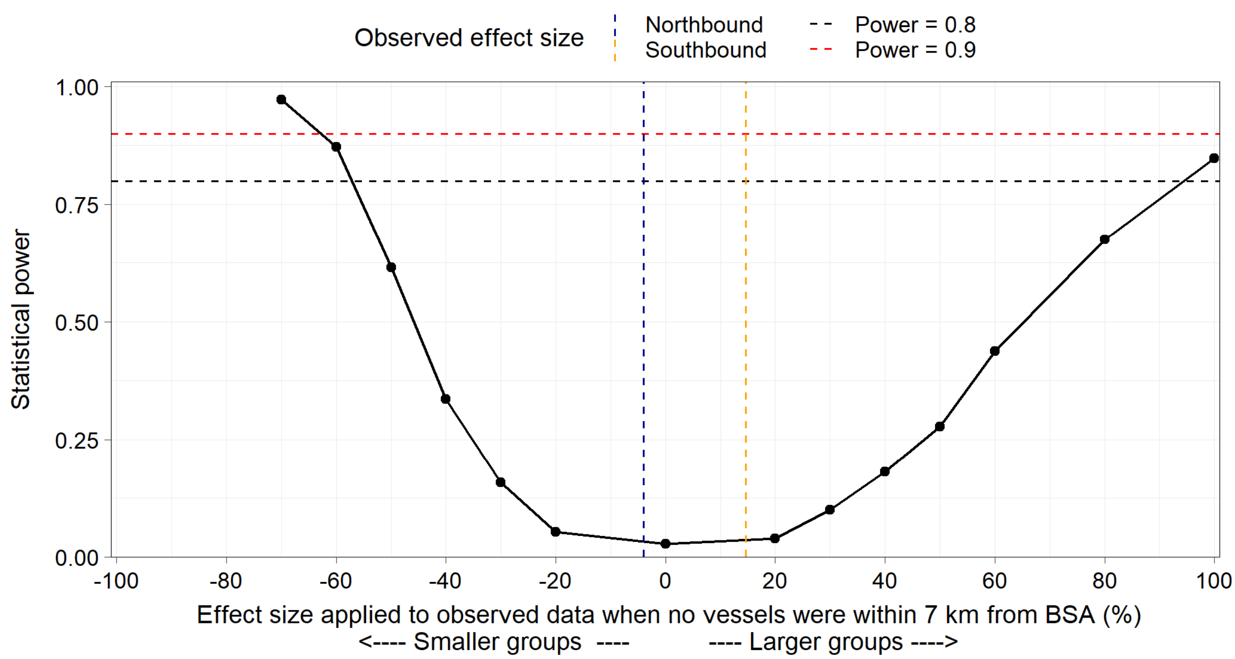


Figure 4: Statistical power of the overall model of group size to detect a significant effect of distance from vessel, showing observed effect sizes for north- and southbound vessels.

Group Composition – Presence of Calves or Yearlings

There was sufficient power (>0.8) to detect an effect of directional distance from vessel on presence of calves or yearlings within observed groups at effect sizes of approximately -80% or +350% (Figure 5). In comparison, observed effect sizes were +21% (for a northbound vessel) and +45% (for a southbound vessel). Statistical power to estimate the observed effects was low. Since observed effect sizes were below the effect size required to achieve sufficient statistical power, the original analysis did not find a significant effect of vessel distance (Section 6.4.2.1 in main report).

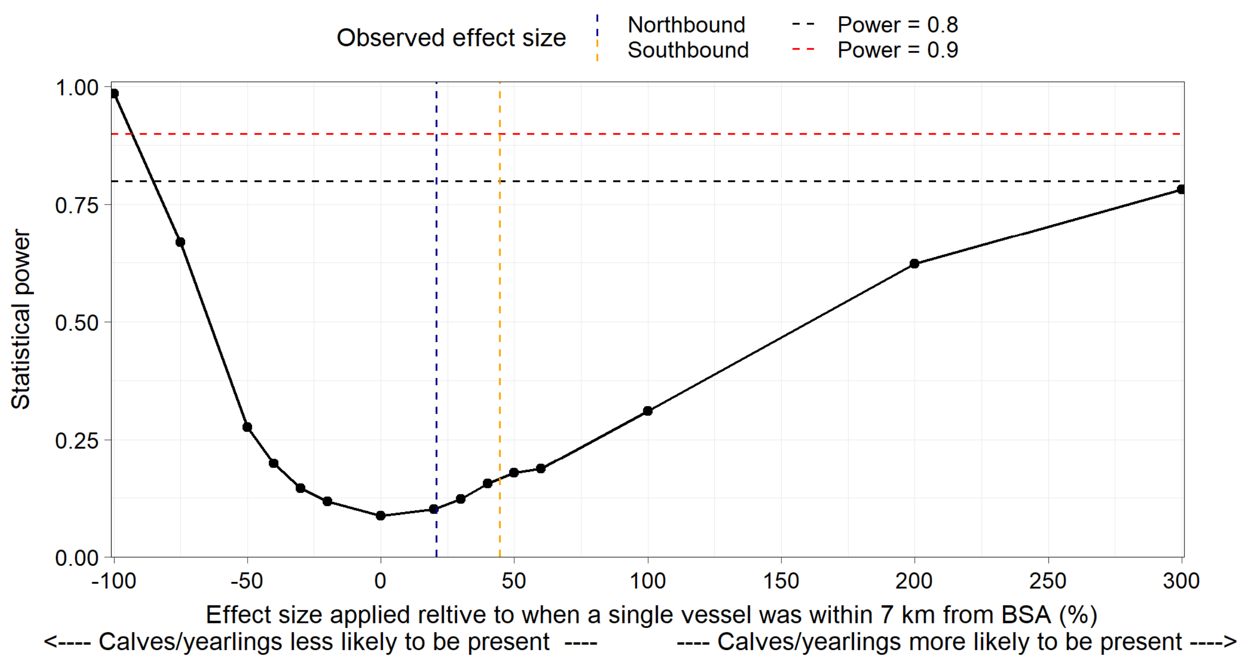


Figure 5: Statistical power of the overall model of presence of calves or yearlings to detect a significant effect of distance from vessel, showing observed effect sizes for north- and southbound vessels.

Group Spread

There was sufficient power (>0.8) to detect an effect of distance from vessel on group spread at effect sizes of approximately -90% or +350% (Figure 6). In comparison, observed effect sizes at a distance of 0 km from vessels were -1% (for a northbound vessel) and +14% (for a southbound vessel). Statistical power to estimate the observed effects was less than 0.25. Since most observed effect sizes were below the effect size required to achieve sufficient statistical power, the original analysis did not find a significant effect of vessel distance (Section 5.4.6 in main report).

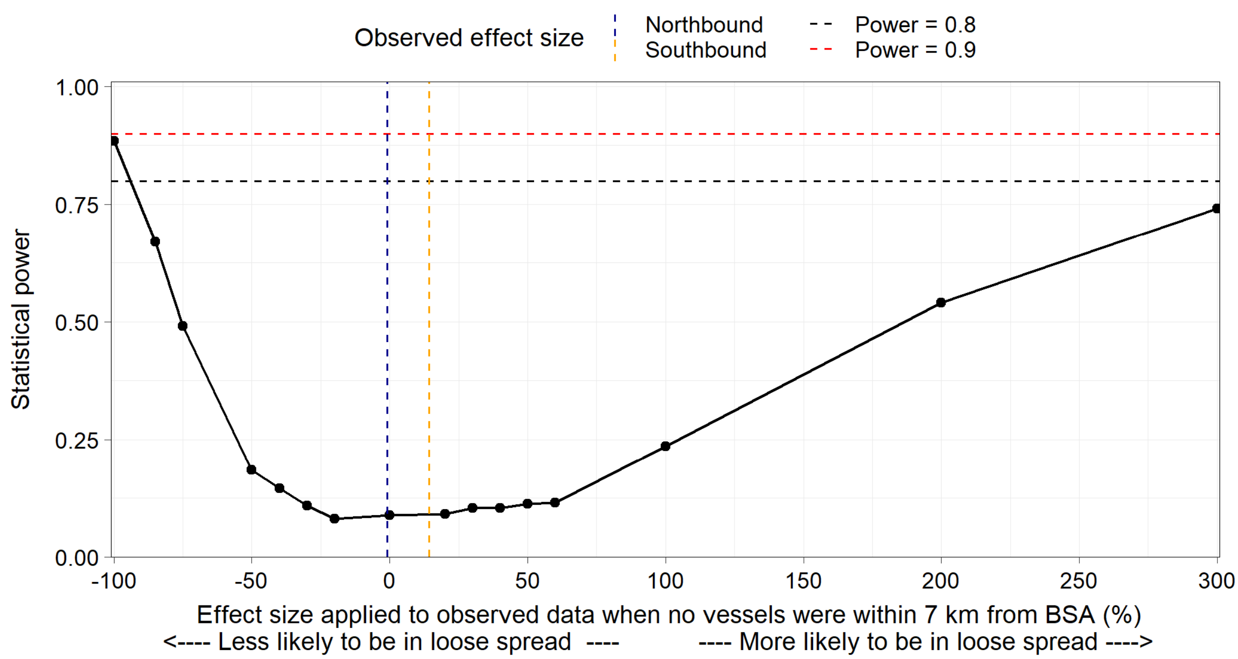


Figure 6: Statistical power of the overall model of group spread to detect a significant effect of distance from vessel, showing observed effect sizes for north- and southbound vessels.

Group Formation

There was sufficient power (>0.8) to detect an effect of distance from vessel on group formation at effect sizes of approximately -95% or +300% (Figure 7). In comparison, observed effect sizes at a distance of 0 km from vessels were -26% (for a northbound vessel) and -49% (for a southbound vessel). Statistical power to estimate the observed effects was low. Since the observed effect sizes were below the effect size required to achieve sufficient statistical power, the original analysis did not find a significant effect of vessel distance (Section 6.4.4 in main report).

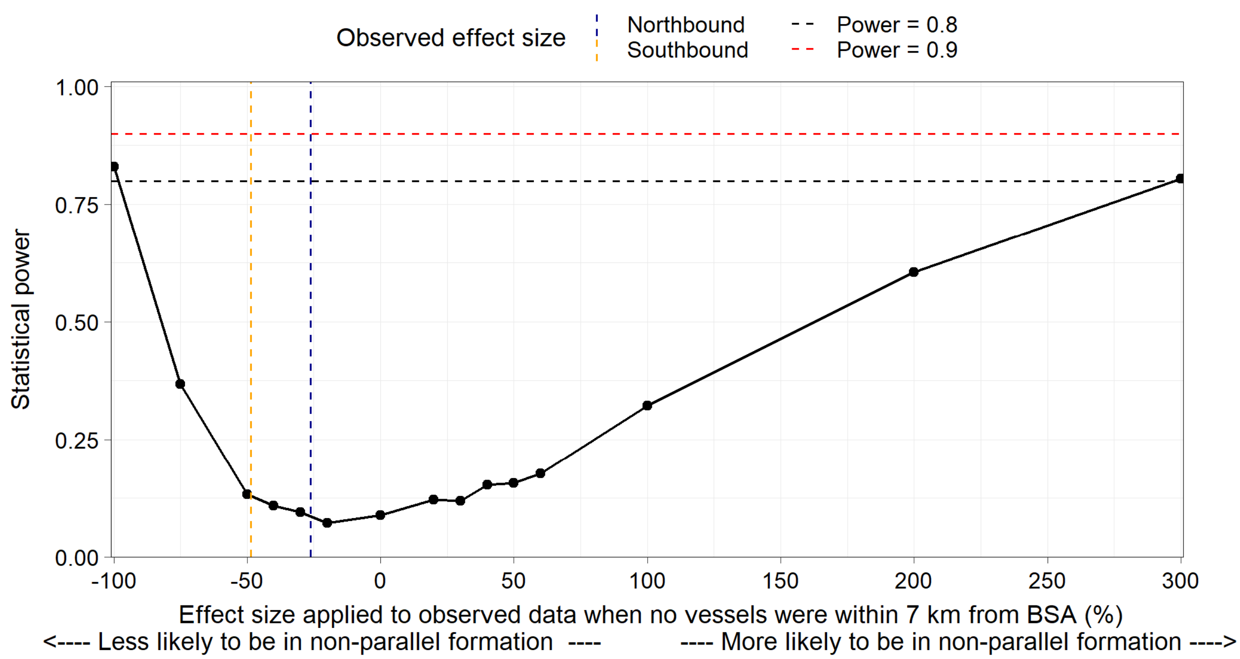


Figure 7: Statistical power of the overall model of group formation to detect a significant effect of distance from vessel, showing observed effect sizes for north- and southbound vessels.

Group Direction

There was not sufficient power (>0.8) to detect an effect of distance from vessel on group direction at any of the examined effect sizes (Figure 8). Estimated effect sizes at a distance of 0 km from vessels were +1,126% (for a northbound vessel) and 6,116% (for a southbound vessel). Statistical power to estimate these effects was very low. The estimated effect sizes were very large due to the nonlinear nature of the logit transformation used in analysis of binomial data. On the probability scale (which extends from 0 to 1), the probability of a group to travel south increased from 0.97 when no vessels were present within 7 km to 0.998 when a northbound vessel was at 0 km, and to 0.999 when a southbound vessel was at 0 km. Due to the low power, the original analysis did not find a significant effect of vessel distance (Section 6.4.5 in main report).

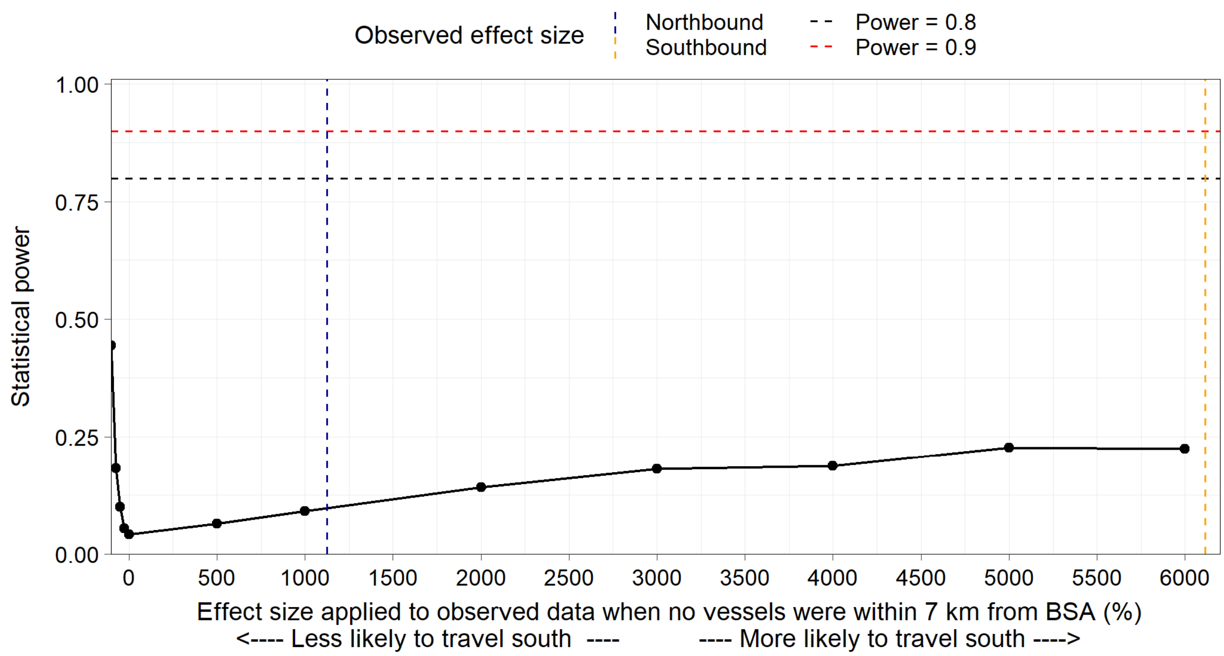


Figure 8: Statistical power of the overall model of group direction to detect a significant effect of distance from vessel, showing observed effect sizes at various vessel directions within Milne Inlet and position relative to BSA.

Travel Speed

There was not sufficient power to detect an effect of distance from vessel on group travel speed at the examined effect sizes (Figure 9). Observed effect sizes at a distance of 0 km from vessels were +3% (for a northbound vessel) and -43% (for a southbound vessel). Statistical power to estimate the observed effects was less than 0.2 for observed effect sizes at a distance of 0 km from vessels. The original analysis did not find a significant effect of vessel distance on group travel speed (Section 6.4.6 in main report).

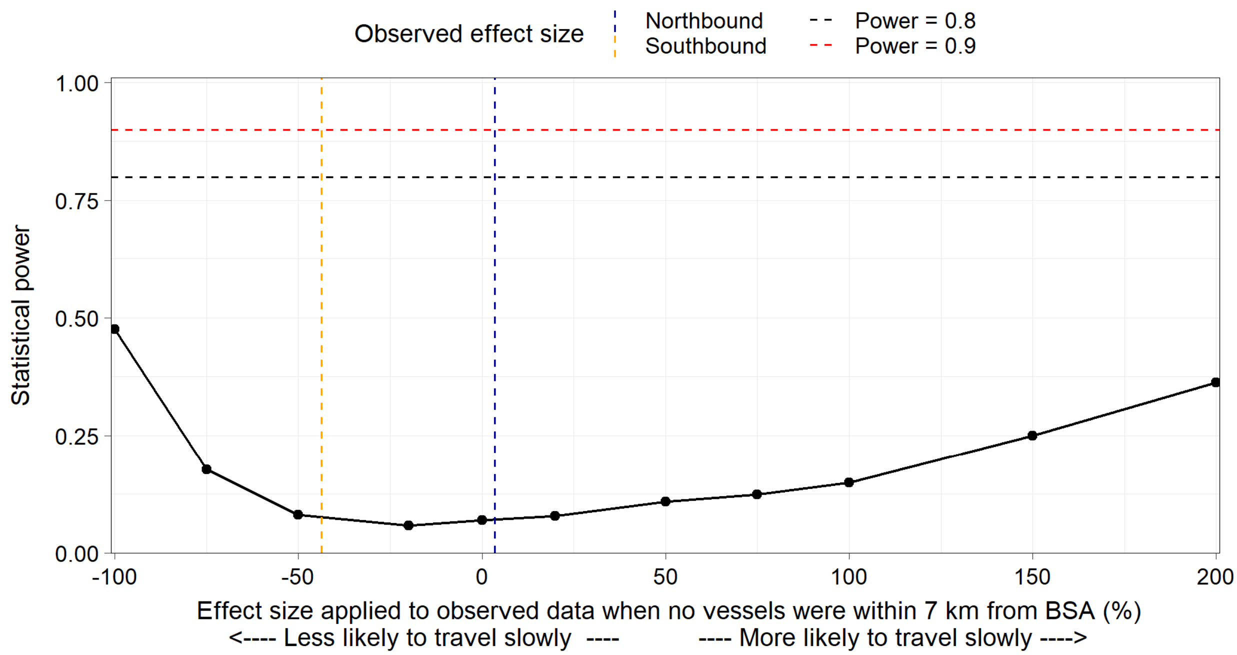


Figure 9: Statistical power of the overall model of group travel speed to detect a significant effect of distance from vessel, showing observed effect sizes for north- and southbound vessels.

Distance from Bruce Head Shore

There was not sufficient power to detect an effect of distance from vessel on group distance from shore at the examined effect sizes, and an effect size of +275% would be required for power >0.8 (Figure 10). Observed effect sizes at a distance of 0 km from vessels were -59% (for a northbound vessel) and -65% (for a southbound vessel). Statistical power to estimate the observed effects was less than 0.2, however the original analysis still found a significant effect of vessel distance on group distance from shore (Section 6.4.7 in main report).

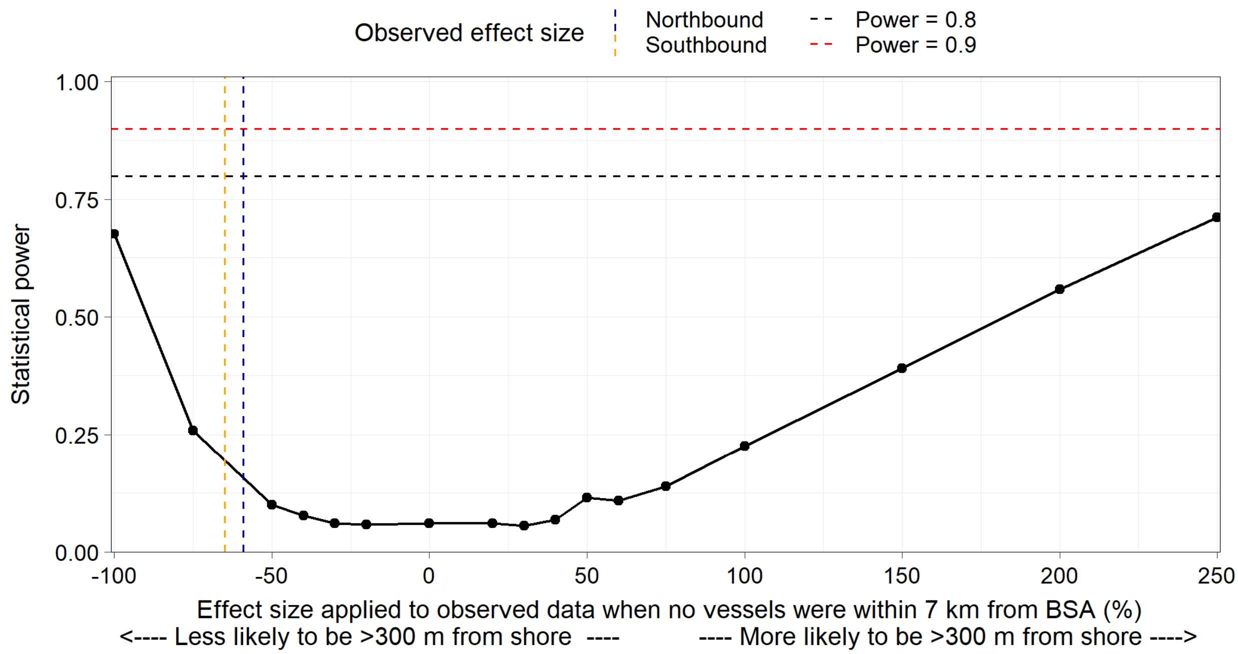


Figure 10: Statistical power of the overall model of group distance from shore to detect a significant effect of distance from vessel, showing observed effect sizes at various vessel directions within Milne Inlet and position relative to BSA.

Summary

Most of the assessed analyses required large effect sizes for sufficient (>0.8) statistical power to detect an effect of distance from vessels (reductions of 60-90% or increases of 85-300% in the odds or in the incidence rates; Table 1).

This result is likely a combination of several factors:

- Inherent data variability
- Sparse data in the immediate vicinity of vessels (only 153 and 28 cases in behavioural data when vessels were within 2 km and within 1 km from the BSA centroid, respectively, with only 3 additional cases being collected in 2020)

- Smaller dataset for group composition and behaviour data (5,854 cases, compared to 40,362 for RAD data), which reduces the statistical power of tests performed on group behaviour and composition data relative to the RAD data
- The spatial extent included in the “exposure to vessels” (7 km) may be too large, based on results of narwhal tagging (Golder 2020a). This would result in an increase in variability and a reduction in the ability to detect vessel effects, especially at shorter distances from vessels.

In the original analyses, the RAD analysis and one of the eight group composition and behaviour analyses detected an overall effect of distance from vessel, with potential effect noted for additional four variables. Overall, the results of the power analysis presented here indicate that group composition analyses generally had low power, therefore the effect of distance from vessel should be assessed using effect sizes rather than a strict adherence to statistical significance. As additional data are collected, and especially if the spatial extent of exposure to vessels is reduced further from the current 7 km limit, it is expected that statistical power would increase.

Table 1: Power to detect effects of distance from a single vessel

Analysis	Effect size for power ≥0.8 (%)	Range of observed effect sizes at 0 km (%)	Effect detected in original analysis?
RAD	-65% or +85%	-29% and -41%	Y
Group size	-57% or +95%	-4% and +15%	N
Group composition – presence of calves or yearlings	-80% or +350%	+21% and +350%	N, but noted potential effect
Group spread	-90% or +350%	-1% and +14%	N
Group formation	-95% or +300%	-26% and -49%	N, but noted potential effect based on effect size
Group direction	None of the examined effect sizes	+1,126% to +6,116%	N, but noted potential effect
Travel speed	None of the examined effect sizes	+3% and -43%	N, but noted potential effect
Distance from Bruce Head shore	275%	-59% and -65%	Y

APPENDIX C

Vessel Track Information

Medium (>50 m) and large (>100 m) vessel traffic in SSA during 2020 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 in SSA (max)
1	August 7, 2020	(12:57 - 14:12)	Nordic Orion	Bulk (ore) carrier	south	under 9.0
2	August 7, 2020	(13:07 - 14:18)	Miena Desgagnes	General Cargo	north	under 9.0
3	August 7, 2020	(13:48 - 15:19)	Botnica	Ice Breaker	south	under 9.0
4	August 7, 2020	(14:22 - 16:11)	Pabur	Bulk (ore) carrier	south	under 9.0
5	August 8, 2020	(14:55 - 16:10)	Sagar Samrat	Bulk (ore) carrier	north	under 9.0
6	August 9, 2020	(13:04 - 14:18)	Golden Opportunity	Bulk (ore) carrier	north	under 9.0
7	August 10, 2020	(11:02 - 12:17)	Pabur	Bulk (ore) carrier	north	under 9.0
8	August 11, 2020	(08:18 - 09:44)	Golden Saguenay	Bulk (ore) carrier	south	under 9.0
9	August 12, 2020	(06:58 - 09:20)	NS Energy	Bulk (ore) carrier	south	under 9.0
10	August 12, 2020	(12:32 - 13:48)	Golden Saguenay	Bulk (ore) carrier	north	under 9.0
11	August 12, 2020	(19:09 - 20:24)	Golden Bull	Bulk (ore) carrier	south	up to 9.1
12	August 13, 2020	(00:47 - 02:03)	Golden Ice	Bulk (ore) carrier	south	under 9.0
13	August 13, 2020	(15:37 - 17:03)	NS Energy	Bulk (ore) carrier	north	under 9.0
14	August 14, 2020	(18:41 - 19:55)	Golden Bull	Bulk (ore) carrier	north	under 9.0
15	August 14, 2020	(21:11 - 22:29)	Golden Opal	Bulk (ore) carrier	south	up to 9.1
16	August 15, 2020	(09:57 - 11:34)	Botnica	Ice Breaker	north	under 9.0
17	August 15, 2020	(18:42 - 19:57)	Golden Ice	Bulk (ore) carrier	north	under 9.0
18	August 16, 2020	(15:46 - 17:06)	Nordic Oasis	Bulk (ore) carrier	south	under 9.0
19	August 16, 2020	(20:18 - 21:32)	Golden Opal	Bulk (ore) carrier	north	under 9.0
20	August 17, 2020	(01:34 - 02:47)	Sea Pluto	Bulk (ore) carrier	south	under 9.0
21	August 17, 2020	(05:19 - 06:47)	Botnica	Ice Breaker	south	under 9.0
22	August 17, 2020	(20:57 - 22:32)	Nordic Oasis	Bulk (ore) carrier	north	under 9.0
23	August 19, 2020	(00:47 - 02:01)	Sea Pluto	Bulk (ore) carrier	north	up to 9.1
24	August 20, 2020	(00:00 - 01:10)	Nordic Oshima	Bulk (ore) carrier	south	under 9.0
25	August 20, 2020	(05:11 - 06:27)	Taiga Desgagnes	General Cargo	south	under 9.0
26	August 20, 2020	(20:05 - 21:20)	Georg Oldendorff	Bulk (ore) carrier	south	under 9.0
27	August 21, 2020	(00:12 - 01:31)	Nordic Oshima	Bulk (ore) carrier	north	under 9.0
28	August 21, 2020	(01:20 - 02:43)	Nordic Odyssey	Bulk (ore) carrier	south	under 9.0
29	August 21, 2020	(06:09 - 07:22)	Vitus Bering	Bulk (ore) carrier	south	up to 9.4
30	August 21, 2020	(16:10 - 17:39)	Taiga Desgagnes	General Cargo	north	under 9.0
31	August 22, 2020	(08:23 - 09:40)	Georg Oldendorff	Bulk (ore) carrier	north	under 9.0

32	August 22, 2020	(16:04 - 17:20)	Admiral Schmidt	General Cargo	south	under 9.0
33	August 23, 2020	(06:17 - 07:39)	Nordic Odyssey	Bulk (ore) carrier	north	under 9.0
34	August 23, 2020	(09:00 - 10:15)	Nordic Odin	Bulk (ore) carrier	south	under 9.0
35	August 23, 2020	(15:04 - 16:37)	Sarah Desgagnes	Oil And Chemical Tanker	south	under 9.0
36	August 24, 2020	(13:06 - 14:38)	Botnica	Ice Breaker	north	under 9.0
37	August 24, 2020	(14:17 - 15:30)	Vitus Bering	Bulk (ore) carrier	north	under 9.0
38	August 24, 2020	(16:44 - 18:05)	NS Yakutia	Bulk (ore) carrier	south	under 9.0
39	August 25, 2020	(19:42 - 21:02)	Rio Tamara	Bulk (ore) carrier	south	up to 10.1
40	August 26, 2020	(05:35 - 06:52)	Admiral Schmidt	General Cargo	north	under 9.0
41	August 26, 2020	(07:05 - 08:22)	Botnica	Ice Breaker	south	under 9.0
42	August 27, 2020	(09:12 - 10:28)	Nordic Odin	Bulk (ore) carrier	north	under 9.0
43	August 27, 2020	(11:39 - 12:53)	Golden Ruby	Bulk (ore) carrier	south	under 9.0
44	August 27, 2020	(16:56 - 18:10)	Sarah Desgagnes	Oil And Chemical Tanker	north	under 9.0
45	August 28, 2020	(06:29 - 07:52)	NS Yakutia	Bulk (ore) carrier	north	under 9.0
46	August 28, 2020	(08:57 - 10:16)	MV Golden Brilliant	Bulk (ore) carrier	south	under 9.0
47	August 29, 2020	(09:44 - 11:04)	Rio Tamara	Bulk (ore) carrier	north	under 9.0
48	August 29, 2020	(12:33 - 13:50)	Nordic Olympic	Bulk (ore) carrier	south	under 9.0
49	August 29, 2020	(18:23 - 19:40)	Botnica	Ice Breaker	north	under 9.0
50	August 30, 2020	(06:53 - 08:04)	Golden Ruby	Bulk (ore) carrier	north	up to 9.1
51	August 30, 2020	(09:34 - 10:59)	Bulk Destiny	Bulk (ore) carrier	south	under 9.0
52	August 31, 2020	(05:55 - 07:11)	Flag Mette	Bulk (ore) carrier	south	under 9.0
53	August 31, 2020	(10:16 - 11:40)	MV Golden Brilliant	Bulk (ore) carrier	north	under 9.0
54	August 31, 2020	(18:48 - 20:11)	Despina V	General Cargo	south	under 9.0
55	September 1, 2020	(15:13 - 16:32)	Nordic Olympic	Bulk (ore) carrier	north	under 9.0
56	September 1, 2020	(17:39 - 18:53)	Nordic Orion	Bulk (ore) carrier	south	up to 9.1

APPENDIX D

Test Statistics and Coefficients

RAD analysis

Table D-1: Test statistics of mixed generalized linear model of narwhal counts in SSA (type II *P* values)

Parameter	Chi squared	Df	*P* value
Negative binomial component of model			
Day	15.647	2	**<0.001**
Year	10.666	5	0.058
Stratum	745.973	9	**<0.001**
Substratum	371.138	2	**<0.001**
Glare	70.719	2	**<0.001**
Beaufort scale	146.555	5	**<0.001**
Tide	71.9	3	**<0.001**
Directional distance	11.783	4	**0.019**
North- or southbound vessel	4.107	1	**0.043**
Vessel presence within 7 km from substratum	8.927	1	**0.003**
Hunting event within 70 minutes prior to observation	22.413	1	**<0.001**
Zero-inflation component of model			
Stratum	41.447	9	**<0.001**
Substratum	29.813	2	**<0.001**
Year	93.057	5	**<0.001**
Beaufort scale	26.911	5	**<0.001**

Table D-2: Coefficient estimates for fixed effects in a mixed generalized linear model of narwhal counts

Parameter	Coefficient	SE	*z* value	*P* value
Negative binomial component of model				
Intercept (Year=2014, Glare="N", Beaufort = 0, Stratum = "A", Substratum = "1", no vessels within 7 km from substratum, Tide = low slack, no hunting within preceding 70 minutes	-2.816	0.421	-6.682	<0.001
Day of year[1]	54.723	27.903	1.961	0.050
Day of year squared[1]	-98.078	27.858	-3.521	<0.001
Year (2015)	0.555	0.513	1.083	0.279
Year (2016)	0.887	0.520	1.706	0.088
Year (2017)	0.884	0.523	1.690	0.091
Year (2019)	0.746	0.528	1.413	0.158
Year (2020)	-0.432	0.541	-0.798	0.425
Stratum (B)	-0.189	0.156	-1.213	0.225
Stratum (C)	0.418	0.161	2.590	0.010
Stratum (D)	1.830	0.163	11.245	<0.001
Stratum (E)	1.968	0.157	12.551	<0.001
Stratum (F)	2.374	0.156	15.222	<0.001

Parameter	Coefficient	SE	*z* value	*P* value
Stratum (G)	2.764	0.155	17.861	<0.001
Stratum (H)	2.975	0.157	18.978	<0.001
Stratum (I)	2.718	0.158	17.205	<0.001
Stratum (J)	2.874	0.189	15.189	<0.001
Substratum (2)	-0.168	0.053	-3.152	0.002
Substratum (3)	-1.262	0.078	-16.191	<0.001
Glare (L)	0.151	0.032	4.737	<0.001
Glare (S)	-0.454	0.074	-6.097	<0.001
Beaufort (1)	0.008	0.073	0.103	0.918
Beaufort (2)	-0.343	0.079	-4.340	<0.001
Beaufort (3)	-0.721	0.102	-7.095	<0.001
Beaufort (4)	-1.003	0.133	-7.564	<0.001
Beaufort (5)	-1.116	0.197	-5.652	<0.001
Tide (Flood)	-0.282	0.040	-7.108	<0.001
Tide (High slack)	-0.364	0.049	-7.432	<0.001
Tide (Ebb)	-0.180	0.040	-4.524	<0.001
Distance from vessel[1]	-1.173	2.577	-0.455	0.649
Distance from vessel squared[1]	16.596	5.689	2.917	0.004
Distance from vessel cubed[1]	2.939	2.642	1.112	0.266
Vessel heading away from substratum	-3.661	3.610	-1.014	0.311
Vessel southbound	-0.185	0.091	-2.027	0.043
One vessel within 7 km from substratum centroid	-0.352	0.118	-2.988	0.003
Hunting occurred within preceding 70 minutes	0.191	0.040	4.734	<0.001
Zero-inflation component of model				
Intercept (Year=2014, Beaufort = 0, Stratum = “A”, Substratum = “1”)	-3.706	0.756	-4.905	<0.001
Stratum (B)	-0.012	0.363	-0.033	0.973
Stratum (C)	0.341	0.338	1.010	0.313
Stratum (D)	0.495	0.332	1.490	0.136
Stratum (E)	0.141	0.321	0.438	0.661
Stratum (F)	0.124	0.314	0.395	0.693
Stratum (G)	-0.044	0.311	-0.142	0.887
Stratum (H)	-0.237	0.311	-0.763	0.446
Stratum (I)	-0.393	0.312	-1.262	0.207
Stratum (J)	-0.419	0.327	-1.281	0.200
Substratum (2)	0.436	0.107	4.069	<0.001
Substratum (3)	0.726	0.133	5.456	<0.001
Year (2015)	2.333	0.665	3.508	<0.001
Year (2016)	2.273	0.659	3.448	0.001

Parameter	Coefficient	SE	*z* value	*P* value
Year (2017)	-0.238	1.102	-0.216	0.829
Year (2019)	3.016	0.662	4.557	<0.001
Year (2020)	3.040	0.668	4.552	<0.001
Beaufort (1)	0.333	0.158	2.103	0.035
Beaufort (2)	0.224	0.167	1.338	0.181
Beaufort (3)	0.695	0.189	3.675	<0.001
Beaufort (4)	0.524	0.269	1.951	0.051
Beaufort (5)	1.141	0.304	3.753	<0.001

(1) Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Group Composition and Behaviour Analysis

Group Size

Table D-3: Test statistics of mixed generalized linear model of group size (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	54.384	5	**<0.001**
Glare	2.548	2	0.280
Beaufort scale	8.464	4	0.076
Tide	2.78	3	0.427
Directional distance from vessel	2.137	2	0.343
North- or southbound vessel	0.28	1	0.597
Large vessel presence within 7 km from BSA	0.095	1	0.758
Hunting event within 70 minutes prior to observation	33.468	1	**<0.001**
Directional distance:North- or southbound vessel	2.221	2	0.329

Table D-4: Coefficient estimates for fixed effects in a mixed generalized linear model of group size

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 7 km from BSA, Tide = low slack, no hunting within preceding 70 min	1.004	0.144	6.972	<0.001
Year 2015	0.253	0.128	1.970	0.049
Year 2016	-0.343	0.114	-3.004	0.003
Year 2017	-0.122	0.109	-1.111	0.267
Year 2019	-0.291	0.111	-2.633	0.008
Year 2020	-0.278	0.117	-2.367	0.018
Glare Low	-0.032	0.053	-0.604	0.546
Glare Severe	0.101	0.076	1.323	0.186
Beaufort scale 1	0.049	0.089	0.550	0.582
Beaufort scale 2	0.067	0.092	0.727	0.467

Parameter	Coefficient	SE	*z* value	*P* value
Beaufort scale 3	0.209	0.100	2.083	0.037
Beaufort scale ≥4	0.154	0.111	1.388	0.165
Tide Flood	-0.080	0.063	-1.280	0.20
Tide High slack	-0.021	0.074	-0.282	0.778
Tide Ebb	-0.009	0.063	-0.149	0.882
Directional distance[1]	3.180	1.893	1.680	0.093
Directional distance squared[1]	2.188	2.642	0.828	0.407
North- or southbound vesselSouthbound	0.166	0.178	0.935	0.35
Large vessel presence within 7 km from BSA	-0.040	0.131	-0.308	0.758
Hunting event within 70 min prior to observation	0.282	0.049	5.785	<0.001
Directional distance[1]:North- or southbound vesselSouthbound	-3.216	2.780	-1.157	0.247
Directional distance squared[1]:North- or southbound vesselSouthbound	-3.370	3.780	-0.892	0.373

(1) Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable

Group Composition

Table D-5: Test statistics of mixed generalized linear model of group composition (presence of calves or yearlings; type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	6.803	5	0.236
Group size	29.947	2	**<0.001**
Glare	8.705	2	**0.013**
Beaufort scale	4.682	4	0.322
TideF	2.151	3	0.542
Directional distance	3.002	2	0.223
North- or southbound vessel	0.315	1	0.575
Vessel presence within 10 km from BSA	0.649	1	0.420
Hunting event within 3 h prior to observation	0.057	1	0.811
Directional distance : North- or southbound vessel	3.305	2	0.192

Table D-6: Coefficient estimates for fixed effects in a mixed generalized linear model of group composition (presence of calves or yearlings)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 7 km from BSA, Tide = low slack, no hunting within preceding 70 minutes, average group size)	-0.012	0.383	-0.031	0.975
Year 2015	0.353	0.397	0.888	0.374
Year 2016	0.808	0.352	2.299	0.022

Parameter	Coefficient	SE	*z* value	*P* value
Year 2017	0.401	0.339	1.184	0.237
Year 2019	0.582	0.345	1.689	0.091
Year 2020	0.562	0.369	1.526	0.127
Group size[1]	-0.202	2.392	-0.085	0.933
Group size squared[1]	13.907	2.585	5.380	<0.001
Glare L	-0.026	0.125	-0.211	0.833
Glare S	-0.595	0.207	-2.883	0.004
Beaufort scale 1	-0.429	0.202	-2.130	0.033
Beaufort scale 2	-0.395	0.221	-1.792	0.073
Beaufort scale 3	-0.435	0.250	-1.744	0.081
Beaufort scale 4 or higher	-0.364	0.296	-1.229	0.219
Tide Flood	-0.042	0.147	-0.285	0.775
Tide High slack	0.046	0.173	0.268	0.789
Tide Ebb	0.139	0.149	0.932	0.351
Directional distance[1]	6.232	3.025	2.060	0.039
Directional distance squared[1]	-4.617	4.598	-1.004	0.315
Southbound vessel	0.176	0.342	0.515	0.607
Large vessel presence within 7 km from BSA	0.190	0.236	0.806	0.42
Hunting event within 70 min prior to observation	0.027	0.112	0.240	0.81
Directional distance[1] : Southbound vessel	-8.624	4.746	-1.817	0.069
Directional distance squared[1] : Southbound vessel	-0.074	6.656	-0.011	0.991

(1) Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Group Spread

Table D-7: Test statistics of mixed generalized linear model of group spread (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	28.1	5	**<0.001**
Group size (categorical)	156.487	1	**<0.001**
Glare	0.019	2	0.991
Beaufort scale	3.024	4	0.554
TideF	1.689	3	0.639
Directional distance	0.03	2	0.985
North- or southbound vessel	0.125	1	0.723
Vessel presence within 7 km from BSA	0.001	1	0.975
Hunting event within 70 minutes prior to observation	6.171	1	**0.013**
Directional distance : North- or southbound vessel	0.785	2	0.675

Table D-8: Coefficient estimates for fixed effects in a mixed generalized linear model of group spread

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare=”N”, Beaufort = 0, no vessels within 7 km from BSA, Tide = low slack, no hunting within preceding 70 minutes, group size of 2)	-3.456	0.555	-6.230	<0.001
Year 2015	1.634	0.526	3.107	0.002
Year 2016	1.196	0.480	2.490	0.013
Year 2017	1.762	0.468	3.766	<0.001
Year 2019	1.680	0.469	3.579	<0.001
Year 2020	2.296	0.492	4.667	<0.001
NF>2	1.094	0.087	12.509	<0.001
Glare L	0.016	0.169	0.093	0.926
Glare S	-0.020	0.262	-0.075	0.941
Beaufort scale 1	0.225	0.284	0.794	0.427
Beaufort scale 2	0.109	0.301	0.363	0.717
Beaufort scale 3	-0.070	0.337	-0.209	0.835
Beaufort scale 4 or higher	0.347	0.374	0.927	0.354
Tide Flood	-0.006	0.198	-0.029	0.977
Tide High slack	0.131	0.235	0.559	0.576
Tide Ebb	0.196	0.199	0.985	0.324
Directional distance[1]	-1.257	3.863	-0.325	0.745
Directional distance squared[1]	2.296	5.360	0.428	0.668
Southbound vessel	0.118	0.470	0.252	0.801
Large vessel presence within 7 km from BSA	-0.010	0.330	-0.032	0.975
Hunting event within 70 min prior to observation	-0.377	0.152	-2.484	0.013
Directional distance[1] : Southbound vessel	2.203	6.157	0.358	0.72
Directional distance squared[1] : Southbound vessel	-6.652	8.223	-0.809	0.419

(1) Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Group Formation

Table D-9: Test statistics of mixed generalized linear model of group formation (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	31.933	5	**<0.001**
Group size	391.002	1	**<0.001**
Glare	11.802	2	**0.003**
Beaufort scale	7.044	4	0.134
TideF	1.464	3	0.691
Directional distance	4.416	2	0.110
North- or southbound vessel	1.296	1	0.255

Parameter	Chi squared	Df	*P* value
Vessel presence within 10 km from BSA	0.926	1	0.336
Hunting event within 3 h prior to observation	0.04	1	0.842
Directional distance:North- or southbound vessel	0.044	2	0.978

Table D-10: Coefficient estimates for fixed effects in a mixed generalized linear model of group formation

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare=”N”, Beaufort = 0, no vessels within 7 km from BSA, Tide = low slack, no hunting within preceding 70 minutes, average group size)	-1.876	0.423	-4.433	<0.001
Year 2015	0.990	0.396	2.503	0.012
Year 2016	1.176	0.360	3.268	0.001
Year 2017	1.316	0.343	3.832	<0.001
Year 2019	1.564	0.349	4.486	<0.001
Year 2020	1.793	0.362	4.948	<0.001
Group size[1]	0.935	0.047	19.774	<0.001
Glare L	0.044	0.139	0.319	0.749
Glare S	0.703	0.207	3.402	0.001
Beaufort scale 1	-0.091	0.232	-0.390	0.696
Beaufort scale 2	0.027	0.241	0.112	0.911
Beaufort scale 3	-0.418	0.269	-1.554	0.12
Beaufort scale 4 or higher	0.090	0.294	0.308	0.758
Tide Flood	-0.107	0.168	-0.637	0.524
Tide High slack	-0.224	0.203	-1.105	0.269
Tide Ebb	-0.166	0.168	-0.985	0.325
Directional distance[2]	3.704	3.929	0.943	0.346
Directional distance squared[2]	7.659	5.672	1.350	0.177
Southbound vessel	-0.364	0.457	-0.797	0.426
Large vessel presence within 7 km from BSA	-0.304	0.316	-0.962	0.336
Hunting event within 70 min prior to observation	0.026	0.130	0.200	0.842
Directional distance[2] : Southbound vessel	-1.254	6.157	-0.204	0.839
Directional distance squared[2] : Southbound vessel	-0.452	8.480	-0.053	0.957

(1) Variable was standardized prior to modeling.

(2) Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Group Direction

Table D-11: Test statistics of mixed generalized linear model of group direction (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	13.22	5	**0.021**
Group size	0.82	1	0.365
TideF	0.233	3	0.972
Directional distance	0.591	2	0.744
North- or southbound vessel	0.626	1	0.429
Vessel presence within 7 km from BSA	1.554	1	0.213
Hunting event within 70 minutes prior to observation	3.240	1	0.072
Directional distance:North- or southbound vessel	4.879	2	0.087

Table D-12: Coefficient estimates for fixed effects in a mixed generalized linear model of group direction

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare=”N”, Beaufort = 0, no vessels within 7 km from BSA, Tide = low slack, no hunting within preceding 70 minutes)	6.368	2.267	2.809	0.005
Year 2015	1.896	2.407	0.787	0.431
Year 2016	-2.368	2.260	-1.048	0.295
Year 2017	-2.493	2.260	-1.103	0.27
Year 2019	-2.451	2.229	-1.099	0.272
Year 2020	-5.338	2.530	-2.110	0.035
Group size	0.115	0.127	0.905	0.365
Tide Flood	-0.189	0.940	-0.201	0.841
Tide High slack	-0.451	1.129	-0.400	0.689
Tide Ebb	-0.070	0.980	-0.072	0.943
Directional distance before breakpoint (at 0 km)	0.513	1.597	0.321	0.748
Directional distance after breakpoint (at 0 km)	1.162	3.105	0.374	0.708
Southbound vessel	1.630	3.041	0.536	0.592
Large vessel presence within 7 km from BSA	2.510	2.014	1.247	0.213
Hunting event within 70 min prior to observation	1.286	0.715	1.800	0.072
Directional distance before breakpoint (at 0 km) : Southbound vessel	1.264	2.344	0.540	0.59
Directional distance after breakpoint (at 0 km) : Southbound vessel	-7.484	4.795	-1.561	0.119

(1) Variable was standardized prior to modeling.

(2) Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Travel Speed

Table D-13: Test statistics of mixed generalized linear model of travel speed (slow travel vs. medium travel speed; type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	24.246	5	**<0.001**
Group size	59.415	1	**<0.001**
Glare	0.015	2	0.993
Beaufort scale	14.200	4	**0.007**
TideF	1.357	3	0.716
Directional distance	1.481	2	0.477
North- or southbound vessel	0.115	1	0.734
Vessel presence within 7 km from BSA	0.003	1	0.959
Hunting event within 70 min prior to observation	2.962	1	0.085
Directional distance:North- or southbound vessel	1.752	2	0.416

Table D-14: Coefficient estimates for fixed effects in a mixed generalized linear model of travel speed (slow travel vs. medium travel speed)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 7 km from BSA, Tide = low slack, no hunting within preceding 70 min, average group size)	-1.562	0.810	-1.929	0.054
Year 2015	1.360	0.800	1.699	0.089
Year 2016	1.532	0.663	2.310	0.021
Year 2017	1.457	0.654	2.227	0.026
Year 2019	2.670	0.655	4.076	<0.001
Year 2020	1.684	0.689	2.443	0.015
Group size[1]	-0.541	0.070	-7.708	<0.001
Glare L	0.019	0.284	0.067	0.947
Glare S	0.048	0.412	0.116	0.907
Beaufort scale 1	-0.764	0.472	-1.618	0.106
Beaufort scale 2	-1.517	0.501	-3.029	0.002
Beaufort scale 3	-1.488	0.551	-2.699	0.007
Beaufort scale 4 or higher	-1.326	0.608	-2.182	0.029
Tide Flood	0.245	0.329	0.746	0.456
Tide High slack	-0.092	0.393	-0.234	0.815
Tide Ebb	0.050	0.329	0.152	0.879
Directional distance[2]	-5.716	7.117	-0.803	0.422
Directional distance squared[2]	-6.903	9.389	-0.735	0.462
Southbound vessel	-0.544	0.868	-0.627	0.531
Large vessel presence within 7 km from BSA	0.032	0.619	0.052	0.959

Parameter	Coefficient	SE	*z* value	*P* value
Hunting event within 70 min prior to observation	-0.459	0.267	-1.721	0.085
Directional distance²:Southbound vessel	-1.438	10.218	-0.141	0.888
Directional distance squared²:Southbound vessel	17.623	13.406	1.315	0.189

(1) Variable was standardized prior to modeling.

(2) Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Distance from Bruce Head Shore

Table D-15: Test statistics of mixed generalized linear model of distance from Bruce Head shore (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	15.950	5	**0.007**
Group size	16.551	1	**<0.001**
Glare	0.879	2	0.644
Beaufort scale	15.665	4	**0.004**
Tide	2.068	3	0.558
Directional distance	14.499	4	**0.006**
North- or southbound vessel	0.206	1	0.650
Vessel presence within 7 km from BSA	2.599	1	0.107
Hunting event within 70 minutes prior to observation	0.880	1	0.348
Directional distance:North- or southbound vessel	3.652	4	0.455

Table D-16: Coefficient estimates for fixed effects in a mixed generalized linear model of distance from Bruce Head shore

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 7 km from BSA, Tide = low slack, no hunting within preceding 70 minutes	-1.138	0.778	-1.462	0.144
Year 2015	-1.725	0.834	-2.069	0.039
Year 2016	-0.263	0.683	-0.384	0.701
Year 2017	0.087	0.680	0.128	0.898
Year 2019	0.240	0.670	0.359	0.72
Year 2020	0.834	0.711	1.173	0.241
Group size¹	-0.199	0.049	-4.068	<0.001
Glare L	-0.211	0.249	-0.849	0.396
Glare S	-0.254	0.398	-0.638	0.524
Beaufort scale 1	0.083	0.412	0.202	0.84
Beaufort scale 2	-0.349	0.456	-0.765	0.444
Beaufort scale 3	-0.980	0.511	-1.919	0.055
Beaufort scale 4 or higher	-1.272	0.580	-2.193	0.028

Parameter	Coefficient	SE	*z* value	*P* value
Tide Flood	0.310	0.285	1.086	0.277
Tide High slack	0.279	0.336	0.831	0.406
Tide Ebb	0.395	0.289	1.366	0.172
Directional distance[2]	-8.009	5.989	-1.337	0.181
Directional distance squared[2]	7.911	8.876	0.891	0.373
Directional distance cubed[2]	6.859	4.989	1.375	0.169
Directional distance to the power of 4[2]	-15.471	6.684	-2.315	0.021
Vessel southbound	-0.125	0.813	-0.153	0.878
Large vessel presence within 7 km from BSA	-0.901	0.559	-1.612	0.107
Hunting event within 70 min prior to observation	-0.210	0.223	-0.938	0.348
Directional distance[2] : Vessel southbound	-6.132	9.123	-0.672	0.502
Directional distance squared[2] : Vessel southbound	11.583	14.310	0.809	0.418
Directional distance cubed[2] : Vessel southbound	-8.641	7.605	-1.136	0.256
Directional distance to the power of 4[2] : Vessel southbound	6.169	9.781	0.631	0.528

(1) Variable was standardized prior to modeling.

(2) Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

APPENDIX E

Model Diagnostics

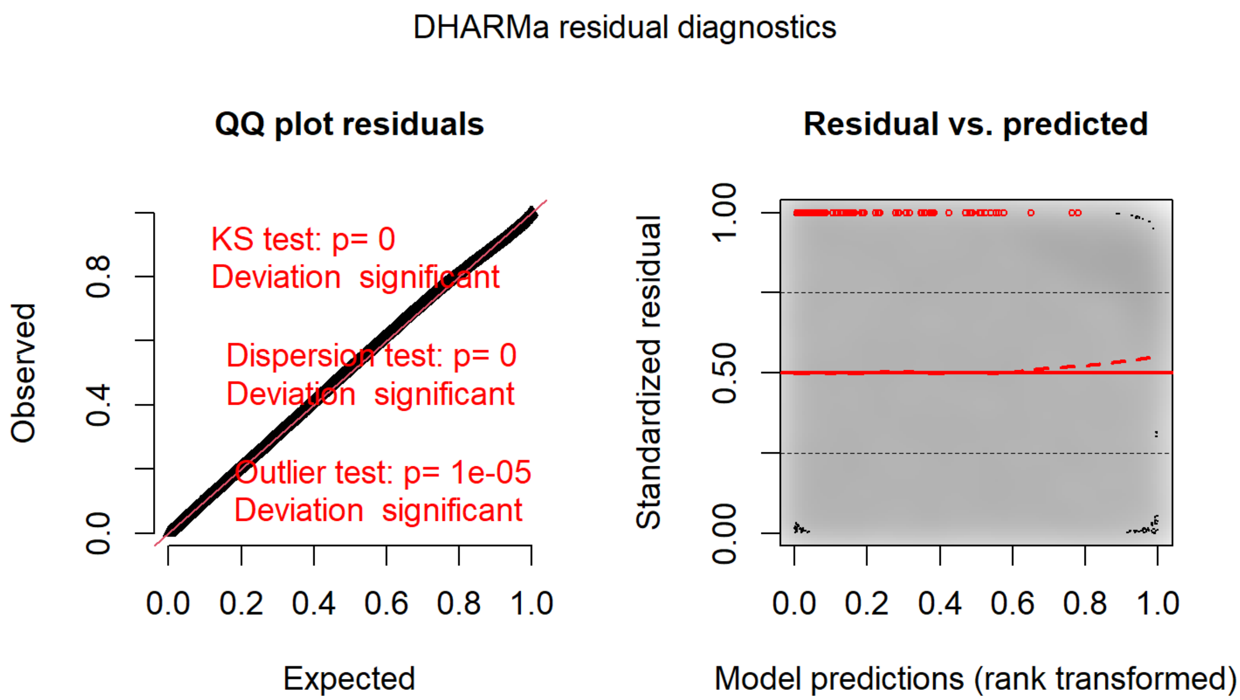


Figure E-1: Residual diagnostics for Density model – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

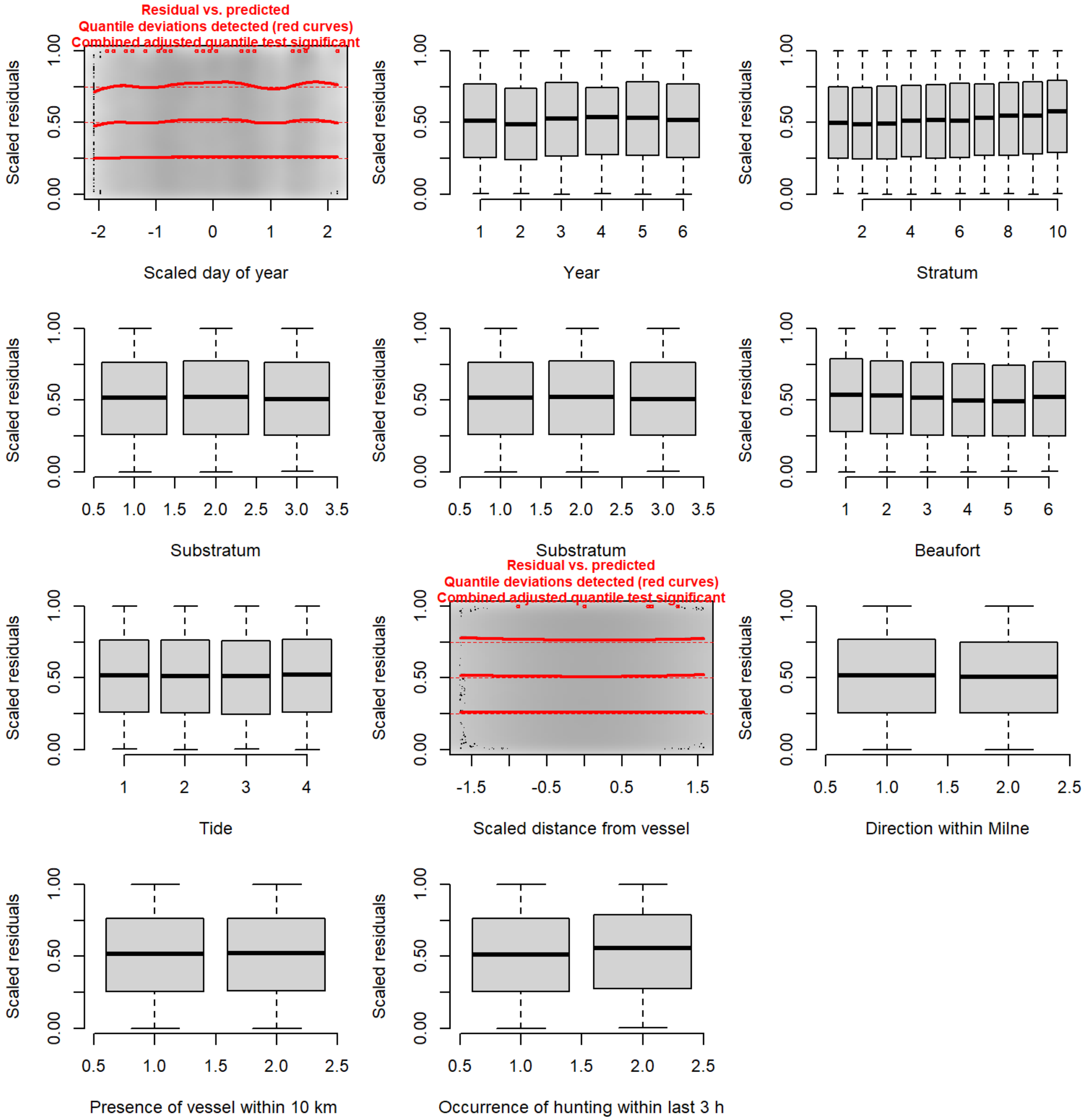


Figure E-2: Residual diagnostics for Density model – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

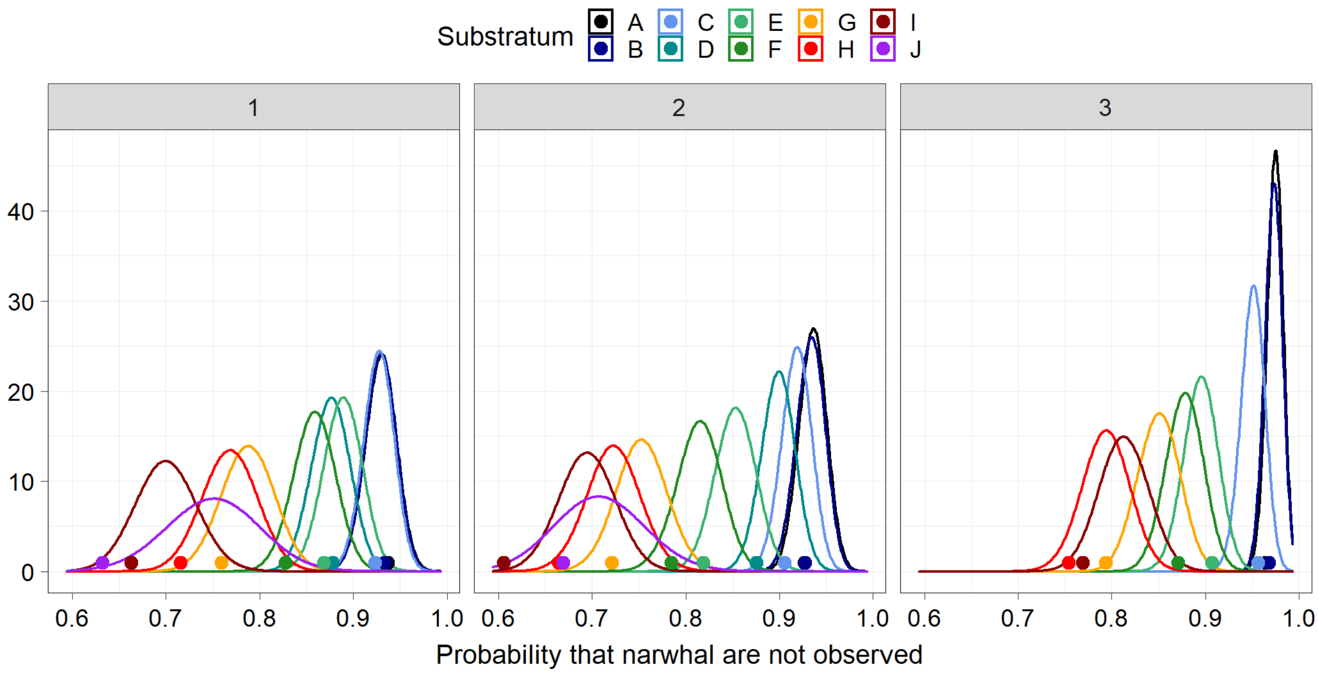


Figure E-3: Density model diagnostics – simulated zero counts. Each panel represents a different substratum (1, 2, or 3). Densities are values from 1000 data sets simulated from model selected for interpretation. Points represent the observed data.

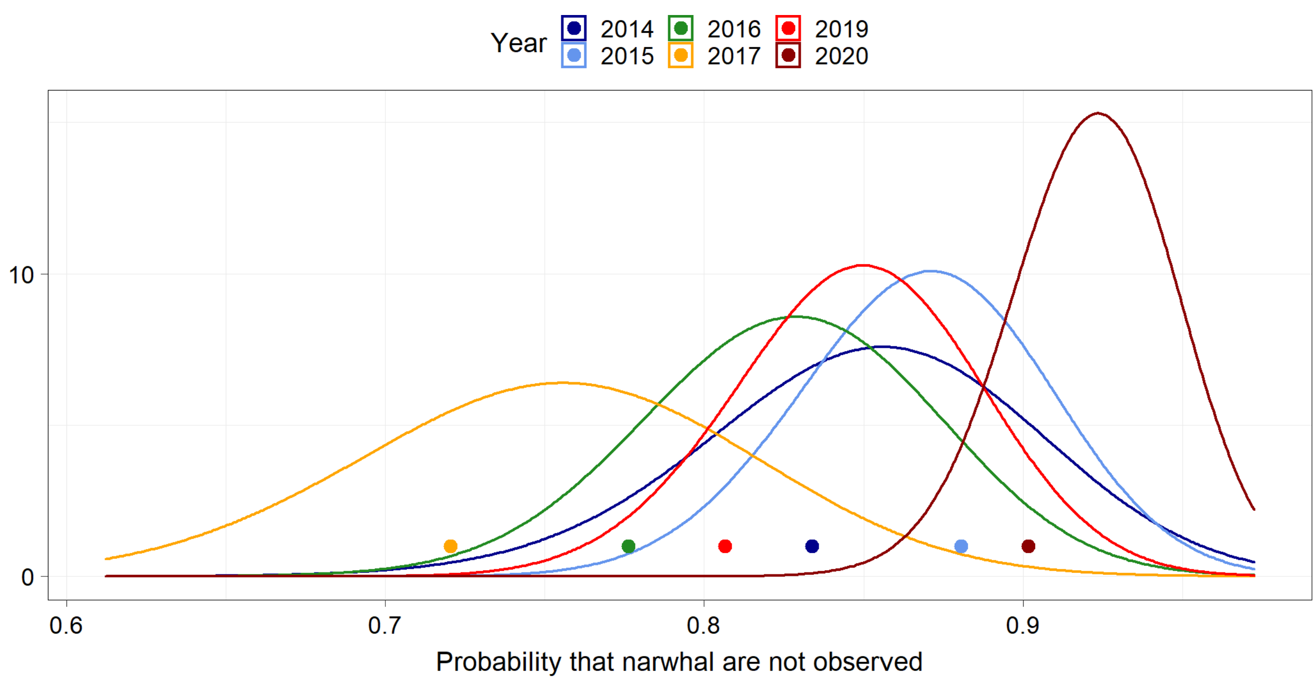


Figure E-4: Density model diagnostics – simulated zero counts. Each curve represents a different sampling year. Densities are values from 1000 data sets simulated from model selected for interpretation. Points represent the observed data.

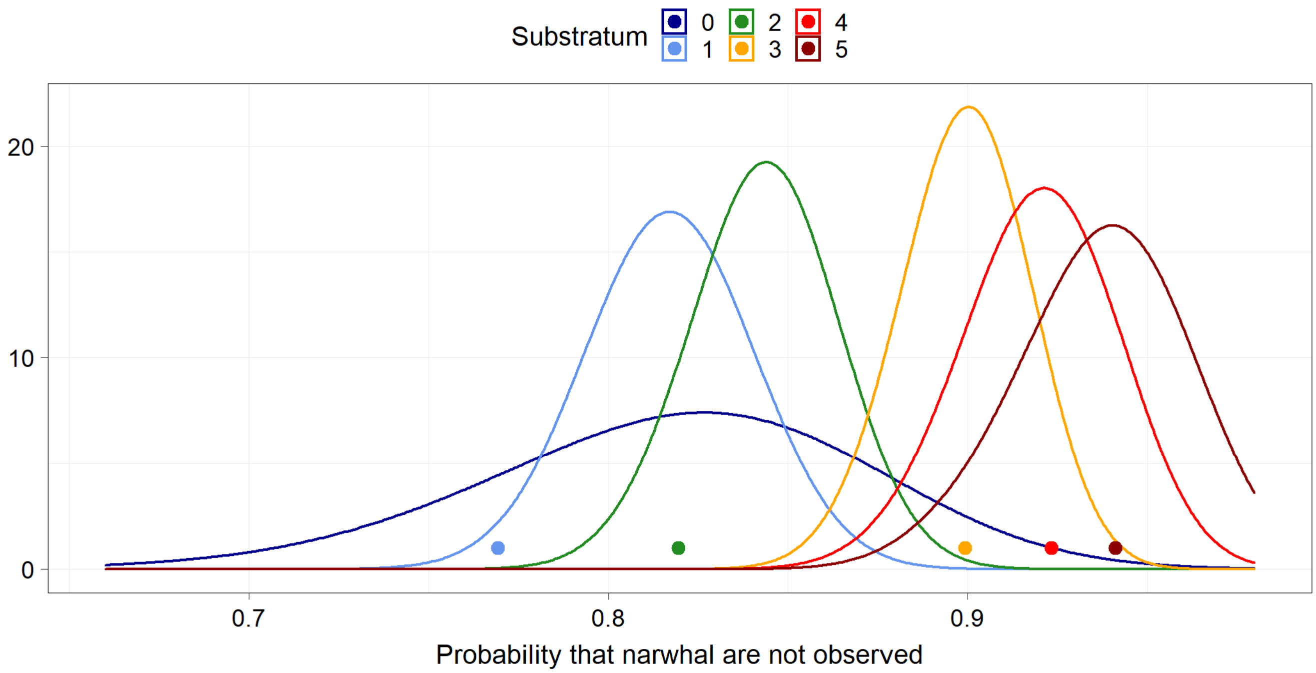


Figure E-5: Density model diagnostics – simulated zero counts. Each curve represents a different Beaufort scale value. Densities are values from 1000 data sets simulated from model selected for interpretation. Points represent the observed data.

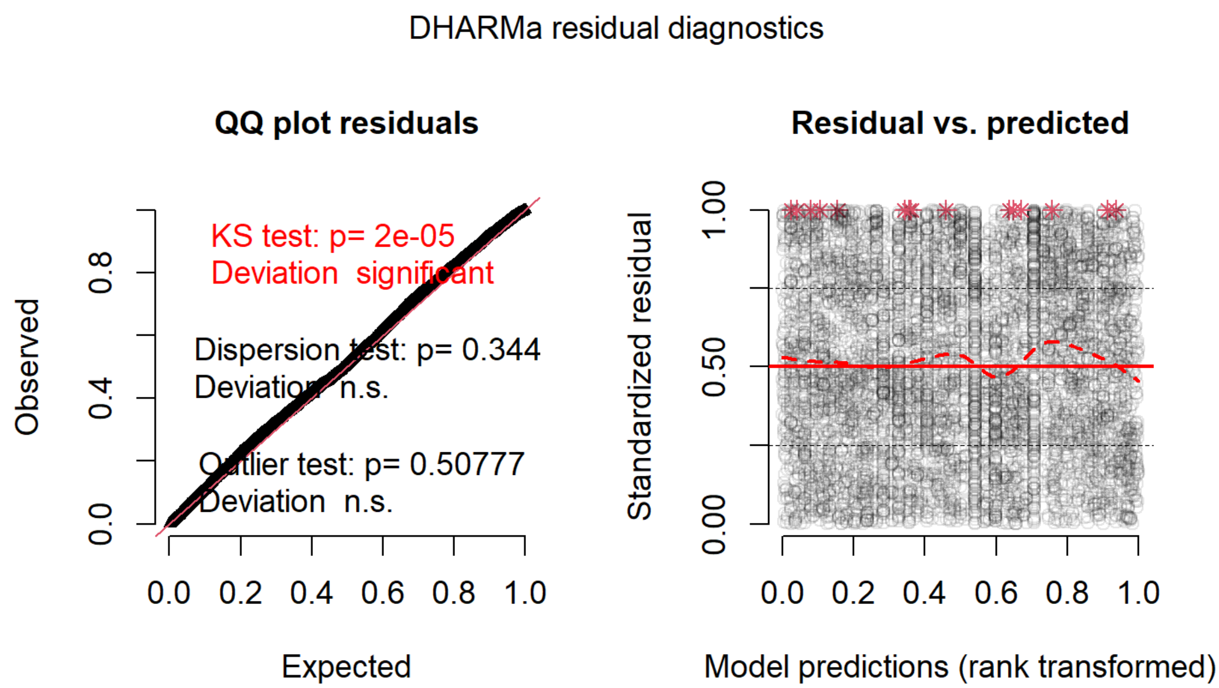


Figure E-6: Residual diagnostics for model of group size – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

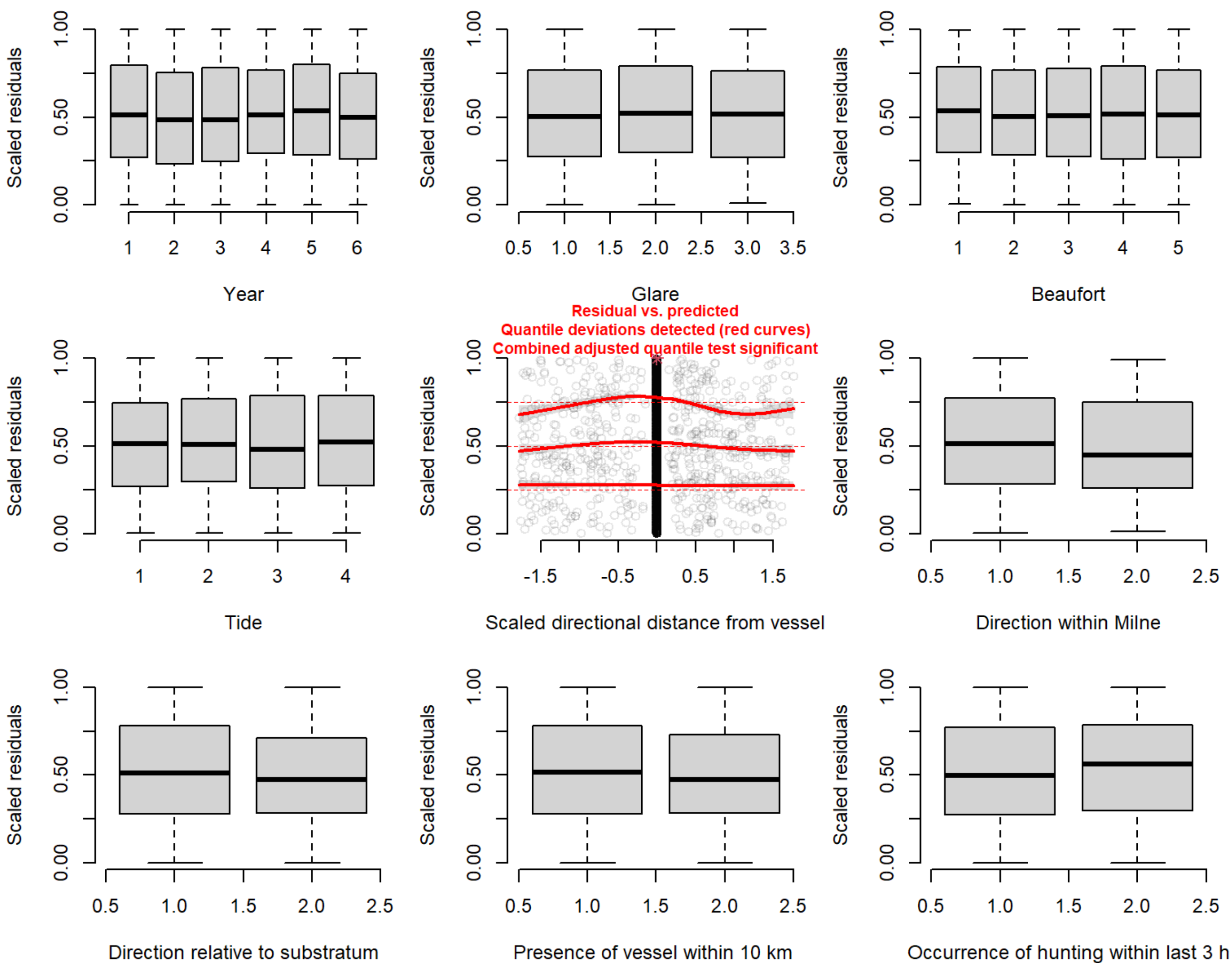


Figure E-7: Residual diagnostics for model of group size – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

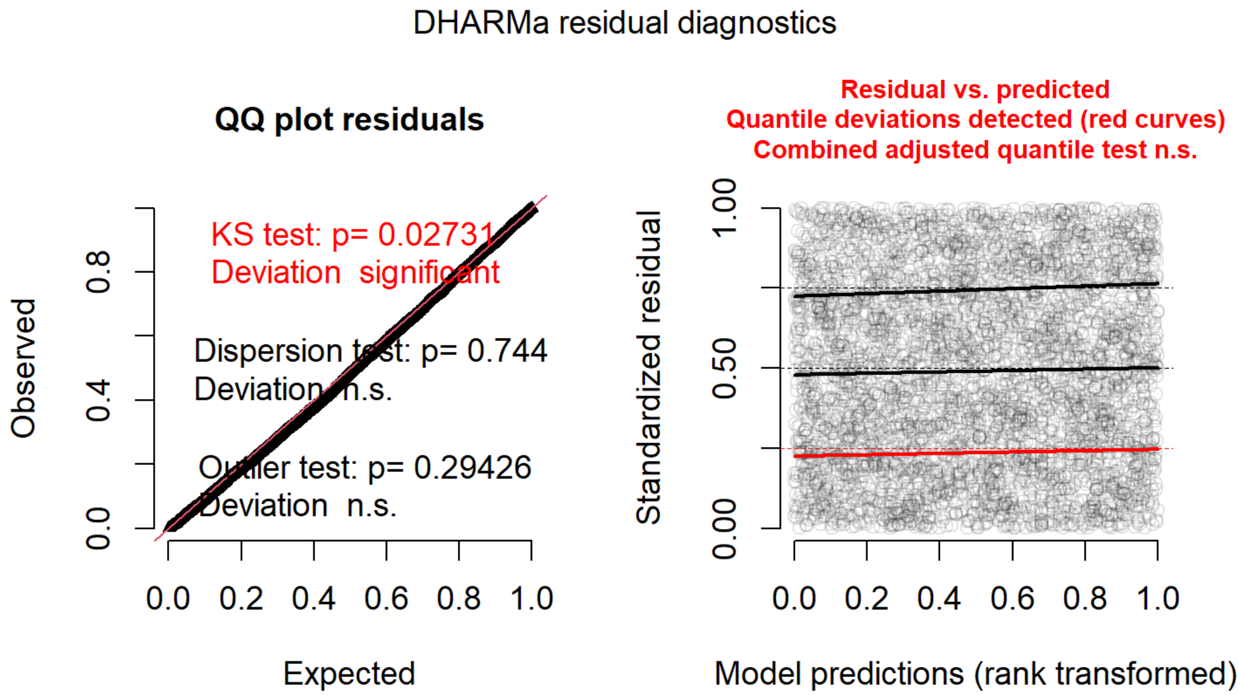


Figure E-8: Residual diagnostics for model of group composition – presence of calves and yearlings – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

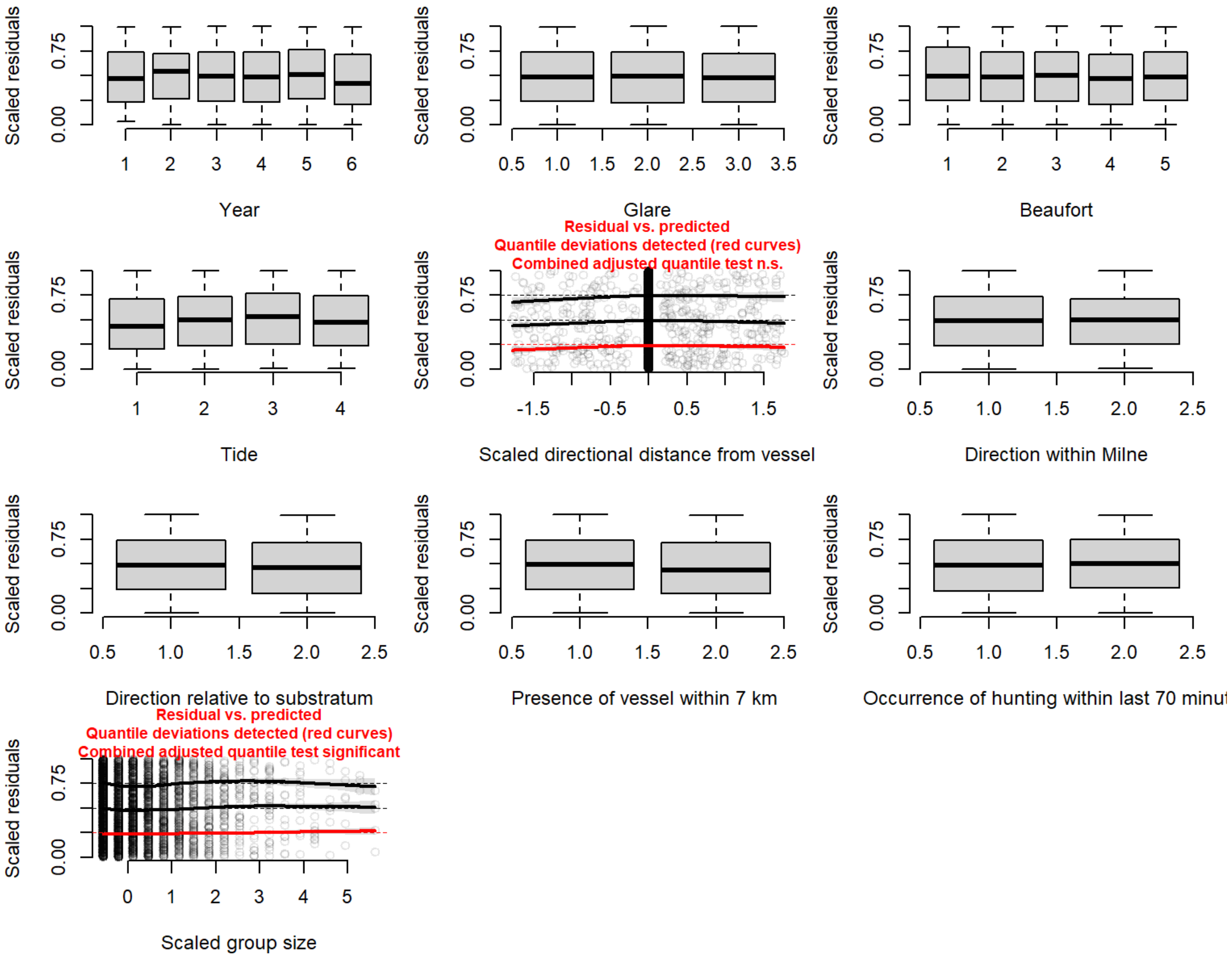


Figure E-9: Residual diagnostics for model of group composition – presence of calves and yearlings – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

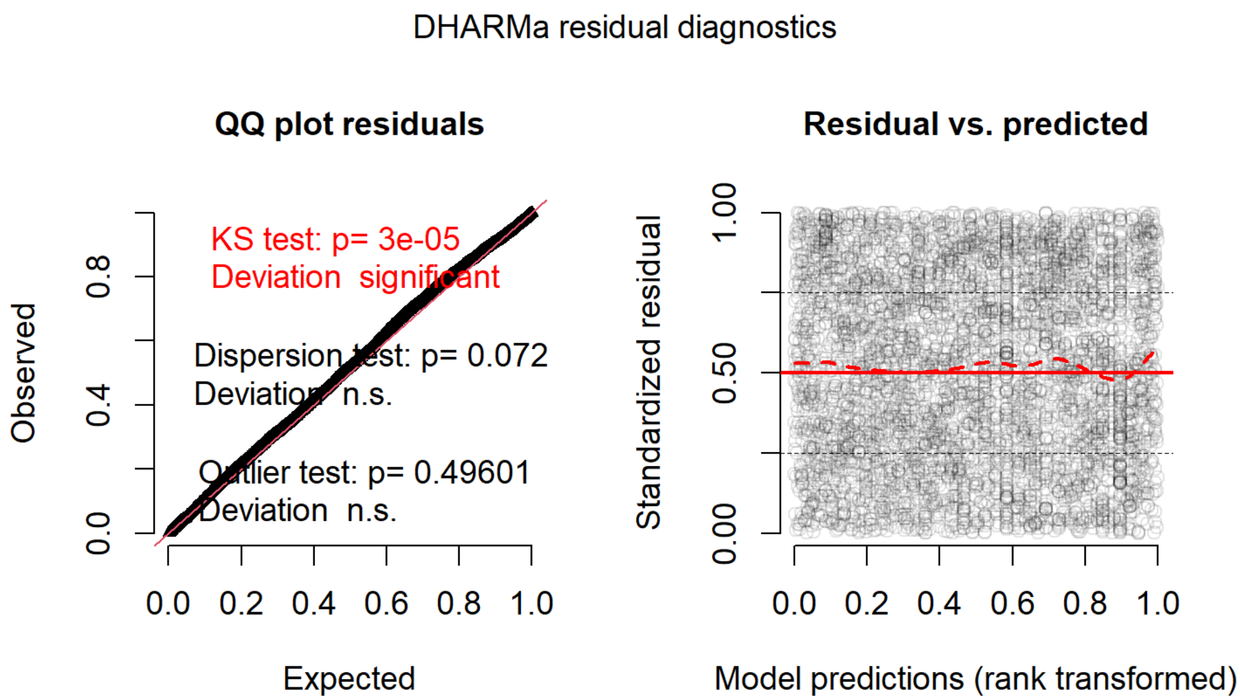


Figure E-10: Residual diagnostics for model of groups observed in a loose (rather than a tight) spread – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

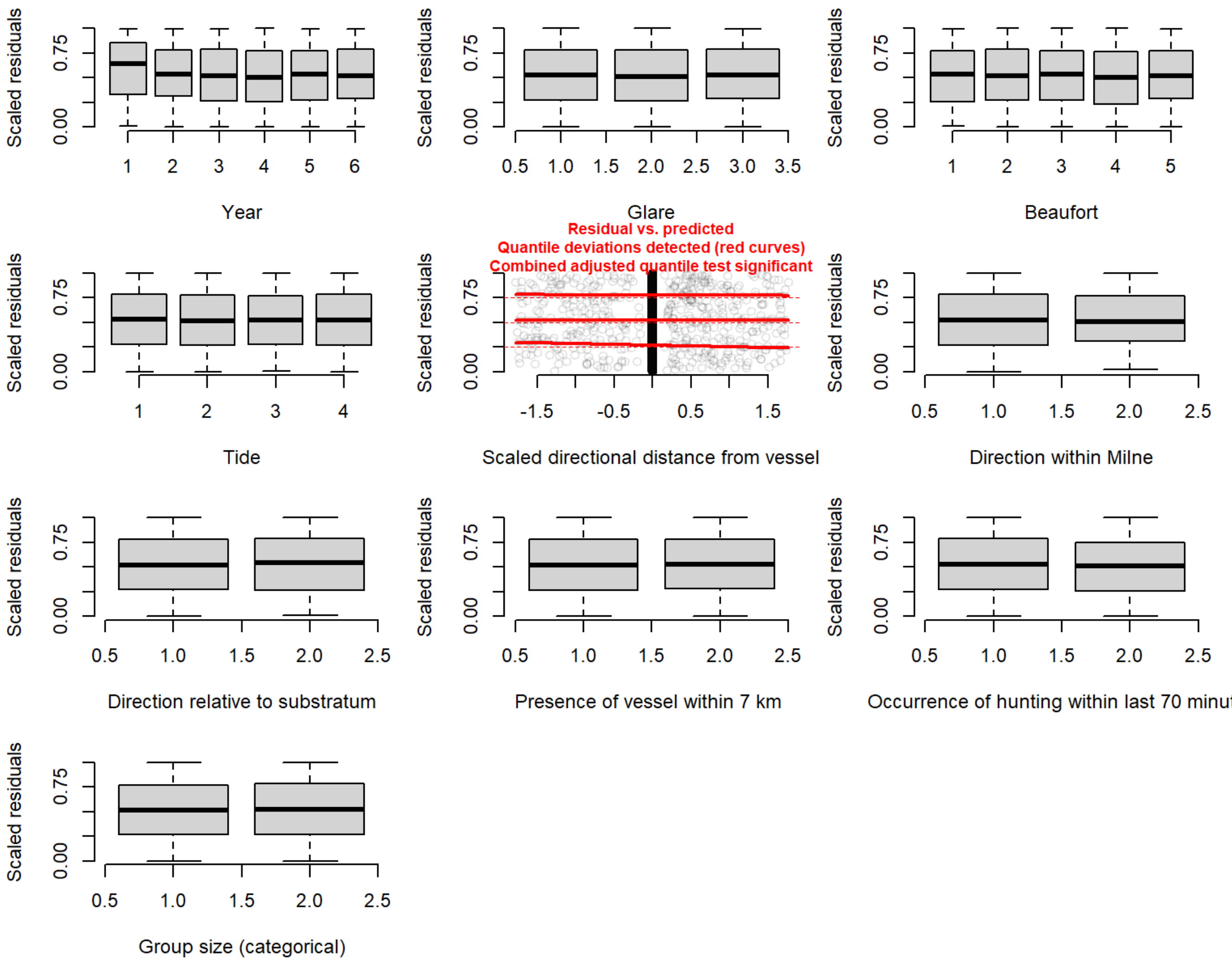


Figure E-11: Residual diagnostics for model of groups observed in a loose (rather than a tight) spread – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

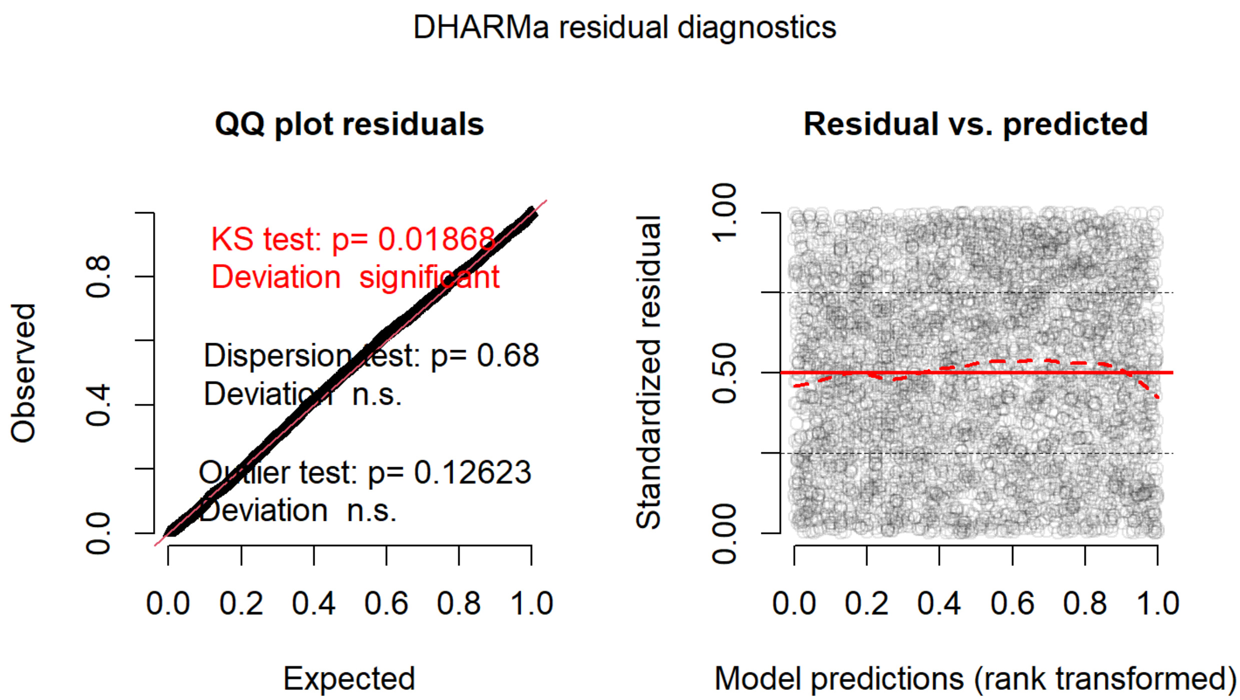


Figure E-12: Residual diagnostics for model of groups observed in non-parallel formation – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

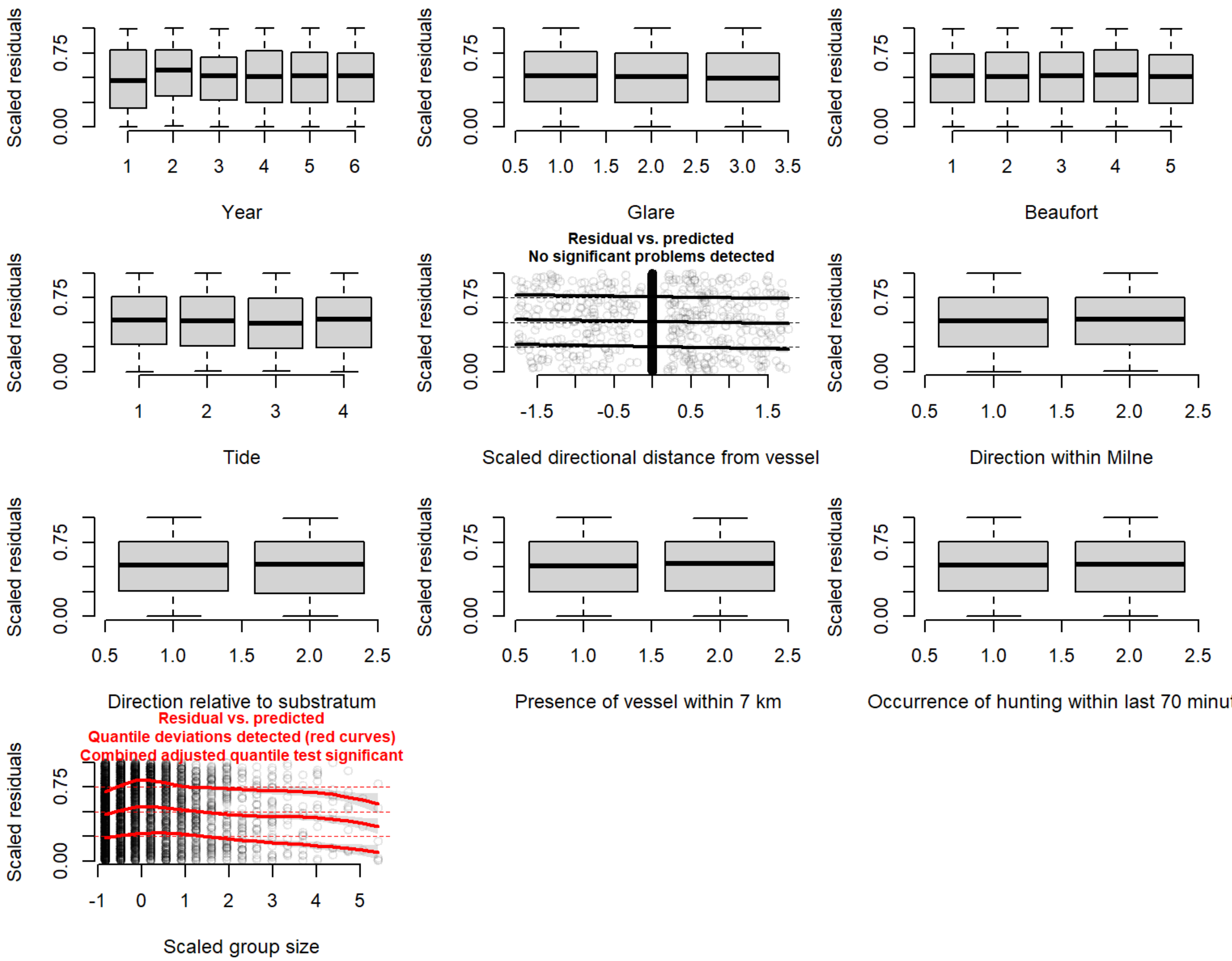


Figure E-13: Residual diagnostics for model of groups observed in non-parallel formation – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

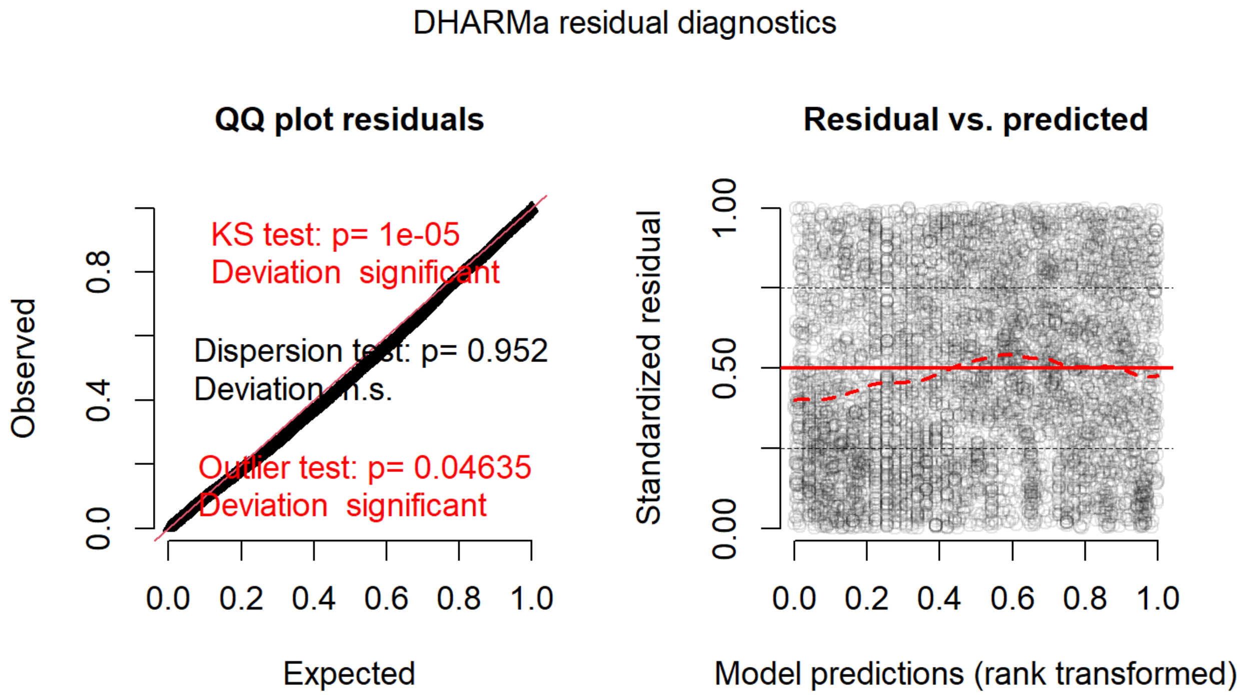


Figure E-14: Residual diagnostics for model of groups observed travelling south (rather than north) – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

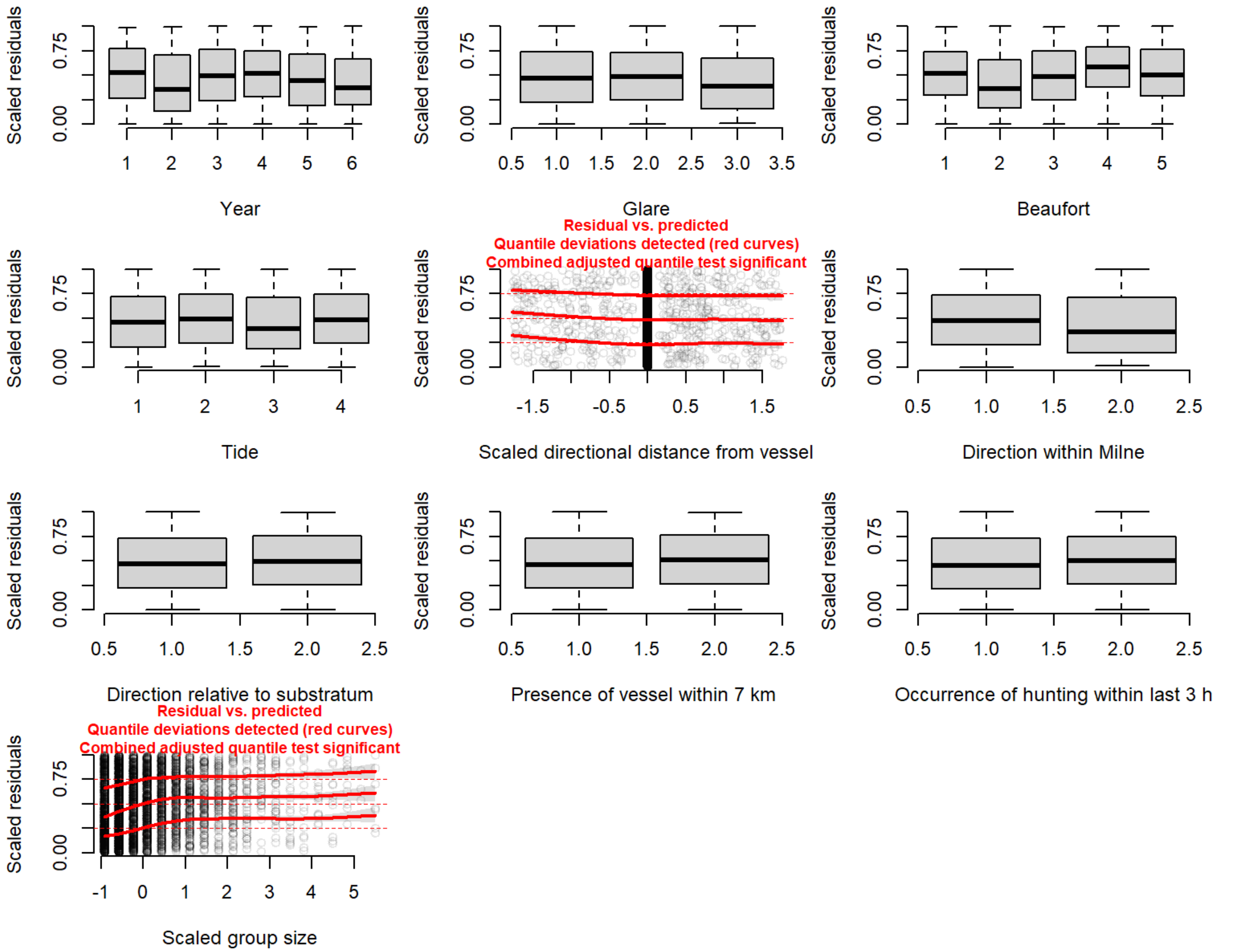


Figure E-15: Residual diagnostics for model of groups observed travelling south (rather than north) – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

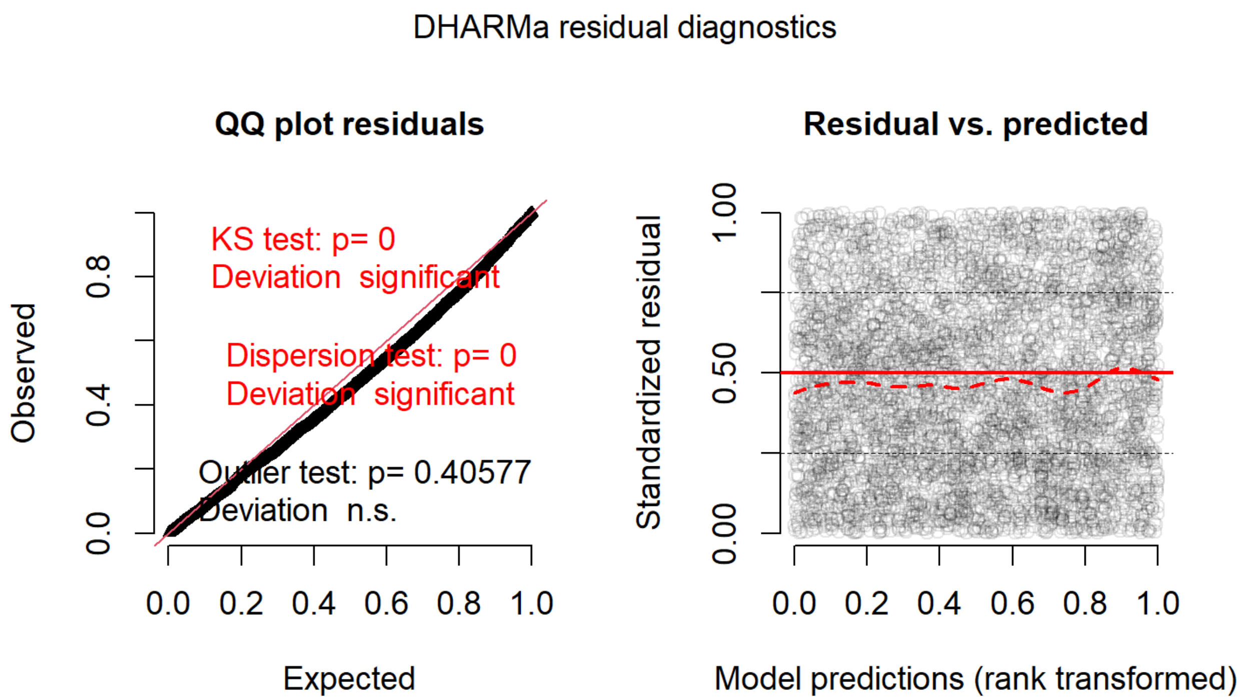


Figure E-16: Residual diagnostics for model of group travel speed (medium vs slow) – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

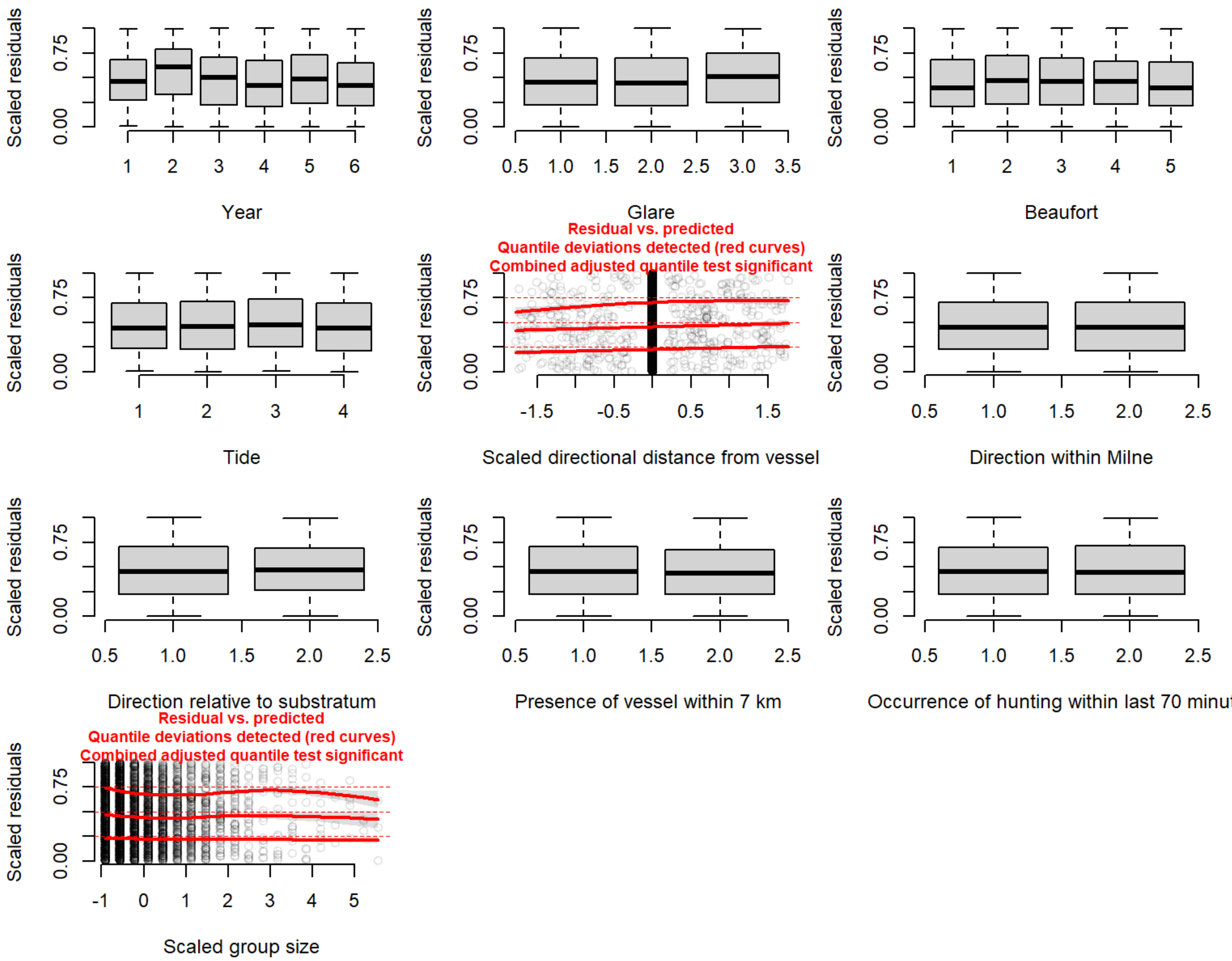


Figure E-17: Residual diagnostics for model of group travel speed (medium vs slow) – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

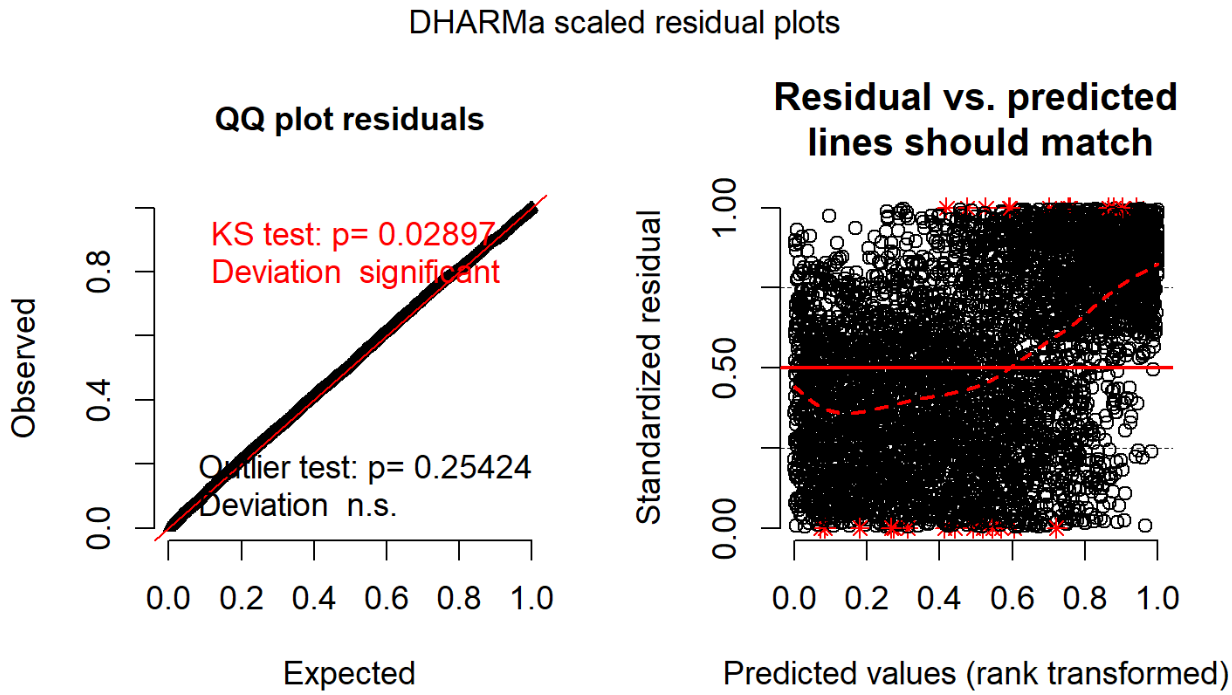
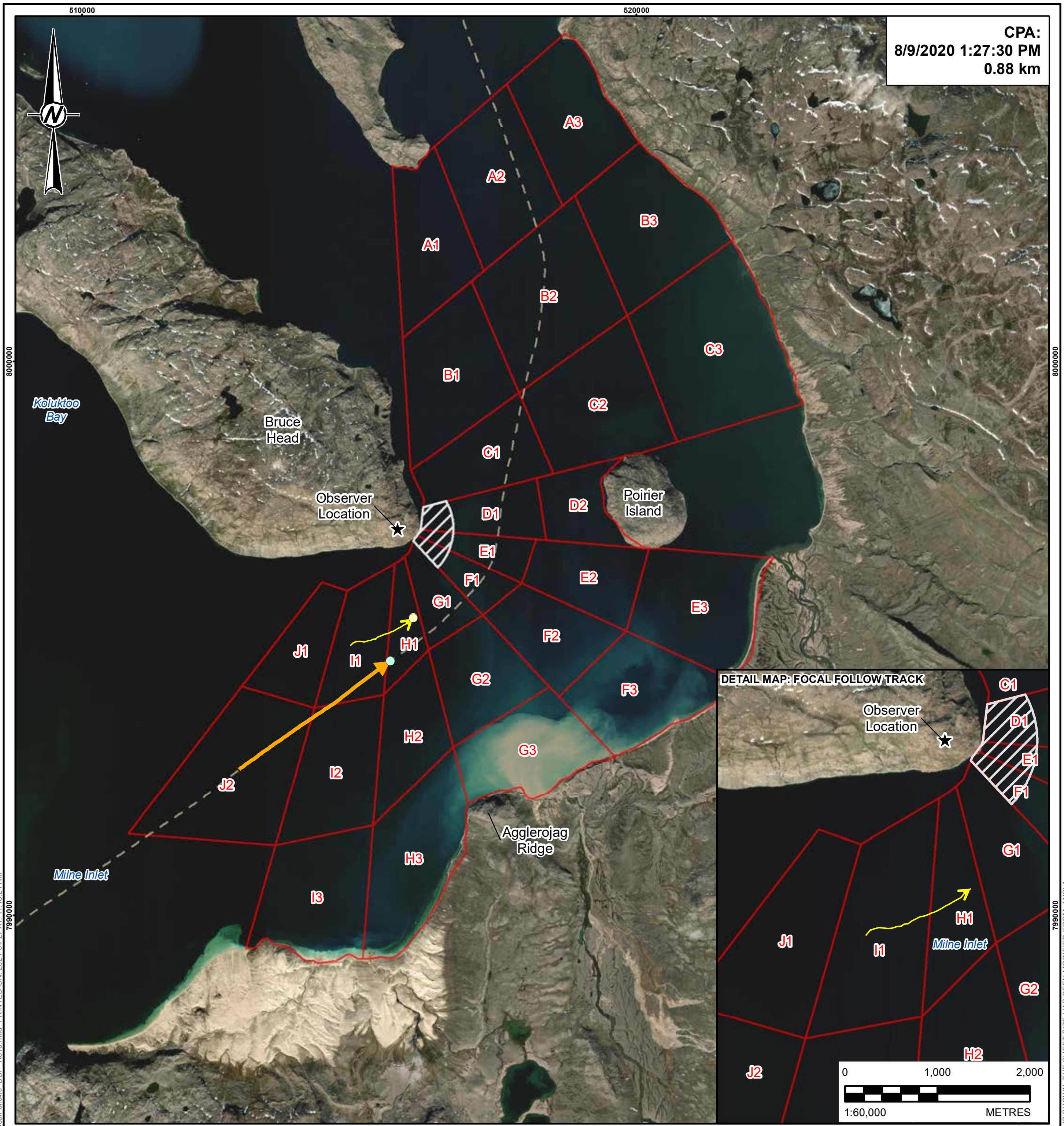


Figure E-18: Residual diagnostics for model of groups observed >300 m from shore – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

APPENDIX F

Focal Follow Survey Tracks Relative to Vessel Tracks



LEGEND

- COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 11 (2020-08-09 1:14 PM, 12 m 5 s)
- ACTIVE VESSEL TRANSIT (GOLDEN OPPORTUNITY)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN OPPORTUNITY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

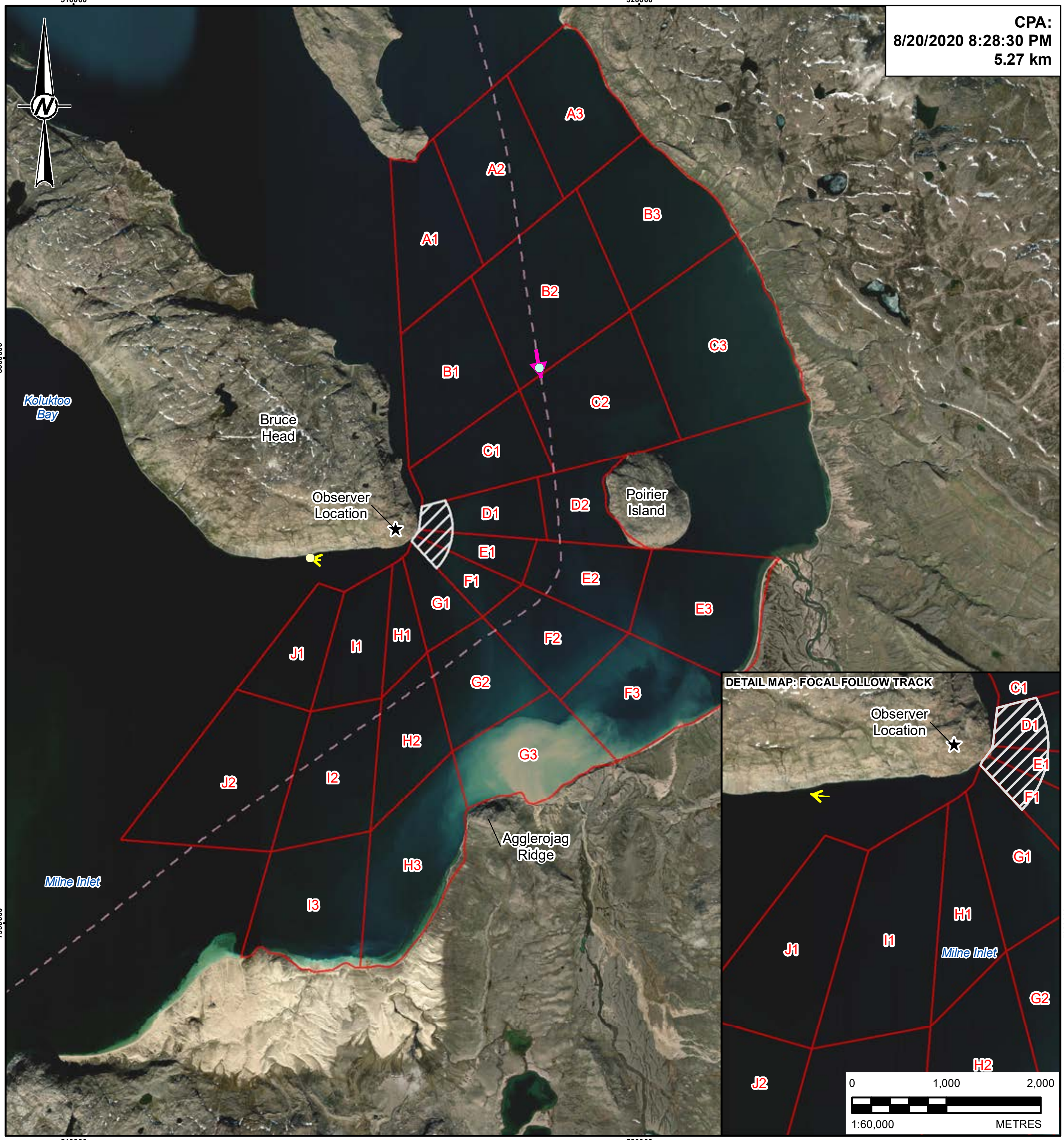
TITLE
FOCAL FOLLOW 11 AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-1



LEGEND

- COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 69 (2020-08-20 8:27 PM, 1 m 10 s)
- ACTIVE VESSEL TRANSIT (GEORG OLDENDORFF)
- NON-ACTIVE VESSEL TRANSIT (GEORG OLDENDORFF)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

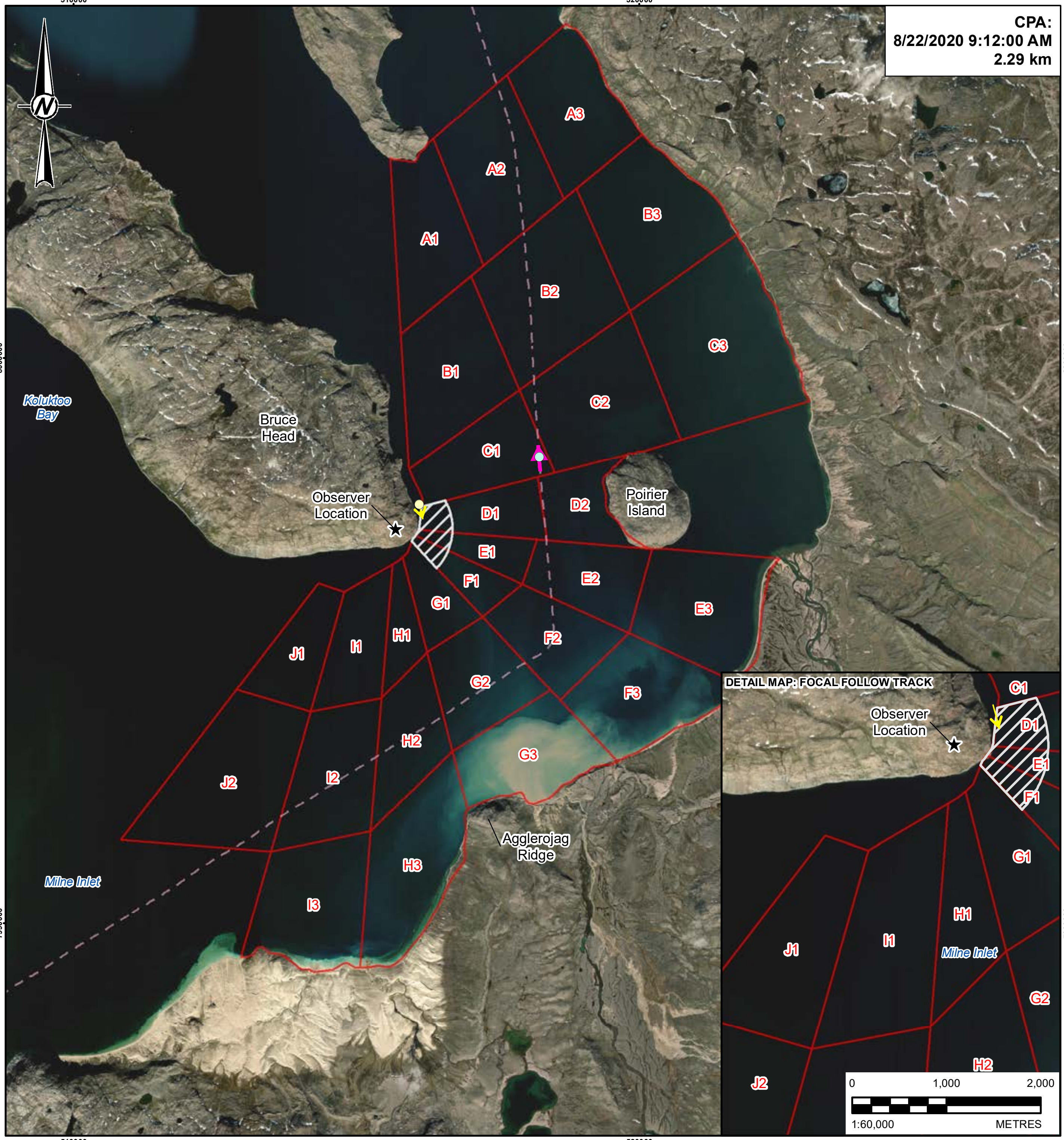
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 69 AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-2



LEGEND

- • COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- ★ OBSERVER LOCATION
- FOCAL FOLLOW TRACK 78 (2020-08-22 9:11 AM, 1 m 59 s)
- ACTIVE VESSEL TRANSIT (GEORG OLDENDORFF)
- NON-ACTIVE VESSEL TRANSIT (GEORG OLDENDORFF)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 78 AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

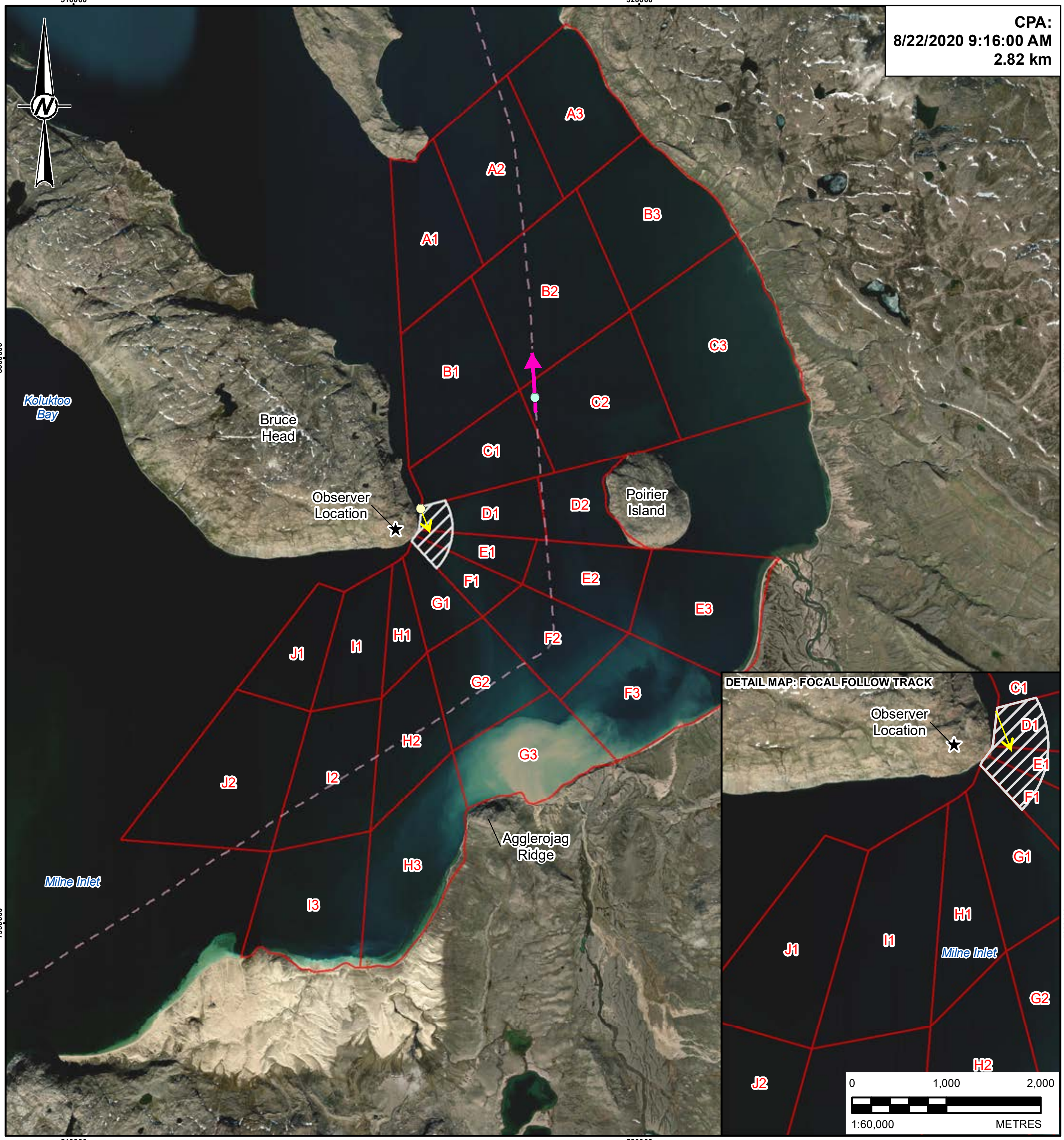
YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-3

PATH: I:\2016\1663724\Mapping\MXD\33000_UAV_Program\1663724_33000_05_FigF1_F16_FocalFollows_DDP_Rev0.mxd PRINTED ON: 2021-04-27 AT: 11:18:35 AM

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

0 25mm



LEGEND

- • COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- ★ OBSERVER LOCATION
- FOCAL FOLLOW TRACK 79 (2020-08-22 9:15 AM, 4 m 6 s)
- ACTIVE VESSEL TRANSIT (GEORG OLDENDORFF)
- NON-ACTIVE VESSEL TRANSIT (GEORG OLDENDORFF)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

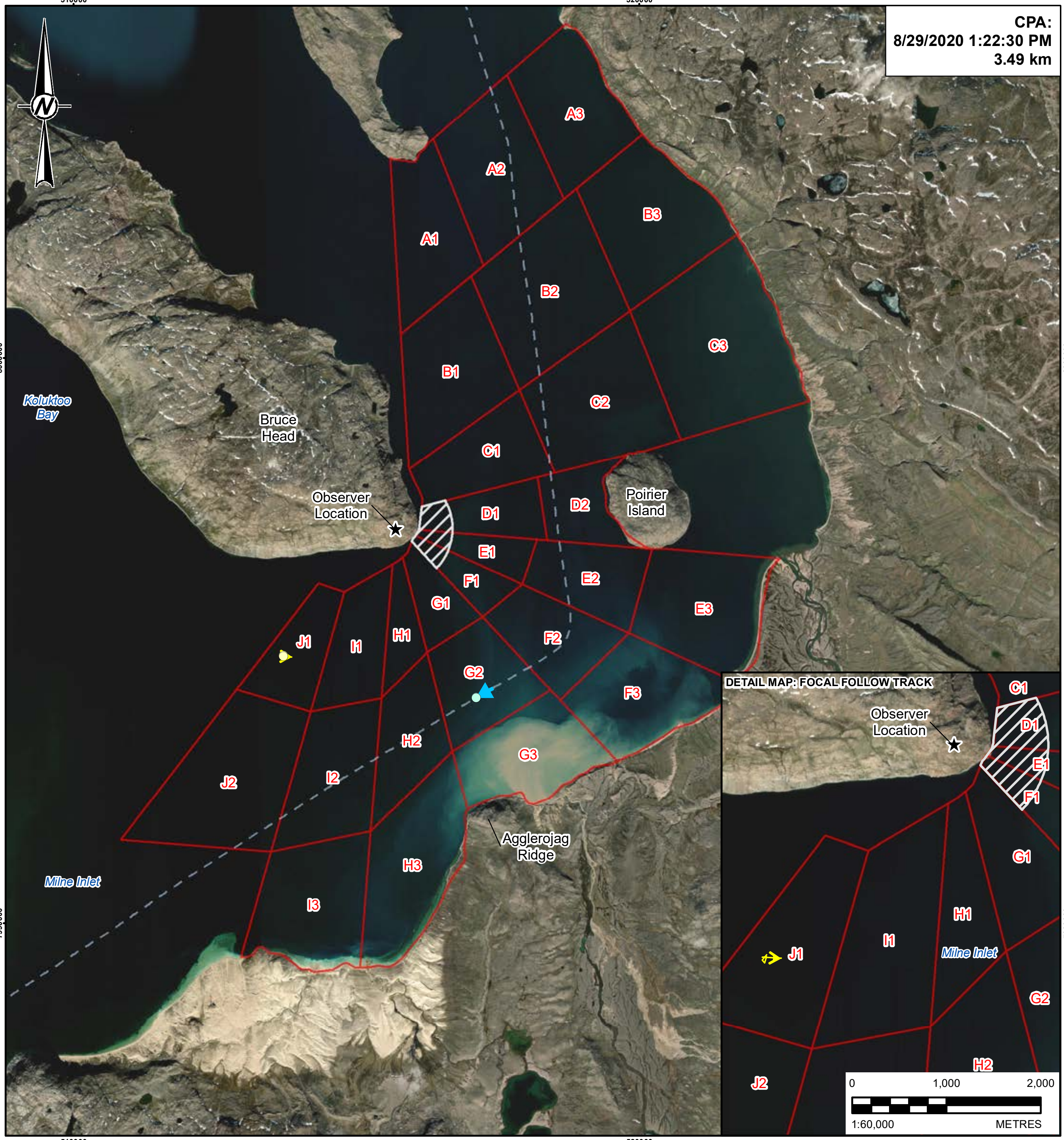
TITLE
FOCAL FOLLOW 79 AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-4



LEGEND

- COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 85 (2020-08-29 1:25 PM, 1 m 21 s)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

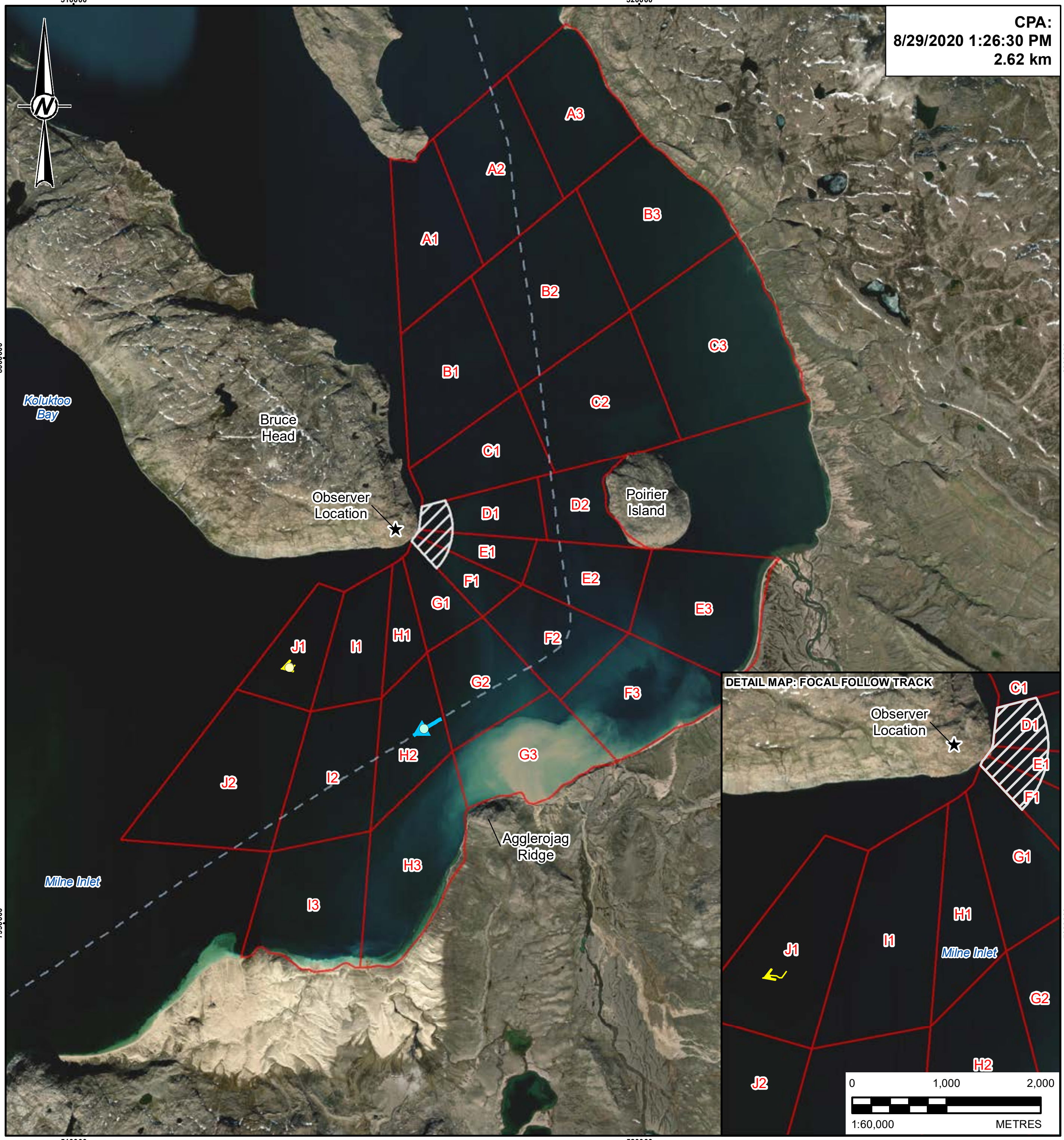
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 85 AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-5



LEGEND

- COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 86 (2020-08-29 1:25 PM, 1 m 10 s)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 86 AND ACTIVE VESSEL TRANSIT

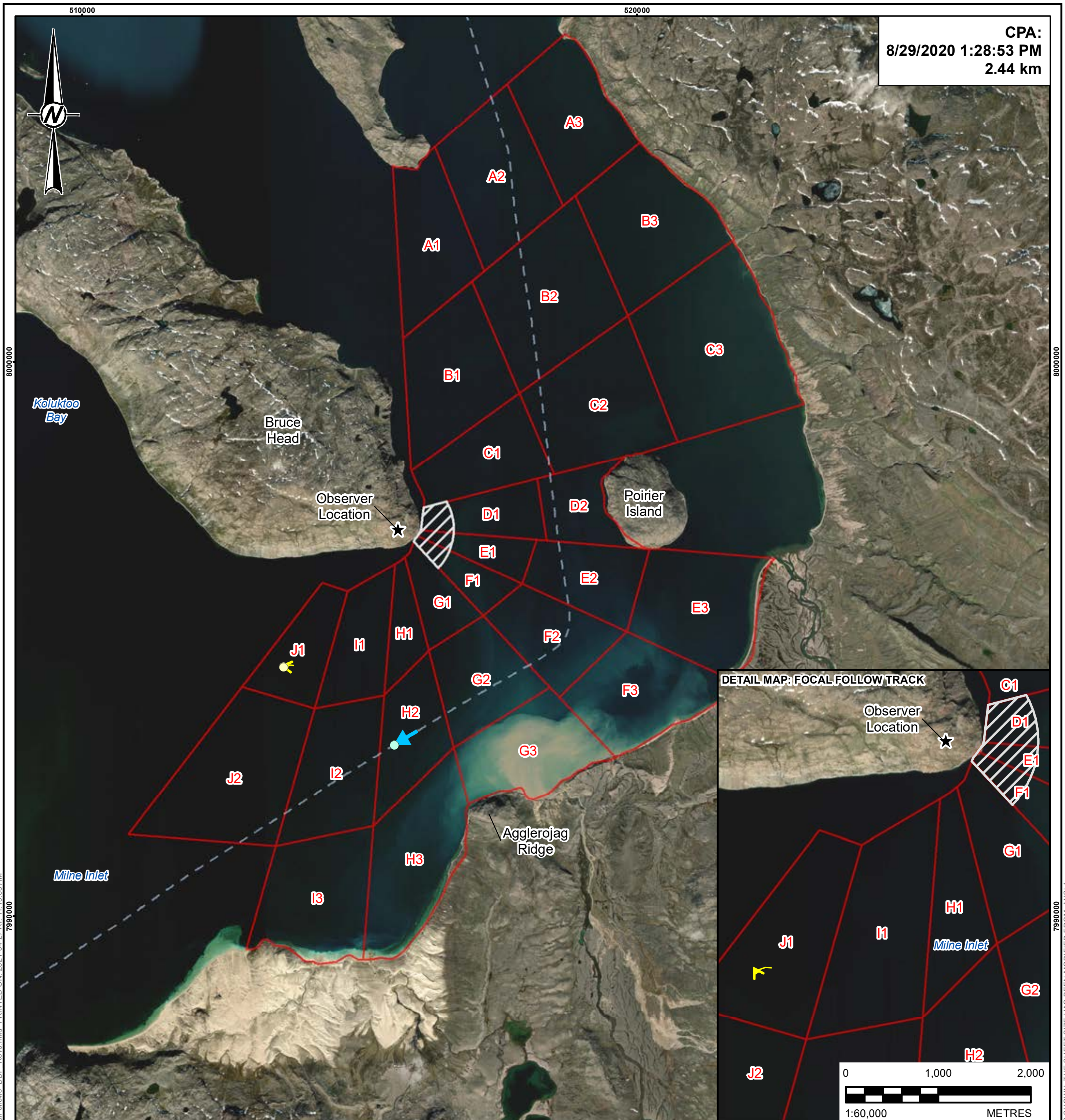
CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-6

PATH: I:\2016\1663724\Mapping\MXD\33000_UAV_Program\1663724_33000_05_FigF1_F16_FocalFollows_DDP_Rev0.mxd PRINTED ON: 2021-04-27 AT: 11:18:56 AM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25mm
0



LEGEND

- • COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- ★ OBSERVER LOCATION
- FOCAL FOLLOW TRACK 87 (2020-08-29 1:27 PM, 1 m 30 s)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

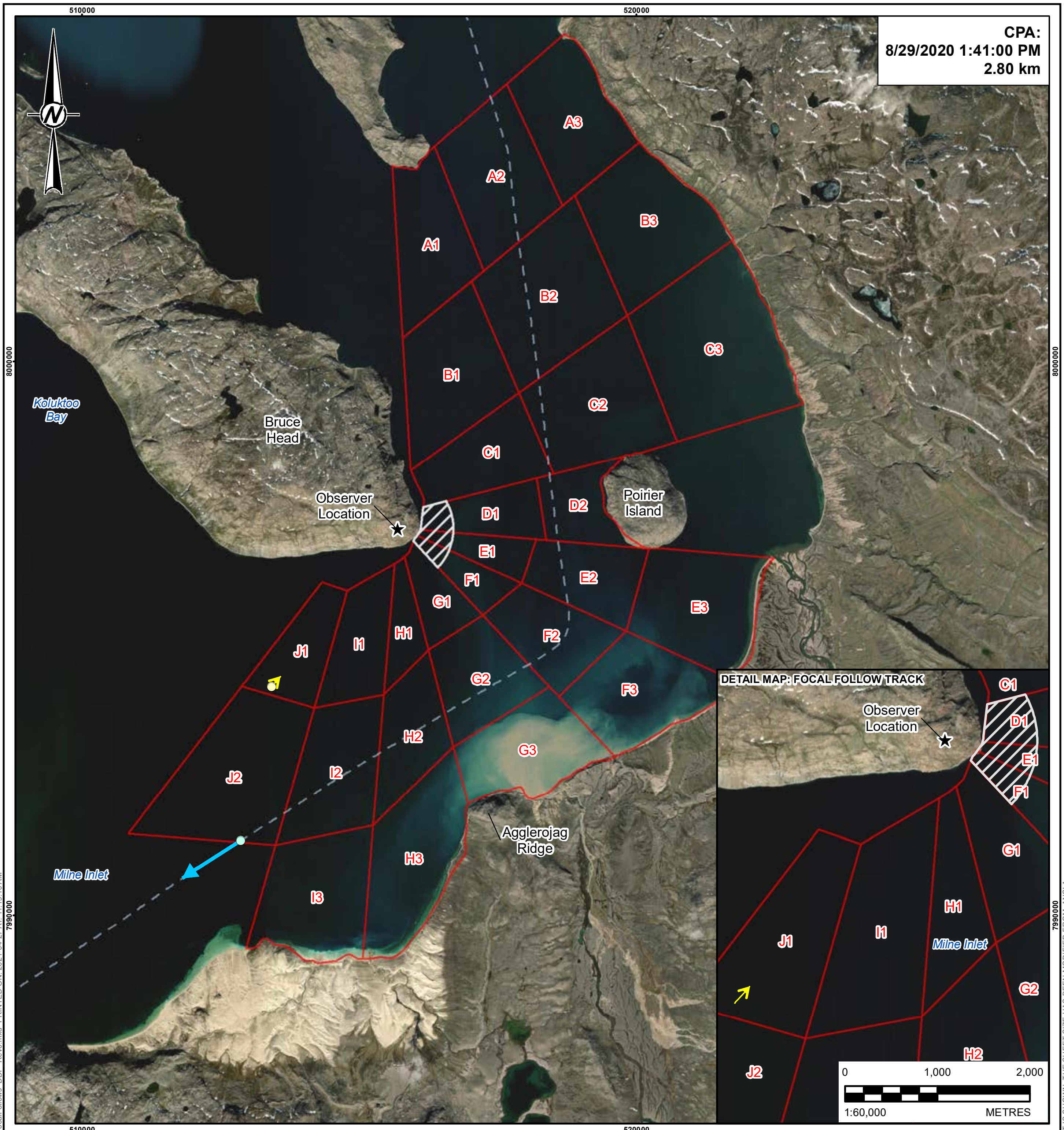
TITLE
FOCAL FOLLOW 87 AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-7



LEGEND

- COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 88 (2020-08-29 1:41 PM, 3 m 55 s)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

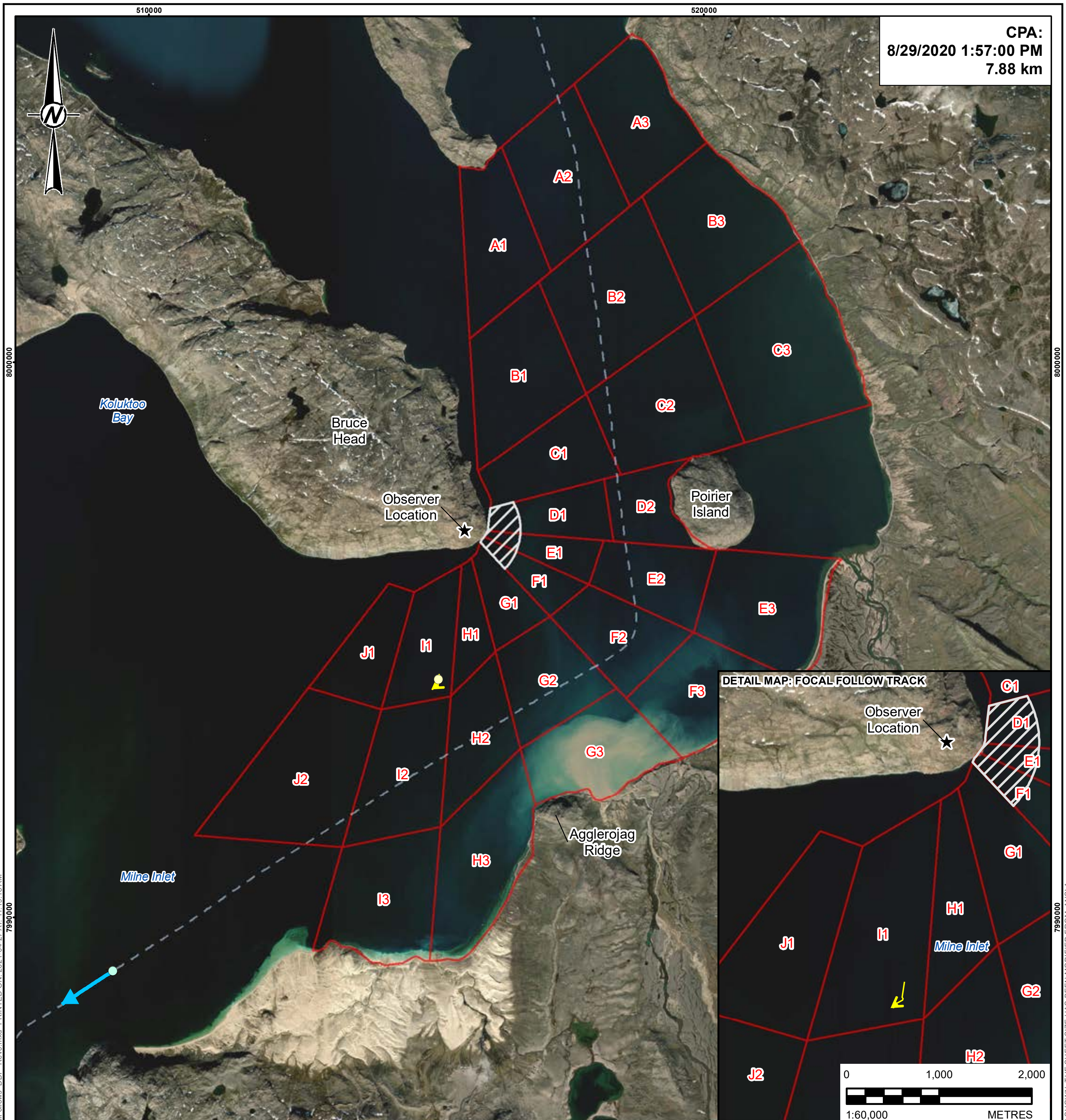
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 88 AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-8



LEGEND

- • COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- ★ OBSERVER LOCATION
- FOCAL FOLLOW TRACK 89 (2020-08-29 1:37 PM, 3 m 47 s)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 89 AND ACTIVE VESSEL TRANSIT

CONSULTANT

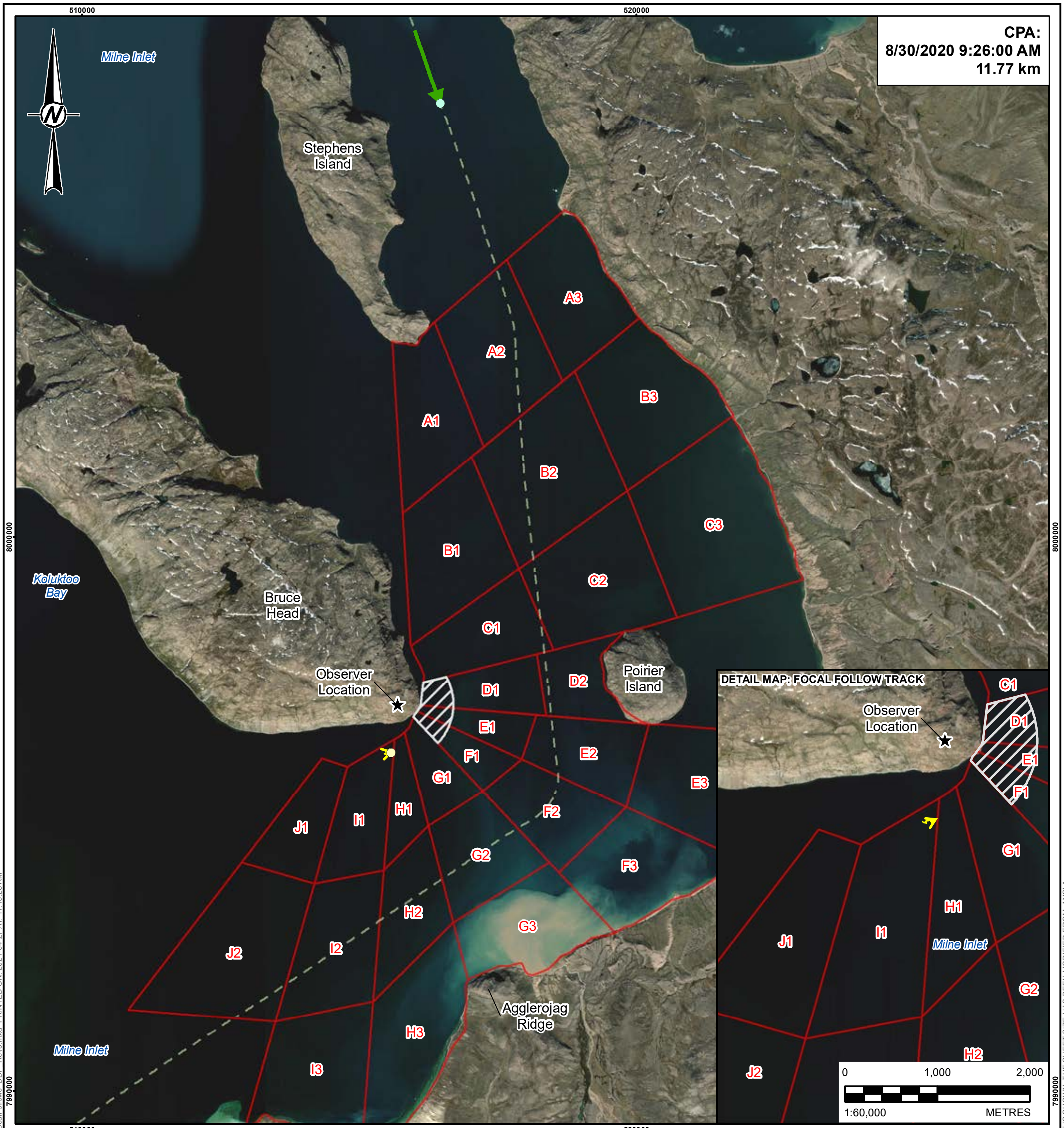
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-9

PATH: I:\2016\1663724\Mapping\MXD\33000_UAV_Program\1663724_33000_05_FigF1_F16_FocalFollows_DDP_Rev0.mxd PRINTED ON: 2021-04-27 AT: 11:19:18 AM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25mm
0



LEGEND

- COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 102 (2020-08-30 9:20 AM, 6 m 18 s)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

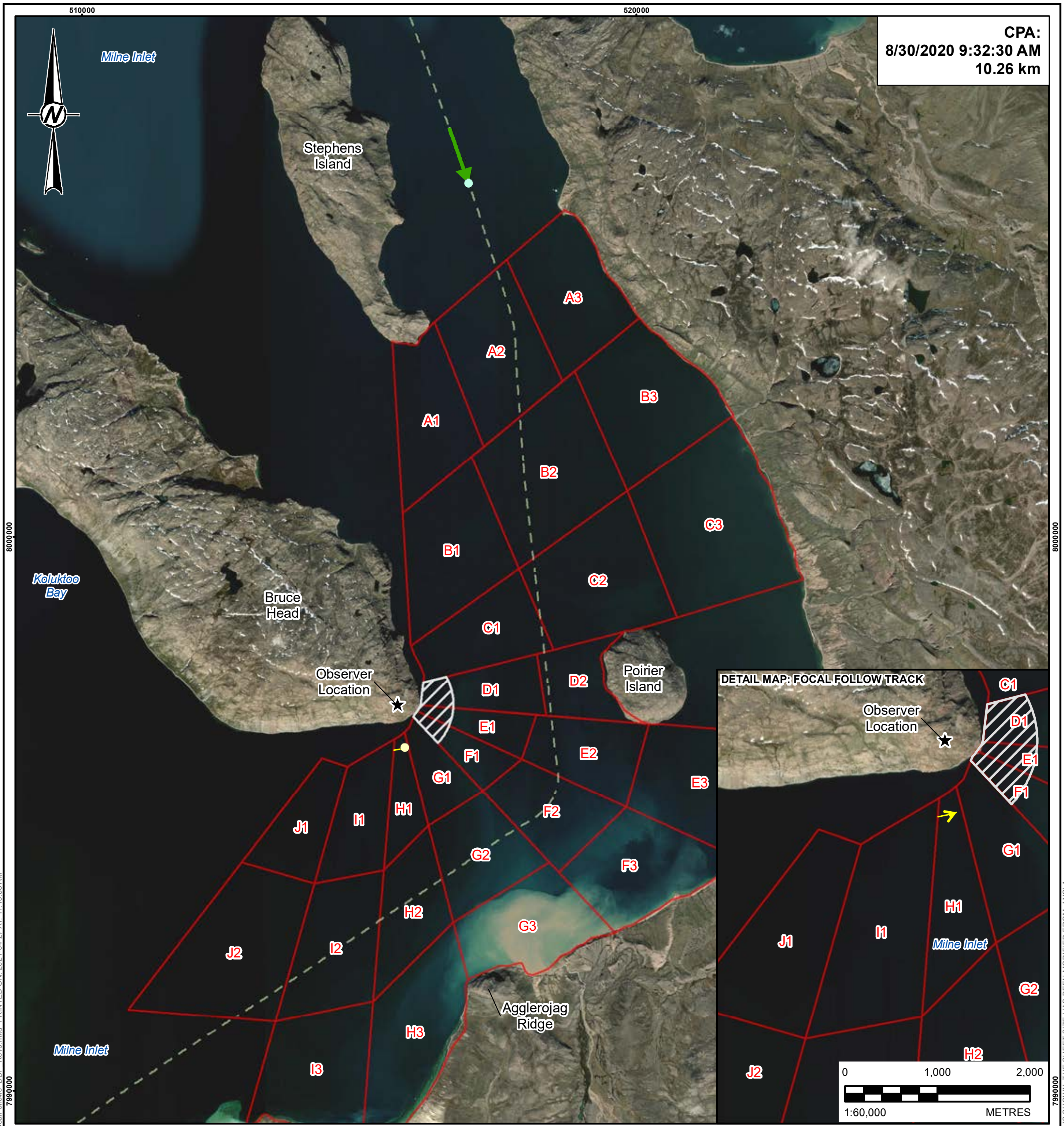
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 102 AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-10



LEGEND

- COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 103 (2020-08-30 9:28 AM, 4 m 15 s)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

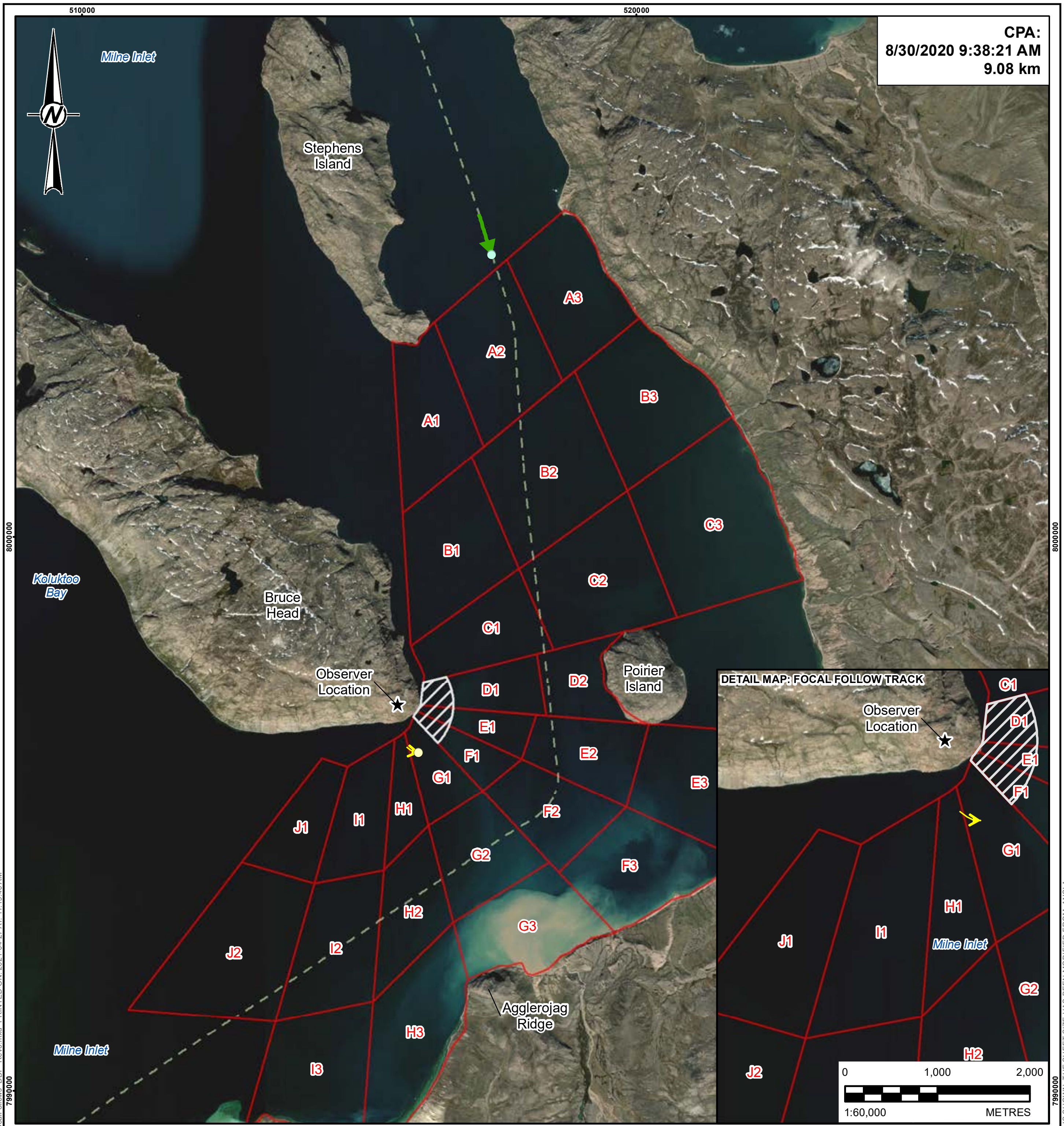
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 103 AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-11



LEGEND

- • COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- ★ OBSERVER LOCATION
- FOCAL FOLLOW TRACK 104 (2020-08-30 9:35 AM, 3 m 21 s)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

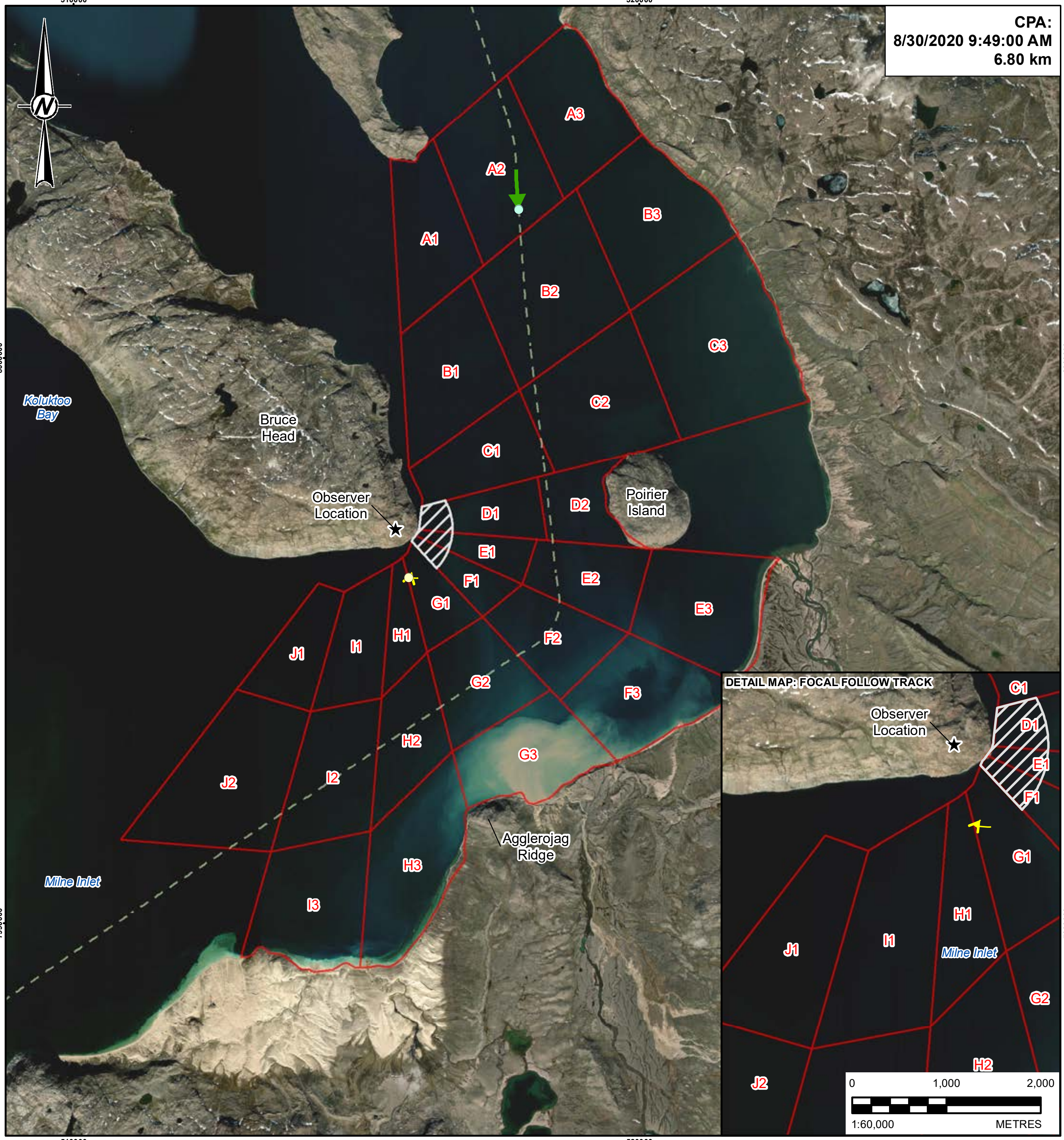
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 104 AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-12



LEGEND

- COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 105 (2020-08-30 9:46 AM, 2 m 40 s)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

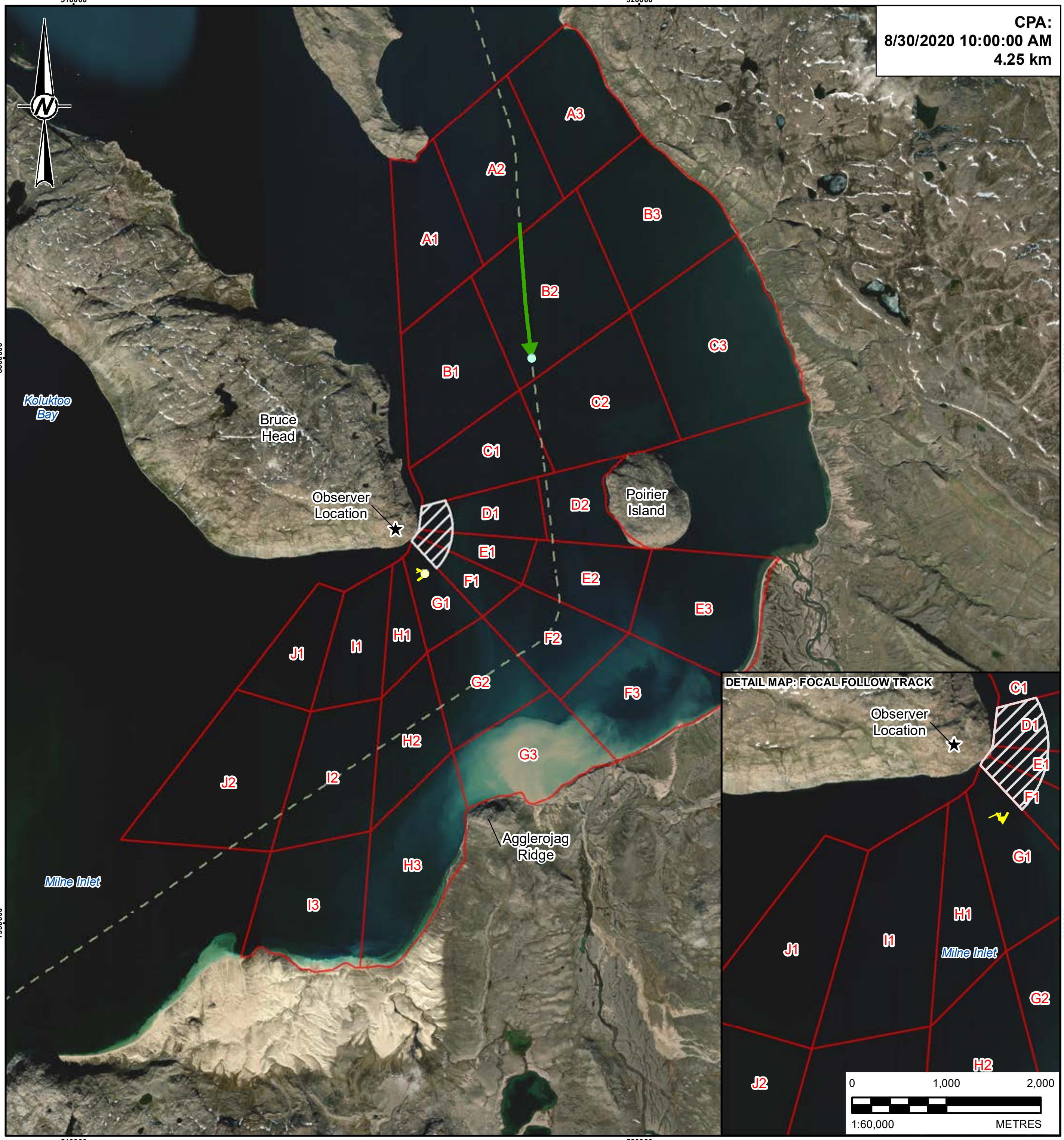
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 105 AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-13



LEGEND

- COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 106 (2020-08-30 9:50 AM, 10 m 0 s)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

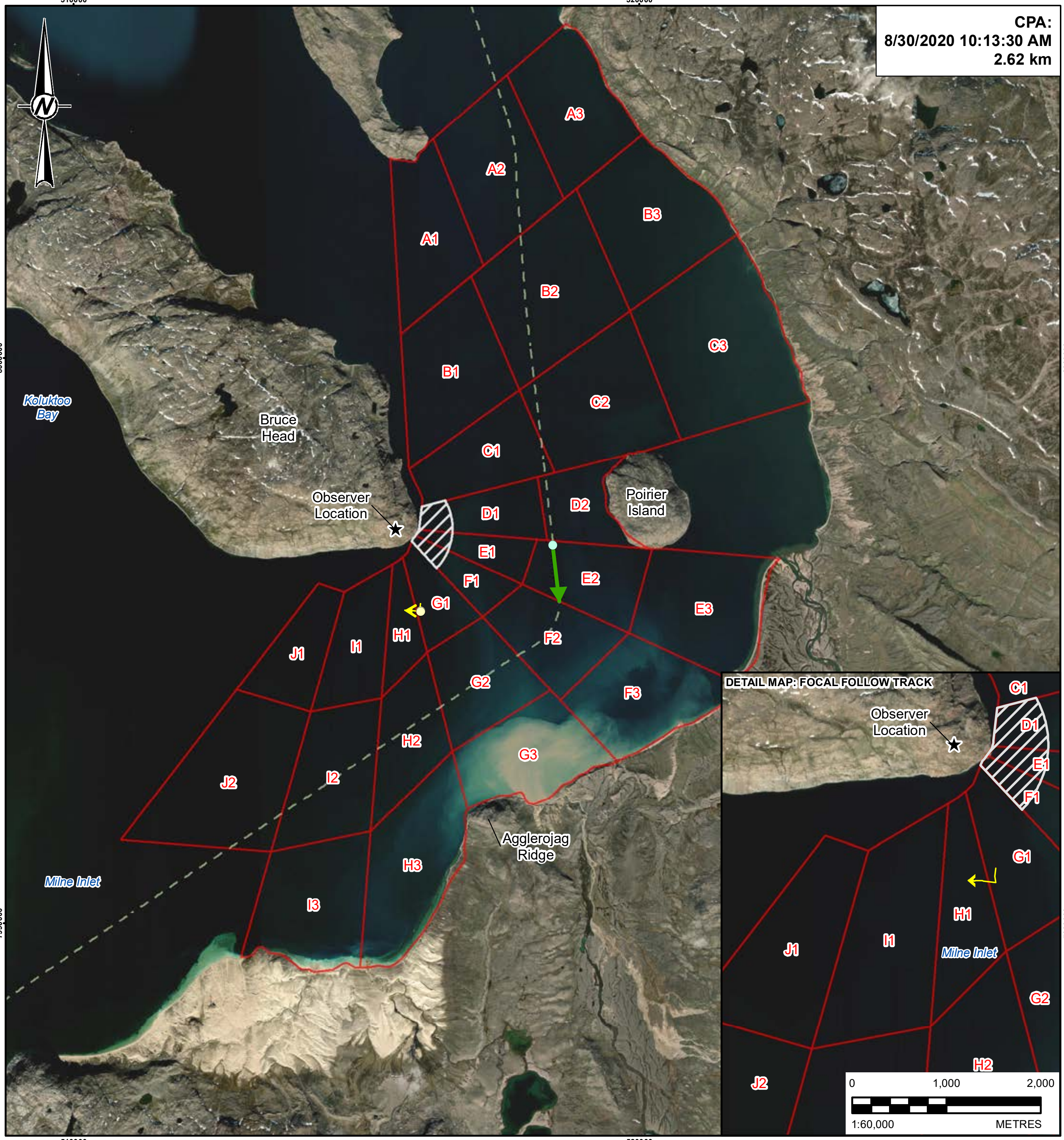
TITLE
FOCAL FOLLOW 106 AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-14



LEGEND

- COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 107 (2020-08-30 10:13 AM, 4 m 45 s)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

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 BIM, JULY 14, 2020.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

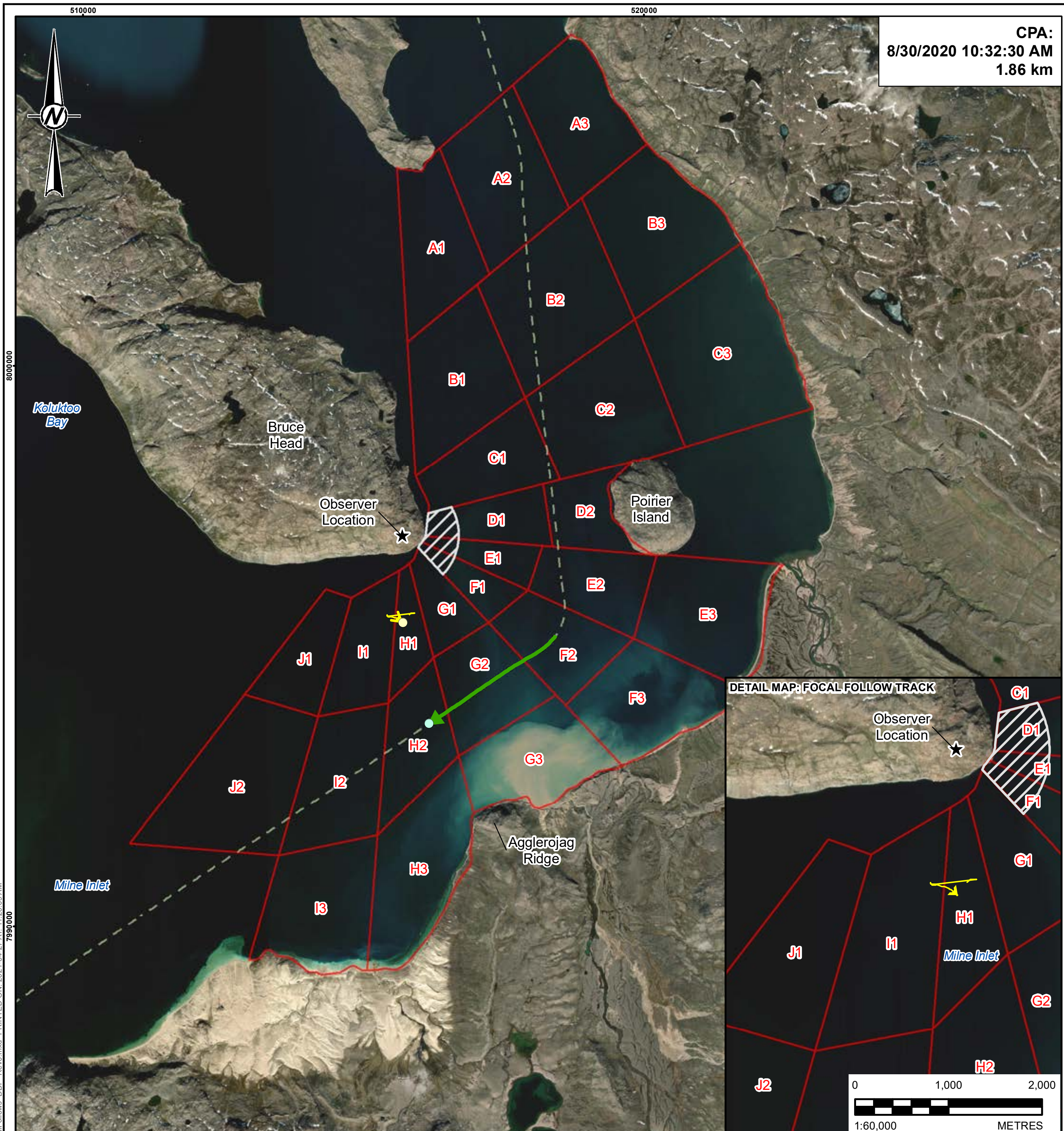
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 107 AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-15



LEGEND

- COMMUNITY
- CPA (FOCAL FOLLOW)
- CPA (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 108 (2020-08-30 10:20 AM, 12 m 49 s)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 108 AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-04-27
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	33000	0	F-16

APPENDIX G

Information Requests

Name: Marianne Marcoux

Agency / Organization: Fisheries and Oceans Canada

Date of Comment Submission: July 9, 2021

#	Document Name	Section Reference	Comment	Baffinland Response
1	Mary River Project 2020 Bruce Head Shore-based Monitoring Program	P iv. Executive Summary -Group Composition and Behaviour	BIM states that "*Specific to this response variable (i.e., group size), no evidence is presented for large-scale avoidance behaviour, displacement effects, or abandonment of the summering grounds (high severity responses), which might in turn result in a population or stock-level consequence (consistent with the definition of a significant effect used in the FEIS).*" This interpretation of the results is misleading since this data does not provide information on large-scale avoidance or abandonment. These data only provide information of the group size and behaviour of narwhals that stayed within the study area. These results do not provide evidence that large-scale avoidance or abandonment is not happening.	Large-scale avoidance in the Bruce Head study would be considered a long-duration response (high severity response). This is defined in the report in Section3.0 as: <<What constitutes a long-duration response is different for each situation and species, although it is likely dependent upon the magnitude of the response and species characteristics such as body size, feeding strategy, and behavioural state at the time of the exposure. In general, a response would be considered 'long-duration' if it lasted up to several hours, or enough time to significantly disrupt an animal's daily routine. For the derivation of behavioural criteria in this study, a long duration was defined as a response that lasted for the full duration of vessel exposure or longer. This assumption was made because examination of behavioural response data suggests that had the vessel exposure continued, the behavioural responses would have continued as well.>>

#	Document Name	Section Reference	Comment	Baffinland Response
2	Mary River Project 2020 Bruce Head Shore-based Monitoring Program	P iv. Executive Summary -Group Composition and Behaviour - Group composition	BIM compared the proportion of juveniles of 2020 to other years. What is the variance around the measures of the proportion of juvenile? Are the difference between years significant? How precise are the measure of proportion of juveniles?	Table 6-5 in the 2021 Bruce Head Shore-based Monitoring Program has been revised to include the measure of variance (standard deviation) for 'daily proportion of immatures.' The proportions were not statistically tested for significant differences between years, given that this test would not account for other variables (such as changes in hunting activity, and differences in glare [which affects detection of young] between years). While the proportions of immatures were not statistically tested, the differences in presence/absence of immatures between years were assessed as part of a mixed model. The differences in presence / absence of immatures between years in this model were not statistically significant. That is, after accounting for other variables, there is no significant difference in presence of immatures between years.

#	Document Name	Section Reference	Comment	Baffinland Response
3	Mary River Project 2020 Bruce Head Shore-based Monitoring Program	P iv. Executive Summary UAV Focal Follow Surveys	BIM provides the % of time narwhals spent doing different behaviours and suggest that the behavioural budget does not change in presence of ships. What statistical test was used to come to this conclusion?	Additional text has been added to Section 7.4 to clarify future analysis intent. Specifically, once sufficient data are collected, the quantitative analysis for the focal follow surveys is expected to be similar to the generalized linear mixed models performed for the 2017-2018 narwhal tagging data (Golder 2020a), where various response variables were defined based on the collected behavioral data, and vessel distance was used as a predictor to assess shipping effects on narwhal behavior.
4	Mary River Project 2020 Bruce Head Shore-based Monitoring Program	Table 5-1: Group composition and behavioural data collected in the BSA	How was narwhal speed measured? Was there a standard way to quantify narwhal speed?	It has been acknowledged in the report (i.e. the Executive Summary and Section 8.0), that this response variable (travel speed) is inherently subjective (variable by observer) and that the results may be influenced by the data being recorded by multiple observers. This lowers the overall confidence in the effectiveness of using travel speed as a behavioral response variable using this method. Based on attempts at tracking narwhal in the BSA using a theodolite during previous years at Bruce Head, it has proved challenging to follow narwhal groups long enough to collect an accurate travel speed measurement. Efforts are being made to track this response variable more accurately using UAVs and/or a fixed video camera (with shoreline reference points) in 2021.

#	Document Name	Section Reference	Comment	Baffinland Response
5	Mary River Project 2020 Bruce Head Shore-based Monitoring Program	p. 37 5.4.2 Statistical Models 5.4.2.1 Updates to Analytical Approach -Small vessel effects	It is stated that small vessels passing directly below the observation platform might be missed. Could you comment on missing narwhal observations directly under the observation platform?	Narwhal typically travel through the BSA in a predictable pattern and at a relatively slow speed, which gives the MMOs an extended window to document behavioural observations. Sighting of animals may become obscured by the cliff along a small segment of the shoreline directly below the platform. The introduction of a no-fly zone in relative to proximity of the hunting camps along the shorelines means it is not possible to use UAVs to capture sightings of the narwhal obscured by the platform or shoreline.
6	Mary River Project 2020 Bruce Head Shore-based Monitoring Program	p.39 5.4.2.3 Narwhal Density Modelling	How did you account for the potential bias in narwhal detectability in each substratum for this analysis?	To evaluate observer detection performance (i.e., the ability of MMOs to effectively detect animals in all substrata), the SSA was to be surveyed via UAV concurrently with shore-based observers and then numbers compared. However, due to a mechanical issue with the drone, this component of the Program was not able to be carried out in 2020. We will aim to validate sightings using the UAV as part of the 2021 program, provided that this is still possible following 2021 implementation of the 'UAV no-fly-zone' over the BSA and hunting camp at Bruce Head as requested by hunters.
7	Mary River Project 2020 Bruce Head Shore-based Monitoring Program	p.53 6.3 Relative Abundance and Distribution	Could you provide the exact number of killer whale sightings in 2020 (similarly to the other species)?	Killer whale sightings information is presented in Section 6.6.1 of the report. For killer whales, the maximum number observed at one time is presented in table 6-8. A total of three RAD surveys conducted on 26 August and seven RAD surveys conducted on 27 August included killer whale sightings.

#	Document Name	Section Reference	Comment	Baffinland Response
8	Mary River Project 2020 Bruce Head Shore-based Monitoring Program	p.4 1.2.1 Applicable Early Warning Indicators (EWIs)	BIM proposes to use the proportion of juvenile from 2014 to set the threshold for changes in this early warning indicator. Ideally, baseline data should be based on several years of data. Is there additional data available from the 2007-2008 and 2013-2014 aerial surveys? These data might help to determine if 2014 was a representative year.	Baffinland currently derives the EWI, namely the proportion of immature narwhal (i.e., calves and yearlings), based on group compositional data collected by shore-based marine mammal monitors at the Bruce Head observation platform. Alternatively, the EWI can also be monitored via narwhal group compositional data collected via UAV-based surveys undertaken at Bruce Head in 2020 and 2021. This is the plan for 2021 with results presented as part of the 2021 Bruce Head Monitoring Report. The UAV-based approach would allow for an assessment of variation in the group compositional data, as related to time of year, observer bias (i.e., repeatability in age class identifications), or other applicable factors. Unfortunately, aerial- and UAV-based group compositional data cannot be directly compared to the Bruce Head shore-based group compositional data given differences in data collection, analyses and due to differences in detection cues and conditions (e.g., availability bias) between the two methods. For example, the proportion of calves recorded by the shore-based observers at Bruce Head is likely to be higher than that derived via the aerial surveys because 1) shore-based observers have an extended sighting period to accurately detect and characterize narwhal groups including cryptic group members

#	Document Name	Section Reference	Comment	Baffinland Response
				such as calves (whereas aerial surveys rely on a single image, i.e., snapshot in time), and 2) calves can react to aircraft overflights by moving under their mother and therefore affect calf detection by observers (thus downward biasing of counts). However, it would be possible to use UAV imagery independently as an alternative to shore-based monitoring data for the purpose of long-term monitoring of this EWI (interannual comparison of historical aerial photographs).
9	Mary River Project 2020 Bruce Head Shore-based Monitoring Program	p.117 7.0 DISCUSSION 7.1 Relative Abundance and Distribution	One possible hypothesis of the lower number of narwhals in 2020 is the displacement of the Eclipse Sound narwhals to other summer stock area. It should be noted that the early warning indicator of number of juvenile is only an indicator of the population size and health, and that it is not an indicator of displacement.	Baffinland acknowledges this point and would like to clarify that it does not consider the proportion of immatures (i.e., calves and yearlings) as an indicator for displacement. Potential displacement of narwhal from the RSA is assessed using existing indicators incorporated in the Marine Mammal Aerial Survey Program (MMASP). These indicators do not have to be labelled “early warning” indicators (EWIs) to be effective indicators. As demonstrated in the 2020 MMASP Report, these indicators are capable of yielding important information on regional changes in narwhal abundance and distribution (i.e., displacement) within a relatively short time period (i.e., statistical comparison b/w 2019 and 2020 data was completed within one year).

#	Document Name	Section Reference	Comment	Baffinland Response
10	Mary River Project 2020 Bruce Head Shore-based Monitoring Program	p.17 3.0 SEVERITY SCORE RANKING AND SELECTION OF BEHAVIORAL RESPONSE VARIABLES	BIM uses the work of Southall et al. (2007) and Finneran et al. (2017) to rank the severity of the behavioural response of narwhals. These papers mainly focused on the levels of disturbance for pulsed and temporary noise. Their paper was not intended for long-term recurrent noise. Therefore, the interpretation of the level of severity from these papers should be done with that in consideration. Repeated disturbance should looked at in the context of population consequences of disturbance (e.g. Pirotta et al 2018) Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene Jr, C.R., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., and others. 2007. Marine mammalnoise-exposure criteria: initial scientific recommendations. Aquatic Mammals 33(4): 411–522. Finneran, J., Henderson, E., Houser, D., Jenkins, K., Kotecki, S., and Mulsow, J. 2017. Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III). SSC Pacific. Pirotta, E., Booth, C.G., Costa, D.P., Fleishman, E., Kraus, S.D., Lusseau, D., Moretti, D., New, L.F., Schick, R.S., Schwarz, L.K., Simmons, S.E., Thomas, L., Tyack, P.L., Weise, M.J., Wells, R.S., and Harwood, J. 2018. Understanding the population consequences of disturbance. Ecol Evol 8(19): 9934–9946. doi:10.1002/ece3.4458.	The level of daily ship noise exposure presently experienced by narwhal in the RSA would not be accurately characterized as being 'long-term recurrent noise' as suggested in the comment. To date, results from the 2020 Bruce Head Monitoring Program indicate that narwhal behavioural responses to shipping are limited to temporary, localized avoidance behaviours. The maximum distance at which narwhal behaviour was shown to be influenced by vessel traffic was 4 km (relative to the ship). This is consistent with previous years' findings and similar to results from the 2017/2018 narwhal tagging study (Golder 2020). Short-term, localized avoidance of the sound source (i.e., vessel) by narwhal is indicative of a moderate severity response (Southall et al. 2007). As the observed response was of short duration (i.e., less than the duration of the vessel exposure), no significant alteration of natural behavioural patterns in narwhal or disruption to their daily routine in the RSA is anticipated. Localized avoidance of a vessel within 4 km would be equivalent to a total exposure period of 29 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behavior following the exposure period (temporary effect). During the 2020 Bruce Head Program (Aug 07 to Sept 01), there were approximately 2 transits per day in the SSA (56 one-way transits in SSA over a 26-day period). The daily

#	Document Name	Section Reference	Comment	Baffinland Response
				vessel exposure period was therefore equivalent to approximately 1 hour. On a heavy vessel day (assuming 4 transits per day), the daily vessel exposure period would be on the order of 2 hours. As previously stated, this level of potential noise disturbance from shipping would not be accurately described as 'long-term recurrent noise'. Notwithstanding the above points, in Southall et al. (2007) nowhere is it stated explicitly that the severity ranking scale is not appropriate for long-term, recurrent noise. The authors define the quantitative scoring paradigm for severity, providing examples in the context of both repetitive pulsive noise (e.g., seismic surveys) and non-pulsive (i.e., continuous) noise sources (i.e., vessel noise). The authors describe the scoring paradigm as 'a method to numerically rank, as a severity scaling, behavioural responses observed in either field or laboratory conditions.' While recognizing the limitations of the framework in describing cumulative and ecosystem-level effects, the ranking scale is still a relevant resource for assessing the relative biological importance of behavioural responses given the lack of numerical threshold values for behavioural disturbance. In Finneran et al. (2017), the discussion on 'auditory effects on marine mammals from anthropogenic noise exposure' is focused on naval operations including sonar, air gun arrays, pile driving, and blasting (i.e., explosives). The authors

#	Document Name	Section Reference	Comment	Baffinland Response
				discuss non-pulsive noise sources in the manuscript (including sonar and vibratory pile driving noise) and the criteria used in Navy Phase III analyses to predict behavioural effects on marine mammals from these repetitive non-pulsive noise sources. Finneran et al. (2017) go on to state that "training and testing activities are numerous, with thousands of events per year for the Navy Study Areas". Based on this statement, the behavioural response criteria applied in this study should be considered relevant to long-term, recurrent anthropogenic noise sources. It is worth also noting that many of the naval operational activities considered in Finneran et al. (2017) are considerably higher energy sources than vessel noise (i.e., they emit higher levels of underwater sound), (e.g. source levels ramping up from 152 - 158 dB to 198 - 214 dB (re 1µPa @ 1m) and emit noise across a broader frequency band compared to ship noise. The use of the severity ranking scale is probably more conservative when applied to shipping than these alternative noise sources for which the publication is largely based. Finneran et al. (2017) further state that any repeated or sustained disruption of an animal's critical life functions is more likely to have a demonstrable effect on vital rates than a single, brief disturbance episode. Relevant to this point, it is important to note that there is presently no evidence from the existing monitoring programs indicating that the present level of shipping (acknowledged as being a 'repeat activity') is disrupting narwhal

#	Document Name	Section Reference	Comment	Baffinland Response
				critical life functions' (i.e. feeding, nursing, calving, etc.) in the RSA. Therefore, existing narwhal behavioural response data do not justify the need to assess shipping effects on narwhal through a PCOD model at the present time. Finneran et al. (2017) further state that "…substantive behavioral reactions to noise exposure (such as disruption of critical life functions, displacement, or avoidance of important habitat) are considered more likely to be significant if they last more than one diel period or recur on subsequent days." It is acknowledged that shipping does occur on subsequent days, although no 'significant' behavioural reactions by narwhal to shipping have been demonstrated to date based on the existing monitoring program. 'Significance' in this context is clearly defined in Section 3.0 of the 2020 Bruce Head Shore-based Monitoring Report.

Name: Kristin Westdal

Organization: Oceans North

Date of Comment Submission: July 8, 2021

#	Document Name	Section Reference	Comment	Baffinland Response
1	2020 Bruce Head Shore-Based Monitoring Program	2.5 Locomotive Behaviour Page 11	Summary noted overall localized avoidance of the vessel within approximately 4 km for study years indicative of a moderate severity response and limited and temporary in nature. In this section, change in travel orientation relative to transiting vessels is noted at 5-10 km (depending on directionof vessel) corresponding to almost 1 hour of disturbance/displacement. -What is limited and temporary disturbance time frame over the course of a day? What could be a total time of disturbance on a heavy vessel day be for any given animal? In 2021 and if Phase 2 were approved? Please include this information in the Annual Report, as it would assist the MEWG in determining the best course forward in adaptive management.	Localized avoidance of a vessel within 4 km would be equivalent to a total exposure period of 29 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behavior following the exposure period (temporary effect). During the 2020 Bruce Head program (Aug 07 to Sept 01), there were approximately 2 transits per day in the SSA (56 one-way transits in SSA over a 26-day period). The daily vessel exposure period was therefore equivalent to approximately 1 hour. On a heavy vessel day (assuming 4 transits per day), the daily vessel exposure period would be on the order of 2 hours. The frequency of shipping in 2021 is anticipated to be similar to that incurred in 2020. The vessel exposure periods anticipated for the 2021 shipping season would

				therefore be similar or lower than the values referenced above for 2020. The last comment provided is in reference to the proposed Phase 2 operations. MEWG members have been asked to provide comments on Baffinland's existing monitoring programs undertaken in support of its existing operations (Early Revenue Phase and 6 MPTA operations). The opportunity for Oceans North provide comments on BIM's Phase 2 Proposal has been provided through the various Phase 2 Technical Meetings and the Final Hearing.

#	Document Name	Section Reference	Comment	Baffinland Response
2	2020 Bruce Head Shore-Based Monitoring Program	2.5.2 Dive behaviour Page 14	Same as above. The exposure period was noted for up to 36 min where animals shortened and altered dives, inhibiting feeding behaviour. Tagged narwhal was only near vessels for 1% of the time (2017 & 2018), but what time frame could a narwhal be looking at for disturbance under 2020 and 2021 shipping conditions, and under Phase 2 vessel volumes? If an animal was within 5-10 km of each ship that passed? Please include this information in the Annual Report, as it would assist the MEWG in determining the best course forward in adaptive management.	This comment does not pertain to the 2020 Bruce Head Shore-based Monitoring Report.
3	2020 Bruce Head Shore-Based Monitoring Program	UAV Focal Follow Surveys Pages vi+vii	Percentages are given for behaviors in the presence and absence of vessels. Were these compared statistically to test for difference?	As explained in Section 5.4.3 (methods for focal follow analysis), the sample size of data collected was not sufficient to conduct a meaningful statistical analysis.

#	Document Name	Section Reference	Comment	Baffinland Response
4	2020 Bruce Head Shore-Based Monitoring Program	Diet Page 10	Report cites Finley and Gibb (1982) noting that feeding in narwhal is the most intensive in spring near the floe edge and in the open leads. Looking at cumulative impacts, could this not be another potential reason for the significant decline in narwhal in 2020? Early and heavy ice breaking impacting critical feeding time at the floe edge?	Baffinland would like to clarify that there was no icebreaking at the floe edge in 2020. The floe edge had already dissipated well before the first day of icebreaking (21 July 2020), as documented in Figure 5 of Golder (2020). This is also evident in available sea ice imagery for the region including from Canadian Ice Service charts and based on other satellite imagery sources (e.g., Jul 21 2020 AM | Zoom Earth) The period of ice break-up in Eclipse Sound is when ice cracks would be present in the region. This process would occur over a very brief window in mid to late July (Finley and Gibb 1982; Golder 2020 – also see above referenced satellite imagery). Regional ice conditions on 21 July included 9-10/10 ice concentrations throughout Eclipse Sound, with 4-6/10 ice concentrations in Milne Inlet North, Tremblay Sound, and southern portion of Navy Board Inlet. A consolidated ice field of 9-10/10 concentrations persisted in Eclipse Sound until 26 July, resulting in a total of six days in which part of the Northern Shipping Route was transited through heavy ice conditions (≥9/10) (limited to one transit per day in these areas). Open-water conditions were present in the RSA as

#	Document Name	Section Reference	Comment	Baffinland Response
				early as 28 July 2020 (one week after the first day of shipping). It is unrealistic to assume that a significant proportion of the Eclipse Sound summer stock was directly lost (i.e., mortality) due to icebreakers interfering with narwhal feeding opportunities given the brief period of ice break-up involved (<1 week, one transit per day), particularly so rapidly following this potential disturbance event. Baffinland's marine mammal aerial survey results indicate that the combined number of narwhal in Eclipse Sound and Admiralty Inlet did not significantly change in 2020. This does not suggest large scale mortality of narwhal, but rather a potential displacement of narwhal. The potential cause(s) of this displacement are still being assessed and, as proposed in Golder (2020), could include disturbance from icebreaking in the RSA, disturbance from impact pile driving at Pond Inlet, increased killer whale presence, direct or indirect effects of climate change climate change effects, food availability, foraging interference, natural variability or other unknown factors. At present, it is unknown if one or more of these variables may have

#	Document Name	Section Reference	Comment	Baffinland Response
				acted independently, or in a cumulative or additive manner, to result in the potential displacement event. Golder. 2020. Preliminary summary of 2020 narwhal monitoring programs. Technical Memorandum #1663724-285-TM-Rev1-48000. 7 April 2021.
5	2020 Bruce Head Shore-Based Monitoring Program		Exposure time and distance does not seem to be consistent throughout this report. What is the assumed distance and time of maximum length of disturbance per vessel (or transit) pass?	Throughout the report, distances up to and including 7 km are considered “exposure”; the effects are compared to previous analyses in which distances up to 10 km and 15 km were considered “exposure”. Exposure time has not been quantified in this analysis, given that the extent of disturbance would be affected by the speed and direction of both the vessel and the narwhal. Hence, exposure time would not be a reliable measure of disturbance. Without guidance as to where a lack of consistency was observed in the report, we cannot further address this comment.

#	Document Name	Section Reference	Comment	Baffinland Response
6	2020 Bruce Head Shore-Based Monitoring Program	Page 129	Cumulative effects: Results show a change in relative abundance, change in density, change in distance to shore, yet BIMC has chosen to ship in 9/10th ice when more conservative options are available, including choosing not to break ice this season out of an abundance of caution and concern over what another year of low narwhal numbers could mean. Please describe how this is a precautionary approach.	Since this draft report was released, Baffinland has taken a precautionary approach and did not conduct any icebreaking during the 2021 early shoulder season. The final 2020 MMASP report has been revised to include this updated mitigation measure.
7	2020 Bruce Head Shore-Based Monitoring Program	Page 130	How will shipping an estimated 8 days later allow for “investigation of potential causal factors of the observed change” What is BIMC doing at this time to investigate or tease apart factors (as suggested by BIMC) that may have contributed to decrease in narwhal abundance? This comment does not pertain to the 2020 Bruce Head Shore-based Monitoring Report. Baffinland notes Oceans North was provided opportunities to comment on Baffinland’s 2021 Adaptive Management Response Plan via the NIRBs comment and response period on the 2020 Marine Mammal Monitoring Preliminary Results Memo, Baffinland’s 2020 Annual Report to the NIRB and during two MEWG meetings in	This comment does not pertain to the 2020 Bruce Head Shore-based Monitoring Report. Baffinland notes Oceans North was already provided opportunities to comment on Baffinland’s 2021 Adaptive Management Response Plan via the NIRBs comment and response period on the 2020 Marine Mammal Monitoring Preliminary Results Memo, Baffinland’s 2020 Annual Report to the NIRB and during two MEWG meetings in May and June 2021, respectively.

#	Document Name	Section Reference	Comment	Baffinland Response
			May and June 2021, respectively. The two other factors proposed by BIMC as possible contributors to decline in narwhal numbers in 2020 were killer whales and the small craft harbour work In Pond Inlet. There will be no killer whales at this time and small craft harbour work intends to use a bubble curtain during pile driving work.	
8	2020 Bruce Head Shore-Based Monitoring Program	4.2.2 Potential Contribution Factors to 2020 Findings Page 65	What is the distance of disturbance (120 dB for BIMC studies) from the Pond Inlet construction site? P32 – Appendix E: Could disturbance already be modelled if some sounds were picked up on BIMC hydrophones? If so, why has BIMC waited a year for the dates? If this is a main concern of BIMC, why not use this data to tease apart why narwhal numbers were lower? BIMC reports that acoustic compliance monitoring for the harbour construction indicated that acoustic injury threshold of 30kPa was exceeded at 10 m from the source. At what distance does BIMC think this sound was an issue for disturbance? Is this a realistic contributing factor to narwhal decline compared to ice breaking or cumulative effects of project shipping?	This comment does not pertain to the 2020 Bruce Head Shore-based Monitoring Report. Baffinland notes Oceans North was already provided opportunities to comment on Baffinland's 2021 Adaptive Management Response Plan via the NIRBs comment and response period on the 2020 Marine Mammal Monitoring Preliminary Results Memo, Baffinland's 2020 Annual Report to the NIRB and during two MEWG meetings in May and June 2021, respectively.

#	Document Name	Section Reference	Comment	Baffinland Response
9	2020 Bruce Head Shore-Based Monitoring Program	Potential Contribution Factors to 2020 Findings	Did the small craft harbour construction in Pond Inlet in 2018 and 2019 include pile driving when the narwhal survey showed no decline in population? Killer whales have been visiting Eclipse Sound and Milne Inlet for generations, and seasonally each year for long before the mine began shipping. How are both of these factors considered to contribute to the low narwhal population estimate as opposed to the cumulative effects of regular shipping transits? Why has the cumulative effects of project shipping not been considered?	This comment does not pertain to the 2020 Bruce Head Shore-based Monitoring Report. Baffinland notes Oceans North was already provided opportunities to comment on Baffinland's 2021 Adaptive Management Response Plan via the NIRB's comment and response period on the 2020 Marine Mammal Monitoring Preliminary Results Memo, Baffinland's 2020 Annual Report to the NIRB and during two MEWG meetings in May and June 2021, respectively.

Baffinland

Name: Chantal Vis, Allison Stoddart, Jordan Hoffman

Agency / Organization: Parks Canada Agency

Date of Comment Submission: July 8th, 2021

#	Document Name	Section Reference	Comment	Baffinland Response
13	2020 Bruce Head Shore-based Monitoring Program	Executive Summary: (Group Composition and Behaviour), pg. iv “The mean daily proportion of calves recorded in the BSA (relative to the total number of narwhal observed per day) was higher in 2020 (annual mean of 11.3%) than three of previous years…”	Please cite relevant literature on the movement of individuals by sex. Displacement behaviour by sex of individuals could have an effect on these calf proportions (i.e., if males or females without calves are more likely to travel further if disturbed).	This Early Warning Indicator (EWI), namely the proportion of calves relative to total number of narwhal observed, is derived from group compositional data collected in the BSA from the observer platform. This component of the study does not look at avoidance/ displacement behaviour, as the spatial scale of the BSA is too small for this purpose. Local displacement behaviour is derived from the RAD data collected in the SSA from the observer platform. At this spatial scale, it is not possible for the visual observers to resolve sightings to gender as presence of tusk cannot be confirmed at the larger distances. As such, the Bruce Head study does not look at changes in the proportion of calves as a function of gender composition of adult narwhal groups or gender-specific displacement behaviour in response to Project vessels.

#	Document Name	Section Reference	Comment	Baffinland Response
				There is no available literature on sex-specific displacement behaviour in narwhal as a result of anthropogenic disturbance. The following summarizes the present state of knowledge regarding narwhal movement patterns as a function of sex: • Differences in dive rates (number of dives per hour) and dive depth have been found to vary between size and sex of narwhal tagged, with female narwhal generally diving shallower and having lower dive rates than males (Heide-Jørgensen and Dietz 1995). • Female narwhal are reported to spend more time at depth compared to males (Watt et al. 2015), despite hypotheses that those with larger body size (i.e., males) would have enhanced ability to dive deeper and for greater periods of time. • Whether a female is with or without a calf may also influence dive behavior, given the aerobic limitations of the young and its reliance on maintaining an echelon position with its mother (Watt et al. 2015), though studies conducted by Heide-Jørgensen and Dietz (1995) found no difference in dive behavior between female narwhal with and without calves.

Baffinland

#	Document Name	Section Reference	Comment	Baffinland Response
				• Animal-borne tagging data collected from six individuals from the Eclipse Sound stock in 2017 and 2018 demonstrated: 1) no difference in dive rate between male and females; 2) females spent longer periods within the deepest 20% of each dive than males; 3) dive duration in females was on average higher than that of males; 4) dive descent speed in females was on average higher than that of males (Golder 2020). • Available IQ for the Eclipse Sound stick indicates that narwhal first enter Eclipse Sound in July through leads in the ice, with large males typically entering ahead of females and calves (JPCS 2017). • Mean swimming speed of satellite-tagged narwhal in Northwest Greenland demonstrated no difference in swimming speed between males and females (Dietz and Heide-Jorgensen 1995). • No differences in foraging ecology between sexes were observed in West Greenland narwhal (Louis et al. 2021) Dietz, R. and M.P. Heide-Jorgensen. 1995. Movements and swimming speed of narwhals, Monodon monoceros, equipped with satellite transmitters in Melville

#	Document Name	Section Reference	Comment	Baffinland Response
				Bay, Northwest Greenland. Canadian Journal of Zoology. 73: 2106-2119. Golder. 2020. 2017-2018 Integrated Narwhal Tagging Study – Technical Data Report. Report No. 1663724-188-R-Rev0-12000. 14 August 2020. Heide-Jørgensen M.P. and R. Dietz. 1995. Some characteristics of narwhal, Monodon monoceros, diving behavior in Baffin Bay. Canadian Journal of Zoology. 73: 2120–2132. Jason Prno Consulting Services Ltd (JPCS). 2017. Technical Supporting Document (TSD) No. 03: Results of Community Workshops Conducted for Baffinland Iron Mines Corporation's – Phase 2 Proposal. Report submitted to Baffinland Iron Mines Corporation. January 2017. Louis, M., M. Skovrind, E. Garde, M.P. Heide-Jorgensen, P. Szpak and E.D. Lorenzen. Population-specific sex and size variation in long-term foraging ecology of belugas and narwhals. Royal Society Open Science. 8(2) Watt, C.A., J.R. Orr, M.P. Heide-Jørgensen, N.H. Nielsen and S.H. Ferguson. 2015. Differences in dive behavior among the world's three narwhal Monodon monoceros

#	Document Name	Section Reference	Comment	Baffinland Response
				populations correspond with dietary differences. Marine Ecology Progress Series. 525: 273-285.
14	2020 Bruce Head Shore-based Monitoring Program	Methods: 5.4.2.4.6 Travel Speed	How is it ensured that observers are consistent with defining travel speed? This is an area where the use of a theodolite would provide a quantitative measure of travel speed to avoid bias from rotating observers.	It has been acknowledged in the report (Executive Summary, Section 8.0), that this response variable (travel speed) is inherently subjective (variable by observer) and that the results may be influenced by the data being recorded by multiple observers. This lowers the overall confidence in the effectiveness of using travel speed as a behavioral response variable using this method. Based on attempts at tracking narwhal in the BSA using a theodolite during previous years at Bruce Head, it has proved challenging to follow narwhal groups long enough to collect an accurate travel speed measurement. Efforts are being made to track this response variable more accurately using UAVs and/or a fixed video camera (with shoreline reference points) in 2021.
15	2020 Bruce Head Shore-based Monitoring Program	Methods 5.4.3 Focal Follow (UAV) Analysis	For future UAV surveys is there going to be an increase in effort for future surveys to increase the sample size of focal follows in the presence of vessels? For example, would focal follows overlap with ship transits through the study area? Would qualitative analyses of the focal follow data be sufficient for determining the severity response? Can the video data be analyzed	This was the primary objective of the 2020 focal follow surveys, however field surveys were constrained by weather (as UAV surveys cannot be flown in rain, fog or high wind conditions). The sample size is also dependent on having an adequate number of ship transits in the study area during times when narwhal are present. The continued objective in 2021 is to increase the focal follow sample size

#	Document Name	Section Reference	Comment	Baffinland Response
			quantitatively to determine linearity of narwhal movement and swim speed (i.e., measures that can be made using a theodolite)? Have UAV surveys been more beneficial to prevent 'lost' animals when they dive compared to past work by LGL (i.e., using theodolites)?	particularly during vessel exposure periods. In order to assist with this objective, we will be running two independent drone teams to allow for simultaneous focal follow surveys in the SSA (effectively doubling data collection potential). While qualitative analyses of focal follow data may loosely inform severity responses, severity responses cannot be fully assessed without conducting a quantitative analysis with a sufficient sample size. Travel direction and orientation relative to vessel traffic (i.e., response variables akin to linearity) will be assessed using video data collected during the UAV surveys. Tracking groups of narwhal via UAV is a preferred method to theodolite tracking for reasons identified in Baffinland's response to QIA #14.
16	2020 Bruce Head Shore-based Monitoring Program	Results 6.4.2 Group Composition	Given that the proportion of calves is used as an Early Warning Indicator a measure of variance should be given for inter-annual comparisons.	Table 6-5 in the 2021 Bruce Head Shore-based Monitoring Program has been revised to include the measure of variance (standard deviation) for 'daily proportion of immatures.'

#	Document Name	Section Reference	Comment	Baffinland Response
	2020 Bruce Head Shore-based Monitoring Program	Results 6.4.3 Group Spread (last paragraph page 77)	Are the results of past studies on dive behaviour in agreement with these general conclusions? Are there potential energetic costs to marine mammals associated with vessel traffic (e.g., from increased dive times or long distance movement)?	Group spread was not assessed in the 2017-2018 narwhal tagging study (i.e., the study that assessed dive behavior) given that only single individuals were tagged as part of this program (not narwhal groups) and there is no way to know if and when tagged animals later grouped up with other animals, and what group composition and group spread would have look like in these circumstances. Therefore, it is not possible to comment on whether the dive patterns of single narwhal derived from tagging studies are in agreement with the findings on group spread.
17	2020 Bruce Head Shore-based Monitoring Program	Discussion 7.4 Focal Follows (UAV), page 122 "Through the focal follow surveys, special attention was paid to assessing behavioural changes of mothers (presumed) with dependent young (i.e., calves and yearlings) in relation to shipping activities.	Given that data is limited to a qualitative assessment from UAV focal follows and there is a low sample size for narwhal in the presence of shipping will it be feasible to assess behavioural changes of mothers and dependent young to inform the EWI for adaptive management purposes? Will the study methods be changed to target mothers and dependent young to inform the EWI?	The EWI is defined as 'the proportion of calves relative to total number of narwhal observed'. There is no behavioural component for this indicator. Given the small sample size available of focal follows involving mothers with dependent young in the presence of vessels, this data will not be used to quantitatively assess EWI until sufficient data are collected. To increase sample size, focal follow surveys conducted during the 2021 field season will be carried out continuously whenever a vessel is present (weather permitting) and will include focal follows of mother/calf pairs although this

#	Document Name	Section Reference	Comment	Baffinland Response
				group type will not be targeted exclusively.
18	2020 Bruce Head Shore-based Monitoring Program	Discussion 7.4 Focal Follows (UAV), page 123 "As the sample size of focal follow surveys conducted in the presence of vessels is currently too small to allow statistical analyses, it is recommended that focal follow surveys be continued in future monitoring campaigns at Bruce Head in order to increase the sample size and allow for a quantitative assessment.	How will a quantitative assessment be carried out?	Once sufficient data are collected, the quantitative analysis is expected to be similar to the generalized linear mixed models performed for the 2017-2018 narwhal tagging data (Golder 2020a), where various response variables are defined based on the collected behavioural data, and vessel distance is used as a predictor to assess shipping effects on narwhal behaviour. Additional text has been added to Section 7.4 of the report to clarify the above.

Baffinland

Name: Jeff Higdon, Bruce Stewart

Agency / Organization: Qikiqtani Inuit Association

Date of Comment Submission: 08 July 2021

#	Document Name	Section Reference	Comment	Baffinland Response
1	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	General (including s. 6.3.1, s. 6.4.2.1, s. 6.4.3, s. 6.4.5, s. 6.4.6, s. 6.4.7)	Vessel presence had an effect on narwhal density, with a significant decrease in narwhal density when vessels were present within 1-2 km for northbound vs 3-4 km for southbound vessel transits. Effect sizes for a number of assessed variables were also often much larger for southbound compared to northbound vessels (*e.g.,* s. 6.4.2.1, s. 6.4.3, s. 6.4.5, s. 6.4.6, s. 6.4.7 For ore carriers, we would expect loaded (northbound) vessels to be louder than unloaded (southbound) vessels, and thus potentially noisier. Cargo vessels and fuel tankers would be the opposite, coming in (southbound) loaded. Were there differences in narwhal responses to ore carriers and other Project vessels? What factors could be responsible	Based on statistical analyses of the RAD data, the effects of 'distance from vessel' and 'vessel travel direction' were shown to be statistically significant, which means that both these predictor variables had a significant effect on narwhal density. The model predicted reduced narwhal densities in the SSA when a northbound vessel was within 2 km of a substratum and moving away and when a southbound vessel was within 4 km of a substratum and moving away or within 3 km and moving toward the substratum. It is likely that the difference in narwhal response to north- and southbound vessels is due to the spatial distribution of narwhal throughout the SSA at the time of vessel exposure and the difference in noise

#	Document Name	Section Reference	Comment	Baffinland Response
			for this difference with vessel direction?	propagation of vessels transiting southbound in ballast compared to vessels transiting north laden with ore. While an ore-laden vessel is heavier and therefore the sound output is expected to be greater, the presence of land masses and the associated impedance of sound propagation from vessels must also be considered. Of note, the majority of narwhal near Bruce Head are typically located throughout the mouth of Koluktoo Bay and in the southern strata of the SSA. Landmasses may shelter these animals from the noise of northbound vessels that are moving away from the substratum but not from noise generated by southbound vessels. For example, noise radiating from the stern of northbound vessels located in the northern substrata may be impeded by the Bruce Head peninsula, creating a smaller zone of influence (i.e., 2 km) relative to southbound vessels, while noise generated by southbound vessels may propagate with less impediment near the entrance of Koluktoo Bay and in the southern strata of the SSA, where the majority of narwhal are usually located.

#	Document Name	Section Reference	Comment	Baffinland Response
				In either case, narwhal behavioural responses to Project shipping observed at Bruce Head remain temporary and localized. On this basis, no additional open water shipping mitigations appear required at this time. Responses by narwhal to different vessel types (non-ore carriers) were not tested, as the number of transits in the SSA by other vessel types (e.g., cargo vessels and fuel tankers) is limited compared to ore carrier vessel transits, making the sample size insufficient for quantitative/statistical analyses.
2	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	General	Integration of IQ is needed to better understand 2020 narwhal distribution (*e.g.,* were animals displaced to the Clyde River or Resolute Bay areas?). What are the Proponent's plans for IQ integration in its ongoing investigation?	In follow-up to the release of the 2020 Preliminary Summary of Marine Monitoring Programs, Baffinland provided to representatives from the Hamlet and HTOs of each of the five impacted communities an update on its plans for the 2021 Shipping Season. Baffinland is also working under the assumption that comments provided by the QIA on all monitoring reports reflect relevant information from harvesters that the QIA would have consulted with in preparing this submission. If QIA as the Designated Inuit Organization representing

#	Document Name	Section Reference	Comment	Baffinland Response
				these communities has any additional information from harvesters that would be relevant to Baffinland's analysis of Project effects monitoring, Baffinland invites QIA to share this information as soon as practicable. Baffinland will continue to engage directly with Inuit in the investigation into the 2020 marine mammal monitoring program results. Baffinland notes that input from the Hamlet of Pond Inlet and the MHTO drove the enhancement of proposed mitigation measures to initiate the 2021 shipping season. Prior to planning for the 2022 shipping season commences, Baffinland will engage Inuit in the interpretation of the 2020 and 2021 marine mammal monitoring programs to outline where our observations align and diverge with the experiences of Inuit. Should Baffinland propose any formal IQ workshops as part of the investigation, Baffinland will work with QIA consistent with the provisions of the Mary River IIBA.

#	Document Name	Section Reference	Comment	Baffinland Response
3	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	General	The Nunavut Impact Review Board expects the Marine Environment Working Group to collaboratively and cooperatively develop Project monitoring. Decisions on design and analysis changes (*e.g.,* the switch to density rather than counts, the switch from 10 km to 7 km distance) should be made cooperatively with the MEWG, not unilaterally. At minimum, MEWG members should be informed of program changes prior to data collection and analyses, not after the fact.	Baffinland is not aware of the NIRB's expectation to collaboratively develop its monitoring programs with the MEWG. Rather, Baffinland is aware of Project Certificate No. 005 Term and Condition, which requires Baffinland to consult with and seek input from the MEWG on mitigations and monitoring program design. Consultation on the decision to revise the spatial scale of the model from 10km to 7km was made based on specific recommendations from the MEWG to increase the statistical power of the analyses. The outcome of the recommendation on the treatment of the data should be fairly obvious when its being made by the advisory Parties. Secondly, the opportunity for the MEWG to provide feedback is occurring as part of the MEWG's review of the draft 2020 Bruce Head Report. If QIA disagrees with this methodological decision, the opportunity to advise why that is the case could have been accomplished through this very forum.

4	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	General	What data, if any, are available on observer variability and repeatability in age class identifications?	The current data collection methodology (i.e. one data recorder and one observer, with some level of Marine Mammal Observer (MMO) changeover from season to season) does not enable for a comparison of observer variability and repeatability within a year or between years. The MMOs working at Bruce Head undergo a comprehensive theoretical and practical training session prior to the start of each field season. The Program's Technical Lead works closely with the Crew Leads and MMOs throughout the Program to test and refine observations in an effort to minimize observer bias and variability. UAV surveys are being incorporated in future monitoring years to test and validate observations by MMOs relative to the UAV data in order to account for potential observer variability and repeatability. The Early Warning Indicator (EWI) combines calves and yearlings into a single group category, and juveniles and adults into another separate group category, to reduce the

#	Document Name	Section Reference	Comment	Baffinland Response
				potential for observer variability." Also see response to DFO Comment #8.
5	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	Executive Summary, page ii	"… a more in-depth understanding of potential effects of shipping activities to narwhal could be obtained through the integration of an Unmanned Aerial Vehicle (UAV) and by correlating visual observations with concurrent acoustic data. As such, the use of a UAV was incorporated into the 2020 Program to enhance the collection of observational data on narwhal group composition and behaviour." The report makes no mention of the Passive acoustic Monitoring (PAM) device that was deployed at Bruce Head. What are the Proponent's plans and schedule for analyses and reporting of these data? How will they be integrated into the analyses of Bruce Head observational data?	The 2021 Passive Acoustic Monitoring (PAM) report is in preparation. This report is currently scheduled for delivery to the MEWG in Q3 2021.

#	Document Name	Section Reference	Comment	Baffinland Response
6	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 1.3, page 4	This section refers to a 2019 study, should be 2020.	Acknowledged. The text in the report has been updated accordingly.
7	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 2.1, page 7	"Both narwhal populations in Canada are not presently considered at risk and are not listed under the federal *Species at Risk Act*." This is partially correct. Narwhal are not SARA-listed but are listed (as one unit, not two populations) as Special Concern by COSEWIC, and are therefore considered "at risk".	Legal protective status for marine wildlife in Canadian waters is only recognized under the federal *Species at Risk Act* (SARA). COSEWIC remains an advisory body to Environment and Climate Change Canada (ECCC). Under SARA, the government of Canada takes COSEWIC designations into consideration when establishing the official list of wildlife species at risk. Nevertheless, the text in Section 2.1 has been updated to reflect COSEWIC's consideration of narwhal as a species of special concern.

#	Document Name	Section Reference	Comment	Baffinland Response
8	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 2.5, page 12	"Understanding confounding effects such as the presence of predators in a system is important when assessing movement behaviour of cetaceans in relation to vessel traffic." What opportunities are available to better monitor killer whale occurrence? PAM? IQ surveys? There are limited data at present, mostly aerial survey and Bruce Head observations, which do not capture the full occurrence of killer whales in the Regional Study Area or even in Milne Inlet but out of view of the observers (also see below re: killer whales).	It is not possible to capture the full extent of killer whale occurrence within the RSA in the absence of a comprehensive satellite tagging program. While PAM may inform killer whale presence when these animals are vocalizing, it will not detect killer whales when they are non-vocal, which is commonplace for killer whales when hunting acoustically sensitive prey such as ringed seal and narwhal. This was confirmed by a preliminary review of underwater acoustic data obtained at Bruce Head (i.e., AMAR 3) on 26 August 2020 when a total of 67 killer whales were recorded in the study area and were actively hunting narwhal. During this event, only a few faint killer whale calls were detected on the recording despite animals being in close proximity to the recorder. It is our understanding that in 2020, DFO and the MHTO are collaborating on a killer whale monitoring program that will enhance understanding of killer whale presence in the area.

#	Document Name	Section Reference	Comment	Baffinland Response
9	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 3.0, page 17	"In general, a response would be considered 'long-duration' if it lasted up to several hours, or enough time to significantly disrupt and animal's daily routine." How long does a disturbance need to last to disrupt a feeding narwhal? Or a nursing narwhal? What data are available specifically for narwhal, from IQ or other sources?	As noted in section 3.0 of the Report, a long duration was defined as a response that lasted for the full duration of vessel exposure or longer. Based on other marine mammal monitoring results collected by Baffinland (i.e., 2017-2018 narwhal tagging study), animals that are presumed to be foraging (i.e., undertaking deep, bottom dives) may exhibit a temporary deviation from that behavior but typically for a period that is considerably shorter than the duration of the vessel exposure. Baffinland has not yet collected adequate empirical data on the behavioral responses of narwhal to shipping during active nursing events (such to allow for quantitative / statistical analyses). Future UAV data collection aims to fill this existing data gap.
10	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring	s. 3.0, pages 17-18	For high severity responses, what is the definition for "long-term" in regards to abandonment of an area, and "prolonged" in regards to separation of females and calves? How are "panic", "flight" and "stampede" defined?	This is defined in the preceding paragraph in Section 3.0 of the report: <<What constitutes a long-duration response is different for each situation and species, although it is likely dependent upon the magnitude of the response and species characteristics such as body size, feeding strategy, and behavioural state at the time of the exposure. In general, a

#	Document Name	Section Reference	Comment	Baffinland Response
	Rpt-Draft for MEWG.pdf)			response would be considered ‘long-duration’ if it lasted up to several hours, or enough time to significantly disrupt an animal’s daily routine. For the derivation of behavioural criteria in this study, a long duration was defined as a response that lasted for the full duration of vessel exposure or longer. This assumption was made because examination of behavioural response data suggests that had the vessel exposure continued, the behavioural responses would have continued as well.>> “Panic”, “flight” and “stampede” are examples provided in the referenced literature. These are considered obvious behavioural responses that are essentially one in the same, with the caveat that ‘stampede’ refers to the response being displayed by more than one individual. For the purpose of this study, these ‘responses’ are defined as ‘a sudden, overt, and directed high-speed movement away from a particular threat or disturbance source’. This definition has been added to the final version of the report.

#	Document Name	Section Reference	Comment	Baffinland Response
11	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 3.2, page 20	Re: the EWI, it can be an appropriate indicator as long as the necessary data are collected. Changes in the proportion of immature animals will be sensitive to changes in fertility, calf survival and juvenile survival, as Booth et al. (2020) noted. The Proponent does not have data on fertility and calf or juvenile survival. Changes in the proportion of immature animals cannot be linked to demographic factors without additional data.	Monitoring for fertility, calf survival and juvenile survival are not realistic components to add to the Bruce Head Shore-based Monitoring Program. The EWI selected provides an early warning of potential changes to the narwhal population abundance by detecting changes in proportion of immature (calves and yearlings) narwhal in the population. This represents a proxy indicator of calf recruitment and survival that can serve as an early indicator of potential population decline.
12	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 3.7, page 23	Some of the studies described here as "satellite tagging studies" did not employ satellite telemetry - for example, Steltner et al. (1984) is based on boat-based observations, and Ferguson et al. (2012) compiled Inuit observations collected via semi-directed interviews. The studies cited are all relevant, but used a variety of methods and were not limited to telemetry.	The text has been revised to clarify that the studies were not exclusively limited to telemetry.

#	Document Name	Section Reference	Comment	Baffinland Response
13	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 4.1, page 24	The three objectives identified for the Unmanned Aerial Vehicle (UAV) are all important, with the evaluation of observer detection performance especially so. This objective was not met in 2020 due to mechanical issues with the drone system assigned to meet this (and one other) objective. More details on the drone malfunction are requested, including what will be done during the 2021 program to reduce the likelihood of further malfunctions.	The drone batteries had been exposed to extreme temperatures when transported to site, therefore limiting the flight distance capabilities for this drone. In 2021, to address any potential battery issues arising from transport (extreme temperature exposure and/or potential physical damage such as crushing or puncture), all batteries were thoroughly inspected upon arrival at site. No damage or signs of cell puffing was observed, and no smell arising from a puffed lithium polymer battery was detected. Batteries were then charged to full capacity and tested with their associated drone on a battery test flight, where the drone was not flown out over the ocean but remained close to the landing site in the event that a quick landing was required. Furthermore, the type of batteries that had failed in the 2020 program were not used for the 2021 program as that brand of drone was not selected for the Program this year.

#	Document Name	Section Reference	Comment	Baffinland Response
14	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 5.4.1.2, page 33	The change to a 7 km assessment range (from 15 km and then 10 km) is contingent upon a 120 dB disturbance threshold, which has not been empirically determined for narwhal. IQ would suggest that narwhal are more sensitive to noise disturbance than other species. How does the Proponent's understanding of IQ support the use of 120 dB as a threshold for determining assessment range?	The reduction of the exposure zone from 10 km to 7 km was not based on the 120 dB disturbance threshold. It was primarily based on data obtained from Baffinland's behavioral response studies that specifically evaluated narwhal responses to vessel traffic and associated noise. These programs include the 2017/2018 Narwhal Tagging Study and the 2014-2020 Bruce Head Shore-based Monitoring Program. Both programs considered a wide range of response variables in their study design. Statistically significant changes were identified for several of these response variables, along with specific distances at which these responses were elicited (along with distances for which they were not). To date, behavioral responses by narwhal to shipping have been limited to a range of 5 km or less from a vessel (and not beyond), irrespective of what received sound levels narwhal would have experienced at these distances. These results outlined the need to reduce the spatial extent of the exposure zone in order to better quantify the effects at

#	Document Name	Section Reference	Comment	Baffinland Response
				closer distances and improve resolution in data where interactions are known to be most pronounced. Reducing the 'exposure zone' from 10 to 7 km allows for a more accurate characterization of response range, response (exposure) duration and response severity to meet the overall objectives of the program. The decision to revise the spatial scale of the model from 10km to 7km was also an outcome of specific recommendations from the MEWG to increase statistical power of the analyses. By re-scaling the exposure zone to encompass the area where there is the highest likelihood of effects and the highest proportion of effects, overall power of the model increases due to removal of noise in the data for both 'exposure' and 'non-exposure' treatments. It should also be noted that narwhal are high frequency cetaceans that are less sensitive and reactive to low frequency shipping noise compared to low frequency cetaceans (i.e., baleen whales) for which the 120 dB threshold was originally derived, as the

#	Document Name	Section Reference	Comment	Baffinland Response
				majority of underwater sound generated by vessel traffic is concentrated below 200 Hz (Veirs et al. 2016), which is below the assumed peak hearing sensitivity of narwhal (>1 kHz). Baffinland's acoustic monitoring program has demonstrated that Project vessel noise is generally below 120 dB re: 1µPa at distances beyond 7 km from the vessels (Austin and Dofher 2021). This further supports the 120 dB threshold being an appropriately conservative disturbance threshold for informing the exposure zone. With respect to comments that IQ suggests narwhal are more sensitive to noise than other marine mammals, Baffinland would be interested in discussing this with QIA further. The Tusaqtuvut studies prepared by QIA – particularly considering those developed in collaboration with Arctic Bay/Clyde River and Hall Beach/Igloolik state several times that all marine mammal species are sensitive to noise. Emphasis is made with respect to narwhal but also

#	Document Name	Section Reference	Comment	Baffinland Response
				on several occasions, seal and walrus sensitivity to noise disturbance is highlighted. While we acknowledge the valuable insights within these reports regarding the sensitivity of these marine mammals to underwater noise, no evident hierarchy of species-specific sensitivity to noise disturbance is apparent in a review of the available reports. We would kindly request that QIA provide a reference for this specific IQ statement ('IQ would suggest that narwhal are more sensitive to noise disturbance than other species').
15	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 5.4.1.7, page 36	The removal of RAD counts and group composition and behaviour data when killer whales were known to be present in southern Milne Inlet could bias the results because you don't know how often or when killer whales were present in the general vicinity but not observed. As such, the filtered database may still contain some unknown number of counts when killer whale presence affected narwhal presence (to varying degrees depending on distance, killer whale behaviour, etc.). Was an alternate approach,	The inclusion of a variable for the presence of killer whales would be subject to the same bias as pointed out by the reviewer with respect to filtering of the data. It may not always be known when there are killer whales present (in the absence of a comprehensive narwhal and killer whale tagging program). In addition, with killer whale presence only accounting for 3.3% of the RAD data and only 2.5% of the behaviour and group composition data, there is presently not adequate

#	Document Name	Section Reference	Comment	Baffinland Response
			where killer whale presence is included as a variable in the model, considered? How does the group composition and behaviour data collected during the 155 cases when killer whales were present in southern Milne Inlet compare with that collected in the (presumed) absence of killer whales in southern Milne Inlet?	data to incorporate such an effect into the model.
16	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 5.4.2.1, page 37	Models that explicitly consider the effects of multiple vessels should be constructed.	With respect to the 2014-2020 integrated Bruce Head RAD dataset, cases with multiple vessels accounted for 1.6% of all RAD data collected during 'vessels present' periods, and only 0.15% of the RAD data collected overall. Currently, there is not adequate data to account for the effects of multiple vessels in the system.
17	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring	s. 5.4.2.2, page 38	Year - six, not five, categories.	Text revised accordingly.

#	Document Name	Section Reference	Comment	Baffinland Response
	Rpt-Draft for MEWG.pdf)			
18	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 5.4.2.3, page 39	What were the "problematic predictions" observed during preliminary modelling that included the interaction between direction, distance from vessel, and whether the vessel was north- or south-bound?	The prediction referred to consisted of a sharp increase in narwhal density in very close proximity to a southbound vessel moving away from a substratum. This increase was not supported by the data, nor by the estimated density of narwhal in very close proximity to a southbound vessel that is approaching the substratum (i.e., just before the vessel begins to move away). That is, there was a large discontinuity in the estimated narwhal density when a southbound vessel moved through a substratum. This was resolved by removing the three-way interaction between distance, vessel direction, and vessel position relative to a substratum.
19	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring	s. 6.3.1, pages 60-61	How do the tide results compare with other work, *e.g.*, by Marcoux?	Baffinland assumes that the work that is being referred to here is Marcoux et al. (2009) in which narwhal movement patterns near Bruce Head were shown to not consistently follow tidal cycles across years. In our results, narwhal density was highest at low slack, followed by ebb conditions, with lowest densities estimated for

#	Document Name	Section Reference	Comment	Baffinland Response
	Rpt-Draft for MEWG.pdf)			flood and high slack conditions. This differs from estimates by LGL (2017), where narwhal counts were estimated to be highest at ebb conditions. Overall, narwhal density patterns in relation to tidal cycles are not consistent between years, similar to the findings in Marcoux et al. (2009). Marcoux, M., M. Auger-Methe and M.M. Humphries. 2009. Encounter frequencies and grouping patterns of narwhal in Koluktoo Bay, Baffin Island. Polar Biology. 32:1705-1716.
20	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)		s. 6.4.3, pages 75-78 This is an example of where the data removed due to known killer whale presence could allow for important inferences. How does group spread in the known presence of killer whales compare with that when killer whales are presumed absent? Killer whales are present in the north Baffin region throughout the entirety of the open water season. Narwhal were most often observed in tight groups over all six years of sampling regardless of whether narwhals were exposed to	The objective of the Bruce Head study is to assess the effects of shipping on narwhal behaviour. Given that only limited data were collected at Bruce Head in the known presence of killer whales, it was not feasible to account for the effect of killer whales on narwhal behavior via use of additional variables in the models.

#	Document Name	Section Reference	Comment	Baffinland Response
			anthropogenic activity or not. In some cases, this grouping behaviour could be related to the presence of killer whales that were unseen by Bruce Head observers The 2020 Bruce Head team observed killer whales on 26 and 27 August (s. 6.6.1). However, DFO's database of killer whale sightings reports for 2020 (S. Ferguson, DFO, pers. comm.) indicates that killer whales were reported near Pond Inlet on 14 and 15 August, from 18-21 August, 27 and 28 August, and 04 and 13 September. They were present in Admiralty Inlet in early August (1st, 3rd), after most likely migrating westward through Lancaster Sound and possibly Eclipse Sound and Navy Board Inlet, and were recorded again in Admiralty Inlet on 30 August. Killer whales are present in the general area from early August (or earlier), until September (or later). Removing a subset of data when killer whales were seen by Bruce Head observers could bias the dataset and analyses.	

#	Document Name	Section Reference	Comment	Baffinland Response
21	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 7.1, pages 117-118	An update on the current investigation into the 2020 decline in narwhal abundance is required, since the 2020 aerial survey report draft did not provide any update from the earlier memo. Inuit are not satisfied that the currently proposed mitigation will be sufficient, what is the Proponent doing to address their concerns?	Based on results obtained from 2020 marine monitoring programs (including the 2020 aerial survey program), Baffinland has taken a precautionary approach and did not conduct icebreaking during the 2021 early shoulder season. In follow-up to the release of the 2020 Preliminary Summary of Marine Monitoring Programs, Baffinland provided to representatives from the Hamlet and HTOs of each of the five impacted communities an update on its plans for the 2021 Shipping Season. The input from the Hamlet of Pond Inlet and the MHTO drove the enhancement of proposed mitigation measures to initiate the 2021 shipping season. Prior to planning for the 2022 shipping season commences, Baffinland will engage Inuit from Pond Inlet in the interpretation of the 2020 and 2021 marine mammal monitoring programs to outline where our observations align and diverge with the experiences of Inuit. Should Baffinland propose any formal IQ workshops as part of the investigation,

#	Document Name	Section Reference	Comment	Baffinland Response
				Baffinland will work with QIA consistent with the provisions of the Mary River IIBA.
22	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 7.4, page 123	"Collectively, these findings may have implications for the broader shore-based monitoring program at Bruce Head, suggesting that calves and yearlings passing through the BSA may be disproportionately underrepresented given the reduced ability to sight an animal that is underneath of another." This highlights the importance of meeting the other UAV program objectives and making all possible efforts to do so.	Baffinland is in agreement with the importance of meeting the other UAV program objectives and will seek to do so in in 2021.
23	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 9.0, page 129	QIA supports increased UAV-based data collection efforts, and notes that is also important to collect data to meet the other objectives listed for this program component. QIA does not agree with further restricting the vessel exposure zone from 7 km to 5 km. The restriction from 10 to 7 is contingent upon the 120 dB disturbance threshold, which has not been empirically documented for narwhal and is not supported by IQ that indicates narwhal are highly sensitive to noise	Baffinland is in agreement with the importance of meeting the other UAV program objectives and will seek to do so in in 2021. See responses to Comment No. 3 and 14.

#	Document Name	Section Reference	Comment	Baffinland Response
			disturbance. Any decisions should be made following discussion with MEWG in a collaborative manner.	
24	Golder Associates Ltd. 2021. Mary River Project 2020 Bruce Head Shore-based Monitoring Program. Draft document 1663724-269-R-RevB-33000, 12 May 2021. (file name: 2020 Bruce Head Monitoring Rpt-Draft for MEWG.pdf)	s. 11, page 138	The Marcoux and Watt (2020) citation is missing from the Reference list. It is presumably DFO CSAS Res.Doc. 2020/067.	The citation has been added to the report and the reference list has been updated accordingly.

GOLDER

MEMBER OF WSP

golder.com