REPORT

Mary River Project

2023 Bruce Head Shore-based Monitoring Report

Submitted to:

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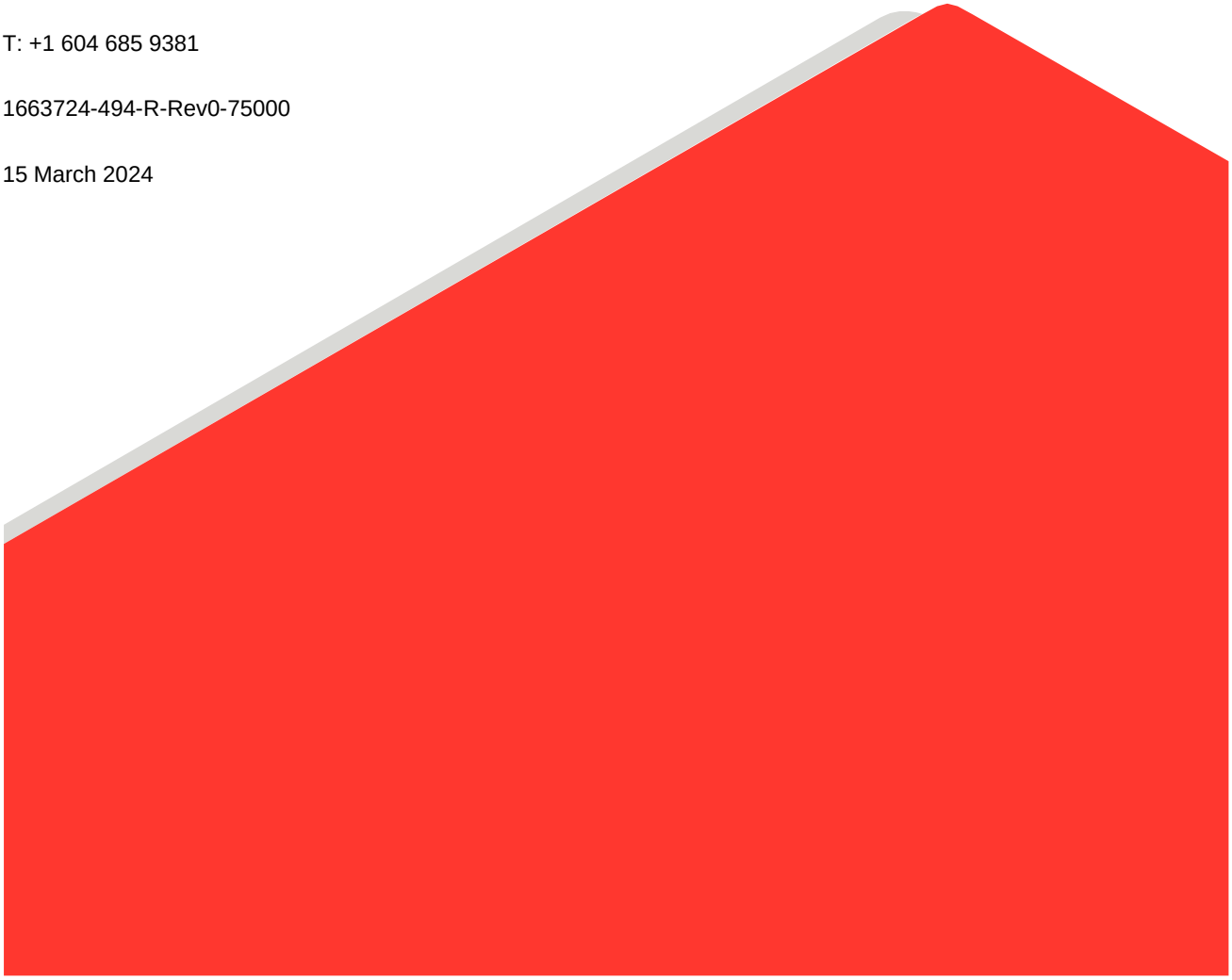

Executive Summary

In August 2023, WSP Canada Inc. (WSP), on behalf of Baffinland Iron Mines Corporation (Baffinland), undertook the Bruce Head Shore-based Monitoring Program ('the Program'), a field-based study conducted annually since 2014 (with the exception of 2018) for the purpose of assessing narwhal responses to Baffinland shipping activities along an active shipping corridor off North Baffin Island, Nunavut. As part of the Program, systematic data on narwhal relative abundance and distribution (RAD), group composition and behaviour were collected from a cliff-based observation platform overlooking the Northern Shipping Route where Project vessels transit through an established narwhal summering ground in Milne Inlet. Ship movements in the study area were recorded using a combination of shore- and satellite-based Automatic Identification System (AIS) vessel tracking systems to provide high-resolution positional data on all medium- (50–100 m in length) and large-sized (>100 m in length) vessels transiting through Milne Inlet. Additional data were collected on environmental conditions and anthropogenic activities (e.g., recreational traffic and hunting activities) to distinguish between the potential effects of Project-related shipping activities and confounding factors that may also influence narwhal behaviour.

The Program specifically addresses Project Certificate (PC) conditions 99c, 101g, 109, 110, 111, and 112 related to evaluating potential disturbance of marine mammals from shipping activities that may result in changes in animal abundance, distribution, and behaviour within the Project's Regional Study Area (RSA). The 2023 Bruce Head Shore-based Program represents the ninth year of Project effects monitoring (EEM) conducted at Bruce Head in support of the Mary River Project.

The following summarizes key findings from the Program based on nine years (2014–2023) of observational data collected in the Stratified Study Area (SSA) and Behavioural Study Area (BSA):

Relative Abundance and Distribution

- Interannual variation in relative abundance: The relative abundance of narwhal (total number of narwhal in the SSA corrected for survey effort) at Bruce Head was lower in 2023 (2.9 narwhal/h) than all previous survey years. The highest relative abundance of narwhal recorded at Bruce Head occurred in 2016 (178.0 narwhal/h), followed by 2017 (121.8 narwhal/h), and 2019 (127.2 narwhal/h). Prior to 2023, the lowest relative abundance of narwhal recorded at Bruce Head occurred in 2020 (47.5 narwhal/h) followed by 2021 (29.4 narwhal/h). Low narwhal numbers in 2023 were thought to be linked to the late break-up of landfast ice in the Regional Study Area (RSA) in 2023. Consolidated sea ice was present throughout the majority of Western Eclipse Sound in early August, with little to no ice leads available for narwhal to enter Milne Inlet (Baffinland 2024a). The late break-up period also resulted in a delay to the start of the 2023 shipping season with the first inbound ship transit in Milne Inlet taking place on 09 August. Narwhals were not observed in the Bruce Head study area until 05 August 2023, with narwhal numbers slowly increasing towards the end of the Bruce Head Program. Aerial surveys conducted in the RSA in parallel with the Bruce Head Program indicated that narwhal abundance in the RSA was 10,492 animals (CV= 0.05; CI = 9,578-11,494) on 12-13 August and 9,572 animals (CV= 0.05; CI = 8,706-10,524) on 23-25 August 2023 (WSP 2024a). These abundance estimates were not significantly different to baseline levels (2013), when narwhal abundance was estimated at 10,489 animals (CV = 0.24; CI = 6,342 – 17,347) (Doniol-Valcroze et al. 2015). The 2023 aerial survey results also demonstrated that narwhals were primarily concentrated in Tremblay Sound during the first half of August and then shifted into Milne Inlet South during late August (WSP 2024a). Acoustic monitoring data collected in

August 2023 also substantiated this shifting distribution pattern with narwhal calls notably increasing at the Bruce Head acoustic recorder in mid- to late August 2023 (Austin et al. 2024). These results help explain the low narwhal numbers observed at Bruce Head prior to program ending on 22 August 2023.

- Density: The effect of "distance from vessel" was shown to have a significant effect of narwhal density, while "vessel travel direction" did not. The model predicted significantly reduced narwhal densities in the SSA only when northbound (i.e., outbound) vessels were in close proximity to a given substratum (within 2 km), with effect sizes suggesting a moderate biologically significant effect up to a distance of 2.4–2.6 km from northbound vessels. Once a northbound vessel passed through the SSA, heading away from the strata, narwhal density was shown to gradually increase as the vessel moved away. The same pattern was observed for a southbound vessel moving away from the substrata, although the observed increase was smaller, mirroring the smaller decrease in density when a southbound vessel approached the substrata, compared to a northbound vessel. This pattern could represent a refractory period during which narwhal reoccupy the SSA after their initial avoidance of the vessel. The observed effect was equivalent to a maximum period of 18–25 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). During the 2023 Bruce Head Program, there were approximately two vessel transits per day in the SSA (32 one-way transits in SSA over a 20-day period). Therefore, the maximum period per day associated with shipping effects on narwhal density was 50 min. These findings were consistent with previous years' findings and with behavioural results from the narwhal tagging study (Golder 2020a), which indicated that narwhal density in the SSA was influenced by vessel traffic, but this was limited to northbound vessels and only at close distances (i.e., within several kilometers). Localized avoidance of the sound source (i.e., the vessel) by narwhal is consistent with a moderate severity behavioural response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., 18–25 min per vessel transit), this would not be considered a biologically significant behavioural response and would not be expected to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. Accordingly, no effects are anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which could lead to population-level effects. Observed responses are in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

Group Composition

- Group Composition: The number of narwhal groups in the BSA in 2023 was the lowest observed since the start of the nine-year study period, with a total of 40 narwhal groups (comprising 163 individuals) recorded. All narwhal life stage categories (adults, juveniles, yearlings, and calves) were recorded in the BSA throughout the nine-year monitoring program, with the majority of the sightings consisting of adult narwhal, followed by juveniles, calves, and yearlings.
- Proportion of Immatures (Early Warning Indicator [EWI]): Findings from the combined multi-year dataset indicate that the relative proportion of immature narwhal observed in the BSA in 2023 (0.242) was significantly higher than that recorded during baseline years (0.152 in 2014 and 0.167 in 2015), representing a 57% increase from baseline conditions. This result should be interpreted with caution given the relatively small sample size available at Bruce Head in 2023. For comparative purposes, the EWI was also calculated using the 2023 aerial survey data (dedicated 1000 ft. survey data). Results from the aerial data analysis indicated that the proportion of immature narwhal in Eclipse Sound in 2023 (0.131) was within the range of

the 2014/2015 baseline condition (0.154 in 2014 and 0.110 in 2015) (WSP 2024b). A statistical comparison was not possible since the raw data from 2014/2015 aerial surveys were not available. Both Bruce Head and aerial-based EWI datasets were associated with high variability and low sample sizes, resulting in high uncertainty in the EWI estimates. In summary, while the EWI data collected at Bruce Head in 2023 suggests an increase in the relative proportion of immature narwhal in Milne Inlet South, the equivalent EWI analysis derived from the spatially broader aerial survey dataset provided no indication that the proportion of immature narwhal in the RSA had changed since the start of shipping operations (2014/2015) (WSP 2024b). Ongoing EWI monitoring through both the Bruce Head Shore-based Monitoring Program is recommended.

The following summarizes key findings pertaining to narwhal responses to ship traffic at Bruce Head based on four years (2020–2023) of unmanned aerial vehicle (UAV)-based focal follow surveys in Milne Inlet:

- Primary behaviour: Focal follow survey results provide possible, though conflicting, support that narwhal groups may alter the proportion of time they spend engaged in important activities (defined as ‘resting, milling, or social activity’) when in the presence of vessels. Adult groups were shown to engage less frequently in important activities when within 3 km of a vessel. Conversely, mixed groups without immatures engaged more frequently in important activities when within 2.5 km of a vessel. For mother-immature pairs and groups with immatures, no effect of vessel presence on important activities was observed at any distance. The conflicting trends amongst narwhal group types questions the validity of the observed effect. Additional focal follow monitoring is recommended to increase the overall sample size of the corresponding dataset to further examine the relationship between shipping and important narwhal activities.
- Unique behaviours: Unique behaviour displays by narwhal tended to occur less frequently by all narwhal group types in close proximity (<2.7 km) to a transiting vessel, although the observed decrease was not significant. The lack of significance may be associated with low sample sizes and high data variability at close distances (<2 km) to the vessel. The results suggest that social behaviours such as rubbing, rolling, nursing, and sexual displays may potentially be disrupted in close proximity (<2.7 km) to vessel traffic, though this finding is based on a very limited sample size at close range to vessels. Additional monitoring is recommended to increase the overall sample size and the robustness of the corresponding analysis.
- Association of immatures with presumed mother: Immature narwhal were recorded in 148 of the 397 (37%) focal follow surveys conducted to date. Of these events, immature narwhal occurred on their own in 35 of the surveys, with their presumed mother in 64 of the surveys, and in mixed groups in 49 of the surveys. Nursing behaviour was recorded during 30 of the surveys, five of which coincided with a vessel being present within 5 km of the focal group.
  - Presence of nursing behaviour: Immature narwhal engaged less often in nursing when in the presence of vessel traffic (vessel within 5 km of the focal group); although modelling results indicate that this effect was not significant despite an effect size of -65%. The lack of a significant effect may be associated with low sample sizes and high data variability at close distances to the vessel. The model was based on limited and unbalanced data; specifically, only four of the 30 surveys involved active nursing occurred in the presence of vessels (<5 km). As a result, the above findings should be interpreted with caution. Additional monitoring is recommended to increase overall sample size and the robustness of the corresponding analysis.
  - Relative and distal positioning of immatures: The estimated effect of vessels on the relative position of immature narwhal relative to their mothers was small, uncertain, and not statistically significant. These results do not suggest that the position of immatures (relative to their mother) is affected when vessels

are present (within 5 km from groups). Additional monitoring is recommended to increase sample size, thereby allowing for a more robust analysis**.**

- Group formation: Narwhal groups frequently shifted their formations between parallel, linear, and cluster throughout a given focal follow survey, both in the presence and in the absence of vessels. The biological purpose of these formations in narwhal groups is not well understood and there remains uncertainty regarding how these formations relate to internal group cohesion of narwhal specifically. Therefore, further monitoring of narwhal group formation may contribute to a better understanding of 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). As discussed in Section 3.0, a change in group cohesion (e.g., change in group formation) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect (i.e., change in group formation within 1 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 7 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which could lead to population-level effects. This response was in line with impact predictions made in the Final Environmental Impact Statement (FEIS) for the Early Revenue Phase (ERP), in that vessel noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.
- Group spread: The results indicate a non-statistically significant but potentially large effect of vessels on the frequency of a tight group spread when vessels were within 3 km of narwhal groups. However, the estimated effect sizes suggested that tight group association was less frequent at close distances from vessels (0.5 and 1 km) but more frequent when vessels were 2–3 km away. The inconsistent direction of the effect, and lack of statistical significance due to high uncertainty in the estimated relationship, means that no reliable conclusions can be drawn regarding the effect of vessel presence on group spread based on the available data. As discussed in Section 3.0, a change in group cohesion (e.g., change in group spread) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect observed (i.e., groups associating less tightly when within 3 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 21 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which could lead to population-level effects. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.
- Group size: Findings based on the combined multi-year UAV dataset do not suggest a strong or consistent effect of vessel presence on group size of narwhal, based on the available data. One exception was for mother-immature pairs, for which there was medium (≥25%) increase in group size when within 3 km of a vessel, although the effect was not statistically significant and was based on a limited sample size. For the other group types, effect sizes were small and do not suggest a biologically significant effect of vessels on group size. As discussed in Section 3.0, a change in group cohesion (e.g., change in group size) by narwhal

would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect (i.e., increase in group size for mother-immature pairs when within 3 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 21 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which could lead to population-level effects. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

- Travel speed: Findings suggest an effect of vessel distance on narwhal travel speed at close distances (up to 1 km). When vessels were within 1 km, adult groups and mixed groups with immatures travelled approximately 35% to 64% faster, respectively, than when vessels were not present. However, there was no effect on travel speed for mixed groups without immatures. No data was available for mother-immature pairs. Overall, the data suggest an effect of vessel presence on travel speed in close proximity to the vessel, with the strongest evidence for adult groups. As discussed in Section 3.0, a change in energy expenditure (e.g., change in travel speed) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect (i.e., increase in group travel speed for adult groups and mixed groups with immatures when within 1 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 7 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which could lead to population-level effects. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

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ᐋᒃᑐᓂ 2023-ᒥ, WSP ᑲᓇᑕᒥ ᐃᓚᐅᐸᐊᕐᓱᑎᑦᓂᒃ, ᐱᓕᕆᔨᐸᔨᓪᓗᑎᑦ ᕿᓂᐅᓪᓚᖅᑎᑦ ᐅᑦᑐᖓᓂᐊᖅᑎᑦ ᓄᐊᐸᐊᕐᓱᓕᕆᔨᒃᑯᑦ (ᕿᓂᐅᓪᓚᖅ), ᐱᓕᕆᐊᖅᑳᒪᐅᖅᑐᑦ ᐃᓚᖓᑎᑦ ᖃᐅᔨᓴᖅᑎᑦᑐᑦ ᐱᓕᕆᐊᖅᑐᑦ (ᐱᓕᕆᐊᖅ), ᓄᓕᒥ–ᑐᖓᓴᓚᓕᓚᒃ ᖃᐅᔨᓴᖅᑎᑦᑐᑦ ᐱᓕᕆᐊᖓᖃᑦᑕᖅᑐᑦ ᐊᖏᖅᑐᒍᒪᒻᒪᑦ 2014-ᒥᓂᑦ (ᐱᖅᐅᓇᓂ 2018) ᐱᔨᔪᑕᐅᔨᓪᓗᓂ ᖃᐅᔨᓴᖅᑎᑦᑕᐅᓂᓂᑦ ᑐᓴᐅᔨᒃ ᐃᓕᓴᖅᑎᑦᑕᖅᑐᒪᑦᑐᑦ ᕿᓂᐅᓪᓚᖅᑎᑦᑐᑦ ᐅᑎᐊᖏᔪᖃᖅᑎᑦᑕᓂᓂᑦᑎᔪᑦ ᐅᑦᐊᖏᓇᓂᓂᑦ ᑕᐅᐳᓇ ᐅᑎᐊᖏᑦ ᐊᖅᓂᒪᑎᓇᐸᒃᑐᒪᔪᑦ ᐅᐊᖓᓇᓂᓂ ᖃᑭᖅᑕᒻᒥᓂᑦ. ᐃᓕᑎᐅᐳᓪᓗᓂ ᐱᓕᕆᐊᖅᑐᑦ ᐊᐅᓚᖅᑎᑦᑕᐅᓂᑦᑐᑦ (RAD), ᖃᑎᖓᓚᐅᖅᑐᑦ ᖃᓄᐃᓕᓴᓂᑦᑐᑦ ᐃᓕᓴᖅᑎᑦᑕᐅᓂᑦᑐᑦ ᐊᖏᖅᑎᑦᑐᑦ ᐱᓕᕆᐊᖅᑐᑦ ᐃᓕᓴᖅᑎᑦᑕᐅᓂᑦᑐᑦ ᐊᐅᓚ

ᐊᑯᓪᐃᓐᓂᑦ ᐃᒪᓐᓇᑎᑎ (CI) = 6,342 – 17,347) (ᑐᓂᐅᓪᓗ-ᓇᐅᑯᓴᑦ ᐊᑕᖏᖅᓯᓗᑎᒃ 2015). 2023-ᒥ ᖃᓄᒪᑕᓯᒃᑯᑦ ᖃᐅᔨᓴᓂᖓᒥ ᖃᐅᔨᓴᐅᔪᑦ ᓴᖅᑭᓪᓕᐅᖓᒥᔪᑦ ᑐᐃᓐᓕ ᐊᑕᖃᓄᖅᓯᓂᓐᓂᓐᓂᓂᖅ ᑕᓯᐅᔪᒥ ᓯᓚᐃᓐᓇᖅᑐᖅ ᑕᓯᓚᐃᓐᓇᖅᑐᖅ ᑕᓯᓚᐃᓐᓇᖅᑐᖅ ᑕ

(SBA) ᐱᓕᕆᐊᖑᓂᓵᑦᑕᕐᓂᓐ 9-ᓂ ᐊᖏᕐᕌᔪᓂ ᖃᐅᔨᖏᖅᐊᖏᓕᓪᓕᐊᑦᑕᕐᓂᓐᓇᖅᓂᖅᓯᒪᓂ ᐱᓕᕆᐊᒥ, ᐊᒥᓱᓂᖏᖅᓯᑦ ᑕᑯᐅᐅᔪᑦ ᐱᑕᖃᖅᑐᓴᓂᖅ ᐃᓐᓇᑦᖃᓕᔪᓂᖅ ᑐᓴᓕᓂᖅ, ᑭᖑᓂᐊᒍᑦ ᐃᓐᓇᑦᖃᓕᒫᑦᑕᑦ, ᐅᑎᐊᑦ ᐊᓪᓚᓗ ᐊᖏᕐᓂᓯᑦ.

- ᐃᓕᓐᑦ ᐃᓐᓇᑦᖃᓕᒫᑦᑕᑦ (ᖃᐅᔨᓴᓕᓕᖅᑎᖃᕆᐊᓕᓂᑦ ᓇᓗᓇᐃᖅᑭᔪᓂᑦ [EWI]): ᖃᐅᔨᖅᐅᐅᔪᑦ ᑲᑎᖓᐅᖅᑐᓂᓐ ᐱᑎᖏᕐᓂᓂᖅᓯᓂᖅ ᓇᓗᓇᐃᖅᑭᔪᑦ ᑕᐅᓂᓐ ᐊᒥᐊᑐᓂᓐ ᐃᓕᓐᑦ ᐃᓐᓇᑦᖃᓕᒫᑦᑕᑦᑕᓂᓐ ᑐᓴᓕᓂᓐ ᐅᔨᓴᖅᐅᓕᓕᔪᓂᑦ ᐃᓕᓴᓂᓕᓕᓴᐸᑦᑕᓂᓵᓂᖅ ᖃᐅᔨᓴᖏᐅᖅᑕᐅᔪᑦ (SBA) 2023-ᒥ (0.242) ᖏᑦᕕᓂᓵᖏᓴᓐᓇᕆᔨᒪᐅᖅᑐᑦ ᐅᑎᐊᔪᐊᖃᖅᑎᑎᑕᓂᓵᓕᒍ ᓴᓴᐅᑎᐅᔪᓂᖅ 2014-ᒥ ᐊᓪᓚ 2015-ᒥ (0.152 ᐊᓪᓚᓗ 0.167, ᐅᖃᖅᓯᐅᔪᓂᖅ), ᑭᓱᖅᑕᐃᓕᓗᓂ 57%-ᒥᑦ ᐅᓄᖅᓯᒋᐊᖅᓯᒪᔪᑦ ᐱᒋᐊᕈᑕᐅᔪᓂ ᖃᐅᔨᓴᖅᑎᑕ ᖃᓄᐃᓕᓐᓂᓴᐅᔪᓂ. ᑕᑉᓓ ᖃᐅᔨᖅᐅᐅᔪᖏᖅ ᑐᓂᓯᐅᖅᑕᐅᓵᓕᐊᖅᑐᑦ ᐅᑭᖅᓯᖅᑕᐅᓵᑕᖅᑎᐊᖓᔪᓂ ᐱᔨᔪᑎᑎᓕᓕᒫᑦ ᐅᖃᖅᓯᐅᔪᖏᖅ ᒥᑦᑎᖅᑐᓂᓐᓇᕐᓂᖅᓯᒪᔪᑦ ᐅᖃᖅᓯᐅᔪᖏᖅ ᒥᑦᑎᖅᑐᓂᓐᓇᕐᓂᖅᓯᒪᔪᑦ (Ċᑦᔪᓓᖓᓕᓪᓕᑕᑦ ᖃᐅᔨᓴᖅᑎᑎᑕᓂᓐ ᑎᑎᖅᑐᓂᓐᓇᕐᓂᖅᓯᒪᔪᑦ). ᖃᐅᔨᖅᐅᐅᔪᑦ ᖃᖓᑕᕐᓂᓵᔪᓂ ᑎᑎᖅᑐᓂᓐᓇᕐᓂᖅᓯᒪᔪᑦ ᐱᓕᕆᐊᒥᐊᑐᓂᓐ ᐃᓐᓇᑦᖃᓕᒫᑦᑕᑦᑕᓂᓐ ᑐᓴᓕᓂᓐ ᑎᑎᖅᑐᓂᓐᓇᕐᓂᖅᓯᒪᔪᑦ ᐱᔨᔪᑎᑎᓕᓕᒫᑦ ᐱᓕᕆᐊᒥᐊᑐᓂᓐ ᐃᓐᓇᑦᖃᓕᒫᑦᑕᑦᑕᓂᓐ ᐅᑭᐅᖃᖅ

ᖃᐅᔨᔪᐅᔪᓂ ᐃᒪᓕᓇᓯᓄᓇᓂᕐᔪᓂ ᐅᓄᖅᑐᑎᓪᓗᓯᓂ ᐃᓕᓴᐅᓯᖅᑐᓯᓂ, ᖃᓄᐃᓯᒥᓄᓂᕐᓂ, ᖃᓄᖅᑐᑎᓪᓗᓯᓂ ᐅᓂᐅᓕᖅᑐᓂ ᐃᓚᒋᑦᑐᑎᓪᓗᓯᓂ ᐃᓕᓴᐅᓯᖅᑐᓯᓂ ᐃᓚᒋᑦᑐᑎᓪᓗ

ᑭᓪᓕᐅᔪᓂᖅ. ᑕᒪᓐᓇ ᐃᓕᓴᕐᕕᐅᓕᖅᑐᑎᒃ ᒪᓕᓪᑐᒃ ᐊᓪᑐᐃᓂᕐᓂᒃ ᓇᓕᐅᖅᑕᖅᑕᐅᓯᒪᔪᓂᒃ ᑕᐃᑲᓂ ᑭᖓᓗᓕᓴᕐᕕᑎᑦ ᐊᓂᒪᒥᑦ ᐊᓪᑐᐃᓇᓂᐅᓂᖅᑐᑎᒃ ᐅᓂᓪᑲᓂᑦ (FEIS) ᐊᒻᒪᓗ ᑭᓇᐅᓪᓴᓴᓕᓚᓯᐊᓂᕐᒥ (ERP), ᑕᒪᑯᐊᐃ ᐅᒥᐊᖅᓯᐊᑦ ᓂᐱᖓᓂᓂ ᐊᓪᑐᐃᓇᓂᑦ ᑐᓴᐅᒃᑐᓂᒃ ᐊᒻᒪᓗ ᐃᓐᓇᓕᐅᑲᑲᓂᓯᓂᖓᓂᓂᓂᑦ, ᓄᓇᖓᓂᑐᐊᖅ ᑕᑯᖏᑦᑕᐅᑎᑦᑕᐃᓕᓚᓂᖅᑎᑦ ᐃᓕᓴᕐᕕᑯᖏᓐᓂᒃ.

- ᑲᑎᖓᐅᖅᑐᑦ ᐅᖓᓗᓂᑐᑦᓂᖓᓂᑦ: ᖃᐅᔨᓴᐅᔪᓂ ᓇᓗᓇᐃᖅᓯᔪᓂ ᐃᓴᐅᑎᑎᒍᑦ ᐊᖏᓂᔨᖓᑦᑐᑦ ᑭᓯᓇᓂᓕᒃ ᑐᑭᑕᐃᓴᖅᑐᑦ ᐊᑐᐅᑉᐳᖅᑐᑦ ᐃᓕᓴᕐᕕᑦ ᐊᑐᐅᑉᐳᖅᑐᑦ ᐃᓕᓴᕐᕕᑦ ᐃᓗᐊᓂᑦᑕᓂᓗᓂᑦ 3 ᑭᓪᒥᑕᑦ ᑐᐃᓐᓂᓪᑐᒃ ᑲᑎᖓᐅᖅᑐᑦᑐᓄᑦ. ᑭᓯᐊᓂᓕ ᒥᖃᕐᖃᖅᑕᐅᓯᒪᔪᓂᑦ ᐊᖏᑐᓂᖅᓴᓂᑦ ᐊᖏᑐᓂᖅᓴ ᐃᒪᐃᑎᑕᑦᑐᓂᖅᓴᓂᑦ ᑕᒪᓐᓇᐅᑦᑐᓂᖅᓴᓂᑦ ᐊᖏᑐᓂᖅᓴ ᐃᒪᐃᑎᑕᑦᑐᓂᖅᓴᓂᑦ ᐊᖏᑐᓂᖅᓴᓂᑦ ᐊᖏᑐᓂᖅᓴᓂᑦ ᐊᖏ

ᑭᓇᐅᔨᕆᕕᒃᑕᓇᓱᐊᕐᓂᖏᑦ (ERP), ᑕᒪᐃᓂᐊ ᐅᒥᐊᕐᕕᐊᑦ ᓂᐱᖏᓐᓂ ᐊᐃᑐᐊᓂᑦ ᑐᑎᓪᓗᓂ ᑭᓚᓐᓂᒃ ᐊᓪᒪᓗ ᐃᓐᓇᓕᐅᑲᐅᓂᐊᕐᓂᖏᓐᓂ, ᓄᓇᖓᓂᑐᐊᖅ ᑕᓂᖅᑕᑕᐅᑎᑕᑐᑕᐃᓕᓚᒥᐅᑦ ᐃᓕᓴᐅᓂᖅ.

- ᐃᖏᕐᕋᑎᓪᓗᑎᑦ ᓱᐲᓕᓂᖏᓐᓂ: ᖃᐅᔨᔨᐅᐅᓯᑦ ᐃᒪᐃᑎᑎᑦᑎᖅᑯᓗᔨᑦ ᐊᐃᑐᐃᓂᖏᓐᑦ ᐅᒥᐊᕐᕕᐊᑦ ᐅᖓᓱᓐᖏᓐᓂᓐᓂ ᑐᑎᓪᓗᒍᖏᓐᓂ ᓱᐲᓕᓂᖏᓐᑦ ᖃᓂᒋᔨᖏᓐᓂ (ᑎᑭᓗᒍ 1 ᑭᓪᒥᑕᑦ). ᐅᒥᐊᕐᕕᐊᑦ ᐃᓗᐊᓂᑎᓪᓗᑎᑦ 1 ᑭᓪᒥᑕᑦ, ᐃᓐᓇᑕᖅᓭᒪᔨᑦ ᑲᑎᖓᐅᖅᑐᑦ ᐊᓪᒪᓗ ᑲᑎᖓᐅᖅᑐᑦ ᐃᓐᓇᑕᖅᓭᒪᔨᑦᑐᓪᓗ ᐃᖏᕐᕋᖃᑦᑕᖅᑐᑦ 35%-ᒥᑦ 64%-ᓴᓚᖖᒧᑦ ᓱᐲᓕᓂᖅᓴᐅᓪᓗᑎᑦ, ᐅᖃᐅᓱᖅᑎᓪᓗᑕ, ᐅᒥᐊᕐᕕᐊᑦ ᐱᑕᖃᖅᖏᓐᓄᑦ. ᑭᓱᐊᓂᓕ ᐊᐃᑐᐃᓂᖅᓴᖃᖅᖏᓐᓂᑐᖅ ᐃᖏᕐᕋᖃᑦᑕᑦᓂᓂᖏᓐᓂᑕ ᓱᐲᓕᓂᖏᓐᓂᓐᓂ ᑲᑎᖓᐅᖅᑐᑦ ᐃᓐᓇᑕᖅᓭᒪᔨᖅᑕᖅᖏᓐᓂᑐᖅ ᐃᓕᐅᕐᐸᐅᖅᑐᓪᓗᑎᑦ. ᑎᑎᖅᖃᓄᑕᖃᖅᖏᓐᓂᑐᖅ ᐊᑲᓇᒋᐢ–ᐅᒥᐊᓱᑦ ᖃᓄᖅᓴᑎᓪᓗᑎᑦ. ᑕᒪᐃᓐᓇᓪᓚᑦᑕᖅ, ᑎᑎᖃᖅᓯᓂᑦ ᐃᒪᐃᖅᓄᓂᑎᔨᑦ ᐊᐃᑐᐃᓂᑦ ᐅᒥᐊᕐᕕᖅᑕᖃᖅᑎᑦᓯᓂᒥᑦ ᐱᑕᖅᓭᒪᔨᑦᑐᓂᑦ ᖃᓄᖅᓴᖏᓐᓂᑐᖅ ᐅᒥᐊᕐᕕᐊᑦ, ᓇᓗᓇᐃᕈᑎᖃᓕᖓᓪᓗᑎᑦ ᐃᓐᓇᑕᖅᓭᒪᔨᑦ ᖃᓄᖅᓴᐅᖅᑐᑦ.ᐅᖃᖃᓄᑭᔪᑕᐅᖅᖃᐅᖅᓯᑦ ᐊᐃᕐᑐᖅᓭᒪᔨᖅ 3.0, ᐊᓱᔨᕐᖅᑐᑦ ᖃᓄᖅᓴᐅᖅᑐᓂ (ᓱᑦᓗ ᐊᓱᔨᕐᖅᑐᑦ ᖃᓄᖅᓴᐅᖅᑐᑦ ᖃᓇᐃᓕᓴᖏᓐᓂᑦ) ᑐᐃᓐᓇᑦ ᒪᓕᑐᐃᓐᓇᕐᓂᖅᑐᑦ ᐱᓗᐊᖏᓕᑐᑎᑦ ᐊᓱᓴᓕᔭᖅᑐᒍᑦ ᐃᓕᖓᓂᖅᑐᑦ ᖃᓇᐃᓕᓴᖏᓐᓂᑦ ᐃᓗᐊᓂ 1 ᑭᓪᒥᑕ ᐅᒥᐊᕐᕕᐊᒥᑦ), ᑕᑦᓇ ᖃᐅᔨᔨᐅᐅᓯᖅ ᓂᓗᐅᑎᔨᐅᐅᖏᖅᑐᑦᑐᖅ ᐊᓱᔨᐅᑎᓂᑦ ᐃᓕᖓᓂᖅᑐᑦ ᖃᓇᐃᓕᓴᖏᓐᓂᑦ ᐃᓗᐊᓂ 1 ᑭᓪᒥᑕ ᐅᒥᐊᕐᕕᐊᒥᑦ), ᑕᑦᓇ ᖃᐅᔨᔨᐅᐅᓯᖅ ᓂᓗᐅᑎᔨᐅᐅᖏᖅᑐᑦᑐᖅ ᐊᓱᔨᐅᑎᓂᑦ (ᓱᑦᓗ ᐊᓱᔨᕐᖅᑐᑦ ᖃᓇᐃᓕᓴᖏᓐᓂᑦ) ᑐᐃᓐᓇᑦ ᒪᓕᑐᐃᓐᓇᕐᓂᖅᑐᑦ ᐱᓗᐊᖏᓕᑐᑎᑦ ᐊᓪᓚᐊᕐᑎᑕᖅᑐᑦ ᐊᓱᓴᓕᔭᖅᑐᒍᑦ ᐃᓕᖓᓂᖅᑐᑦ (ᓱᑦᓗ ᐊᓱᔨᕐᖅᑐᑦ ᖃᓇᐃᓕᓴᖏᓐᓂᑦ ᐃᓗᐊᓂ 1 ᑭᓪᒥᑕ ᐅᒥᐊᕐᕕᒥᑦ), ᑕᑦᓇ ᖃᐅᔨᔨᐅᐅᓯᖅ ᓂᓗᐅᑎᔨᐅᐅᖏᖅᑐᑦᑐᖅ ᐊᓱᔨᐅᑎᓂᑦ ᐃᓗᐊᓂ ᐊᐃᑐᐃᓂᖅᓴᖃᖅᖏᓐᓂᑦ ᐃᓐᓇᑕᖅᓭᒪᔨᑦ ᐃᓕᖓᓂᖅᑐᑦ ᐊᓪᒪᓗ ᐊᐃᑐᐃᓂᖅᓴᖃᖅᖏᓐᓂᑦ ᐃᓐᓇᑕᖅᓭᒪᔨᑦ ᐃᓕᖓᓂᖅᑐᑦ ᐊᓱᔨᐅᑎᓂᑦ ᐃᓗᐊᓂ 1 ᑭᓪᒥᑕ ᐅᒥᐊᕐᕕᒥᑦ), ᑕᑦᓇ ᖃᐅᔨᔨᐅᐅᓯᖅ ᓂᓗᐅᑎᔨᐅᐅᖏᖅᑐᑦᑐᖅ ᐊᓱᔨᐅᑎᓂᑦ ᐃᓗᐊᓂ ᐊᐃᑐᐃᓂᖅᓴᖃᖅᖏᓐᓂᑦ ᐃᓐᓇᑕᖅᓭᒪᔨᑦ ᐃᓕᖓᓂᖅᑐᑦ

Study Limitations

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Acronyms / Abbreviations

AIS	Automatic Identification System
Baffinland	Baffinland Iron Mines Corporation
BB	Baffin Bay
BSA	Behavioural Study Area
CPA	Closest Point of Approach
CI	Confidence interval
CV	Coefficient of variation
DFO	Fisheries and Oceans Canada
DSLR	Digital single lens reflex
ERP	Early Revenue Phase
EWI	Early Warning Indicator
FEIS	Final Environmental Impact Statement
FFID	Focal follow Identification
GPS	Global Positioning System
h	Hour
Hz	Hertz
ICI	Inter click interval
IQ	Inuit Qaujimajatuqangit
JASCO	JASCO Applied Sciences
kHz	Kilohertz
km	Kilometers
LOESS	Locally estimated scatterplot smoothing
m	Meters
m/s	Meters per second
MHTO	Mittimatalik Hunters and Trappers Organization
MMOs	Marine Mammal Observers
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
SD	Standard deviation
SEL	Sound exposure level
SFOC	Special Flight Operations Certificate
SPL	Sound pressure level
SPL_{rms}	Sound pressure level (root mean square)
SSA	Stratified Study Area

Steenbsy Port	Proposed port facility in Steensby Inlet
the Program	Bruce Head Shore-based Monitoring Program
the Project	Mary River Project
UAV	Unmanned Aerial Vehicle
WSP	WSP Canada Inc.

1.0 INTRODUCTION

This report presents the integrated results of a nine-year shore-based monitoring study of narwhal (*Monodon monoceros*) conducted near Bruce Head on North Baffin Island, Nunavut. During the open-water seasons of 2014–2023 (with exception of 2018), systematic data on narwhal relative abundance and distribution (RAD), group composition and behaviour were collected from a cliff-based observation platform overlooking an established shipping corridor as part of the Bruce Head Shore-based Monitoring Program (the Program). The objective of the Program was to investigate potential narwhal responses to open-water shipping activities. Additional data were collected on environmental conditions (e.g., glare, Beaufort wind scale level) 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 (e.g., hunting, killer whale predation, recreational boat traffic).

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) 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 million tonnes per annum (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 2018–2025 through Project Certificate amendments (Baffinland 2018, 2020a, 2022, 2023a). During the first year of ERP operations in 2015, Baffinland shipped ~918,000 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 4.1 million tonnes involving 58 return ore carrier voyages. Following approved production increase to 6.0 Mtpa, a total of 5.1 million tonnes of ore were shipped via 71 return voyages in 2018, 5.9 million tonnes of ore were shipped via 81 return voyages in 2019, 5.5 million tonnes were shipped via 72 return voyages in 2020, 5.6 million tonnes were shipped via 73 (one vessel was released unloaded) return voyages in 2021, and 4.7 million tonnes were shipped via 62 return voyages in 2022. In 2023, a total of 6.02 million tonnes of iron ore were shipped via 75 return voyages with the first inbound transit of the season occurring on 9 August and the last outbound transit of the season occurring on 31 October 2023.

1.2 Program Objective

The objective of the Program is to investigate and characterize narwhal behavioural responses to shipping along the Northern Shipping Route in Milne Inlet, with data collected on RAD, group composition, and behaviour. Additionally, data are collected on environmental conditions and anthropogenic activities (e.g., shipping and hunting activities), as well as predation events by killer whales (*Orcinus orca*), to distinguish between the potential effects of Project-related shipping activities and confounding factors that may also influence narwhal behaviour.

LEGEND

- COMMUNITY
- PROJECT SITE
- 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 INSTITURE. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
PROJECT LOCATION

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

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1.3 Regulatory Context

In accordance with existing Terms and Conditions of the Nunavut Impact Review Board (NIRB) Project Certificate (PC) No. 005 (the Project Certificate), Baffinland is responsible for the establishment and implementation of a Marine Monitoring Plan (MMP), which includes detailed information on Baffinland's Project effects monitoring programs that are conducted over a sufficient time to meet the following objectives:

- Measure the relevant effects of the Project on the marine environment.
- Confirm that the Project is being carried out within the terms and conditions relating to the protection of the marine environment.
- Assess the accuracy of the predictions contained in the Final Environmental Impact Statement (FEIS) for the Project.

The Program represents one of several environmental effects monitoring (EEM) programs for marine mammals conducted by Baffinland in support of the Mary River Project. The Program was designed to specifically address PC conditions related to evaluating potential disturbance of marine mammals from shipping activities that may result in changes to animal distribution, relative abundance, and behaviour in the Project's Regional Study Area (RSA; Figure 1-1). Specifically, this included 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."*

1.4 Early Warning Indicators

Adverse effects of the Project on narwhal may be promptly identified and mitigated through the development of appropriate Early Warning Indicators (EWIs). Baffinland has developed a number of indicators in support of the Project aimed at the rapid identification of adverse impacts on narwhal along the Northern Shipping Route consistent with PC Conditions (PC) No. 110 and 112, as outlined in the Marine Mammal Trigger Action Response Plan (TARP; Baffinland 2021c, 2023). Many of these indicators, monitored across multiple monitoring programs, are suitable for the purpose of early detection of adverse effects on narwhal resulting from Project activities and/or other contributing factors in the marine environment.

Of these, one indicator has been formally identified as an early warning indicator (EWI) for narwhal, based on consolidated input from members of the MEWG since 2018. This EWI was defined as 'a statistically significant decrease in the proportion of immature narwhal[1] (relative to the observed population in the RSA) as compared to the '2014/2015 baseline condition'. This EWI was originally proposed by Fisheries and Oceans Canada (DFO) in their October 2018 submission of EWI suggestions and was also confirmed as being of high importance by the Mittimatalik Hunters and Trappers Organization (MHTO) (Golder 2020).

In more recent engagements with the MEWG, Fisheries and Oceans Canada (DFO) recommended that an index of variability in the EWI measurement be included, as well as an indication related to the error around the measurement (Baffinland 2021b). Therefore, the assessment of variation in the EWI analysis, in relation to the baseline levels (i.e., proportion of immature narwhal in 2014–2015), was modified to include an index of variability. The revised EWI threshold (currently in place for the Project) is now defined as a "statistically significant difference between a year's least squares mean and the average of 2014–2015 least squares mean values". This EWI is presently included as one of the moderate and high-risk threshold indicators in the Marine Mammal Threshold Action Response Plan (TARP; Baffinland 2023b), as outlined in Section 1.5.

Further information on the analysis of EWI is provided in Section 4.3.1.3. A detailed description of the EWI selection process, including engagement with the MEWG, is provided in Golder (2020d) and WSP (2023b).

1.5 Adaptive Management Protocol

Adaptive management is a planned and systematic process for continuously improving environmental management practices by learning about their outcomes (CEAA 2009). Adaptive management provides flexibility to identify and implement new mitigation measures or to modify existing ones during the life of a project. Adaptive strategies are implemented when unanticipated adverse effects are observed, or if effects exceed identified thresholds.

In support of Baffinland's Phase 2 Proposal for the Project, Baffinland developed a draft Adaptive Management Plan (AMP), which provides a framework for how adaptive management is incorporated into Project operations (Baffinland 2020b). As part of this process, a Marine Mammal Trigger Action Response Plan (TARP) was developed for the Project, which identifies a number of performance indicators, effect thresholds and pre-defined actions (i.e., responses) that are used to evaluate and respond to potential Project effects on narwhal (and other marine mammal species in the Project area; Baffinland 2021c). The TARP shares the same objective as the EWI identified in Section 1.4, although uses a broader range of effect indicators that are measured against a series of

[1] Defined as calves and yearlings. Calves = dark grey in colour, approx.1/3 to 1/2 the length of the accompanying adult female, usually in close position to its mother. Yearlings = Light to uniformly dark grey in colour, approx. 2/3 the length of the accompanying adult female.

tiered thresholds (i.e., low, moderate and high-risk thresholds) that are designed to guide short-term and long-term adaptive management strategies. The pre-defined actions identified in the TARP describe the responses that Baffinland would implement should the corresponding threshold levels be exceeded and assuming there is some degree of certainty that the measured change is Project-related. Three levels of action have been identified: low, moderate, and high. These responses range from increased monitoring and data analysis (e.g., trend analysis); identification of possible sources; to risk assessment and/or mitigation. Baffinland released the most current version of the Marine Mammal TARP and Action Toolkits as part of the draft MMP submitted to the NIRB on 15 May 2023 (Baffinland 2023b).

1.5.1 Low Risk Threshold

As part of the tiered approach for adaptive management for the Project, the following criteria have been identified which represent 'Low Risk' thresholds for narwhal:

- Confirmed[2] moderate severity behavioural responses (Severity Score 5 and 6)[3] that do not persist for a prolonged period (i.e., for several hours) following the exposure event[4], as described in Section 3.0.

For the threshold to be met, response in movement behaviour would need to be observed as a trend in the data across individuals. In the event that these threshold criteria are exceeded, a commensurate 'Low Risk' response would be triggered (Baffinland 2023b).

1.5.2 Moderate Risk Threshold

As part of the tiered approach for adaptive management for the Project, the following criteria have been identified which represent 'Moderate Risk' thresholds for narwhal:

- Confirmed 'moderate severity' behavioural responses (Severity Score 5 and 6) that persist for a prolonged period (i.e., for several hours) following the exposure event, as described in Section 3.0.

AND

- A statistically significant decrease in the proportion of immature narwhal relative to baseline conditions (2014/2015 values), quantified as a statistically significant difference between the annual least squares mean value and the average of the 2014–2015 least squares mean values.

[2] Confirmed indicates that the Risk Status/ Threshold trigger has been observed in at least two consecutive monitoring programs, whether during the regular monitoring schedule or confirmed through a special study.

[3] Moderate severity behavioural responses are consistent with Level 5 and 6 severity response scores from Southall et al. (2007, 2021) and Finneran et al. (2017). These consist of responses that could become significant (defined for this purpose as responses with potential to impact critical life functions and/or responses consistent with the level of 'harassment' as defined under the U.S. Marine Mammal Protection Act) if sustained over a longer duration (lasting over a period of several hours, or enough time to significantly disrupt a narwhal's daily routine). Also see Section 3.0 for a detailed description.

[4] The exposure event is considered the period during which the vessel remains within 5 km of the exposed animal.

For the threshold to be met, behavioural responses would need to be observed as a trend in the data across individuals. In the event that these threshold criteria are exceeded, a commensurate 'Moderate Risk' response would be triggered (Baffinland 2023b).

1.6 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 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 Stephens Island to the north to the entrance of Koluktoo Bay. Poirier Island is visible directly east of the survey platform.

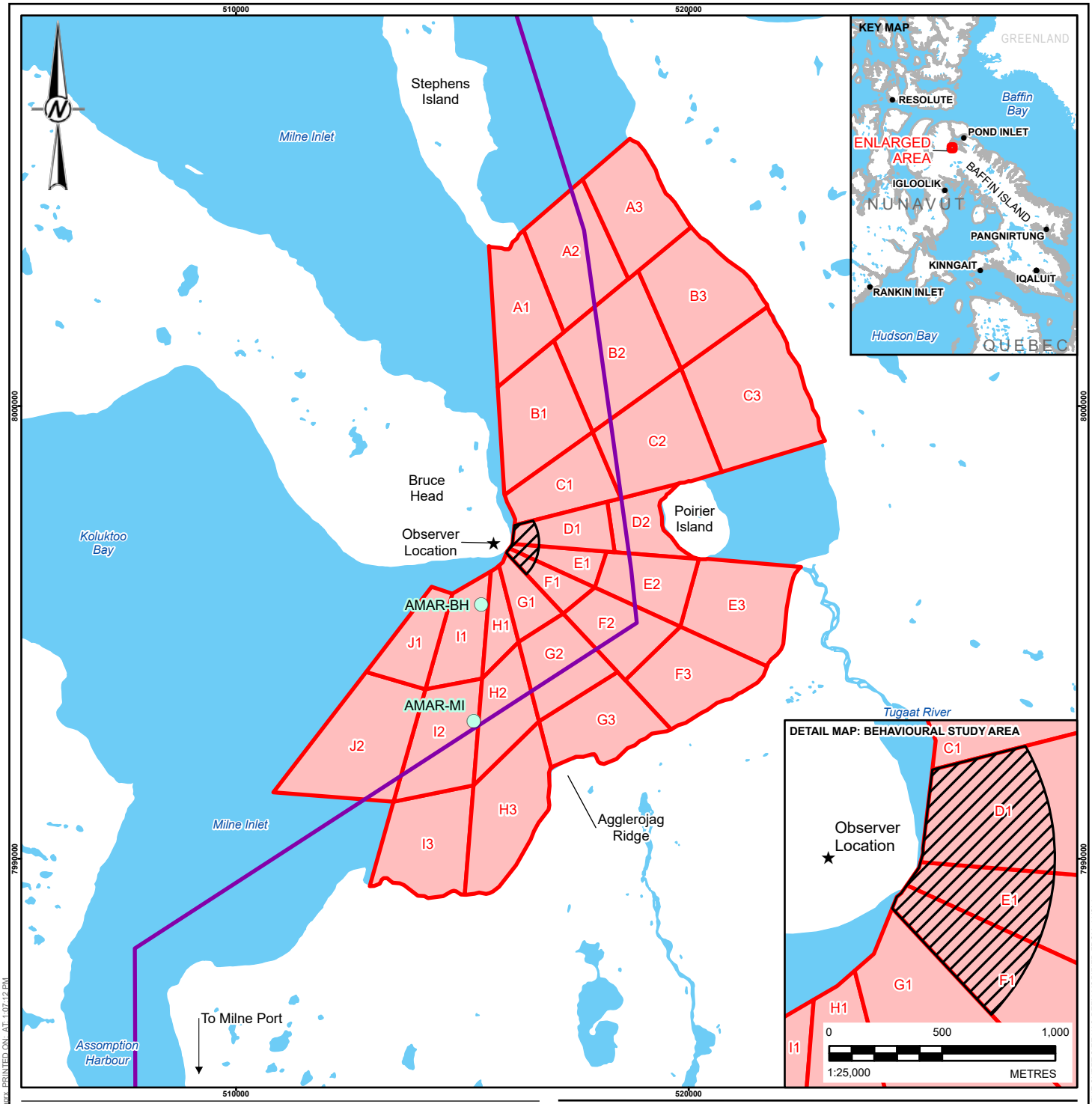
Consistent with previous years, monitoring data is collected within two study areas: a confined Behavioural Study Area (BSA) that is nested within a larger Stratified Study Area (SSA) (Figure 1-2).

1.6.1 Stratified Study Area

Data on narwhal relative abundance and distribution data (RAD) is collected within the boundaries of the SSA which covers a total area of 90.5 km^2. The SSA is stratified into strata A (northernmost stratum) through J (southernmost stratum; added in 2019) and further separated into substrata 1 through 3 (substrata 1 being closest to the Bruce Head shore/observation platform and substrata 3 being the furthest away). There are a total of 28 substrata within the SSA, as strata D and J only have two substrata each, 1 and 2. Substratum boundaries are visually defined in the field using definitive landmarks on the far shore of Milne inlet and nearby islands.

1.6.2 Behavioural Study Area

Narwhal group composition is collected within the boundaries of the BSA which covers portions of strata D, E, and F that extends 600 m from the shoreline below the Bruce Head observation platform. The shoreline adjacent to the BSA is an established Inuit hunting camp. From 2014–2021, the BSA was used to record group composition and behavioural data. Since 2022, only group composition has been recorded in the BSA. Behavioural data has since been recorded through the UAV component of the program, with UAV data collected primarily in the SSA, with a focus along the Southern Shipping Route (noting however that UAV surveys avoid the BSA to minimize interference between UAV operations and hunting activities at the existing hunting camp immediately adjacent to the BSA).



LEGEND

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

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY 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
BRUCE HEAD SHORE-BASED MONITORING PROGRAM – STRATIFIED STUDY AREA (SSA) AND BEHAVIOURAL STUDY AREA (BSA)

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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1.6.3 High Risk Threshold

As part of the tiered approach for adaptive management for the Project, the following criteria have been identified which represent ‘High Risk’ thresholds for narwhal:

- Confirmed moderate severity behavioural responses (Severity Score 5 and 6) that persist for a prolonged period (i.e., for several hours) following the exposure event, as described in Section 3.0.

AND/OR

- Confirmed high severity responses (Severity Score 7 to 10) as described in Section 3.0.

AND

- A statistically significant decrease in the proportion of immature narwhal relative to baseline conditions (2014/2015 values), quantified as a statistically significant difference between the annual least squares mean value and the average of the 2014–2015 least squares mean values.

AND/OR

- >25.0% decrease in the Eclipse Sound stock size (abundance) relative to the 2019 aerial survey abundance.

For the threshold to be met, behavioural responses would need to be observed as a trend in the data across individuals. In the event that these threshold criteria are exceeded, a pre-determined ‘High Risk’ response would be triggered, as defined in Baffinland (2023).

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 recognizes seven distinct narwhal stocks 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*).

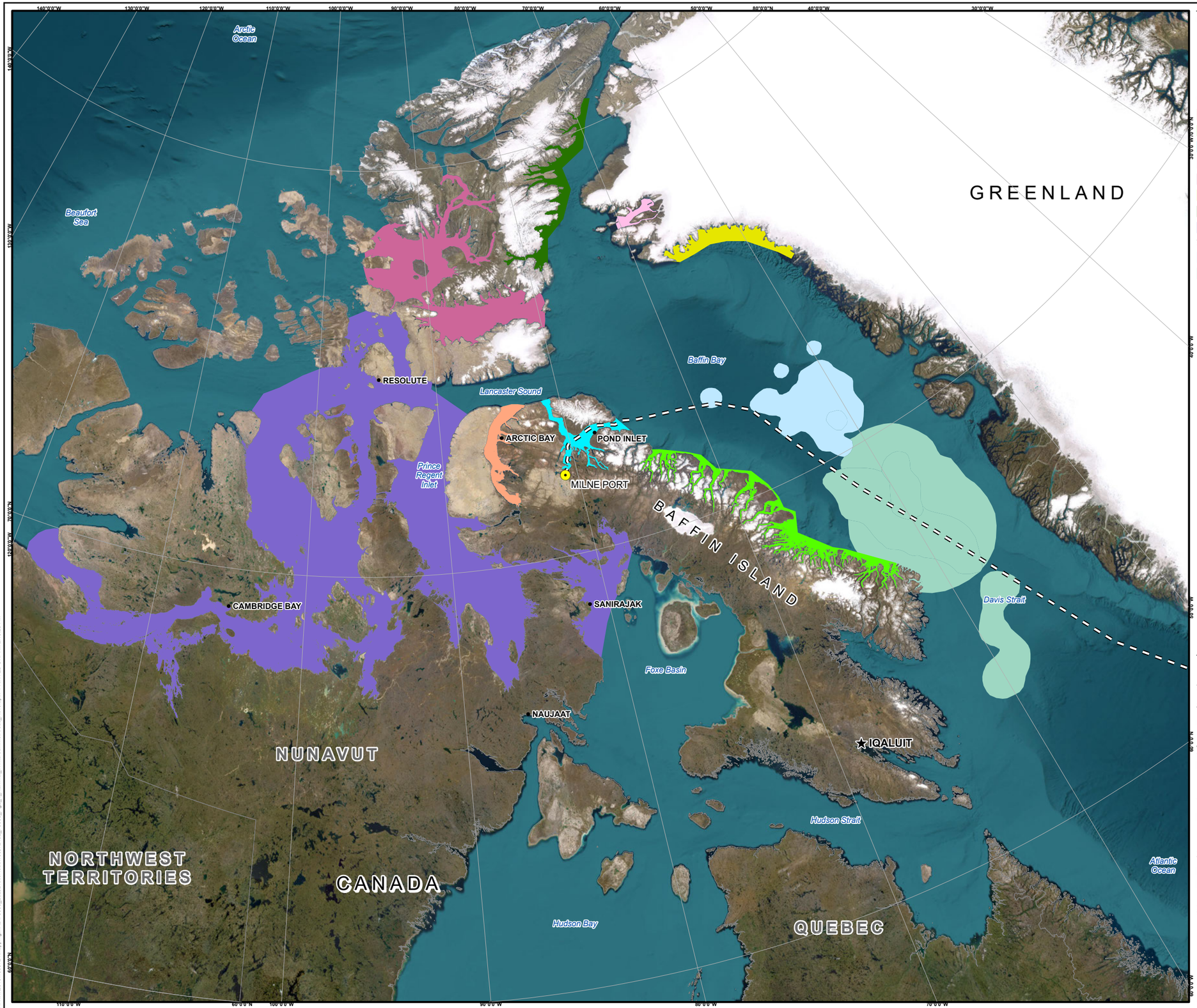
The Canadian High Arctic Cetacean Survey conducted by DFO in August 2013 represents the most complete simultaneous survey conducted of the six major summer stocks in the Canadian Arctic (Doniol-Valcroze et al. 2015). The current abundance estimate for the Baffin Bay population, corrected for diving and observer bias, is 141,909 individuals (Coefficient of Variation (CV) by stock = 0.2 to 0.65; Doniol-Valcroze et al. 2015).

Although narwhal stocks are thought to be geographically segregated from one another during the summer months, annual variation in stock size estimates between the Eclipse Sound and Admiralty Inlet summer stock areas suggests that there is some degree of exchange between these stocks during the open-water season (Thomas et al. 2015; DFO 2020a). The 2013 abundance estimate for the Eclipse Sound stock was 12,039 narwhal (CV = 0.23; DFO 2020a) while the 2013 abundance estimate for the Admiralty Inlet stock was 35,043 narwhal (CV = 0.42) (Doniol-Valcroze et al. 2015; Doniol-Valcroze et al. 2020).

Results from aerial surveys conducted by WSP in 2023 indicated an abundance estimate of 40,706 narwhal for the combined Eclipse Sound and Admiralty Inlet stocks (Coefficient of Variation (CV) = 0.11, 95% confidence interval ((CI) = 32,711-50,655; WSP 2024a), which fell within the 95% CI of DFO's 2013 abundance estimate of the combined stock (45,532 narwhal, CV= 0.33, 95% CI = 22,440 – 92,384; Doniol-Valcroze et al. 2015). Results from aerial surveys conducted by WSP in 2022 indicated an abundance estimate of 46,408 narwhal for the combined Eclipse Sound and Admiralty Inlet stocks (Coefficient of Variation (CV) = 0.13, 95% confidence interval (CI) = 36,129–59,611; WSP 2023a), which fell within the 95% CI of DFO's 2013 abundance estimate of the combined stock (45,532 narwhal, CV= 0.33, 95% CI = 22,440 – 92,384; Doniol-Valcroze et al. 2015). Previously, results from aerial surveys conducted by Golder Associates Ltd. (Golder; now WSP Canada Inc.) in 2021 indicated an abundance estimate of 75,177 narwhal for the combined Eclipse Sound and Admiralty Inlet stocks (CV = 0.08, 95% CI = 63,795 – 88,590; Golder 2022a). Results from aerial surveys conducted by Golder in 2020 indicated an abundance estimate of 36,044 narwhal for the combined Eclipse Sound and Admiralty Inlet stocks

(CV = 0.12, 95% CI = 28,267– 45,961; Golder 2021a), which fell within the 95% CI of DFO's 2013 abundance estimate of the combined stock (45,532 narwhal, CV=0.33, CI = 22,440–92,384; Doniol-Valcroze et al. 2015).

For the Eclipse Sound stock alone, the 2023 abundance estimate was 10,492 narwhal (CV = 0.05, 95% CI of 9,578–11,494, WSP 2024a), which is statistically different than the 2022 estimate of 4,592 narwhal (CV = 0.10, 95% CI of 3,754–5,617, WSP 2023a) (t-test = 8.678, $p < 0.001$), the 2021 estimate of 2,595 (CV = 0.33, 95% CI of 1,369–4,919; Golder 2022a) (t-test = 7.916, $p < 0.001$), and the 2020 abundance estimate of 5,018 narwhal (CV = 0.03, 95% CI = 4,736–5,317; Golder 2021a) (t-test = 10.728, $p < 0.001$). The 2023 abundance estimate is not significantly different than the 2013 baseline abundance estimate for the Eclipse Sound Stock (10,489 narwhal, CV = 0.24, CI = 6,342-17,347) or the 2016 abundance estimate reported by DFO (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

0 250 500

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. WORLD IMAGERY: EARTHSTAR GEOGRAPHICS
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

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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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 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 1,000 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 (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 Life History and Reproduction

Narwhal are one of the longest-lived of the toothed whales, living for more than 100 years according to research that assessed chemical changes in the eye lens (Garde et al. 2007; NAMMCO 2017). Female narwhal are believed to mature at eight to nine years of age and produce their first young at nine to ten 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, at the floe edge east of Pond Inlet, and at the north end of Navy Board Inlet (JPCS 2017). 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) and multiple sexual displays were observed during drone-based surveys conducted during the 2021 open-water season. 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 to170 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 immatures (females with body lengths <337 cm and males with body lengths <388 cm; Garde et al. 2007). 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 were 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 Seasonal Migratory 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 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).

Telemetry studies (DFO 2020b) and available IQ (NWMB 2016a; 2016b; QWB 2022) indicate that some degree of mixing occurs between narwhals in the Admiralty Inlet and Eclipse Sound summer stock areas. 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. Natural exchange between the two summering areas was proposed as a possible reason why the 2013 aerial survey results for Admiralty Inlet (~35,000 narwhal) and Eclipse Sound (~10,000 narwhal) differed substantially from previous survey results for the same stocks (18,000 for Admiralty Inlet in 2010 and 20,000 for Eclipse Sound in 2004) (Doniol-Valcroze et al. 2015). While tagging data provides evidence of overlap in narwhal use of Admiralty

Inlet and Eclipse Sound, overall site fidelity to specific summering areas is still thought to be high (Laidre et al. 2004; Richard et al. 2010; DFO 2020b).

Available IQ suggests that the geographic and genetic distinction between the Admiralty Inlet, Eclipse Sound, and East Baffin Island summer stocks may be invalid (NWMB 2016a; 2016b; QWB 2022). The following is a summary of available IQ regarding the degree of exchange between narwhal occurring in the Eclipse Sound, Admiralty Inlet and East Baffin Island summer stock areas and Inuit insight on what drives the summer distribution and abundance of narwhal in these areas of North Baffin Island:

- *Narwhal move freely throughout the waters of Northern and Eastern Baffin Island (NEBI). Their distributions and abundances change across NEBI waters between years, showing that individual narwhal do not always return to the same specific areas within NEBI waters every year (QWB 2022).*
- *In spring, narwhal arrive at various areas in waters of NEBI at varying times each year, depending on the development of open water within variable patterns at the floe edges, leads in the ice in various areas, and ice break-up into summer. These patterns and their timing vary from year to year, and can affect the abundance and distributions of narwhal across NEBI waters into August and September (QWB 2022).*
- *Throughout the open-water period, narwhal move as needed for their biological needs like birthing and mating, as well as in response to environmental factors like changing food concentrations, killer whales, and ships. Narwhal also probably move in response to factors largely unknown to humans (QWB 2022).*
- *'I'm sure that you're going to keep saying that Pond Inlet and Arctic Bay narwhal are different stock, different population, but as our Elders have observed and we keep saying at HTO, that is not the case; they're one population. But you don't want to admit that, and we cannot change your mind, because it's been conceived that way. That's that one.' E. Ootoova; 2016 NIRB Public Hearing - 28 November 2016 (NWMB 2016a)*
- *I'm not a hunter anymore. I'm just an Inuk. Long before Qallunaat arrived, Inuit survived solely on wildlife by daily hunting and harvesting, and as observers of these wildlife and these whales, we know that there's peaks and lows of the number of whales, both migratory and summer stocks. And if in a particular year they happen to migrate somewhere else, the department or scientists would say that they decreased, but Inuit would know that they're migrating through somewhere else or for food. And Inuit know that. We Inuit have that knowledge. Inuit are very in tune with the wildlife around them. And I think that it's better if you connect with Inuit at that level. You would understand what we're talking about because it was our daily life, and when we feel that there hasn't really been any change, and when there's a proposal to decrease the number of the TAH, it doesn't really make sense to us. That's what I wanted to say.' Mr. Kilukshak; 2016 NIRB Public Hearing – 28 November 2016 (NWMB 2016a)*
- *'According to the Inuit knowledge, I don't think that is included in this estimate. And they say that there's only one stock, one stock of narwhal from Eclipse Sound and Admiralty Inlet narwhal, one stock. But DFO is considering they're two different stocks, and what was mentioned that the -- are you going to be looking at this when you have that workshop? I know that the communities don't agree with that because you have separated the two stocks. Are you going to be looking at that during the workshop, whether it's one stock or two?' Mr. Irrgaut; 2016 NIRB Public Hearing – 28 November 2016 (NWMB 2016a)*
- *'Go back to the table and really look at the narwhal population. They're not separate. They're not a separate stock like Eclipse Sound or Admiralty Inlet. If there was no more polar bear or narwhal, we wouldn't be having this discussion or debate; but fortunately, there are, so that's why we're talking about summer and migratory*

stocks. So I give it back to you to recommend to you to put it into one stock because they're not separate.' Mr. Tango; 2016 NIRB Public Hearing - 28 November 2016 (NWMB 2016a)

- *'Just to supplement that. When there's early ice breakup, the Lancaster Sound to Kitikmeot area, when we didn't have narwhal in our area we heard from Kitikmeot that they have lots of narwhal now. And it's not only the shipping traffic that is contributing to the movement of narwhal. It's early ice breakup that it's obvious they're going further into the western area. Especially this summer, we observed it. It depends year to year, as we keep saying, ever since I can remember as a child, every year is different. And I know that what we're presenting might be of some use.' E. Ootoova; 2016 NIRB Public Hearing - 28 November 2016 (NWMB 2016a)*
- *'Yes, yes. Thank you, Mr. Chairman. As we have been saying, there are a lot of killer whales around when they did the survey. During the month of August, killer whales were around, so the narwhal had to move elsewhere to get away from the killer whales. And perhaps, if there were less killer whales you would have seen more narwhal. Yes, that is the reason why the narwhal were not around because the killer whales were around too much.' Mr. Killiktee; 2016 NIRB Public Hearing - 28 November 2016 (NWMB 2016a)*
- *'Just to add. Yeah, I agree with my fellow board member. I just want to add: August 2013 when they did a survey, there were no other records that they did back in -- there was nothing from 2012, 2014. And we keep saying that they do come back, and they move away. And they do the survey for only a few days in a month, and then they give us a result saying that our narwhal are decreasing so we have to change the total allowable harvest. That's what they told us.' E. Ootoova; 2016 NIRB Public Hearing - 28 November 2016 (NWMB 2016a)*
- *'But I want to reiterate that the narwhal, they don't go back and forth. And I know it will be different in years, because sometimes there are more in Eclipse Sound, and some years there are more in Admiralty Inlet. I know that there's going to be a narwhal in Eclipse Sound all the time, and I know that because there's just one stock that go back and forth between Admiralty Inlet and Eclipse Sound, and when they were -- we're not trying to distinguish the two different ones, and I know they are the same population. When they come through Eclipse Sound, some stay around, and some go over to Admiralty Inlet, and then they come back to Eclipse Sound after Admiralty Inlet. But nowadays there are more migratory narwhal perhaps because the sea ice is decreasing. So they are migrating west, more west. And if there were no more narwhal in Pond Inlet -- and I know that our narwhal would also decrease, but now we're not concerned about that right now because they keep going back and forth, depends what kind of a year it is. There was lots of narwhal in Admiralty Inlet, so they're increasing, and maybe they had moved over to Admiralty Inlet from Eclipse Sound.' Mr. Naqitarvik; 2016 Public NIRB Hearing – 29 November 2016 (NWMB 2016b)*
- *'Yes, we believe that it is one stock going to Admiralty Inlet and Eclipse Sound.' Mr. Attitaq; 2016 Public NIRB Hearing – 29 November 2016 (NWMB 2016b)*
- *'When Arctic Bay and Pond Inlet have stated that it's one stock, they usually migrate through Pond Inlet waters, and then they dive and go to Arctic Bay, Admiralty Inlet, and there's no more whales in Pond because they're in Arctic Bay area; and then when they migrate back -- when there's none left in Arctic Bay, there's lots of whales in Pond Inlet. That's how they're always continuously moving forward, moving forward.' Mr.Qaunaq; 2016 Public NIRB Hearing – 29 November 2016 (NWMB 2016b)*

2.6 Group Composition

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[5] or clusters[6] averaging 3.5 individuals (range: 1 to 25), and in herds[7] of up to hundreds of clusters (Marcoux et al. 2009; Golder 2020b). According to Marcoux et al. (2009), herds observed from the Bruce Head Peninsula were composed of one to 642 clusters, with a mean of 22.4 clusters/herd. Observations from the Bruce Head Peninsula also revealed 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. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b, 2022b).

2.7 Response to Predators

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 narwhals were killed by a pod of killer whales over a six-hour period in Admiralty Inlet. 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 (Smooth er al. 2016, 2017; Golder 2021a; Sweeney et al. 2022). Killer whale predation events have been observed from Bruce Head in previous years, in which cases narwhal were typically observed travelling close to shore in tight groups in the BSA (Sweeney et al. 2022).

[5] Group = a group of narwhal within one body length of one another (a single narwhal = group size of 1)

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

[7] Herd = an aggregation of clusters

2.8 Movement behaviour

Like many cetacean species that inhabit patchy and/or dynamic environments (Laidre et al. 2003), narwhal surface movement and dive behaviour vary depending on where they are distributed on their summering grounds (Watt et al. 2017; Golder 2020a). The following sections provide context regarding the current understanding of narwhal movement 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).

2.8.1 Surface Behaviour

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, tagged narwhal were rarely recorded 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) suggesting active avoidance of ships at close ranges.

2.8.2 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 min for one narwhal tagged in 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 recorded during a tagging study in East Greenland was 23.6 min (Tervo et al. 2021). Maximum dive depths recorded for narwhal tagged in Tremblay Sound in August 2010 and August 2011 were between 400 and 800 m (Watt et al. 2017), indicating that these dives occurred in deeper waters located adjacent to Tremblay Sound (i.e., Milne Inlet/Eclipse Sound). Similar dive depths were recorded for a single narwhal tagged in East Greenland in 2013 (Ngô et al. 2019) and individuals tagged in East Greenland from 2013–2019 (n=13; Tervo et al. 2021). The majority of the 8,609 dives undertaken by the single tagged male in 2013 were less than 200 m (Ngô et al. 2019), while the majority of the dives performed by the 13 narwhal taqged from 2013–2019 were less than 100 m with a maximum dive depth of 890 m (Tervo et al. 2021). Most recently, one narwhal tagged during Baffinland's 2017 Narwhal Tagging Program was recorded undertaking a dive for 30.1 min in Milne Inlet with a maximum depth of 332.5 m (Golder 2020a).

During the summer months, narwhal spend a large proportion of time near the surface, milling[8] and socially interacting with one another (Pilleri 1983; Heide-Jørgensen et al. 2001). Narwhal 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 (n=23; Watt et al. 2015). Innes et al. (2002) reported similar results, with narwhal spending 38% of the time 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) spent 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, the 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 the time narwhal spent at the surface (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. In one study that tracked 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 the locally available 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, respectively) and had shorter bottom times (4.1 min vs 5.0 min, respectively) than U-dives (Tervo et al. 2021). The tagged narwhal also utilized prolonged gliding during descent, active fluke stroking (i.e., tail strokes) 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

[8] When a group of cetaceans remain at the surface and have little or no directional movement but instead socialize with each other (Weilgart and Whitehead 1990).

ability to dive deeper and for longer periods of time. Whether a female is with or without a calf may also influence dive behaviour (i.e., shorter, shallower dives or shorter bottom times), 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, 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 2.7, 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 statistically 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 (i.e., dives completed to depths that exceed 75% of the available bathymetry) 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.

2.9 Acoustic Behaviour

Like all cetaceans, narwhal depend on the transmission and reception of sound to carry out the majority of important life functions (i.e., communication, navigation, prey detection, avoidance of predators, reproductive and social activities; 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).

2.9.1 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 comprise 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; Ames et al. 2021; Zahn et al. 2021).

2.9.2 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).

2.9.3 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 behaviour (slowed or ceased movement) 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). Narwhal have also been observed reacting to simultaneous seismic airgun and vessel noise trials (Heide-Jørgenson et al. 2021).

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: $1\mu Pa^2 \cdot s$). 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, 2021; Ellison et al. 2012; Williams et al. 2013; NMFS 2018; Southall et al. 2019).

Between 2018 and 2022, underwater noise levels emitted by Project vessels transiting in the RSA were recorded and quantified by JASCO Applied Sciences at multiple recording locations along the shipping route (Austin and Dofher 2021; Austin et al. 2022a, 2022b; Frouin-Mouy et al. 2019, 2020). Results indicated that Sound Exposure Levels (SELs) did not exceed the thresholds for acoustic injury[9] (i.e., temporary or permanent hearing loss) at the recording sites in the RSA. Assessed relative to the behavioural disturbance Sound Pressure Level (SPL) threshold of 120 dB re 1 µPa[10] for continuous-type sounds such as vessel noise, ship noise exceeded the disturbance threshold for <1 hour per day. The results demonstrated that while noise from Project vessels was detectable in the underwater soundscape, vessel noise exposure was temporary in nature and below sound levels that could cause acoustic injury to marine mammals and that there would be substantial periods each day when marine mammals would not be disturbed by Project vessel noise.

[9] 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).

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

3.0 SEVERITY SCORE RANKING

Current scientific practice involves categorizing marine mammal behavioural responses to anthropogenic stressors based on a scale of increasing severity, commonly referred to as a "severity scale", which includes descriptors of response type, magnitude, and duration (Southall et al. 2007, 2021; Finneran et al. 2017). Initially proposed by Southall et al. (2007) and adapted by Finneran et al. (2017), the severity scale scoring system includes tiered behavioural responses (categorized as low, moderate, or high severity), and has recently evolved to include a framework for linking behavioural responses of free-ranging marine mammals to vital rates (Southall et al. 2021). The most current severity score ranking derived by Southall et al. (2021) assesses behavioural responses of free-ranging marine mammals and their potential impact on (1) survival, (2) reproduction, and (3) foraging. Segregating behavioural responses into these three distinct categorical "tracks" follows the rationale that changes in each category may differentially affect individual fitness and/or vital rates, which may ultimately affect population parameters. The three categorical tracks evaluate behavioural responses related to the following activities:

- Survival: includes effects on defense, resting, social interactions, and navigation
- Reproduction: includes effects on mating and parenting behaviours
- Foraging: includes effects on search, pursuit, capture, and consumption of prey

It is not a requirement for test subjects to exhibit all behavioural responses across all three tracks for a given score to be assigned. Instead, subjects will have a score assigned for a severity category if any of the responses are displayed (Southall et al. 2021). To be conservative, the highest (or most severe) score is assigned for instances where a subject exhibits several responses from the different tracks. While there is some redundancy across these descriptors (e.g., behaviours that relate both to foraging and survival), the intent is to provide a means of evaluating behavioural responses in a manner that assists in interpreting consequences in terms of vital rates (Southall et al. 2021).

While it is appropriate to assess behavioural responses as they relate to individual fitness (i.e., using the three categorical tracks), the general basis for previously describing responses as low, moderate, and high severity remain appropriate (similar to the threshold categories outlined in Section 1.5 and in Baffinland 2023). That is, low severity responses are considered those 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; moderate severity responses are not considered significant behavioural responses if they last for a short duration (i.e., temporary) and the animal immediately returns to their pre-response behaviour; and high severity responses include those with immediate consequences to growth and survival, and those affecting animals in vulnerable life stages (i.e., calf, yearling; Southall et al. 2007; Finneran et al. 2017). While it is acknowledged that certain behavioural responses such as a change in foraging/dive behaviour and/or a change in vocal behaviour are relevant to assessing changes in individual fitness, the methodology of the current Program is not designed to detect all such changes[11]. Therefore, any further discussion of severity scaling in the present report is specific to

[11] Changes to narwhal foraging/dive behaviour are assessed in the 2017-2018 Integrated Tagging Study (Golder 2020a); changes to narwhal vocal behaviour are assessed through the Passive Acoustic Monitoring (PAM) Program.

those responses that may be detectable through (or informed by) the shore-based observer and/or drone-based components of the Bruce Head Program.

Behavioural responses that would be considered low severity (i.e., response score 0–3; Southall et al. 2021) and may be detectable through (or informed by) the Bruce Head Program include the following:

- No response
- Identifiable, sustained and/or multiple vigilance responses including interruption of resting behaviour
- Individual startle response
- Behavioural state changes from advertisement and courtship to other behaviour

Table 3-1 provides a summary of these responses (segregated by behavioural track) as they relate to the specific response variables assessed through the Bruce Head Program.

Table 3-1: Low severity behavioural responses described by Southall et al. (2021) that are evaluated as part of the Bruce Head Shore-based Monitoring Program.

Response score	Behavioural changes affecting survival	Behavioural changes affecting feeding	Behavioural changes affecting reproduction
0	No response detected		
1	Identifiable change in behaviour indicating vigilance response: - Interruption of resting • As detected by changes in primary behaviours (UAV)	-	Detectable interruption of advertisement and courtship behaviour • As detected by changes in unique behaviours, namely sexual displays (UAV)
2	Sustained or multiple vigilance responses • As detected by changes in primary behaviours (UAV).		
3	-	-	Behavioural state changes from advertisement and courtship to other behaviour • As detected by changes in unique behaviours, namely sexual displays (UAV)

Moderate severity responses would be considered biologically 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, the context of the exposure (e.g., behavioural state of the receptor at the time of the exposure, site conditions), and individual variability within the species group (e.g., familiarity with the stressor, age and health of the receptor). 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 persisted several hours after vessel exposure or longer.

Behavioural responses that would be considered moderate severity (i.e., response score 4–6; Southall et al. 2021) and may be detectable through (or informed by) the Bruce Head Program include the following:

- Change in group cohesion
- Detectable elevation in energy expenditure
- Avoidance of area near sound source (e.g., vessel sound)
- Reduction of advertisement and courtship behaviours potentially sufficient to reduce reproductive success
- Increase in mother-offspring cohesion
- Disruption of nursing and parental attendance behaviour
- Separation of females and dependent offspring (exceeding baseline case)
- Displays of aggression

Table 3-2 provides a summary of these responses (segregated by behavioural track) as they relate to the specific response variables assessed through the Bruce Head Program.

Table 3-2: Moderate severity behavioural responses described by Southall et al. (2021) that are evaluated as part of the Bruce Head Shore-based Monitoring Program.

Response score	Behavioural changes affecting survival	Behavioural changes affecting feeding	Behavioural changes affecting reproduction
4	Change in group cohesion • As detected by changes in group spread, group formation, and/or group size (UAV)	Detectable elevation in energy expenditure • As detected by an increase in travel speed (UAV) and changes in primary behaviour (UAV)	Non-reproductive (advertisement and courtship) state longer than typical • As detected by changes in unique behaviours, namely sexual displays (UAV)
5	Onset of avoidance behaviour (e.g., heading away and/or increasing range from source) • As detected by changes in narwhal density relative to vessels (SSA) Increase in mother-offspring cohesion • As detected by relative and distal association between mother and immature pairs (UAV).	Detectable change in nursing behaviour • As detected by changes in unique behaviours, nursing behaviour (UAV)	-

Response score	Behavioural changes affecting survival	Behavioural changes affecting feeding	Behavioural changes affecting reproduction
6	Individual aggressive behaviour, including movement potentially directed at conspecifics • As detected by changes in unique behaviours, namely "jousting[12]" (UAV) Sustained avoidance behaviour • As detected by changes in narwhal density relative to vessels (SSA) Separation of females and dependent offspring (exceeding baseline case) • As detected by changes in group composition (BSA) and changes in distal association between mother and immature pairs (UAV) Group aggressive behaviour • As detected by changes in unique behaviours, namely "jousting" (UAV)	Sustained disruption of nursing behaviour • As detected by changes in unique behaviours, nursing behaviour (UAV)	Reduction of advertisement and courtship behaviours potentially sufficient to reduce reproductive success • As detected by changes in unique behaviours, namely sexual displays (UAV) Disruption of parental attendance behaviour • As detected by changes in group composition (BSA) and changes in distal association between mother and immature pairs (UAV)

High severity responses include those with immediate consequences to growth survival, or reproduction. High severity responses are always considered to be significant, particularly if sustained for a long duration by animals in vulnerable life stages. Responses that would be considered high severity (i.e., response score 7–9; Southall et al. 2021) and may be detectable through (or informed by) the Bruce Head Program include the following:

- Prolonged displacement to areas of increased predation risk or suboptimal foraging
- Sustained avoidance
- Disruption of group social structure (i.e., breaking pair bonds/alliances, altering dominance structure)
- Disruption of breeding behaviour sufficient to compromise reproductive success
- Prolonged separation of females and dependent offspring
- Panic, flight, or stampede[13]
- Stranding

[12] For the purpose of the present study, "jousting" is defined as directed movement (typically sudden) by a tusked individual toward another.

[13] 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'.

Table 3-3 provides a summary of these responses (segregated by behavioural track) as they relate to the specific response variables assessed through the Bruce Head Program.

Table 3-3: High severity behavioural responses described by Southall et al. (2021) that are evaluated as part of the Bruce Head Shore-based Monitoring Program.

Response score	Behavioural changes affecting survival	Behavioural changes affecting feeding	Behavioural changes affecting reproduction
7	Separation of females and dependent offspring sustained for long enough to compromise reunion • As detected by changes in group composition (BSA) and changes in distal association between mother and immature pairs (UAV) Clear anti-predator response (e.g., severe and/or sustained avoidance or aggressive behaviour) • As detected by changes in narwhal density relative to vessels (SSA) Displacement to area of increased predation risk or sub optimal foraging • As detected by changes in relative abundance and distribution (SSA)	-	Interruption of breeding behaviour • As detected by changes in primary and unique behaviours, namely social behaviour and sexual displays (UAV)
8	Prolonged separation of females and dependent offspring • As detected by changes in group composition (BSA) and changes in distal association between mother and immature pairs (UAV)	-	Disruption of breeding behaviour sufficient to compromise reproductive success • As detected by changes in primary and unique behaviours, namely social behaviours and sexual displays (UAV) Disruption of group social structure (e.g., breaking pair bonds/alliances, altering dominance structure) • As detected by changes in group composition (BSA)
9	Risk that behavioural response leads to serious injury or mortality (e.g., outright panic, flight, stampede, stranding, mother-offspring separation) • As detected by changes in group composition (BSA), changes in unique behaviours (UAV), changes in distal association between mother and immature pairs (UAV)	Disruption of energetic balance sufficient to result in morbidity or mortality • As detected by change in primary behaviour (UAV) and/or nursing behaviour (UAV)	

Narwhal behavioural response variables evaluated through 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 behavioural responses observed, the response variables assessed herein are considered in relation to the revised and adapted severity score ranking outlined above.

4.0 METHODS

4.1 Study Team and Training

The 2023 field program took place between 27 July and 22 August 2023 and consisted of 16 hours of daily monitoring effort (weather permitting), undertaken by two teams of five individuals each, alternating at four-hour observation intervals. Study teams consisted of WSP biologists with previous arctic marine mammal survey experience, qualified MMO subcontractors, and local Inuit researchers from Pond Inlet and Arctic Bay. The drone operations team, comprised of two individuals from Aeria Drone Systems Ltd., worked closely with WSP biologists to plan and execute systematic focal follow surveys[14] using a drone-based video system.

Upon arrival to the Bruce Head camp on 27 July 2023, the field team participated in an on-site orientation led by the Camp Manager and Site Supervisor. Topics covered during the orientation included general camp etiquette expectations, proper use of camp facilities, and health and safety considerations such as firearm storage and use requirements 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 WSP and Baffinland were reviewed and discussed.

The study team also participated in a comprehensive training session led by the Field Technical Lead, with topics covered including 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 (WSP 2023b). Topics covered during the training session included the following study components:

- Spatial boundaries of the SSA and 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

4.2 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, predators, hunting pressure). Narwhal are a highly gregarious species (Marcoux et al. 2009; Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b, 2022b; WSP 2023c) 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

[14] A focal follow consists of a detailed quantitative and qualitative observation of a specific individual or small group of animals that are followed over an extended period while continuously recording their activities, behaviour and group composition over this time.

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 Program included information on narwhal RAD, group composition, and 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 narwhal RAD data in the SSA. The second group, composed of two MMOs, was responsible for collecting data on narwhal group composition 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 2023 Program, the drone operations team was responsible for collecting narwhal behavioural data and 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 annual programs are provided in the respective annual reports (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b, 2022b; WSP 2023c).

4.2.1 Relative Abundance and Distribution (SSA)

Consistent with previous years' data collection methods, RAD surveys were conducted throughout the SSA in 2023. 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.

4.2.2 Group Composition (BSA)

Group composition data were collected for all narwhal observed within the BSA. Survey and scan sampling protocols (Mann 1999) were used to record group-specific data (Table 4-1, Table 4-2). 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 herding[15] events took place and RAD team members were not conducting a RAD count, they assisted in collecting group composition data in the BSA. The data collection protocols were similar across all years of sampling, with the exception that only group composition data were collected in the BSA in 2023 (behavioural data were assessed exclusively through UAV-based focal follow surveys; see section 4.2.3). A detailed description of group composition data collected is provided in the Training Manual (WSP 2023d).

[15] A herding event consists of an aggregation of narwhal clusters (i.e., a group of narwhal with no individual more than 10 body lengths apart from any other; Marcoux et al. 2009), typically with animals all travelling in the same general direction. A herding event was considered terminated when no narwhal were observed for 30 min.

Table 4-1: Narwhal group composition 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 4-2)

Notes:

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

Table 4-2: 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	Dark grey; no or only light spotting on their back	Light to uniformly dark grey	White or uniformly light (slate) grey, or brownish-grey

4.2.3 Behaviour (UAV-based Focal Follow Surveys)

To augment the narwhal behavioural response data collected via shore-based monitoring in the BSA from 2014 to 2021, fine-scale behavioural data was also collected via focal follow surveys using Unmanned Aerial Vehicles (UAVs) from 2020 to 2023. This modification to the program was required after the nominal shipping lane adjacent to Bruce Head was re-routed further offshore from the BSA in 2020 as a mitigation strategy to avoid disturbing hunting activities at the Bruce Head hunting camp due to ships travelling near the Bruce Head shoreline. This new mitigation measure resulted in a decrease in vessel-narwhal interactions in the BSA at the exposure distances of interest (<5 km), given the increased distance between the re-routed shipping corridor and the BSA. Therefore, starting in 2022, the collection of narwhal behavioural data was undertaken exclusively through UAV-based focal follow surveys and no longer through the shore-based visual observation program (i.e., exclusively in the BSA). In addition to information on group composition data, the focal follow surveys (Table 4-2) also involved collection of behavioural data (Table 4-3) including data on primary behaviour, unique behaviours, position of immatures (i.e., calves and yearlings) relative to their mother, group formation (Table 4-4), group spread, group size, and group travel speed.

The use of UAVs equipped with high-resolution video or digital single lens reflex (DSLR) cameras, combined with other sensors, is a valuable tool commonly used for assessing fine-scale behaviours of cetaceans (Broker et al. 2019). As such, aerial imagery of narwhal within the SSA and along the shipping corridor was collected throughout the Program. The drone operations team (Aeria Inc.) worked closely with WSP biologists to carry out systematic 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 three-axis stabilized gimbal, capable of recording video at 8k resolution up to 25 frames per second and capturing 48 megapixel stills. In 2020, focal follow surveys were conducted via a single drone in flight at a time whereas two drones were typically flown simultaneously during the 2021, 2022, and 2023 field seasons to increase sample size. All survey footage was recorded at 4k resolution 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). When both vessels and narwhal were present, focal follows strived to follow narwhal groups in close proximity to shipping. Detailed focal follow procedures are presented in the Bruce Head training manual (WSP2023d).

For each focal follow survey, the drone was flown to a predetermined start point either within the SSA or near the shipping corridor slightly to the south of the SSA (toward Koluktoo Bay). Upon arrival to the start point, the drone was oriented north (to facilitate data entry and analysis later) and then flown in a non-systematic direction until the first group of narwhal was encountered. It is important to note that, since 2021, emphasis was placed on following groups that included immature narwhal to better inform behavioural responses of animals in vulnerable life stages to vessel traffic. The UAV team followed the focal group for as long as it remained visible and terminated the survey once the group dove deeply out of sight and did not re-surface for an extended duration, or if members of the group dispersed widely, or when other logistical factors (e.g., low battery levels or inclement weather) necessitated termination of the survey. In instances when groups dispersed widely, the UAV pilot increased the altitude of the drone to better track and remain with the focal group for as long as possible.

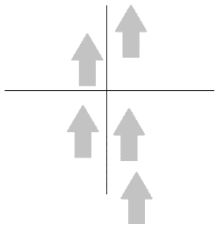
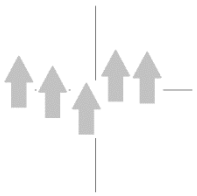
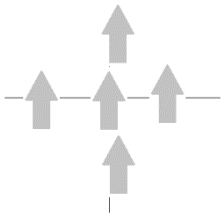
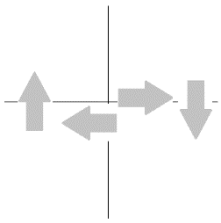
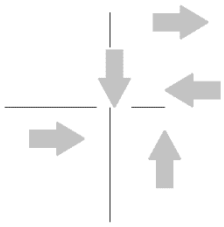
Effort was made to conduct consecutive focal follow surveys during active ship transits through the SSA, regardless of whether narwhal were visible to observers at the Bruce Head survey platform at the time. These surveys were considered “searches” and did not always result in focal groups being followed.

Table 4-3: Narwhal behavioural data collected via UAV-based focal follow surveys.

Data recorded	Description
Primary behaviour	■ Travelling (directed movement) ■ Milling (non-directional movement) ■ Resting (not moving or moving slightly in a low-activity state; logging) ■ Social (clear interaction between conspecifics)
Unique behaviours	■ Nursing ■ Rubbing ■ Vertical roll ■ Horizontal roll ■ Sexual display ■ Jousting (directed movement toward another by tusked individual)
Association of immature with presumed mother	■ Distal position (tight, loose) ■ Relative position (left, right, front, behind, top, under)
Group formation	■ See Table 4-4 (Formation).

Data recorded	Description
Group spread	■ Tight: narwhal ≤ body width apart ■ Loose: narwhal >1 body width apart
Group size	Number of narwhal within 1 body length of one another. Includes group size of 1.
Group travel speed	Assessed using UAV GPS metadata.

Table 4-4: 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
				

4.2.4 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. Automatic Identification System (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, 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 (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b, 2022b), 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 study area.

4.2.5 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 eight-year program, 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 4-1**). 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 4-1: 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.

4.2.6 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 (%), precipitation and ice cover (%) were recorded. Beaufort wind scale level, sun glare, and an overall assessment of sightability (i.e., Excellent, Good, Moderate, Poor, and Impossible) were recorded for each substratum within the SSA and also in the BSA. Sightability was categorized as impossible when water was completely obscured by fog, ice, high sea state, or severe glare, resulting in virtually no ability of detecting a marine mammal. Substrata where sightability was deemed impossible were not surveyed for marine mammals. Details on the classification of glare, Beaufort level, and sightability can be found in the training manual (WSP 2023d). 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. Since 2021, a Davis Vantage Pro 2 weather station was set up at the observation platform to provide real-time updates of changing weather conditions, including wind speed and wind direction.

4.3 Data Analysis

4.3.1 Data Preparation for Analysis

4.3.1.1 Automatic Identification System (AIS) Data

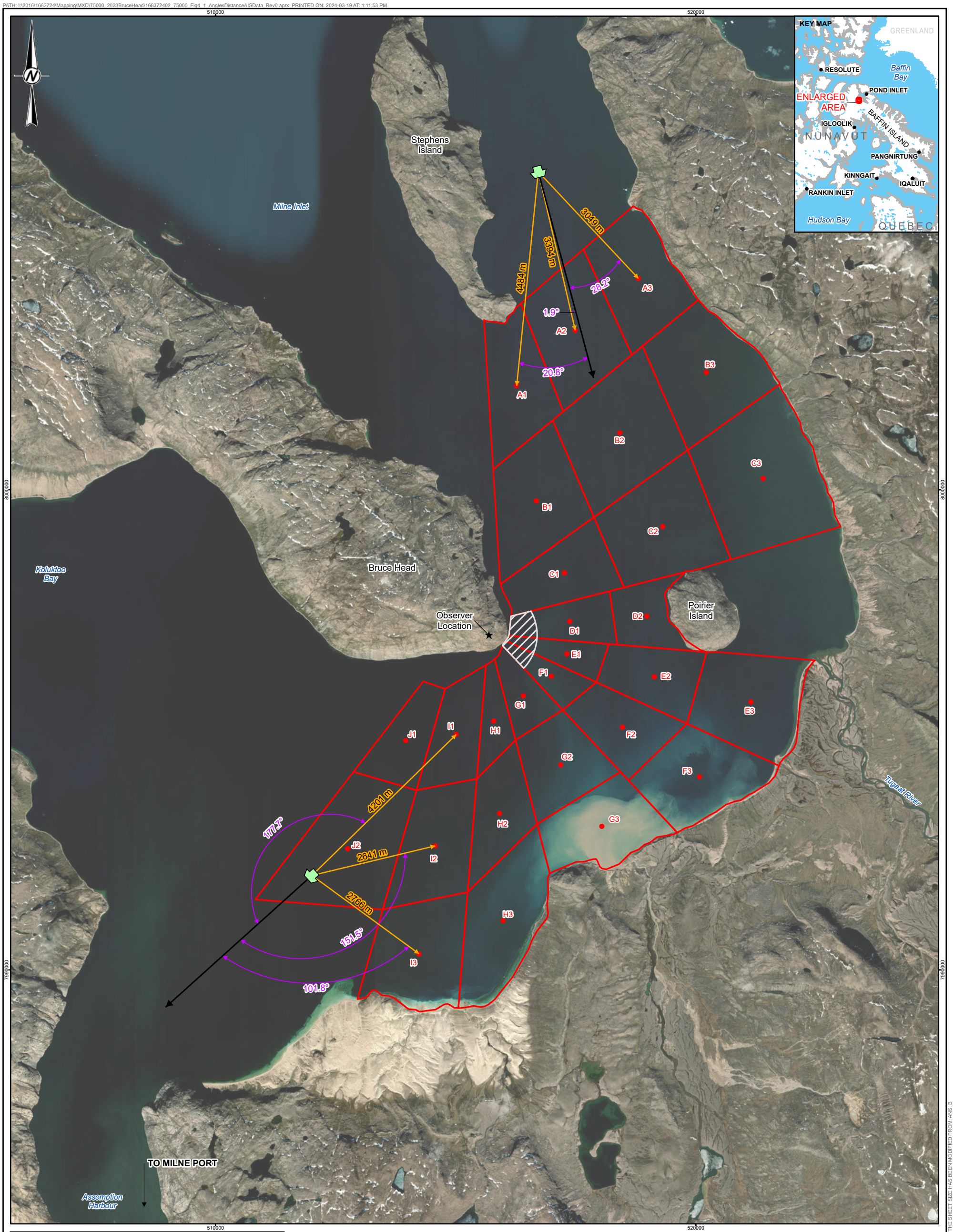
Satellite-based AIS data were merged with the AIS base station data. The full AIS dataset was clipped to only include ship track data collected in the Bruce Head study area (between Stephens Island and Milne Port). The full positioning dataset obtained in 2023 from the shore-based AIS station at Bruce Head had a mean of 0.3 min between positions (range of 0.2–2.6 min, median of 0.2 min, standard deviation [SD] of 0.13 min). The distances between positions ranged from 0.01 km to 0.56 km (mean of 0.06 km, median of 0.05 km, and SD of 0.03 km). Positioning data from the AIS satellite only (i.e., without Bruce Head antenna data) had a mean of 1.1 minutes between positions (range of 0.0.2–592.5 min, median of 1.1 min, SD of 6.4 min). The distances between positions ranged from 0 km to 1.1 km (mean of 0.25 km, median of 0.25 km, and SD of 0.16 km).

AIS data were subsequently filtered to only include data collected during active survey periods at the platform. In AIS positioning data filtered to the temporal extent of RAD/BSA sampling, <1% of the AIS data were contributed by satellite data. The combined shore-based and satellite-based AIS dataset had a mean of 0.3 minutes between positions (range of 0.2–2.7 min, median of 0.2 min, SD of 0.15 min). The distances between positions ranged from 0.01 km to 0.57 km (mean of 0.06 km, median of 0.05 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 considered 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 vessel's position and each centroid of the 28 SSA substrata (Figure 4-1). 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, observations where 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 was therefore not that it departed the actual substratum, but that it was 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 GPS position of the group at each time stamp in the UAV video analysis dataset as the reference point.

Previously, 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 2020b). However, based on narwhal movement data collected as part of the 2017–2018 narwhal tagging program (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, on average, was below 120 dB re: 1µPa beyond 5 km of the vessel (i.e., forward and aft average distances to 120 dB re: 1µPa for both ore carrier vessels and cargo vessels ≤4.64 km; Austin and Dofher 2021). Therefore, the study design was conservatively modified in 2020 to reduce the 10 km exposure zone to 7 km and further in 2021 to 5 km, to more accurately capture the predicted zone of disturbance for narwhal. This reduction in spatial extent was intended to reduce potential statistical noise (unexplained variation) in the data at farther distances, which would allow to better quantify the effects at closer distances, where effects were likely to be stronger.



LEGEND

- ★ OBSERVER LOCATION
- SAMPLE VESSEL LOCATION
- STRATIFIED STUDY AREA (SSA) SUBSTRATA CENTROID
- ANGLE BETWEEN HEADING AND SUBSTRATA
- DIRECTION TO SUBSTRATA
- SAMPLE AIS VESSEL HEADING
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

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 ©20210811 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

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

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4.3.1.2 Relative Abundance and Distribution (RAD) Data (SSA)

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 min 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 5 km away from a centroid were not considered to affect relative abundance, distribution, or behaviour of narwhal. This spatial filter corresponded to the distance at which vessel noise levels were, on average, below 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.

4.3.1.3 Group Composition Data (BSA)

In preparation for the statistical analysis of the group composition data, for each sampling year at Bruce Head, the number of narwhal groups recorded in that year was divided into ten bins with equal number of groups per bin (Table 4-5). This binned dataset was used for statistical testing of EWI values relative to the baseline 2014–2015 years.

Table 4-5: Number of narwhal groups recorded in each sampling year at Bruce Head.

Year	Number of narwhal groups (number of individuals)	Number of groups per bin
2014	250 (1,086)	25
2015	268 (1,479)	26–27
2016	761 (2,476)	76–77
2017	2,416 (8,913)	241–242
2018	N/A	N/A
2019	1,301 (4,986)	130–131
2020	878 (2,847)	87–88
2021	80 (263)	8
2022	1,523 (5,864)	152–153
2023	40 (163)	4

Note: A narwhal group is defined as the number of narwhal within one body length of one another.

4.3.1.4 Behavioural Data (UAV-based Focal Follow Surveys)

Similar to the process previously described to calculate vessel distance and angle relative to SSA centroids for RAD data (see section 4.3.1.1), behavioural data from UAV-based focal follow surveys were also allocated vessel distance and angle, using the GPS position of the group at each time stamp in the UAV video analysis dataset.

4.3.1.5 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 the eight-year program. 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 2020b). As part of the analysis of the combined 2014–2019 dataset (Golder 2020b), 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 min following a shooting event were significantly different from the number of narwhal recorded during periods of no hunting activity (P values of <0.009 for all) and that narwhal group sizes were significantly different up to 70 min following a shooting event when compared to group sizes when no hunting occurred (P=0.028; Golder 2020b). Significant differences in other response variables between hunting and no-hunting periods were not found (Golder 2020b). 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 re-defined as 70 min, and narwhal recorded more than 70 min following a shooting event were considered as “no hunting” observations.

4.3.1.6 Environmental Data

4.3.1.6.1 Tides

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.

4.3.1.6.2 Environmental Variables During Focal Follow Surveys

For the analysis of UAV focal follow data, the following three environmental variables were added in 2023 to capture uncertainties related to subsurface animal detection: sea state, glare, and water clarity. Sea state was categorized based on the Beaufort scale, following the same classification as used for the RAD and BSA surveys (WSP 2023d). Glare was defined based on the level of surface reflectivity (Figure 4-2), as follows:

- Good: no surface reflections

- Light: surface reflection present with marginal effect on detecting subsurface behaviours
- Severe: surface reflection significantly affects ability to detect subsurface behaviour

Water clarity at Bruce Head was affected by turbidity, particularly after heavy rain or strong wind events. Decreased water clarity cany impede the ability to identify narwhal below the water's surface. Subsurface patterns were often visible in the trail of a narwhal during periods of poorer water clarity, presumably caused by the narwhal swimming between layers of fresher, more turbid water and clearer, denser seawater.

Water clarity was defined based on the extent of subsurface patterns and the ability to identify narwhal below surface (Figure 4-3). Water clarity included the following three categories:

- Good: no patterns and high subsurface visibility
- Moderate: some faint subsurface patterns and some subsurface visibility
- Poor: clear subsurface patterns showing behind animals and animals barely visible beneath surface

The three environmental variables (sea state, glare, and water clarity) were applied to the entire 2020–2023 focal follow dataset. For each focal follow, a single category was assigned for each environmental variable; that is, the same environmental condition was applied to the entire focal follow (this being the most representative category during that period).

Figure 4-2: Examples of three surface reflection categories during focal follow surveys: Severe (left), Light (center) and Good (right).

Figure 4-3: Examples of three water clarity categories from UAV focal follows, showing poor clarity, with clear subsurface patterns showing behind animals and animals barely visible beneath surface (left), moderate clarity with some faint subsurface patterns and some subsurface visibility (center), and good clarity, with no patterns and high subsurface visibility (right).

4.3.1.7 Data Filtering

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

- One 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.
- Data collected during periods of “impossible” sightability and cases with Beaufort level 6 (see description in WSP 2023d) or higher (2,672 cases representing 3.8% of total individual substratum surveys). These cases 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 in southern Milne Inlet (1,780 cases, representing 2.5% of total individual substratum surveys). Killer whale presence was recorded from several sources, including sighting made by the Bruce Head MMOs in the immediate vicinity of Bruce Head, sightings made by MMOs on aerial surveys (when aerial surveys were conducted in Milne Inlet South), and through observations made by local hunters via community radio updates (interpreted by the Inuit MMOs at Bruce Head team). Killer whales were present on four days of the combined 2014–2020 dataset: 12 August 2015, 18 August 2019, 26-27 August 2020, and 10 August 2021. These cases were removed because narwhal behaviour and distribution are strongly affected by the presence of killer whales.
- Cases with narwhal density of ≥200 narwhal/km² (two cases, <0.01% of total individual substratum surveys) to resolve model convergence issues.

- Data collected between 30 July and 3 August 2023 (inclusive; 2,016 cases representing 2.9% of total individual substratum surveys) were omitted from all analyses due to the ice blockage of North Milne Inlet in early August, preventing narwhal from accessing Bruce Head (Appendix G).
- Data collected between 06:00 and 07:59 on 18 August 2023 and between 13:00 and 14:59 on 20 August 2023 were removed, as during these RAD surveys a bulk carrier without an operational AIS system (NORDIC OLYMPIC) transited through the SSA. That is, the presence of the vessel could not be accounted for accurately due to lack of GPS data, and these surveys were removed (112 cases).

Note that some of these cases overlapped. For example, in 110 substratum surveys, sightability was “impossible” and Beaufort level was 6 or higher, and in 34 cases, the data collected between 30 July and 3 August 2023 also had sightability recorded as “impossible”.

No data were omitted from the multi-year dataset of behavioural data collected via UAV-based focal follow surveys, since data were only collected when sightability was adequate, and since no UAV data were collected on days when killer whales were present in the area. Where data were omitted from analyses of specific variables, the rationale was detailed in the Section 4.3.2.

4.3.2 Statistical Models

4.3.2.1 Analytical Approach

The following summarizes the analytical methods applied in the current study:

- Vessel effects were considered when vessels were within 5 km from SSA centroids (i.e., exposure zone <5 km), as detailed in Section 4.3.1.1.
- Continuous variables were modelled as linear effects unless otherwise noted. For predictor variables where exploratory plotting or residual diagnostics (see below) suggested non-linear effects, natural cubic splines were used. Continuous variables were standardized by subtracting the mean and dividing by the standard deviation of the variable.
- Where possible, a simple, positive, non-directional distance was used, without variables accounting for the vessel’s direction within Milne Inlet, or relative position of vessel (i.e., vessel moving toward or away from centroid). This was done to increase sample size and hence increase the models’ power to detect a shipping effect. For response variables where previous work identified significant effects of vessel’s direction within Milne Inlet, vessel direction was retained as a predictor variable in the model to correctly account for differences in shipping effect as a function of vessel direction. For response variables where previous work identified significant effects of relative position of vessel, directional distance was used as a predictor, where 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. The directional distance approach was used for all response variables previously (Golder 2021b), as was the positive, non-directional distance (Golder 2018, 2019, 2020b). The use of either approach depending on the response variable allowed for an increase in power where possible, while accounting for the effects of shipping on each response variable.

- Small vessel effects — In the current analysis, the presence/absence of small vessels (<50 m) in the SSA was included in the models to account for potential effects. Of the 49 records of small vessels, five of the vessels were Project-related (carrying field crews for other study programs).
- Models were fit using the package glmmTMB (Brooks et al. 2017) in the statistical package R v. 4.3.2 (R 2023). Model fit was assessed via diagnostic and residual plots using the DHARMa package (Hartig 2019). Model diagnostic included tests of overall distribution and dispersion of residuals and fitted values, temporal autocorrelation tests, and plots of residuals versus each predictor variable to assess patterns in the residuals. Where patterns were found for continuous variables, the degrees of freedom of splines were changed to resolve the identified lack of fit.
- The calculation of effect sizes depended on the type of analysis, as follows:
  - Where a logistic mixed effects model was used, the effect sizes were based on odds ratios (Faul et al. 2009), which describe the ratio between odds of an outcome for scenario 1 over the odds of that outcome for scenario 2 (Bland and Altman 2000). For example, for the analysis of primary behaviours, the effect for a vessel at a distance of 0 km is based on the odds of observing a group engaging in resting, milling, or social activity predicted for when a vessel is present at 0 km, relative to the odds of observing a group engaging in resting, milling, or social activity predicted for when no vessels are present within 5 km. Since effect sizes are calculated on the odds scale, there's a linear relationship between the odds of the outcome under the two scenarios (Figure 4-4, top panel). Due to the nonlinear nature of the logistic function used in logistic models, the same relationship, when expressed on the probability scale, is nonlinear (Figure 4-4, middle panel). Moreover, when probabilities are close to either 0 or 1 in the absence of vessels, then relatively small differences in probabilities between vessel presence and absence correspond to large effect sizes on the odds ratio scale (Figure 4-4, bottom panel). For instance, if the probability of the outcome in the absence of vessels is 0.5, then an application of a +500% effect size results in a probability of the outcome increasing to 0.86 (a difference of 0.36), while if the probability is 0.05 or 0.95, then the application of the +500% effect size only results in an increase of 0.19 and 0.04 on the probability scale, respectively.
  - Where a negative binomial or a truncated Poisson mixed effects model was used, the effect sizes were based on incidence rate ratio, which describe the ratio between predicted values for scenario 1 and the predicted values for scenario 2. For example, in the RAD, the effect size at a distance of 0 km would be calculated as the predicted narwhal density for a vessel at 0 km from the substratum centroid, divided by the predicted narwhal density for when no vessels are present within 5 km from substrata. A ratio of 1.25 would indicate a 25% increase in narwhal density, whereas a ratio of 0.75 would indicate a 25% decrease in density.
  - Where a Gaussian mixed effects model was used (only applicable to travel speed model), the effect sizes were calculated as regular percents – that is, the difference between predicted values for scenario 1 and the predicted values for scenario 2, divided by the predicted values for scenario 2, and multiplied by 100%. For example, the effect size at a distance of 0.5 km would be calculated as the difference between the predicted speed for a vessel at 0.5 km and the predicted speed for when no vessels were present within 5 km; this difference would then be divided by the predicted speed for when no vessels were present within 5 km from substrata, and multiplied by 100%.

- Effect size application based on distance from vessels — It was assumed that effects would be strongest at the closest distance between narwhal and vessels; that is, at a distance of 0 km. However, while RAD data were available for such close distances (with nearest distance between narwhal and vessels of 0.03 km), for the UAV-based dataset, the closest distance between narwhal and vessels was 0.4 km. Therefore, effect sizes for the RAD analysis were estimated for 0 km distance between narwhal and vessels, while for the UAV-based dataset, effect sizes were calculated at 0.5 km from vessels, to decrease extrapolation from models where no data were available.
- Effect size magnitude — In the current analysis, effect sizes are described as small (≥10%), medium (≥25%), or large (≥50%), similar to effect size criteria used in other behavioural response studies related to vessel exposure (Cohen 1988; Richter 2006; Zapetis et al. 2017). Effect sizes associated with vessel exposure that were medium or large (≥25%) were considered as biologically significant and were interpreted as evidence of impact of shipping operations. Given the uncertainty around effect size estimates for many of the response variables due to data variability and small sample size, small effect sizes (10%–25%) were not considered to be strong evidence of impact of shipping operations. However, sample sizes of narwhal observations within the exposure zone of vessels (≤5 km) were small for many response variables, which resulted in low statistical power and high uncertainty in the estimated effect of vessels. Therefore, the effect size, uncertainty, and statistical significance and power should be considered together before ruling out the effect of vessels for particular response variables. In cases with small sample sizes for vessel exposure, high uncertainty around estimated effects, and low statistical power, the modelling results do not provide strong evidence for or against the effect of vessels, which limits the strength of conclusions.

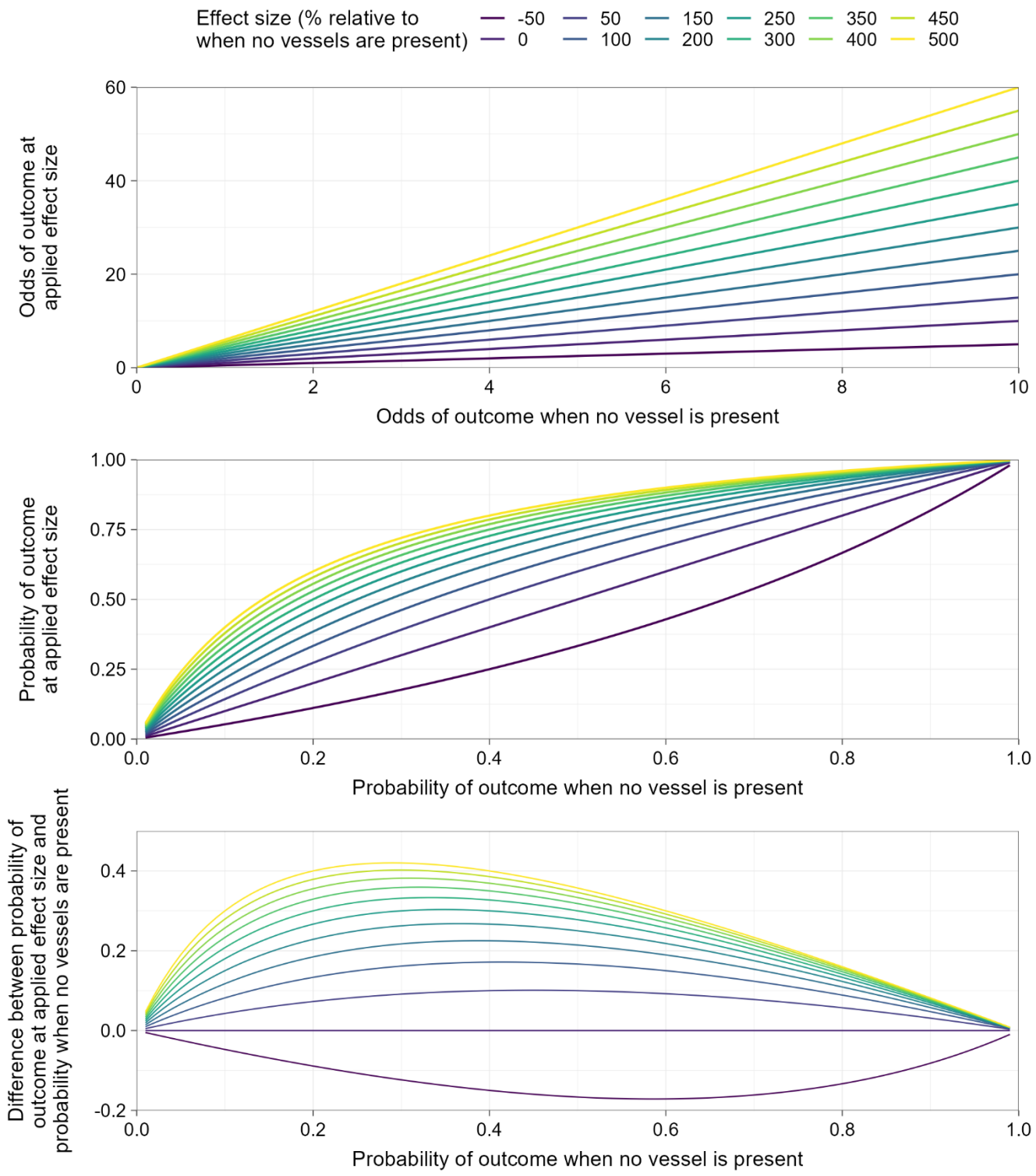

Figure 4-4: Application of effect sizes to visualize the linear application of effect sizes on the odds-scale (top) and the same values becoming nonlinear on the probability scale (middle). The bottom panel shows the difference between the probability after application of the effect size and the probability when no vessels were present, plotted versus the probability of outcome when no vessels were present.

4.3.2.2 Narwhal Density Modeling

Narwhal RAD data collected in the SSA were analysed as the total density of narwhal observed in each substratum during each RAD survey completed across nine years of sampling. A generalized linear mixed model with a zero-inflation component was used to evaluate narwhal density. The response variable was narwhal counts per substratum 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 the RAD analysis included the following:

- Glare (within SSA strata, as applicable) was used as a categorical variable with the following categories: None (N), Low (L), Moderate (M), and Severe (S). A detailed description of glare categories is available in Golder (2022c).
- Beaufort level (within SSA strata, as applicable) was used as a categorical variable, with categories ranging from 0 to 5 (noting data recorded in Beaufort level >6 were excluded from the analysis; Section 4.3.1.6.2). A detailed description of Beaufort Scale categories is available in Golder (2022c).
- Tide was used as a categorical variable with the following categories: Low Slack, Flood, High Slack, and Ebb, as detailed in Section 4.3.1.3.
- Directional distance from vessel was used as a continuous variable (in km) calculated as the distance between vessel location and each of the SSA substratum centroids. The values were negative when the vessel was heading toward the centroid and positive when the vessel was heading away from centroid.
- Vessel direction within Milne Inlet was used as a categorical variable with two categories: Northbound and Southbound, used for RAD analysis.
- Interaction between vessel distance and vessel direction.
- Vessel presence within the exposure zone (≤5 km) from the substratum centroid was used as a categorical variable with two categories: “No vessel present within the exposure zone” and “At least one vessel present within the exposure zone, where exposure zone was ≤5 km (see Section 4.3.2.1).
- Whether hunting occurred within a pre-defined window prior to a sighting was used as a categorical variable with two categories: Hunting Occurred and No Hunting Occurred. For the RAD analysis, 70 min was selected as the pre-sighting cut-off limit for a hunting activity, as detailed in Section 4.3.1.5.
- Year was used as a categorical variable with nine categories: 2014, 2015, 2016, 2017, 2019, 2020, 2021, 2022, and 2023.
- Day of year was used as a continuous variable, where January 1 of each year is assigned a value of 1.
- Substratum UTM northing was used as a continuous variable, modeled as a natural cubic spline with two degrees of freedom to allow for a non-linear north-to-south spatial trend within the SSA.
- Substratum UTM easting was used as a continuous variable, modeled as a natural cubic spline with two degrees of freedom to allow for a non-linear east-to-west spatial trend within the SSA.
- Interaction between substratum UTM northing and easting splines.
- Presence or absence of small vessels within the SSA when each observation was made was used as a categorical variable.

The effect of “day of year” was expressed as an orthogonal polynomial, rather than raw polynomial, 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 for transparency.

The selected modelling framework was a zero-inflated mixed effect negative binomial model with a random effect of substratum (as a categorical variable), which accounted for the repeated measures nature of the data, where each substratum was sampled repeatedly over time. Spatial effects within the SSA were accounted by using the cubic spline predictors of the easting and northing coordinates and their interaction. The zero-inflation portion of the model was modelled to depend on the splines of substratum easting and northing and their interaction, a polynomial of day of year, and Beaufort level, thus reflecting the unequal distribution of zero counts of narwhal across 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 relationship — i.e., accounting for the mean spatial trend in narwhal density across the SSA. The model was used for inference of statistical significance based on *P*-values of effects and the estimated effect sizes. 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.

For effects that were statistically significant, population-level model predictions (i.e., model prediction for a typical substratum) 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: mean substratum easting and northing, Beaufort level of 2, survey year 2017, mean day of year (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 what distance the estimated response values became significantly different from values predicted when no vessels were present within 5 km. All comparisons were made using the package emmeans (Lenth 2020) in R v. 4.3.1 (R 2023).

4.3.2.3 Proportion of Immatures (Calves and Yearlings)

In preparation for the statistical analysis of proportion of immatures, for each sampling year at Bruce Head, the number of narwhal groups recorded in that year was divided into ten bins with equal number of groups per bin (see Table 4-5). Within each bin, the total number of immatures and the total number of observed narwhal of identified life stage were summed. A generalized linear model with a negative binomial distribution was used to analyse temporal changes in proportion of immatures. The response variable in the analysis was combined number of immatures for each bin, and an offset term of natural log-transformed total observed narwhal allowed for the analysis of EWI data as a proportion, rather than simply analyzing numbers of immatures per bin.

The model was used to compare the proportion immatures between the baseline years combined (2014–2015) and each sampling year. While shipping took place in 2015, it was assumed that the annual proportion of immatures observed in 2015 would be based on mating/breeding success the year prior (2014) during which no iron ore shipping took place, and hence 2015 was included as a baseline year for this particular indicator. Least squared means were used for the comparison to baseline conditions, and the effect size was expressed as a percent difference relative to the baseline years. A set of planned contrasts was constructed for the EWI dataset, so that each sampling year was compared to the average of 2014–2015 mean least squares. Since the question of interest was whether each sampling year was different from the baseline 2014–2015 years (as opposed to whether an overall difference between years existed), an overall test of the significance of the effect of year was not run before performing the planned contrasts. An effect size was calculated as the difference between each year's least squares mean and the average of 2014–2015 least squares mean values, expressed as percentage out of the average of 2014–2015 least squares mean values. The revised EWI threshold was deemed to have been exceeded if a statistically significant difference was observed between the survey year's least squares mean and the average of the 2014–2015 least squares mean values.

4.3.2.4 Behaviour (UAV-based Focal Follow Surveys)

Group composition and behavioural data collected for each focal follow survey conducted between 2020 and 2022 were entered into a database in 30 sec segments. Response variables considered in the focal follow analysis included primary behaviour, unique behaviour, position of immatures (i.e., calves and yearlings) relative to their mother, group formation, group spread, group size, and group travel speed. One of the motivating factors in assessing the 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 (e.g., vessel presence, hunting event, predation event). Unique behaviours that would not be expected under stressful conditions, such as nursing, social rubbing, sexual displays, and rolling (either vertically in the water column or horizontally) were also documented in 30 sec segments to assess whether such behaviours were displayed less often in the presence of vessels.

The analytical approach used herein was adapted from methods described by Arranz et al. (2021) in which the proportion of time that specific behaviours were elicited in both vessel-presence and vessel-absence conditions was calculated. Special attention was paid to assessing the behaviour of immatures (i.e., calves or yearlings) with their presumed mother relative to vessel exposure, with a focus on nursing behaviour, and the relative and distal positioning of immatures to their presumed mother.

Focal groups were divided into five categories based on composition: 1) mother-immature pairs (groups composed strictly of presumed mothers with calves or yearlings), 2) mixed groups with immatures (groups composed of calves or yearlings with the addition of other adults or juveniles in the group), 3) mixed groups

without immatures (groups composed of adults and juveniles or only juveniles, with no immatures), 4) strictly adult groups, and 5) lone immatures.

Statistical analyses of data collected via drone footage were performed for all assessed response variables — primary behaviour, unique behaviour, association of immatures with presumed mother, nursing behaviour, group formation, group spread, group size, and group travel speed. The analyses were performed using mixed models fitted in the package glmmTMB (Brooks et al. 2017) in R v. 4.2.3 (R 2023). Model fit was assessed via diagnostic and residual plots using the DHARMa package (Hartig 2019). The analytical approach described in Section 4.3.2.1 was used in the analysis. However, the effects of vessel distance was simplified to an effect of absolute distance from a vessel, to increase statistical power and to simplify interpretation of modeling results.

Most models included a random effect of the focal follow survey for most models, except for the models of the relative position and distal position of immatures, given that multiple immatures were often present within each sampling time. These two models included a random effect that uniquely identified both the immature and the focal follow.

If a significant effect of “distance from vessel” was identified, multiple comparisons (with Dunnett-adjusted *P*-values) were performed to estimate at what distance the estimated response values became significantly different from values predicted when no vessels were present within 5 km. All comparisons were made using the package emmeans (Lenth 2020) in R v. 4.2.3 (R 2023).

The following sections describe the models used for analyzing the narwhal behavioural data. For each behavioural response variable, if effects were statistically significant, and for all shipping effects regardless of their statistical significance, population-level model predictions (i.e., model prediction for a typical focal follow group) were plotted against observed data to visualize the estimated relationships between narwhal behaviour and the various predictor variables. 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.

4.3.2.4.1 Primary Behaviour

In the analysis of primary behaviour, narwhal behaviours were binned in two categories – “travel” or “resting, milling or social activity”, with the latter category assumed to comprise non-stressed behavioural state activities. A mixed-effects model with a binomial distribution (i.e., logistic regression) was used to analyse the data. Fixed effects included vessel presence within 5 km from the group, distance from vessel (modeled as a linear relationship), group type, and an interaction between distance from vessel and group type. In addition, Beaufort value and water clarity classification were included to account for differences in observation conditions, and group size (modeled as a natural cubic spline, due to relationship nonlinearity) was included in the model to account for the observed differences in primary behaviours between larger and smaller groups. Due to sample size limitations, Beaufort scale values were binned such that all values of 3 or larger were collapsed into a single bin, resulting in Beaufort values of 0, 1, 2, and ≥2 that were used in the analysis. The group types assessed included mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups, while lone immatures were removed from the analysis due to insufficient sample size. The random effect was an intercept of focal follow ID, which accounts for the variability between groups and the correlation of observations within group.

4.3.2.4.2 Unique Behaviour

In the analysis of unique behaviour, behaviours were binned in two categories – “unique behaviour” which included rolling, rubbing, nursing, sexual displays and tusking; and “no unique behaviour”. A mixed-effects model with a binomial distribution was used to analyse the data. Fixed effects included vessel presence within 5 km from the group, distance from vessel (modeled as a natural cubic spline with three degrees of freedom), group type, Beaufort value and water clarity classification, primary behaviour, and group size (modeled as a natural cubic spline, due to relationship nonlinearity). An interaction between distance from vessel and group type could not be included due to the low sample size. The group types assessed included mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups, while lone immatures were removed from the analysis due to insufficient sample size. Group size was included in the model to account for increased likelihood of unique behaviours being observed when more narwhal are present in the group. The random effect was an intercept of focal follow ID, which accounts for the variability between groups and the correlation of observations within group.

4.3.2.4.3 Association of Immatures with Presumed Mother

4.3.2.4.3.1 Proportion of Immatures

For the analysis of proportion of immatures, data were filtered to include only focal follows that had at least one immature present in the group for at least one 30-second time interval within the focal follow period. Group type was assigned as the first group type when the group size within the focal follow was largest. That is, as opposed other analyses, the group type was assigned to all observations within a focal follow, as opposed to changing within the focal follow, with changes in group composition (e.g., if adults leave a mixed group with immatures, leaving only mother-immature pairs in the focal follow). This was done so that proportion immatures could be tracked throughout the focal follow, while accounting for the inherent differences in proportion immatures between different group types. Due to the reassignment of group type and the filtering of data to only include groups with at least one immature, the resulting dataset did not include any adult-only groups.

A mixed-effects model with a binomial distribution was used to analyze proportion immatures, where the response variable was a matrix with the count of immature narwhal and the count of all other life stages for each time stamp in each focal follow. Fixed effects included vessel presence within 5 km from the group, distance from vessel (modeled as a natural cubic spline with two degrees of freedom), the group type recorded when the focal follow had the most narwhal, an interaction between distance from vessel and group type, Beaufort value, and group size (modeled as a natural cubic spline, due to relationship nonlinearity). The effect of water clarity was omitted from the model, since most of the data with “Poor” water clarity in this dataset were collected in 2023, when the most common group type was mother-immature pairs, leading to collinearity in the two predictors. The random effect was an intercept of focal follow ID, which accounts for the variability between groups and the correlation of observations within group.

4.3.2.4.3.2 Presence of Nursing Behaviour

In the analysis of nursing activity, a mixed-effects model with a binomial distribution was used. The model included fixed effects of group size (modeled as a linear relationship), group type, and vessel presence, but not vessel distance, given the limited data available for narwhal-vessel interactions at the exposure zone distances (<5 km). The random effect was an intercept of focal follow ID.

4.3.2.4.3.3 Relative Positioning of Immatures

The analysis of relative position used only data from mother-immature pairs and mixed groups with immatures, since mixed groups without immatures, adult groups, and lone immatures did not provide data on relative or distal position between immatures and their mothers.

In the analysis of relative position, of the five relative positions recorded (on top, under, abreast, behind, in front), one (on top) was removed from the data analyses due to low sample size. In addition, to increase sample size, the remaining relative positions were grouped into the following two categories: “under” and “lateral”, the latter which included “abreast”, “in front” and “behind” relative positions. To analyze the dataset, a mixed-effects model with a binomial distribution was used. Fixed effects included vessel presence within 5 km from the group, distance from vessel (modeled as a linear relationship), group type, Beaufort value, water clarity classification, primary behaviour, and group size (modeled as a natural cubic spline, due to relationship nonlinearity). An interaction between distance from vessel and group type could not be included due to low sample size. The random effects were an intercept of focal follow ID, and the ID of the immature within the focal follow, nested within the focal follow ID; these two effects accounted for the correlation of observations within group, and the correlation of observations of each individual immature narwhal within groups that had multiple immatures.

4.3.2.4.3.4 Distal Positioning of Immatures

The analysis of distal position used only data from mother-immature pairs and mixed groups with immatures, since mixed groups without immatures, adult groups, and lone immatures did not provide data on relative or distal position between immatures and their mothers.

In the analysis of distal position (tight or loose), a mixed-effects model with a binomial distribution was used. Fixed effects included vessel presence within 5 km from the group, distance from vessel (modeled as a natural cubic spline with two degrees of freedom), relative position of immature, Beaufort value, water clarity classification, primary behaviour, and group size (modeled as a natural cubic spline, due to relationship nonlinearity), and group type. An interaction between distance from vessel and group type or relative position could not be included at this time due to low sample size. Of the five relative position categories considered in the study design (i.e., on top, under, abreast, behind, in front), two categories (i.e., behind and in front) had low sample sizes; therefore, data were re-grouped into one of the following three categories: “on top”, “under” and “lateral”, the latter which included “abreast”, “in front”, and “behind” relative positions. The random effects were an intercept of focal follow ID, and the ID of the immature within the focal follow, nested within the focal follow ID; these two effects accounted for the correlation of observations within group, and the correlation of observations of each individual immature narwhal within groups that had multiple immatures.

4.3.2.4.4 Group Formation

In the analysis of group formation, formations were binned in two categories – “parallel” and “linear, cluster, non-directional line, or no formation”. A mixed-effects model with a binomial distribution was used to analyse the data. Fixed effects included vessel presence within 5 km from the group, distance from vessel (modeled as a natural cubic spline with two degrees of freedom), group size (modeled as a linear relationship), Beaufort value, water clarity classification, primary behaviour, group type, and the interaction between group type and distance from vessel. The group types assessed included mother-immature pairs, mixed groups with immatures, mixed groups

without immatures, and adult groups, while lone immatures were removed from the analysis due to insufficient sample size. Group size was included in the model to account for decreased likelihood of a strictly parallel formation in larger groups. The random effect was an intercept of focal follow ID, which accounted for the variability between groups and the correlation of observations within group.

4.3.2.4.5 Group Spread

In the analysis of group spread, a mixed-effects model with a binomial distribution was used. Fixed effects included vessel presence within 5 km from the group, distance from vessel (modeled as a natural cubic spline with three degrees of freedom), group type, Beaufort value, water clarity classification, primary behaviour, and group size (modeled as a natural cubic spline with two degrees of freedom, due to relationship nonlinearity). An interaction between distance from vessel and group type could not be included due to convergence issues during modelling. Due to sample size limitations, Beaufort scale values were binned such that all values of 3 or larger were collapsed into a single bin, resulting in Beaufort values of 0, 1, 2, and ≥2 that were used in the analysis. The group types were mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups (lone immatures were removed from the analysis due to low sample size). The random effect was an intercept of focal follow ID, which accounts for the variability between groups and the correlation of observations within group.

4.3.2.4.6 Group Size

In the analysis of group size, a mixed-effects model with a truncated Poisson distribution was used. The analysis of group size was performed on the following group types: mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups (lone immatures were removed from analysis). The goal of the analysis was to assess whether groups disperse (resulting in a decreased group size) or merge with other groups (resulting in an increased group size) in response to vessel traffic. For all group types, there was a minimum group size that could not be any smaller – a group size of one for adult groups and mixed groups without immatures, and group size of two for mother-immature pairs and mixed groups with immatures. These minimum-sized groups could only increase in group size, whereas groups sized larger than the minimum could either increase or decrease in size. Hence, the modeling needed to account for the difference in initial group size. Due to the differences in minimum group size between groups with and without immatures, a separate model was constructed for each group type. Fixed effects in each model were as follows:

- Mother-immature pairs: vessel presence within 5 km from the group, distance from vessel (modeled as a natural cubic spline with two degrees of freedom), Beaufort values, and whether the group size was at minimum value in the previous time stamp in the survey.
- Mixed with immatures: vessel presence within 5 km from the group, distance from vessel (modeled as a natural cubic spline with three degrees of freedom), Beaufort values, water clarity, and whether the group size was at minimum value in the previous time stamp in the survey.
- Mixed without immatures: vessel presence within 5 km from the group, distance from vessel (modeled as a natural cubic spline with three degrees of freedom), Beaufort values, water clarity, and whether the group size was at minimum value in the previous time stamp in the survey.

- Adult groups: vessel presence within 5 km from the group, distance from vessel (modeled as a natural cubic spline with three degrees of freedom), Beaufort values, and whether the group size was at minimum value in the previous time stamp in the survey.

The effect of water clarity was omitted from the models for adult groups and mother-immature pairs, due to spurious estimates.

The random effect was an intercept of focal follow ID, which accounted for the variability between groups and the correlation of observations within groups.

4.3.2.4.7 Group Travel Speed

The dataset of group travel speed was filtered to omit the following cases:

- Cases where the drone was not directly above the narwhal group (since the drone's GPS position was used to represent the narwhal group's position, these cases would bias group position, and hence the travel speed estimates).
- Cases where the drone was at high altitude during focal follow surveys.
- The first position from each focal follow survey as the drone was typically still at high altitude and not necessarily positioned directly overhead of the focal group.
- A single case where estimated travel speed was greater than 4.0 m/s, from a mixed group without immatures recorded in 2022. This value was presumed to be the result of a measurement error, as narwhal travel speeds are not likely to be higher than 2.5 m/s (Heide-Jorgensen et al. 2002, 2013a), and the second-highest value in the dataset was 3.7 m/s, suggesting a possible break in the data.

Travel speed values were only analyzed at each time stamp associated with the video footage analysis, as opposed to the high-resolution (<1 sec) GPS data available from the drone track, so that group composition could be included in the analysis. This subsampling of the available high-resolution positioning data avoided the bias of speed estimates that may result due to small corrective movements made by the UAV during flights.

In the analysis of group travel speed, a mixed-effects model with a normal distribution was used. Fixed effects included vessel presence within 5 km from the focal group, distance from vessel (modeled as a natural cubic spline with two degrees of freedom), primary behaviour, Beaufort value, water clarity classification, group type, and the interaction between group type and distance from vessel. Due to sample size limitations, Beaufort scale values were binned such that all values of 3 or larger were collapsed into a single bin, resulting in Beaufort values of 0, 1, 2, and ≥2 that were used in the analysis. The group types were mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups (lone immatures were removed from analysis due to limited data in presence of vessels). The random effect was an intercept of focal follow ID, which accounted for the variability between groups and the correlation of observations.

4.3.2.5 Power Analysis

To assess the statistical power of the analyses performed in this report, a 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 A for detailed methods and results of the power analysis.

5.0 RESULTS

5.1 Observational Effort and Environmental Conditions

Each annual monitoring campaign at Bruce Head (2014–2017 and 2019–2023) was timed to extend over an approximate four-week period, coinciding with the open-water season (Table 5-1; Figure 5-1). In general, the study area was ice-free during each annual program, with occasional presence of drifting ice floes in the SSA. Survey dates and survey effort varied between years (Table 5-1), 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 ten-hour monitoring shift per day, while previous years consisted of two daily rotating eight-hour shifts. In 2019, two daily shifts were resumed, with each team monitoring for eight hours (16 hours total). The 2019 monitoring schedule was replicated in 2020–2023.

Table 5-1: Number of narwhal and vessel transits recorded during RAD survey effort presented by survey year.

Statistic	Survey year									Total
	2014	2015	2016	2017	2019	2020	2021	2022	2023	
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	27 Jul – 30 Oct	30 Jul – 13 Oct	3 Aug – 31 Oct[5]	-
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	01 Aug – 26 Aug	30 Jul – 23 Aug	30 Jul – 23 Aug[6]	-
No. of active survey days	23	29	27	26	26	26	24 (BSA), 22 (RAD)	24 (RAD)	25[6]	181
No. of survey days lost to weather	14	9	11	2	3	0	4	0	0	43
No. of observer hours (total)	79.6	148.7	159.3	97.3	151.5	193.0	163.0	184.4	144.2	1,321.1
Average daily survey effort (h)	8.9	12.1	11.0	6.4	10.9	13.9	11.9	13.3	14.8	11.4
No. of attempted RAD surveys	180	314	321	160[1]	288	351	289	341	281	2,524
No. of complete RAD surveys	166	313	311	109	169	206	188	278	173	1,913
Number of RAD surveys with 0 narwhal counts[2]	75	164	127	35	71	236	197	152	269	1,326
No. of narwhal (total)	10,463	14,599	28,309	11,862	19,210	9,047	4,762	15,548	421	114,221
No. of narwhal excluding 'impossible' sightability	10,463	14,599	28,309	11,831	19,200	9,047	4,762	15,548	421	114,180
No. of narwhal excluding 'impossible' sightability, standardized by effort (total narwhal / total h)	131.4	98.2	178.0	121.8	127.2	47.5	29.4	84.9	2.9	86.9[4]
No. of vessel transits during RAD effort	7	11[3]	21[3]	22	32[3]	42	31	40	17	223
No. of RAD surveys with >1 vessel transiting	1	0	1	2	2	3	1	4	3	17

(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, as the RAD was performed in the same direction as a herding event. 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 5-2 due to transits occurring outside of a RAD count or the vessel being farther than 5 km from relevant substrata during the RAD count.
(4) Total number of observed narwhal, divided by total effort.
(5) Although the first inbound transit of a Project vessel in Milne Inlet did not occur until 09 Aug, the first Project vessel present in the RSA in 2023 occurred on 03 Aug (two tug vessels that remained east of Pond Inlet).
(6) Surveys between 30 July and 3 August 2023 (inclusive) were shown for total effort, but omitted from all other counts and analyses due to the presence of heavy ice in North Milne Inlet up to 03 Aug, which prevented narwhal from proceeding southbound into Milne Inlet towards Bruce Head. All other values shown for 2023 in this table and elsewhere exclude these surveys.

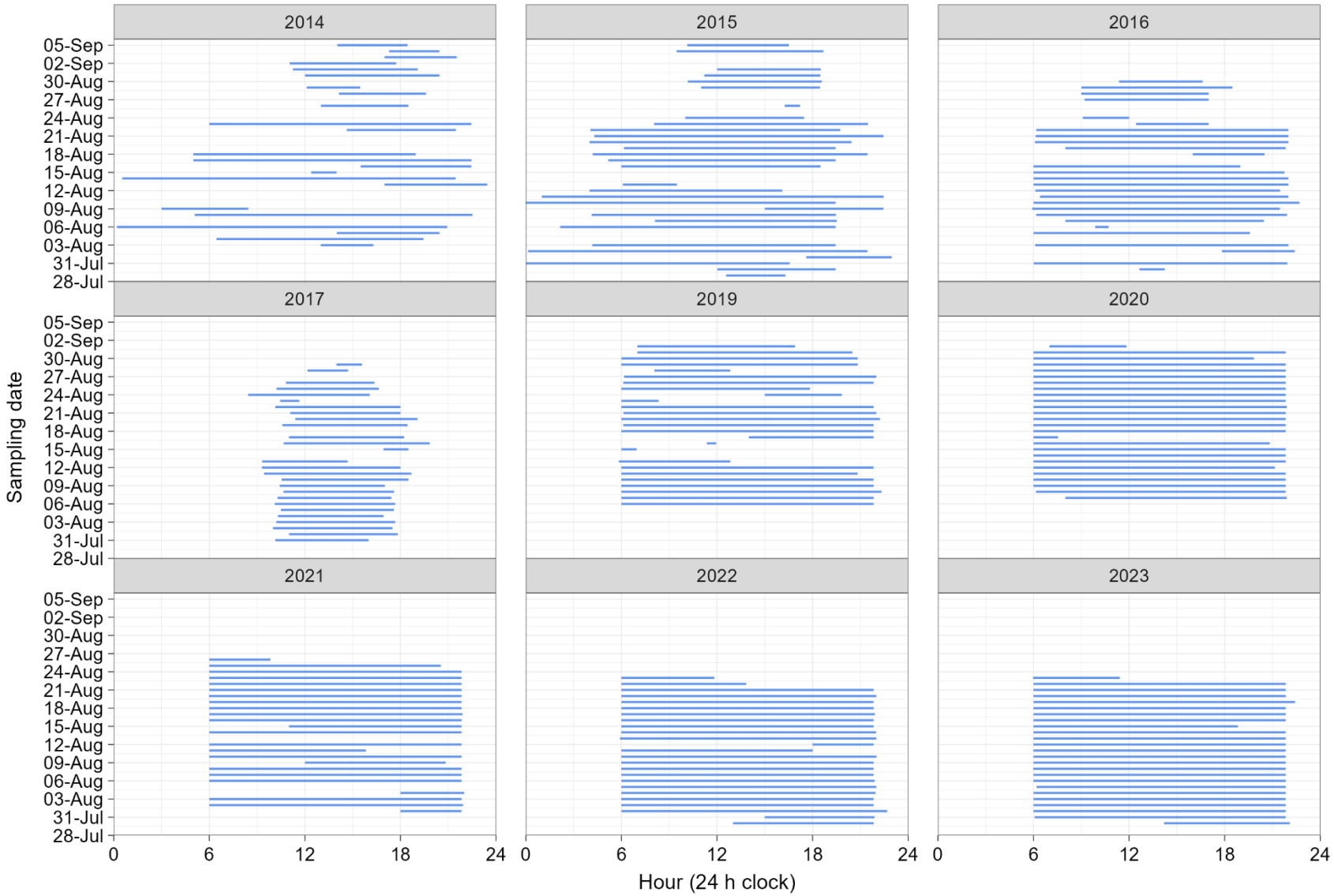

Figure 5-1: Observer effort (h) by survey day, presented by year; lines extend from first to last observations made within each day.

Across the nine-year dataset, 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 5-2). All sightings made during “impossible” sighting conditions or during wind conditions of Beaufort level 6 or higher were removed from the multi-year analysis, equivalent to 2,672 rows of RAD data (3.8% of the total 2014–2017 and 2019–2023 dataset).

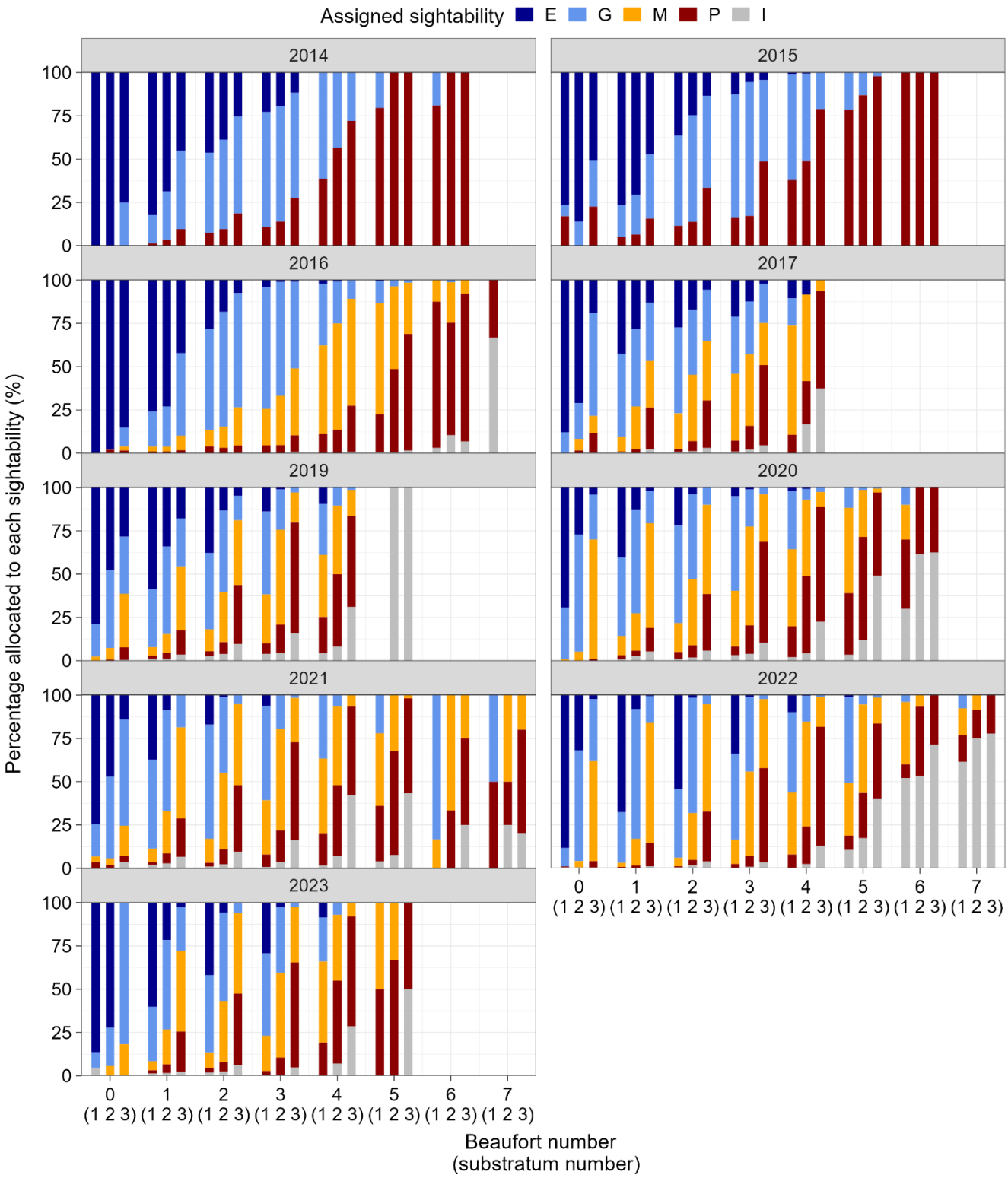

Figure 5-2: Sightability conditions during RAD surveys in the SSA relative to recorded Beaufort wind scale, glare, and substratum location (plotted by year): (E) Excellent, (G) Good, (M) Moderate, (P) Poor, (I) Impossible.

5.2 Vessel Transits and Other Anthropogenic Activity

5.2.1 Baffinland Vessels and Other Large/Medium-Sized Vessels

The total number of annual one-way vessel transits that passed through the SSA during the Bruce Head study period and throughout the full shipping season is summarized in Table 5-2 and Figure 5-3. In 2023, sightings data were recorded during 17 of 32 (53%) of all vessel transits that occurred during the study period. Medium and large vessel (>50 m) traffic in the SSA consisted primarily of Project-related bulk ore carriers (26 one-way transits; Table 5-2; Appendix B). Other medium and large Project-related vessels included general cargo vessels and fuel tankers. No passenger vessels (i.e., cruise ships) were recorded in the SSA in 2023 during the Bruce Head sampling period. Recorded tracklines of all vessel transits through the SSA during the full extent of all shipping seasons combined are presented in Figure 5-4. Recorded tracklines of vessel transits occurring during the 2023 survey period specifically are presented in Figure 5-5.

Vessel speeds were plotted by vessel type for each year (Figure 5-6). As part of Baffinland's vessel management practices, a maximum vessel speed limit of nine knots along the Northern Shipping Route is enforced. No ore carriers exceeded the 9-knot speed limit in the SSA in 2023.

Table 5-2: Summary of 1-way 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	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	186 (186)	56 (56)	42 (75%)
2021	175 (175)	58 (58)	36 (62%)
2022	150 (148)	56 (54)	37 (63%)
2023	202 (200)	32 (32)	17 (53%)
Total	**1,198 (1,071)**	**418 (393)**	**239 (57%)**

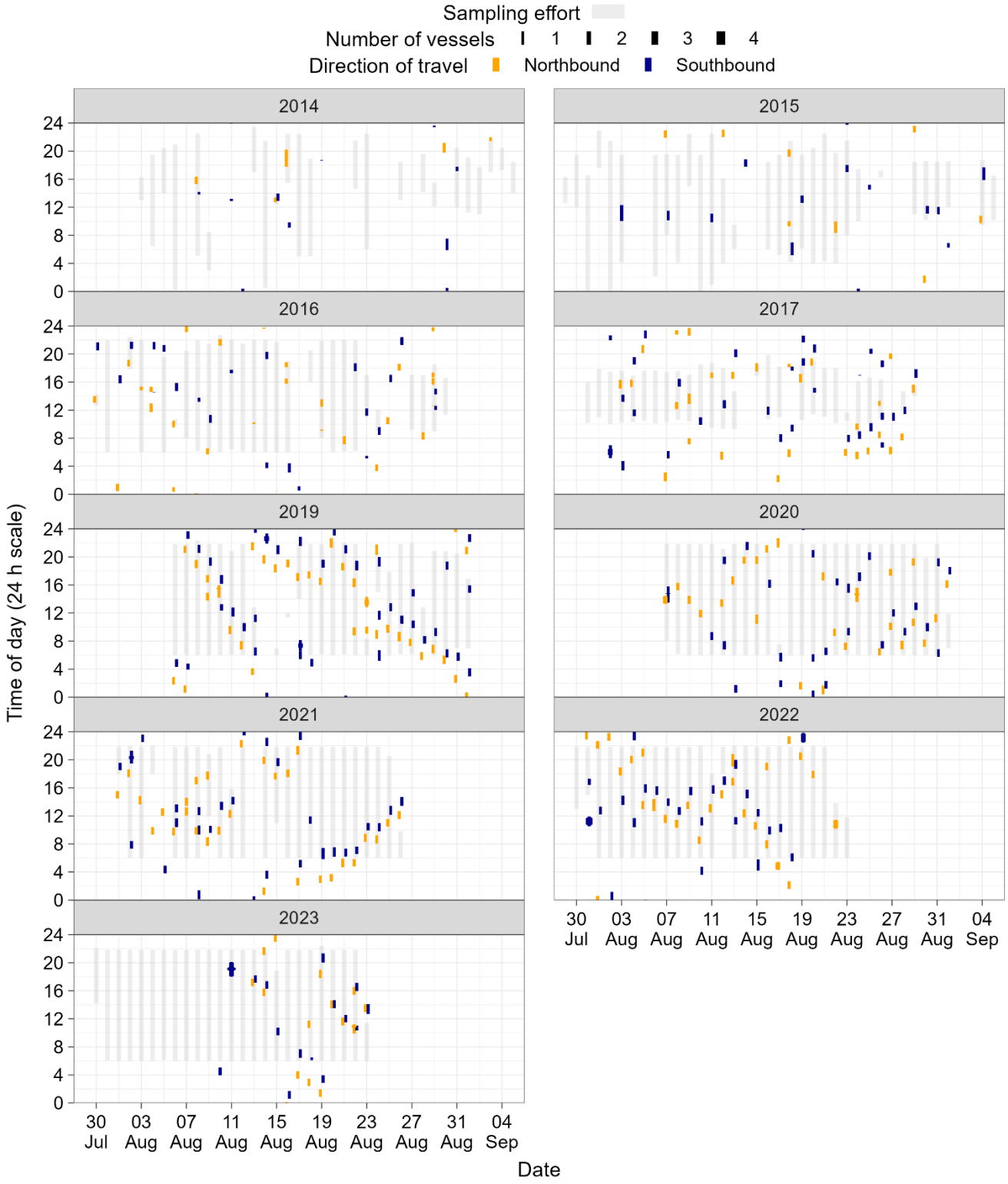

Figure 5-3: Daily summary of vessel transits in SSA with associated survey effort. Grey boxes indicate daily monitoring periods and correspond to observer survey effort shown in Figure 5-1; grey boxes extend from first to last observations made within each day.

A) 2014 VESSEL TRANSITS

B) 2015 VESSEL TRANSITS

C) 2016 VESSEL TRANSITS

C) 2017 VESSEL TRANSITS

LEGEND

VESSEL TRANSIT ROUTES BY LENGTH AND CLASS

LARGE VESSELS (>100 m)

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

MEDIUM VESSELS (>50 m AND ≤100 m)

- CARGO CARRIER
- ICEBREAKER
- OTHER (NON-PROJECT RELATED)

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

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

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CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

TITLE
TRACKLINES OF LARGE AND MEDIUM-SIZED VESSEL TRANSITS IN SSA DURING ENTIRE SHIPPING SEASON (2014-2017)

PROJECT NO.	CONTROL	REV.	FIGURE
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E) 2018 VESSEL TRANSITS

F) 2019 VESSEL TRANSITS

G) 2020 VESSEL TRANSITS

Milne Inlet
Stephens Island
Bruce Head
Koluktoo Bay
Poirier Island
Tugsat River
Assomption Harbour

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 E1 E2 E3 F1 F2 F3 G1 G2 G3 H1 H2 H3 I1 I2 I3 J1 J2

NO BRUCE HEAD SAMPLING WAS UNDERTAKEN IN 2018.

510000 520000 530000
8010000 8000000 7990000

LEGEND

VESSEL TRANSIT ROUTES BY LENGTH AND CLASS

LARGE VESSELS (>100 m)

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

MEDIUM VESSELS (>50 m AND ≤100 m)

- CARGO CARRIER
- ICEBREAKER
- OTHER (NON-PROJECT RELATED)

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

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PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

CONSULTANT
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DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

TITLE
TRACKLINES OF LARGE AND MEDIUM-SIZED VESSEL TRANSITS IN SSA DURING ENTIRE SHIPPING SEASON (2018-2020)

PROJECT NO.	CONTROL	REV.	FIGURE
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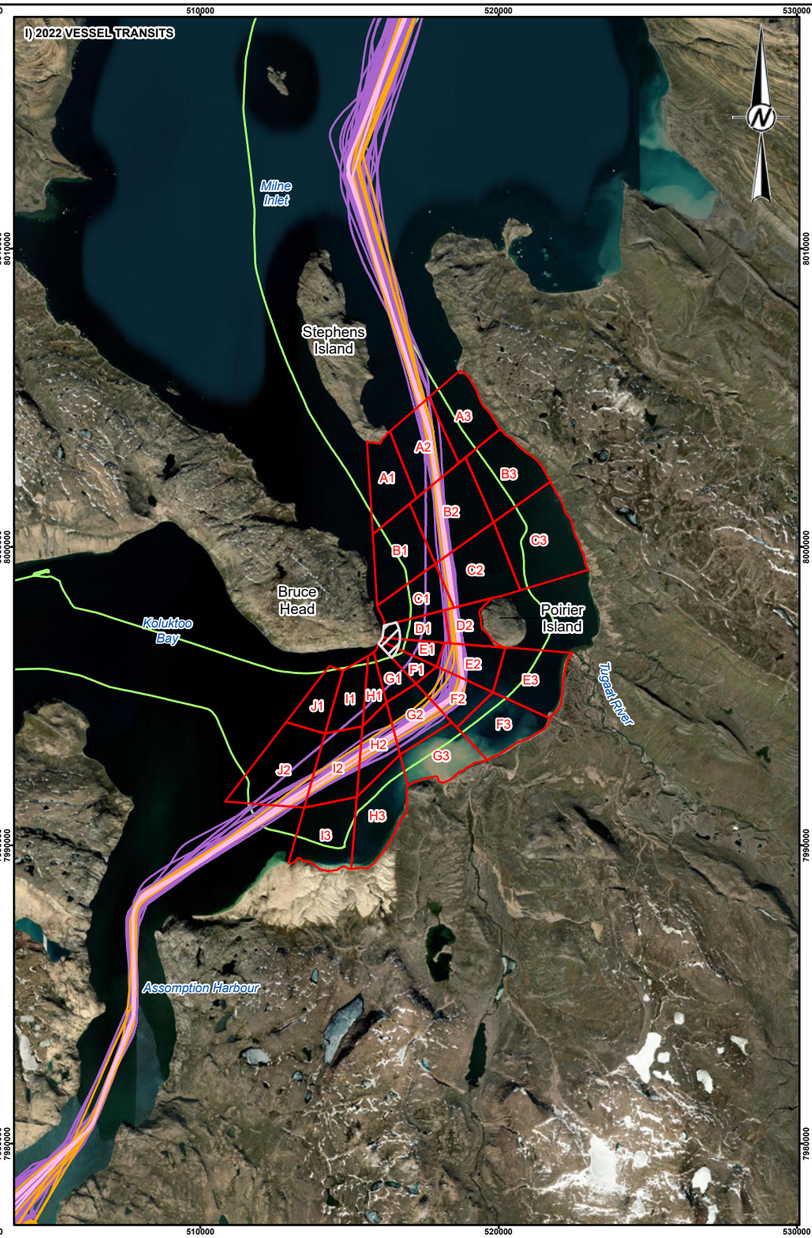

LEGEND

VESSEL TRANSIT ROUTES BY LENGTH AND CLASS

LARGE VESSELS (>100 m)

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

MEDIUM VESSELS (>50 m AND ≤100 m)

- CARGO CARRIER
- ICEBREAKER
- OTHER (NON-PROJECT RELATED)

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

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PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

MARY RIVER PROJECT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

TITLE

TRACKLINES OF LARGE AND MEDIUM-SIZED VESSEL TRANSITS IN SSA DURING ENTIRE SHIPPING SEASON (2021-2023)

PROJECT NO.	CONTROL	REV.	FIGURE
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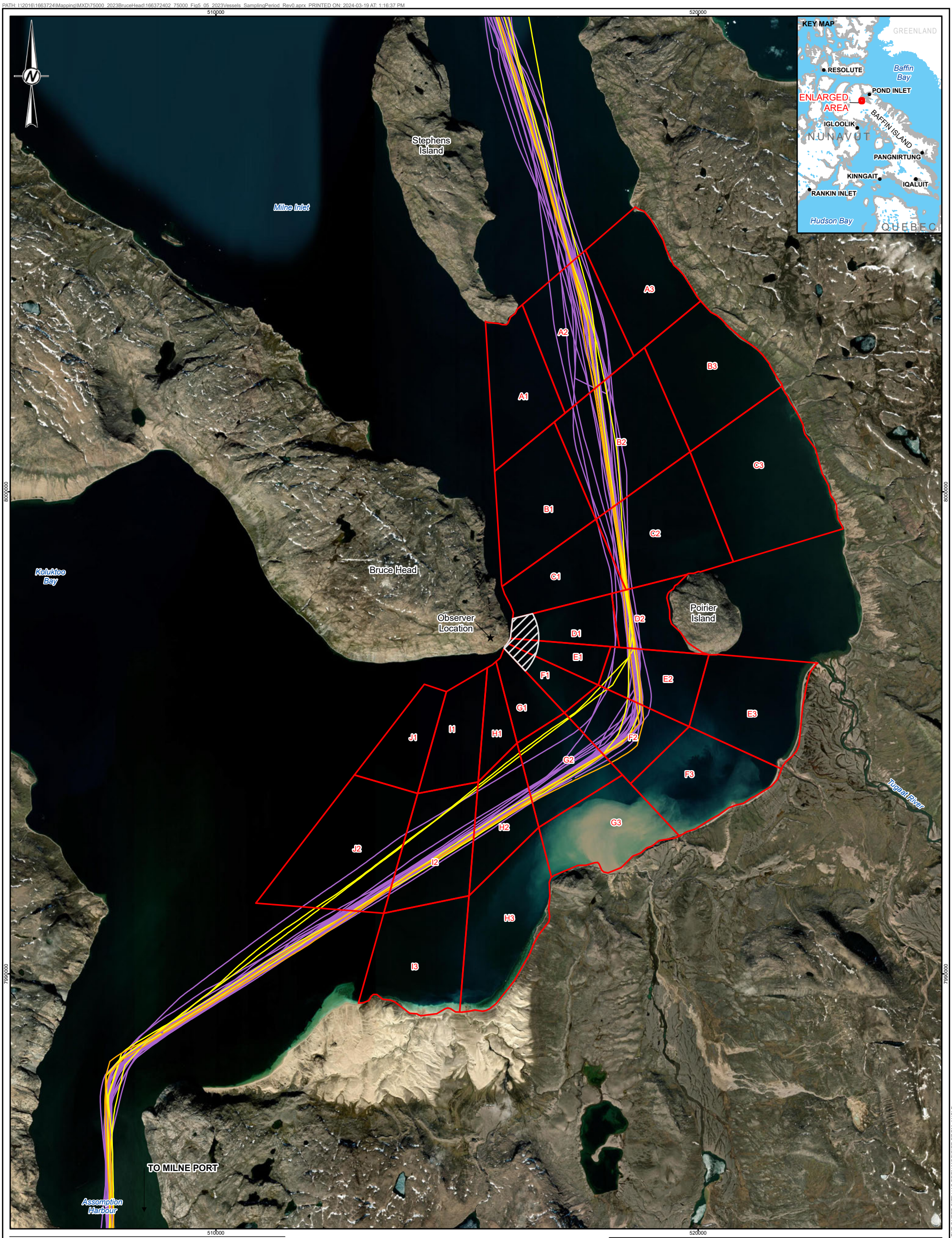

LEGEND

- ★ OBSERVER LOCATION

VESSEL TRANSIT ROUTES BY LENGTH AND CLASS

LARGE VESSELS (>100 m)

- BULK (ORE) CARRIER
- CARGO CARRIER
- FUEL TANKER

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

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CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
TRACKLINES OF VESSEL TRANSITS IN SSA DURING 2023 BRUCE HEAD PROGRAM (30 JULY -23 AUGUST 2023)

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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Figure 5-6: Travel speed (knots) of all vessels in the SSA presented by survey year. Shaded area represents speeds >9 knots (9 knot speed restriction was implemented starting in 2018).

Note: “Other” vessel types included Canadian Navy vessels, passenger vessels, and pleasure craft.

5.2.2 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 2023 field program specifically, the hunting camp was visited or occupied by local hunters for only a portion of the study period.

Since 2014, the majority of RAD surveys were performed more than 70 min after the last shooting event (81–98% of surveys; Figure 5-7). Where hunting occurred within 70 min prior to surveys, 1–16% of the surveys were performed within 10 min 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 began in 2019, 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.

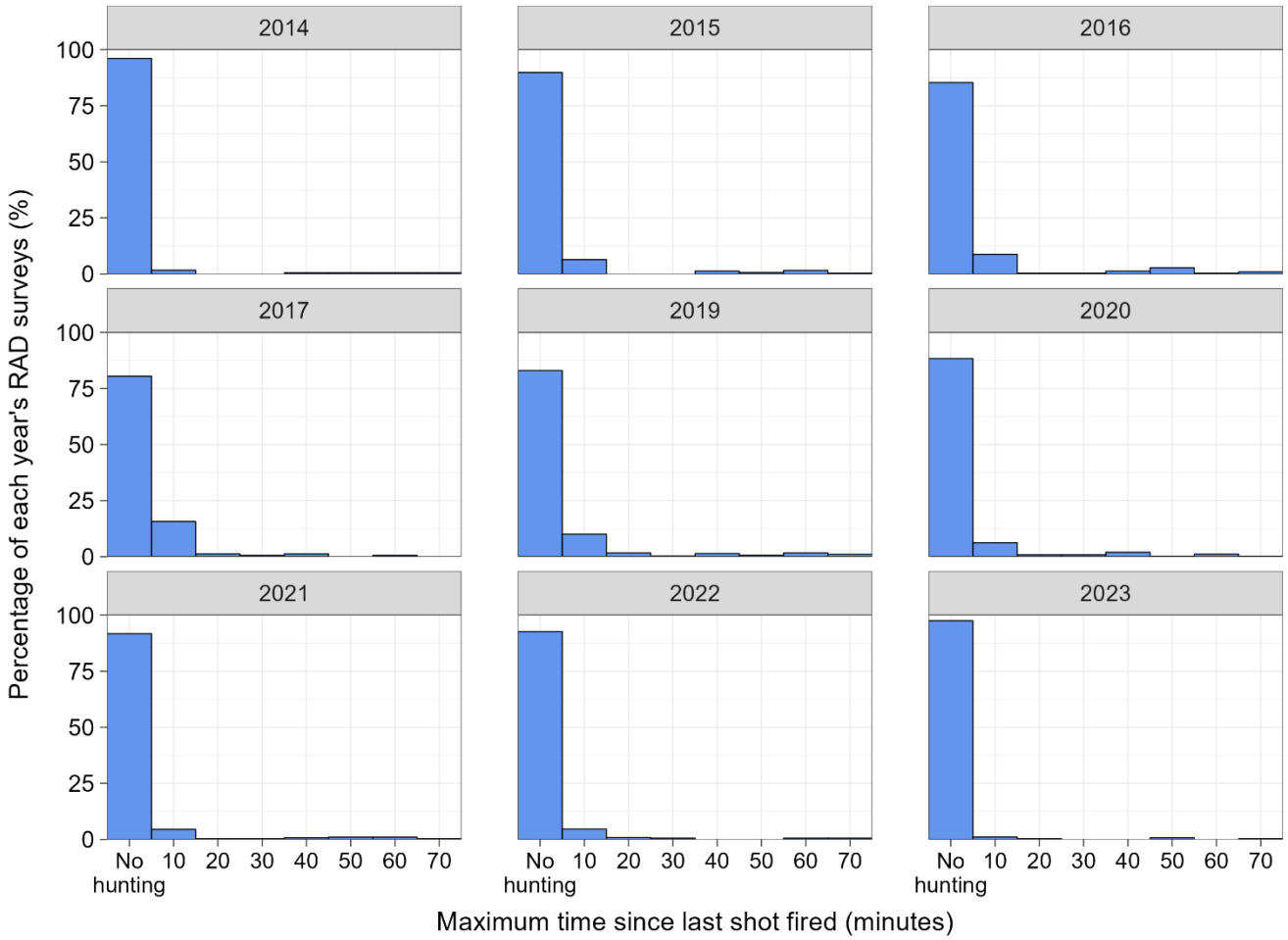


Figure 5-7: Relative proportion of hunting activity at Bruce Head presented by sampling year showing "maximum time since shooting occurred" breakdown.

5.3 Relative Abundance and Distribution (RAD)

Sampling in 2023 took place between 30 July and 23 August. However, data collected between 30 July and 03 August (inclusive) were excluded from all analyses due to no narwhal being present in Milne Inlet at this time. Extensive landfast ice coverage in western Eclipse Sound in early August (as shown in ice imagery in Appendix G) would have prevented narwhal from entering Milne Inlet up until Aug 04, when several ice leads developed in the consolidated ice field that would have allowed narwhal to proceed southbound into Milne Inlet. A total of 277 RAD surveys were completed over the course of 20 days between 04–23 August 2023. A summary of the 2023 RAD data, compared to that collected from 2014 to 2022, is presented in Table 5-1. Similar to previous years, narwhal was the most common cetacean species recorded at Bruce Head in 2023. Less common cetacean sightings recorded in the SSA in 2023 included bowhead whale (n=2). No beluga or killer whales were observed in 2023. The relative abundance of narwhal in the SSA in 2023 (corrected for effort; total narwhal/total h) was 2.9 narwhal/h. In comparison, prior to 2023, the lowest relative abundance of narwhal recorded was in 2021 (29.4 narwhal/h), while the highest was in 2016 (178.0 narwhal/h; Golder 2022b). Over the nine years of data collection, the number of RAD surveys performed per year ranged from 160 in 2017 to 351 in 2020 (see Table 5-1). 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 6.4 h in 2017 to 14.8 h in 2023. The lower number of RAD surveys in 2017 reflected a reduction in survey effort that year (one observation shift vs. two rotating observation shifts). The filtering of RAD data prior to analysis is detailed in Section 4.3.1.6.2.

A total of 114,221 narwhal were recorded in the SSA over nine years of data collection (see Table 5-1). Annual numbers of narwhal recorded ranged from 421 (2023) to 28,309 (2016), reflecting annual variation in both narwhal abundance 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 2.9 narwhal/h in 2023 to 178.0 narwhal/h in 2016 (Figure 5-8). Over the nine-year program, numerous RAD surveys were conducted where no narwhal were observed (see Table 5-1). The proportion of zero-count RAD surveys was 41% in 2014, 52% in 2015, 41% in 2016, 22% in 2017, 25% in 2019, 67% in 2020, 68% in 2021, 45% in 2022, and 96% in 2023. This variation strongly affected annual mean values. Annual median standardized counts ranged from 0.0 narwhal/h in 2023 to 106 narwhal/h in 2017 (Figure 5-8).

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 5-8). 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 narwhal numbers were recorded: 9 August (142 narwhal/h), 22 August (183 narwhal/h), and 29 August (153 narwhal/h). In 2021, two peaks in narwhal numbers were recorded: 9 August (116 narwhal/h) and 19 August (212 narwhal/h). Daily numbers of narwhal in 2021 were the lowest observed since monitoring began in 2014. In 2022, narwhal counts were higher compared to 2020 and 2021, with two peaks in standardized counts: 331.3 narwhal/h on 14 August and 212 narwhal/h on 21 August. In 2023, a single small peak was recorded between 19 August and 21 August, with a maximum of 34.8 narwhal/h on 20 August 2023 (Figure 5-8).

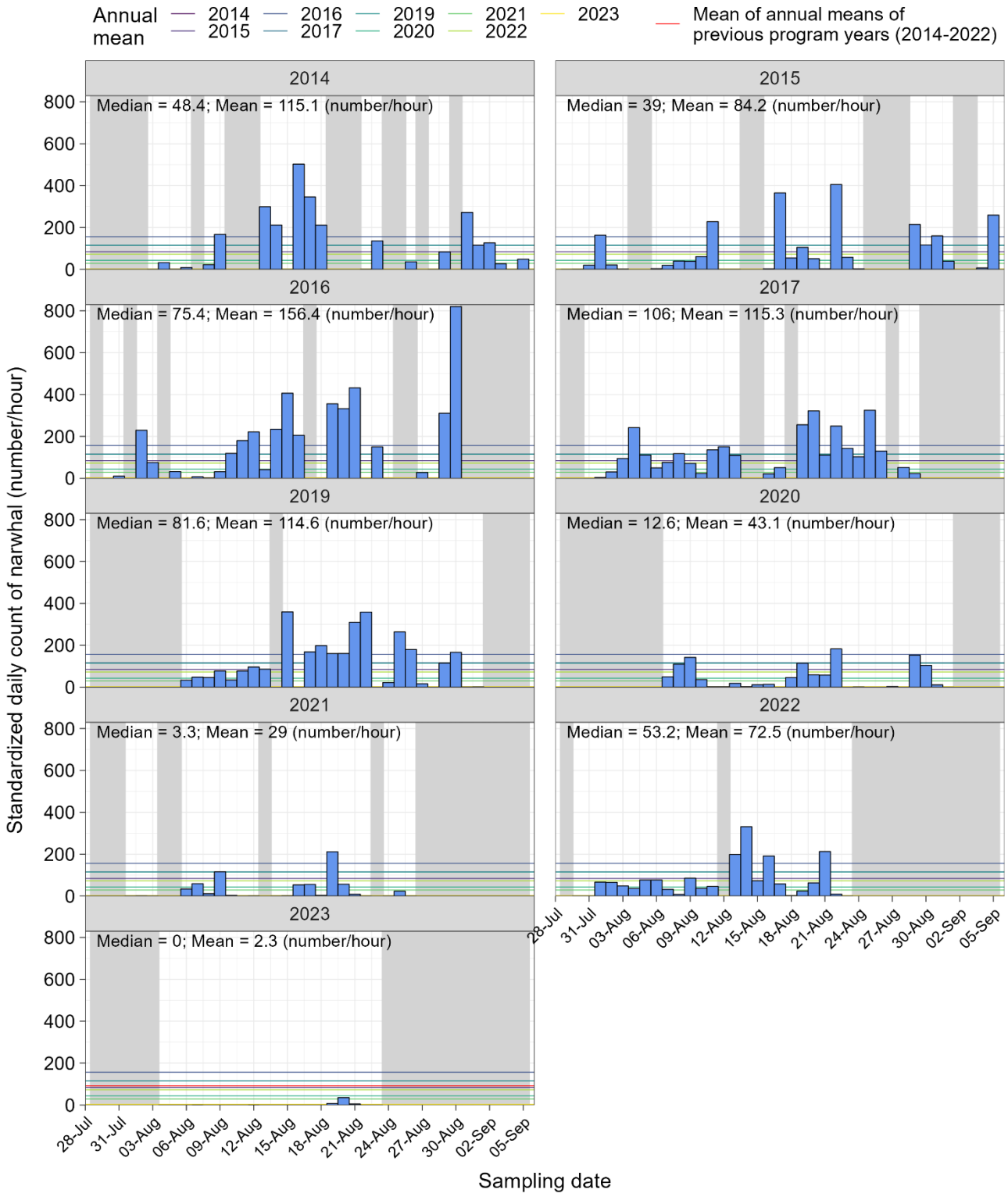


Figure 5-8: Standardized daily numbers of narwhal recorded in the SSA from 2014–2023, excluding 2018. Shaded area represents days where no data was collected.

In general, higher numbers of narwhal were recorded in the southern strata (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b, 2022b, WSP 2023c). In each survey year, strata G, H, and I had the highest proportion of narwhal (Figure 5-9), accounting for 62–72% of total narwhal recorded in 2014–2017, and 47–57% of total narwhal recorded in 2019–2023 (influenced by the introduction of new stratum J in 2019). Stratum J accounted for 16–28% of the total narwhal recorded in 2019–2023. The number of narwhal recorded also varied with substratum distance from the observation platform (Figure 5-9). Each year, substrata 2 (i.e., the mid-channel substrata) had the highest proportion of total narwhal recorded, accounting for 48–62% of total annual narwhal observations. In addition to stratum and substratum location, sightability also affected the number of narwhal recorded (Figure 5-9). Number of narwhal recorded per RAD survey was considerably higher during periods when sightability was considered “excellent” or “good”.

The proportion of narwhal observed in the presence of at least one vessel (i.e., vessel present within 5 km of the substratum centroids) was 0.4% in 2014, 1.4% in 2015, 3.2% in 2016, 11.6% in 2017, 9.1% in 2019, 6.2% in 2020, 8.9% in 2021, 10.6% in 2022, and 0.7% in 2023. Of the narwhal recorded during periods when a single vessel was within 5 km, the majority were recorded when vessels were northbound (100%, 81%, 65%, 65%, 55%, and 53% in 2014, 2016, 2017 and 2020–2022, respectively), with the exception of 2015, 2019, and 2023, in which 33%, 47%, and 0% of narwhal were recorded when vessels were northbound, respectively.

In the combined multi-year RAD dataset, the majority of narwhal were recorded when no vessels were present (n=59,410 surveys of individual substrata, with 105,346 individuals counted), with a mean of 1.8 narwhal per substratum and a mean density of 0.7 narwhal/km² (Figure 5-10).

During periods of single vessel exposure (single vessel ≤5 km), a total of 4,470 surveys of individual substrata were conducted, with a total of 6,649 individuals recorded (mean count of 1.5 narwhal per substratum and mean density of 0.7 narwhal/km²). In 2023, the mean number of narwhal per substratum during periods of single vessel exposure was 0.012 individuals, with a mean density of 0.005 narwhal/km².

During periods of multiple vessel exposure (two or more vessels ≤5 km), a total of 80 surveys of individual substrata were conducted, with a total of 44 narwhal recorded (mean count of 0.6 narwhal per substratum and mean density of 0.2 narwhal/km²). In 2023, no narwhal were recorded during periods of multiple vessel exposure.

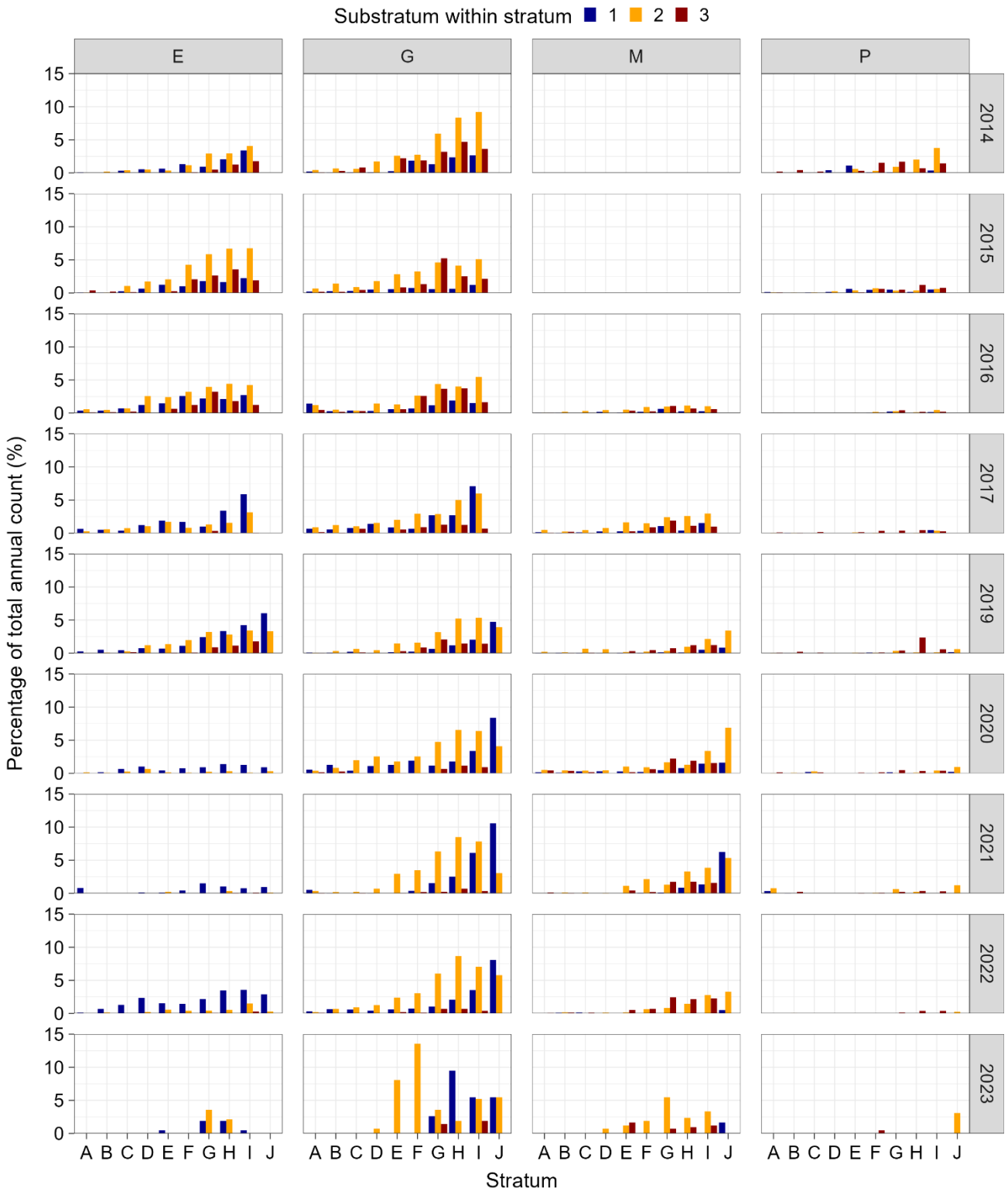


Figure 5-9: Relative proportion of narwhal counts in each substratum as a function of sampling year and sightability (relative to total narwhal counts). Sightability categories: E = excellent, G = good, M = moderate, P = poor.

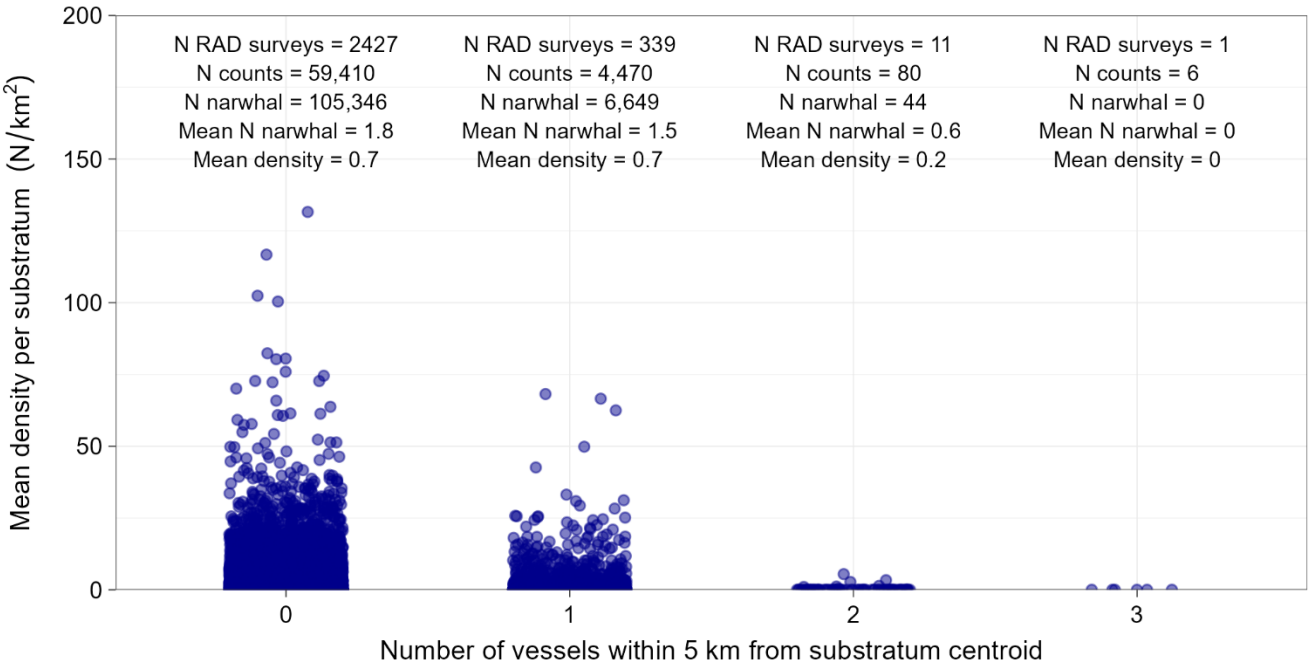


Figure 5-10: Summary of surveys conducted in the SSA relative to vessel exposure level (no exposure, single vessel, and multiple vessels within 5 km); data exclude impossible sightability, cases with Beaufort levels of 6 or higher, and days with killer whales present in Milne Inlet South.

In summary, the relative abundance of narwhal (total number of narwhal corrected for survey effort) in the SSA in 2023 (2.9 narwhal/h) was lower than all previous survey years (i.e., lowest relative abundance since the start of monitoring at Bruce Head). It is presumed that low narwhal numbers observed at Bruce Head in 2023 was related to delayed access by narwhal into Milne Inlet South in early August due to the extensive landfast ice coverage in Western Eclipse Sound at this time (Appendix G), with little to no ice leads available for narwhal to enter Milne Inlet (Baffinland 2024a). The late break-up period also resulted in a delay to the start of the 2023 shipping season with the first inbound ship transit in Milne Inlet taking place on 09 August. Narwhals were not observed in the Bruce Head study area until 05 August 2023, with narwhal numbers slowly increasing towards the end of the Bruce Head Program. Aerial surveys conducted in the RSA in parallel with the Bruce Head Program indicated that narwhal abundance in the RSA was 10,492 animals (CV= 0.05; CI = 9,578-11,494) on 12-13 August and 9,572 animals (CV= 0.05; CI = 8,706-10,524) on 23-25 August 2023 (WSP 2024a). These abundance estimates were not significantly different to baseline levels (2013), when narwhal abundance was estimated at 10,489 animals (CV = 0.24; CI = 6,342 – 17,347) (Doniol-Valcroze et al. 2015). The 2023 aerial survey results also demonstrated that narwhals were primarily concentrated in Tremblay Sound during the first half of August and then shifted into Milne Inlet South during late August (WSP 2024a). Acoustic monitoring data collected in 2023 also substantiated this shift in narwhal distribution towards Milne Inlet South during in late August 2023 with narwhal calls notably increasing on the Bruce Head recorder at this time (Austin et al. 2024). This supports the low sighting rates recorded at Bruce Head prior to the Bruce Head Program ending on 22 August 2023.

5.4 Density

Of the total 63,966 RAD surveys undertaken of individual substrata (excluding data detailed in Section 4.3.1.6.2), 4,470 surveys (7.0%) were associated with a single vessel exposure event and 86 surveys (0.1%) were associated with a multiple vessel exposure event.

Based on the distribution of the observed counts (i.e., not accounting for any other pertinent variables), an increase in narwhal density was commonly observed at vessel distances of 2–4 km (relative to the substratum), regardless of whether the vessel was moving toward or away from the substratum (Figure 5-11). In the presence of southbound vessels, this effect was less pronounced. Overall, the data suggest that narwhal density in the SSA may have been influenced by “vessel travel direction” (northbound vs. southbound). In the combined 2014–2023 dataset, narwhal density was less influenced by “vessel orientation relative to substratum” (moving towards vs. moving away) than in previous reporting years.

A generalized linear mixed model with a zero-inflation component was used to assess narwhal density. Test statistics and coefficient estimates for the narwhal density model are provided in Appendix C. Residual diagnostic plots are provided in Appendix D.

The full model had a zero-inflation component that depended on the substratum coordinates (as splines of easting and northing, and their interaction), day of year, and Beaufort level. All five variables were significant predictors in the zero-inflation component of the model ($P<0.044$; see Appendix C, Table C-1). This indicates that these fixed effect predictors affect not only narwhal density, but also the probability of recording narwhal presence, whether due to sighting conditions (Beaufort level), seasonal variability (day of year effect) or spatial distribution within the SSA.

A comparison between the observed data and model predictions for narwhal density, as a function of distance from vessel, vessel direction, vessel orientation relative to a given substratum, and sampling year (i.e., predictor variables associated with statistically significant changes), is presented in Figure 5-12. The orange line and points represent the predicted mean narwhal density for a specific set of predictor values (Section 4.3.2.2) whereas the blue bars summarize the entirety of the observed data. This leads to some visual discrepancies between the observed and predicted values.

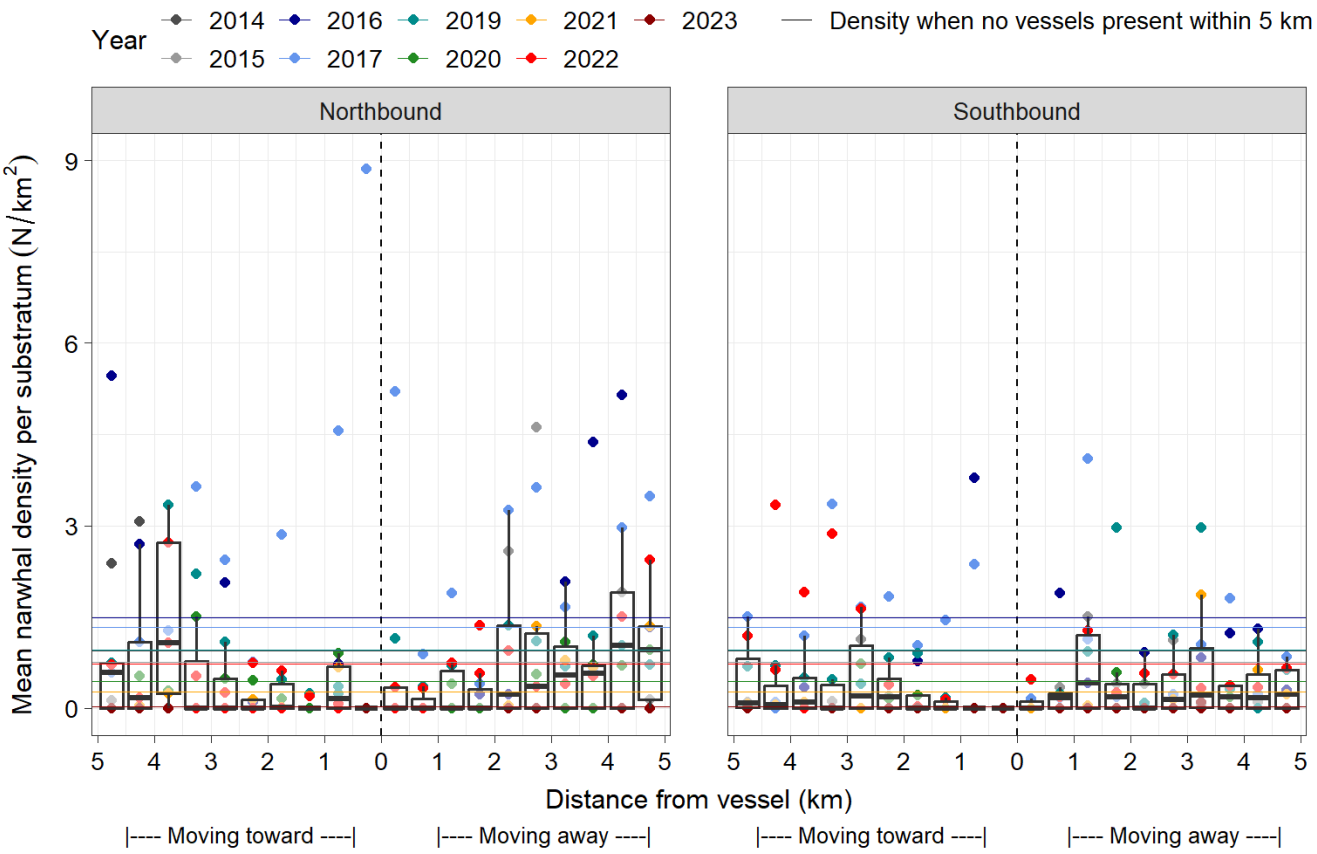


Figure 5-11: Mean narwhal density per substratum as a function of distance from vessel (rounded up to 0.5 km), vessel travel direction, vessel orientation relative to substratum, and sampling year. Horizontal lines depict mean density of narwhal per substratum during vessel non-exposure periods.

In the model of narwhal density, the effect of distance from vessel was significant (P<0.001; see Appendix D, Table D-1), while the effect of vessel direction was not significant (P=0.07) and the interaction between vessel direction and distance from vessel was not significant (P=0.4). When exposed to northbound vessels, predicted mean narwhal density decreased by 18% for each kilometre that the vessel moved closer toward the substratum (P<0.001 for the slope), and predicted mean density increased by 22% for each kilometre that the vessel moved farther away from the substratum (P<0.001 for the slope; Figure 5-12). When exposed to southbound vessels, narwhal density decreased by 9% for each kilometre the vessel moved closer toward the substratum (slope significance of 0.104). On the other hand, the 14% increase in density for each kilometre the vessel moved farther away from the substratum was significant (slope significance of 0.049). Mean narwhal density was significantly lower in the presence of a northbound vessel (for both approaching and departing vessels) at distances ≤2 km from a substratum when compared to mean narwhal density during vessel non-exposure periods (>5 km; Table 5-3). For example, when a southbound vessel was at 0 km, density was 0.9 narwhal/km^2; when no vessels were present, density was 1.8 narwhal/km^2 (Figure 5-12). This is equivalent to an effect size of -47% (Table 5-3). In comparison, in the presence of southbound vessels (both approaching or departing), narwhal density was significantly lower at distances ≤3 km from a substratum when compared to mean narwhal density during vessel non-exposure periods. Effect sizes at 0 km were -51% and -47% for a northbound and a southbound vessel, respectively. Effect sizes at 1 km were -44 to -41% for both northbound and southbound vessels. The effect sizes of northbound vessels decreased below ±25% at 2.4–2.6 km (effect sizes at 3 km were -13% for a vessel moving toward the substratum and -16% for a vessel moving away). For a southbound vessel, effect sizes remained above ±25% at greater distances and only decreased below ±25% at 3.8 km for a vessel moving toward the substratum (effect size of -23% at 4 km) and at 3.0 km for a vessel moving away from the substratum (effect size of -24.9% at 3 km). These findings suggest that there may have been a moderate biologically significant effect (i.e., >25% change in density – as per Section 4.3.2.1) up to a distance of 2.6 km from a northbound vessel and up to a distance of 3.8 km from a southbound vessel. The model had sufficient power (≥0.8) to detect a -40% or +45% effect size in the test of the overall effect of distance from vessel (see Appendix A), while the observed effect size was -51% (for a northbound vessel) and -47% (for a southbound vessel). That is, the observed effect size was larger than the minimum effect size required to achieve sufficient statistical power (≥0.80), therefore statistical power to detect the observed effect size was high.

Other variables that were statistically significant predictors of narwhal density included day of year, year, spatial effects, glare, Beaufort level, tide, and hunting (P<0.001 for all; see Appendix D, Table D-1). The effect of presence of small vessels in the SSA was not significant (P=0.6). Statistically significant variables that were not related to shipping were further tested using pairwise comparisons. The effect of survey year was also significant (P<0.001), indicating that at least one of the survey years was significantly different from the other years. A significant effect of survey year may indicate a long-term change in narwhal density. In pairwise comparisons of survey years, narwhal density was significantly lower in 2023 compared to all previous years (Figure 5-12; P<0.001 for all comparisons).

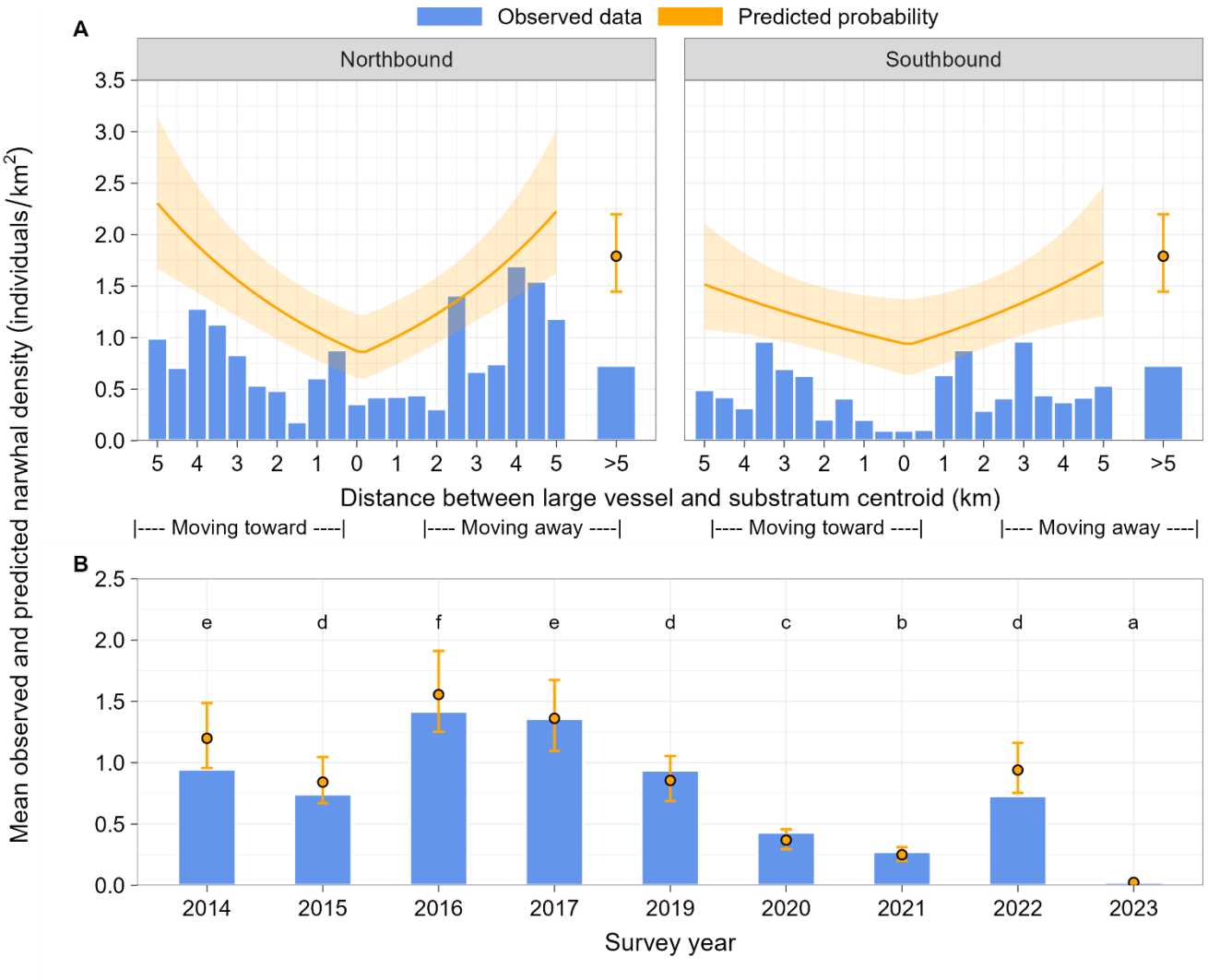


Figure 5-12: Mean narwhal density (individual/km²) as a function of distance from vessel, vessel travel direction, vessel orientation relative to substratum (combined nine-year dataset; Panel A) and survey year (Panel B).

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 5-3: Effect sizes and multiple comparisons of narwhal density predictions between vessel exposure (0 to 5 km distances) and non-exposure periods (>5 km). Statistically significant values shown in bold.

Distance from vessel (km)	Multiple comparisons to no-exposure – effect sizes (%) with *p* values in brackets			
	Northbound vessel, toward substratum	Northbound vessel, away from substratum	Southbound vessel, toward substratum	Southbound vessel, away from substratum
0	**-51% (<0.001)**	**-51% (<0.001)**	**-47% (0.007)**	**-47% (0.007)**
1	**-44% (<0.001)**	**-41% (<0.001)**	**-42% (0.001)**	**-42% (0.003)**
2	**-31% (0.01)**	**-28% (0.001)**	**-36% (<0.001)**	**-34% (0.002)**
3	-16% (0.6)	-13% (0.2)	**-30% (0.002)**	**-25% (0.035)**
4	+2% (1.0)	+6% (1.0)	-23% (0.2)	-15% (0.8)
5	+24% (0.5)	+29% (0.6)	-15% (0.9)	-3% (1.0)

Narwhal density was significantly higher when a hunting event occurred within the preceding 70 min (P<0.001, effect size of 18%). This was likely an artefact of the association between narwhal density and hunting, since hunting was more likely to take place when narwhal were present in larger numbers. Predicted mean densities were significantly higher during low slack and ebb compared to during flood or high slack conditions (P<0.001 for all, effect sizes between 22–30%); no difference was found between high slack and flood or between low slack and ebb conditions (P>0.5 for all). Predicted mean densities were significantly lower under severe glare conditions than during no-glare or low-glare conditions (P<0.001 for both, effect sizes of -40% and -57%, respectively); no significant difference was found between no-glare and low-glare conditions (P=0.2, effect size of 5%). Predicted mean densities were 41% higher at Beaufort value of 0 compared to Beaufort value of 1 (P<0.001), 15% higher at Beaufort value of 1 compared to Beaufort value of 2 (P=0.002), not significantly different between Beaufort values of 2 and 3 (P=0.3, effect size of 13%), and 94% higher at Beaufort value of 3 compared to Beaufort values of 4 or 5 (P=0.004).

In summary, there was a statistically significant effect of vessels on predicted narwhal density. Estimated effect sizes indicated a decrease in narwhal density of 9% to 22% per kilometre of distance closer to the vessel, depending on the vessel direction within Milne Inlet (northbound or southbound) and orientation (moving towards or away from substrata). The maximum predicted effect sizes, at a distance of 0 km, were a 51% and 47% decrease in narwhal density for northbound and southbound vessels, respectively. The decrease in predicted narwhal density, compared to when no vessel was present, was small (<25%), at distances greater than 2.4–2.6 km for northbound vessels and 3.0–3.8 km for southbound vessels, or the equivalent to a total disturbance period of 18–25 min per vessel assuming transit speed of 9 knots, with no significant difference between north- and southbound vessels. These findings suggest that the effect of vessels on narwhal density was mostly limited to when vessels were within a few kilometers of the substratum where narwhal were located (i.e., a temporary effect of shipping).

5.5 Group Composition (BSA)

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 2023, data were collected in the BSA on 25 days (Table 5-4), of which five days (July 30 to August 3, inclusive) were removed from all analyses due to the ice blockage of North Milne Inlet in early August, preventing narwhal from accessing Bruce Head. While total annual hours of observation in 2023 (306 h) was similar to effort in 2020 and 2022 (290 h and 295 h, respectively), number of narwhal groups and individuals observed in 2023 was substantially lower.

The majority of narwhal groups in the BSA were recorded during “excellent” sightability conditions in all sampling years except for 2016, 2020, 2021, and 2023, during which the majority of narwhal groups were recorded during “good” sightability conditions (Figure 5-13). The proportion of narwhal groups recorded during “poor” sightability conditions was relatively high in 2015 (21%) and 2023 (20%). Of these two years, the 2015 result was likely 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. A total of 42 groups were recorded under “impossible” sightability conditions (8, 19, 2, and 13 groups in 2017, 2020, 2022, and 2023, respectively) and were excluded from further analyses. The numbers of narwhal groups (*n*=40) and individuals (*n*=163) in the BSA in 2023 were the lowest observed since the start of the nine-year study period (Table 5-4).

Table 5-4: Number of narwhal groups and individuals (i.e., absolute counts) recorded in BSA presented by sampling year.

Survey year	# Sampling days	Total hours of observation	# Narwhal groups	# Narwhal
2014	11	26	250	1,086
2015	16	45	268	1,479
2016	27	282	761	2,476
2017	27	138	2,416	8,913
2019	25	229	1,301	4,986
2020	24	290	878	2,847
2021	23	268	80	263
2022	25	295	1,523	5,864
2023[5]	25	306	40	163

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.

(1) Surveys between 30 July and 3 August 2023 (inclusive) were shown for total effort, but omitted from all other counts and analyses due to the ice blockage of North Milne Inlet in early August, preventing narwhal from accessing Bruce Head. All other values shown for 2023 in this table and elsewhere exclude these surveys.

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=6,928; 92.1%). A total of 580 sightings occurred during single vessel exposure periods (7.7%) and nine sightings occurred when two vessels were present within 5 km on 13 August 2022 and 11 August 2023. Annually, the percentage of sightings that occurred when no vessels were present within the BSA ranged from 88% in 2015 and 2023 to 100% in 2014. In 2023, 88% of the sightings occurred when no vessels were present. The percentage of observations when vessels were present within 5 km of BSA ranged from 5% in 2021 to 13% in 2015 and 2023.

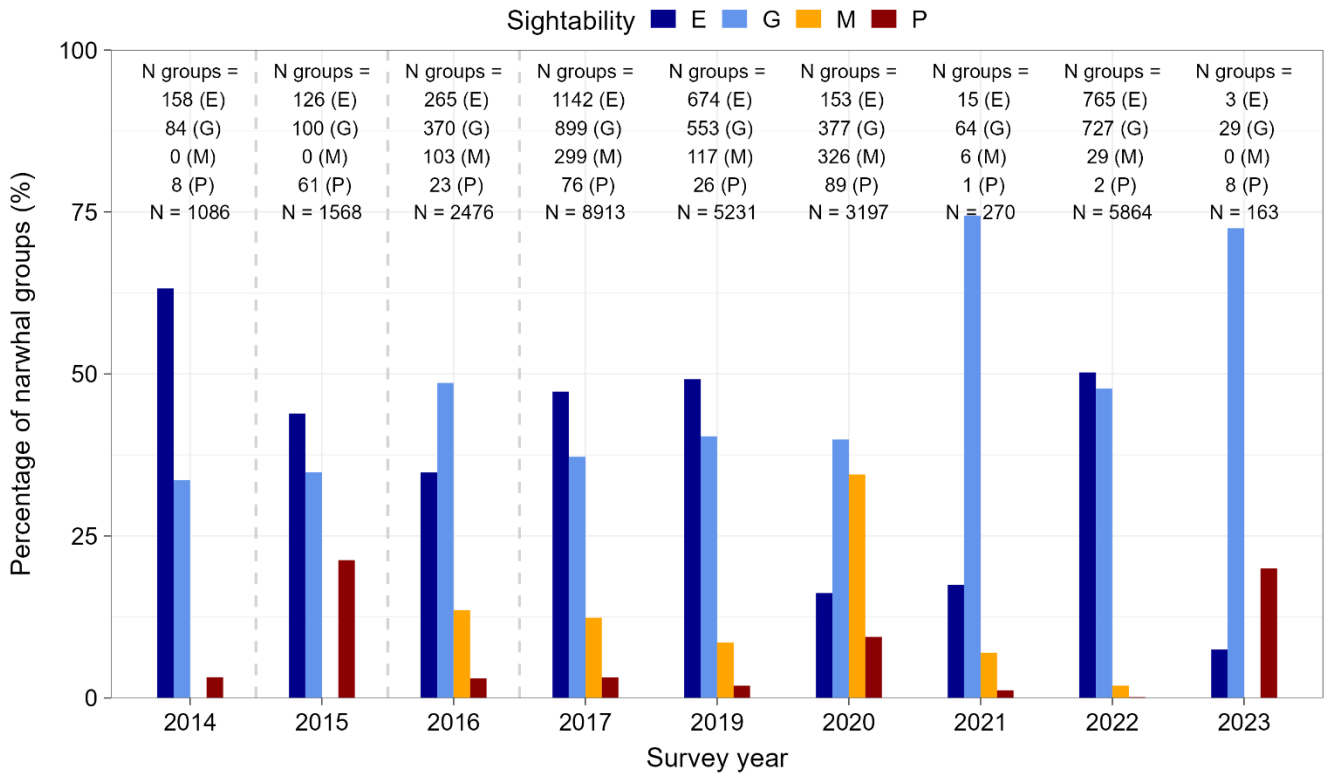


Figure 5-13: Relative proportion of narwhal groups in the BSA as a function of sightability category and sampling year.

Note: Annual group counts and total number of narwhal observed by sightability are provided for each year. E=excellent, G=good, M=moderate and P=poor (sightability categories).

A qualitative assessment of group composition by life stage in 2023 indicated similar group composition to previous years, with the majority of the sightings consisting of adult narwhal, followed by juveniles, calves, and yearlings (Figure 5-14). Prior to 2016, yearlings were not uniquely categorized as they were grouped together with calves. Similar to previous years, calves were observed on most sampling days when narwhal were within the BSA in 2023, with the exception of three days (5, 6, and 19 August) when no calves were recorded in the BSA. Yearlings were observed on 8 of the 10 days in which narwhal were observed in the BSA in 2023.

In 2023, the daily proportion of calves present in the BSA (relative to total narwhal counts) ranged between 0% (on 5, 6, and 19 August) and 50% (18 August 2023; sightings in the BSA on that day were limited to one mother-calf group). The daily proportion of yearlings (relative to total narwhal counts) ranged from 0% (18 and 19 August) to 30% (6 August, when observations were limited to a single group of 10 narwhal, of which three were yearlings). The life stage of two narwhal (1.2% of all narwhal recorded in the BSA in 2023) was unknown, due to either visibility restrictions or logistical challenges of accurately documenting all individuals during periods of high activity.

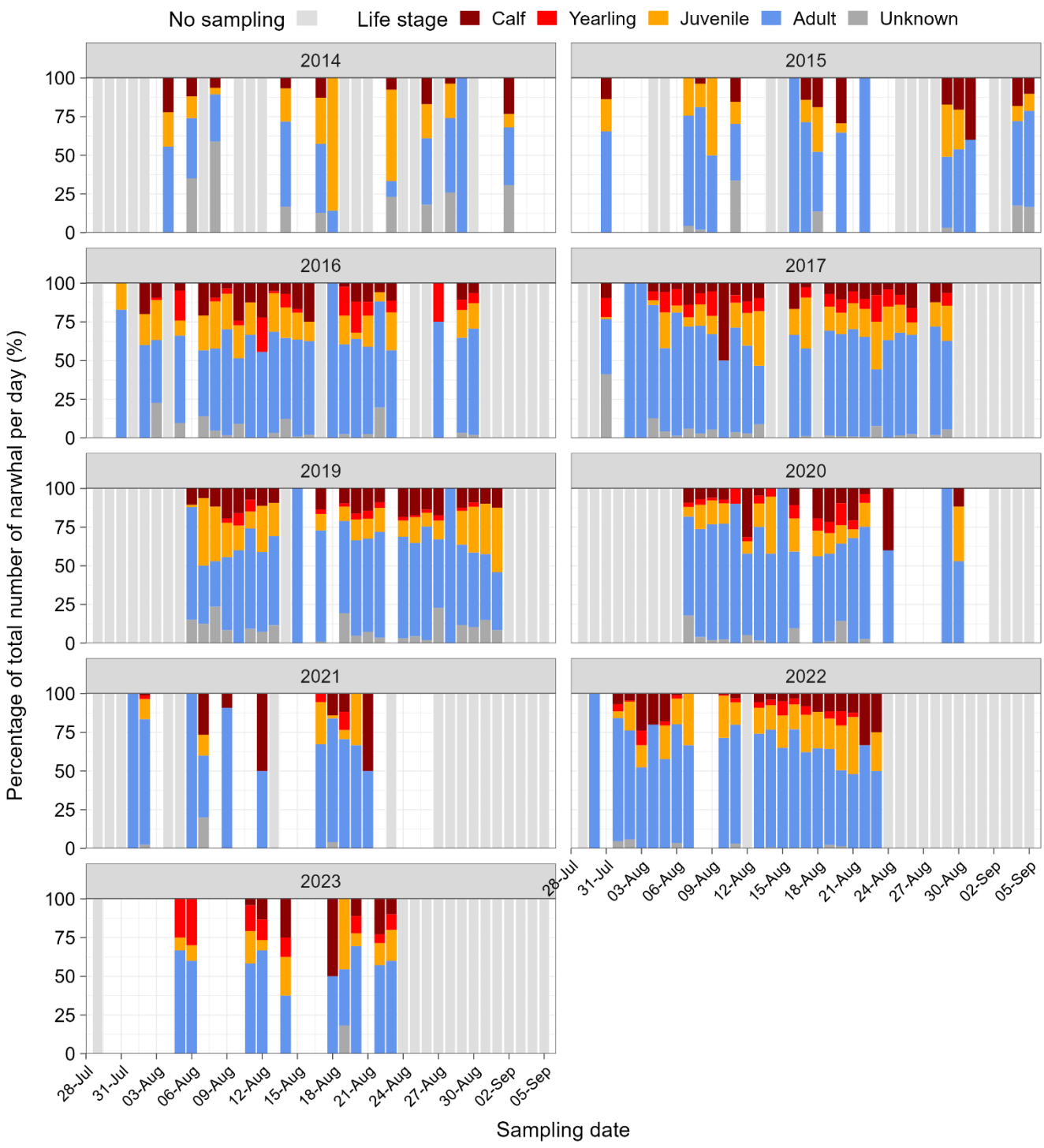


Figure 5-14: Relative daily proportion of narwhal life stages observed in the BSA presented by survey year.

The most common group type recorded during the nine-year study period was exclusively adult narwhal groups (Figure 5-15), accounting for 37% of all observed narwhal groups with known composition. Mixed groups with and without immatures both accounted for 25% of all observed groups, respectively, while mother-immature pairs accounted for 13% of all observed groups. In 2023, the distribution of group types differed from previous years, where groups with immatures accounted for most of the observed groups, possibly due to adult-only groups diverting elsewhere due to ice blockage of North Milne Inlet in early summer. Thus, exclusively adult groups accounted for only 18% of all groups, mixed groups with and without immatures accounted for 35% and 20% of groups, respectively, and mother-immature pairs accounted for 23% of groups. Other group types, such as lone immatures or groups of juveniles, accounted for the remaining 4% of group observations.

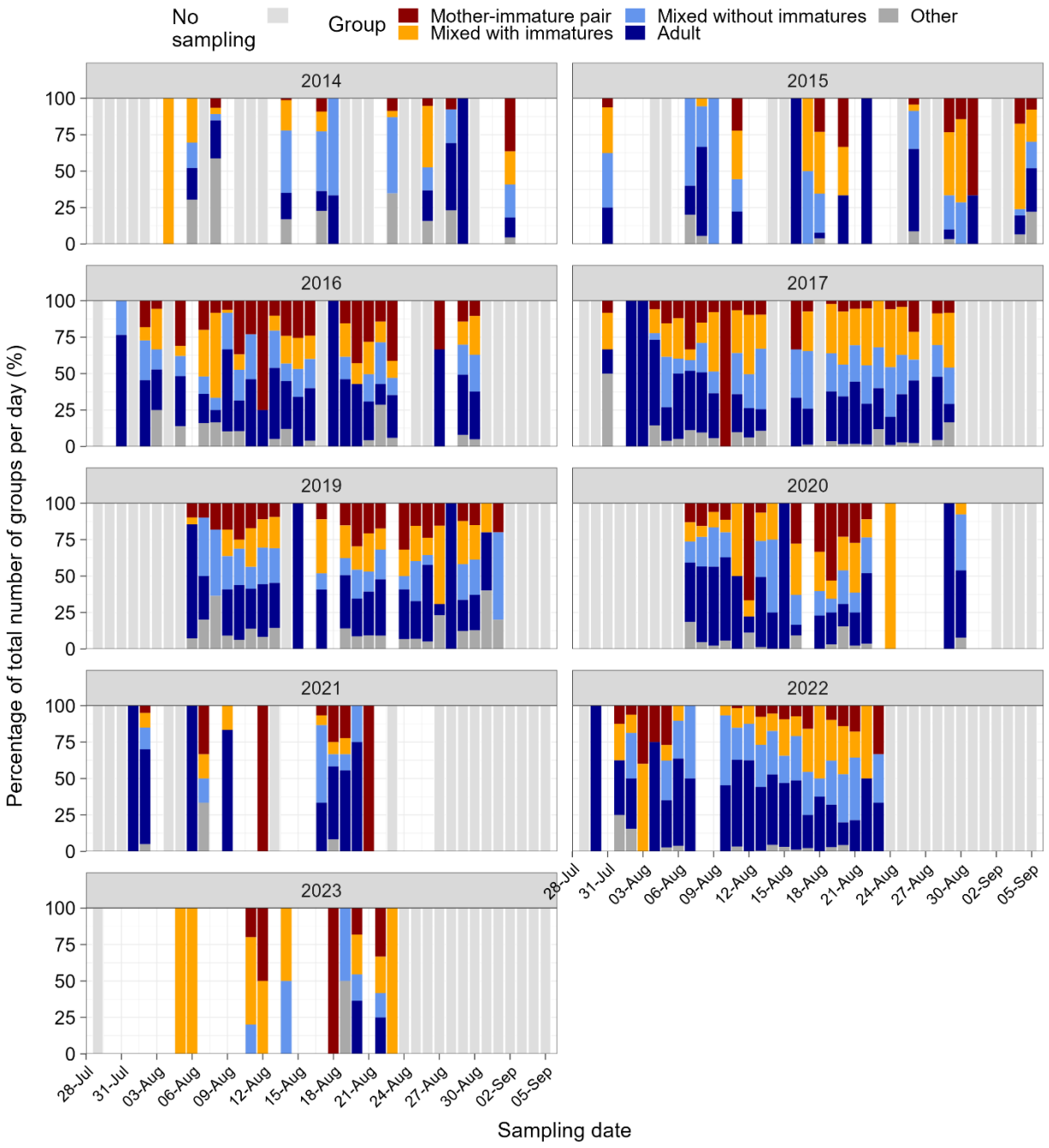


Figure 5-15: Relative daily proportion of narwhal group composition categories observed in the BSA presented by survey year.

5.5.1 Proportion of Immatures (Early Warning Indicator)

The combined annual proportion of immature narwhal recorded during nine years of monitoring at Bruce Head are presented in Table 5-5, in addition to the annual mean of daily proportions of immatures (and associated standard deviation) for each year. Values presented for 2014 (0.152) and 2015 (0.167) represent pre-shipping operation conditions (noting that the number of immatures in a given season is largely influenced by activities occurring the previous season).

During 2023, a total of 40 narwhal groups (comprising 163 individuals) were observed in the BSA, including 19 calves and 20 yearlings. The combined annual proportion of immatures observed in the BSA in 2023 was 0.242. This was higher than all previous sampling years, including the 2014 pre-shipping year, representing a 59% increase from the 2014 combined annual proportion of 0.152 (Table 5-5). When accounting for interannual variability, the 2023 estimate was higher than all previous years, representing a 57% increase from the 2014–2015 baseline condition that was statistically significant (P=0.03; Figure 5-16 and Table 5-6). The model had sufficient statistical power (≥0.8) to detect effect sizes of -30% or +42% in the comparison of 2023 data relative to baseline (2014–2015 data; see Appendix A). The observed effect size and its 95% confidence interval (CI; +4% to +137%) suggest an increase in the 2023 annual proportion of immatures relative to the baseline values. However, this increase was likely due to the low counts of narwhal overall, and due to adult-only groups possibly moving elsewhere due to ice blockage of North Milne Inlet in early summer. Therefore, while the EWI statistic was nominally high, the overall findings warrant further investigation via analysis of 2023 aerial survey data. Findings from the analysis of 2023 aerial survey data (WSP 2024a) are discussed in Section 6.3.

In summary, the relative proportion of immature narwhal observed in the BSA in 2023 (0.242) was significantly higher than baseline values in 2014 and 2015 (0.152 and 0.167, respectively), representing a 57% increase from the baseline condition. The effect size and its 95% CI (+4% to +137%) suggest an increase in the 2023 annual proportion of immature narwhal relative to the baseline values. Since this result is likely due to the small sample size and the absence of adult narwhal in the Bruce Head area due to ice blockage of North Milne Inlet in early summer, the proportion of immature narwhal was further investigated through EWI analysis of the 2023 aerial survey data (WSP 2024b).

Table 5-5: Combined annual proportion and mean annual proportion of immatures (i.e., proportion of calves and yearlings) at Bruce Head, 2014–2023.

Year	No. of narwhal groups in BSA (no. of individuals)	Combined annual proportion of immatures	Annual mean of daily proportions of immatures	
			Mean	Standard deviation
2014	250 (1,086)	0.152	0.135	0.102
2015	268 (1,479)	0.167	0.140	0.119
2016	761 (2,476)	0.164	0.182	0.105
2017	2,416 (8,913)	0.164	0.179	0.102
2018	N/A	N/A	N/A	N/A
2019	1,301 (4,986)	0.161	0.151	0.068
2020	878 (2,847)	0.145	0.166	0.120
2021	80 (263)	0.102	0.172	0.193
2022	1,523 (5,864)	0.105	0.126	0.098
2023	**40 (163)**	**0.242**	**0.261**	**0.128**

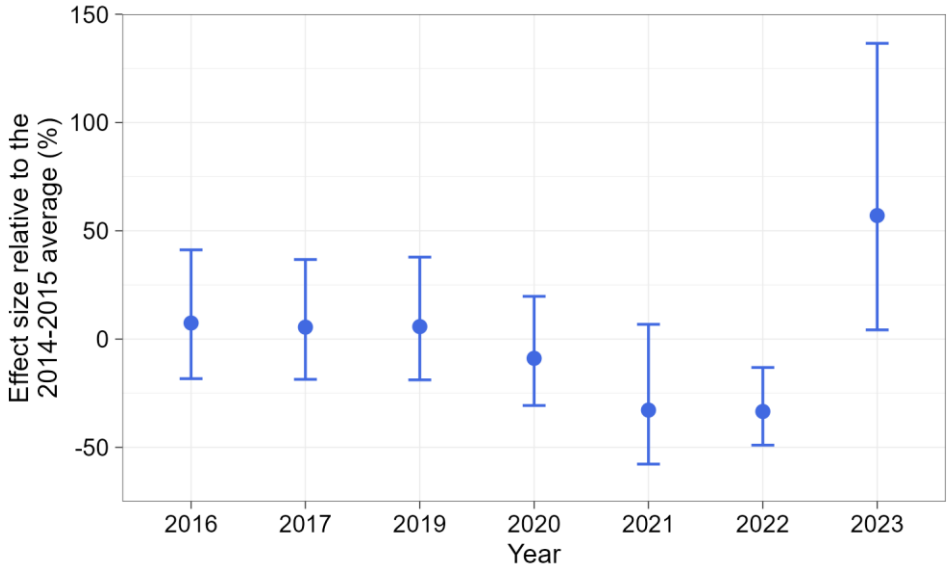


Figure 5-16: Relative change in the proportion of immature narwhal compared to the 2014–2015 baseline condition, based on analysis of annual group composition data, grouped into 10 bins per year. Error bars are 95% confidence intervals.

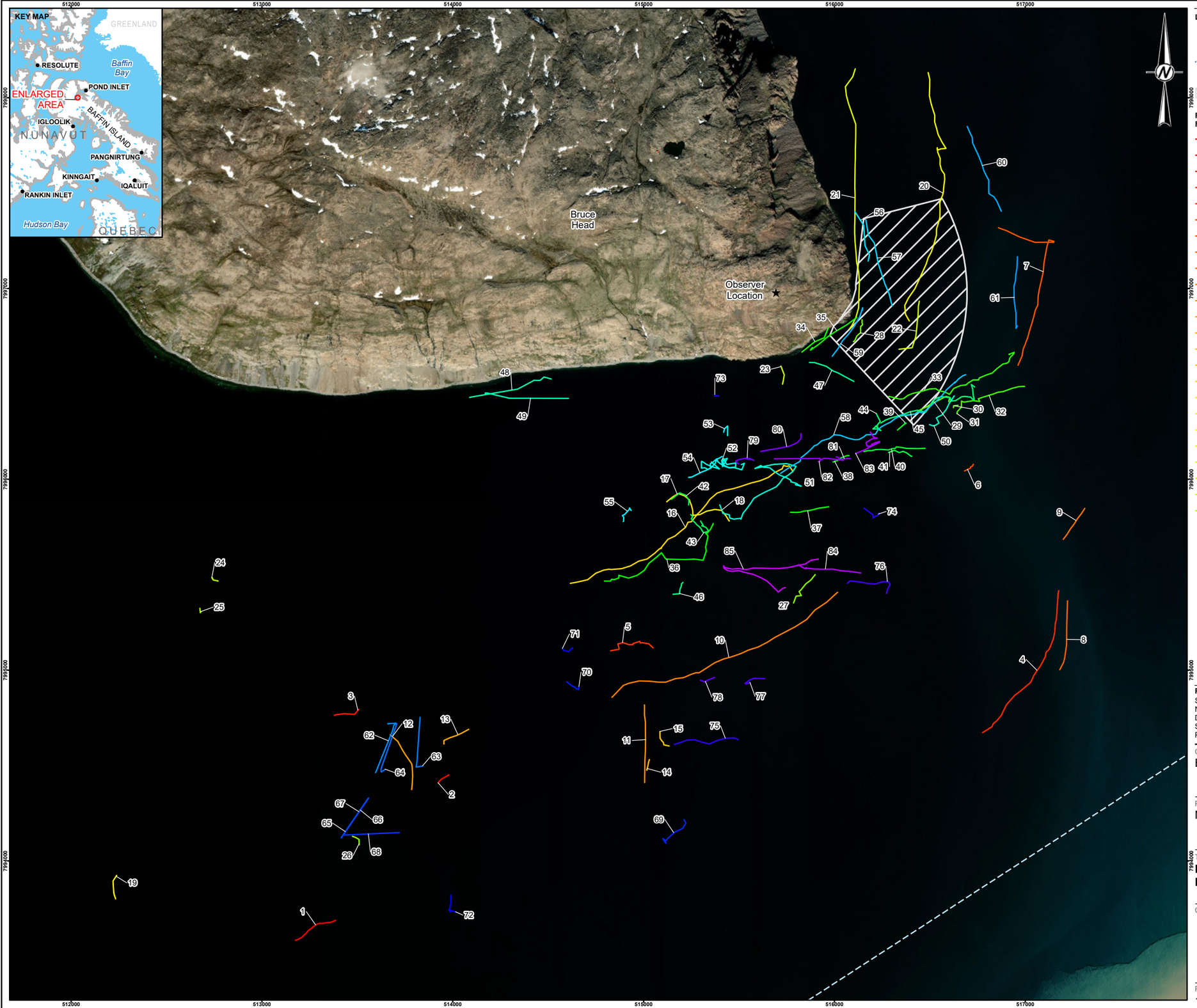
Table 5-6: Change in the annual proportion of immature narwhal compared to the 2014–2015 baseline condition.

Year	*P*-value	Effect size (%)	
		Mean	95% confidence interval
2016	0.6	+7.4	-18.3 to +41
2017	0.7	+5.5	-18.6 to +37
2018	N/A	N/A	N/A
2019	0.7	+5.8	-18.8 to +38
2020	0.5	-8.9	-30.7 to +20
2021	0.09	-32.8	-57.7 to +7
2022	0.003	-33.4	-49 to -13
2023	0.03	+57	+4.2 to +137

5.6 Behaviour (UAV-based Focal Follow Surveys)

A total of 85, 164, 148, and 15 focal follow surveys of narwhal were undertaken in 2020, 2021, 2022, and 2023, respectively, representing a total of 38.9 h of behavioural observations recorded during 412 surveys (Figure 5-17, Figure 5-18, Figure 5-19, Figure 5-20). In 2020, vessels were present (within 5 km of the focal group) for 13 of the 85 surveys (15%), representing 1.1 h of recorded behaviour during “vessel exposure” periods, with the closest point of approach (CPA) ranging from 0.9 to 4.0 km. In 2021, vessels were present for 30 of the 164 surveys (18%), representing 2.8 h of recorded behaviour during “vessel exposure” periods, with the CPA ranging from 0.4 to 4.7 km. In 2022, vessels were present for 44 of the 148 surveys (30%), representing 4.2 h of recorded behaviour during “vessel exposure” periods, with the CPA ranging from 0.8 km to 4.9 km. In 2023, vessels were present for 1 of the 15 surveys (6.7%), representing two minutes of recorded behaviour during “vessel exposure” periods, with CPA of 3.2 km. To assess narwhal behavioural responses to vessel traffic, UAV-based focal follow surveys conducted between 2020 and 2023 were analyzed, with findings presented in sections 5.6.1 to 5.6.8.

Each unique focal follow survey was denoted with its own identification number (Focal Follow Identification or FFID). Survey tracklines of the 88 total focal follow surveys involving a vessel transit are presented in Appendix E, with an example survey provided below (FFID #01, 2023; Figure 5-21). A description of each of the focal follow surveys conducted within 5 km of vessels is provided in Appendix F. For illustrative purposes, photos associated with 2023 focal follow survey numbers 01, 03, 04, and 20 are presented in Figure 5-22 to Figure 5-25, respectively.



LEGEND

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

FOCAL FOLLOWS FLIGHTS

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85

0 500 1,000

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REFERENCE(S)

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CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

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

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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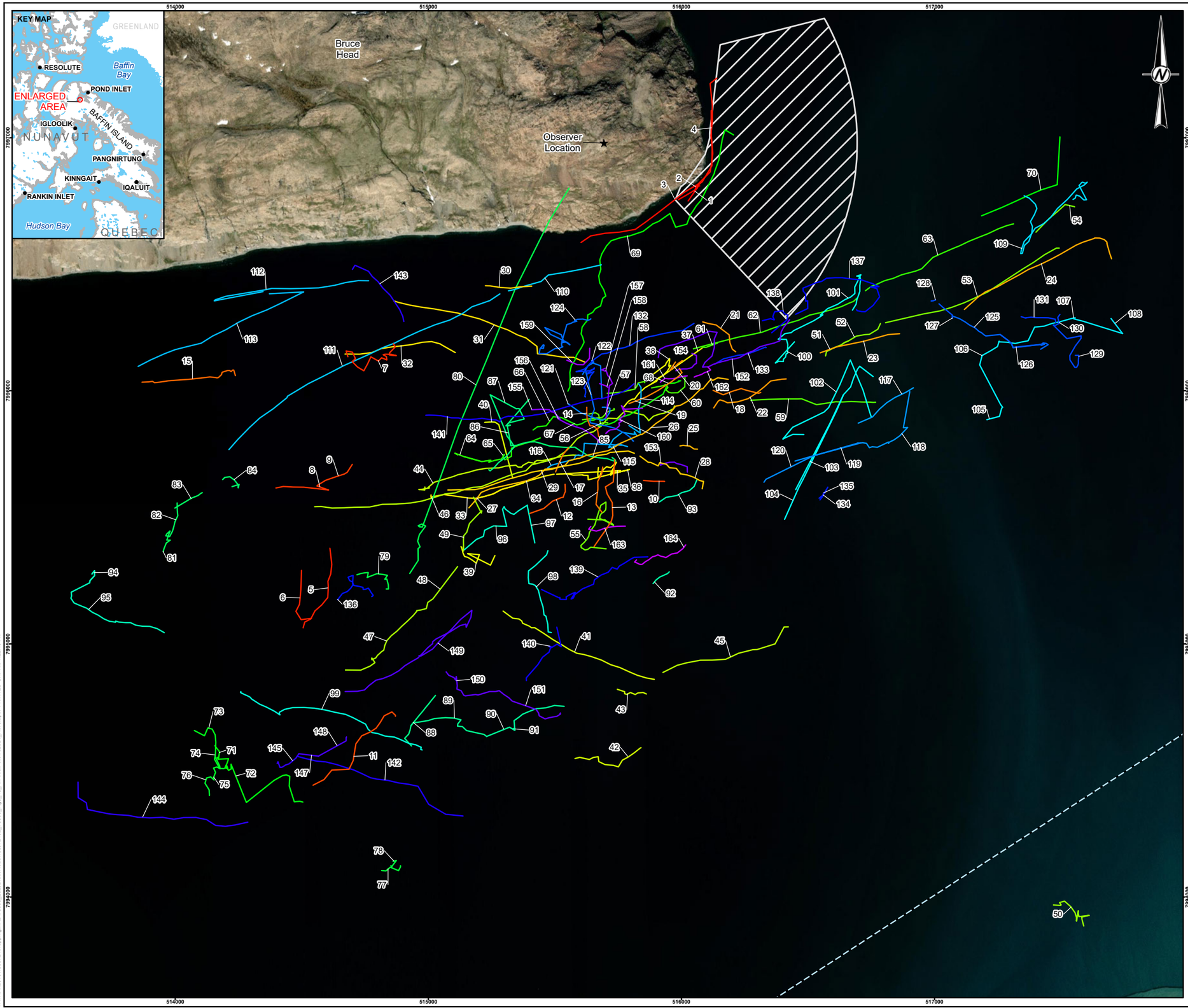

LEGEND

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

FOCAL FOLLOWS FLIGHTS

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164

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PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW SURVEYS CONDUCTED DURING THE 2021 FIELD SEASON AT BRUCE HEAD

CONSULTANT

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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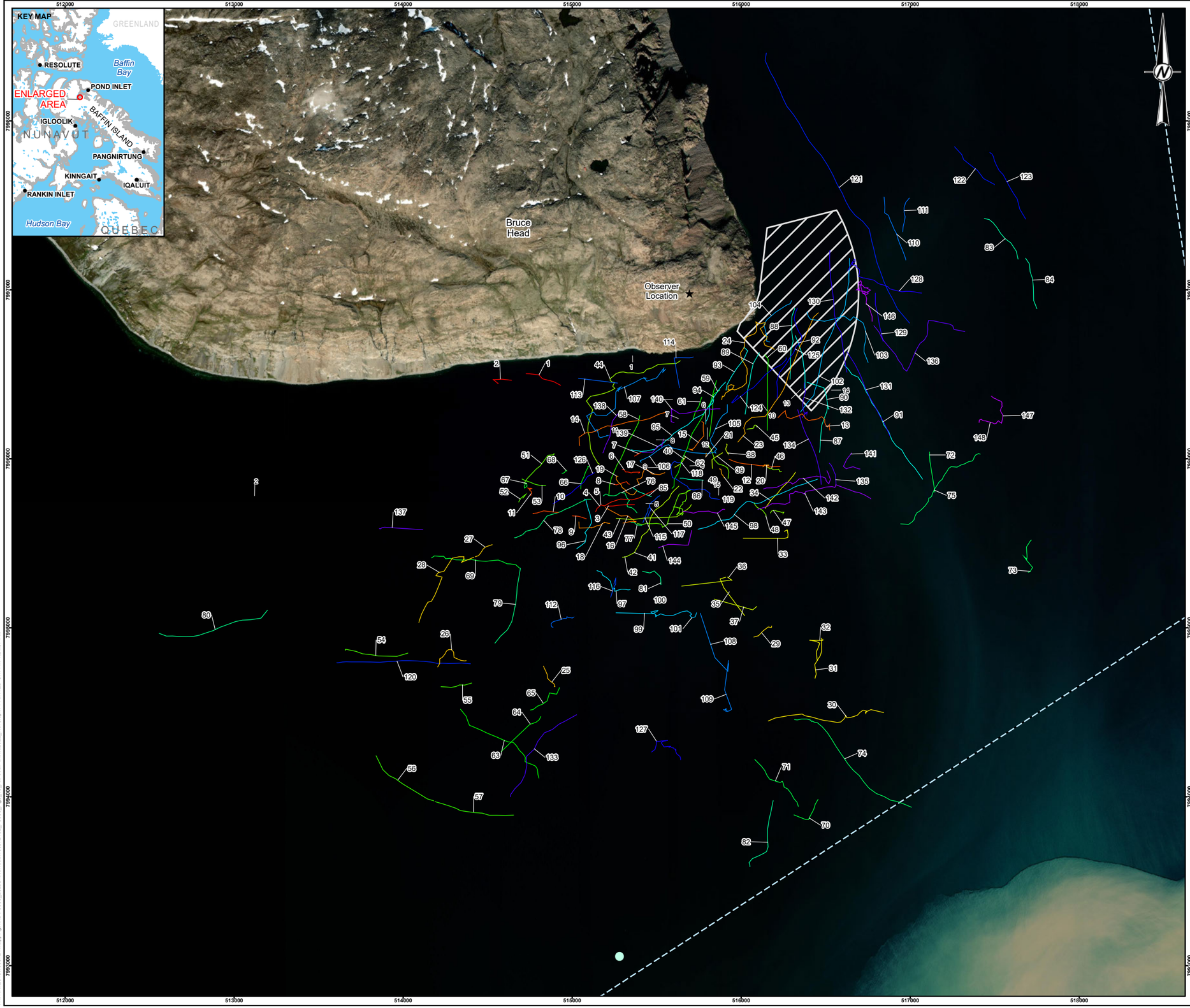

LEGEND

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

FOCAL FOLLOWS FLIGHTS

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148

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PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW SURVEYS CONDUCTED DURING THE 2022 FIELD SEASON AT BRUCE HEAD

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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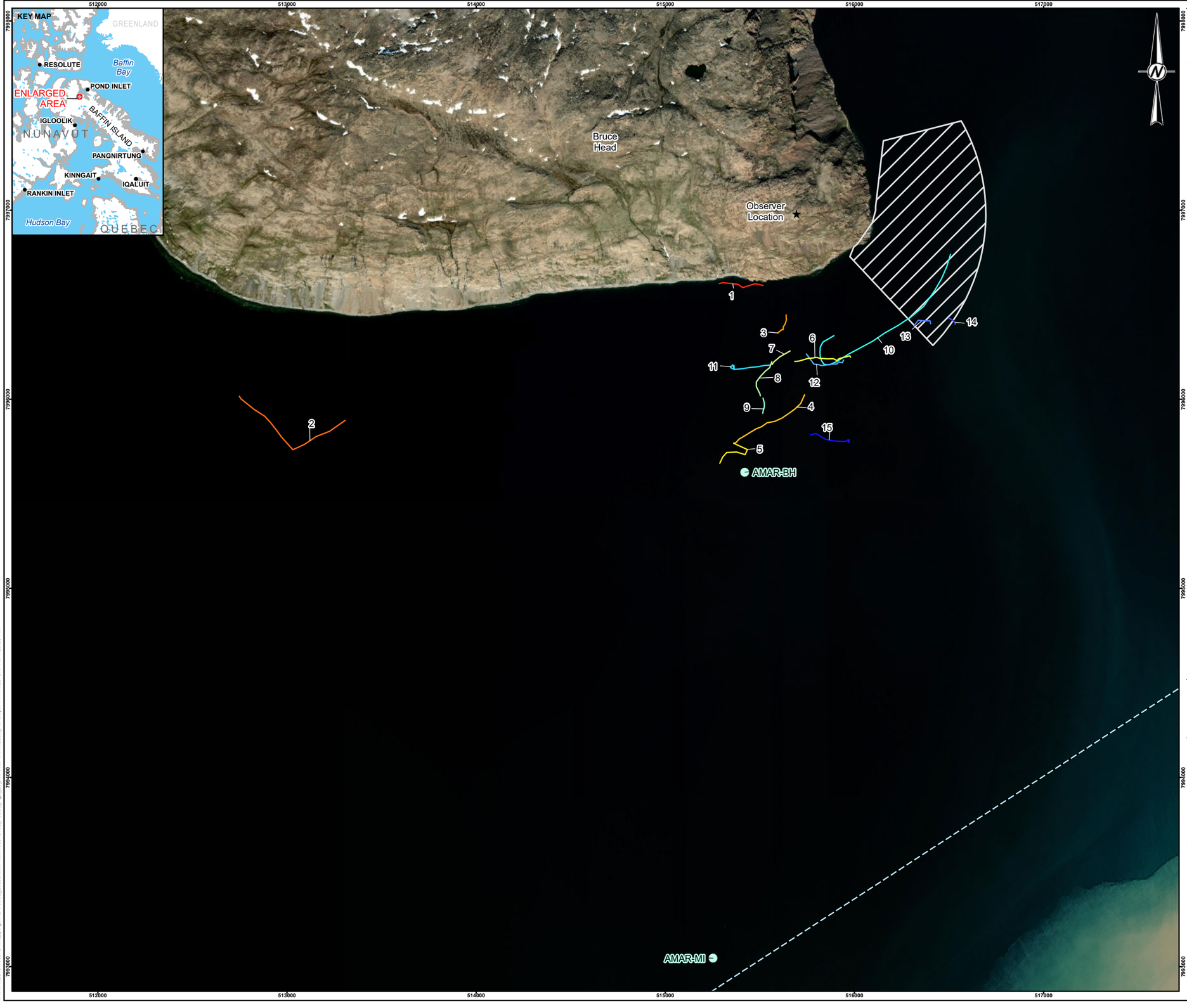

LEGEND

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

FOCAL FOLLOWS FLIGHTS

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15

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PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW SURVEYS CONDUCTED DURING THE 2023 FIELD SEASON AT BRUCE HEAD

CONSULTANT

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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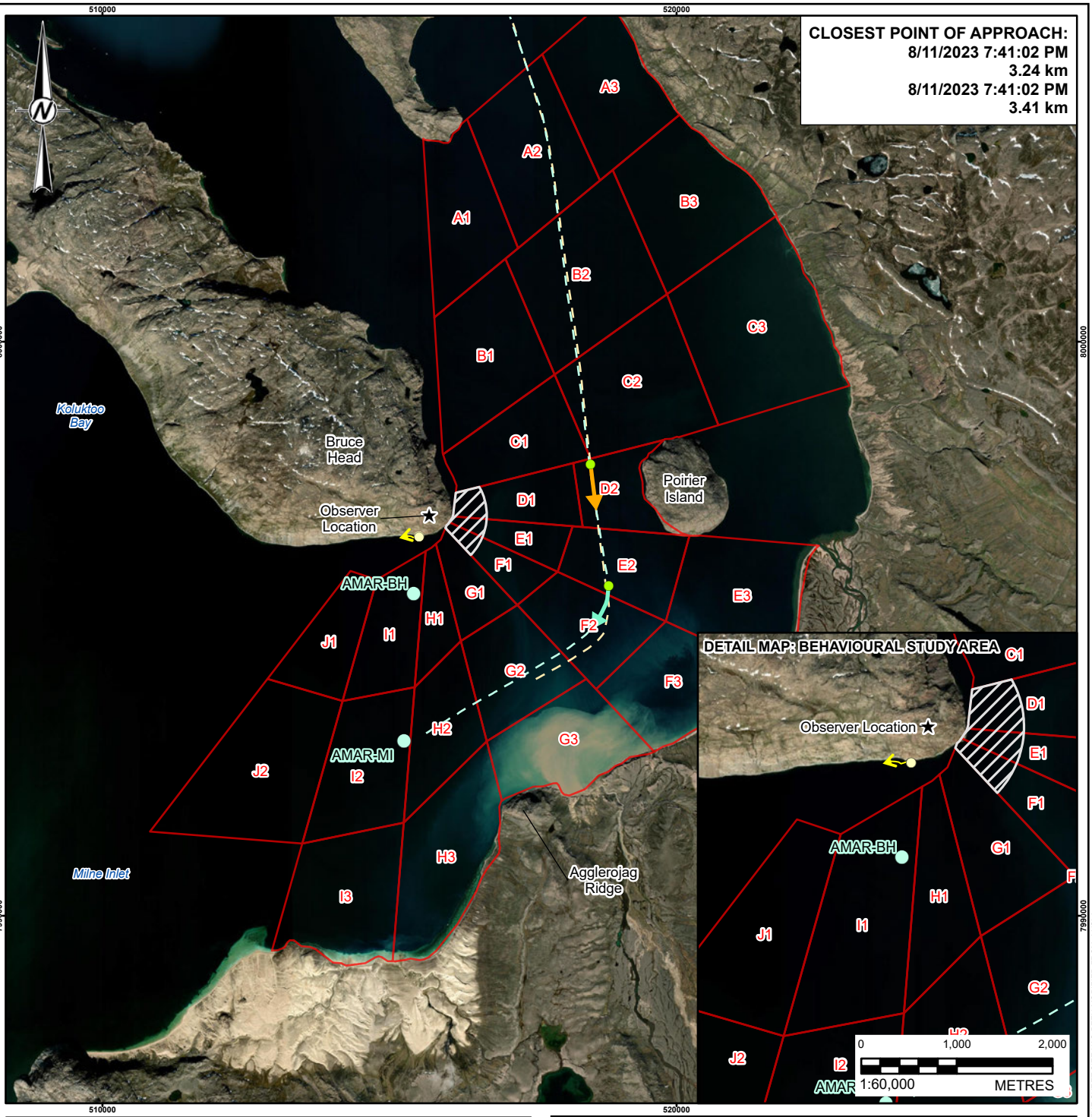

LEGEND

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- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- CLOSEST POINT OF APPROACH (VESSEL)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 1 (2023)
- ACTIVE VESSEL TRANSIT (GOLDEN OPAL)
- ACTIVE VESSEL TRANSIT (NORDIC ODYSSEY)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN OPAL)
- NON-ACTIVE VESSEL TRANSIC (NORDIC ODYSSEY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

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PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 1 (2023) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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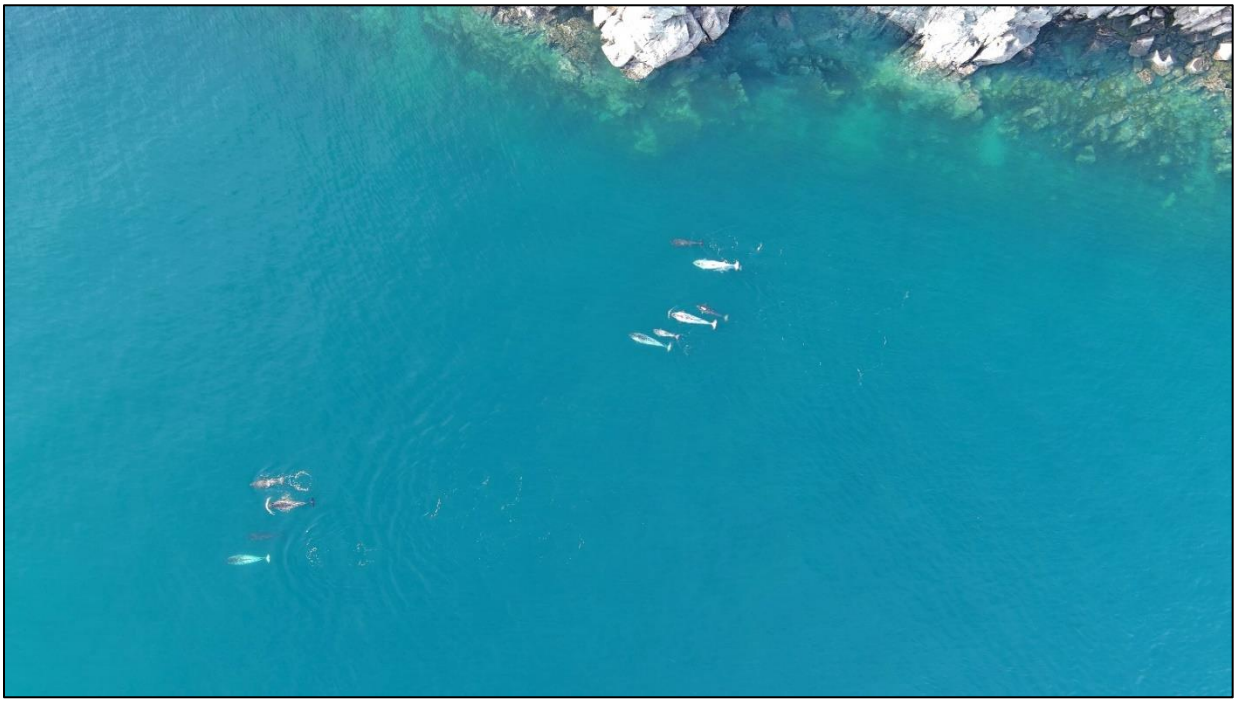

Figure 5-22: Still image from FF#01 showing two narwhal groups (11 individuals) located 3 km from southbound vessel Golden Opal and 3.4 km from southbound vessel Nordic Odyssey on 11 Aug 2023.

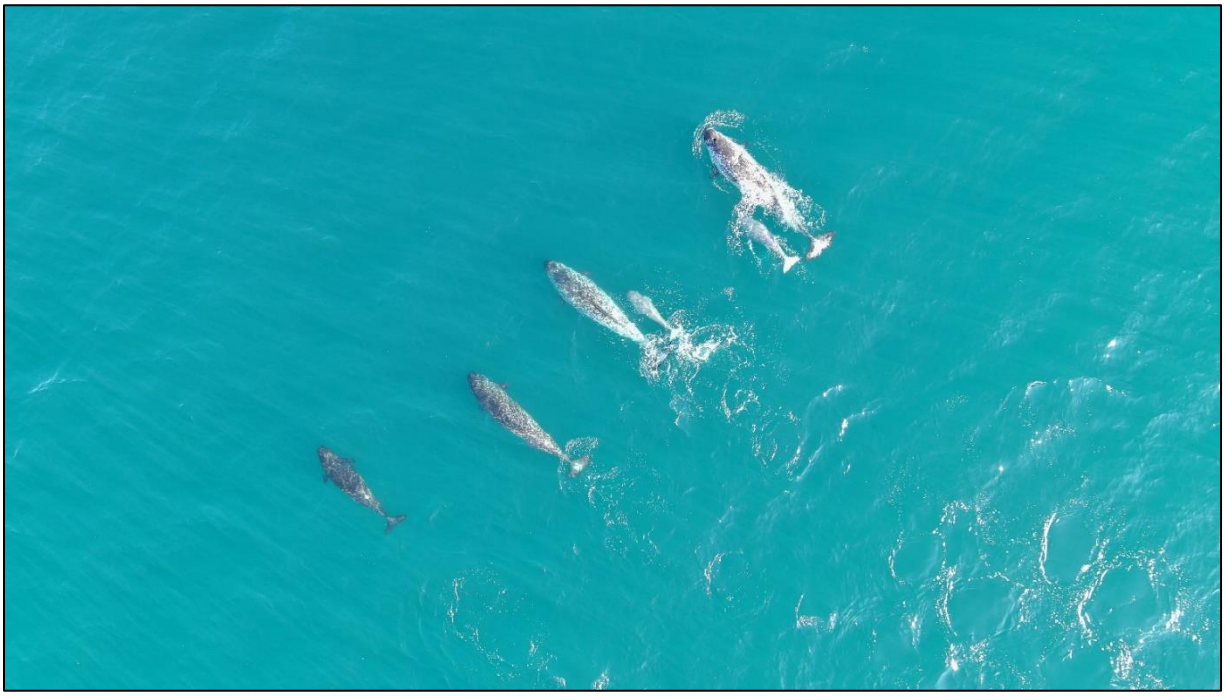

Figure 5-23: Still image from FF#03 showing a group of mother-immature pairs travelling northwest in loose parallel formation on 14 Aug 2023.

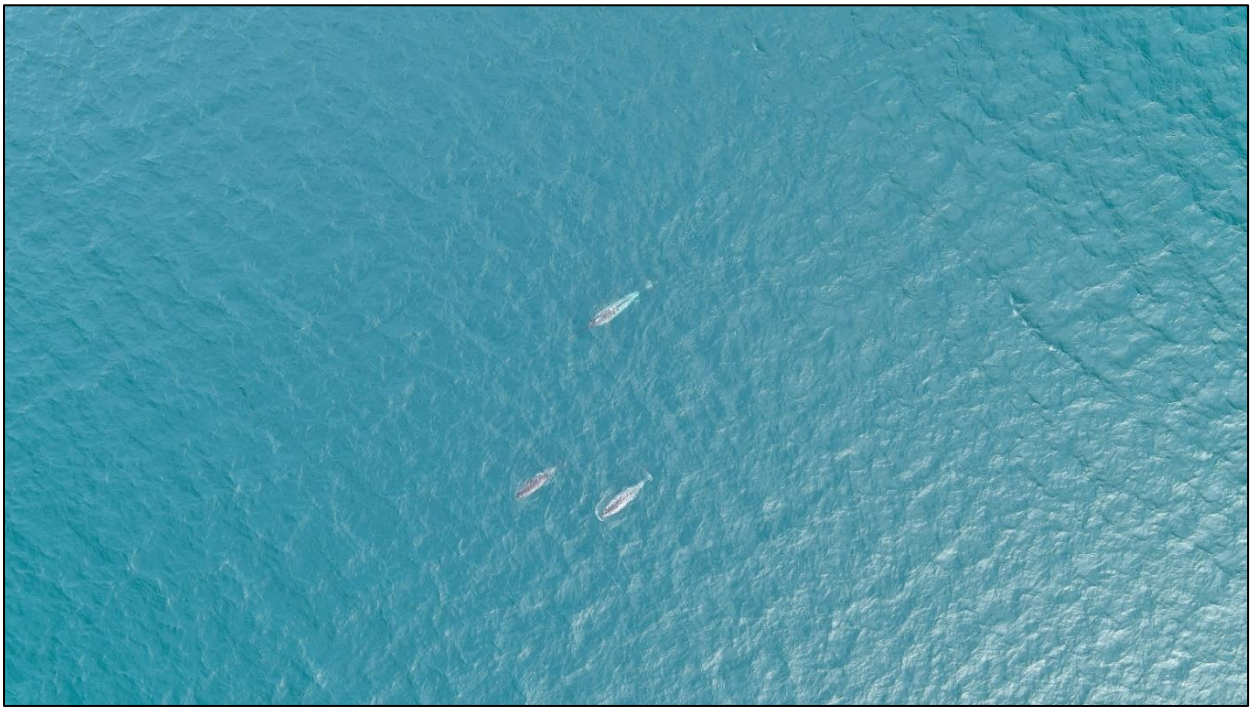

Figure 5-24: Still image from FF#04 showing three adults (two tusked) travelling southwest in loose cluster formation on 19 Aug 2023.

Figure 5-25: Still image from FF#20 showing two narwhals engaged in rubbing behaviour on 20 Aug 2023.

The ability to conduct UAV-based focal follow surveys was highly dependent on weather conditions and external factors such as helicopter traffic in the area and local hunting activity. On days when surveys were flown, the number of surveys completed per day ranged from one (8, 9, 11, and 14 August 2020, 4 and 17 August 2022, and 11, 12, and 14 August 2023) to 22 surveys (20 August 2021; Figure 5-26). The total daily amount of time spent following groups (excluding UAV transit and search time) ranged from 50 sec on 14 August 2020 to 186 min (3.1 h) on 20 August 2021 (Figure 5-27). The daily number of focal follow surveys conducted in the presence of vessels ranged from one (9 August 2020, 17 August 2022, and 11 August 2023) to nine (7 and 19 August 2021). The daily amount of time spent following groups when a vessel was present ranged from 1.5 min (11 August 2023) to 54.0 min (20 August 2021).

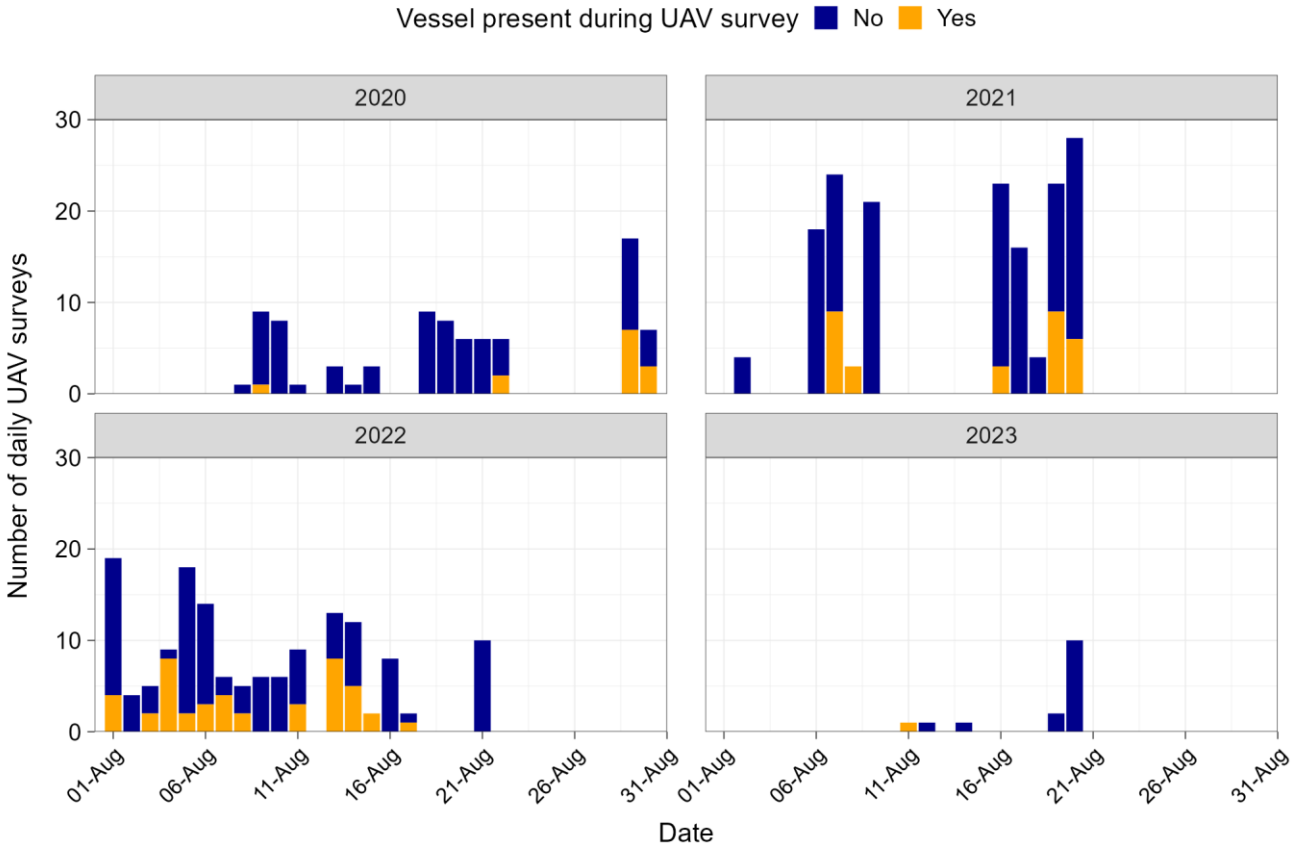

Figure 5-26: Time series of total number of daily UAV surveys conducted in 2020–2023.

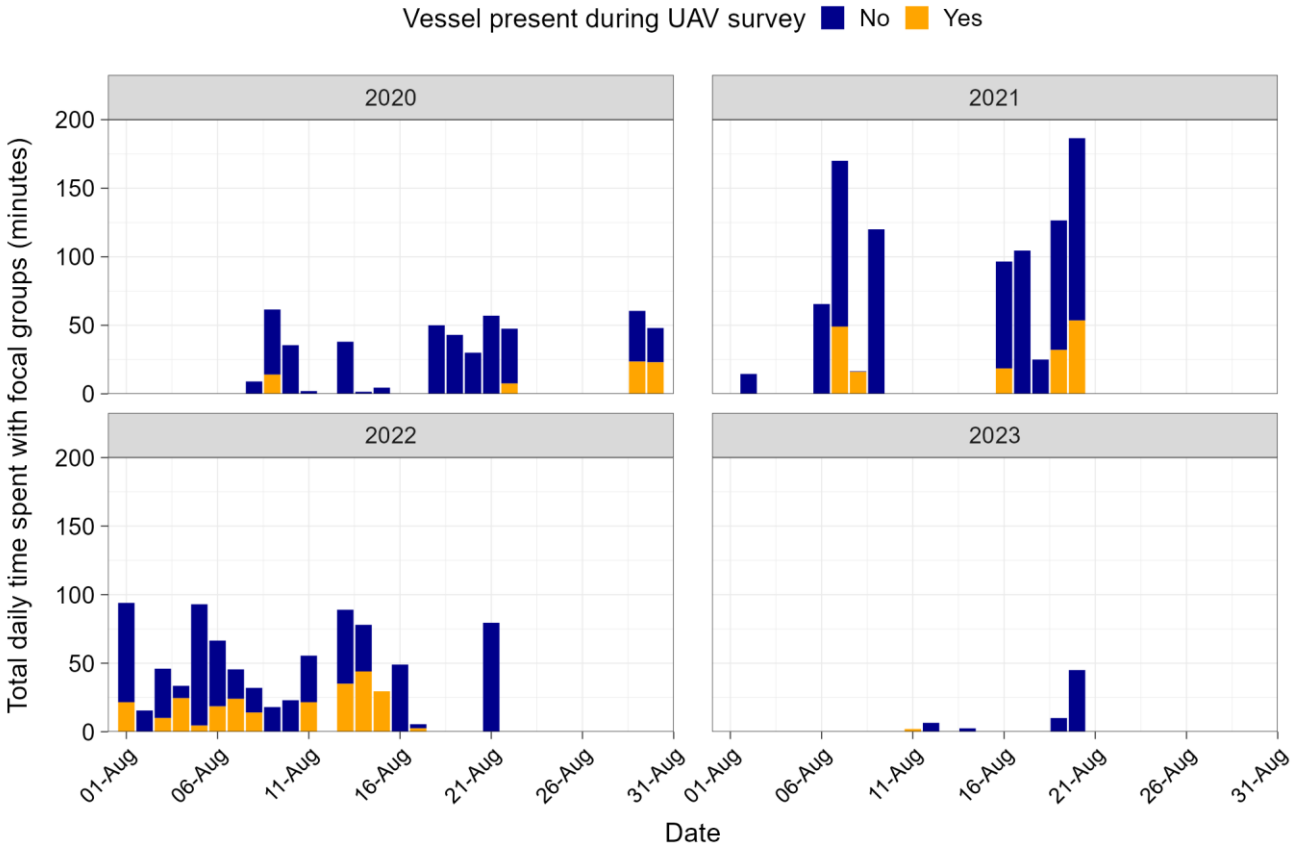

Figure 5-27: Time series of total daily time spent with focal groups in 2020–2023.

5.6.1 General Characteristics of Focal Groups

Of the focal groups surveyed via UAV throughout 2020–2023, adult narwhal were observed most frequently (58–72% of all narwhal, in 2023 and 2021, respectively), followed by juveniles (17–24%), calves (5–12%) and yearlings (5–9%; Figure 5-28). In 2021 and 2022, a greater emphasis was placed on following groups with immatures to inform behavioural responses of animals in vulnerable life stages to vessel traffic. When vessels were present (i.e., within 5 km of focal group), focal groups recorded throughout 2020–2023 were composed of 45% adults, 23% juveniles, 13% yearlings, and 3% calves (16% were categorized as “unknown”). When no vessels were present, focal groups were composed of 49% adults, 26% juveniles, 10% yearlings, and 10% calves (5% were categorized as “unknown”). A total of 1,217 of the focal groups surveyed were composed of one or more females with dependent young (36 in both 2020 and 2021, 49 in 2022, and six in 2023), of which 33 coincided with vessel passages (six in 2020, seven in 2021, 19 in 2022, and one in 2023).

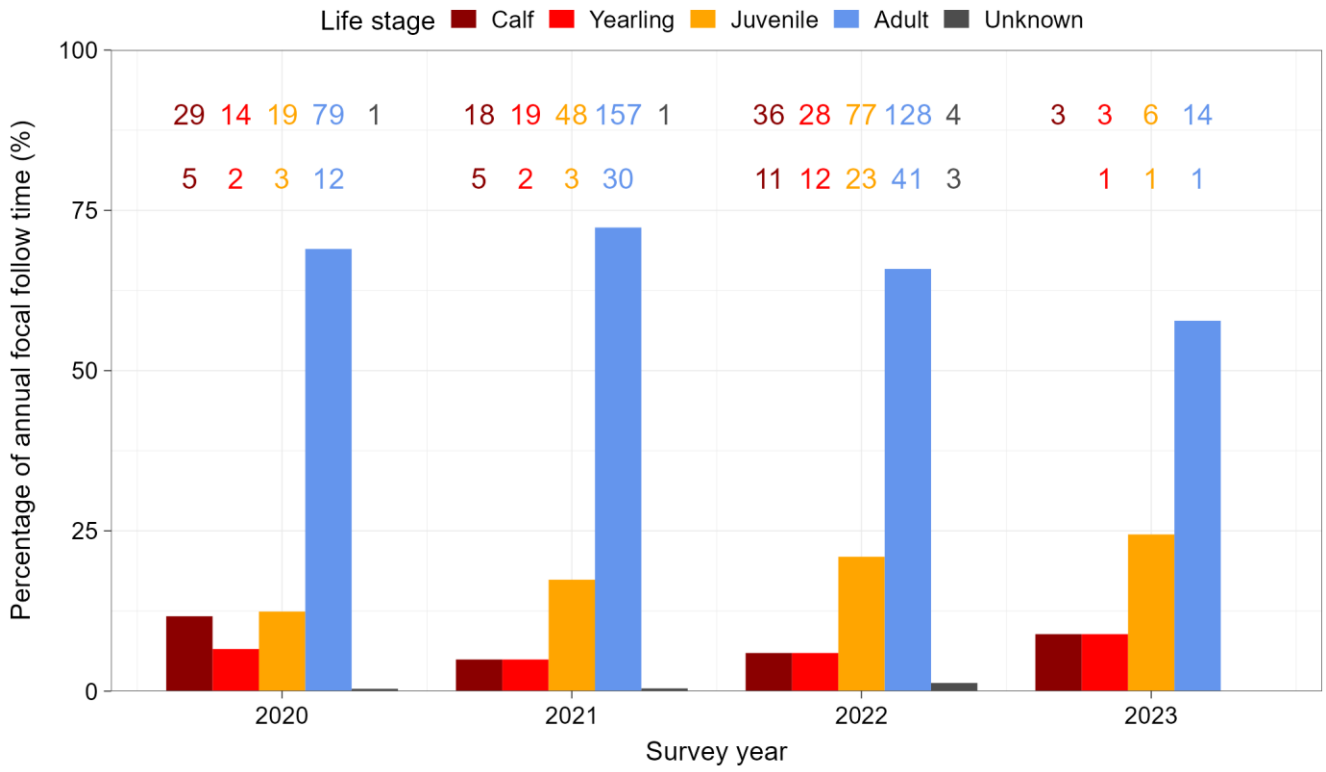

Figure 5-28: Group composition recorded during focal follow surveys, 2020–2023; the total number of focal follows and the number of focal follows during vessel exposure are shown for each life stage (top row and bottom row, respectively).

When no vessels were present within 5 km of the observed groups (i.e., vessel non-exposure periods), the majority of data collected was on adult groups (Figure 5-29), including a total of 189 unique focal follow surveys representing 730 min (12.2 h) of recorded behaviour. Mother-immature pairs were observed in 69 individual focal follow surveys for a total of 254 min (4.2 h), while mixed groups with immatures were observed in 52 focal follow surveys for a total of 233 min (3.9 h) of recorded data. Mixed groups without immatures were observed in 107 focal follow surveys for a total of 401 min (6.7 h) of recorded data. Finally, immature individuals were observed on their own (i.e., either as a single calf/yearling or as multiple calves/yearlings) during 37 individual focal follow surveys, for a total of 228 min (3.8 h) of recorded data.

When vessels were present within 5 km of focal groups (i.e., vessel exposure periods), the majority of the data were collected when vessels were at a distance of 2–3 km, including a total of 42 unique focal follow surveys representing 182 min (3 h) of recorded behaviour, coinciding with 21 different vessel transits (Figure 5-29). In close proximity to vessels (0–1 km from the groups), six unique focal follow surveys were collected representing 14 min of recorded behaviour, coinciding with five vessel transits. The discrepancy in the total number of focal follow surveys reported in the text relative to that presented in Figure 5-29 is due to several of the focal follow surveys changing group type within a given survey (where group type changed as narwhal of different life stages joined or left the followed group). Similar to data collected during vessel non-exposure periods, adult groups accounted for the majority of collected data across all distances from vessels. Some groups had very limited data in the presence of vessels, which makes conclusions less robust for these groups. While focal follow surveys of

adult groups provided 228 min of recorded behaviour in the presence of vessels, focal follow surveys of mother-immature pairs provided 44 min, mixed groups with immatures provided 122 min, mixed groups without immatures provided 79 min, and lone immatures provided 16 min.

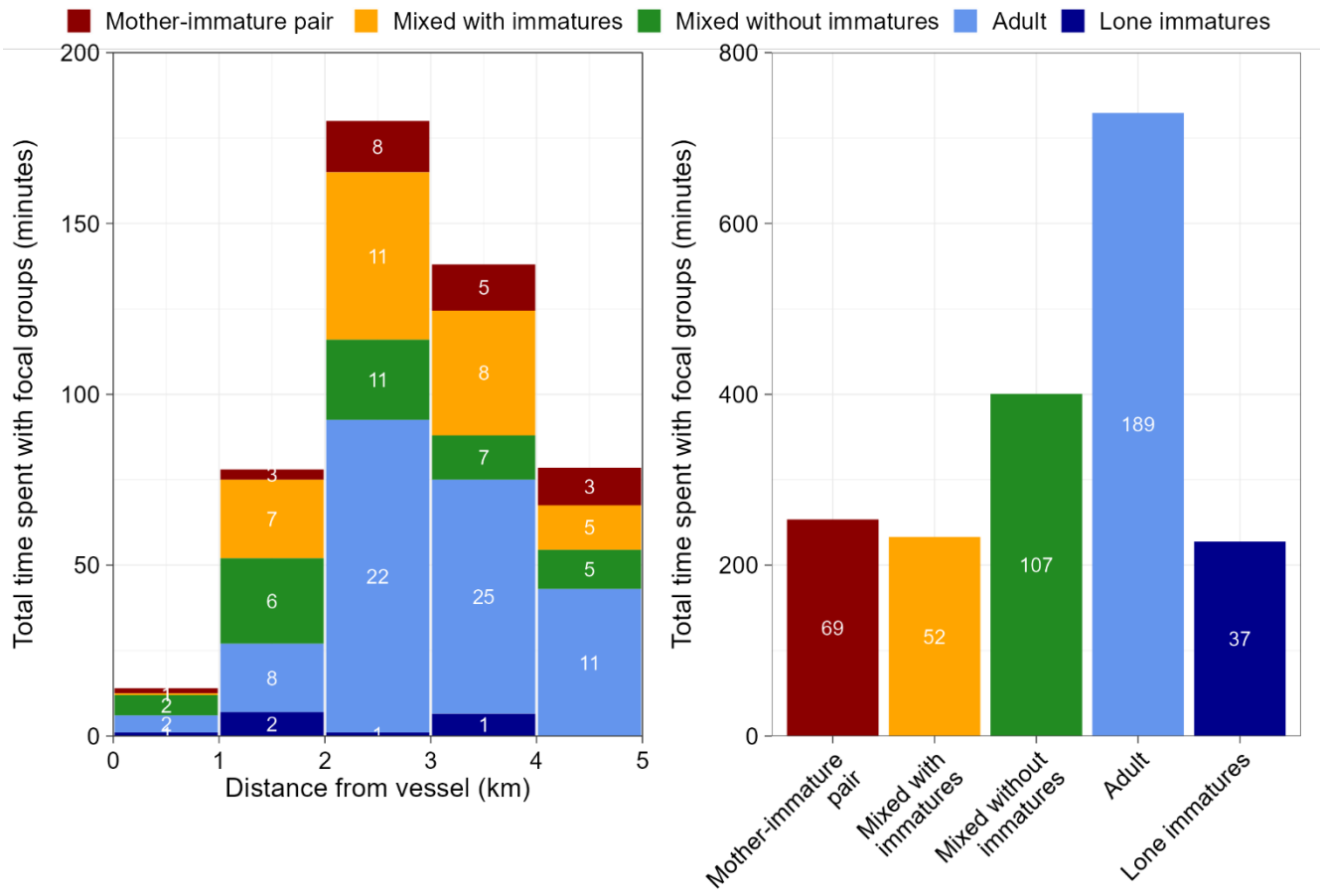

Figure 5-29: Total time spent with focal groups in 2020-2023 UAV surveys, presented relative to distance from vessel (vessels ≤5 km; left panel) and by group type when no vessels were present (vessels >5 km; right panel). White text provides number of unique focal follows within each group type. Distances are rounded up to nearest km.

5.6.2 Primary Behaviour

Primary behaviours assessed included travelling (i.e., directional movement), milling (i.e., non-directional movement at the surface), resting (i.e., not moving/logging or moving slightly) and social behaviour (i.e., clear interaction between individuals with physical contact). Of the followed groups with an identified primary behaviour, narwhal spent the majority of time travelling (62–83% of the time), followed by resting or milling (16–31% of the time), and engaging in social behaviours (2–12% of the time; Figure 5-30). The proportion of time that narwhal spent travelling was slightly higher when vessels were present (76%) compared to when no vessels were present (67%). The proportion of time that narwhal spent resting or milling was slightly lower when a vessel was present

(16%) compared to when no vessels were present (25%), while the proportion of time that narwhal spent performing social behaviours was similar between vessel presence (11%) and absence (13%) scenarios (assessed for groups of ≥2 individuals).

Groups with immatures (i.e., those considered more vulnerable to disrupted opportunities for rest) included mother-immature groups, mixed groups with immatures, and lone immatures. For mother-immature groups, the proportion of time spent resting or milling was higher in the absence of vessels (36%) compared to in the presence of vessels (0–23%, depending on distance from vessel; Figure 5-31). For lone immatures, the proportion of time spent resting or milling was also higher in the absence of vessels (43%) compared to in the presence of vessels (0–14%, depending on distance from vessel). For mixed groups with immatures, the proportion of time spent resting or milling in the absence of vessels (23%) was within the range observed in the presence of vessels (0–32%, depending on distance from the vessel).

For groups that did not include life stages considered vulnerable to disrupted opportunities for rest, the proportion of time spent resting or milling was 19% and 20% in the absence of vessels for mixed groups without immatures and adult groups, respectively. In the presence of vessels, the proportion of time mixed groups without immatures spent resting or milling ranged from 4–42% depending on distance from vessel, and the proportion of time that strictly adult groups spent resting or milling ranged from 10–26% depending on distance from vessel.

These results are based on a small sample size (Figure 5-29) with high data variability, and do not account for other variables, unlike the statistical analysis below; therefore strong conclusions cannot be drawn from these data summaries.

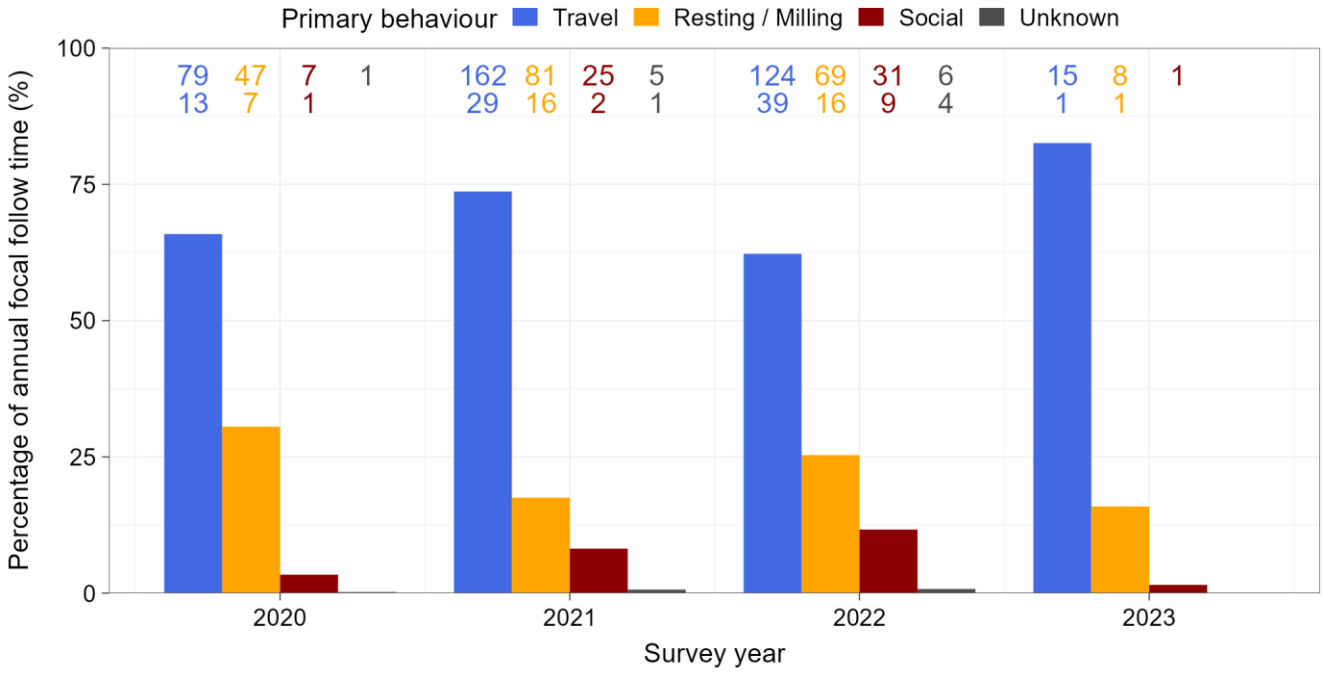

Figure 5-30: Primary behaviour recorded during focal follow surveys, 2020–2023. Sample size is shown as the number of unique focal follows in the absence of vessels (top row) and when vessels were present within 5 km from groups (second row).

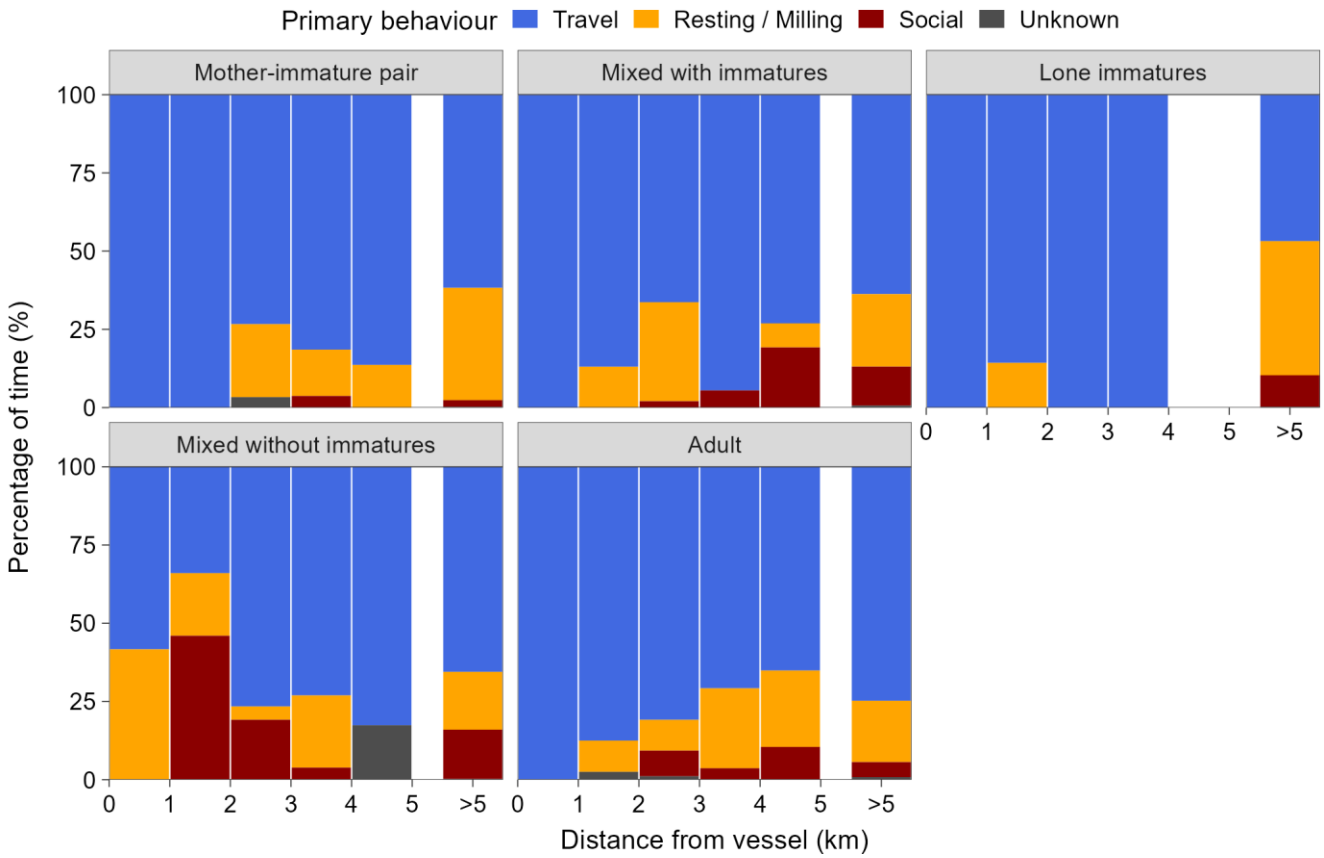

Figure 5-31: Percent time narwhal groups performed primary behaviours relative to distance from vessel, presented by group type, 2020–2023.

In the statistical analysis of primary behaviour, which used a logistic regression, narwhal behaviours were binned into two categories: “travel" and “resting, milling, or social activity”, with the latter category assumed to represent important life activities for narwhal. Thus, an increase in resting, milling, or social behaviours meant a reduction in travel, while a decrease in resting, milling, or social activity behaviours meant an increase in travel behaviour. The interaction between group type and distance from vessel was significant (P=0.01), reflecting the difference in the effect of vessels on behaviour between the group types (Figure 5-32). Specifically, predicted probabilities of engagement in resting, milling, or social activities in close proximity to vessels decreased for adult groups but increased for mixed groups without immatures. Neither group type with immatures (i.e., mother-immature pairs and mixed groups with immatures) was predicted to change its proportional engagement in primary behaviours relative to distance from vessels. Of the multiple comparisons between vessel absence and vessel presence at various distances, none of the multiple comparisons for any of the groups were significant (P>0.1 for all; Table 5-7), due to the high uncertainty associated with the model predictions (Figure 5-32). Note that sample sizes in proximity to vessels were small. For example, adult groups at <0.5 km from a vessel were only recorded in a single focal follow (FFID 117 in 2021), during which a lone adult was observed over a 3-min period, travelling adjacent to a passing vessel, but did not appear to increase speed or move away from the vessel.

Effect sizes were calculated based on the odds ratio for when a vessel was present at a particular distance relative to when no vessel was present. Estimated effect sizes for mother-immature pairs and for mixed groups with immatures ranged from -3% at 0.5 km (i.e., an odds ratio of 0.97 [see Section 4.3.2.1]) to -42% at 5 km

(Table 5-7). For these two group types that included immatures, these results suggest decreasing odds of resting, milling, or social activity with increasing distance from the vessel. However, for both groups types that included immatures, there was little difference between the probability of resting, milling, or social activity when a vessel was not present and when one was at close proximity (0.5 km; Figure 5-32). The effect size for this comparison was <10% in absolute value, which is less than the cutoff defining a small effect size. This suggests little effect of vessel presence on the probability of resting, milling, or socializing for mother-immature pairs and mixed groups with immatures.

For mixed groups without immatures, the estimated effect size decreased from +1,154% at 0.5 km to +119% at 2.0 km, and to -31% at 3.0 km, suggesting that a large biologically significant effect may exist (i.e., >50% change, as detailed in Section 4.3.2.1). This suggests greater probability of resting, milling, or social activity with increasing proximity to a vessel. For adult groups, effect sizes increased from -88% at 0.5 km to -23% at 3.0 km, and to +59% at 4.0 km. The absolute effect sizes of mother-immature pairs and mixed groups with immatures were less that 25% at close proximity to vessels (0.5 km). The absolute effect sizes of mixed groups without immatures and adult groups decreased below 25% when vessels were farther than 2.5 km and 3.0 km from groups, respectively.

The effect sizes reported above are based on odds ratios, which describe the odds of one behaviour type (resting, milling, or social activity) relative to another (travel). Due to the nonlinear nature of the logistic function used in the model, when probabilities are small in the absence of vessels, then relatively small differences in probabilities between vessel presence and absence correspond to large differences in the effect sizes on the odds ratio scale (see Section 4.3.2.1). For instance, the difference in probability of resting, milling, or social activity by adults between a vessel in close proximity (0.5 km) and vessel absence was -0.104, which corresponded to an effect size of -88%. For mixed groups without immatures, the difference in probability was 0.56 between a vessel at close proximity and vessel absence, which corresponded to an effect size of 1,154%. To understand the magnitude of effects of vessels, it is useful to consider both the probability-scale (Table 5-7) and the reported effect sizes, which are based on odds ratios.

The effect of group size was significant (P=0.02). The probability of engaging in milling, resting, or social activity (rather than traveling) was low for small group sizes, estimated to peak at group sizes of six to nine narwhal, and declined for larger groups (Figure 5-33). However, data on large groups came from a limited set of focal follow surveys, with only 20 surveys having group sizes of more than 10 narwhal, and only seven surveys having groups sizes of more than 15 narwhal. The effect of water clarity was not significant (P=0.9), while the effect of Beaufort scale value was significant (P<0.001), with the odds of observing a group engaging in milling, resting, or social activity being 11–14 times higher at Beaufort values of 0, 1, and 2 compared to Beaufort values of >2 (P=0.09, P<0.001, and P<0.001, respectively; Figure 5-33). Note that due to sample size limitations, Beaufort scale values were binned such that all values of 3 or larger were collapsed into a single bin, resulting in Beaufort values of 0, 1, 2, and ≥2 that were used in the analysis.

Overall, the modelling results do not suggest a difference in the probability of narwhal engaging in important activities for mother-immature groups and for mixed groups with immatures when a vessel was present, compared to when no vessels were present within 5 km from the focal group. On the other hand, for adult groups there was a decrease in the probability of engaging in important activities when vessels were within 3 km from the group, whereas for mixed groups with immatures there was a predicted decrease in the probability of engaging in such behaviours when vessels were within 2.5 km from the group. These findings indicate some support for the alternate hypothesis that vessel presence has an effect (i.e., potential decrease) on important narwhal activities when narwhal are in close proximity to vessels, but not for all group types.

The statistical power to estimate the maximum observed effect size (for mixed groups without immatures) was approximately 0.78 (see Appendix A). That is, the maximum observed effect size was still smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model only had sufficient power (≥0.8) to detect an effect size >1,500% (see Appendix A). This effect size corresponds to the increase in probability of a group resting, milling, or socializing from 0.117 to 0.679 for mother-immature pairs, from 0.147 to 0.734 for mixed groups with immatures, from 0.217 to 0.816 for mixed groups without immatures, and from 0.120 to 0.685 for adult groups.

In summary, findings based on the multi-year UAV dataset provide some support that narwhal groups engaged less frequently in important activities when in close proximity to vessels, but this effect was not consistent across all group types. Adult groups engaged less frequently in important activities when within 3 km of a vessel. Conversely, mixed groups without immatures engaged more frequently in important activities when within 2.5 km of a vessel. For mother-immature pairs and groups with immatures, no effect of vessel presence on important activities was observed at any distance. The conflicting trends amongst narwhal group types questions the validity of the observed effect. Additional focal follow monitoring is recommended to increase the overall sample size of the corresponding dataset to further examine the relationship between shipping and important narwhal activities.

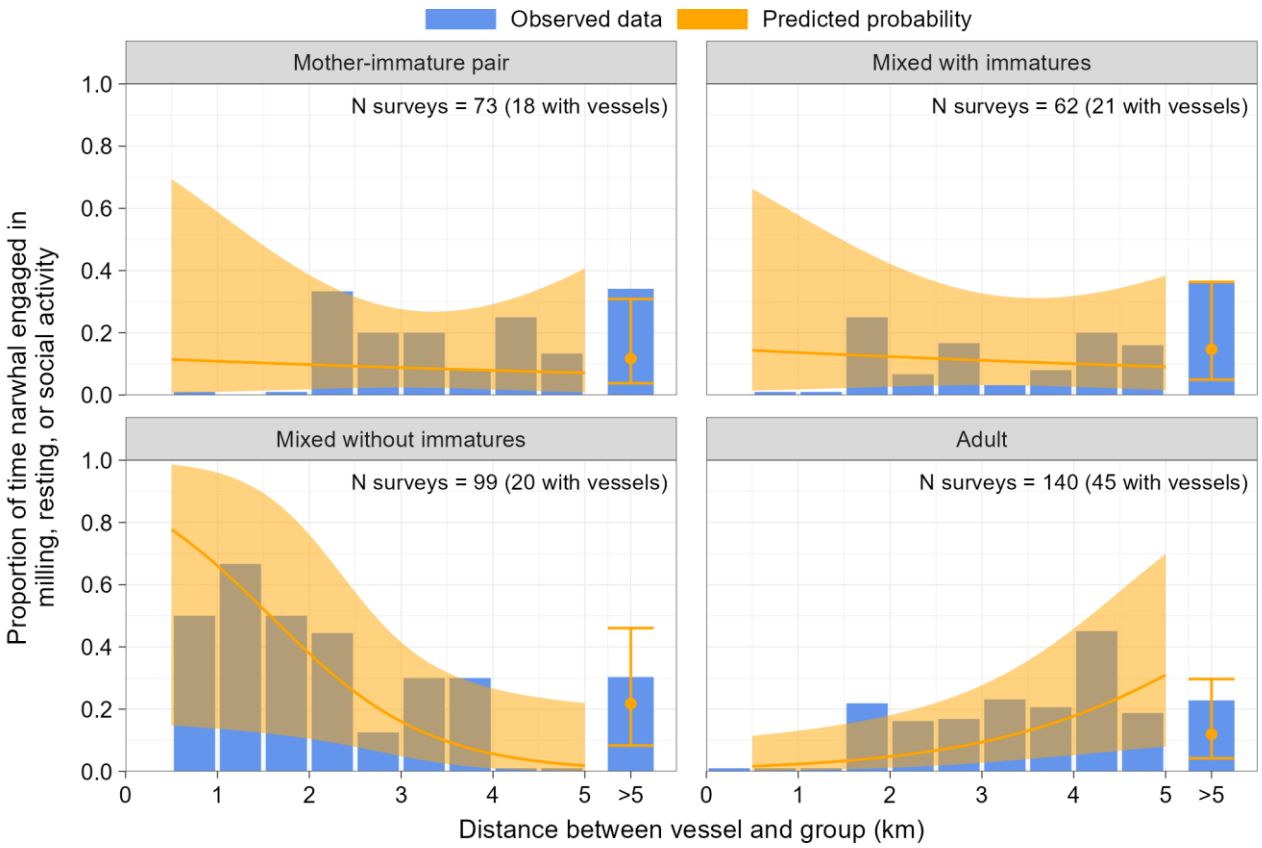

Figure 5-32: Observed proportion of time (bars) and estimated probability (line and points) that narwhal groups engaged in milling, resting, or social activity (rather than traveling) as a function of distance (rounded up to nearest 0.5 km value) from vessel, presented by group type, 2020–2023.

Notes: observed data depict the between-surveys average proportion of time groups were to engage in milling, resting, or social activity (rather than traveling) at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant.

Table 5-7: Effect sizes and multiple comparisons of predicted probability of observing groups engaging in milling, resting, or social activity (rather than traveling) between vessel exposure (0.5 to 5 km distances) and non-exposure periods (>5 km). Statistically significant values shown in bold.

Distance from vessel (km)	Multiple comparisons to no-exposure – Effect sizes (%) with *p* values in brackets			
	Mother-immature pair	Mixed with immatures	Mixed without immatures	Adult
0.5	-3% (1.0)	-3% (1.0)	+1,154% (0.3)	-88% (0.09)
1	-8% (1.0)	-8% (1.0)	+601% (0.4)	-82% (0.1)
2	-18% (1.0)	-18% (1.0)	+119% (0.7)	-63% (0.2)
3	-27% (0.8)	-27% (0.8)	-31% (0.8)	-23% (0.9)
4	-35% (0.9)	-35% (0.8)	-79% (0.1)	+59% (0.7)
5	-42% (0.9)	-42% (0.9)	-93% (0.1)	+231% (0.2)

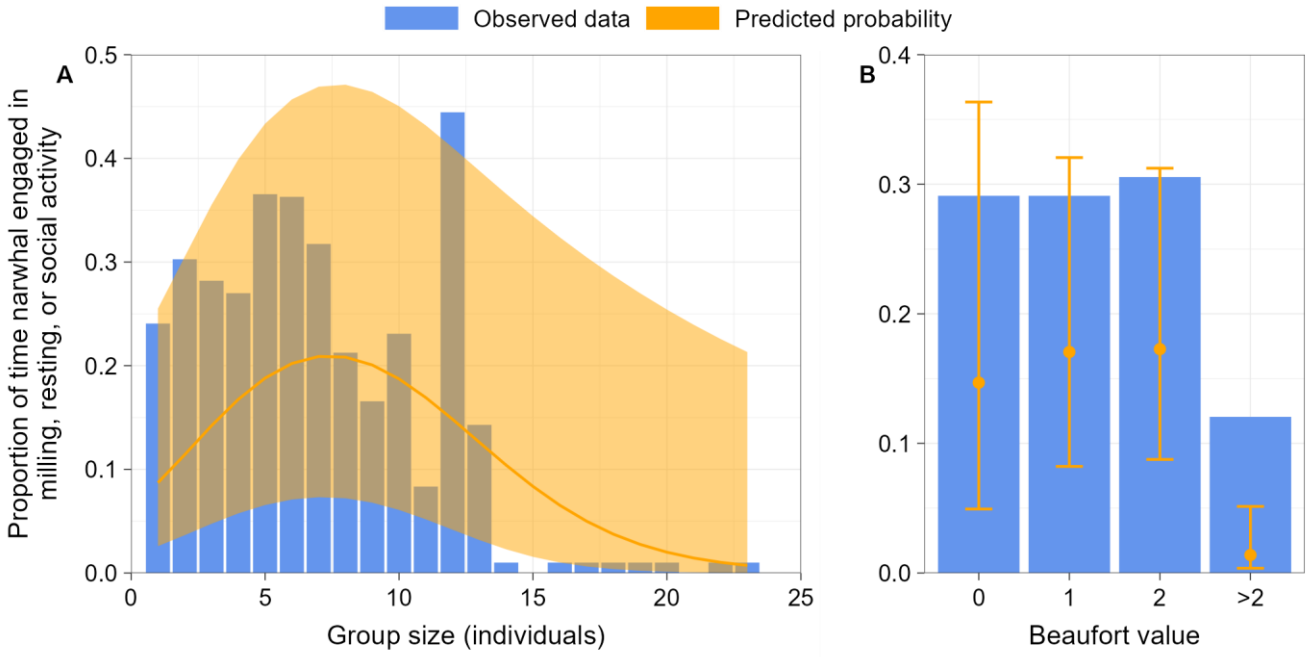

Figure 5-33: Observed proportion of time (bars) and estimated probability (line and points) that narwhal groups engaged in milling, resting, or social activity (rather than traveling) as function of narwhal group size (Panel A) and Beaufort scale value (Panel B), 2020–2023.

Notes: observed data depict the between-surveys average proportion of time groups were to engage in milling, resting, or social activity (rather than traveling) at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant.

5.6.3 Unique Behaviours

Unique behaviours that would not be expected under stressful conditions, such as nursing, social rubbing, sexual displays, and rolling (either vertically in the water column or horizontally) were recorded for a total of 553 min in 204 of the total 411 focal follow surveys conducted. Of the followed groups, narwhal spent the majority of time not engaging in unique behaviours, with values ranging from 68% (2022) to 95% of the time (2023; Figure 5-34). Unique behaviours were recorded for mother-immature pairs 29% of the time in the absence of vessels and 0 to 41% when a vessel was present, depending on distance from vessel (Figure 5-35). For mixed groups with immatures, unique behaviours were recorded 34% of the time in the absence of vessels and 0–62% of the time in the presence of vessels, depending on distance from vessel. For mixed groups without immatures, unique behaviours were recorded 32% of the time in the absence of vessels and 8–52% of the time in the presence of vessels, depending on distance from vessel. Strictly adult groups displayed unique behaviours 15% of the time in the absence of vessels and 10–28% of the time in the presence of vessels, and lone immatures displayed unique behaviours 19% of the time in the absence of vessels and 0–29% of the time when vessels were present, depending on distance from vessel.

Sexual displays and associated interactions were observed during three separate focal follow surveys conducted in 2022 and during six surveys conducted in 2021, and during a single survey in 2020. Of those observed in 2021, four displays were between adult male narwhal and two were between adult males and tusked juveniles. In 2022, all observed sexual displays occurred between an adult (tusked) and a juvenile, with the juveniles in FFID 62 and FFID 119 possessing no tusk, and the juvenile in FFID 124 possessing a tusk. FFID 124 represented the single occurrence of sexual behaviour in the presence of a vessel in 2022, which occurred in a group of two adult males, one adult female, and a tusked juvenile, at a distance of approximately 3 km from the vessel. In 2021, another occurrence of sexual behaviour was observed in the presence of a vessel, which was observed in a group of three adult males when the vessel was at a distance of approximately 4 km from the group. No sexual displays were observed during focal follows surveys in 2023.

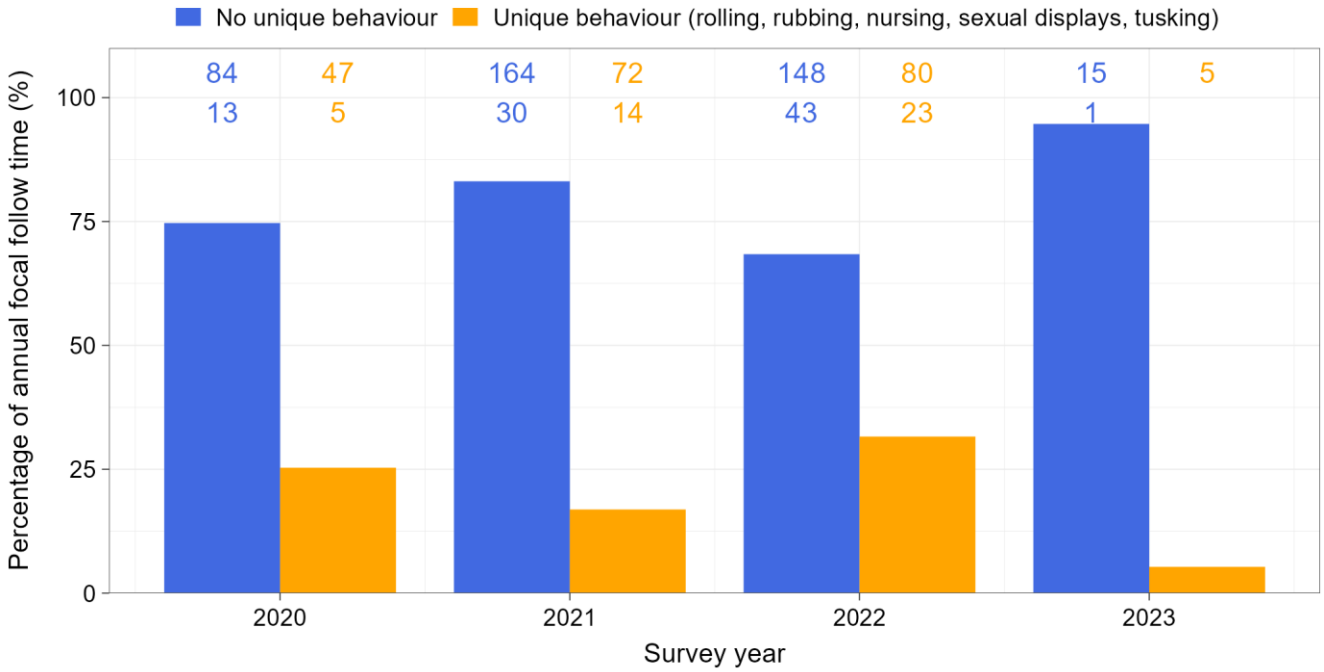

Figure 5-34: Unique behaviour recorded during focal follow surveys, 2020–2023. Sample size is shown as the number of unique focal follows in the absence of vessels (top row) and when vessels were present within 5 km from groups (second row).

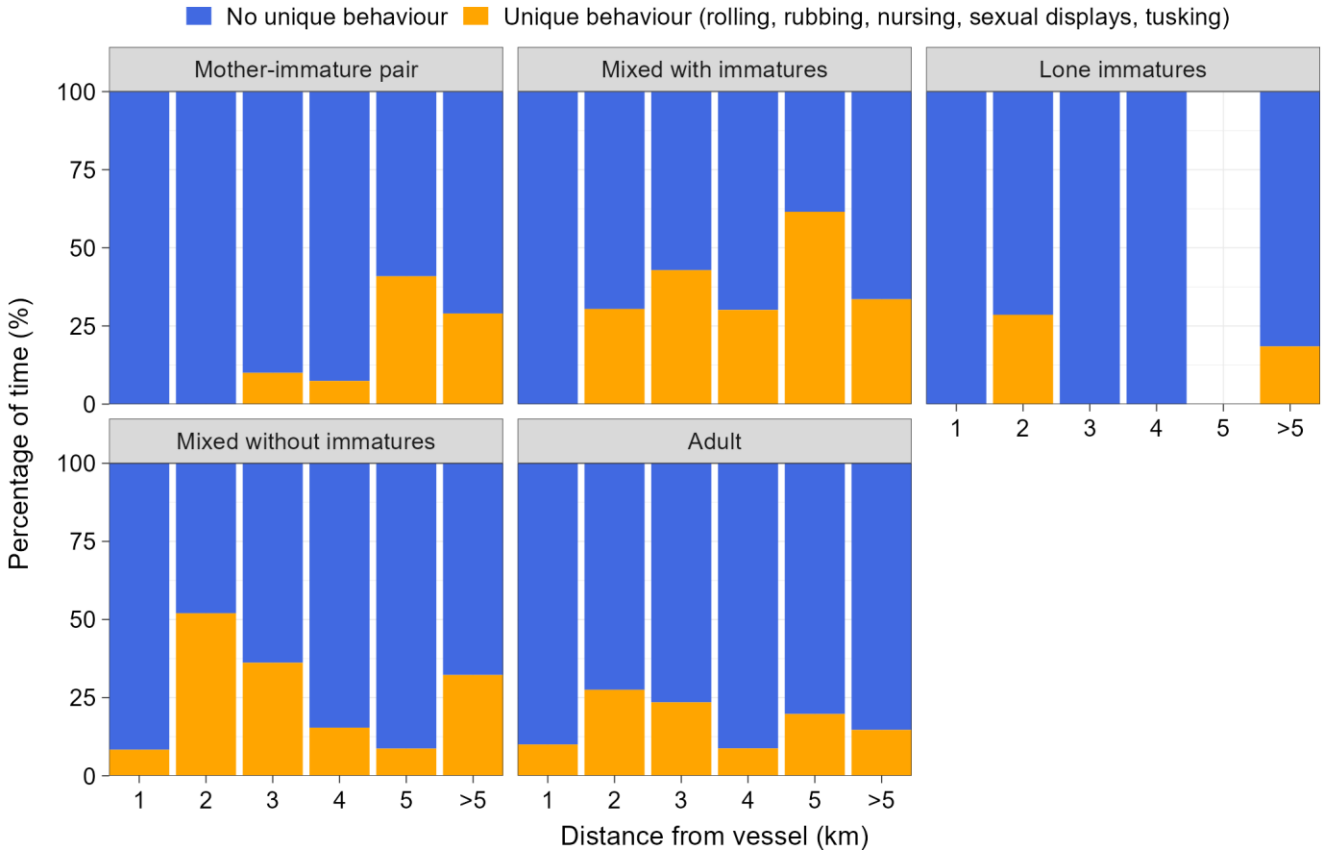

Figure 5-35: Percent time narwhal groups performed unique behaviours relative to distance from vessel, presented by group type.

In the statistical analysis of unique behaviour, which used a logistic regression, behaviours were binned in two categories – “unique behaviour” (including rolling, rubbing, nursing, sexual displays, and tusking) and “no unique behaviour”. The overall effect of vessel distance on the probability of focal groups displaying unique behaviours was significant (P=0.03). The predicted probability of individuals engaging in unique behaviours was low at closer distances (≤1 km), peaked at distances of 1.8–2.6 km from a vessel, and at distances greater than 2.6 km decreased to levels similar to when no vessels were present (Figure 5-36). The odds of engaging in a unique behaviour decreased by 59% at a distance of 0.5 km relative to when no vessels were present within 5 km from groups (Table 5-8). Of the multiple comparisons between vessel absence and vessel presence at various distance, only comparisons at 5 km were significant (Table 5-8), due to the higher estimated probability of engaging in unique behaviour at a distance of 5 km from a vessel, which was likely a spurious finding due to high variability and small sample size. For the comparisons at other distances, the uncertainty associated with modelling estimates resulted in lack of statistical significance (Figure 5-36). Sample size at close proximity to vessels was small (see Figure 5-29 and Figure 5-34), with only six surveys conducted at distance <1 km and a single survey at a distance <0.5 km.

Estimated effect sizes for a vessel at 0.5 km, 1.0 km, and 2.0 km distance from the group were -59%, -28% and +49%, respectively, for all group types (Table 5-8). The absolute values of effect sizes were below 25% at a distance of 2.7 km from vessels. These effect sizes suggest that a large biologically significant effect (i.e., ±50% change in odds of engaging in unique behaviour (see Section 4.3.2.1) may exist at immediate proximity to the vessel (0.5 km), and a moderate biologically significant effect (i.e., ±25%) may exist up to a distance of 2.7 km from vessels. This finding was in agreement with the hypothesis that narwhal may engage less often in unique behaviours in response to vessel traffic. The effects of group type, group size, and primary behaviour were also significant (P=0.001, P<0.001, and P<0.001, respectively). Multiple comparisons between group types indicated that adult groups were significantly less likely to engage in unique behaviours than mother-immature pairs, mixed groups with immatures, or mixed groups without immatures (P=0.007, P=0.006, and P=0.03, respectively, effect sizes of -54%, -55%, and -43%, respectively). No differences were found between mixed groups with or without immatures or mother-immature pairs (P>0.7 for all). The probability of engaging in unique behaviours was low for small group sizes, estimated to peak at group sizes of 9 to 12 narwhal, and declined for larger groups (Figure 5-37). However, data on large groups came from a limited set of focal follow surveys, with only 20 surveys having group sizes of more than 10 narwhal, and only seven surveys having groups sizes of more than 15 narwhal. Groups were significantly more likely to engage in unique behaviour during social interactions, when compared to when traveling or resting, or milling (P<0.001 for both, effect sizes of +1,413% and +523%, respectively). Groups were also significantly more likely to engage in unique behaviour while resting or milling, when compared to traveling (P<0.001, effect size of +143%). The effects of Beaufort scale value and water clarity were not significant predictors of unique behaviour (P=0.2 and P=0.09), respectively.

The statistical power to estimate the observed effect size (-59%) of the effect of vessel distance on unique behaviour was low (<0.4; see Appendix A). That is, the observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model only had sufficient power (≥0.8) to detect an effect size >750% (see Appendix A). This effect size corresponded to the increase in probability of a group engaging in unique behaviour from 0.159 to 0.616 for mother-immature pairs, from 0.162 to 0.622 for mixed groups with immatures, from 0.132 to 0.563 for mixed groups without immatures, and from 0.080 to 0.424 for adult groups.

In summary, unique behaviours were displayed less frequently by all narwhal group types in close proximity (<2.7 km) to transiting vessels. However, the multiple comparisons of groups at close proximity to the vessel compared to vessel absence scenarios were not statistically significant despite large effect sizes at 0.5 km and 1.0 km from vessels. The lack of statistical significance may have been associated

with the low sample size and high data variability at close range (<2 km) to vessels. The results suggest that unique behaviours such as rubbing, rolling, nursing, and sexual displays may be temporarily disrupted in close proximity (<2.7 km) to vessel traffic, though this finding is based on a very small sample size at close range to vessels. Additional focal follow monitoring is therefore recommended to increase the overall sample size and the robustness of the corresponding analysis.

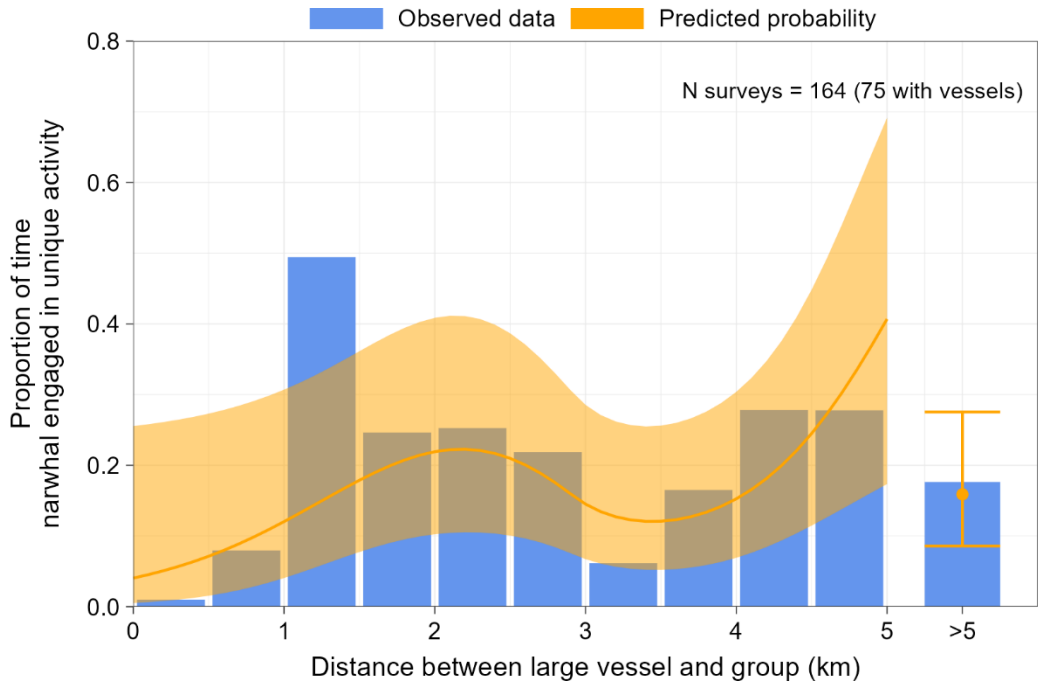

Figure 5-36: Observed proportion of time (bars) and estimated probability (line and points) that narwhal groups engaged in unique behaviours as a function of distance (rounded up to nearest 0.5 km value) from vessel, 2020-2023.

Notes: observed data depict the between-surveys average proportion of time groups were to engage unique behaviour at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant.

Table 5-8: Effect sizes and multiple comparisons of predicted probability of observing groups engaging in unique behaviours between vessel exposure (0.5 to 5 km distances) and non-exposure periods (>5 km). Statistically significant values shown in bold.

Distance from vessel (km)	Multiple comparisons to no-exposure – effect sizes (%) with *p* values in brackets
	All group Types
0.5	-59% (0. 7)
1.0	-28% (0.9)
2.0	+49% (0.6)
3.0	-10% (1.0)
4.0	-5% (1.0)
5.0	**+263% (0.048)**

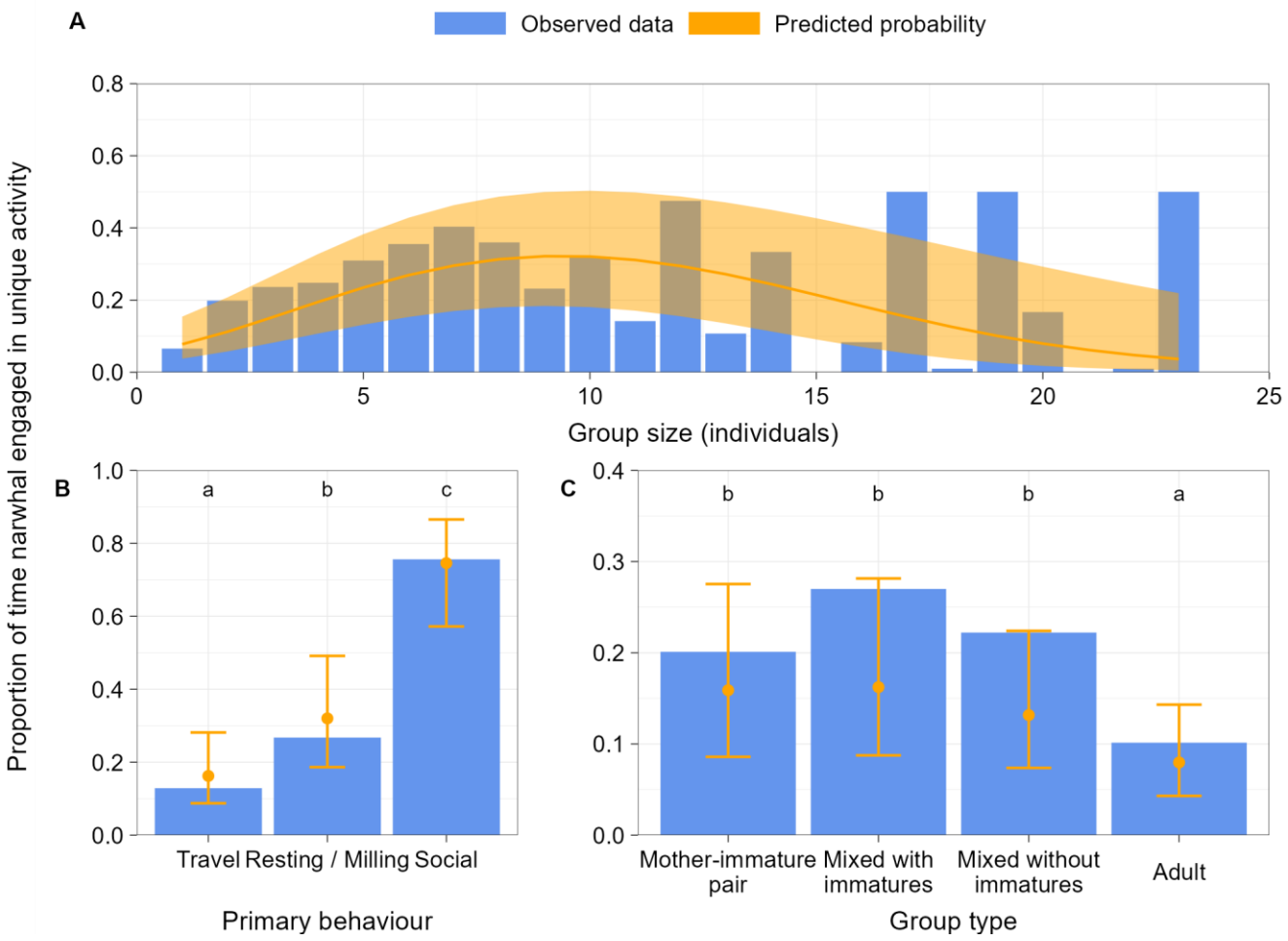

Figure 5-37: Observed proportion of time (bars) and estimated probability (line and points) that narwhal groups engaged in unique behaviours as a function of narwhal group size (Panel A), primary behaviour (Panel B), and group type (Panel C), 2020-2023.

Notes: observed data depict the between-surveys average proportion of time groups were to engage in unique behaviour at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant.

5.6.4 Association of Immatures with Presumed Mother

To assess the potential for vessel traffic to disrupt animals in the most vulnerable life stages (i.e., calves and yearlings), the proportion of immatures in groups, the presence of nursing behaviour observed by immatures, and the relative and distal associations of immatures in relation to their presumed mother were examined relative to vessel traffic.

5.6.4.1 Proportion Immatures

Of the followed groups with at least one immature recorded throughout the focal follow, the proportion of immatures that was most common was 0.50 (i.e., half of the group), recorded in 86 out of the 138 focal follows (62%), followed by 0.33 (45 focal follows; 33%; Figure 5-38). The distribution between when vessels were present and absent differed by year, although in three of the four sampling years, high proportion immature values (>0.75) were recorded more often when vessels were absent compared to when they were present, while low proportion immature cases (<0.25) had the opposite trend (Figure 5-38).

For groups with immatures, the observed proportion immatures decreased from 0.3 when no vessels were present within 5 km to 0.08 when vessels were within 1 km from groups (Figure 5-39). For mother-immature pairs, the observed proportion immatures was 0.6 when no vessels were present within 5 km from groups, and ranged from 0.42 to 0.72 when vessels were present, depending on distance from vessels. For groups that at their largest group size were mixed groups without immatures or lone immatures, data were only available when no vessels were present, and proportion immatures was 0.03 and 0.96, respectively.

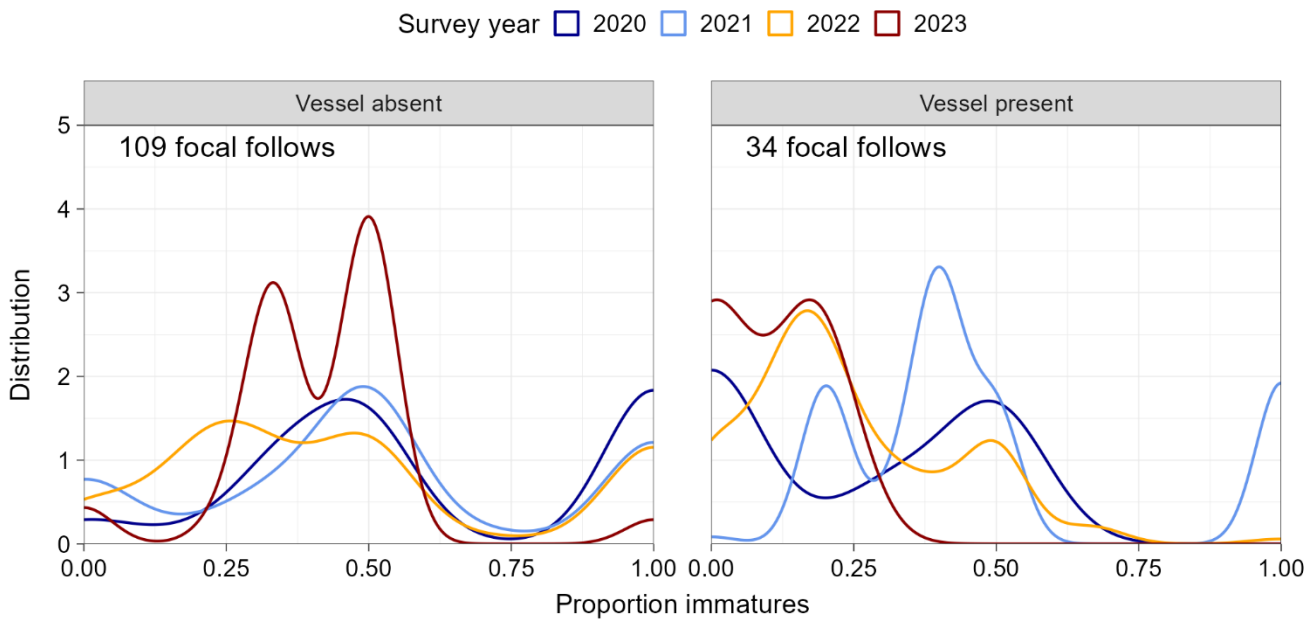

Figure 5-38: Distribution of proportion of immatures relative in the group recorded during focal follow surveys, 2020–2023, colour-coded by survey year. Sample size is shown as the number of unique focal follows.

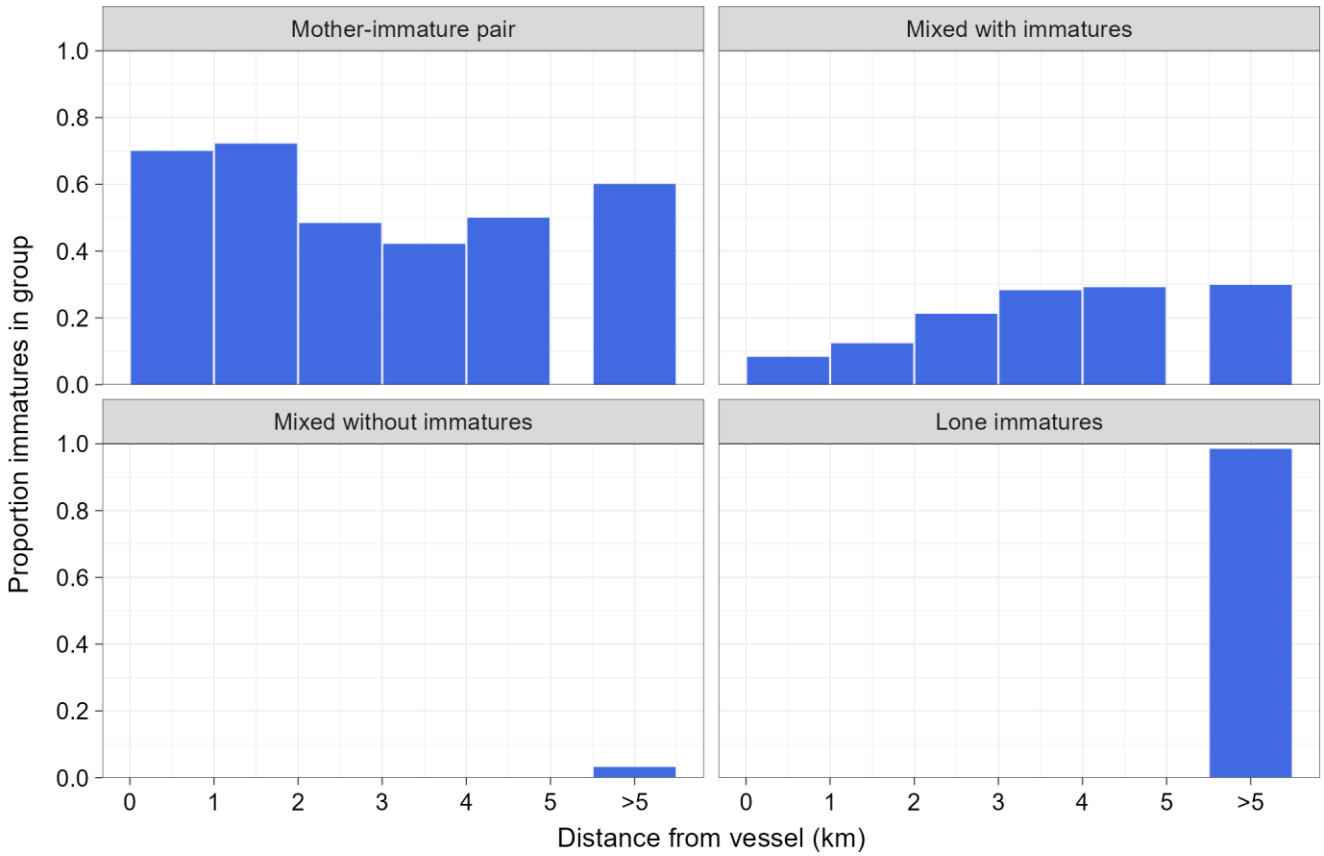

Figure 5-39: Mean proportion immatures in surveyed groups, relative to distance from vessel, by group type, 2020–2023.

In the statistical analysis of proportion immatures, the interaction between the effect of distance from vessel and group type, as well as the main effect of distance on proportion immatures were not statistically significant (*P*=0.3 for both). The lack of significance, despite the estimated relationship (Figure 5-40), is likely due to data scarcity, with data collected for distances <2 km available only from three and eight focal follows for mother-immature pairs and mixed groups with immatures, respectively. Due to the lack of significance, multiple comparisons were not performed, however relevant effect sizes were calculated (see Table 5-9).

Effect sizes were large (≥50% in absolute value; see Section 4.3.2.1) when vessels were within 2 km for mixed groups with immatures (-69%, -58%, and -28% at 0.5, 1, and 2 km from a vessel, respectively; see Table 5-9), and decreased below an absolute value of 25% at 2.2 km (effect size of -22%). For mother-immature pairs, effect sizes were medium in proximity to vessels (effect size of +46% and +32% at 0.5 km and 1 km, respectively), and decreased below an absolute value of 25% at 1.3 km (effect size of +24%). That is, the effect of shipping was small for both group types when vessels were farther than 2.2 km from groups. Within this distance, the results suggest a decreasing proportion of immatures with distance from vessel for mixed groups but an increasing proportion of immatures with distance for mother-immature pairs.

The effects of group size and group type were statistically significant (*P*<0.001 for both). The predicted mean proportion immatures decreased from 0.3 at group size of two individuals to 0.2 at a group size of three

individuals (Figure 5-41). Mother-immature pairs had a 144% higher proportion of immatures than mixed groups with immatures (P<0.001). The effect of Beaufort scale was not significant (P=0.1), with effect sizes ranging from -30% to +3%).

The statistical power to estimate the observed effect size of the effect of vessel distance was low (<0.5; see Appendix A). That is, the observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model had sufficient power (≥0.8) to detect effect sizes smaller than -92% or larger than +1,100% (see Appendix A). An effect size of -92% corresponds to the reduction in proportion immatures from 0.385 when no vessels were present to 0.048 when vessels were within 0.5 km from groups (for mother-immature pairs) and from 0.204 to 0.020 for mixed groups with immatures. An effect size of +1,100% corresponds to the increase in proportion immatures from 0.385 when no vessels were present to 0.883 when vessels were within 0.5 km from groups for mother-immature pairs and from 0.204 to 0.755 for mixed groups with immatures.

In summary, the results suggested a medium or large (≥25% for mixed groups and ≥50% for mother-immature pairs) but not statistically significant effect of vessel presence on the proportion of immatures when vessels were within 2.2 km of narwhal groups. The direction of the effect differed between group types, with an increasing proportion of immatures with increasing distance from vessel for mother-immature pairs but a decreasing proportion of immatures with distance for mixed groups with immatures. Reasons for the difference in the direction of the effect between group types are unknown but the results support the hypothesis that vessels at close distances (<2.2 km) affect the behaviour of narwhal groups with immatures, which is reflected by differences in the proportion of immature narwhal.

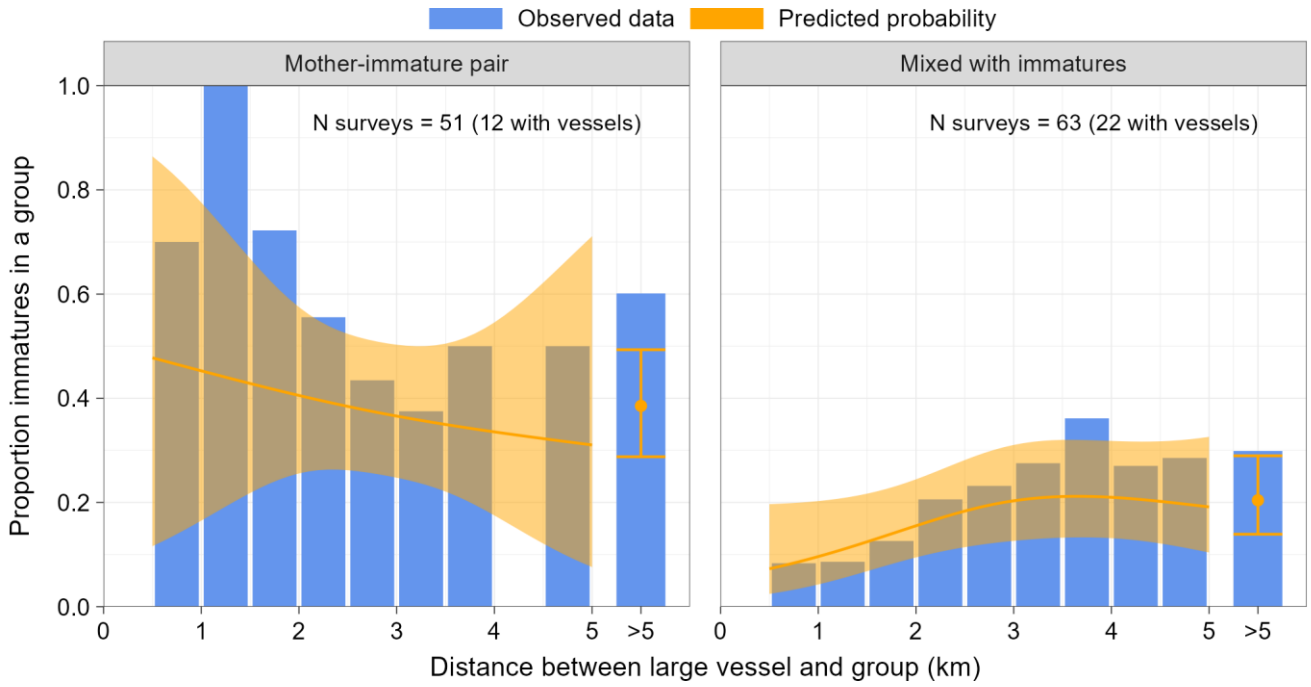

Figure 5-40: Observed (bars) and predicted (curve) proportion immatures in a group as a function of distance (rounded up to nearest 0.5 km value) from vessel, 2020-2023.

Notes: observed data depict the between-surveys average proportion of time immatures were observed in a tight distal position at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant

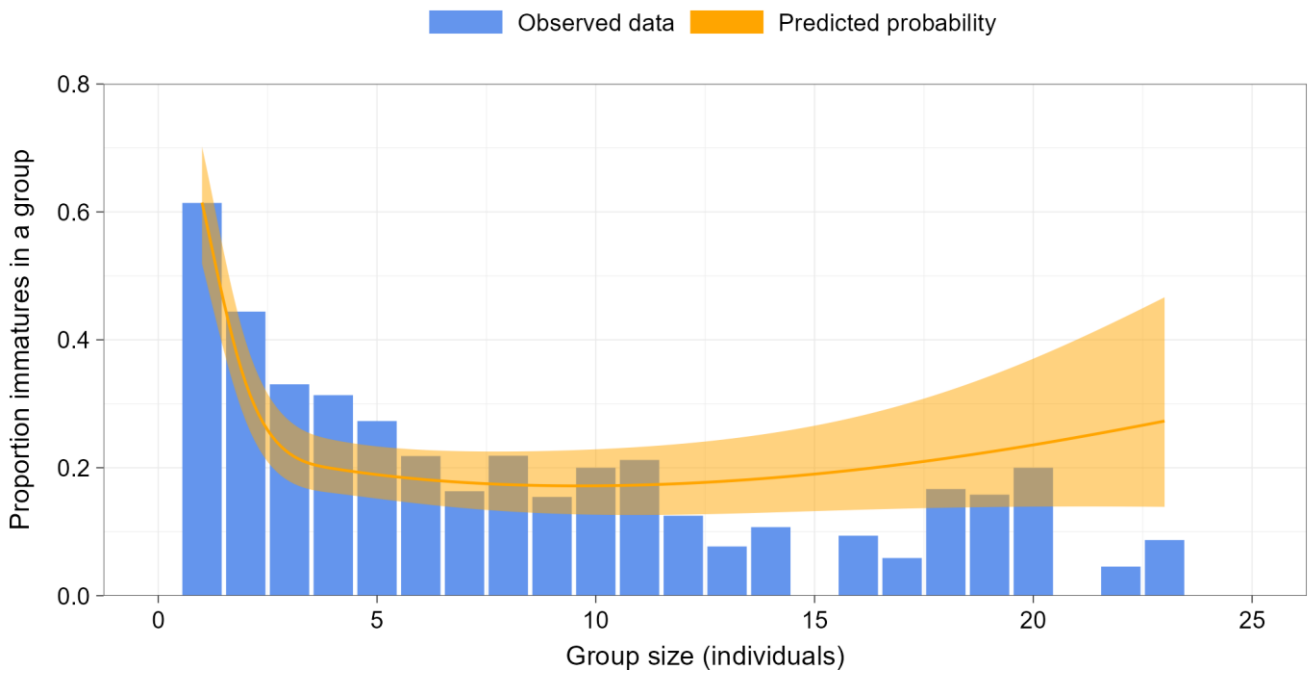

Figure 5-41: Observed (bars) and predicted (curve) proportion immatures in a group as a function of group size, 2020-2023.

Notes: observed data depict the between-surveys average proportion of time immatures were observed in a tight distal position at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant

Table 5-9: Effect sizes of predicted proportion immatures between vessel exposure (0.5 to 5 km distances) and non-exposure periods (>5 km). Statistical comparisons were not performed due to lack of significance of the effect of distance.

Distance from vessel (km)	Effect sizes (%) relative to no-exposure	
	Mother-immature pair	Mixed with immatures
0.5	46%	-69%
1	32%	-59%
2	9%	-28%
3	-8%	-1%
4	-20%	4%
5	-28%	-8%

5.6.4.2 Presence of Nursing Behaviour

Nursing behaviour involving immatures (i.e., calves or yearlings) was recorded during 30 of the total 397 focal follow surveys conducted (12 surveys in 2020, 12 surveys in 2021, and six surveys in 2022; accounting for 14%, 7%, and 4% of all groups in 2020, 2021, and 2022, respectively; Figure 5-42). For all focal groups containing immatures (36 groups in 2020 and 2021, and 54 groups in 2022), nursing was observed at some point during 33% of surveys conducted in 2020 and 2021, and 11% of surveys conducted in 2022. Of these, nursing duration ranged between 5% and 63% of the total survey duration (FFID 137 in 2021 and FFID 81 in 2020, respectively), with a mean of 23% of the survey length (SD of 17%). Nursing behaviour by immatures was not observed in 2023.

All focal follow surveys that included nursing immatures are shown in Figure 5-43. The 30 focal groups with immatures consisted of mother-immature pairs, mixed groups with immatures, and lone immature groups. Of these groups, single immatures were recorded at some point in all 30 surveys, while two immatures were recorded in four surveys, and three immatures were recorded in a single survey in 2021 (FFID 137). Nursing events ranged between a single 30 sec period (one survey in 2020, three surveys in 2021, and two surveys in 2022) to ≥5 min nursing events (FFIDs 33 and 83 in 2020). On average, nursing events observed during a given survey lasted 2.2 min (SD of 1.3 min).

Of the 30 focal follow surveys consisting of nursing immatures, five of the surveys coincided with vessel presence, though for one of these surveys the actual nursing event took place when the vessel was beyond 5 km of the focal group. In this particular survey (FFID 122 in 2021), the immature was observed to nurse for a single 30 sec period at a point in the survey when the vessel was outside of the 5 km exposure distance. During FFID 83 (2020), nursing lasted for 5.5 min, commencing when the vessel was outside of the 5 km exposure zone cut-off, and continuing as the distance to the vessel decreased to 4.5 km, at which point the UAV had to return due to battery limitations. For all surveys containing nursing and coinciding with vessel presence, narwhal were never closer than 2 km from the vessel (Figure 5-44). Of the remaining three surveys recorded in 2022, the immatures nursed for only a single 30-sec period when vessels were at a distance of 3.1 km (FFID 19) and 4.8 km (FFID 26) from the focal group, and for 1.5 min when the vessel was beyond 5 km of the focal group (FFID 30), followed by a single 30 sec interval two minutes later, when the same vessel was at 4.9 km distance from the group. Although this represented a small sample size of nursing events in the presence of vessels, observations of immature narwhal continuing to nurse when within 5 km of a vessel suggested that mother and dependent young continued to carry out nursing behaviour in the presence of vessel traffic. When no vessels were present, nursing was recorded in 28 out of 97 focal follow surveys that included mother-immature pairs (29%), and nursing periods ranged from a minimum of a single 30 sec period (four focal follow surveys) to a maximum of 5 min (one focal follow survey), with a mean of 4.4 min and SD of 2.3 min.

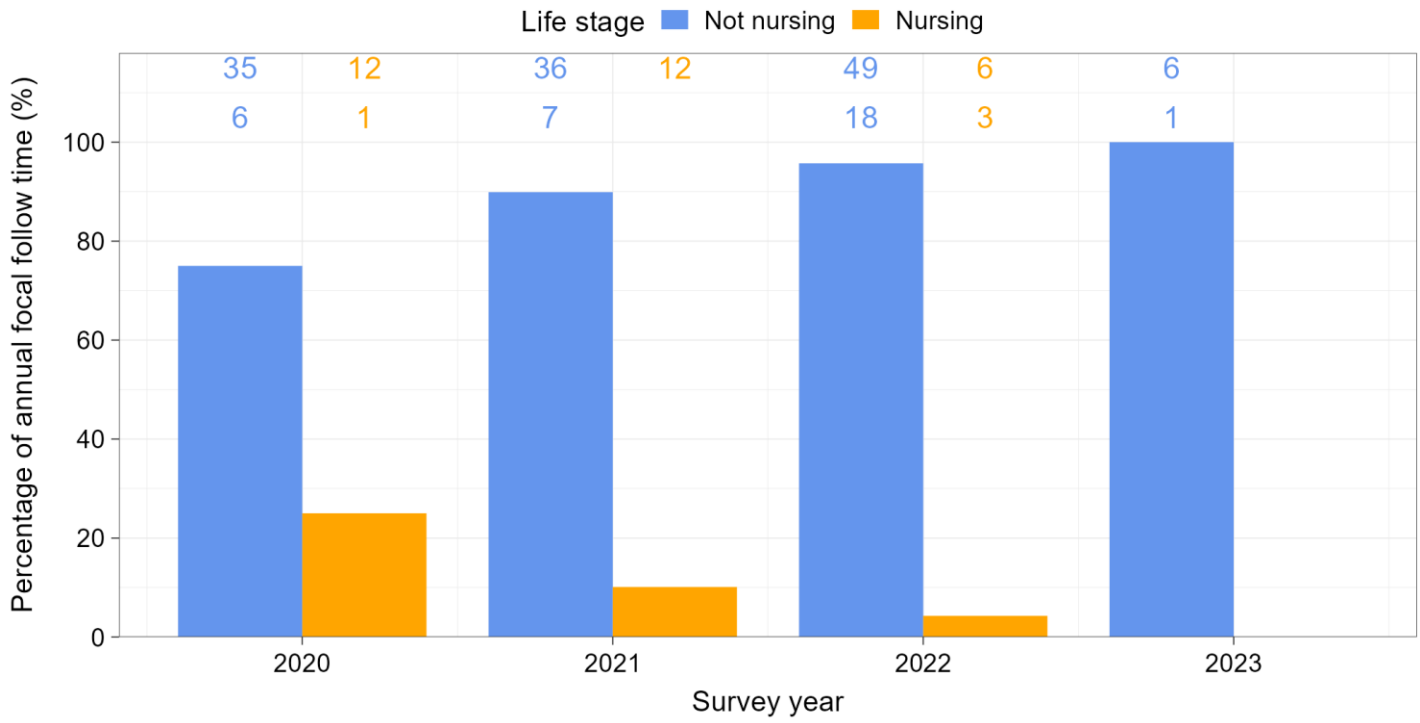

Figure 5-42: Nursing behaviour recorded during focal follow surveys, 2020–2023. Sample size is shown as the number of unique focal follows in the absence of vessels (top row) and when vessels were present within 5 km from groups (second row).

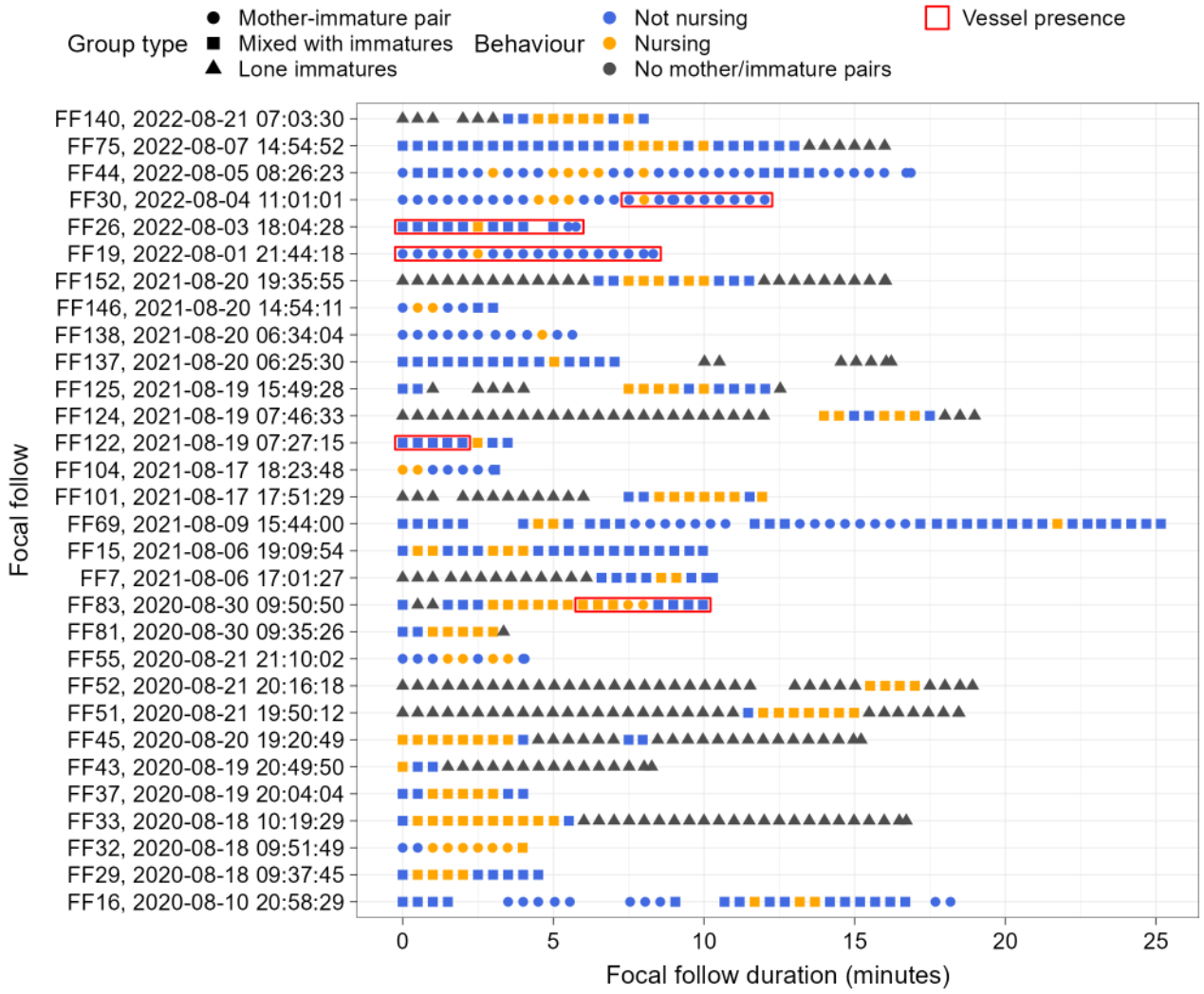

Figure 5-43: Nursing behaviour (yellow) observed in focal follow surveys that included nursing immatures, 2020–2023. Vessel presence (vessel ≤5 km) denoted by red box.

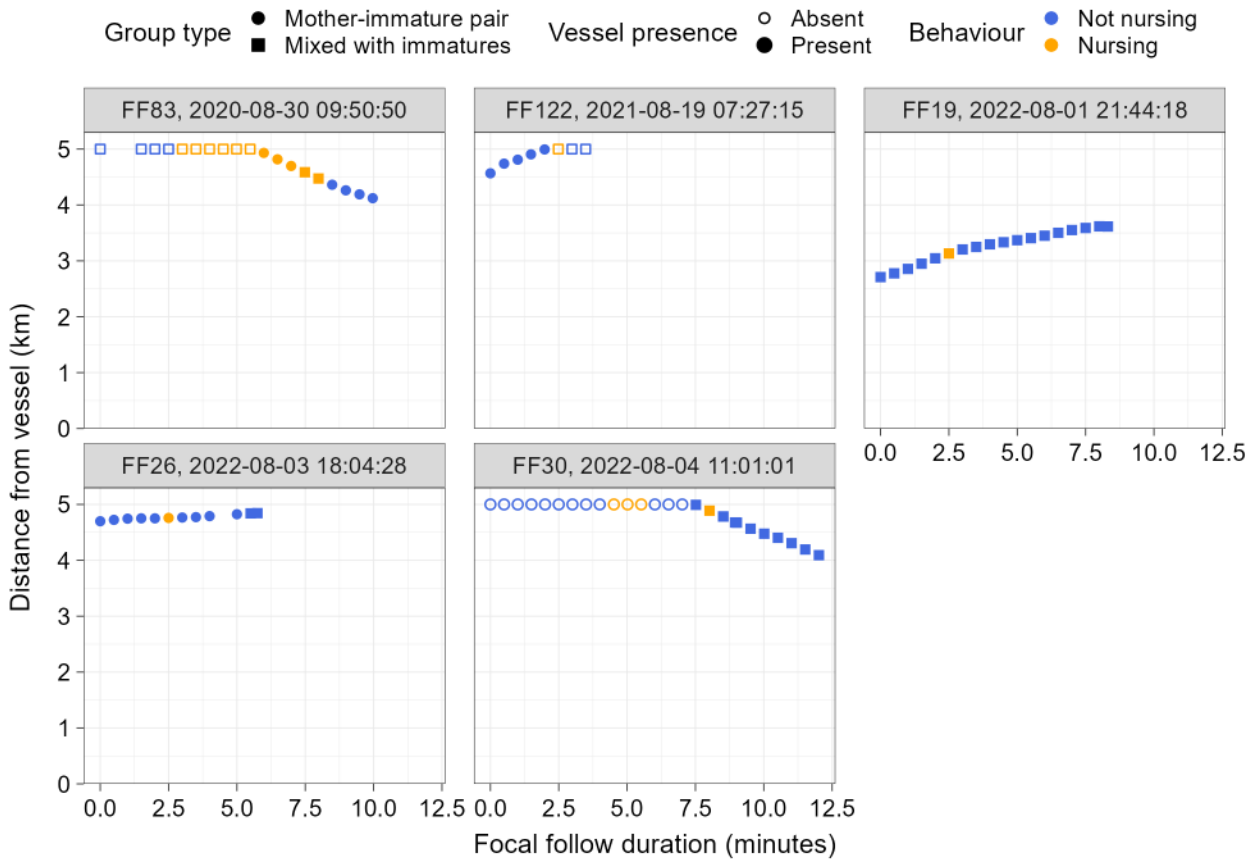

Figure 5-44: Nursing behaviour (yellow) observed in focal follow surveys that included nursing activity when vessels were present (2020–2023).

A mixed-effects model with a binomial distribution (i.e., logistic regression) was used to test for the effect of vessel presence on nursing. The model included fixed effect of group size, group type, and vessel presence, but not vessel distance, given the limited data available for narwhal-vessel interactions at the exposure zone distances. The effect of vessel presence on nursing was not significant (P=0.1; effect size of -65%; Figure 5-45). The lack of a statistically significant effect despite the large effect size was likely due to the low sample size, high variability, and unbalanced data. Specifically, only four of the 30 surveys involving active nursing occurred in the presence of vessels (<5 km). As a result of the small sample size of nursing during vessel presence (Figure 5-42), there is high uncertainty around the conclusions that are drawn from this analysis regarding the effect of vessels on nursing.

The effect of group type on nursing was not significant (P=0.3). The effect of group size was significant (P=0.04), with nursing being significantly less likely to be observed in larger groups (Figure 5-46). However, data on large groups came from a limited set of focal follows (only eight surveys had group sizes larger than 10 individuals, and only four surveys had group sizes larger than 15 individuals).

The statistical power to estimate the observed effect size of vessel distance on nursing behaviour was low (<0.1; see Appendix A). The model only had sufficient power (≥0.8) to detect an effect size of +1,750% (see Appendix A). This effect size corresponds to the increase in probability of nursing behaviour from 0.001 to 0.029 for mother-immature pairs and from 0.003 to 0.058 for mixed groups with immatures.

In summary, immature narwhal engaged in nursing less frequently when in the presence of vessel traffic (vessel within 5 km of the focal group). This effect was not statistically significant despite a large effect size of -65%. The lack of statistical significance was likely due to low sample size, particularly for observations of nursing in the presence of vessels. As a result, there is high uncertainty around the conclusions regarding the effect of vessels on nursing. Additional focal follow monitoring is recommended to increase the overall sample size and the robustness of the corresponding analysis.

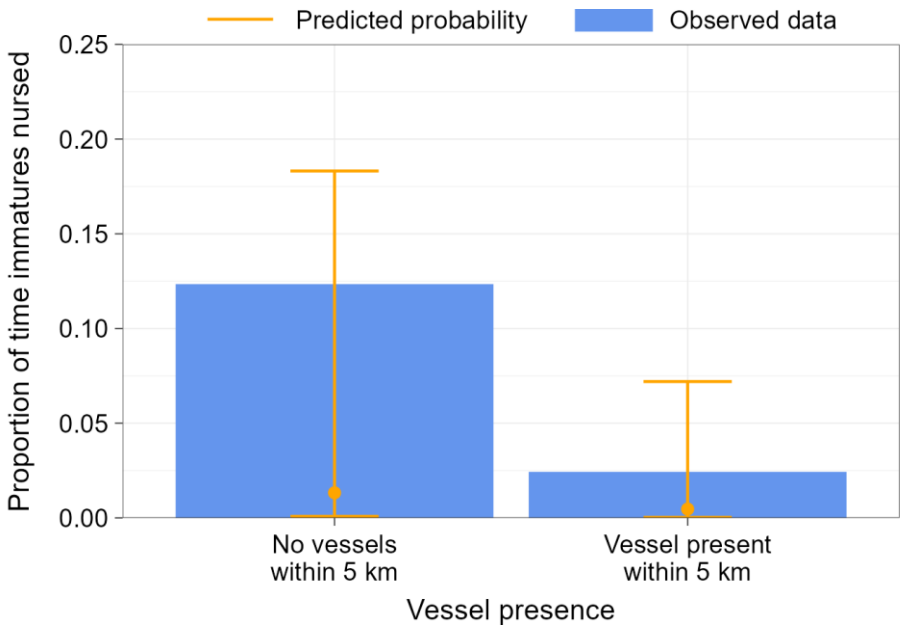

Figure 5-45: Observed proportion of time (bars) and estimated probability (points) that immatures in narwhal groups with immatures engaged in nursing as a function of vessel presence, 2020–2023.

Notes: observed data depict the between-surveys average proportion of time immatures engaged in nursing when vessels were absent or present within 5 km from groups (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant.

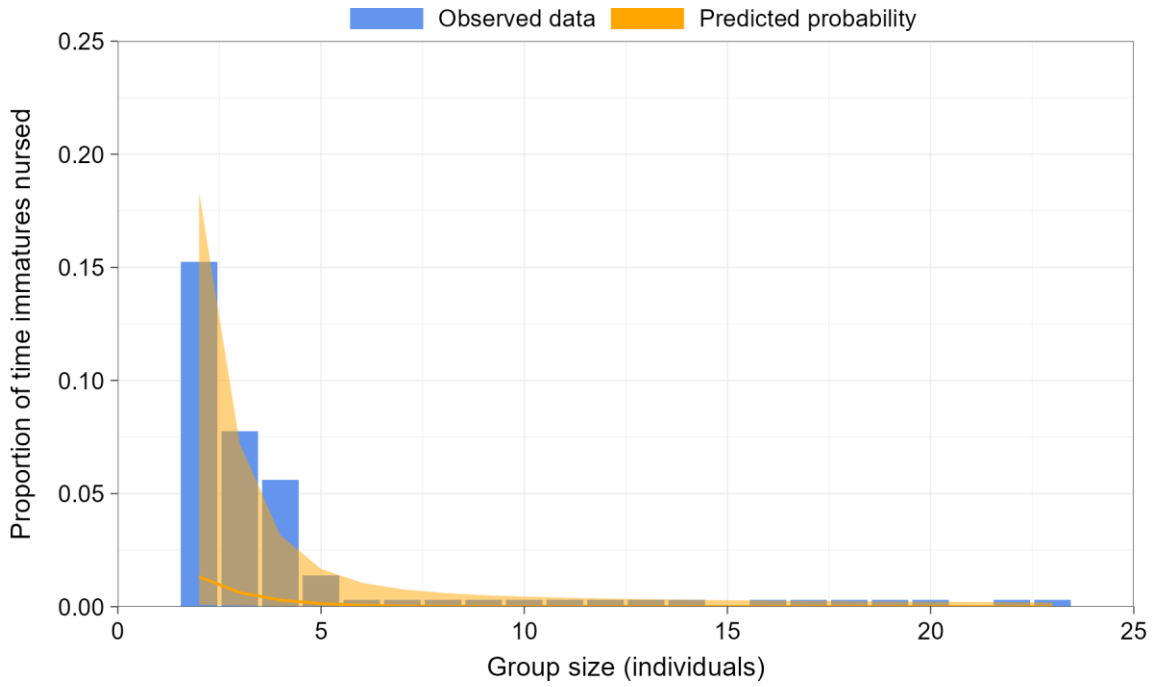

Figure 5-46: Observed proportion of time (bars) and estimated probability (points) that immatures in narwhal groups with immatures engaged in nursing as a function of group size, 2020–2023.

Notes: observed data depict the between-surveys average proportion of time immatures were observed nursing at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant

5.6.4.3 Relative Positioning of Immatures

Of the followed groups with immatures in association with their presumed mother, immatures were most commonly observed under their mother, with values ranging from 30% (2023) to 55% (2020), followed by abreast, with values ranging from 30% (2020) to 43% (2023; Figure 5-47). Percent time spent on top of the presumed mother ranged from 10% (2020) to 23% (2023), while percent time spent behind or in front of the presumed mother ranged from 0% to 5% (Figure 5-47).

Immature narwhal were most commonly observed under their mother compared to other positions in both the presence and absence of vessels (38 and 42% of the time, respectively). Immatures positioned abreast of their mother were the second most common relative positions (32% of the time when a vessel was present and 40% of the time in the absence of vessels). The proportion of time that immatures were recorded on top of their mother was 17% in the presence of vessels and 12% when no vessels were present. The proportion of time that immatures were recorded in front or behind the mother was low: 6% in the presence of vessels and 3% when no vessels were present.

In mother-immature pairs, immatures were generally observed under their mother more often than in mixed groups with immatures, during both vessel presence and absence (Figure 5-48). In mother-immature pairs, the proportion of time that immatures spent under the mother in the presence of vessels ranged from 38% (at 1–2 km) to 67% (at 0–1 km and 2–3 km from vessels); however, sample sizes were <5 at both distances. In the absence of vessels, immatures remained under the mother for 50% of the time in groups of mother-immature pairs. In mixed groups with immatures, immatures spent 0–39% of the time under the mother in the presence of vessels (depending on distance) and 33% of the time under the mother when no vessels were present.

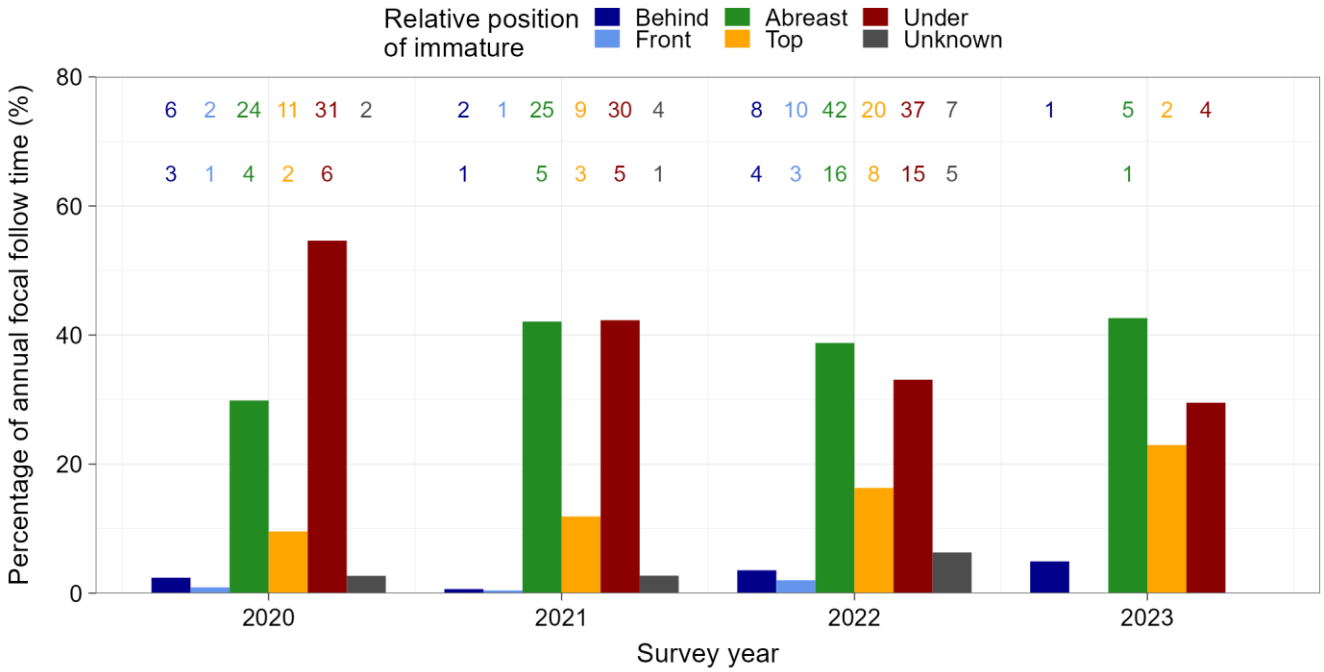

Figure 5-47: Relative position of immatures recorded during focal follow surveys. A separate plot is presented for each individual immature in a given group, 2020–2023. Sample size is shown as the number of unique focal follows in the absence of vessels (top row) and when vessels were present within 5 km from groups (second row).

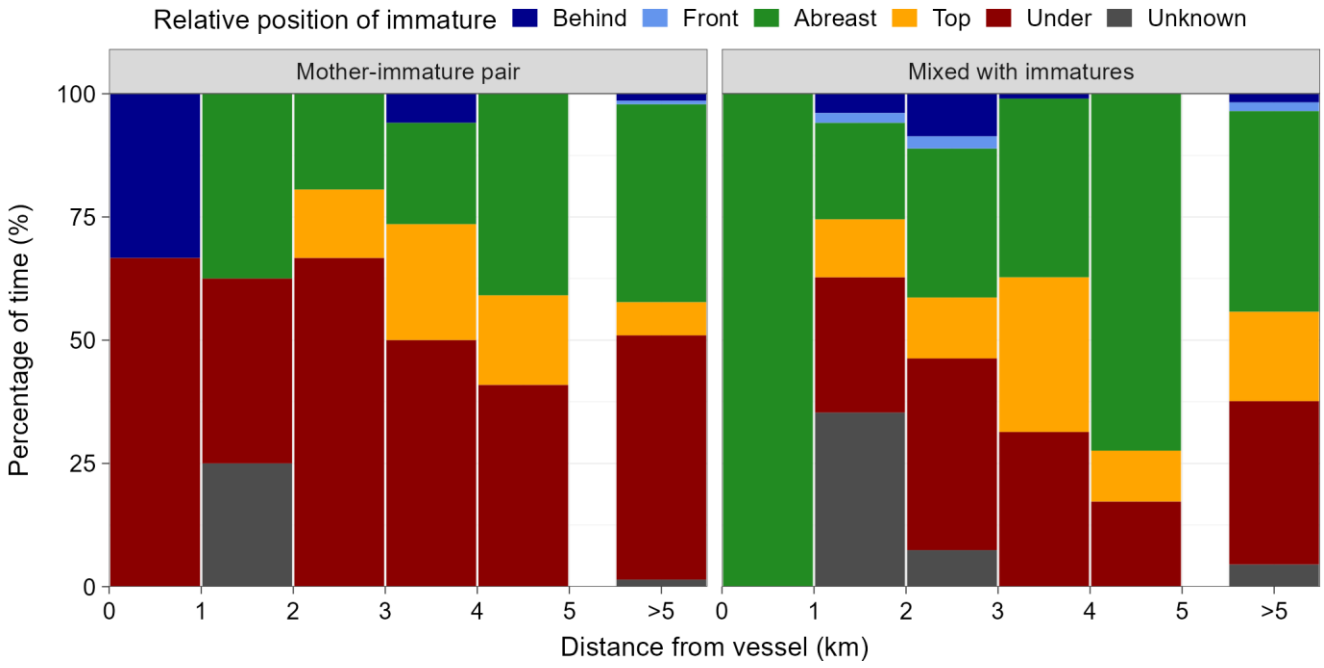

Figure 5-48: Percentage of time immature narwhal associated in relative positions of presumed mother, relative to distance from vessel, presented by group type.

In the statistical analysis of relative position, of the five relative positions recorded (on top, under, abreast, behind, in front), “on top” was removed from the data, due to low sample size (Figure 5-47). In addition, to increase sample size, the remaining relative positions were grouped into two categories – “lateral”, which included abreast relative positions as well as behind and in front of the presumed mother, and “under”.

The effect of distance from vessel was not significant (*P*=0.5), likely due to the high uncertainty around the modelled estimates (Figure 5-49). The estimated effect size of vessel presence at close proximity was small, with estimated effect sizes for a vessel at 0.5 km and 1.0 km of +13% and +3%, respectively (Table 5-10). That is, at 0.5 km from a vessel, there was a 13% increase in odds of an immature being positioned under the mother rather than in a lateral position. This represents a small effect size (i.e., >10% change in relative position of immatures; see Section 4.3.2.1) and was not a statistically significant effect for both mother-immature pairs and groups with immatures. The threshold for a small effect existed up to a distance of 0.7 km from a vessel. Overall, the small effect size at close distances and lack of statistical significance do not provide strong support for the hypothesis that vessel presence.

The effect of primary behaviour was significant (*P*=0.009), with odds of an immature under the mother significantly higher when the group was resting or milling compared to when the group was traveling (*P*=0.03, effect size of +80%) or socializing (*P*=0.04, effect size of +253%; Figure 5-50). There was no significant difference between when groups were traveling or engaging in social activities (*P*=0.4, effect size of +96%), likely due to the low sample size of narwhal engaging in social activity, resulting in high uncertainty for the estimate. The effect of group type was not significant (*P*=0.6), with immatures 18% more likely to be under its mother for mother-immature pairs compared to mixed groups with immatures.

The statistical power to estimate the observed effect of vessel distance on relative position was low (<0.2; see Appendix A). That is, the observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model did not have sufficient power (≥0.8) to detect any of the examined effect sizes, from -100% to +3,000% (see Appendix A). The low power despite the large effect sizes is due to the nonlinear nature of probabilities, where for example, an effect size of +3,000% corresponds to the increase in probability of an immature being found under its presumed mother from 0.703 to 0.987 for mother-immature pairs and from 0.667 to 0.984 for mixed groups with immatures.

In summary, the estimated effect of vessels on the relative position of immature narwhal relative to their mothers was small, uncertain, and not statistically significant. These results do not suggest that the relative position (lateral or under) of immatures and their mother were affected when vessels were within 5 km from groups.

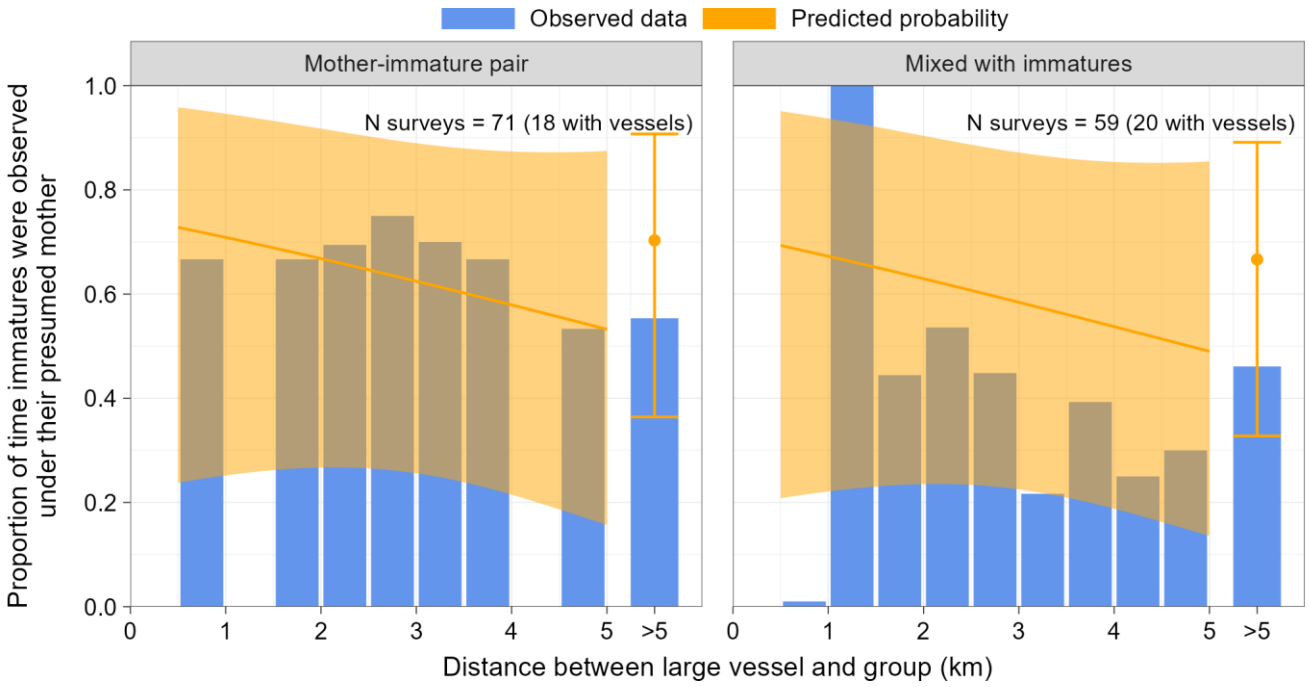

Figure 5-49: Observed proportion of time (bars) and estimated probability (curves and points) that immatures were under their mother as a function of distance (rounded up to nearest 0.5 km value) from vessel, plotted by group type, 2020–2023.

Notes: observed data depict the between-surveys average proportion of time immatures were observed in a tight distal position at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant

Table 5-10: Effect sizes of predicted probability of observing immatures under their mother between vessel exposure (0.5 to 5 km distances) and non-exposure periods (>5 km). Statistical comparisons were not performed due to lack of significance of the effect of distance.

Distance from vessel (km)	Effect sizes (%) relative to no-exposure
	Mixed with immatures and mother-immature pairs
0.5	+13%
1	+3%
2	-15%
3	-30%
4	-42%
5	-52%

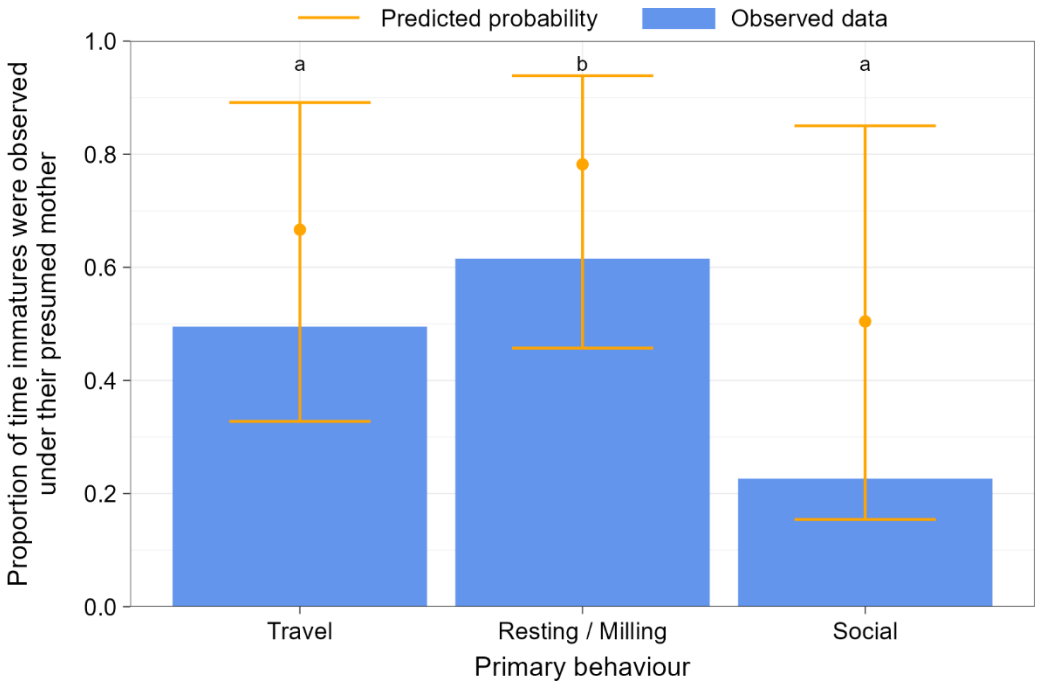

Figure 5-50: Observed proportion of time (bars) and estimated probability (points) that immatures were under their mother as a function of primary behaviour of groups, 2020–2023.

Notes: observed data depict the between-surveys average proportion of time immatures were observed in a tight distal position at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant

5.6.4.4 Distal Positioning of Immatures

Of the followed groups with immatures in association with their presumed mother, immatures were most commonly observed in tight association when under their mother, with values ranging from 98% (2020) to 100% (2023), followed by when immatures were on top of their mother, with values ranging from 84% (2020) to 95% (2021; Figure 5-51). When immatures were positioned abreast of the mother, tight association was recorded between 55% (2020) and 88% of the time (2023).

The proportion of time that mothers and immatures were tightly associated with one another ranged from 67% to 94% for mother-immature pairs in the presence of vessels (depending on distance) and 85% when no vessels were present (Figure 5-52). The proportion of time that mothers and immatures were tightly associated with one another ranged from 59 to 100% for mixed groups with immatures in the presence of vessels (depending on distance) and 82% when no vessels were present.

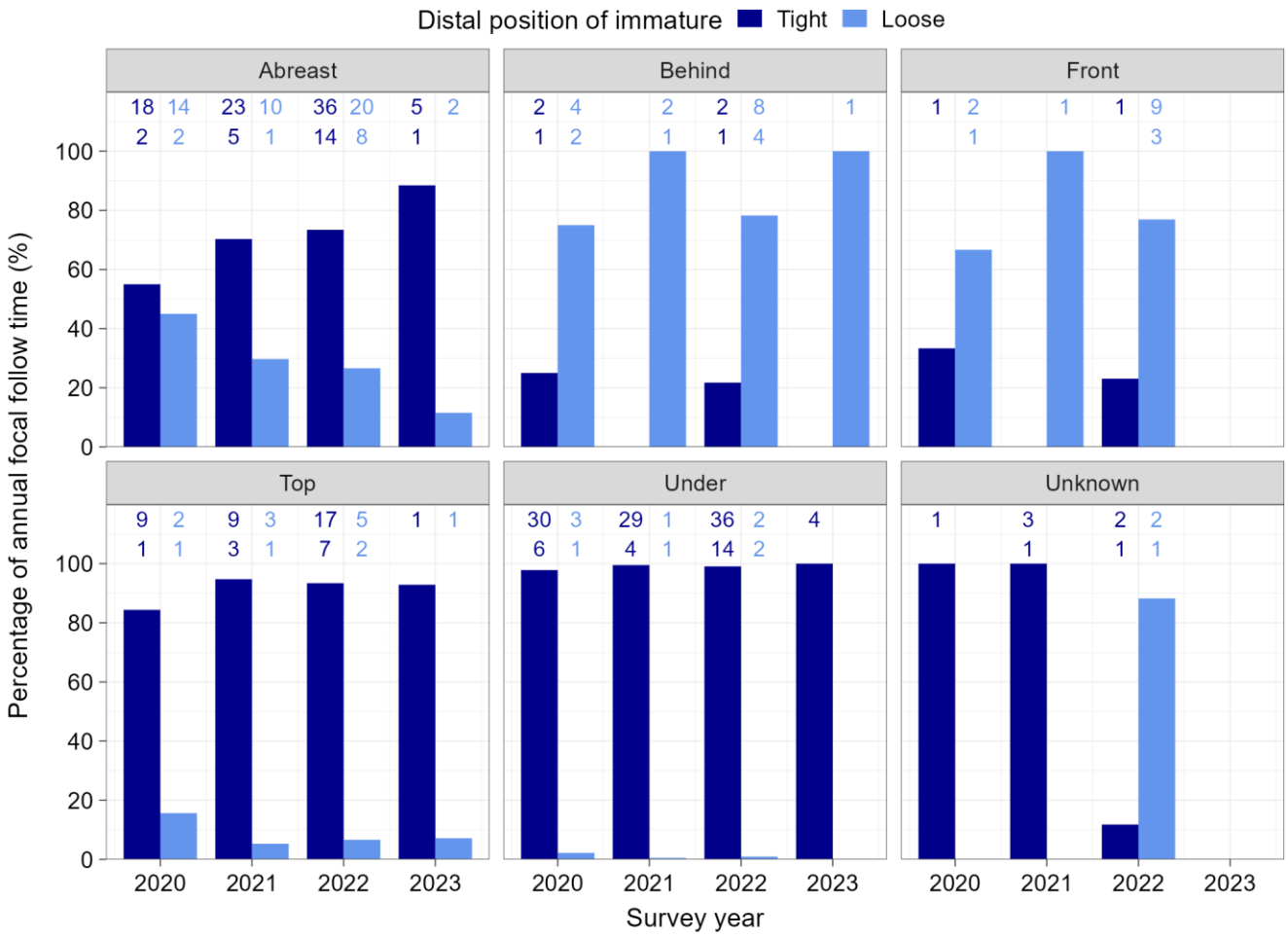

Figure 5-51: Distal position of immatures relative to the presumed mother (tight or loose; shown by bar colour) by relative position, recorded during focal follow surveys, 2020–2023; cases of unknown spread are not shown. Sample size is shown as the number of unique focal follows in the absence of vessels (top row) and when vessels were present within 5 km from groups (second row).

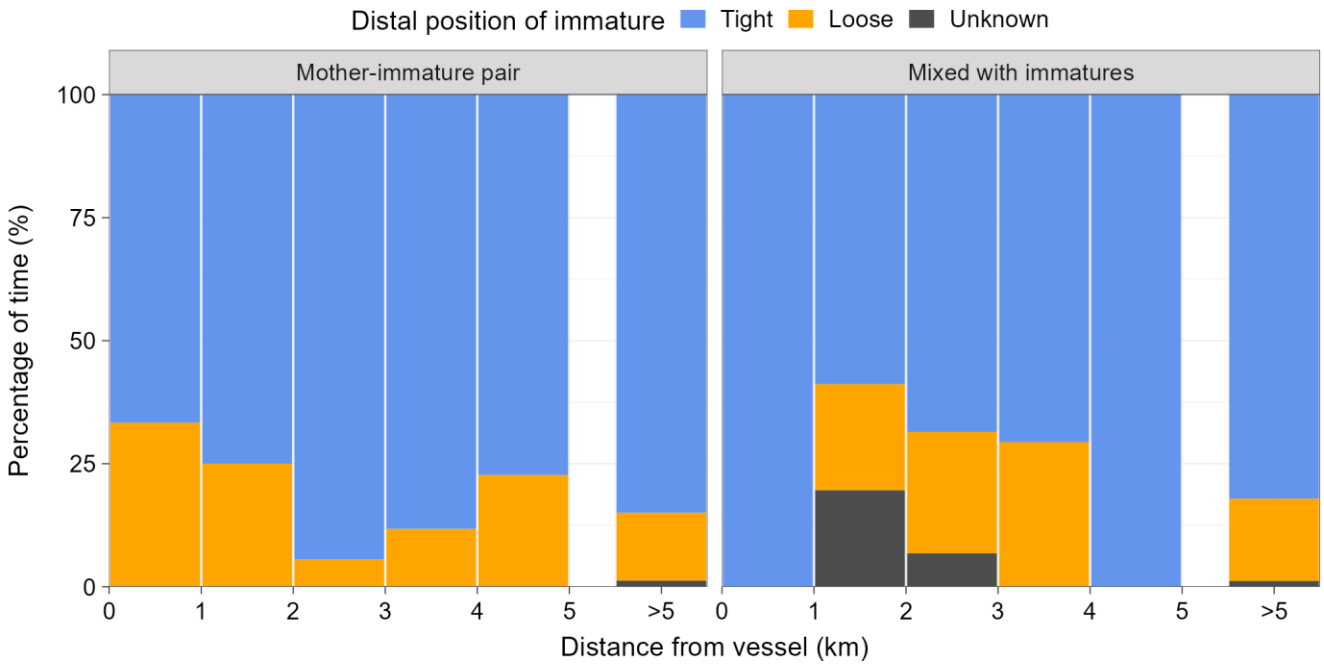

Figure 5-52: Percentage of time immature narwhal spent in each distal position, relative to distance from vessel, presented by group type, 2020–2023.

In the statistical analysis of distal position, which was a logistic regression predicting either tight or loose position of an immature relative to its mother, relative position was used as a predictor. Of the five relative positions recorded (on top, under, abreast, behind, in front), two (behind and in front) had low sample sizes (Figure 5-51). To increase sample size, several relative positions were grouped into the following three categories: “lateral” (which included abreast, in front, and behind), “on top”, and “under”.

The effect of distance from vessel on the distal position of immatures was not significant (P=0.2). The predicted probability of an immature being tightly associated with its mother was estimated to be lowest when vessels were at close proximity to the group (Figure 5-53). Effect sizes, based on the odds ratios, were large (≥50% in absolute value; see Section 4.3.2.1) when vessels were within 4 km (-64%, -73%, -82%, and -80% at 0.5, 1, 2, and 3 km from a vessel, respectively), decreasing below an absolute value of 50% at 4.1 km (effect size of -47%; Table 5-11). The odds of an immature being in tight association with its mother were 64% lower at 0.5 km from a vessel compared to when no vessels were present. The absolute values of effect sizes decreased below 25% at a distance of 4.4 km. That is, the effect of shipping was small when vessels were farther than 4.4 km from groups.

The effects of group size and type (mother-immature pairs and mixed groups with immatures) were not significant (P=0.1 and P=0.9, respectively). The distal position of immatures did not differ significantly between groups of different sizes or between mother-immature pairs and mixed groups with immatures. The effect of relative position was significant (P<0.001), with immatures significantly less likely to be in a tight association with their presumed mother when either on top of the mother or in a lateral position compared to when under the mother (P<0.001 for both, effect sizes of -92% and -99%, respectively; Figure 5-54). Similarly, immatures were significantly more likely to be in a tight association with their presumed mother when on top of the mother, compared to a lateral position (P<0.001, effect size of -91%). The effect of primary behaviour was not significant (P=0.07), but estimated effect sizes ranged from -60% (comparison between social and travel) and -25% (comparison between social behaviour and resting / milling). Lack of statistical significance of primary behaviour was likely due in part to the low sample size for individuals engaging in social behaviour.

The statistical power to estimate the observed effect size of vessel distance on distal positioning was low (<0.2; see Appendix A). The observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model did not have sufficient power (≥0.8) to detect any of the examined effect sizes, from -100% to +2,000 (see Appendix A). The low power despite the large effect sizes is due to the nonlinear nature of probabilities, where the high predicted probabilities of a tight association between immatures and their mothers mean that effect sizes on the odds-scale need to be extremely large to change the predicted probabilities even slightly. For example, an effect size of +2,000% on the odds-scale corresponds to the increase in probability of a tight association between immature and its presumed mother from 0.933 to 0.997 for immatures found in a lateral position relative to the adult, from 0.994 to 1.00 for immatures found on top of the adult, and from 0.999 to 1.00 for immatures found under the adult.

In summary, the estimated effect of vessels on the distal position (tight or loose) of immature narwhal relative to their mothers was highly uncertain, large (effect sizes ≥50%), and not statistically significant. Specifically, immatures were observed less frequently in a tight association with its mother when a vessel was within 4.0 km but this effect was highly uncertain and not statistically significant, due partly to small sample sizes of observations in close proximity to vessels. Based on these results, strong conclusions cannot be drawn but the large estimated effect size suggests the possibility of an effect of vessels on the distal position of immature narwhal.

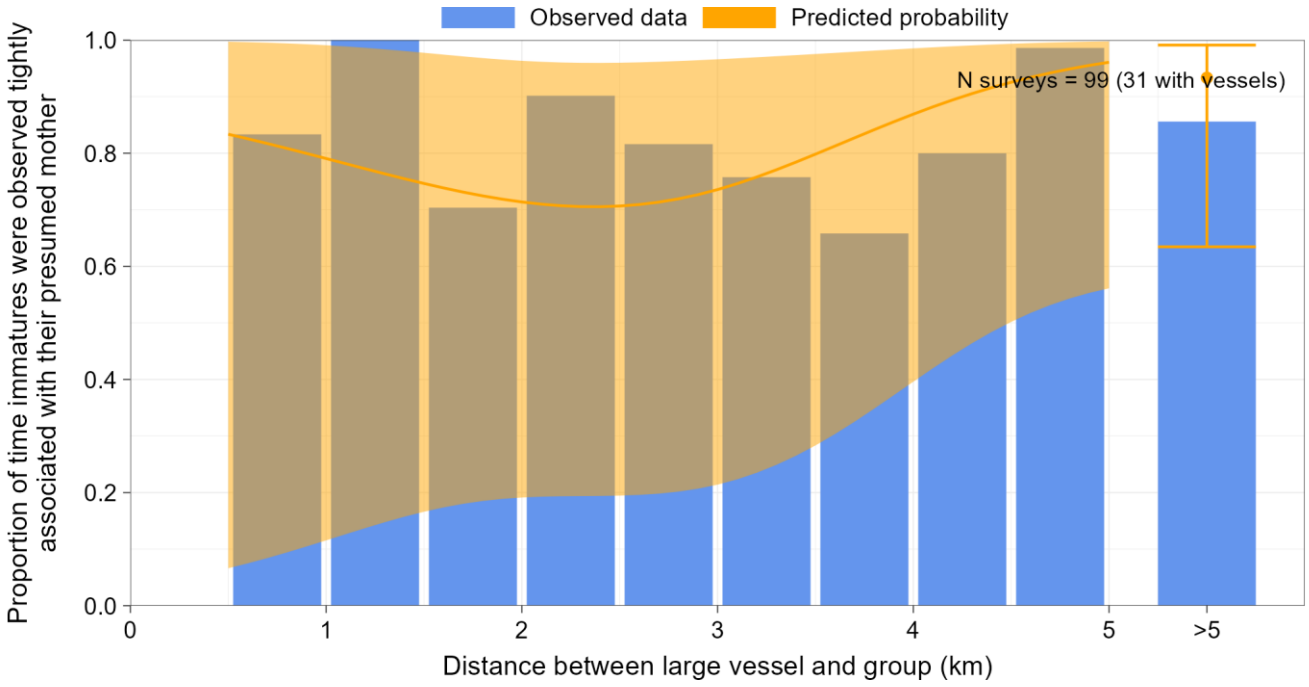

Figure 5-53: Observed proportion of time (bars) and estimated probability (points) that immatures were tightly associated with their presumed mother as a function of distance (rounded up to nearest 0.5 km value) from vessel, 2020–2023.

Notes: observed data depict the between-surveys average proportion of time immatures were observed in a tight distal position at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant

Table 5-11: Effect sizes of predicted probability of observing immatures tightly associated with their presumed mother between vessel exposure (0.5 to 5 km distances) and non-exposure periods (>5 km). Statistical comparisons were not performed due to lack of significance of the effect of distance.

Distance from vessel (km)	Effect sizes (%) relative to no-exposure
	Mixed with immatures and mother-immature pairs
0.5	-64%
1	-73%
2	-82%
3	-80%
4	-53%
5	+75%

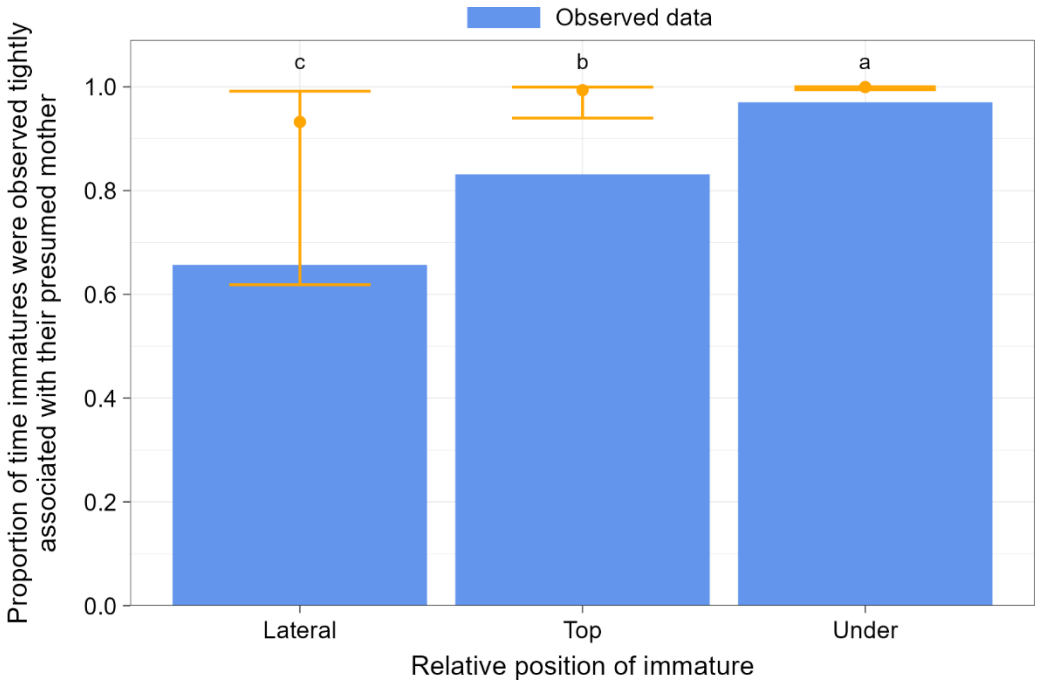

Figure 5-54: Observed proportion of time (bars) and estimated probability (points) that immatures were tightly associated with their presumed mother as a function of relative position of immature (lateral, on top, or underneath the mother), 2020–2023.

Notes: observed data depict the between-surveys average proportion of time immatures were observed in a tight distal position at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant

5.6.5 Group Formation

Of the followed groups, much of the data were collected on groups of a single individual, with values of percent time ranging from 19% (2022) to 42% (2020 and 2021). Of the followed groups with more than one individual, the most common group formation was parallel, with percent time ranging from 35% (2022) to 49% (2023; Figure 5-55). The second most-common formation was cluster formation, with percent time ranging from 21% (2021) to 36% of the time (2022), followed by linear formation, ranging from 13% (2022) to 27% (2020; Figure 5-55). In the absence of vessels, the proportion of groups in parallel formation (39% of the time) was similar to when vessels were present (42%). In contrast, the proportion of groups in linear formation was slightly higher in the absence of vessels (21%) relative to when vessels were present (11%). The proportion of groups in cluster formation was slightly lower when a vessel was absent compared to when a vessel was present (27% and 36%, respectively).

Mother-immature pairs were most often observed in linear formation, whether in the absence of vessels (53% of the time) or the presence of vessels (27–67% of the time, depending on distance; Figure 5-56). This finding should be interpreted with caution, however, as an immature located either above or underneath of its mother would be classified as linear, thereby inflating the likelihood of observing linear formation in strictly mother-immature groups. In comparison, mixed groups with immatures were mostly observed in parallel formation, whether in the absence of vessels (45%) or the presence of vessels (22–100% of the time, depending on distance). Mixed groups without immatures were also most likely to be in parallel formation both in the absence of vessels (36%) and in the presence of vessels (17–58%, depending on distance from vessel). Adult-only groups were often groups of a single animal when vessels were absent (52% of the time) or present (28–70% of the time, depending on distance from vessel). When adult-only groups had at least two individuals, groups were most commonly recorded in cluster or parallel formation when vessels were absent (39 and 38% of time, respectively), and in parallel formations when vessels were present (38–57% of time, depending on distance from vessel). Lone immature groups were usually single individuals (82% of the time in absence of vessels and 100% of the time in presence of vessels).

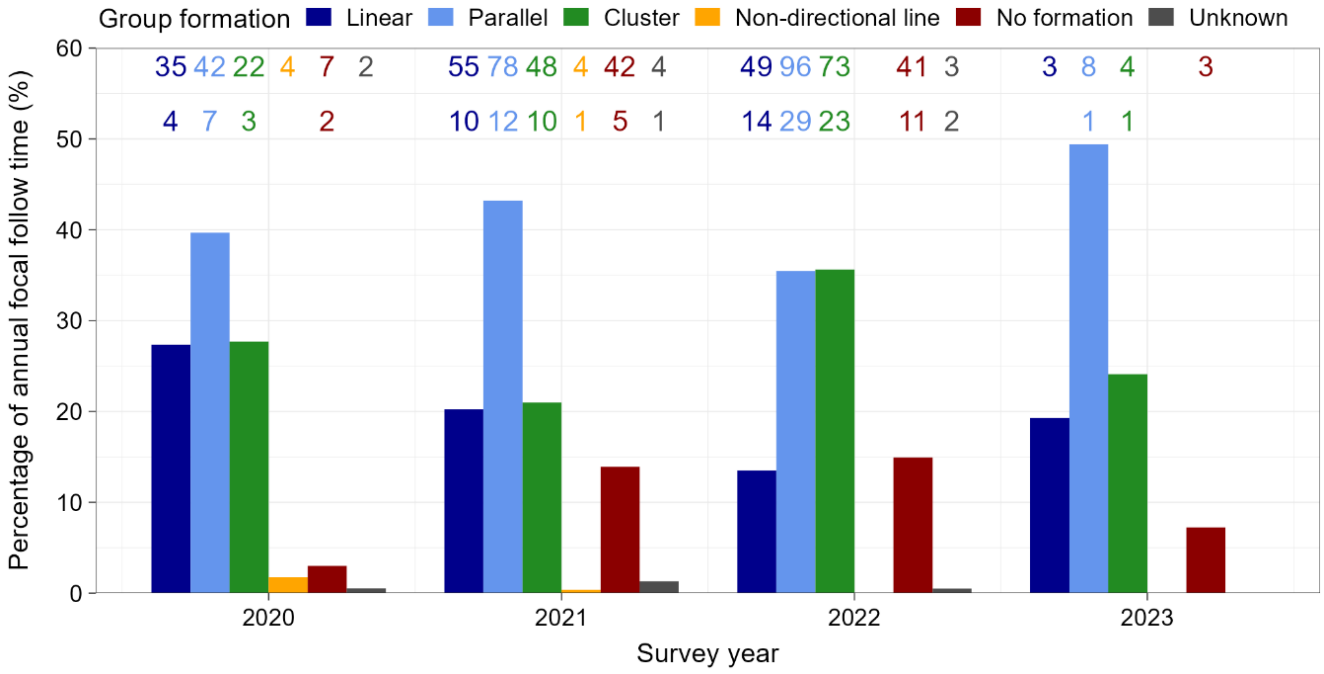

Figure 5-55: Group formation recorded during focal follow surveys, 2020–2023. Sample size is shown as the number of unique focal follows in the absence of vessels (top row) and when vessels were present within 5 km from groups (second row).

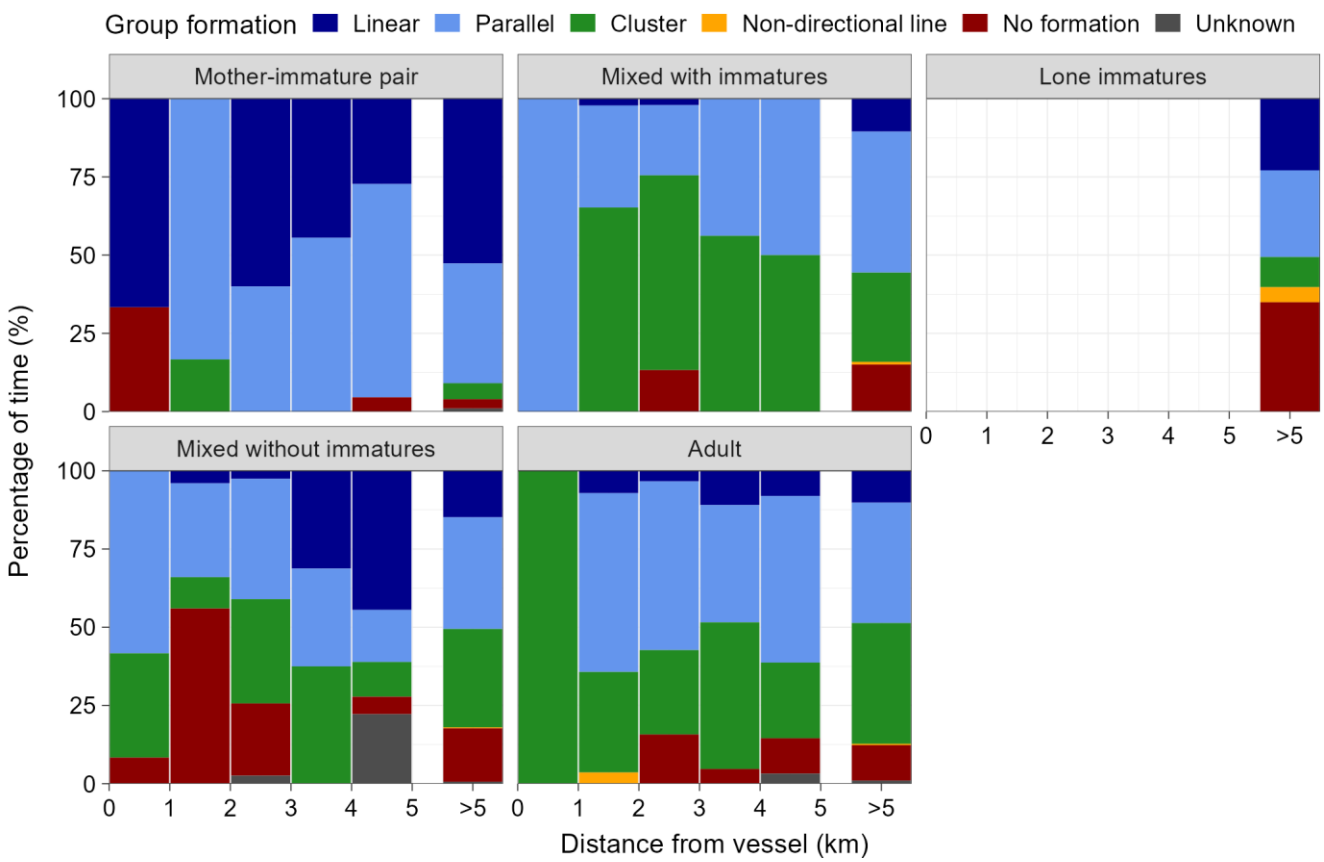

Figure 5-56: Percentage of time narwhal groups spent in each formation relative to distance from vessel, presented by group type (2020-2023).

In the statistical analysis of group formation, formations were binned into the following two categories: “parallel” and “linear, cluster, non-directional line and/or no formation”. In the model, the interaction between group type and distance from vessel was statistically significant (*P*=0.04), reflecting the differences in effects of vessels on group formation between the group types (Figure 5-57). Specifically, mother-immature pairs, mixed groups with immatures, and adult groups were less likely to be in parallel formation in close proximity to vessels, whereas mixed groups without immatures were more likely to be in parallel formation in close proximity to vessels than when vessels were farther away. Of the multiple comparisons between vessel absence and vessel presence at various distances, only comparisons for adult groups at 0.5 km and 1 km from vessels were significant (*P*=0.009 and *P*=0.01, respectively; Table 5-12), None of the other comparisons between the probability of parallel formation during vessel absence compared to vessels at distances within the exposure zone (≤5 km) were statistically significant for any of the other three groups (Table 5-12).

Effect sizes of the effect of vessels on narwhal at close proximity were small for mixed groups with immatures and mixed groups without immatures (-15% and +11%, respectively; Table 5-12 and Figure 5-57). Mother-immature pairs had medium effect sizes at 0.5 km and 1 km distances (-43% and -36%, respectively), while adult groups had large effect sizes at 0.5 km, 1 km, and 2 km distances (-98%, -95%, -64%, respectively). However, data at distances closer than 1 km were obtained from only one or two focal follow surveys per group type, which resulted in high uncertainty at close distances for most group types. Two of the four group types were estimated to have a medium to large effect size, based on decreases in odds of a parallel formation, when vessels were within 1.7 km (mother-immature pairs) and 2.6 km (adult groups), although most of these comparisons were not statistically significant.

The effect of group size was significant (*P*<0.001), with larger groups being significantly less likely to be found in parallel formation than smaller groups (Figure 5-58). The effect of primary behaviour was also significant (*P*<0.001), where groups engaged in traveling were significantly more likely to be in parallel formation than either groups resting/milling or groups engaged in social interactions (*P*<0.001 for both, effect sizes of +232% and +352%, respectively). The effects of water clarity and Beaufort values were not significant (*P*>0.4 for both).

The statistical power to estimate the observed effect sizes of distance from vessel on group formation (ranging between -98% and +11%) was low (<0.7; see Appendix A). The observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model only had sufficient power (≥0.8) to detect an effect size of +1,150% or larger (see Appendix A). This effect size corresponded to an increase in probability of parallel formation of a group from 0.295 to 0.840 for mother-immature pairs, from 0.341 to 0.866 for mixed groups with immatures, from 0.419 to 0.900 for mixed groups without immatures, and from 0.416 to 0.899 for adult groups.

In summary, there was some evidence that narwhal may alter their group formation when in close proximity to vessel traffic but the effect was not consistent across group types. The estimated effect was strongest for adults, where there was a large (>50%) and statistically significant effect on the probability of parallel formation when within 1 km of a vessel. For all other three group types, the effect of vessels on group formation was not statistically significant, and small (<25% for mixed groups with immatures or without immatures) or medium (<50% for mother-immature pairs) when narwhal were within 1 km of a vessel.

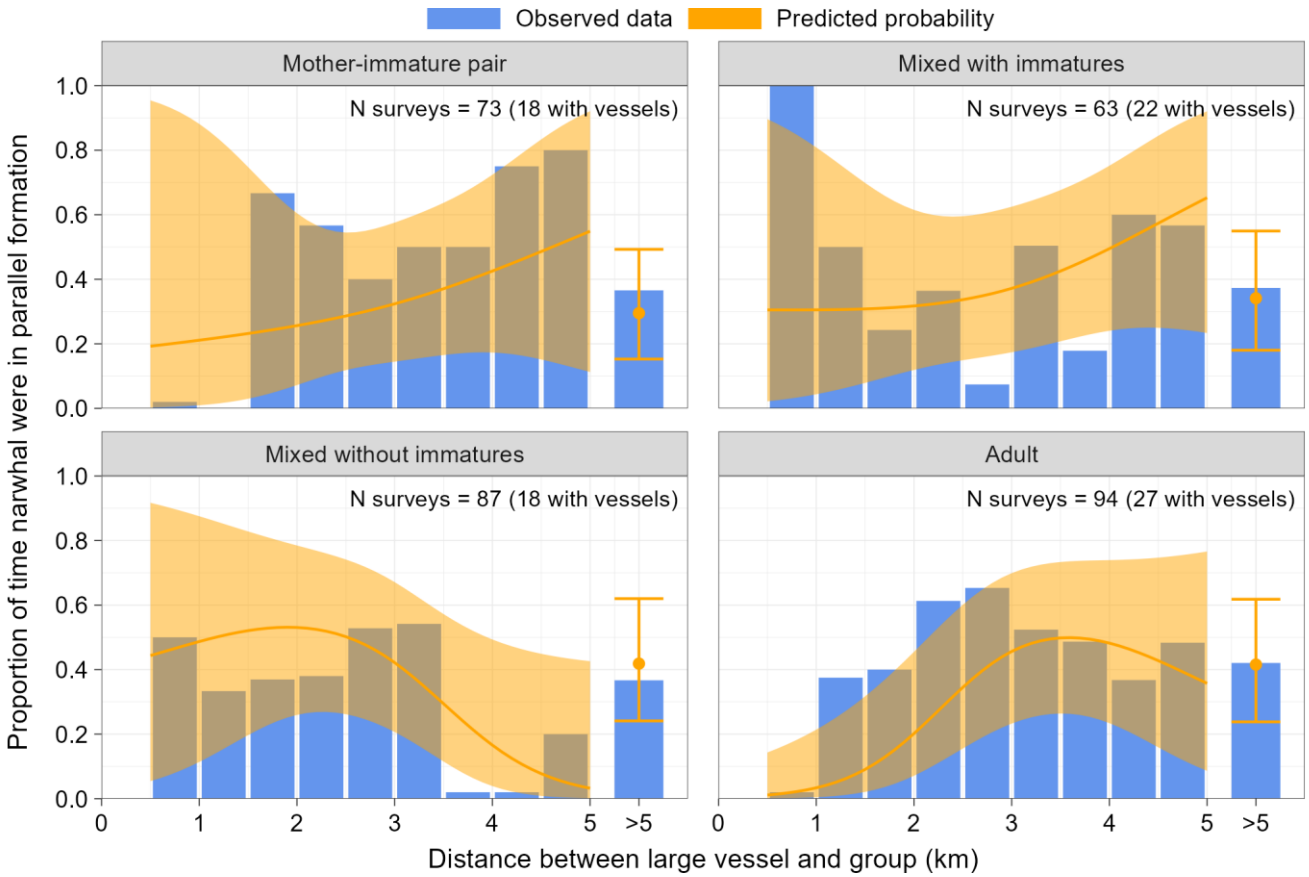

Figure 5-57: Observed proportion of time (bars) and estimated probability (curve and points) that narwhal groups were in parallel formation as a function of distance (rounded up to nearest 0.5 km value) from vessel, presented by group type, 2020–2023.

Notes: observed data depict the between-surveys average proportion of time groups were observed in parallel formation at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant

Table 5-12: Effect sizes and multiple comparisons of predicted probability of observing groups in parallel formation between vessel exposure (0.5 to 5 km distances) and non-exposure periods (>5 km). Statistically significant values shown in bold.

Distance from vessel (km)	Multiple comparisons to no-exposure – effect sizes (%) with *p* values in brackets			
	Mother-immature pair	Mixed with immatures	Mixed without immatures	Adult
0.5	-43% (1.0)	-15% (1.0)	+11% (1.0)	**-98% (0.009)**
1	-36% (1.0)	-15% (1.0)	+32% (1.0)	**-95% (0.01)**
2	-18% (1.0)	-10% (1.0)	+57% (0.8)	-64% (0.1)
3	+14% (1.0)	+14% (1.0)	+1% (1. 0)	+18% (1.0)
4	+77% (0.7)	+89% (0.4)	-72% (0.3)	+31% (0.9)
5	+191% (0.8)	+263% (0.4)	-95% (0.2)	-22% (1.0)

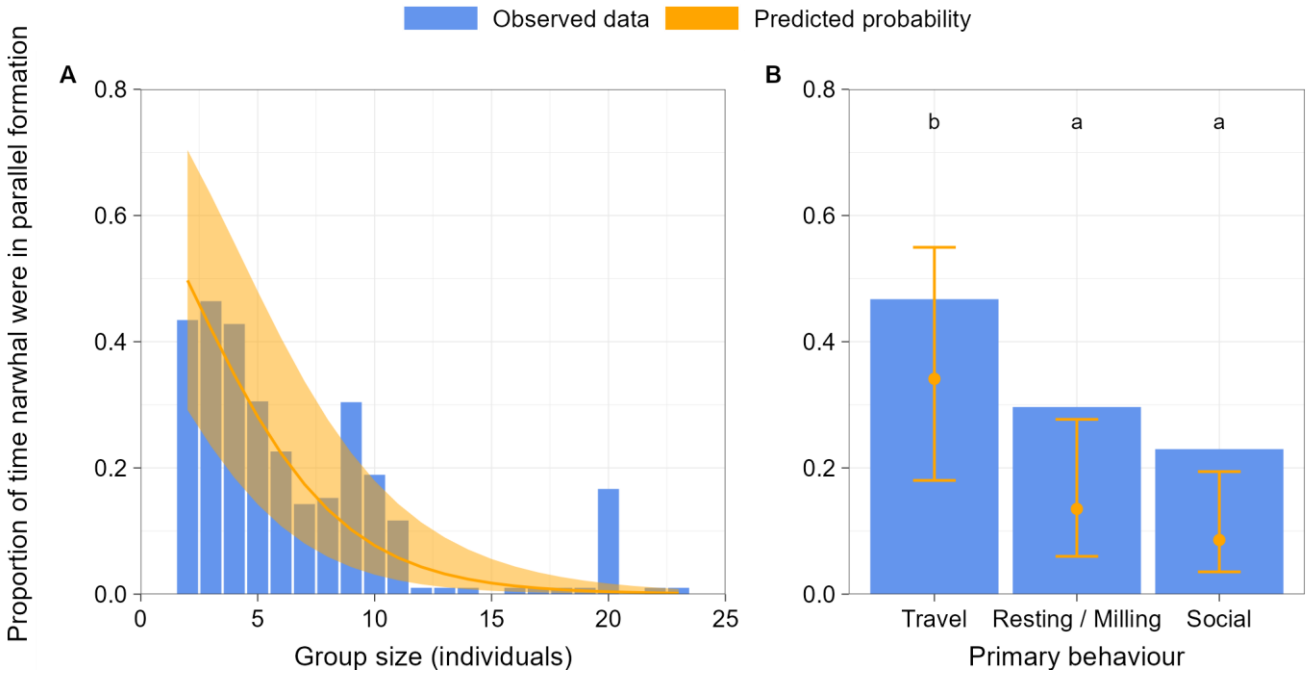

Figure 5-58: Observed proportion of time (bars) and estimated probability (curve and points) that narwhal groups were in parallel formation as a function of group size (Panel A) and primary behaviour (Panel B) , 2020–2023.

Notes: observed data depict the between-surveys average proportion of time groups were observed in parallel formation at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant

5.6.6 Group Spread

Of the followed groups, much of the data were collected on groups of a single individual, with values of percent time ranging from 19% (2022) to 42% (2020 and 2021). The remaining time, groups were more often found in loose than in tight association (Figure 5-59). For groups of two individuals or more, values of percent time spent in tight spread ranged from 30% (2023) to 48% (2020), while percent time spent in loose association ranged from 52% (2020) to 70% (2023). During vessel exposure periods, narwhal groups of two or more individuals tended to spend similar time in tightly associated groups (39%) compared to non-exposure periods (45%). This finding was inconsistent with results obtained from the integrated shore-based monitoring dataset between 2014 and 2021 which found that narwhal formed tighter groups in close proximity (≤2 km) to vessels (Golder 2022).

For groups with immatures, mother-immature pairs were generally observed tightly associated, whether in the absence (78% of the time) or presence of vessels (63–96% of the time, depending on distance; Figure 5-60). In comparison, mixed groups with immatures were mostly observed loosely associated, whether in the absence (72%) or presence of vessels (54–100% of the time, depending on distance). Lone immatures were usually in a group of a single individual (82% of time when vessels were absent and 100% of time when vessels were present, although sample size was limited to four focal follows with vessels present). When groups of two or more lone immatures were recorded, they were most commonly recorded to be tightly associated (53% of time when vessels were absent); groups of two or more immatures were not recorded during vessel exposure periods.

For groups without immatures, mixed groups of two or more individuals were most likely to be loosely associated in the absence of vessels (54%), but their spread varied in the presence of vessels (28–67% loosely associated, depending on distance from vessel). Adult-only groups were often a single animal (52% of the time when vessels were absent and 28–70% of the time when vessels were present, depending on distance from vessel). When adult-only groups had at least two individuals, groups were most commonly recorded loosely associated with one another (70% of time when vessels were absent and 60–100% of the time when vessels were present, depending on distance from vessel).

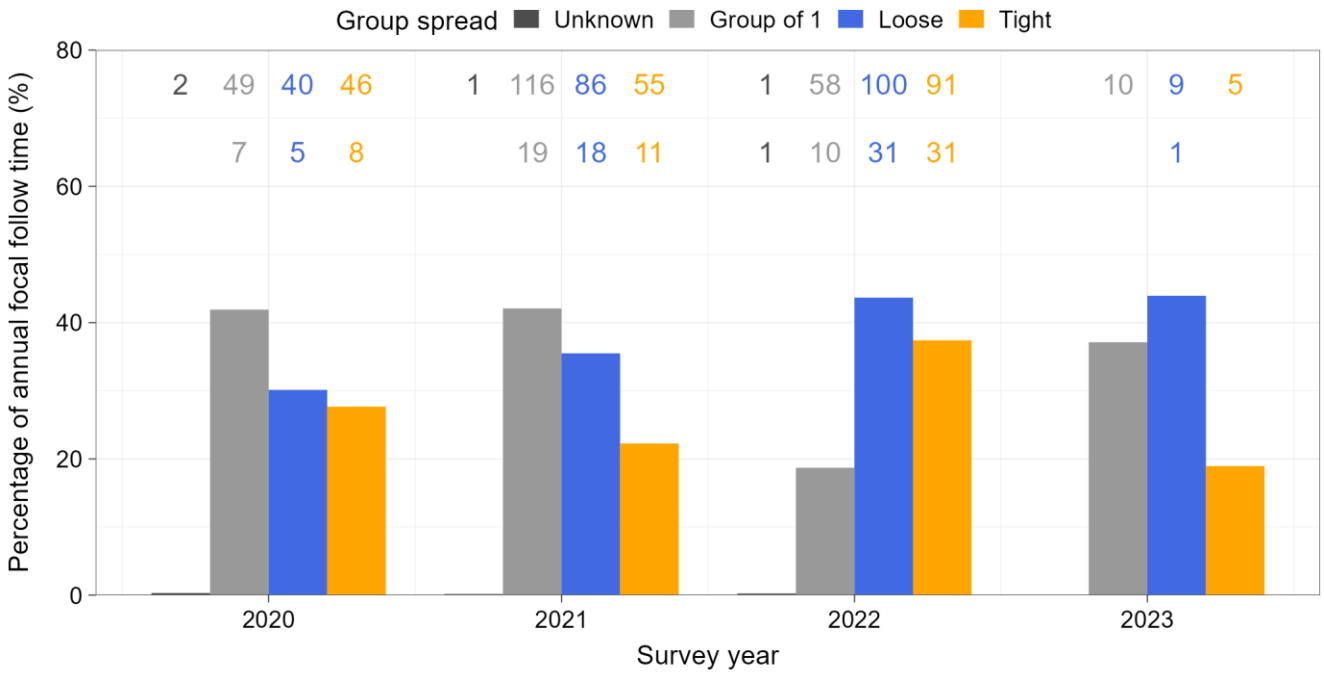

Figure 5-59: Group spread recorded during focal follow surveys, 2020–2023. Sample size is shown as the number of unique focal follows in the absence of vessels (top row) and when vessels were present within 5 km from groups (second row).

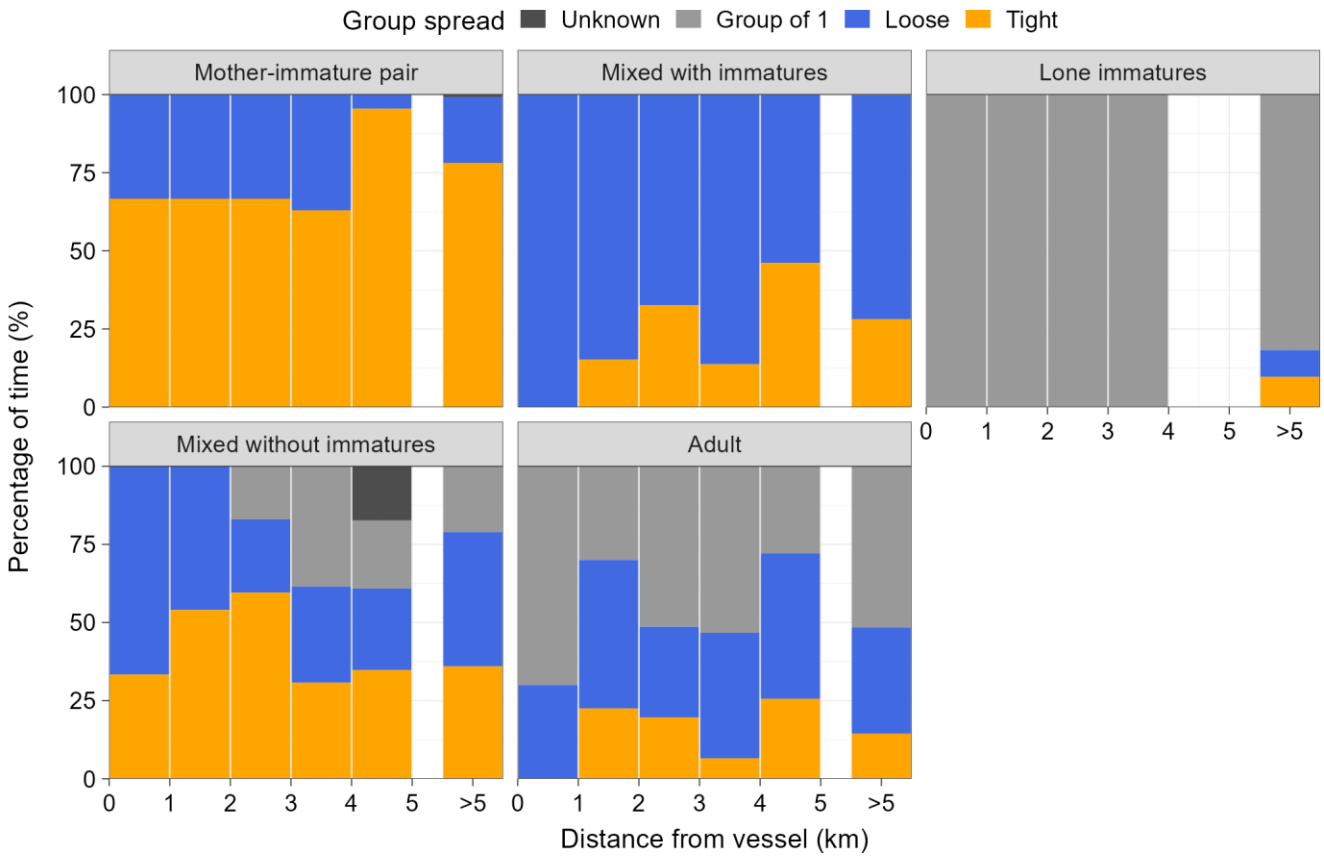

Figure 5-60: Percentage of time narwhal groups tightly associated relative to distance from vessel, presented by group type.

In the analysis of group spread, the effect of distance from vessel was significant (*P*=0.002), reflecting the trends with distance (Figure 5-61). The probability of groups in a tight association was lowest in close proximity to vessels, peaked between 2 and 3 km away from vessels, then decreased to the probability estimated when no vessels were present within 5 km from the group. None of the multiple comparisons between vessel absence and vessel presence at various distances were significant (*P*>0.05 for all; Table 5-7). Effect sizes were large (≥50% in absolute value; see Section 4.3.2.1) when vessels were within 3 km (-90%, -64%, +134%, and +73% at 0.5, 1, 2, and 3 km from a vessel, respectively) when compared to when no vessels were present within 5 km (Table 5-7). That is, the odds of a group to be in tight association were 90% lower at 0.5 km from a vessel compared to when no vessels were present. The effect sizes of decreased below ±25% at a distance of 3.3 km, suggesting that the effect of vessels was small when vessels were farther than 3.3 km from narwhal groups.

The effect of group type was statistically significant (*P*<0.001). The probability of a tight association was significantly higher for mother-immature pairs than for other groups (*P*<0.001, with effect sizes ranging from +934% for comparison with mixed groups without immatures to +4,277 for comparison with adult groups; Figure 5-61).

The effects of primary behaviour, group size, and Beaufort scale values were significant (*P*<0.001, *P*<0.001, *P*=0.003, respectively). Note that due to sample size limitations, Beaufort scale values were binned such that all values of 3 or larger were collapsed into a single bin, resulting in Beaufort values of 0, 1, 2, and ≥2 that were used in the analysis. The probability of a tight association was significantly higher for groups engaging in social behaviour than in either traveling or resting/milling activities (P<0.001 for both, effect sizes of +663% and +950%, respectively; Figure 5-62). The probability of a tight association decreased with group size (from 0.851 at group size of two to 0.678 at group size of five; effect size of -31%; Figure 5-62). However, data on large groups came from a limited set of focal follow surveys, with only 20 surveys having group sizes of more than 10 narwhal, and only seven surveys having groups sizes of more than 15 narwhal. The odds of tight association were significantly higher when Beaufort values were 0 (i.e., calm) compared to when Beaufort values were 2 or larger (*P*=0.01, *P*=0.005, respectively, with effect sizes of +588% and +1,444%, respectively). None of the other comparisons between Beaufort scale values were significant (*P*>0.1 for all).

The statistical power to estimate the observed effect size of distance of vessel on group spread was low (<0.5; see Appendix A). That is, the observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model had sufficient power (≥0.8) to detect an effect size >+3,250% (see Appendix A). This effect size corresponded to the increase in probability of tight spread of a group from 0.945 to 0.998 for mother-immature pairs, from 0.434 to 0.963 for mixed groups with immatures, from 0.622 to 0.982 for mixed groups without immatures, and from 0.280 to 0.929 for adult groups.

In summary, the results indicate a non-statistically significant but potentially large effect of vessels on the frequency of a tight group spread when vessels were within 3 km of narwhal groups. However, the estimated effect sizes suggested that tight group association was less frequent at close distances from vessels (0.5 and 1 km) but more frequent when vessels were 2 to 3 km away. The inconsistent direction of the effect, and lack of statistical significance due to high uncertainty in the estimated relationship mean that strong conclusions about the effect of vessels on group spread cannot be drawn based on the available data.

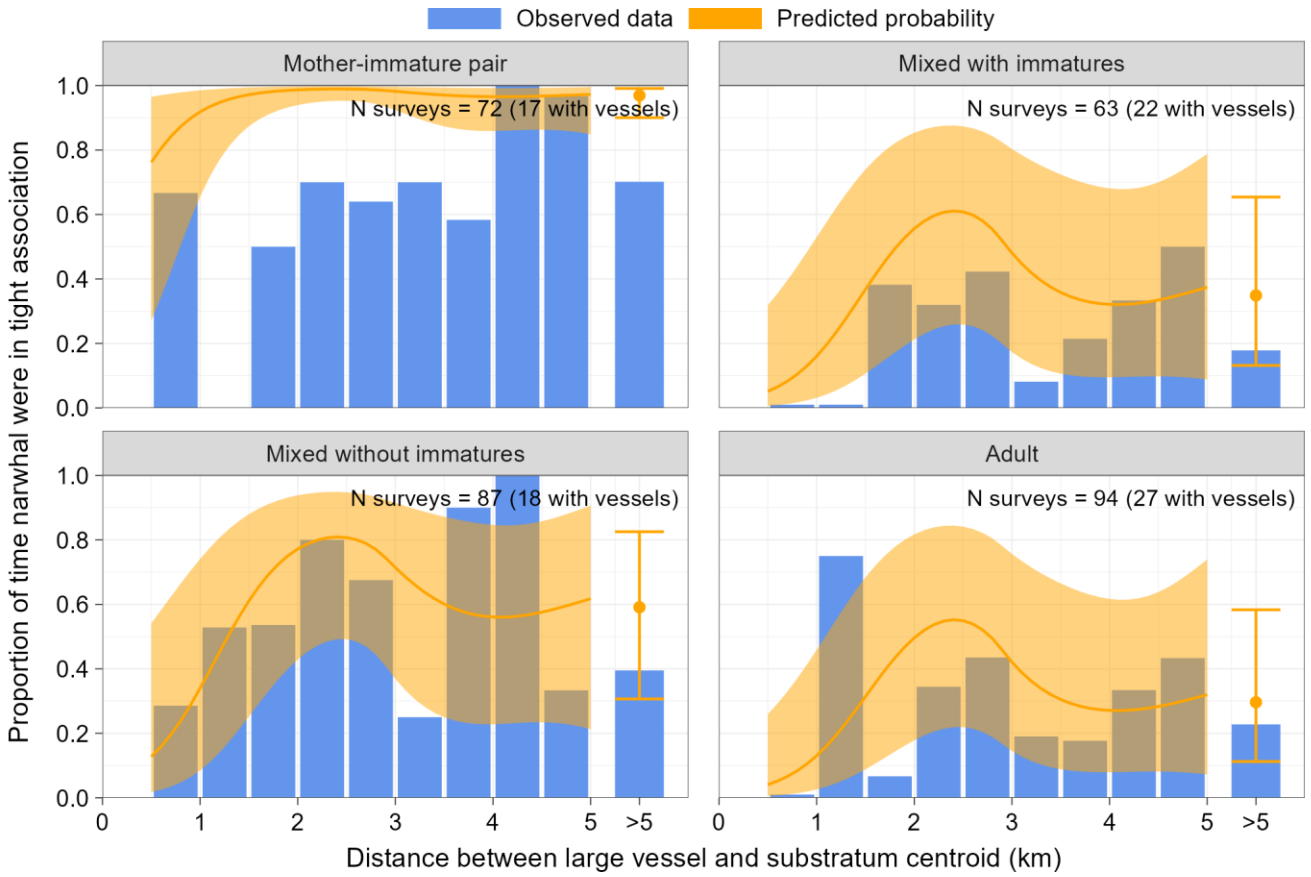

Figure 5-61: Observed proportion of time (bars) and estimated probability (curve and points) that narwhal groups were tightly associated (rather than loosely associated) as a function of distance from vessel, presented by group type, 2020–2023.

Notes: observed data depict the between-surveys average proportion of time groups were observed a tight spread (rather than at loose spread) at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant.

Table 5-13: Effect sizes and multiple comparisons of predicted probability of observing groups tightly associated (rather than loosely associated) between vessel exposure (0.5 to 5 km distances) and non-exposure periods (>5 km). Statistically significant values shown in bold.

Distance from vessel (km)	Multiple comparisons to no-exposure – effect sizes (%) with *p* values in brackets
	All groups
0.5	-90% (0.06)
1	-64% (0.4)
2	+134% (0.4)
3	+73% (0. 7)
4	-12% (1.0)
5	+12% (1.0)

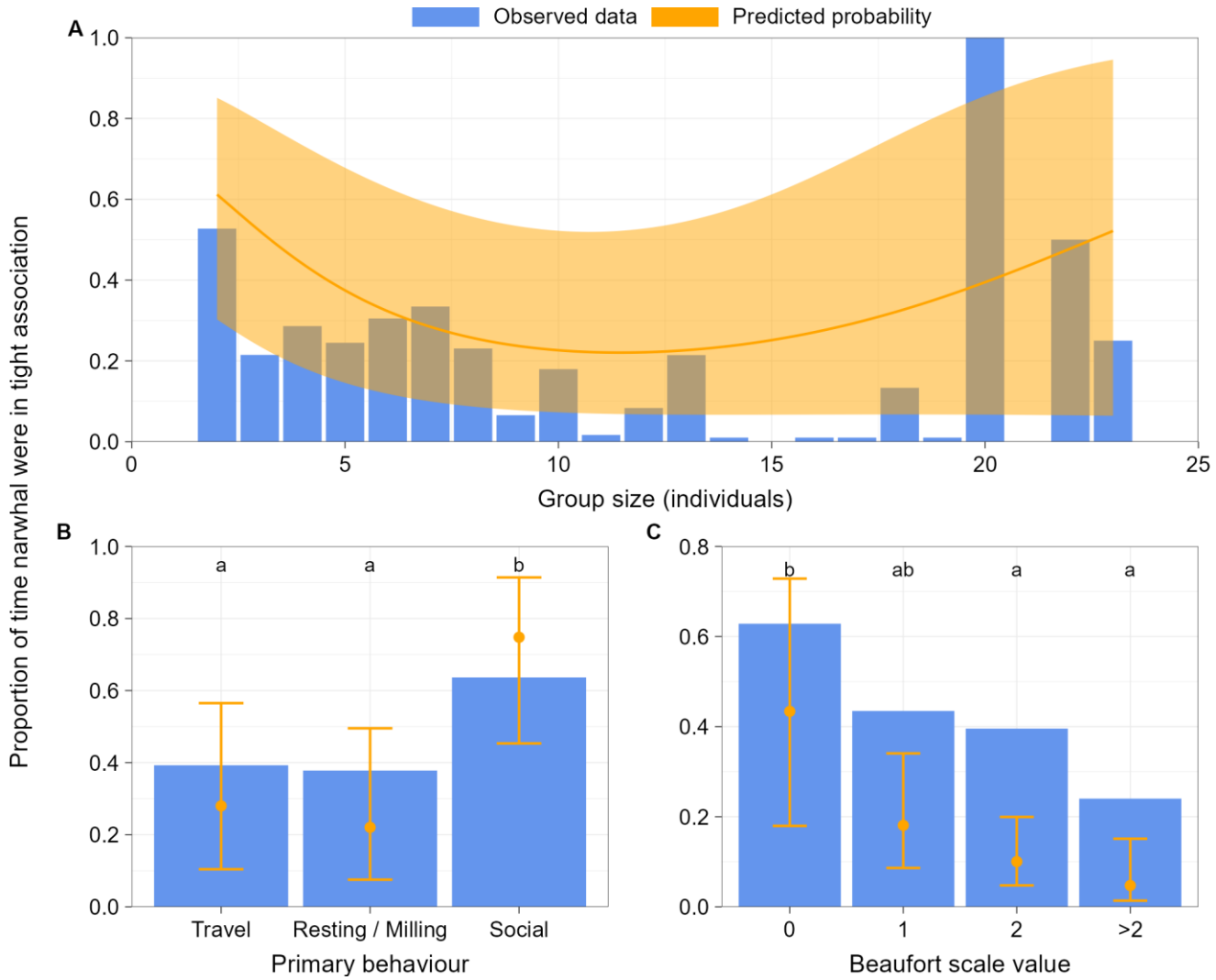

Figure 5-62: Observed proportion of time (bars) and estimated probability (curve and points) that narwhal groups were tightly associated (rather than loosely associated) as a function of narwhal group size (Panel A), primary behaviour (Panel B), and Beaufort scale values (Panel C), 2020–2023.

Notes: observed data depict the between-surveys average proportion of time groups were observed a tight spread (rather than at loose spread) at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant.

5.6.7 Group Size

The majority of the focal follow surveys conducted consisted of small group sizes (Figure 5-63). Focal groups of one or two individuals accounted for 211 of the 412 focal follow surveys conducted (51%). Groups of one or two individuals accounted for 176 of the 335 surveys undertaken when vessels were not present within the 5 km exposure cut-off (53%), and for 40 of the 87 surveys that were undertaken when no vessels were present (46%). Because vessel exposure is limited to a defined spatial zone (i.e., <5 km from the focal group), many of the focal follow surveys collected data during both vessel exposure and non-exposure periods. Groups larger than 10 narwhal were recorded during 20 of the focal follow surveys; four in 2020 (maximum group sizes of 11–13 individuals), three in 2021 (maximum group sizes of 11–18 individuals), 12 in 2022 (maximum group sizes of 11–

23), and one in 2023 (11 individuals). In the absence of vessels, the median value of maximum group size was two narwhal, and the mean group size was 3.5 narwhal (SD of 3.2 narwhal). When vessels were present, the median value of maximal group size was three narwhal, and the mean group size was 3.8 narwhal (SD of 3.7 narwhal). In 2023, recorded group sizes were similar to those recorded in 2020–2022 (Figure 5-63). Conclusions about the overall effect of vessels on group size should not be drawn from these data summaries due to non-random selection of focal groups (i.e., from 2021 onward, focus was placed on following mother-immature pairs) and due to the statistics above not being summarized by group type. The statistical analysis of group size below did incorporate a group type effect, and hence was not affected by the non-random selection of groups.

Mixed groups with immatures tended to be larger than other group types, followed by mixed groups without immatures, mother-immature pairs and adult-only groups (Figure 5-64). In the absence of vessels, mixed groups with immatures had an average maximum group size of 5.4 individuals, compared with 4.4 individuals for mixed groups without immatures, 2.4 individuals for mother-immature pairs, and 2.5 individuals for adult-only groups. Maximum group size of adult groups increased slightly with vessel distance (for example, increasing from 2.3 individuals at 1–2 km to 3.2 individuals at 4–5 km). In comparison, maximum group size of mixed groups without immatures decreased with distance from vessel, from 3.8 individuals at 1–2 km to 2.4 individuals at 4–5 km from vessels. Lone immature focal follow surveys were typically of a single immature (38 of 41 focal follow surveys with lone immatures).

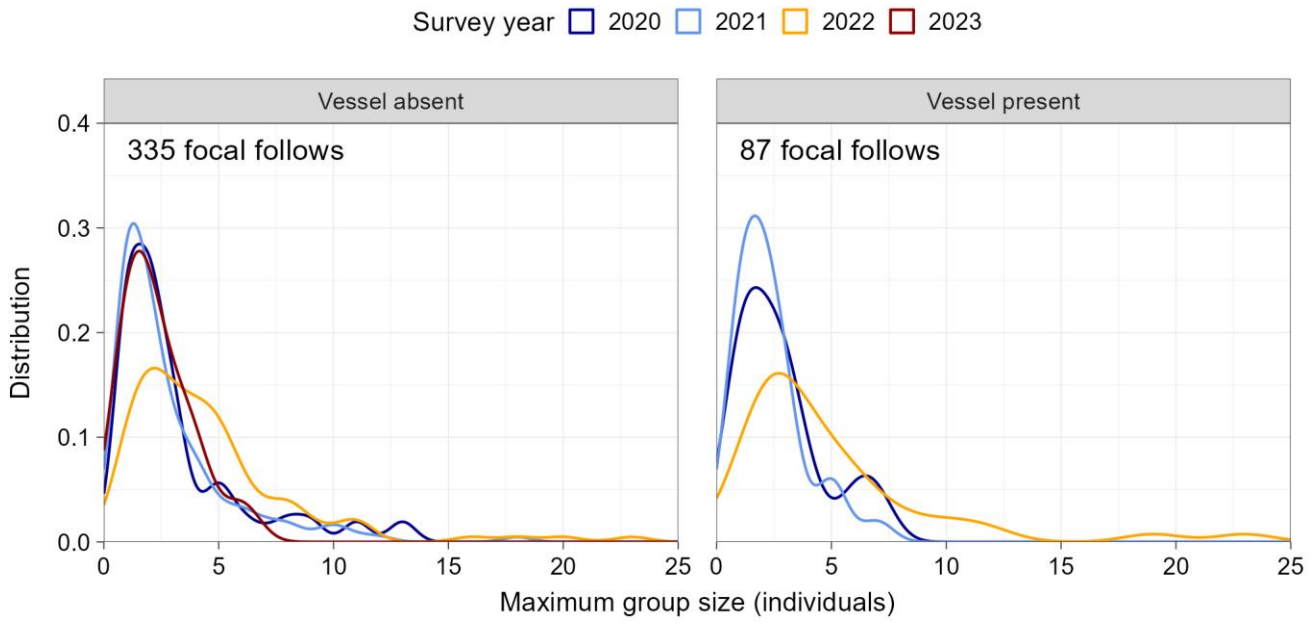

Figure 5-63: Maximum narwhal group size during focal follow surveys relative to vessel presence, 2020–2023. During the single 2023 focal follow with a vessel present within 5 km from the group, maximum group size was 11 individuals. Sample size is shown as the number of unique focal follows.

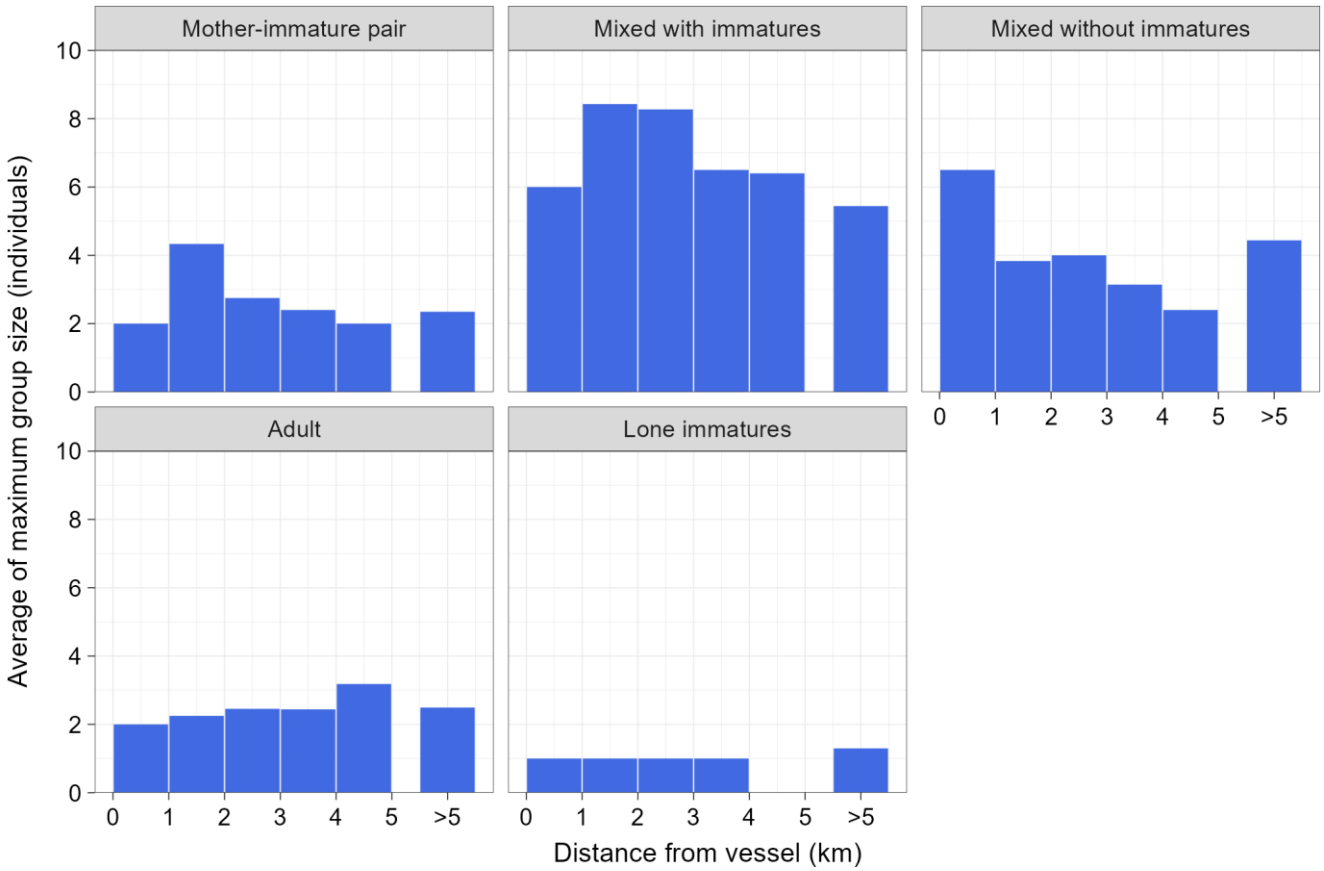

Figure 5-64: Average of maximum narwhal group size during focal follow surveys relative to distance from vessel in 2020–2023, presented by group type.

The statistical analysis of group size was performed separately for each of the following group types: mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups (lone immatures were removed from analysis). The effect of distance from vessel was significant for mixed groups with immatures (P=0.02), but not for any of the other groups (P>0.4 for all). Observed effect sizes at close proximity (0.5 km) were small (between +2% and +24%; Table 5-14) for all group types, except for mother-immature pairs with more than two narwhal, where the effect size was estimated to be +28%. This effect size corresponded to the increase in the group size of mother-immature pairs with more than two narwhal from 2.6 individuals when no vessels were present to 3.3 narwhal at 0.5 km from vessels. However, data on mother-immature pair groups with more than two narwhal in the presence of vessels were limited to distances greater than 1.6 km, and the estimation of an effect size at a distance of 0.5 km from a vessel was based solely on modeling predictions. Data from mother-immature pairs that were collected in close proximity to vessels (CPA = 0.66 km) only included groups with two individuals. That is, vessel distance data were available for mother-immature groups with only two individuals, which accounted for most of the mother-immature pair data (79% of all mother-immature pair focal follow surveys).

The effect size estimated for mother-immature pairs (+28% at 0.5 km) decreased below the cutoff value for a medium effect size (≥25% in absolute value; see Section 4.3.2.1) when vessels were at 3.0 km (effect size of +22% at 3 km from a vessel) when compared to when no vessels were present within 5 km. For mixed groups without immatures, effect sizes were small, estimated at +17% at 0.5 km from vessels. For adult groups, effect sizes were small, estimated at +8% at 0.5 km from vessels. For mixed groups with immatures, for which the effect of distance was significant in the model, effect size at 0.5 km was 2%, which is smaller than the cutoff value for a small effect size (≥10% in absolute value; see Section 4.3.2.1). The significance of the overall effect of vessel distance for this group type was likely caused by the increase in group size at 2–2.5 km from vessels (effect size of +37%, Figure 5-65). Although this is likely a spurious finding, the spatial extent of these medium effect sizes was between 1.4 and 2.8 km (effect size of +25% for both). That is, possible effects of vessels were estimated for mother-immature pairs and mixed groups with immatures. For these groups, effect sizes were small when vessels were farther than 3.0 km from groups.

Statistical power was sufficient to effect sizes of -67% or +110% of vessels on group size for adult groups, while for other group types, larger absolute effect sizes were required for sufficient power (see Appendix A). Although statistical power was low, most observed effect sizes in the analysis were small. The small effect sizes and lack of statistical significance for three of four group types suggest that there are little, if any, effect of vessel distance on group sizes for mixed groups with immatures, mixed groups without immatures, and adult groups, based on the available data. Additional data collected for mother-immature pair groups in close proximity to vessels will be required to confirm effect size of this group type with group size larger than two.

In summary, the results do not suggest a strong or consistent effect of vessels on group size of narwhal, based on the available data. One exception was for mother-immature pairs, for which there was medium (≥25%) increase in group size when within 3 km of vessels, although the effect was not statistically significant and was based on a limited sample size. For the other group types, effect sizes were small and do not suggest a biologically significant effect of vessels on group size.

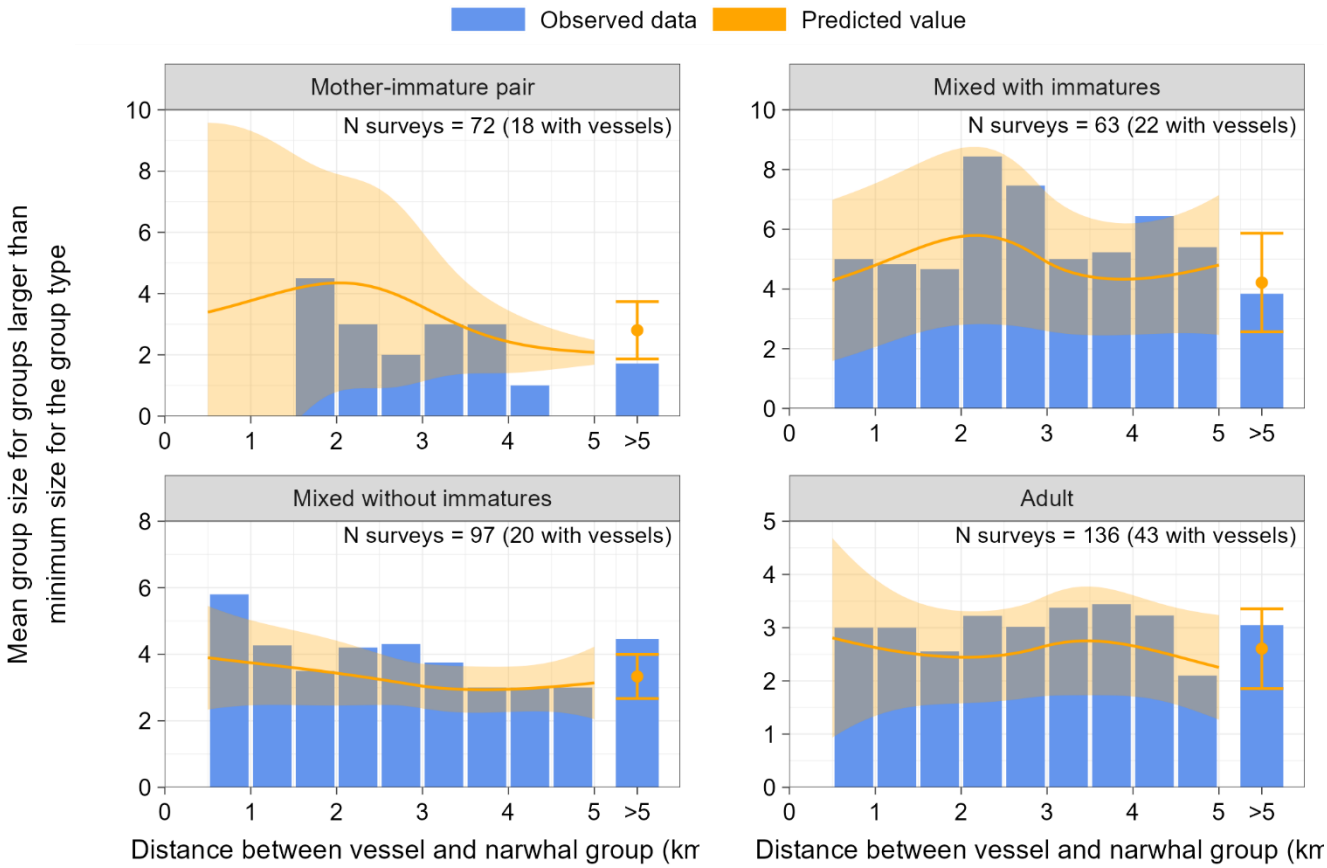

Figure 5-65: Observed (bars) and estimated (curves and points) mean group size for groups larger than minimum size for the group type as a function of distance (rounded up to nearest 0.5 km value) from vessel, presented by group type, 2020–2023.

Notes: observed data depict the between-surveys average group size at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant.

Table 5-14: Effect sizes and multiple comparisons (for groups with a significant effect of distance) of group size between vessel exposure (0.5 to 5 km distances) and non-exposure periods (>5 km). Statistically significant values shown in bold.

Distance from vessel (km)	Multiple comparisons to no-exposure – Effect sizes (%) with *p* values in brackets			
	Mother-immature pair	Mixed with immatures	Mixed without immatures	Adult
0.5	+28%	+2% (1.0)	+24%	+8%
1	+37%	+14% (0.9)	+18%	+1%
2	+46%	**+37% (0.02)**	+4%	-6%
3	+22%	+16% (0.5)	-12%	+2%
4	-9%	+3% (1.0)	-17%	+2%
5	-19%	+14% (0.7)	-8%	-13%

5.6.8 Group Travel Speed

Narwhal travel speed calculated for each time segment within the focal follow surveys ranged from 0 m/s to 3.7 m/s (mean of 0.9 m/s, SD of 0.5 m/s). For data visualization, these speeds were averaged within each survey, to provide a single travel speed for each focal follow. Mean speed calculated for individual focal follows ranged from 0.2 m/s to 2.5 m/s (mean of 1.0 m/s, SD = 0.4 m/s; Figure 5-66). When vessels were absent, mean travel speed of narwhal groups was 1.0 m/s (min = 0.2 m/s, max = 2.5 m/s, SD = 0.5). When vessels were present within 5 km from groups, mean travel speed was 0.9 m/s (min = 0.2, max = 1.9, SD = 0.4). Overall, of the assessed group types, travel speed was lowest for lone immatures (mean of 0.8 m/s) and highest for adult groups (1.0 m/s).

For groups with immatures, mother-immature pairs travelled at an average speed of 0.87 m/s in the absence of vessels and at speeds ranging from 0.52 m/s to 1.18 m/s when vessels were present, depending on distance (Figure 5-67); for these groups, no data were available for distances closer than 1.6 km from vessels. Mixed groups with immatures travelled at an average speed of 1.01 m/s in the absence of vessels and at speeds ranging from 0.90–1.07 m/s when vessels were present, depending on distance. Lone immatures travelled at an average speed of 0.79 m/s in the absence of vessels and at speeds ranging from 0.65–0.76 m/s when vessels were present, depending on distance, however only limited data were available for lone immature travel speed in presence of vessels.

For groups without immatures, mixed groups without immatures travelled at an average speed of 0.90 m/s in the absence of vessels and at speeds ranging from 0.86–1.11 m/s when vessels were present, depending on distance. Finally, adult-only groups travelled at an average speed of 1.05 m/s in the absence of vessels and at speeds ranging from 0.96 m/s to 1.90 m/s when vessels were present, depending on distance.

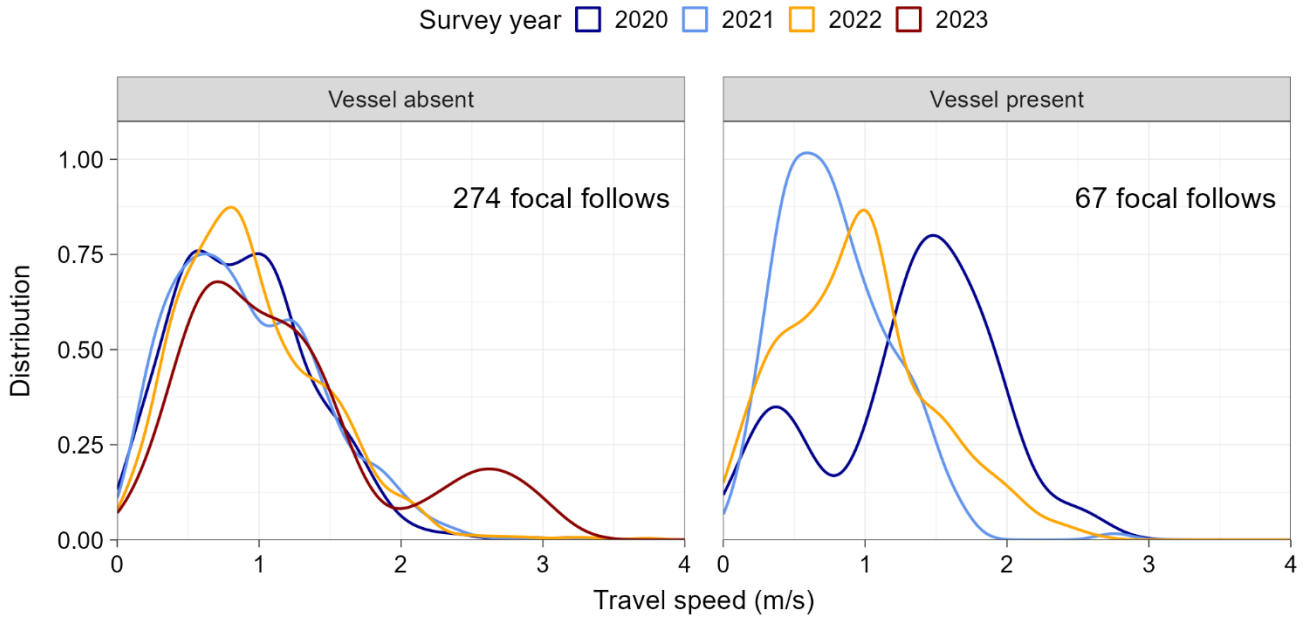

Figure 5-66: Mean travel speed of narwhal focal groups relative to vessel presence, 2020–2023. Sample size is shown as the number of unique focal follows.

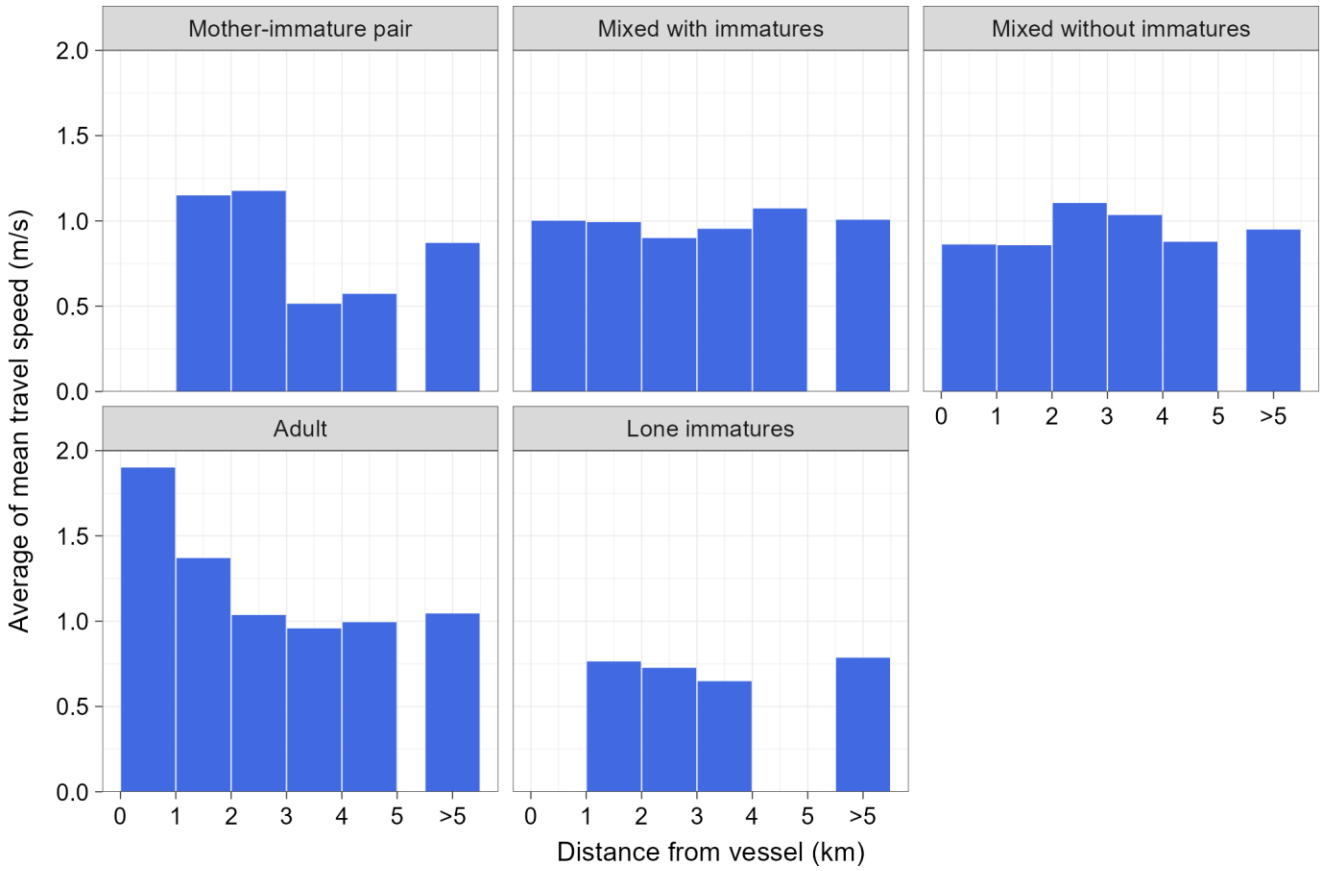

Figure 5-67: Travel speed of narwhal focal groups relative to vessel presence, by group type, 2020–2023.

In the statistical analysis of group travel speed, the interaction between group type and distance from vessel was not significant (*P*=0.2), indicating no difference in the effect of vessel distance on travel speed between group types. The effect of group type was also not significant (*P*=0.2), indicating no difference in speed between group types. The effect of distance from vessel was significant (*P*=0.005), likely due to the stronger trends estimated for adult and mixed groups with immatures (Figure 5-68). For mother-immature groups, mixed groups with immatures, and adult groups, travel speed was estimated to be highest in proximity to vessels, decreasing to lower speeds with greater distance from vessels. Of the multiple comparisons between vessel absence and vessel presence at various distances, the estimates for adult groups at 0.5 km and 1 km from vessels were significantly different from when no vessels were present (*P*=0.004 and *P*=0.03, respectively; Table 5-15). In addition, the estimates for mixed groups with immatures at 2 km were significantly different from when no vessels were present (*P*=0.04; Table 5-15). No significant differences were found for mixed groups without immatures. For mother-immature pairs, data in close proximity to vessels were not available (Figure 5-68).

Effect sizes were medium (≥25% in absolute value; see Section 4.3.2.1) or large (≥50%) when vessels were within 2 km from a mixed group with immatures (+38% at 0.5 km and -27% at 2 km) or within 1 km from adult groups when compared to when no vessels were present within 5 km (+64% and +35%, respectively; Table 5-15). The travel speeds of a group with immatures and a group of adults were 38% and 64% higher, respectively, at 0.5 km from a vessel compared to when no vessels were present. The absolute values of effect sizes decreased below 25% at a distance of 0.8 km and 1.2 km from vessels for groups with immatures and adult groups, respectively. That is, the effect of shipping was small across all group types when vessels were farther than 1.2 km from groups.

The effect of primary behaviour was significant (*P*<0.001), with travel speed estimated to be 49% higher for narwhal whose primary behaviour was “travel” compared to narwhal whose primary behaviour was resting / milling or social (Figure 5-69). The overall effect of Beaufort scale was significant (*P*<0.001), with travel speed significantly faster at Beaufort values larger than 2 compared to values of 0, 1, and 2 (*P*<0.001 for all, effect sizes of 56%, 33%, and 32%, respectively). None of the other comparisons were significant (*P*>0.2 for all; maximum effect size of 18%). Note that due to sample size limitations, Beaufort scale values were binned such that all values of 3 or larger were collapsed into a single bin, resulting in Beaufort values of 0, 1, 2, and ≥2 that were used in the analysis.

The statistical power was sufficient (≥0.8) to detect effect sizes of ±37% (37% increase or decrease in travel speed relative to values when no vessels were present within 5 km from a group; see Appendix A). This corresponds to a change of ±0.34 m/s and ±0.33 m/s for mother-immature pairs and mixed groups with immatures, respectively, ±0.36 m/s for mixed groups without immatures, and ±0.35 m/s for adult groups. Overall, the analysis had sufficient power to detect the observed effect sizes for three of the four group types.

In summary, the results support an effect of vessel distance on narwhal travel speed when vessels were within 1 km of narwhal groups. When vessels were within 1 km, adult groups and mixed groups with immatures travelled approximately 35% to 64% faster than when vessels were not present, however there was no effect on travel speed for mixed groups without immatures, and no data for this comparison for mother-immature pairs. Overall, the data suggest an effect of vessels in close proximity on travel speed of narwhal, with the strongest evidence for groups of adults, but additional data would be needed to confirm whether this effect may also exist for other group types.

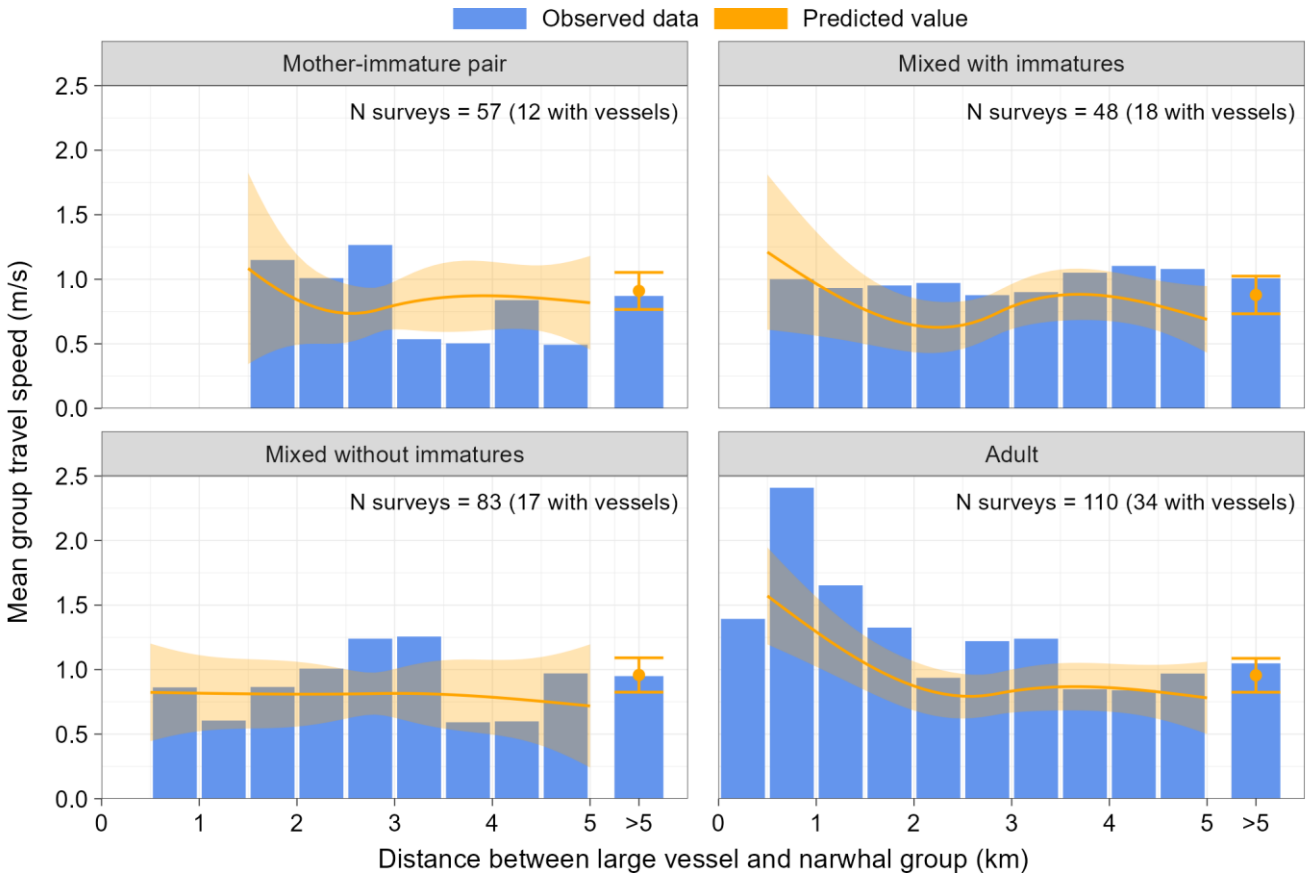

Figure 5-68: Observed (bars) and estimated (curves and points) group travel speed as a function of distance (rounded up to nearest 0.5 km value) from vessel, plotted by group type, 2020–2023.

Notes: observed data depict the between-surveys average group travel speed at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant

Table 5-15: Effect sizes and multiple comparisons of predicted travel speed between vessel exposure (0.5 to 5 km distances) and non-exposure periods (>5 km). Statistically significant values shown in bold.

Distance from vessel (km)	Multiple comparisons to no-exposure – Effect sizes (%) with *p* values in brackets			
	Mother-immature pair	Mixed with immatures	Mixed without immatures	Adult
0.5	**No observed data**	+38% (0.7)	-14% (0.9)	**+64% (0.004)**
1		+10% (1.0)	-15% (0.8)	**+35% (0.03)**
2	-7% (1.0)	**-27% (0.04)**	-16% (0.6)	-9% (0.7)
3	-12% (0.4)	-10% (0.4)	-15% (0.2)	-13% (0.1)
4	-4% (1.0)	-1% (1.0)	-18% (0.6)	-10% (0.5)
5	-10% (1.0)	-22% (0.4)	-25% (0.8)	-18% (0.5)

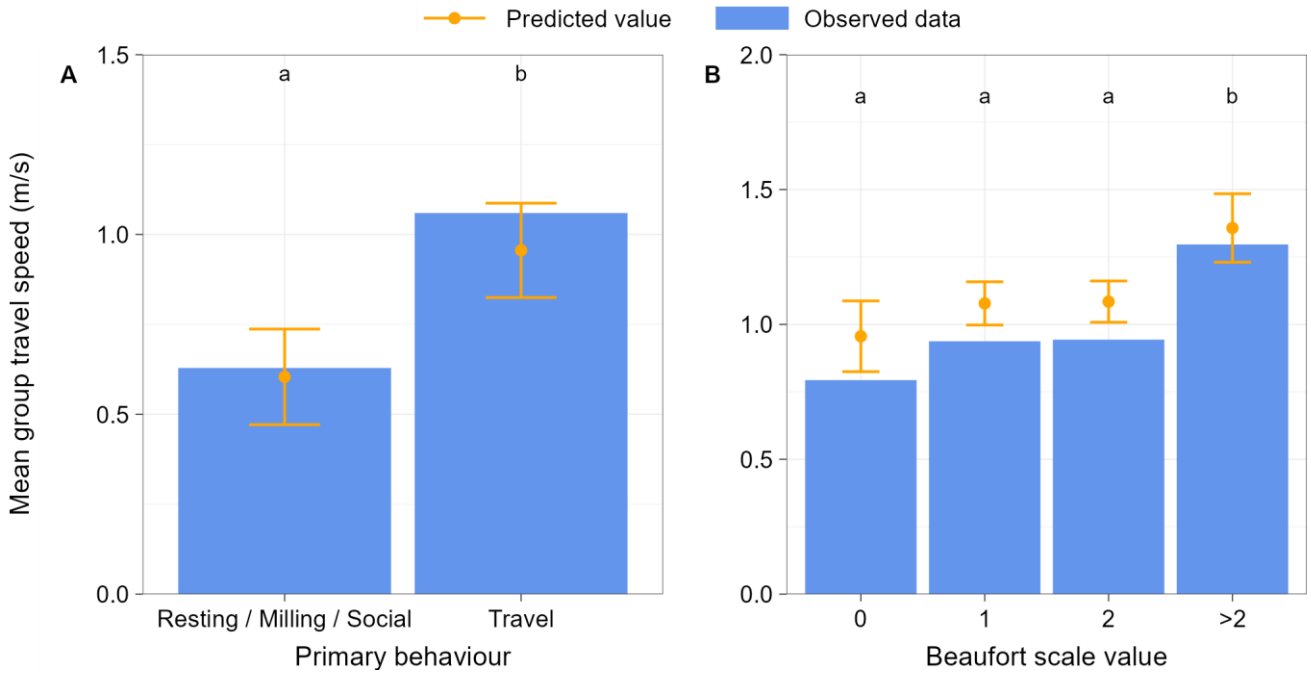

Figure 5-69: Observed (bars) and estimated (points) mean group travel speed as a function of primary behaviour (left) and Beaufort scale value (right), 2020–2023.

Notes: observed data depict the between-surveys average group travel speed at each x-axis value (all other variables are not held constant); predicted values depict mean and 95% confidence intervals for an average survey, holding all other variables constant

5.7 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, 2020c, 2021a, 2022a; WSP 2023c) affirming the importance of Koluktoo Bay as a summering ground for narwhal during the open-water season.

The majority of narwhal observed over the nine years of data collection were engaged in travelling behaviour. Other behaviours observed by narwhal 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) and 2019 (seven occasions). With the introduction of the UAV Program in 2020, nursing behaviour was observed during 12 focal follow surveys in 2020, 12 focal follow surveys in 2021, and six focal follow surveys in 2022. No nursing behaviour was observed during focal follows in 2023. 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, and that these functions are continuing year-over-year in the presence of vessels.

Ad lib observations made throughout the multi-year program suggest that the response of narwhal to ore carrier traffic was variable, ranging from “no obvious response” in which animals remained in close proximity to ore carriers as they transited 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 continued to return to the area shortly thereafter, though the time following a hunting event that individuals returned was variable.

In 2021, a single polar bear (*Ursus maritimus*) was recorded by observers at Bruce Head during the morning monitoring shift on 11 August 2021, situated on the bluff immediately above the Inuit hunting camp. The bear was observed feeding on a seal carcass and remained at Bruce Head for a period of two days before departing the area.

5.7.1 Other Cetacean Species

One other cetacean species was observed in the SSA during the 2023 field season at Bruce Head (Table 5-16).

Bowhead whale (*Balaena mysticetus*) were observed sporadically in the study area, with five sightings documented throughout the 2023 field season. While killer whale (*Orcinus orca*) and beluga (*Delphinapterus leaucas*) have been observed in the study area in prior field seasons, neither were observed in the study area during 2023. As typical, bearded and ringed seals were frequently observed in the SSA throughout the season.

Table 5-16: Other cetacean species observed in the SSA during the 2023 Bruce Head Program.

Species	Date of record	Number of individuals
Bowhead whale (*Balaena mysticetes*)	29 July 2023	3 sightings (likely 1 individual)
	5 August 2023	1
	6 August 2023	1

6.0 DISCUSSION

6.1 Relative Abundance and Distribution – Stratified Study Area

The relative abundance of narwhal (total number of narwhal corrected for survey effort) in the SSA was lower in 2023 (2.9 narwhal/h) than any previous survey year. The highest relative abundance of narwhal recorded at Bruce Head occurred in 2016 (178.0 narwhal/h), followed by 2017 (121.8 narwhal/h), and 2019 (127.2 narwhal/h). Prior to 2023, the lowest relative abundance of narwhal recorded at Bruce Head occurred in 2020 (47.5 narwhal/h) followed by 2021 (29.4 narwhal/h).

Low narwhal numbers in 2023 were thought to be linked to the late break-up of landfast ice in the RSA in 2023. Consolidated sea ice was present throughout the majority of Western Eclipse Sound during early August, with little to no ice leads available for narwhal to enter Milne Inlet (Appendix G; Baffinland 2024a). The late break-up period also resulted in a delay to the start of the 2023 shipping with the first inbound ship transit in Milne Inlet taking place on 09 August. No narwhals were recorded in the Bruce Head study area until 05 August 2023, with narwhal numbers slowly increasing towards the end of the Program. Aerial surveys conducted in the RSA in parallel with the Bruce Head Program indicated that narwhal abundance in the RSA was 10,492 animals (CV= 0.05; CI = 9,578-11,494) on 12-13 August and 9,572 animals (CV= 0.05; CI = 8,706-10,524) on 23-25 August 2023 (WSP 2024a). These abundance estimates were not significantly different to baseline levels (2013), when narwhal abundance was estimated at 10,489 animals (CV = 0.24; CI = 6,342-17,347) (Doniol-Valcroze et al. 2015). The 2023 aerial survey results also demonstrated that narwhal were primarily concentrated in Tremblay Sound during the first half of August and then shifted into Milne Inlet South during late August (WSP 2024a). Acoustic monitoring data collected in 2023 also substantiated this shift in narwhal distribution towards Milne Inlet South during in late August 2023 with narwhal calls notably increasing on the Bruce Head recorder at this time (Austin et al. 2024). This supports the low sighting rates recorded at Bruce Head prior to the Bruce Head Program ending on 22 August 2023.

If it was determined that the changes in narwhal numbers in the RSA were a result of Project-related activities, this would be consistent with a high severity response and would be considered a significant alteration of natural behavioural patterns of narwhal in the RSA and/or disruption to their daily routine (see Section 3.0; Southall et al. 2021). Findings from Bruce Head in 2023 were not consistent with results obtained via aerial surveys conducted in 2023. The aerial survey results indicate that narwhal numbers in the RSA (i.e., Eclipse Sound summer stock area) appear to have rebounded from the low numbers observed in 2021. The relative abundance estimate derived from the 2023 Bruce Head Program, on its own, is therefore not a reliable indicator of the current population status of the Eclipse Sound narwhal stock.

Other Considerations:

For the past five consecutive years (2019–2023), combined surveys of both Admiralty Inlet and Eclipse Sound summering stock areas have been undertaken. The primary impetus for running the combined stock surveys (as opposed to the Eclipse Sound summer stock only) was based on available IQ, which indicated that the geographic and genetic distinction between these two summering stocks may be invalid (NWMB 2016a; 2016b; QWB 2022). DFO has also been investigating the extent to which there may be natural exchange of narwhal between these stock areas during the open-water season (Doniol-Valcroze et al. 2015, 2020; DFO 2020b). Natural exchange between the two summering areas was proposed as a possible reason why the 2013 survey results for Admiralty Inlet (~35,000 narwhal) and Eclipse Sound (~10,000 narwhal) differed substantially from previous survey results for the same stocks (18,000 for Admiralty Inlet in 2010 and 20,000 for Eclipse Sound in 2004) (Doniol-Valcroze et al. 2015).

Given that the combined stock estimate for Admiralty Inlet and Eclipse Sound in 2023 (40,706 animals, CV=0.11, CI = 32,711-50,655; WSP 2024a) indicates that the regional narwhal population is stable relative to pre-shipping levels in 2013 (45,532 animals; CV = 0.33; CI = 22,440 - 92,384; Doniol-Valcroze et al. 2015), and in consideration of the available IQ regarding the degree of exchange between narwhal groups on their summering grounds, the observed changes in narwhal abundance in Eclipse Sound in recent years likely reflects a natural exchange between the two putative stock areas that began prior to Baffinland shipping operations, with animals shifting between Eclipse Sound and Admiralty Inlet based on where habitat conditions may be more favorable that season (e.g., ice coverage, prey availability, predation pressure). With the recent influence of rapidly warming ocean temperatures and longer open-water seasons due to climate change, more pronounced changes in habitat conditions are to be expected throughout the Arctic along with commensurate changes in animal distributions and migratory movements. For example, it is well documented that sea ice in the Arctic is presently undergoing rapid reduction due to climate warming (Stroeve et al. 2012; IPCC 2013; Overland and Wang 2013) and this has been directly associated with notable shifts in species distributions for both Arctic marine mammals (Laidre et al. 2008, 2015; Frederiksen and Haug 2015; Nøttestad et al. 2015; Víkingsson et al. 2015; Albouy et al. 2020; Chambault et al. 2022;) and their prey (Frainer et al. 2017; Steiner et al. 2019, 2021; Møller and Nielsen 2020). How this might be manifesting on a micro-geographic scale in the North Baffin region is presently unclear, although some insight is offered when considering changes reported in other Arctic environments in close proximity to Eclipse Sound.

Two major oceanographic changes have recently been observed in coastal areas of Southeast Greenland; a lack of pack ice in summer and increasing sea temperature (NAAMCO 2021). This has had cascading effects on the marine ecosystem, as observed through shifts in fish species assemblages in the region (i.e., change in fish community structure) and previously undocumented occurrences of temperate water cetaceans in Southeast Greenland in high abundances (e.g., humpback whales, fin whales, killer whales, pilot whales and white beaked dolphins). Traditional narwhal habitat in this area has become restricted by the warming oceans and the ability of narwhal to adapt to warming water temperatures is also limited due to their general physiology. Shifts in narwhal distribution in Greenland have also been documented in recent years, with multiple sightings of narwhal in locations well north of their traditional range (e.g., Dove Bay, Greenland Sea, Northeast water and Petermann glacier front) (NAAMCO 2021). Current evidence suggests that a combination of hunting and climate change is negatively impacting the long-term viability of populations in Southeast Greenland (NAAMCO 2021).

A recent study by Chambault et al. (2022) predicted the future distribution of Eastern Baffin Bay narwhal under two different climate change scenarios using narwhal satellite tracking data collected over two decades. The long-term predictive models suggest that the current distribution of Baffin Bay narwhal during summer will undergo a +200 km northward shift to cope with climate change, and that summer narwhal habitats in this region are predicted to decline by 31 to 66% (depending on the climate model). These changes may already be underway in the eastern Canadian Arctic and may affect Eclipse Sound and Admiralty Inlet differently.

For the above reasons, the potential for climate-driven shifts in species distributions cannot be ignored as a potential explanation of recently observed fluctuations in summer narwhal distribution in Eclipse Sound. To better understand what may be occurring, additional engagements and monitoring with Inuit stakeholders and regulatory agencies are needed, inclusive of collaborative regional-scale monitoring, to better understand how climate change is impacting the Baffin Bay narwhal population as a whole.

6.2 Density

Based on statistical analyses of the RAD data, the effect of “distance from vessel” was shown to have a significant effect on narwhal density, while “vessel travel direction” did not. The model predicted significantly reduced narwhal densities in the SSA when vessels were present in the SSA, but only when exposed to northbound (i.e., outbound) vessels (ore-laden) at distances approaching 2 km. Effect sizes suggest the presence of a moderate biologically significant effect up to a distance of 2.4–2.6 km from northbound vessels. Once a northbound vessel passed through the SSA, heading away from the strata, narwhal density was shown to gradually increase as the vessel moved away. The same pattern was observed for a southbound vessel moving away from the substrata, although the observed increase was smaller, mirroring the smaller decrease in density when a southbound vessel approached the substrata, compared to a northbound vessel. This pattern could represent a refractory period during which narwhal reoccupy the SSA after their initial avoidance of the vessel.

The observed effect was equivalent to a maximum period of 18–25 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). During the Program (30 July to 23 Aug 2022), there were approximately two vessel transits per day in the SSA (32 one-way transits in SSA over a 25-day period). Therefore, the maximum period per day associated with vessel disturbance on narwhal density was 50 min. These findings were consistent with previous years’ findings and with behavioural results from the narwhal tagging study (Golder 2020a), which indicated that narwhal density in the SSA was influenced by vessel traffic, but limited to close distances (i.e., within 2.4–2.6 km of a northbound vessel). Localized avoidance of the sound source (i.e., the vessel) by narwhal was consistent with a moderate severity behavioural response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., 18–25 min per vessel transit), this would not be considered a biologically significant behavioural response and would not be expected to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

6.3 Group Composition – Behavioural Study Area

Demographic characteristics of a population are strongly correlated with the population’s status and are commonly used as indicators of future changes in abundance (Booth et al. 2020). Changes in the group composition may occur over the short-term, with group membership changing in the immediate presence of a disturbance (Bejder et al. 2006a), and over the long-term as a result of reduced reproductive success (Mann et al. 2000; Bejder 2005), ultimately leading to changes in a population’s structure. Therefore, there is concern that prolonged changes in group composition in response to stressors such as vessel activity have the potential to increase disturbance effects to vulnerable cetacean populations.

Two vital rates previously assessed in Booth et al. (2020) have been shown to be sensitive to changes in fertility and calf survival, including the ratio of calves/pups to mature females and the proportion of immature animals in a population. Based on PCoD (population consequences of disturbance) models, the study confirmed that demographic characteristics such as the proportion of immature animals in a population were appropriate indicators of population decline (Booth et al. 2020). This conclusion has been supported by other studies that have 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 long-finned pilot whales (*Globicephala melas*; Hin et al. 2019) and Blaineville's beaked whales (*Mesoplodon densirostris*; Moretti et al. 2019). These studies suggest that a decline in the proportion of immatures was an appropriate early warning indicator (EWI) for identification of population decline in the Eclipse Sound narwhal stock. As discussed in Baffinland (2023), early detection of a decline in the proportion of immatures, combined with detection of prolonged adverse behavioural responses by narwhal to vessel traffic, would suggest that Project-related shipping may be a contributor to the observed population-level effect on narwhal.

Findings from the combined multi-year dataset indicated that the relative proportion of immature narwhal observed in the BSA in 2023 (0.242) was significantly higher than pre-shipping values in 2014 and 2015 (0.152 and 0.167, respectively), representing a 57% increase from the baseline condition. This result should be interpreted with caution given the relatively small sample size available at Bruce Head in 2023.

For comparative purposes, the EWI was also calculated using the 2023 aerial survey data (dedicated 1000 ft. survey data). Results from the aerial data analysis indicated that the proportion of immature narwhal in Eclipse Sound in 2023 (0.131) was within the range of the 2014/2015 baseline condition (0.154 in 2014 and 0.110 in 2015) (WSP 2024b). A statistical comparison was not possible since the raw data from 2014/2015 aerial surveys were not available. Both Bruce Head and aerial-based EWI datasets were associated with high variability and low sample sizes, resulting in high uncertainty in the EWI estimates.

In summary, while the EWI data collected at Bruce Head in 2023 suggested an increase in the relative proportion of immature narwhal in Milne Inlet South, the equivalent EWI analysis derived from the spatially broader aerial survey dataset provided no indication that the proportion of immature narwhal in the RSA had changed since the start of shipping operations (2014/2015) (WSP 2024b).

6.4 Behaviour - UAV-based Focal Follow Surveys

The study of cetacean behaviour by traditional methods such as shore-based or boat-based surveys has been historically challenging due to the majority of marine mammal activity typically occurring below the water surface, combined with the distortion of observations made via a horizontal perspective. The recent emergence of UAVs for cetacean research has provided a non-intrusive platform for replicate and prolonged observations of high-resolution data at an advantageous perspective (Torres et al. 2018; Fetterman et al. 2022; King and Jensen 2022). As such, UAV-based surveys offer significant insights into the behavioural ecology of cetaceans, enabling a better understanding of fine scale movements, collective group behaviour and composition, and social relationships between individuals (Nielsen et al. 2019; Hartman et al. 2020; Orbach et al. 2020; Pedrazzi et al. 2022).

These survey methods have also allowed for the direct observation of novel and unique behaviours that would otherwise be difficult to observe, such as mating, harassment and/or altruistic behaviours (Orbach et al. 2018; Chung et al. 2022; Fernández et al. 2022; Pedrazzi et al. 2022). Such insights into cetacean behaviour extend into assessing disturbance of individuals or groups in the presence of potential stressors, including whale watching vessels, predators, and the UAV itself (Fettermann et al. 2019; Arranz et al. 2021; Azizeh et al. 2021; Castro et al. 2021). Behavioural surveys via UAV have been particularly effective monitoring tools for mothers with dependant young (Wier et al. 2018; Nielsen et al. 2019; Arranz et al. 2021; Azizeh et al. 2021), which is considered to be the most important life stage within a population to monitor for potential disturbance. Therefore, the use of UAVs has been incorporated into the Bruce Head Program since 2020 to assess fine-scale behavioural trends of narwhal groups when in the presence of vessels compared to when vessels are absent, with particular attention paid to the behaviours of mothers with dependent young.

6.4.1 Primary Behaviour

In considering the general responses of animals to stressful or undesirable conditions, it was assumed that animals experiencing disturbance from shipping would be more likely to engage in avoidance behaviours (i.e., travel away from source of disturbance) than in important life activities (i.e., resting, milling, or socializing) during the exposure event. As described by Arranz et al. (2021), resting is a state of low activity and includes whales swimming slowly or in a near-stationary state such as logging behaviour. Should an individual or group be caused to cease this important behavioural state (or others such as foraging or nursing) because of the need to depart or avoid the area of exposure, such interruptions could negatively impact the fitness of individuals by negatively altering their energy expenditure which, under prolonged and repetitive exposure scenarios, could lead to reproductive consequences and, by extension, population-level consequences (Martin et al. 2022). Therefore, primary behaviours such as milling, resting, and socializing, which would not be expected during periods of prolonged disturbance, were considered appropriate to monitor as part of the focal follow survey program.

, findings based on the multi-year UAV dataset provide some support that narwhal groups engaged less frequently in important activities when in close proximity to vessels, but this effect was not consistent across all group types. Adult groups engaged less frequently in important activities when within 3 km of a vessel. Conversely, mixed groups without immatures engaged more frequently in important activities when within 2.5 km of a vessel. For mother-immature pairs and groups with immatures, no effect of vessel presence on important activities was observed at any distance. The conflicting trends amongst narwhal group types questions the validity of the observed effect. Additional focal follow monitoring is recommended to increase the overall sample size of the corresponding dataset to further examine the relationship between shipping and important narwhal activities.

As discussed in Section 3.0, a change in behavioural state (e.g., change in primary behaviour) by narwhal would be consistent with a low to moderate severity behavioural response, depending on the duration for which the response was sustained. Given the temporary and uncertain nature of the effect observed (i.e., conflicting trends in proportion of time engaged in resting, milling or social behaviour among group types, all within 2.5–3 km of vessels), combined with the lack of “flight” behaviour observed by narwhal (i.e., no increase in travel speed observed; see section 5.6.8), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the broader RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 18 to 21 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

6.4.2 Unique Behaviours

Unique behaviours that would not be expected under stressful conditions, such as nursing, social rubbing, sexual displays, and rolling (either vertically in the water column or horizontally) were recorded throughout many of the focal follow surveys conducted between 2020 and 2023, both in the presence and in the absence of vessel traffic. Findings based on the combined multi-year dataset suggest that unique behaviour displays by narwhal tended to occur less frequently by all narwhal group types in close proximity (<2.7 km) to transiting vessels, although the observed decrease was not shown to be significant. The lack of significance may have been associated with the low sample sizes and high data variability at close range (<2 km) to vessels. The results suggest that social

behaviours such as rubbing, rolling, nursing, and sexual displays may potentially be disrupted in close proximity (<2.7 km) to vessel traffic, though this finding is based on a very small sample size at close range to vessels. Additional monitoring is therefore recommended to increase overall sample size and the robustness of the corresponding analysis.

As discussed in Section 3.0, a decrease in the display of unique behaviours by narwhal would be consistent with a low to moderate severity behavioural response, depending on the duration for which the response was sustained. Given the temporary nature of the effect (i.e., unique behaviours displayed less frequently within 2.7 km of vessels), this finding was not anticipated to be a biologically significant behavioural response and would not be expected to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 19 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

6.4.3 Association of Immatures with Presumed Mother

Narwhal calves and yearlings are heavily dependent on their mothers for energy transfer via milk, protection from predators, and acquisition of learned behaviours critical to their survival (Nielsen et al. 2019). Therefore, special attention was paid to assessing behavioural changes of these vulnerable groups (i.e., mothers with dependent young) in relation to shipping activities. Focal follow surveys of narwhal groups containing immatures provided insight into potential moderate severity responses discussed in Section 3.0, such as changes in nursing behaviour and changes in the relative and distal positioning of immatures to their mothers when in the presence of vessels.

Like many other odontocete species, it should be noted that narwhal appear to exhibit alloparental care, meaning that dependent young observed at the surface are often accompanied by another non-parent whale during foraging excursions by their mother. This behaviour has been directly observed during multiple focal follow surveys conducted near Bruce Head (WSP 2023c). Therefore, all associations discussed herein are between immatures and their *presumed* mother.

6.4.3.1 Presence of Nursing Behaviour

Mothers with dependent young represent the group most vulnerable to anthropogenic disturbance. That is, lactating mothers are believed to experience the highest metabolic pressure through nursing and lactation (Arranz et al. 2021) while providing care to their heavily reliant young that is critical for survival into adulthood. Therefore, emphasis was placed on documenting presumed nursing events by immature narwhal. Similar to previous studies that assessed nursing behaviour in cetaceans via UAV focal follow surveys (Nielsen et al. 2019; Arranz et al. 2021; Azizeh et al. 2021), nursing was recorded any time that a calf or yearling was observed underneath of its mother, with its head positioned close to the mammary gland area.

Findings based on the combined multi-year UAV dataset suggest that immature narwhal engaged in nursing less often when in the presence of vessel traffic (vessel within 5 km of the focal group); although modelling results indicated that this effect was not significant despite an effect size of -65%. The lack of a significant effect may have been associated with the low sample size and high data variability available at close ranges to the vessel. The model was based on limited and unbalanced data; specifically, only four of the 30 surveys involving active nursing occurred in the presence of vessels (<5 km). As a result, the above findings should be interpreted with caution. Additional monitoring is recommended to increase overall sample size and the robustness of the corresponding analysis.

As discussed in Section 3.0, a change in the frequency of nursing behaviour between immature narwhal and their mother would be consistent with a moderate severity behavioural response. In considering the small sample size and that nursing behaviour was only assessed relative to vessel presence/absence scenarios and not vessel distance, the specific distance within the 5 km vessel exposure zone that the effect took place is not known. Given the vulnerable nature of mother and immature pairs, further surveys are required to increase sample, thereby allowing for a more robust analysis to determine if the response is supportive of impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

6.4.3.2 Relative and Distal Positioning of Immatures

The relative and distal position of immatures to their presumed mother was assessed to inform whether certain positions by dependent young were favoured when in the presence of vessels. Maintaining close physical contact between mothers and immatures is advantageous in that it provides offspring with easy access for nursing, saves on energetic costs associated with locomotion, provides protection from predators, and minimizes the need for loud and frequent communication that may attract predators (Noren 2008; Noren and Edwards 2011; Videsen et al. 2017; Nielsen et al. 2019). Given the benefits of staying close to one another, it was assumed that mother and immature pairs would demonstrate a tight association, particularly in the presence of a perceived threat.

Findings based on the combined multi-year UAV dataset suggest that the estimated effect of vessels on the relative position of immature narwhal relative to their mothers was small, uncertain, and not statistically significant. These results do not suggest that the relative position (lateral or under) of immatures and their mother were affected when vessels were within 5 km from groups. Further surveys are therefore recommended to increase sample size, thereby allowing for a more robust analysis**.**

As discussed in Section 3.0, a change in group cohesion between a mother and its dependent young would be consistent with a moderate severity response. However, it is important to note that immatures, especially calves, are afforded significant locomotive advantages when swimming tightly associated with their mothers (Noren 2008). This suggests that there is a natural incentive to remain closely associated with one another as a looser association may result in higher energetic costs for the immature. The responses observed were not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

6.4.4 Group Formation

Findings based on the combined multi-year UAV dataset suggest that there was some evidence that narwhal may alter their group formation when in close proximity to vessel traffic but the effect was not consistent across group types. The estimated effect was strongest for adults, where there was a large (>50%) and statistically significant effect on the probability of parallel formation when within 1 km of a vessel. For all other three group types, the effect of vessels on group formation was not statistically significant, and small (<25% for mixed groups with immatures or without immatures) or medium (<50% for mother-immature pairs) when narwhal were within 1 km of a vessel. These findings were consistent with previous studies that demonstrated certain cetacean species respond to disturbance by changing their group formation (Irvine et al. 1981; Au and Perryman 1982). Consistent with shore-based findings from previous years, narwhal groups were most often observed in parallel formation under both vessel presence and vessel absence scenarios.

In general, narwhal groups frequently shifted their formations between parallel, linear, and cluster throughout a given focal follow survey, both in the presence and in the absence of vessels. The biological purpose of these formations in narwhal groups is not well understood and there remains uncertainty regarding how these formations relate to internal group cohesion of narwhal specifically. Therefore, further monitoring of narwhal group formation may contribute to a better understanding of 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).

As discussed in Section 3.0, a change in group cohesion (e.g., change in group formation) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect (i.e., change in group formation within 1 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 7 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

6.4.5 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). There is also evidence that cetacean response to perceived threats such as vessel noise, predation, and hunting, may depend on whether calves are present. For example, dolphin groups containing calves have been found to alter their space use patterns by forming tighter groups, with mothers and calves centrally located (Johnson and Norris 1986). 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 increased their distance from the rest of the group in the presence of tour boats and associated noise. Though these accounts were not considered avoidance responses directly, it was 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 were in agreement with other studies 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 and found that the two species reacted very differently to icebreaking activities; with beluga demonstrating 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 beluga and narwhal behaviour in response to killer whales (Gonzales 2001). During aerial surveys conducted by Golder in 2020, a large group of killer whales (60+ individuals) was observed herding 150 to 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 tightly associated 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 that was observed floating motionless near shore and one probable adult female, potentially the mother to one of the killed calves (Golder 2021a).

Findings based on the combined multi-year UAV dataset suggest that a non-statistically significant but potentially large effect of vessels on the frequency of a tight group spread when vessels were within 3 km of narwhal groups. However, the estimated effect sizes suggested that tight group association was less frequent at close distances from vessels (0.5 and 1 km) but more frequent when vessels were 2–3 km away. The inconsistent direction of the effect, and lack of statistical significance due to high uncertainty in the estimated relationship mean that strong conclusions about the effect of vessels on group spread cannot be drawn based on the available data.

As discussed in Section 3.0, a change in group cohesion (e.g., change in group spread) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect observed (i.e., groups associating less tightly when within 3 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 21 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

6.4.6 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 their group size, spreading out into multiple smaller groups (Arcangeli and Crosti 2009; Pennacchi 2013). Conversely, cetaceans have also been shown to increase their group size in the presence of potential threats. In one study by Mattson et al. (2005), bottlenose dolphins were shown to occur in larger group sizes when in the presence of vessels, including multiple different vessel types (i.e., dolphin tour boats, motorboats, shrimp boats). In another study, long-finned pilot whales (*Globicephala melas*) were shown to

form larger groups in response to three types of disturbance (i.e., killer whale sound playbacks, tagging, and naval sonar), with the most significant increase in group size occurring during and after sonar playback exposure, followed by satellite tagging and killer whale sound playbacks (Visser et al. 2016). The pilot whales also appeared to be attracted to the source and actively approached it. As pilot whales are known to use social defence strategies when detecting and responding to a threat (Curé et al. 2012; de Stephanis 2014), it is plausible that this behaviour may be a form of social defence through mobbing (Visser et al. 2016). Based on these findings, it is evident that cetacean species do not all respond to perceived threats in the same way. One example of species-specific strategies to altering group size is evident in Finley et al. (1990), in which responses were compared 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).

Findings based on the combined multi-year UAV dataset do not suggest a strong or consistent effect of vessels on group size of narwhal, based on the available data. One exception was for mother-immature pairs, for which there was medium (≥25%) increase in group size when within 3 km of vessels, although the effect was not statistically significant and was based on a limited sample size. For the other group types, effect sizes were small and do not suggest a biologically significant effect of vessels on group size.

As discussed in Section 3.0, a change in group cohesion (e.g., change in group size) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect (i.e., increase in group size for mother-immature pairs when within 3 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 21 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

6.4.7 Group Travel Speed

In assessing shore-based monitoring results obtained during previous years at Bruce Head, some change in narwhal travel speed was evident, however the survey method was inherently prone to individual bias and human error, with land-based observers making the determination on travel speed of narwhal groups using categories “slow”, “medium” and “fast”. With the introduction of UAV surveys, narwhal travel speed could be quantified using GPS data derived from the focal follow survey videos. By sub-sampling positional data obtained during UAV-based focal follow surveys, past studies have shown that travel speed of cetacean groups may be more effectively determined (Azizeh et al. 2021). The result was a more precise measurement of animal speed that could be empirically compared to other studies with a higher degree of confidence than the categorical method previously used through shore-based monitoring in the BSA. This method also allowed the travel speeds of narwhal in Milne Inlet to be compared to measured travel speeds of narwhal in other studies (Golder 2020a, Heide Jorgenson et al. 2021).

Findings based on the combined multi-year UAV dataset suggest that the results support an effect of vessel distance on narwhal travel speed when vessels were within 1 km of narwhal groups. When vessels were within 1 km, adult groups and mixed groups with immatures travelled approximately 35% to 64% faster than when vessels were not present, however there was no effect on travel speed for mixed groups without immatures, and no data for this comparison for mother-immature pairs. Overall, the data suggest an effect of vessels in close proximity on travel speed of narwhal, with the strongest evidence for groups of adults, but additional data would be needed to confirm whether this effect may also exist for other group types. While many studies have demonstrated an increase in travel speed by cetacean groups in response to vessel disturbance (Kruse 1991; Nowacek et al. 2001; Williams et al., 2002; Ribeiro et al. 2005; Bejder et al. 2006a; Laidre et al. 2006; Miller et al. 2008; Matsuda et al., 2011; Erbe et al. 2019), narwhal specifically have shown no increase in travel speed when in the presence of ice-breaking vessels, but have been reported to instead demonstrate a slowing or cessation of movement, also known as a “freeze” response (Finley et al. 1990). This latter finding has been supported by analysis of movement data obtained through the narwhal tagging study (Golder 2020a), in which no significant increase in travel speed was detected for narwhal in the presence of vessels compared to periods when no vessels were present.

As discussed in Section 3.0, a change in energy expenditure (e.g., change in travel speed) by narwhal would be consistent with a moderate severity behavioural response, though no such change was evident. Given the temporary nature of the effect (i.e., increase in group travel speed for adult groups and mixed groups with immatures when within 1 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 7 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

6.5 General Observations

The use of UAV surveys at Bruce Head in 2023 yielded further insights into narwhal group composition and behaviour, building on the data collected in 2020–2022. The UAV team was able to increase the number of focal follow surveys conducted, including in the presence of shipping. Despite this increased effort, additional focal follow surveys in the presence of vessels are recommended to increase the sample size for effective quantitative analysis.

7.0 SUMMARY OF KEY FINDINGS

The following summarizes key findings pertaining to narwhal responses to ship traffic at Bruce Head based on nine years of visual-observer data collected in the Program's defined Stratified Study Area (SSA) and Behavioural Study Area (BSA):

7.1 Relative Abundance and Distribution

- Interannual variation in relative abundance: The relative abundance of narwhal (total number of narwhal in the SSA corrected for survey effort) at Bruce Head was lower in 2023 (2.9 narwhal/h) than all previous survey years. The highest relative abundance of narwhal recorded at Bruce Head occurred in 2016 (178.0 narwhal/h), followed by 2017 (121.8 narwhal/h), and 2019 (127.2 narwhal/h). Prior to 2023, the lowest relative abundance of narwhal recorded at Bruce Head occurred in 2020 (47.5 narwhal/h) followed by 2021 (29.4 narwhal/h). Low narwhal numbers in 2023 were thought to be linked to the late break-up of landfast ice in the RSA in 2023. Consolidated sea ice and landfast ice was present throughout the majority of Western Eclipse Sound during early August, with little to no ice leads available for narwhal to enter Milne Inlet (Baffinland 2024a). The late break-up period also resulted in a delay to the start of the 2023 shipping season with the first ship arriving at Milne Port on 11 August 2023. No narwhals were recorded in the Bruce Head study area until 05 August 2023, with narwhal numbers slowly increasing towards the end of the Program. Aerial surveys conducted in the RSA in parallel with the Bruce Head Program indicated that narwhal abundance in the RSA was 10,492 animals (CV= 0.05; CI = 9,578-11,494) on 12-13 August and 9,572 animals (CV= 0.05; CI = 8,706-10,524) on 23-25 August 2023 (WSP 2024a). These abundance estimates were not significantly different to pre-shipping (i.e., baseline) levels in 2013, when narwhal abundance was estimated at 10,489 animals (CV = 0.24; CI = 6,342 – 17,347) (Doniol-Valcroze et al. 2015). The 2023 aerial survey results also showed that narwhal were mostly concentrated in Tremblay Sound during the first half of August and then shifted into Milne Inlet South in late August (WSP 2024a). Acoustic monitoring data collected in August 2023 also substantiated this shifting distribution pattern with narwhal calls notably increasing at the Bruce Head acoustic recorder in mid- to late August 2023 (Austin et al. 2024). These results help explain the low narwhal numbers observed at Bruce Head prior to program ending on 22 August 2023.

- Density: The effect of "distance from vessel" was shown to have a significant effect of narwhal density, while "vessel travel direction" did not. The model predicted significantly reduced narwhal densities in the SSA only when northbound (i.e., outbound) vessels were in close proximity to a given substratum (within 2 km), with effect sizes suggesting a moderate biologically significant effect up to a distance of 2.4–2.6 km from northbound vessels. Once a northbound vessel passed through the SSA, heading away from the strata, narwhal density was shown to gradually increase as the vessel moved away. The same pattern was observed for a southbound vessel moving away from the substrata, although the observed increase was smaller, mirroring the smaller decrease in density when a southbound vessel approached the substrata, compared to a northbound vessel. This pattern could represent a refractory period during which narwhal reoccupy the SSA after their initial avoidance of the vessel. The observed effect was equivalent to a maximum period of 18–25 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). During the 2023 Bruce Head Program, there were approximately two vessel transits per day in the SSA (32 one-way transits in SSA over a 20-day period). Therefore, the maximum period per day associated with shipping effects on narwhal density was 50

min. These findings were consistent with previous years' findings and with behavioural results from the narwhal tagging study (Golder 2020a), which indicated that narwhal density in the SSA was influenced by vessel traffic, but this was limited to northbound vessels and only at close distances (i.e., within several kilometers). Localized avoidance of the sound source (i.e., the vessel) by narwhal is consistent with a moderate severity behavioural response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., 18–25 min per vessel transit), this would not be considered a biologically significant behavioural response and would not be expected to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. Accordingly, no effects are anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which could lead to population-level effects. Observed responses are in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

7.2 Group Composition

- Group Composition: The number of narwhal groups in the BSA in 2023 was the lowest observed since the start of the nine-year study period, with a total of 40 narwhal groups (comprising 163 individuals) recorded. All narwhal life stage categories (adults, juveniles, yearlings, and calves) were recorded in the BSA throughout the nine-year monitoring program, with the majority of the sightings consisting of adult narwhal, followed by juveniles, calves, and yearlings.
- Proportion of Immatures (Early Warning Indicator [EWI]): Findings from the combined multi-year dataset indicate that the relative proportion of immature narwhal observed in the BSA in 2023 (0.242) was significantly higher than that recorded during baseline years (0.152 in 2014 and 0.167 in 2015), representing a 57% increase from baseline conditions. This result should be interpreted with caution given the relatively small sample size available at Bruce Head in 2023. For comparative purposes, the EWI was also calculated using the 2023 aerial survey data (dedicated 1000 ft. survey data). Results from the aerial data analysis indicated that the proportion of immature narwhal in Eclipse Sound in 2023 (0.131) was within the range of the 2014/2015 baseline condition (0.154 in 2014 and 0.110 in 2015) (WSP 2024b). A statistical comparison was not possible since the raw data from 2014/2015 aerial surveys were not available. Both Bruce Head and aerial-based EWI datasets were associated with high variability and low sample sizes, resulting in high uncertainty in the EWI estimates. In summary, while the EWI data collected at Bruce Head in 2023 suggests an increase in the relative proportion of immature narwhal in Milne Inlet South, the equivalent EWI analysis derived from the spatially broader aerial survey dataset provided no indication that the proportion of immature narwhal in the RSA had changed since the start of shipping operations (2014/2015) (WSP 2024b). Ongoing EWI monitoring through both the Bruce Head Shore-based Monitoring Program is recommended.

The following summarizes key findings pertaining to narwhal responses to ship traffic at Bruce Head based on four years (2020–2023) of UAV-based focal follow surveys in Milne Inlet:

- Primary behaviour: Focal follow survey results provide possible, though conflicting, support that narwhal groups may alter the proportion of time they spend engaged in important activities (defined as 'resting, milling, or social activity') when in the presence of vessels. Adult groups were shown to engage less frequently in important activities when within 3 km of a vessel. Conversely, mixed groups without immatures engaged more frequently in important activities when within 2.5 km of a vessel. For mother-immature pairs and groups with immatures, no effect of vessel presence on important activities was observed at any

distance. The conflicting trends amongst narwhal group types questions the validity of the observed effect. Additional focal follow monitoring is recommended to increase the overall sample size of the corresponding dataset to further examine the relationship between shipping and important narwhal activities.

- Unique behaviours: Unique behaviour displays by narwhal tended to occur less frequently by all narwhal group types in close proximity (<2.7 km) to a transiting vessel, although the observed decrease was not significant. The lack of significance may be associated with low sample sizes and high data variability at close distances (<2 km) to the vessel. The results suggest that social behaviours such as rubbing, rolling, nursing, and sexual displays may potentially be disrupted in close proximity (<2.7 km) to vessel traffic, though this finding is based on a very limited sample size at close range to vessels. Additional monitoring is recommended to increase the overall sample size and the robustness of the corresponding analysis.
- Association of immatures with presumed mother: Immature narwhal were recorded in 148 of the 397 (37%) focal follow surveys conducted to date. Of these events, immature narwhal occurred on their own in 35 of the surveys, with their presumed mother in 64 of the surveys, and in mixed groups in 49 of the surveys. Nursing behaviour was recorded during 30 of the surveys, five of which coincided with a vessel being present within 5 km of the focal group.
  - Presence of nursing behaviour: Immature narwhal engaged less often in nursing when in the presence of vessel traffic (vessel within 5 km of the focal group); although modelling results indicate that this effect was not significant despite an effect size of -65%. The lack of a significant effect may be associated with low sample sizes and high data variability at close distances to the vessel. The model was based on limited and unbalanced data; specifically, only four of the 30 surveys involved active nursing occurred in the presence of vessels (<5 km). As a result, the above findings should be interpreted with caution. Additional monitoring is recommended to increase overall sample size and the robustness of the corresponding analysis.
  - Relative and distal positioning of immatures: The estimated effect of vessels on the relative position of immature narwhal relative to their mothers was small, uncertain, and not statistically significant. These results do not suggest that the position of immatures (relative to their mother) is affected when vessels are present (within 5 km from groups). Additional monitoring is recommended to increase sample size, thereby allowing for a more robust analysis**.**
- Group formation: Narwhal groups frequently shifted their formations between parallel, linear, and cluster throughout a given focal follow survey, both in the presence and in the absence of vessels. The biological purpose of these formations in narwhal groups is not well understood and there remains uncertainty regarding how these formations relate to internal group cohesion of narwhal specifically. Therefore, further monitoring of narwhal group formation may contribute to a better understanding of 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). As discussed in Section 3.0, a change in group cohesion (e.g., change in group formation) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect (i.e., change in group formation within 1 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 7 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual

fitness and/or vital rates of narwhal in the RSA, which could lead to population-level effects. This response was in line with impact predictions made in the Final Environmental Impact Statement (FEIS) for the Early Revenue Phase (ERP), in that vessel noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

- Group spread: The results indicate a non-statistically significant but potentially large effect of vessels on the frequency of a tight group spread when vessels were within 3 km of narwhal groups. However, the estimated effect sizes suggested that tight group association was less frequent at close distances from vessels (0.5 and 1 km) but more frequent when vessels were 2–3 km away. The inconsistent direction of the effect, and lack of statistical significance due to high uncertainty in the estimated relationship, means that no reliable conclusions can be drawn regarding the effect of vessel presence on group spread based on the available data. As discussed in Section 3.0, a change in group cohesion (e.g., change in group spread) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect observed (i.e., groups associating less tightly when within 3 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 21 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which could lead to population-level effects. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.
- Group size: Findings based on the combined multi-year UAV dataset do not suggest a strong or consistent effect of vessel presence on group size of narwhal, based on the available data. One exception was for mother-immature pairs, for which there was medium (≥25%) increase in group size when within 3 km of a vessel, although the effect was not statistically significant and was based on a limited sample size. For the other group types, effect sizes were small and do not suggest a biologically significant effect of vessels on group size. As discussed in Section 3.0, a change in group cohesion (e.g., change in group size) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect (i.e., increase in group size for mother-immature pairs when within 3 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 21 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which could lead to population-level effects. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

- Travel speed: Findings suggest an effect of vessel distance on narwhal travel speed at close distances (up to 1 km). When vessels were within 1 km, adult groups and mixed groups with immatures travelled approximately 35% to 64% faster, respectively, than when vessels were not present. However, there was no effect on travel speed for mixed groups without immatures. No data was available for mother-immature pairs. Overall, the data suggest an effect of vessel presence on travel speed in close proximity to the vessel, with the strongest evidence for adult groups. As discussed in Section 3.0, a change in energy expenditure (e.g., change in travel speed) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect (i.e., increase in group travel speed for adult groups and mixed groups with immatures when within 1 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 7 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which could lead to population-level effects. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

8.0 RECOMMENDATIONS

The following are recommendations to future monitoring initiatives for the Bruce Head Shore-based Monitoring Program:

- Continue to increase program emphasis on UAV surveys, given the valuable insight this tool provides with respect to monitoring changes in group composition and fine scale behaviours in the presence of shipping (Broker et al. 2019). 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 to high severity responses such as change in nursing behaviour should they occur.
- Where possible, conduct UAV-based focal follow surveys of narwhal when in the presence of other external and confounding stimuli, such as killer whales or hunting, given the known influence these activities have on narwhal behaviour (Laidre et al. 2006).
- Consider modifying the analysis approach where data are no longer analyzed by group type; instead, the model would account for presence of immatures in the group. This would considerably increase sample size and associated statistical power, particularly for narwhal response variables in the presence of vessels.

9.0 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.

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APPENDIX A

Power Analysis

To assess the statistical power of the analyses performed in this report, a 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. To summarize the results of the power analyses, power curves were produced for each model. Power curves show statistical power, which is the probability of detecting a significant effect, as a function of effect size, which is the proportional change in the response variable of interest.

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 the current study consist of the metrics associated with the different behavioural responses 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. In addition, the statistical power to detect an effect of year on the Early Warning Indicator (EWI) value was assessed for 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 bootstrapping in R v. 4.0.4 (R 2021), 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 5,000 times for the EWI and focal follow analyses, 1,000 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 'Distance from 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 5 km), the effect size was calculated as percent reduction or increase relative to data when no vessels were present within 5 km of the narwhal. Where effects of directional distance were modeled as a polynomial, the effect was only applied up to the distance at which fitted estimates peaked (for example, up to 4 km if the curve peaked at 4 km), and narwhal at >4 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). 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 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 the modeled distance of exposure and a "reference" case (where no vessel was present within the modeled distance of exposure) 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 the exposure distance and cases where vessels were present, but farther than the distance of peak response – if the model used a polynomial of distance effect), 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 exposure distance). 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 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 the exposure distance and a "reference" case (where no vessel was present within the exposure distance) 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 the exposure distance and cases where vessels were present within the exposure distance, but farther than the distance of peak response – if the model used a polynomial distance effect), 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 exposure distance). 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 of Year

In the analysis of differences in EWI between sampling years, the effect size was calculated as percent reduction or increase relative to the mean least squares mean of proportion of immatures in 2014 and 2015. Overall, an increasing effect size resulted in a higher proportion of immatures than the mean baseline 2014-2015 least squares mean values, whereas a decreasing effect size resulted in a lower proportion of immatures. Since each year was tested independently against the 2014-2015 baseline in the original analysis of EWIs using planned contrasts, the power analysis was conducted by only simulating the effect size for the 2021 sampling year, whereas all other sampling years were not subjected to an effect size.

The simulated data were analyzed using the same model as the original analysis of EWIs described in the main report, and the *P*-value for the planned contrast between 2021 and the baseline 2014-2015 years were retained. If this *P*-value was less than 0.05, the difference between 2021 and 2014-2015 was considered to be significant. The proportion of repetitions with *P*-values less than 0.05 was interpreted as the statistical power of the planned contrast for that effect size.

Effect of Vessel Exposure

In the analysis of focal follow data, the effect of vessels on narwhal was assessed as an overall effect of presence of vessels within 5 km from followed groups, regardless of exact distance between vessels and narwhal. The effect size was calculated as percent reduction or increase relative to the mean least squares mean of variables when no vessels were present within 5 km from narwhal.

The simulated data were analyzed using the same model as the original analysis of focal follow data described in the main report, and the *P*-values for the effect of vessel presence on each response variable were retained, which included both the main effect of vessel presence and any interactions with group type, if those were included in the original model. If either of these *P*-values were less than 0.05, it was considered a significant overall effect of 'vessel exposure'. The proportion of repetitions with *P*-values less than 0.05 was interpreted as the statistical power for that effect size.

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. 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.

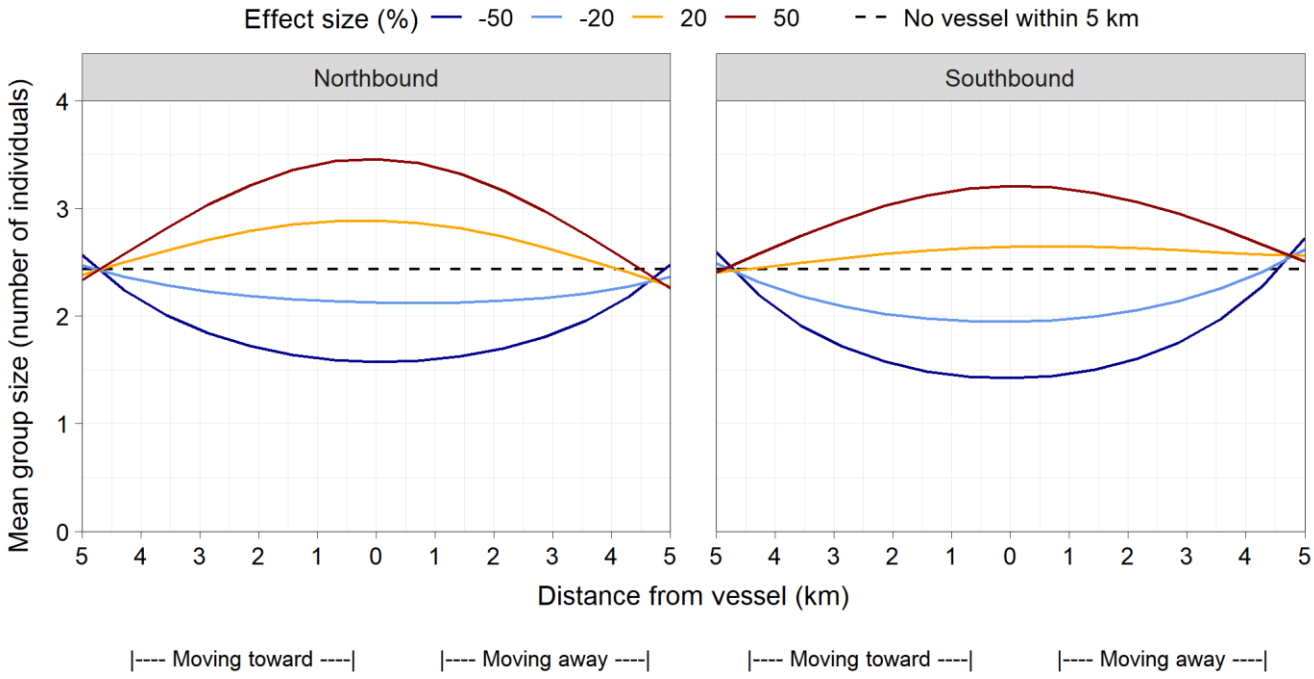


Figure 1: Application of effect sizes to a model with a numeric response variable (group size; effect applied to the full 5 km extent).

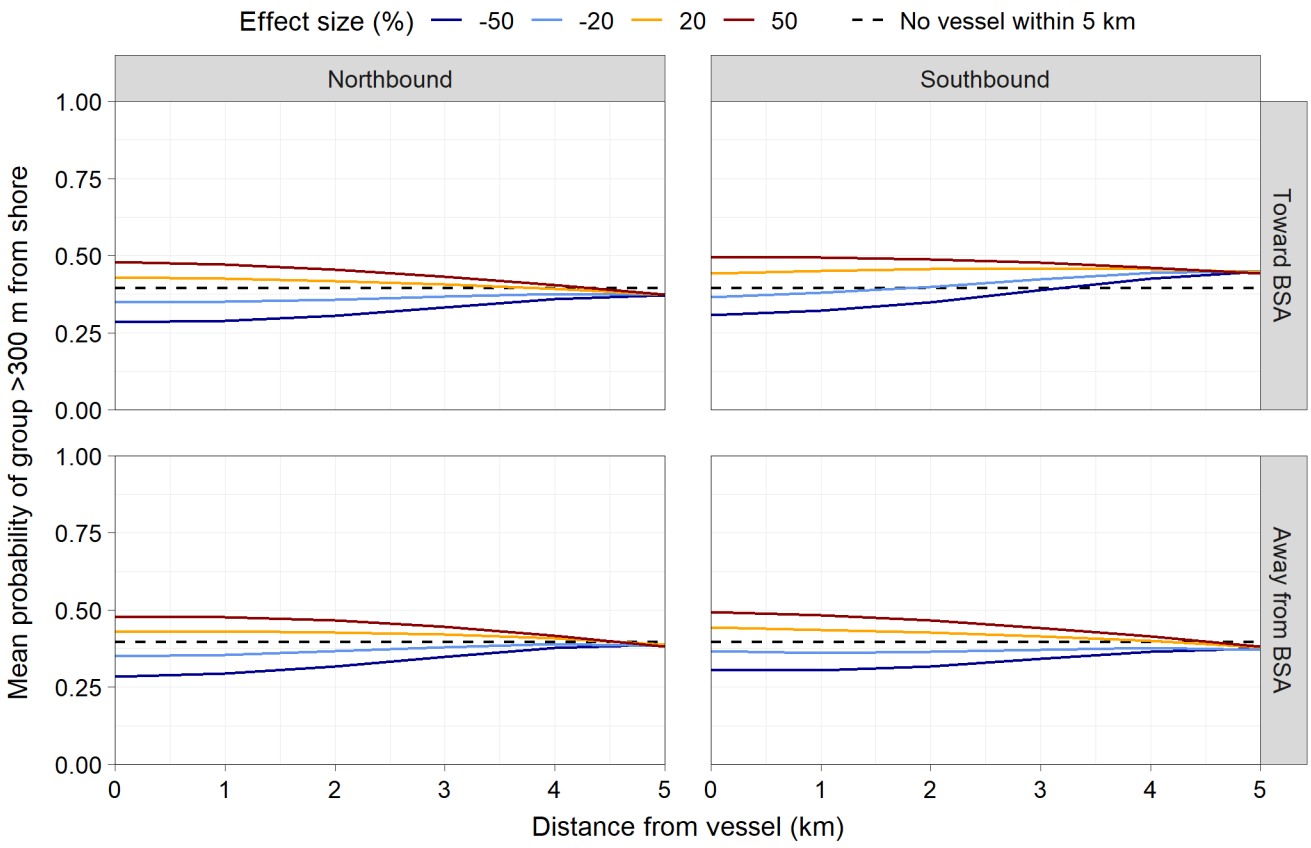


Figure 2: Application of effect sizes to a model with a binary response variable (group distance from shore)

RESULTS

Relative Abundance and Distribution (SSA)

There was sufficient power (≥0.8) to detect an effect of distance from vessel on relative abundance at effect sizes of approximately -40% or +45% (Figure 3). In comparison, observed effect sizes at a distance of 0 km from vessels were -51% (for a northbound vessel) and -47% (for a southbound vessel). Statistical power to estimate the observed effects was approximately 0.98 for northbound vessels and 0.95 for southbound vessels. That is, the analysis had sufficient power to detect effect sizes of -40% or +45%, and hence sufficient power to detect the observed effect sizes in the original analysis.

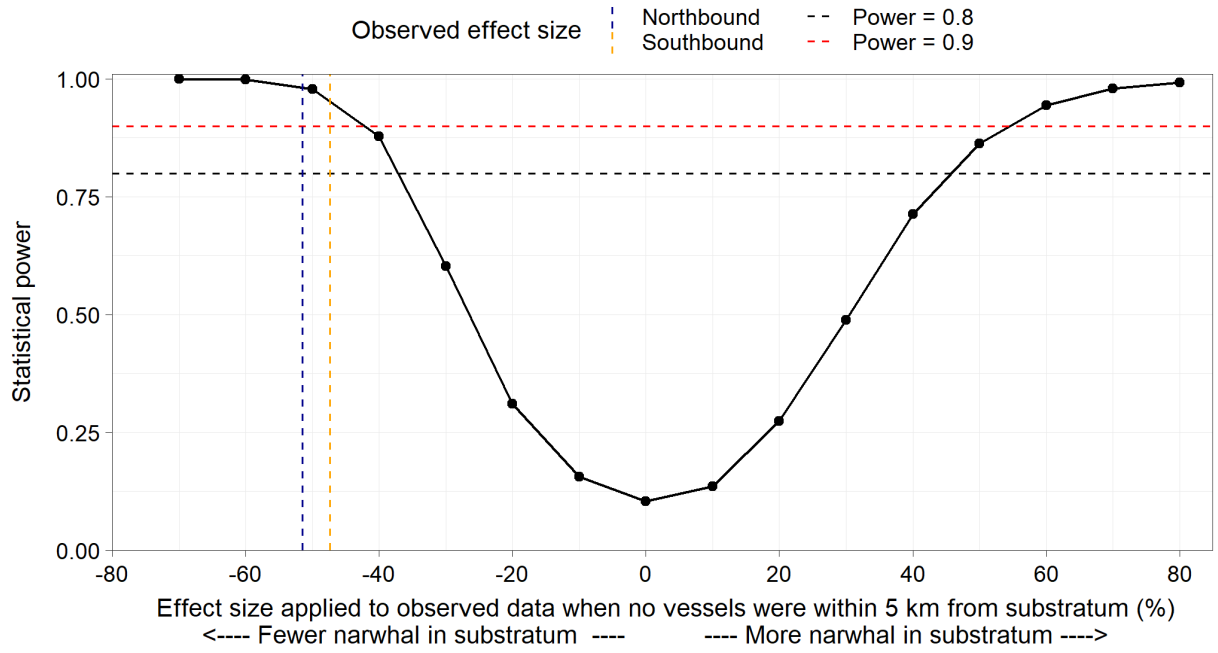


Figure 3: Statistical power of the overall model of RAD to detect a significant effect of distance from vessel, showing observed effect sizes for north- and southbound vessels.

Proportion of Immatures - Early Warning Indicator

There was sufficient power (≥0.8) to detect a significant difference between 2023 and the baseline 2014-2015 data at effect sizes of approximately -30% or +42% (Figure 4). In comparison, observed effect size for 2023 was +57%. Statistical power to estimate the observed effect was 1.0. That is, the analysis had sufficient power to detect effect sizes considerably smaller than that observed, and indeed the original analysis did find a significant difference between 2023 and the baseline 2014-2015 data.

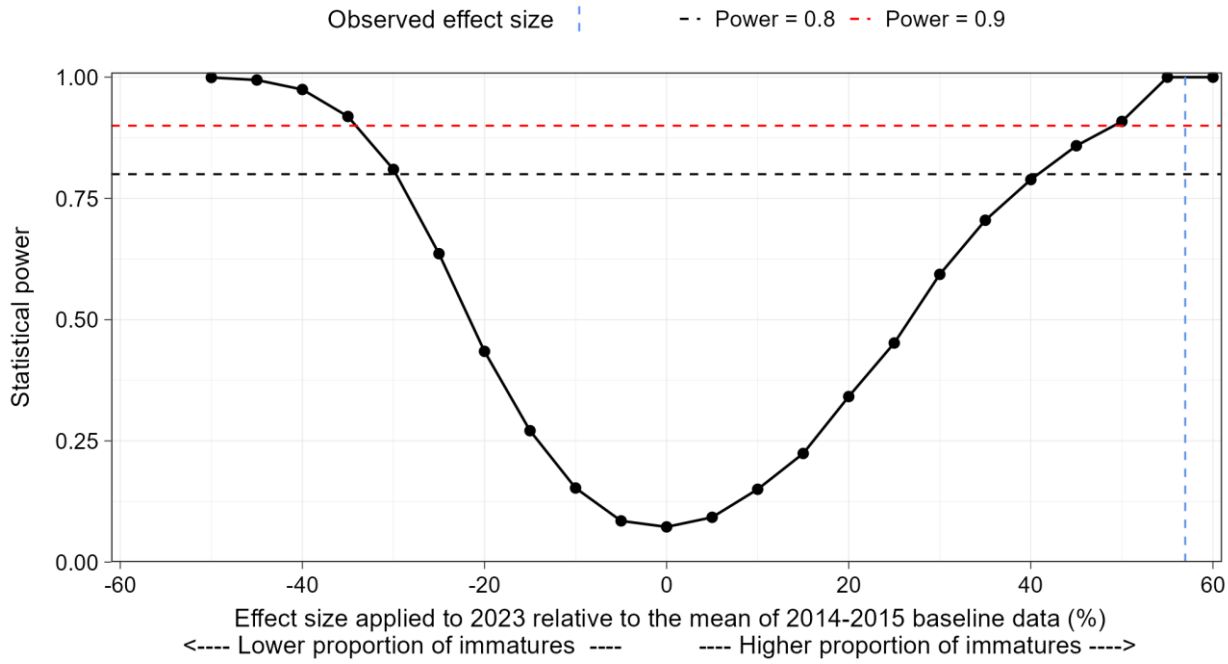


Figure 4: Statistical power of the planned comparison of 2021 to the 2014-2015 baseline data in the overall analysis of proportion of immatures as an Early Warning Indicator, showing observed effect size for 2023.

Focal Follow Surveys

Primary Behaviour

In the power analysis of group primary behaviour, an effect size larger than +1,500% would be required for sufficient power (≥0.8) to detect a significant effect of distance from vessel (Figure 13). This effect size corresponds to the increase in probability of a group resting, milling, or socializing from 0.117 to 0.679 for mother-immature pairs, from 0.147 to 0.734 for mixed groups with immatures, from 0.217 to 0.816 for mixed groups without immatures, and from 0.120 to 0.685 for adult groups.

In comparison, observed effect sizes for group spread in focal follows were -3% for mother-immature pairs and mixed groups with immatures, +1,154 for mixed groups without immatures, and -88% for adult groups. Statistical power to estimate observed effect sizes for adult groups was low (<0.6). Power to detect the effect size for mixed group with immatures was approximately 0.78. Overall, power was insufficient to detect the observed effect sizes, however the analysis did find a significant interaction between distance and group type (*P*=0.012).

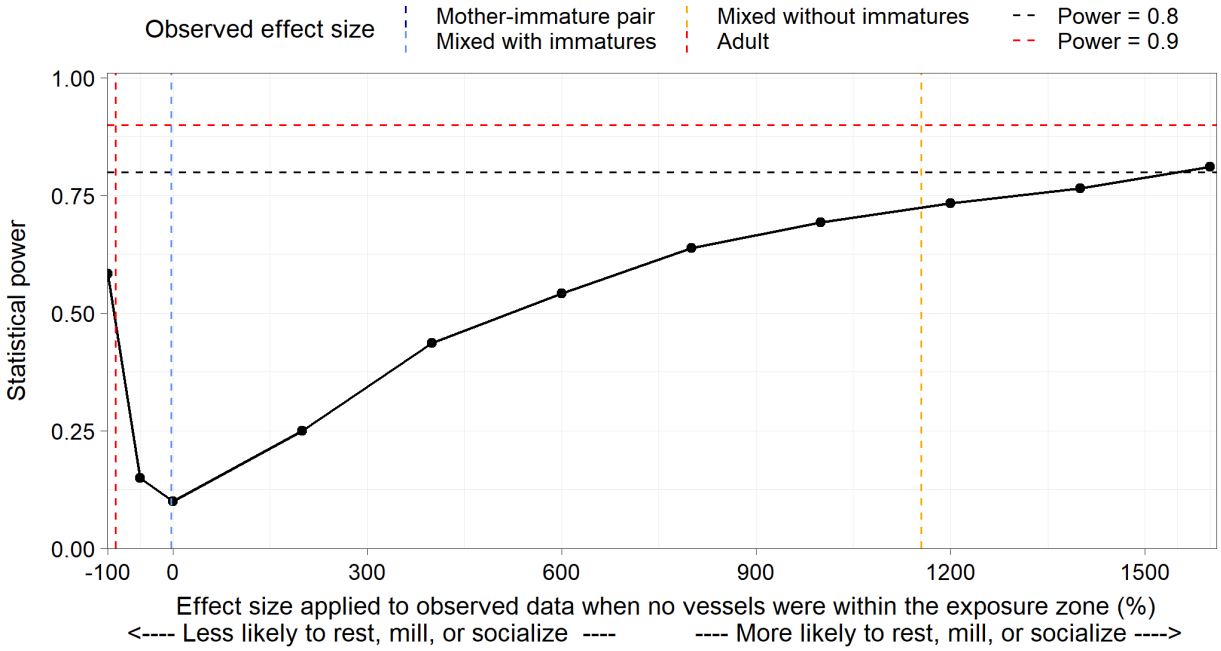


Figure 5: Statistical power of the overall model of group primary activity to detect a significant effect of distance from vessel, showing the observed effect sizes when a vessel was present at a distance of 0.5 km from the followed groups.

Unique behaviour

There was sufficient power (≥0.8) to detect a significant effect of vessel presence on unique behaviour at effect sizes of approximately +750%, but not at any of the negative effect sizes (Figure 6). This effect size corresponds to the increase in probability of a group engaging in unique behaviour from 0.159 to 0.616 for mother-immature pairs, from 0.162 to 0.622 for mixed groups with immatures, from 0.132 to 0.563 for mixed groups without immatures, and from 0.080 to 0.424 for adult groups.

In comparison, the observed effect size for unique behaviour in focal follows was -59% for all groups. Statistical power to estimate observed effect sizes was low (<0.5). Overall, power was insufficient to detect the observed effect sizes, however the analysis did find a significant effect of distance from vessel (*P*=0.033).

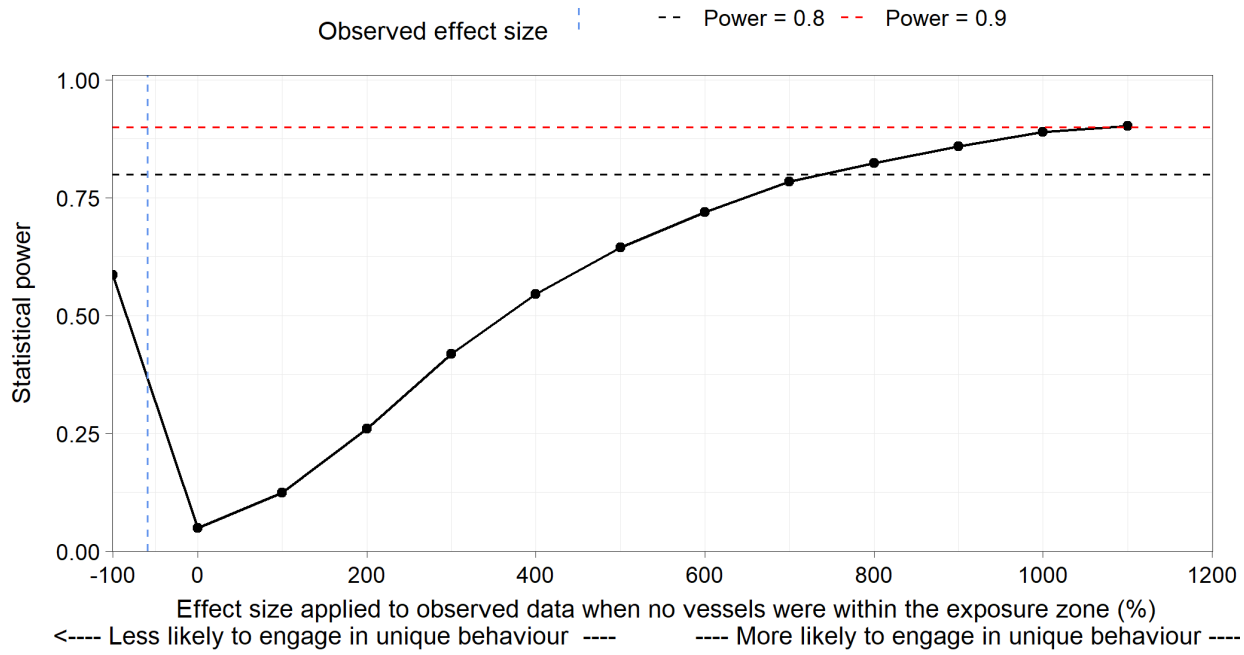


Figure 6: Statistical power of the overall model of unique behaviour to detect a significant effect of distance from vessel exposure, showing the observed effect size when a vessel was present at 0.5 km from the followed group.

Proportion Immatures

There was sufficient power (≥0.8) to detect a significant effect of vessel distance on proportion immatures for effect sizes of -92% or +1,100% (Figure 7). An effect size of -92% corresponds to the reduction in proportion immatures from 0.385 when no vessels were present to 0.048 when vessels were within 0.5 km from groups (for mother-immature pairs) and from 0.204 to 0.02 for mixed groups with immatures. An effect size of +1,100% corresponds to the increase in proportion immatures from 0.385 when no vessels were present to 0.883 when vessels were within 0.5 km from groups (for mother-immature pairs) and from 0.204 to 0.755 for mixed groups with immatures. In comparison, the observed effect sizes for proportion immatures were +46% and -69% for mother-immature pairs and mixed groups with immatures, respectively. Statistical power to estimate the observed effect sizes was <0.5. Overall, power was insufficient to detect the observed effect size; the analysis did not detect a significant effect of vessel distance (*P*=0.5 for interaction between distance from vessel and group type, and *P*=0.3 for main effect of distance from vessel).

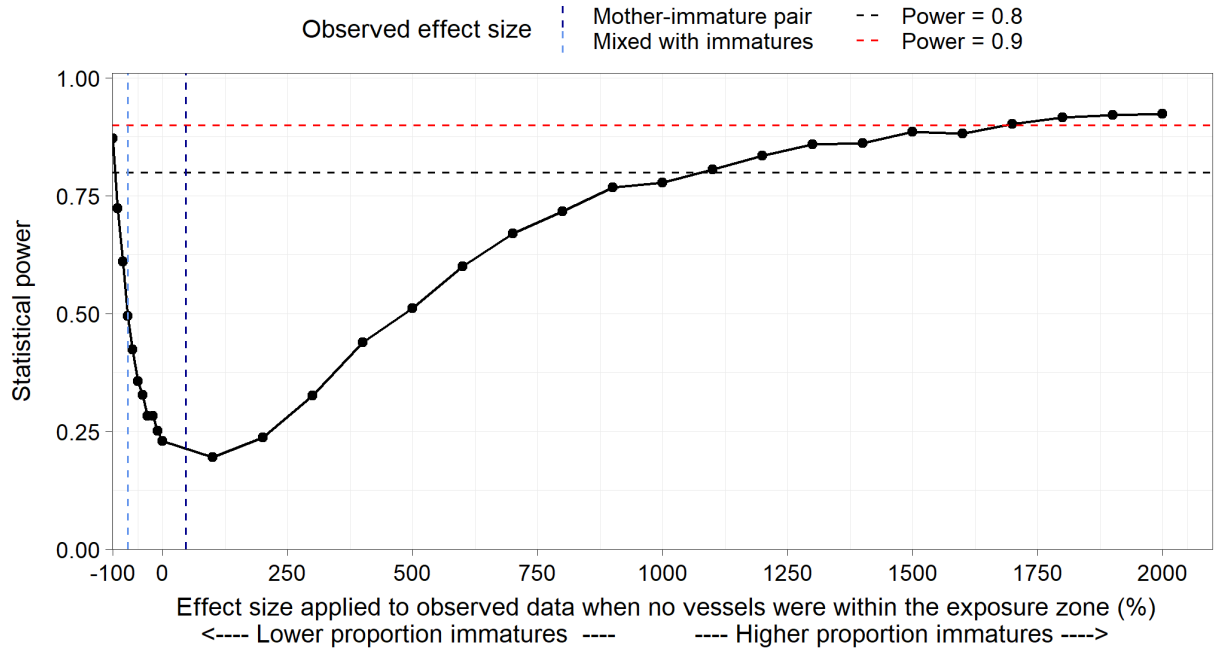


Figure 7: Statistical power of the overall model of proportion immatures to detect a significant effect of vessel distance, showing the observed effect sizes when a vessel was present at 0.5 km from the followed group.

Relative Position of Immature

There was not sufficient power (≥0.8) to detect a significant effect of vessel distance on the relative position of immature and adult at any of the examined effect sizes, from -100% to +3,000% (Figure 8). An effect size of +3,000% corresponds to the increase in probability of an immature being found under its presumed mother from 0.703 to 0.987 for mother-immature pairs and from 0.667 to 0.984 for mixed groups with immatures. In comparison, the observed effect size for relative position of immatures in focal follows was +13% when a vessel was at 0.5 km, relative to when no vessels were present within 5 km from the group. Statistical power to estimate the observed effect sizes was <0.2. Overall, power was insufficient to detect the observed effect size; the analysis did not detect a significant effect of vessel distance (P=0.5).

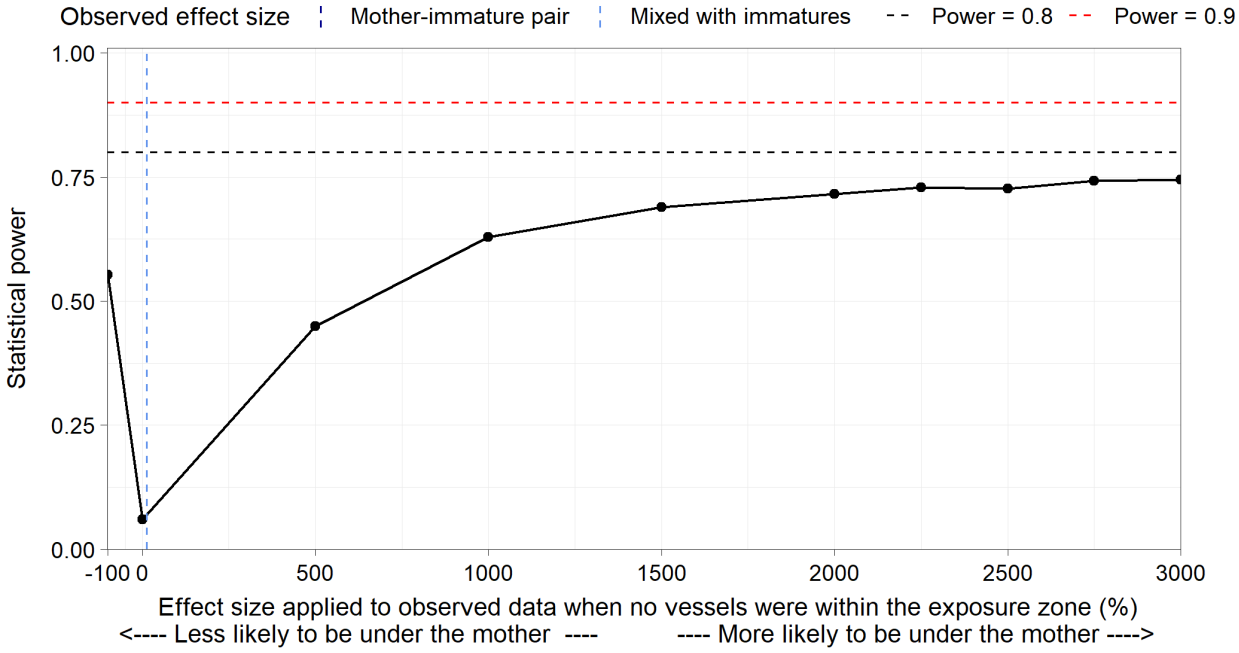


Figure 8: Statistical power of the overall model of relative position of immatures to detect a significant effect of vessel distance, showing the observed effect sizes when a vessel was present at 0.5 km from the followed group.

Spread between Immature and Adult

There was not sufficient power (≥0.8) to detect a significant effect of vessel distance on the spread between immature and adult at any of the examined effect sizes, from -100% to +2,000% (Figure 9). The low power despite the large effect sizes is due to the nonlinear nature of probabilities, where the high predicted probabilities of a tight association between immatures and their mothers mean that effect sizes need to be extremely large to change the predicted probabilities even slightly. For example, an effect size of +2,000% corresponds to the increase in probability of a tight association between immature and its presumed mother from 0.933 to 0.997 for immatures found in a lateral position relative to the adult, from 0.994 to 1.00 for immatures found on top of the adult, and from 0.999 to 1.00 for immatures found under the adult. In comparison, observed effect size for spread between immature and their mother in focal follows was -64%. Statistical power to estimate this observed effect size was low (<0.2). Overall, statistical power was low; the original analysis did not find a significant effect of vessel distance (*P*=0.2).

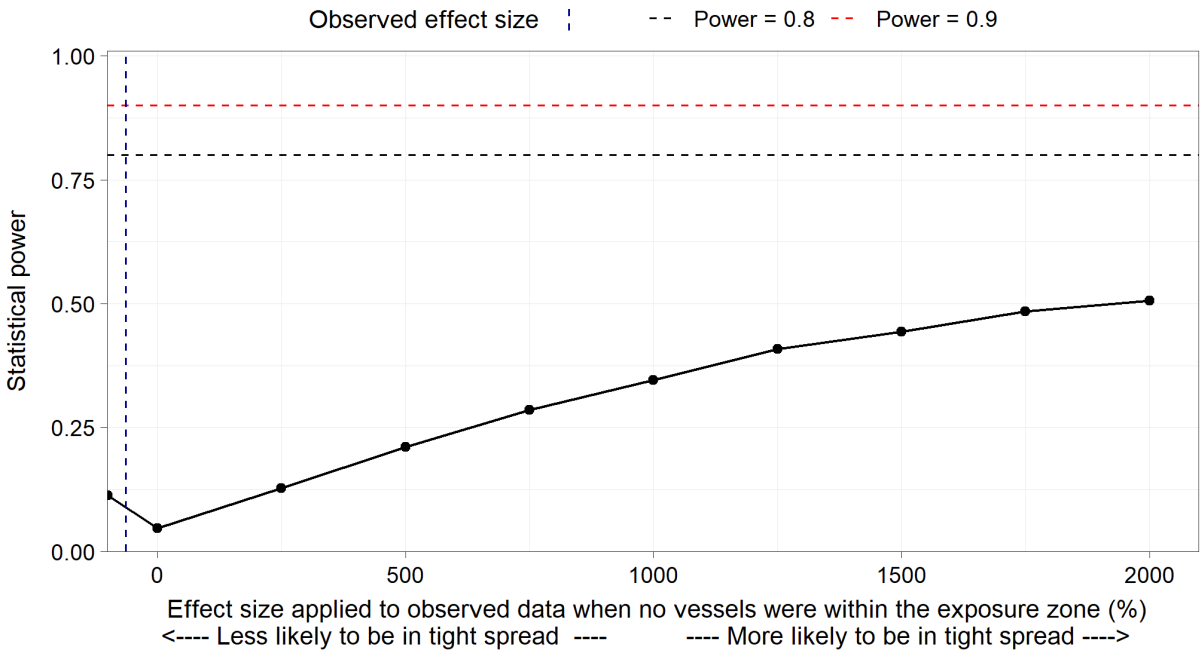


Figure 9: Statistical power of the overall model of distance between immature and adult to detect a significant effect of vessel distance, showing the observed effect sizes when a vessel was present at 0.5 km from the followed group.

Nursing

In the power analysis of nursing behaviour, an effect size of +1,750% would be required for sufficient power (≥0.8) to detect a significant effect of vessel presence within 5 km from the group (**Error! R eference source not found.**). This effect size corresponds to the increase in probability of nursing behaviour from 0.001 to 0.029 for mother-immature pairs and from 0.003 to 0.058 for mixed groups with immatures. In comparison, the observed effect sizes for nursing behaviour was -65% for both group types, since the model did not include an interaction with group type. Statistical power to estimate all observed effect sizes was low (<0.1). Overall, power was insufficient to detect the observed effect size, and the analysis did not find a significant effect of vessel presence (*P*=0.096).

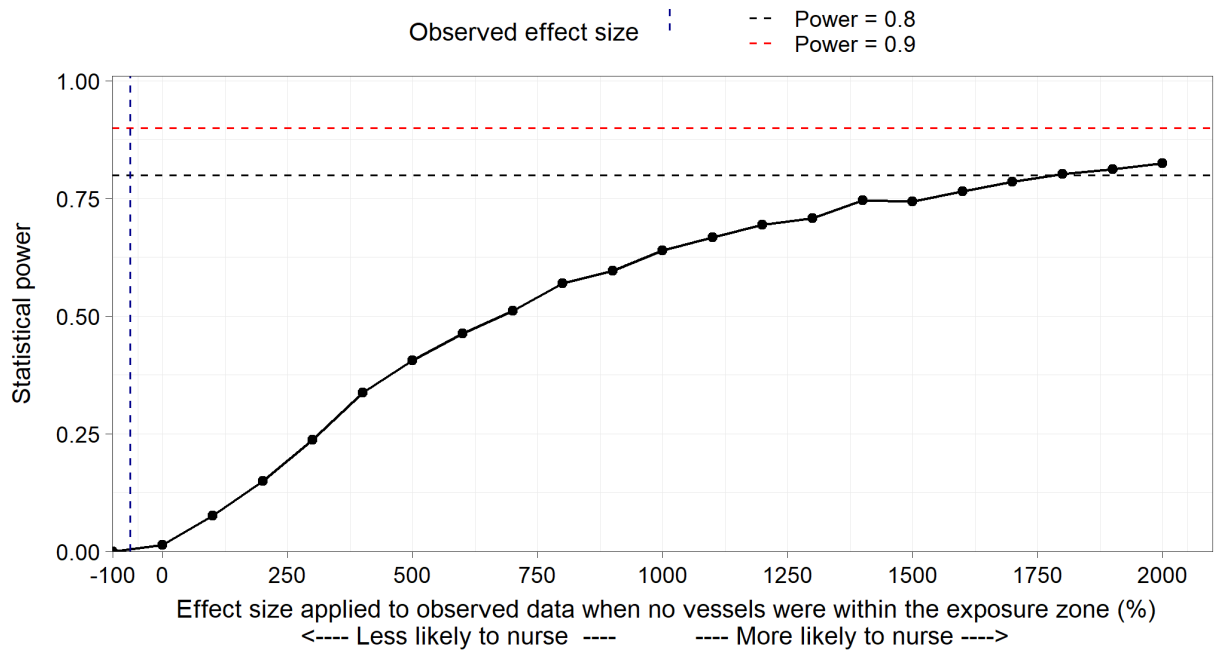


Figure 10: Statistical power of the overall model of nursing to detect a significant effect of vessel exposure, showing the observed effect sizes when a vessel was present within 5 km from the followed group.

Group Size

There was sufficient power (≥0.8) to detect a significant effect of vessel distance on group size at effect sizes of approximately +290% for mother-immature pairs, -72% or +115% for mixed groups with immatures, -75% or +160% for mixed groups without immatures, and -67% or +110% for adult groups (Figure **11**). Observed effect sizes for group sizes in focal follows were small (≤24% absolute value) for all cases, except for mother-immature pairs larger than two narwhal, where the effect size was estimated to be +28%. This effect size corresponds to the increase in the group size of mother-immature pairs with more than two narwhal from 2.6 individuals when no vessels were present within 5 km from groups to 2.6 narwhal at 0.5 km from vessels. However, data on mother-pair groups with more than two narwhal in the presence of vessels was limited to distances larger than 1.6 km, and the estimation of an effect size at a distance of 0.5 km from a vessel as done purely based on modeling estimates. Effect size for mother-immature pairs with only two narwhal was small (1%), and for these groups, data were collected in close proximity to vessels (0.66 km). That is, vessel distance data were available for minimum-sized mother-immature pairs, which accounted for most of the mother-immature pair data (79% of all mother-immature pair focal follows). Overall, the analysis did not have sufficient power to detect small or medium effect sizes for any of the group types. Despite this, the original analysis detected a significant effect of distance from vessels for mixed groups with immatures; however, this was likely due to an artifact of a larger effect sizes at 2-2.5 km from vessels.

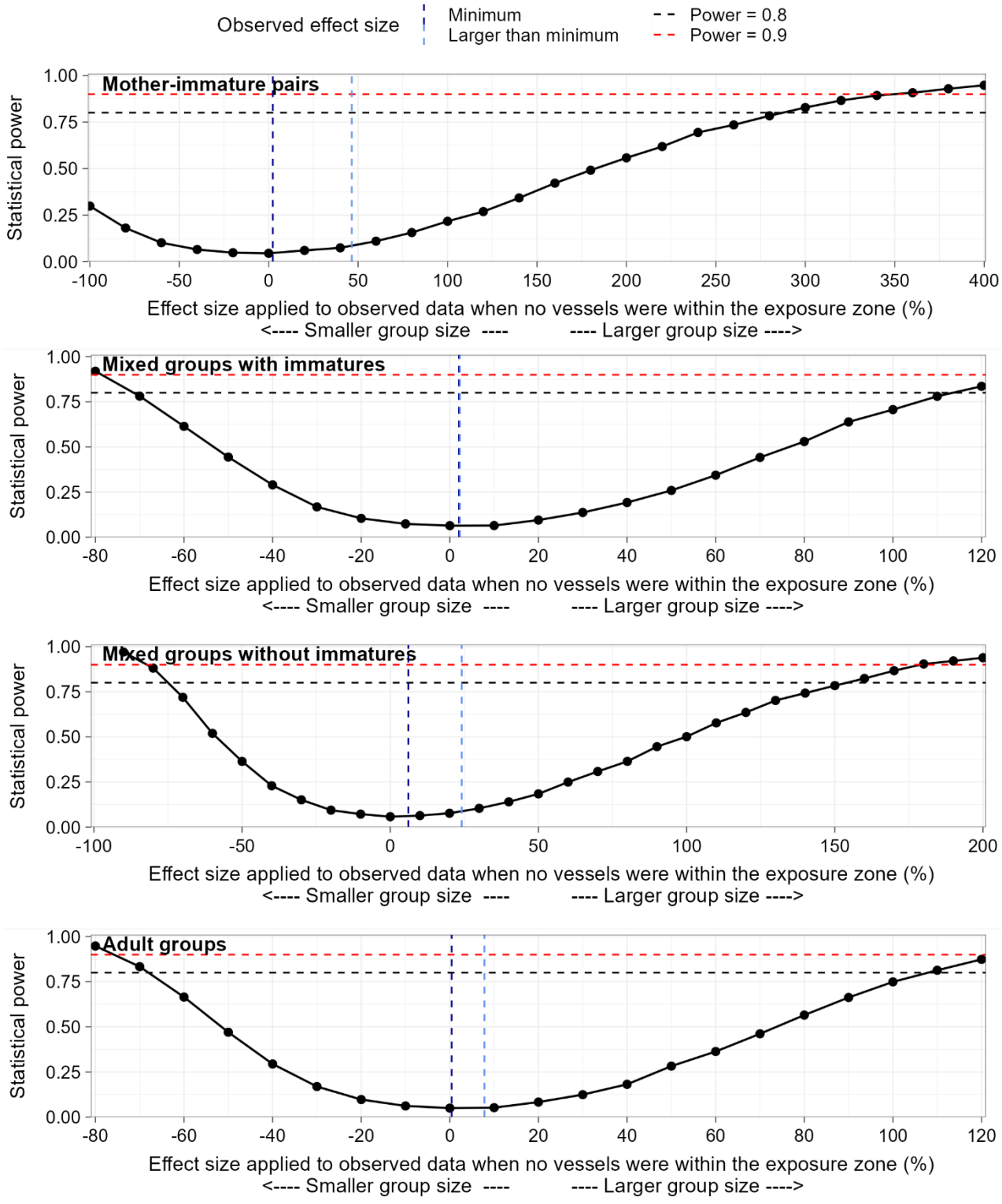
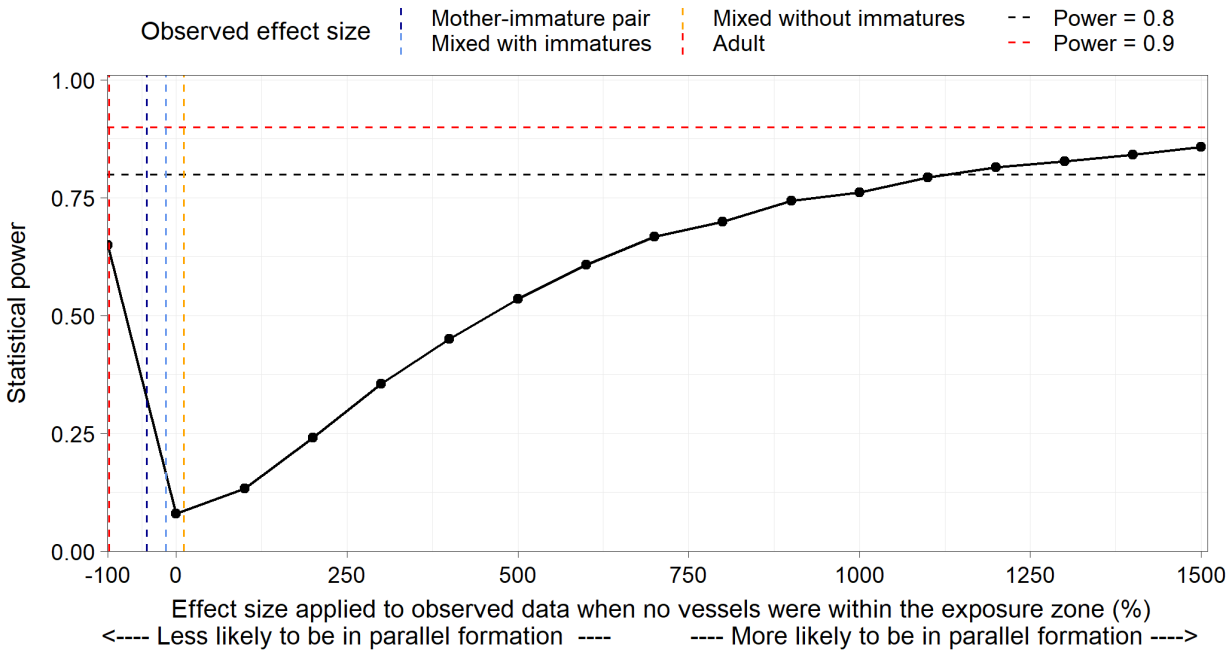


Figure 11**: Statistical power of the overall model of group size to detect a significant effect of vessel distance, showing the observed effect sizes when a vessel was present at 0.5 km from the followed group, shown separately for when groups were at smallest group size possible (single narwhal for mixed groups without immatures and adult groups, or two narwhal for mother-immature pairs and mixed groups with immatures) or larger group size.**

Group Formation

In the power analysis of group formation, an effect size larger than +1,150% would be required for sufficient power (≥0.8) to detect a significant effect of distance from vessel (Figure 13). This effect size corresponds to the increase in probability of parallel formation of a group from 0.295 to 0.840 for mother-immature pairs, from 0.341 to 0.866 for mixed groups with immatures, from 0.419 to 0.900 for mixed groups without immatures, and from 0.416 to 0.899 for adult groups.

In comparison, observed effect sizes for group spread in focal follows ranged between -98% and +11%. Statistical power to estimate all observed effect sizes was low (<0.7). Overall, power was insufficient to detect the observed effect sizes; however, the analysis did find a significant interaction between group type and distance from vessel (*P*=0.037).



Group Spread

In the power analysis of group spread, an effect size of +3,250% would be required for sufficient power (≥0.8) to detect a significant effect of distance from vessel (Figure 13). This effect size corresponds to the increase in probability of tight spread of a group from 0.945 to 0.998 for mother-immature pairs, from 0.434 to 0.963 for mixed groups with immatures, from 0.622 to 0.982 for mixed groups without immatures, and from 0.280 to 0.929 for adult groups.

In comparison, observed effect sizes for group spread in focal follows were -90% for all groups (since the model did not include an interaction between group and distance from vessel). Statistical power to estimate all observed effect sizes was very low (<0.5). Overall, power was insufficient to detect the observed effect sizes, however the analysis did find a significant effect of distance (*P*=0.002).

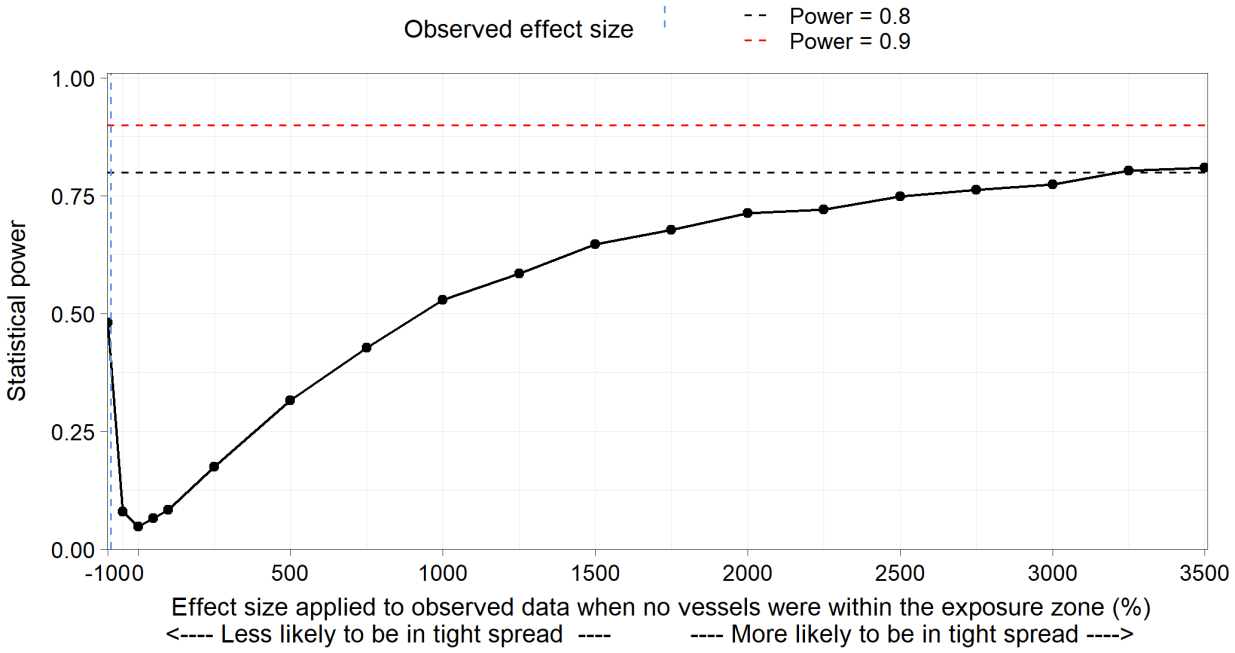


Figure 13: Statistical power of the overall model of group spread to detect a significant effect of distance from vessel, showing the observed effect sizes when a vessel was present at a distance of 0.5 km from the followed groups.

Group Travel Speed

There was sufficient power (≥0.8) to detect a significant effect of vessel distance on group travel speed at effect sizes of approximately ±37% (Figure 14). This effect size corresponds to a 37% increase or decrease in travel speed relative to values when no vessels were present within 5 km from a group – 0.90 m/s and 0.88 m/s for mother-immature pairs and mixed groups with immatures, respectively, 0.96 m/s for mixed groups without immatures, and 0.96 for adult groups. In comparison, observed effect sizes for travel speed in focal follows were: +98% for mother-immature pairs, +38% for mixed groups with immatures, -14% for mixed groups without immatures, and +64% for adult groups. Most of the observed effect sizes were medium or large (i.e., ≥25%). Statistical power to estimate effect sizes of 37% or larger was sufficient (≥0.8), and the original analysis found a significant effect of distance from vessel (*P*=0.005).

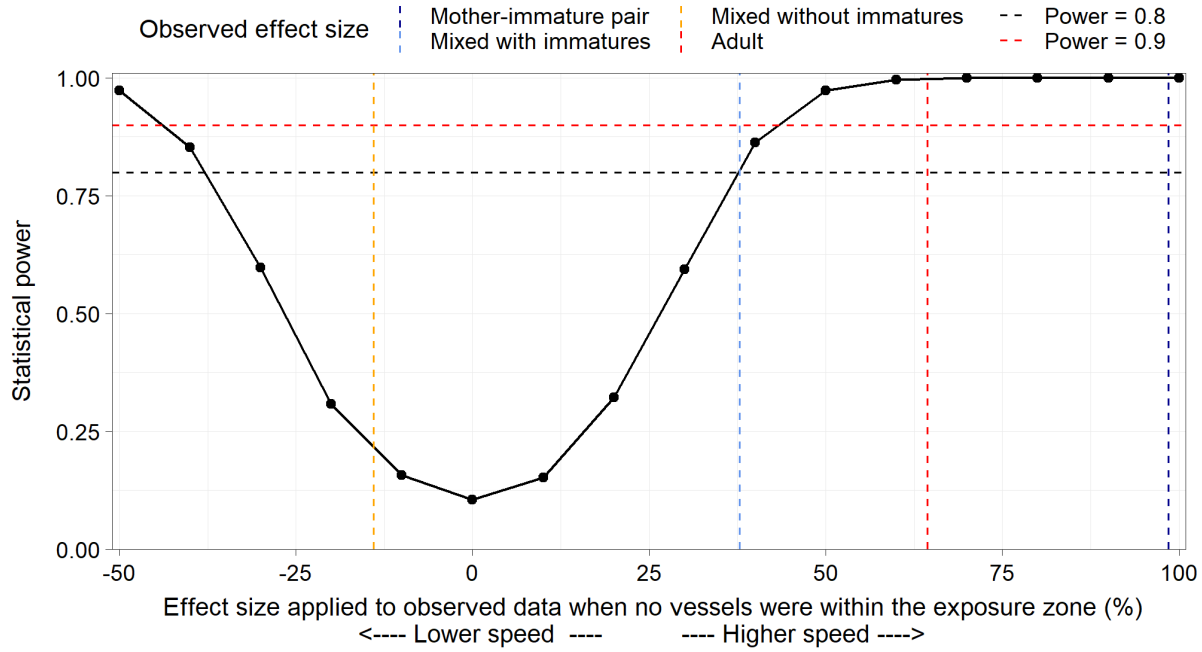


Figure 14: Statistical power of the overall model of group travel speed to detect a significant effect of vessel distance, showing the observed effect sizes when a vessel was present at 0.5 km from the followed group.

SUMMARY

Most of the assessed analyses required large effect sizes for sufficient (≥0.8) statistical power to detect an effect of distance from vessels (absolute value of 50% or more in the odds or in the incidence rates; Table 1).

This is likely due to a combination of the following factors:

- Inherent data variability
- Smaller dataset for focal follow data (4,665 data points from 412 unique focal follows, compared to 63,996 for RAD data), which reduces the statistical power of tests performed on focal follow data relative to the RAD data.

- Only sparse data was available at close approach distances to focal follow narwhal groups. For example, when Project vessels were within 2 km from focal follow groups, only 184 data points from 21 unique focal follows were recorded as part of the focal follow dataset (throughout 2020-2023). When Project vessels were within 1 km from focal follow groups, only 28 data points from 6 unique focal follows were recorded as part of the focal follow dataset (throughout 2020-2023).

The focal follow analyses generally had lower power than RAD data due to the limited sample size, especially in the presence of vessels, and when group type had to be accounted for. As more data are collected, statistical power of focal follow analyses is expected to increase.

In the original analyses, the RAD analysis and six of the ten focal follow analyses detected an overall effect of distance from vessel or a significant interaction between distance from vessel and another variable. Overall, the results of the power analysis presented here indicate that analyses of focal follow data often had low power to detect small to medium effect sizes, therefore the effect of distance from vessel should be assessed using effect sizes rather than a strict adherence to statistical significance.

Table 1: Power to detect effects of distance from a single vessel

Component	Analysis	Effect size for power ≥ 0.8 (%)	Range of observed effect sizes[1] (%)	Effect detected in original analysis?
RAD (SSA)	RAD	-40% or +45%	-51% to -47%	Y
EWI	Proportion of immatures	-30% or +42%	-24%	N
Focal follow surveys	Primary behaviour	+1,154%	Between -88% and +1,154%	Y
	Unique behaviour	+750%	-59%	Y
	Proportion immatures	-92% or +1,100%	-69% and + 46%	N
	Relative position of immature	>+3,000%	+13%	N
	Spread between immature and adult	>+2,000%	-64%	N
	Nursing	+1,750%	-65%	N
	Group size	-67% or +110% for adult groups, larger absolute effect sizes for others	Between 0.4% and +28%	Y (but likely an artefact)
	Group formation	+1,150%	Between -98% and +11%	Y
	Group spread	+3,250%	-90%	Y
	Group travel speed	±37%	Between -14% and +98%	Y

Notes: [1] = effect sizes calculated at 0 km for RAD, 0.5 km in the analysis of UAV-based group behaviour, and as the relative difference between 2021 and the baseline 2014-2015 least squares means for EWIs.

APPENDIX B

Vessel Track Information

Medium (>50 m) and large (>100 m) vessels in SSA during the 2023 Bruce Head Field Program
**Black Text = vessels observed. Grey text = Vessels not observed
*Nordic Olympic had malfunctioning AIS on August 18/20, observed in 0600 RAD on Aug 18, AIS details not available

Count	Date in SSA	Approximate time in SSA (EST)	Vessel Name	Vessel Class	Travel Direction	Vessel speed (kt) in SSA (max)
1	August 10 2023	(04:07 - 05:32)	Claude A Desgagnes	General Cargo	South	Under 8.5
2	August 11 2023	(18:10-19:49)	Nordic Nuluujak	Bulk (Ore) Carrier	South	Under 8.3
3	August 11 2023	(18:18-19:57)	Rossi A. Desgagnes	Oil and Chemical Tanker	South	Under 7.6
4	August 11 2023	(19:09-20:41)	Golden Opal	Bulk (Ore) Carrier	South	Under 8.6
5	August 11 2023	(19:00-20:30)	Nordic Odyssey	Bulk (Ore) Carrier	South	Under 8.2
6	August 13 2023	(16:06-17:35)	Nordic Nuluujak	Bulk (Ore) Carrier	North	Under 8.4
7	August 13 2023	(17:19-18:42)	Nordic Qinngua	Bulk (Ore) Carrier	South	Under 8.8
8	August 14 2023	(14:40-16:11)	Nordic Odyssey	Bulk (Ore) Carrier	North	Under 8.5
9	August 14 2023	(20:34-22:04)	Claude A Desgagnes	General Cargo	North	Under 8.4
10	August 14 2023	(16:27-17:52)	Nordic Siku	Bulk (Ore) Carrier	South	Under 9
11	August 15 2023	(09:47-11:12)	Gaia Desgagnes	Oil and Chemical Tanker	South	Under 8.6
12	August 15 2023	(22:29-23:57)	Golden Opal	Bulk (Ore) Carrier	North	Under 8.6
13	August 16 2023	(00:46-02:16)	Flag Mette	Bulk (Ore) Carrier	South	Under 8.7
14	August 17 2023	(02:57-04:22)	Nordic Qinngua	Bulk (Ore) Carrier	North	Under 8.8
15	August 17 2023	(06:38-08:09)	Golden Suek	Bulk (Ore) Carrier	South	Under 8.1
16	August 18 2023	~06:00	Nordic Olympic*	Bulk (Ore) Carrier	South	Unknown
17	August 18 2023	(01:53-03:19)	Flag Mette	Bulk (Ore) Carrier	North	Under 8.6
18	August 18 2023	(10:09-11:35)	Rossi A. Desgagnes	Oil and Chemical Tanker	North	Under 8.6
19	August 19 2023	(00:24-01:49)	Nordic Siku	Bulk (Ore) Carrier	North	Under 8.7
20	August 19 2023	(03:01-04:27)	Nordic Orion	Bulk (Ore) Carrier	South	Under 8.6
21	August 19 2023	(17:14-18:50)	Golden Suek	Bulk (Ore) Carrier	North	Under 7.7

Count	Date in SSA	Approximate time in SSA (EST)	Vessel Name	Vessel Class	Travel Direction	Vessel speed (kt) in SSA (max)
22	August 19 2023	(20:13-21:54)	Golden Diamond	Bulk (Ore) Carrier	South	Under 7.9
23	August 20 2023	Unknown	Nordic Olympic*	Bulk (Ore) Carrier	North	Unknown
24	August 20 2023	(13:43-15:06)	Nordic Odin	Bulk (Ore) Carrier	North	Under 8.8
25	August 21 2023	(10:33-12:00)	Nordic Orion	Bulk (Ore) Carrier	North	Under 8.7
26	August 21 2023	(11:38-13:03)	Nordic Oshima	Bulk (Ore) Carrier	South	Under 8.6
27	August 22 2023	(09:21-10:52)	Golden Diamond	Bulk (Ore) Carrier	North	Under 8.5
28	August 22 2023	(10:29-11:04)	Nordic Oasis	Bulk (Ore) Carrier	South	Under 8.6
29	August 22 2023	(15:00-16:23)	Gaia Desgagnes	Oil and Chemical Tanker	North	Under 8.9
30	August 22 2023	(16:08-17:45)	Nordic Sanngijuq	Bulk (Ore) Carrier	South	Under 8.7
31	August 23 2023	(12:29-13:54)	Nordic Odin	Bulk (Ore) Carrier	North	Under 8.9
32	August 23 2023	(12:57-14:36)	Nordic Oasis	Bulk (Ore) Carrier	North	Under 8.8

APPENDIX C

Test Statistics and Coefficients

RAD analysis

Table C-1: Test statistics of generalized mixed model of narwhal counts in SSA (type II *P* values)

Parameter	Chi squared	Df	*P* value
Negative binomial component of model			
Day of year	252.333	2	**<0.001**
Year	2288.759	8	**<0.001**
North-south gradient in narwhal counts	29.931	2	**<0.001**
East-west gradient in narwhal counts	14.601	2	**0.001**
Glare	54.265	2	**<0.001**
Beaufort scale	82.93	4	**<0.001**
Tide	83.408	3	**<0.001**
Directional distance	17.546	2	**<0.001**
North- or southbound vessel	3.387	1	0.066
Vessel presence within 5 km from substratum	18.517	1	<0.001
Hunting event within 70 minutes prior to observation	21.165	1	**<0.001**
Presence of small vessels in SSA	0.21	1	0.647
North-south gradient in narwhal counts:East-west gradient in narwhal counts	17.465	4	**0.002**
Directional distance:North- or southbound vessel	1.697	2	0.428
Zero-inflation component of model			
North-south gradient in narwhal counts	56.295	2	**<0.001**
East-west gradient in narwhal counts	82.663	2	**<0.001**
Day of year	153.818	2	**<0.001**
Beaufort scale	202.737	4	**<0.001**
North-south gradient in narwhal counts:East-west gradient in narwhal counts	9.807	4	**0.044**

Behaviour (UAV-based Focal Follow Surveys)

Primary Behaviour

Table C-2: Test statistics of a generalized mixed model of primary behaviour (type II *P* values)

Parameter	Chi squared	Df	*P* value
Vessel presence within 5 km from group	0.692	1	0.406
Distance	0.534	1	0.465
Group type	9.397	3	0.024
Group size	10.729	2	0.005
Beaufort	18.901	3	<0.001
Water clarity	0.076	2	0.963
Distance : Group type	10.937	3	0.012

Unique Behaviour

Table C-3: Test statistics of a generalized mixed model of unique behaviour (type II *P* values)

Parameter	Chi squared	Df	*P* value
Vessel presence within 5 km from group	0.002	1	0.966
Distance	8.701	3	0.034
Group type	15.736	3	0.001
Group size	39.804	2	<0.001
Primary behaviour	192.435	2	<0.001
Beaufort	5.122	3	0.163
Water clarity	4.923	2	0.085

Proportion Immatures

Table C-4: Test statistics of a generalized mixed model of proportion immatures (type II *P* values)

Parameter	Chi squared	Df	*P* value
Vessel presence within 5 km from group	0.084	1	0.772
Distance	2.201	2	0.333
Group type at maximum group size	35.731	1	<0.001
Group size	118.24	3	<0.001
Beaufort	5.392	3	0.145
Distance : Group type at maximum group size	2.29	2	0.318

Presence of Nursing Behaviour

Table C-5: Test statistics of a generalized mixed model of nursing behaviour (type II *P* values)

Parameter	Chi squared	Df	*P* value
Vessel presence within 5 km from group	2.768	1	0.096
Group type	1.121	1	0.29
Group size	4.295	1	0.038

Relative Positioning of Immatures

Table C-6: Test statistics of a generalized mixed model of relative position of immatures (type II *P* values)

Parameter	Chi squared	Df	*P* value
Vessel presence within 5 km from group	0.643	1	0.422
Distance	0.508	1	0.476
Group type	0.232	1	0.63
Primary behaviour	9.491	2	0.009
Group size	4.034	2	0.133
Water clarity	4.964	2	0.084
Beaufort	1.988	3	0.575

Distal Positioning of Immatures

Table C-7: Test statistics of a generalized mixed model of distal position of immatures (type II *P* values)

Parameter	Chi squared	Df	*P* value
Vessel presence within 5 km from group	6.131	1	0.013
Distance	3.304	2	0.192
Relative position of immature	134.106	2	<0.001
Primary behaviour	5.363	2	0.068
Group type	0.016	1	0.899
Group size	4.241	2	0.12
Beaufort	2.425	3	0.489
Water clarity	2.068	2	0.356

Group Formation

Table C-8: Test statistics of generalized mixed model of group formation (type II *P* values)

Parameter	Chi squared	Df	*P* value
Vessel presence within 5 km from group	0.081	1	0.776
Distance	4.029	2	0.133
Group type	3.198	3	0.362
Group size	60.769	1	<0.001
Primary behaviour	92.033	2	<0.001
Water clarity	1.481	2	0.477
Beaufort	1.526	3	0.676
Distance : Group type	13.42	6	0.037

Group Spread

Table C-9: Test statistics of generalized mixed model of group spread (type II *P* values)

Parameter	Chi squared	Df	*P* value
Vessel presence within 5 km from group	2.297	1	0.13
Distance	14.852	3	0.002
Group type	116.918	3	<0.001
Primary behaviour	81.592	2	<0.001
Group size	23.845	2	<0.001
Water clarity	2.69	2	0.261
Beaufort	13.8	3	0.003

Group Size

Table C-10: Test statistics of a generalized mixed model of group size (type II *P* values)

Group	Parameter	Chi squared	Df	*P* value
Adult	Vessel presence within 5 km from group	0.003	1	0.958
	Distance	1.301	3	0.729
	Previous group of minimum size	285.598	1	<0.001
	Beaufort	8.827	3	0.032
Mother-calf pairs	Vessel presence within 5 km from group	2.198	1	0.138
	Distance	1.774	2	0.412
	Previous group of minimum size	51.705	1	<0.001
Mixed with immatures	Vessel presence within 5 km from group	3.526	1	0.06
	Distance from vessel	10.06	3	0.018
	Previous group of minimum size	2.544	1	0.111
	Beaufort	4.186	3	0.242
	Water clarity	1.973	2	0.373
Mixed without immatures	Vessel presence within 5 km from group	0.737	1	0.391
	Distance from vessel	2.658	3	0.447
	Previous group of minimum size	89.952	1	<0.001
	Beaufort	7.566	3	0.056
	Water clarity	0.22	2	0.896

Travel Speed

Table C-11: Test statistics of generalized mixed model of travel speed (type II *P* values)

Parameter	Chi squared	Df	*P* value
Vessel presence within 5 km from group	6.984	1	0.008
Distance	12.654	3	0.005
Group type	4.139	3	0.247
Primary behaviour	339.161	1	<0.001
Water clarity	0.941	2	0.625
Beaufort	22.929	3	<0.001
Distance : Group type	12.144	9	0.205

APPENDIX D

Model Diagnostics

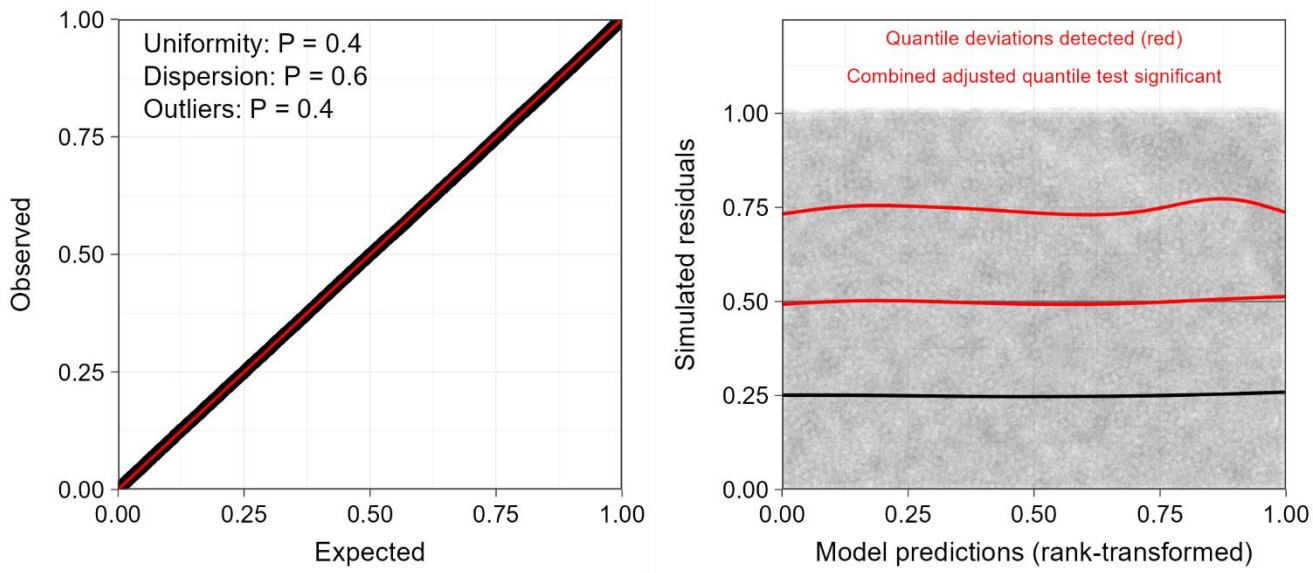


Figure D-1: Residual diagnostics for relative density model – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

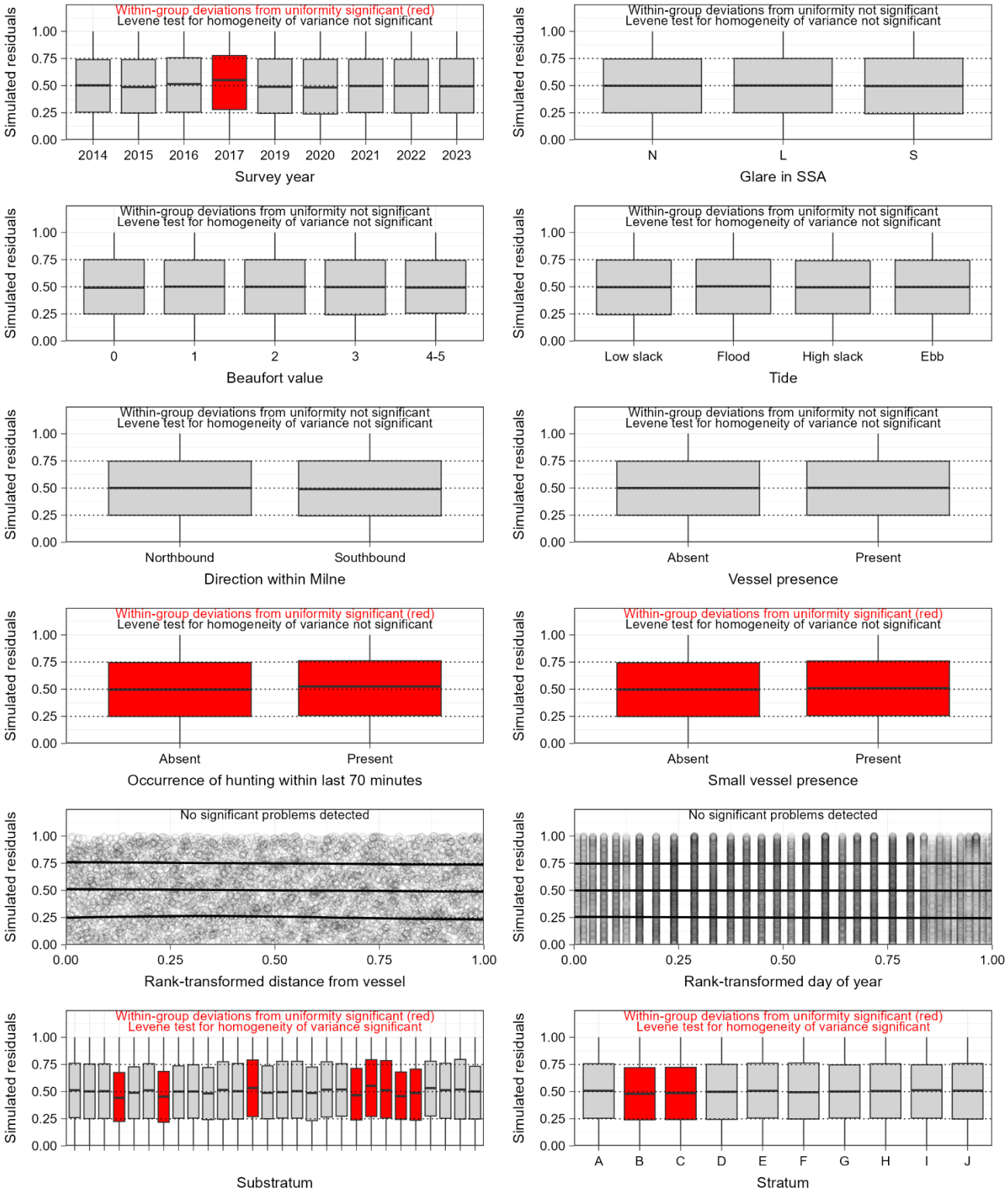


Figure D-2: Residual diagnostics for narwhal density model – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

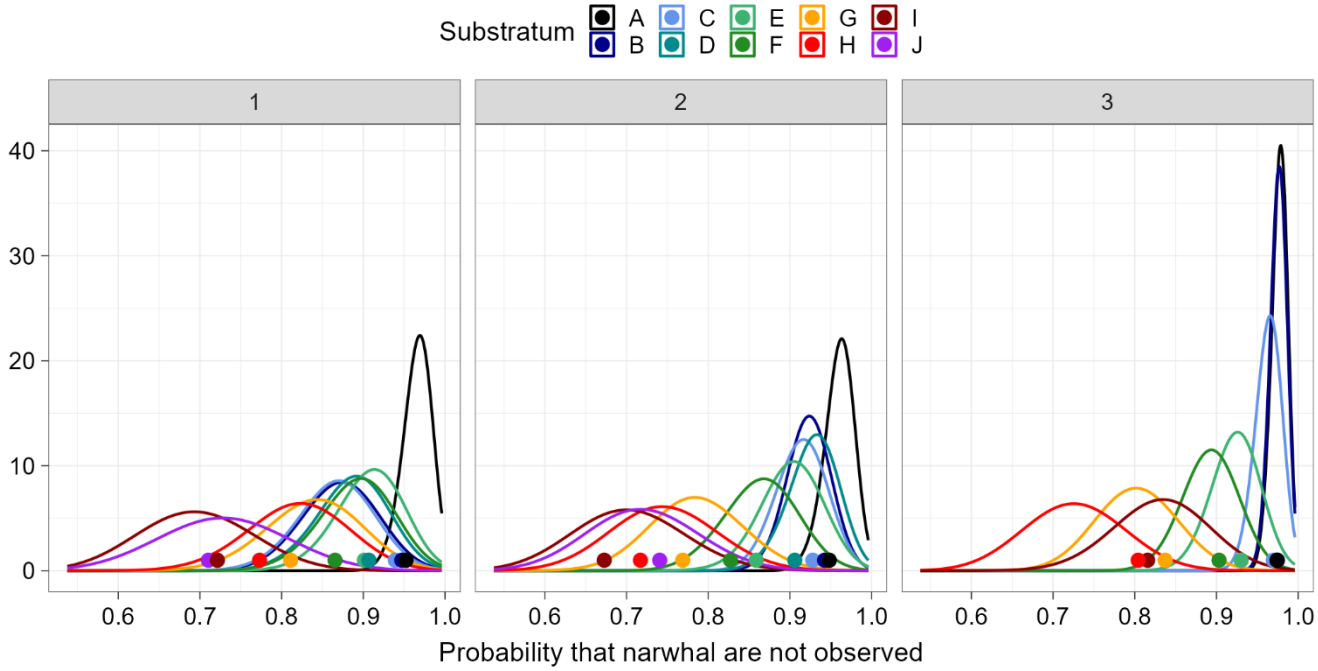


Figure D-3: Density model diagnostics – simulated zero counts. Each panel represents a different substratum (1, 2, or 3). Densities are values from 1000 data sets simulated from model selected for interpretation. Points represent the observed data.

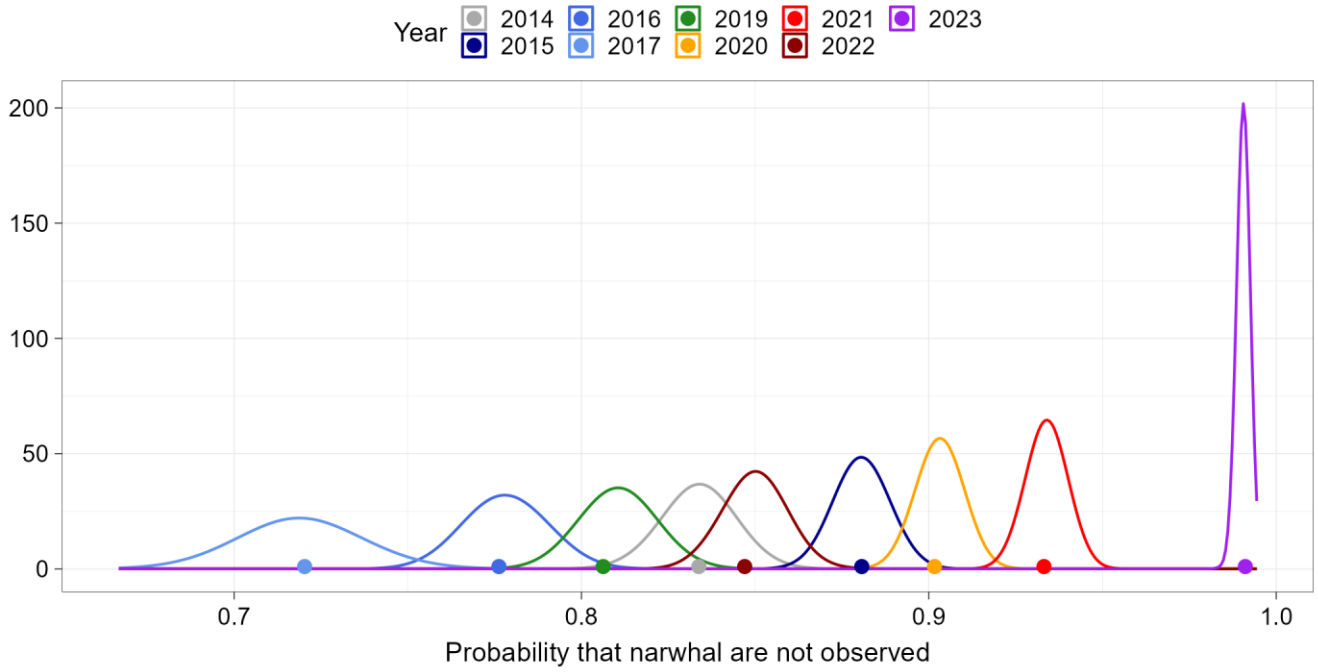


Figure D-4: Density model diagnostics – simulated zero counts. Each curve represents a different sampling year. Densities are values from 1000 data sets simulated from model selected for interpretation. Points represent the observed data.

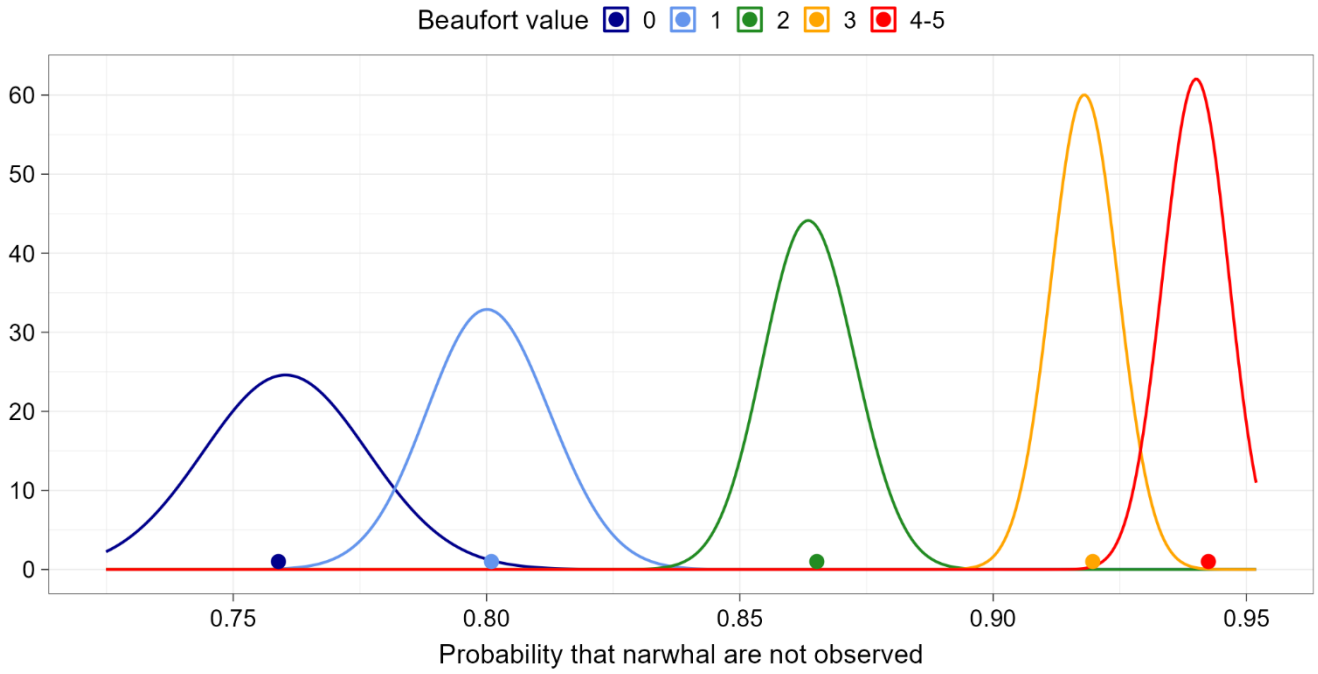


Figure D-5: Density model diagnostics – simulated zero counts. Each curve represents a different Beaufort scale value. Densities are values from 1000 data sets simulated from model selected for interpretation. Points represent the observed data.

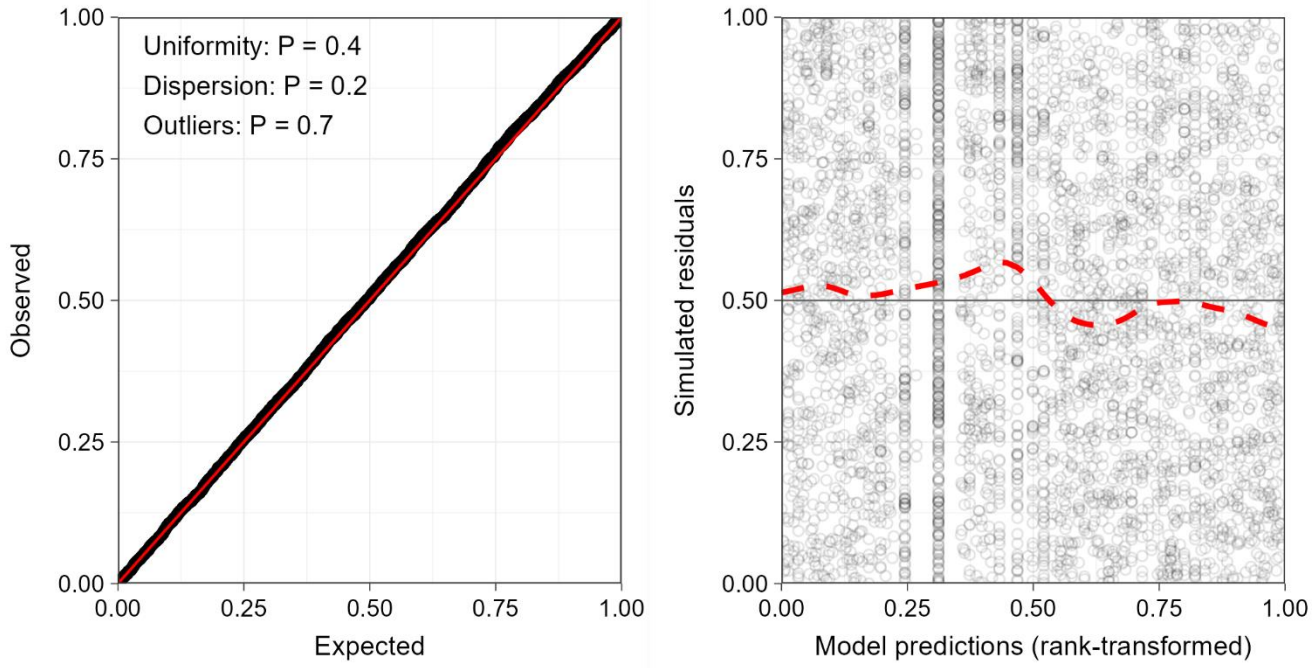


Figure D-6: Residual diagnostics for model of primary behaviour – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

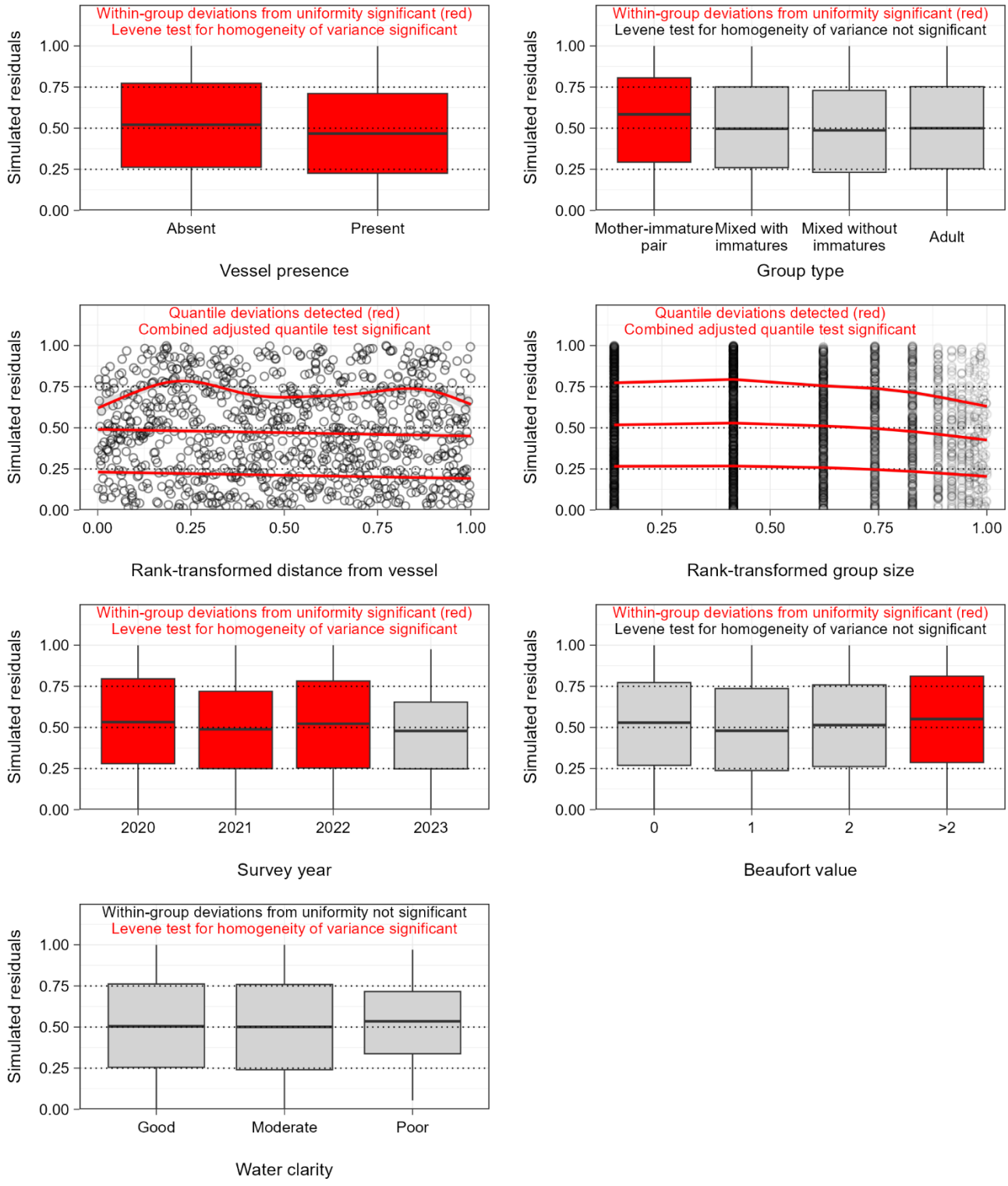


Figure D-7: Residual diagnostics for model of primary behaviour – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

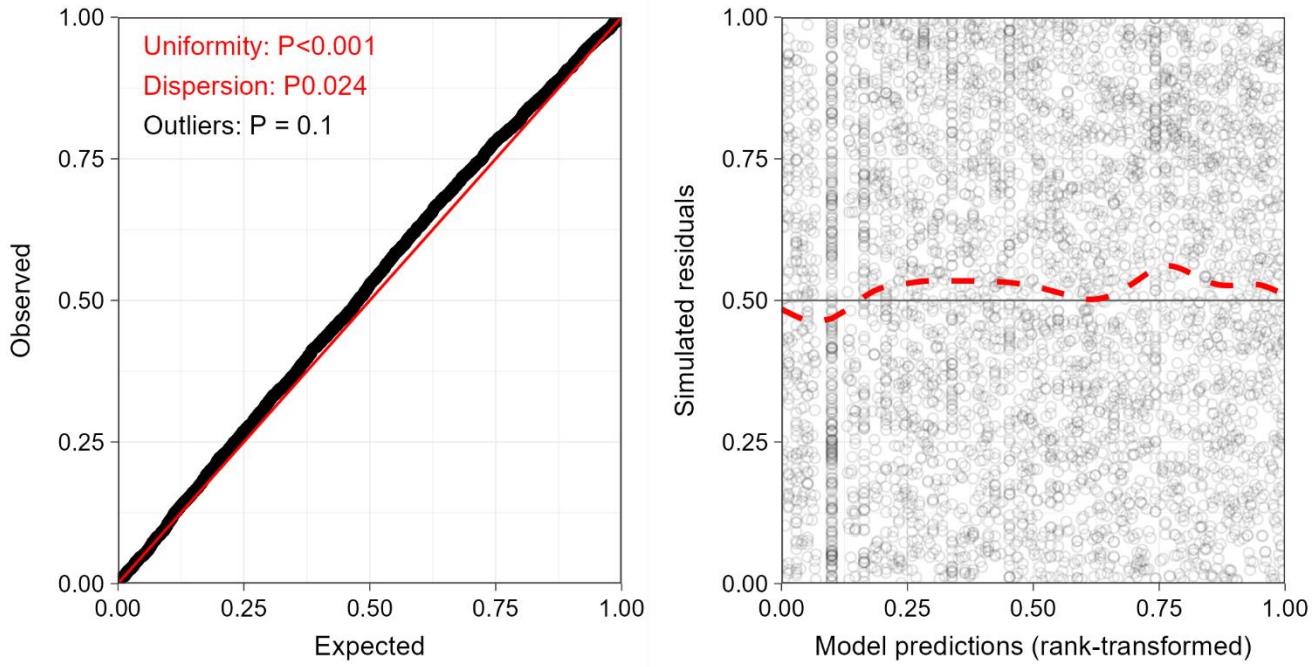


Figure D-8: Residual diagnostics for model of unique behaviour – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

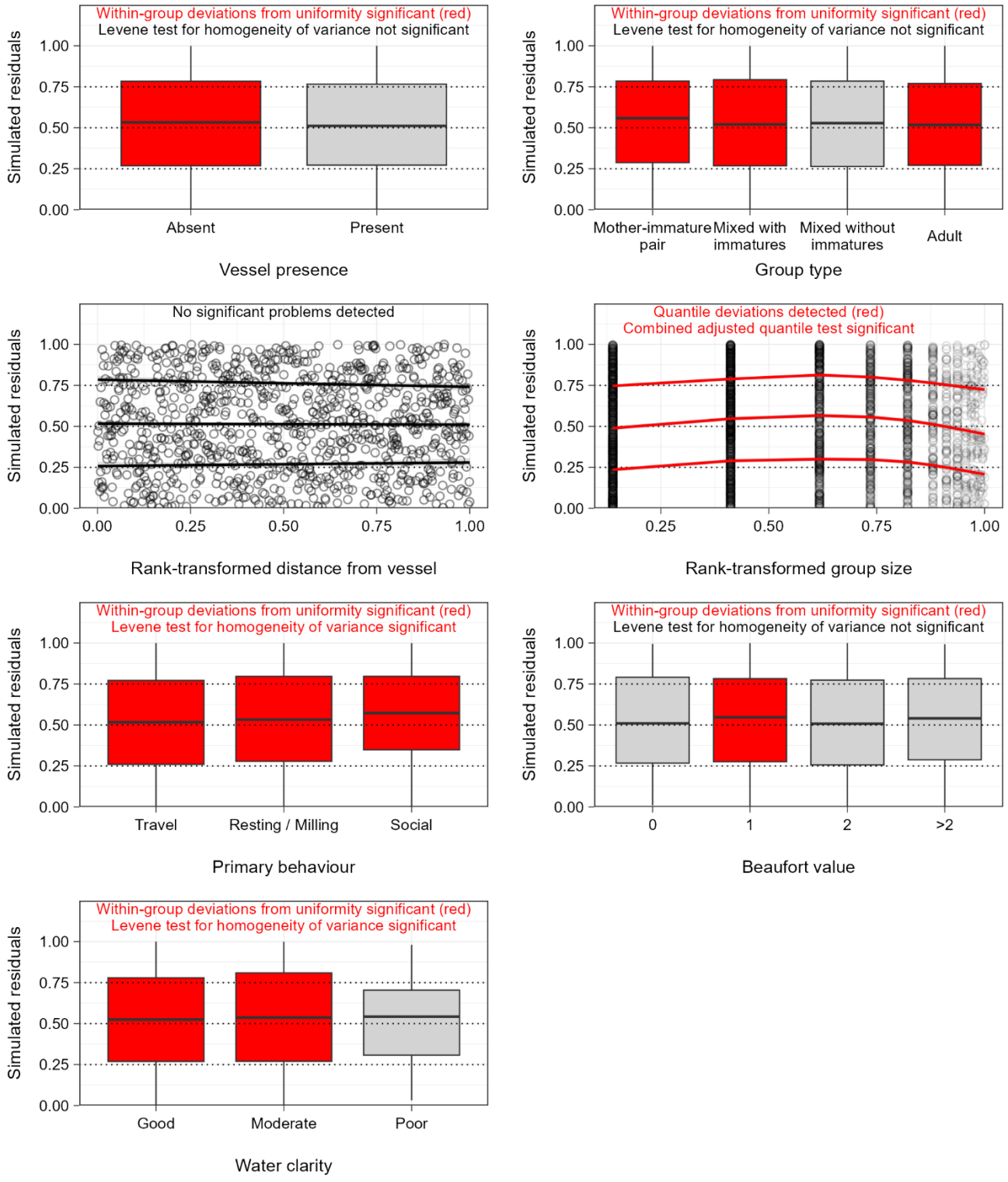


Figure D-9: Residual diagnostics for model of unique behaviour – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

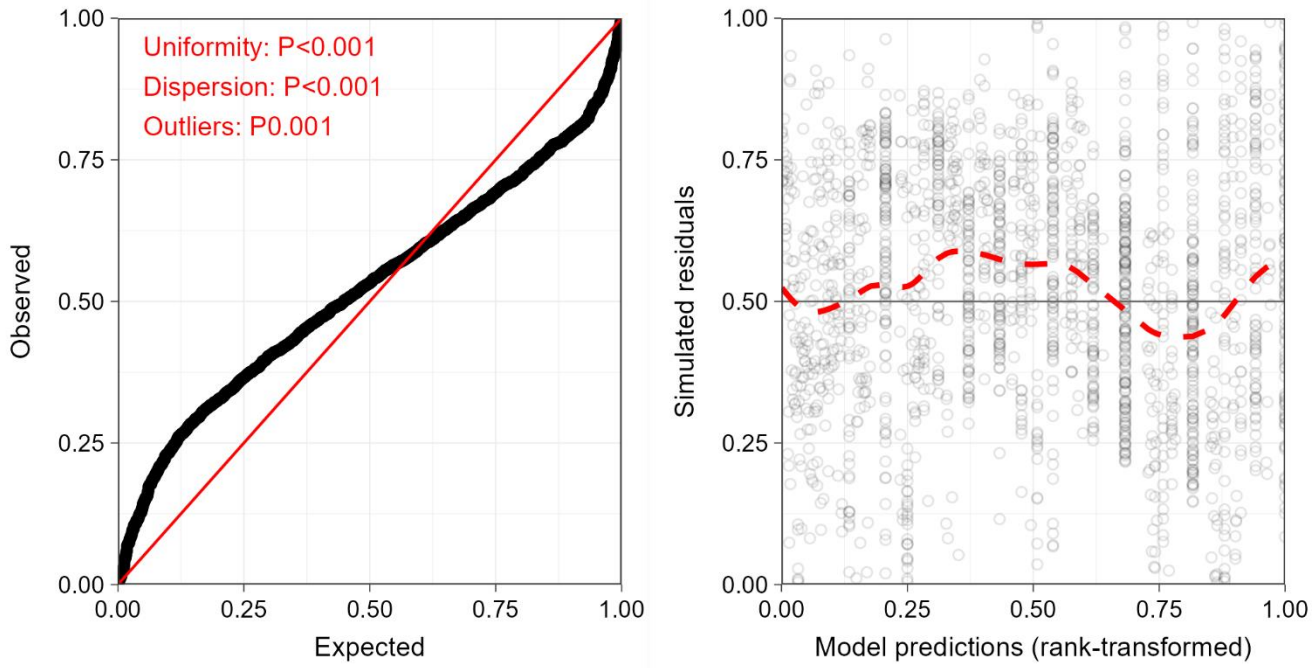


Figure D-10: Residual diagnostics for model of proportion immatures – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

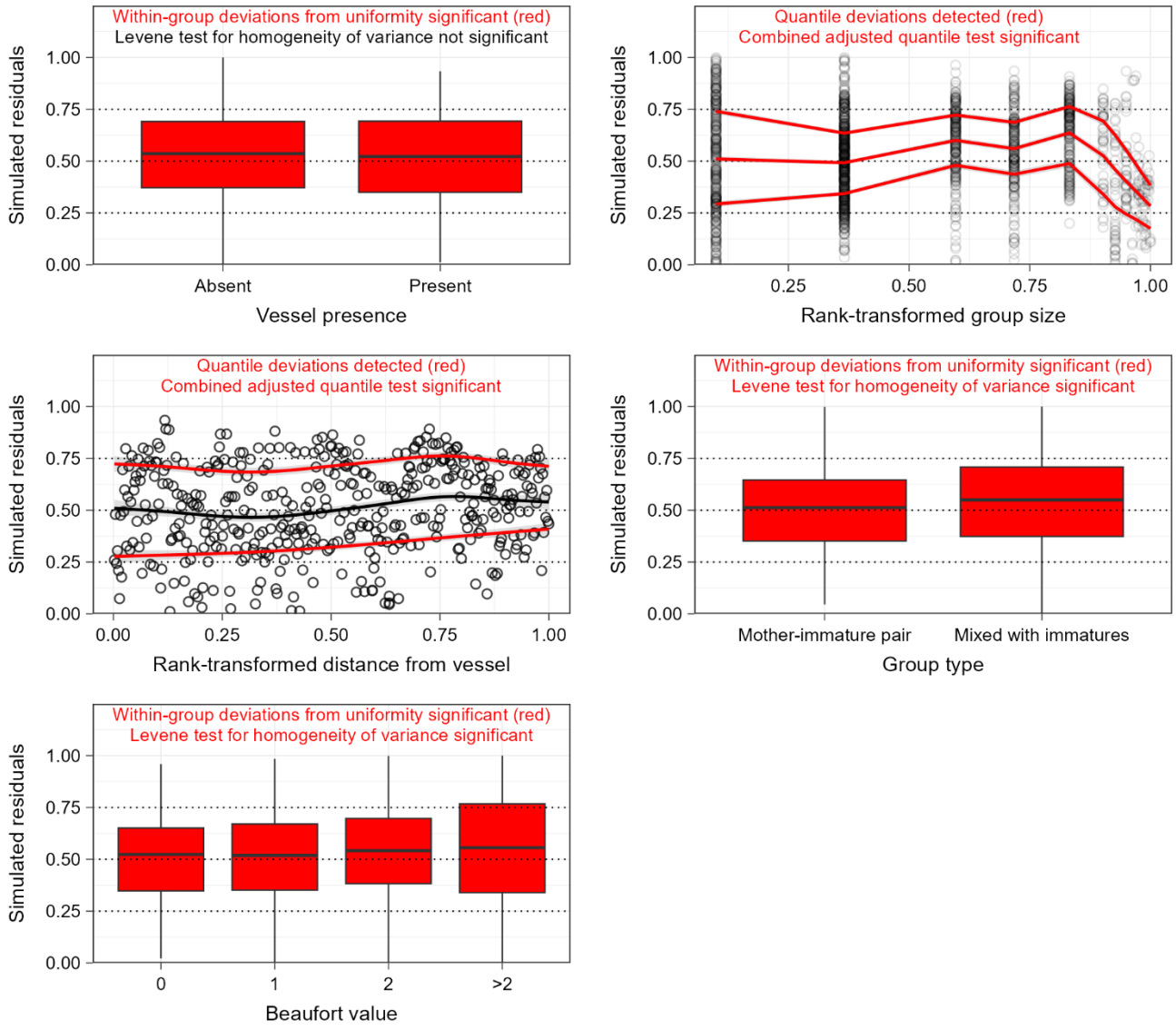


Figure D-11: Residual diagnostics for model of proportion immatures – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

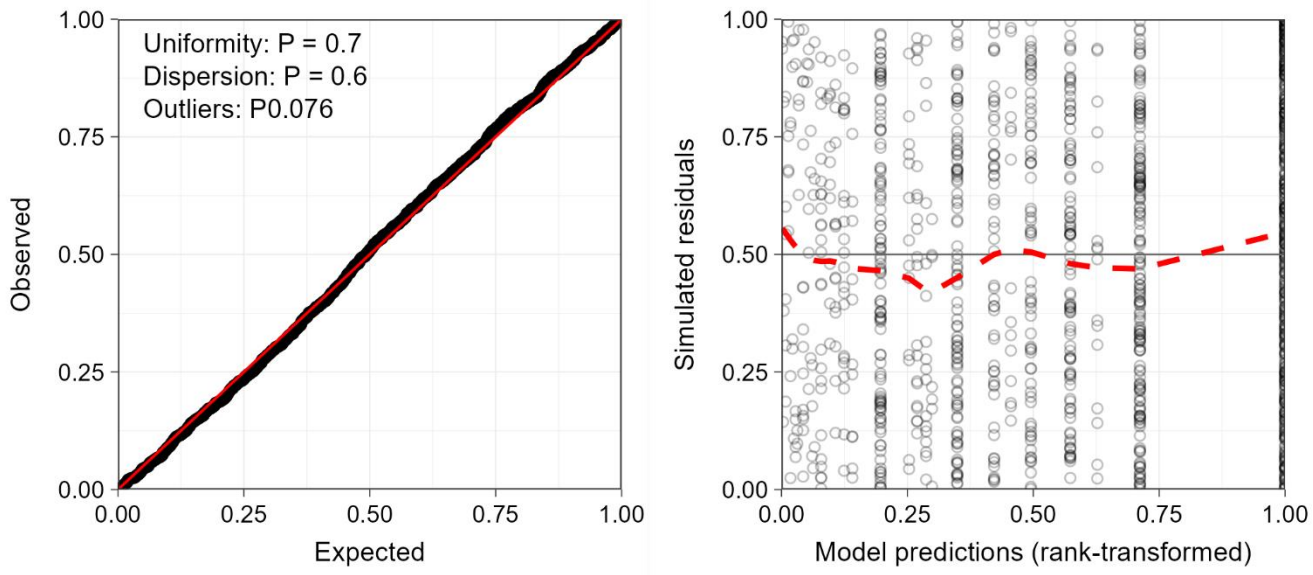


Figure D-12: Residual diagnostics for model of nursing behaviour – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

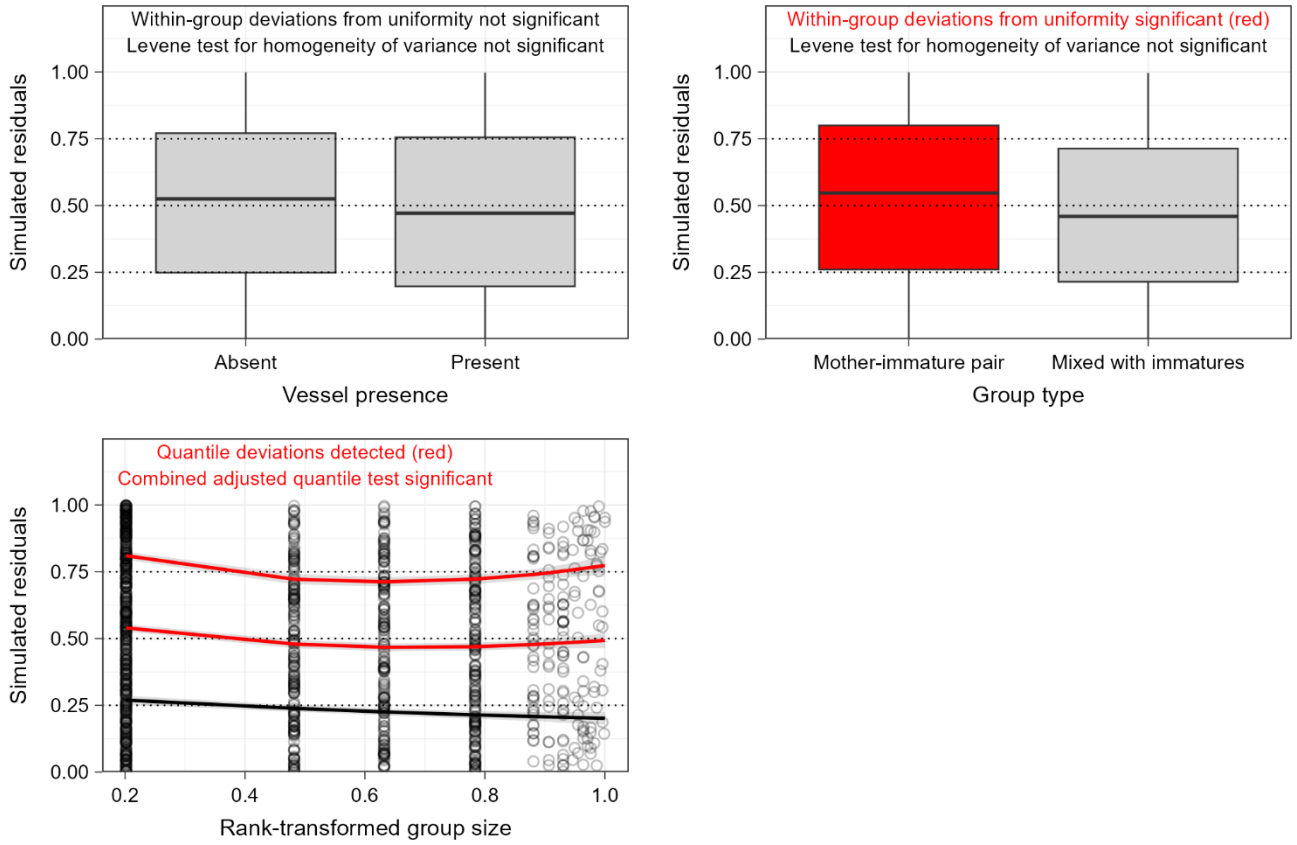


Figure D-13: Residual diagnostics for model of nursing behaviour – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

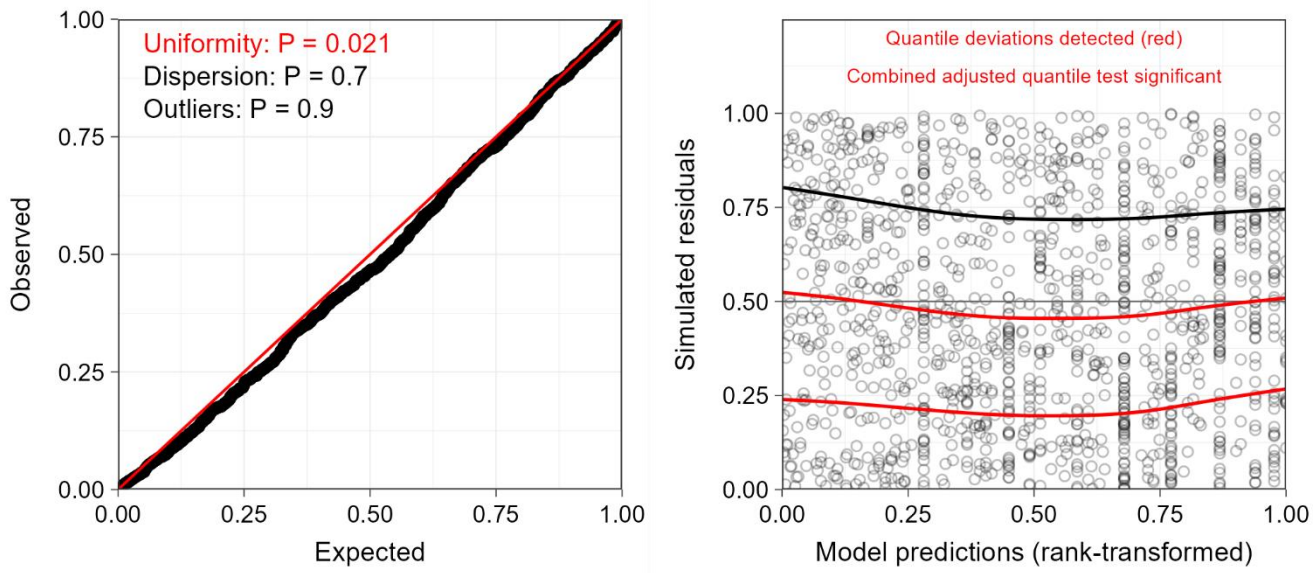


Figure D-14: Residual diagnostics for model of relative position of immature – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

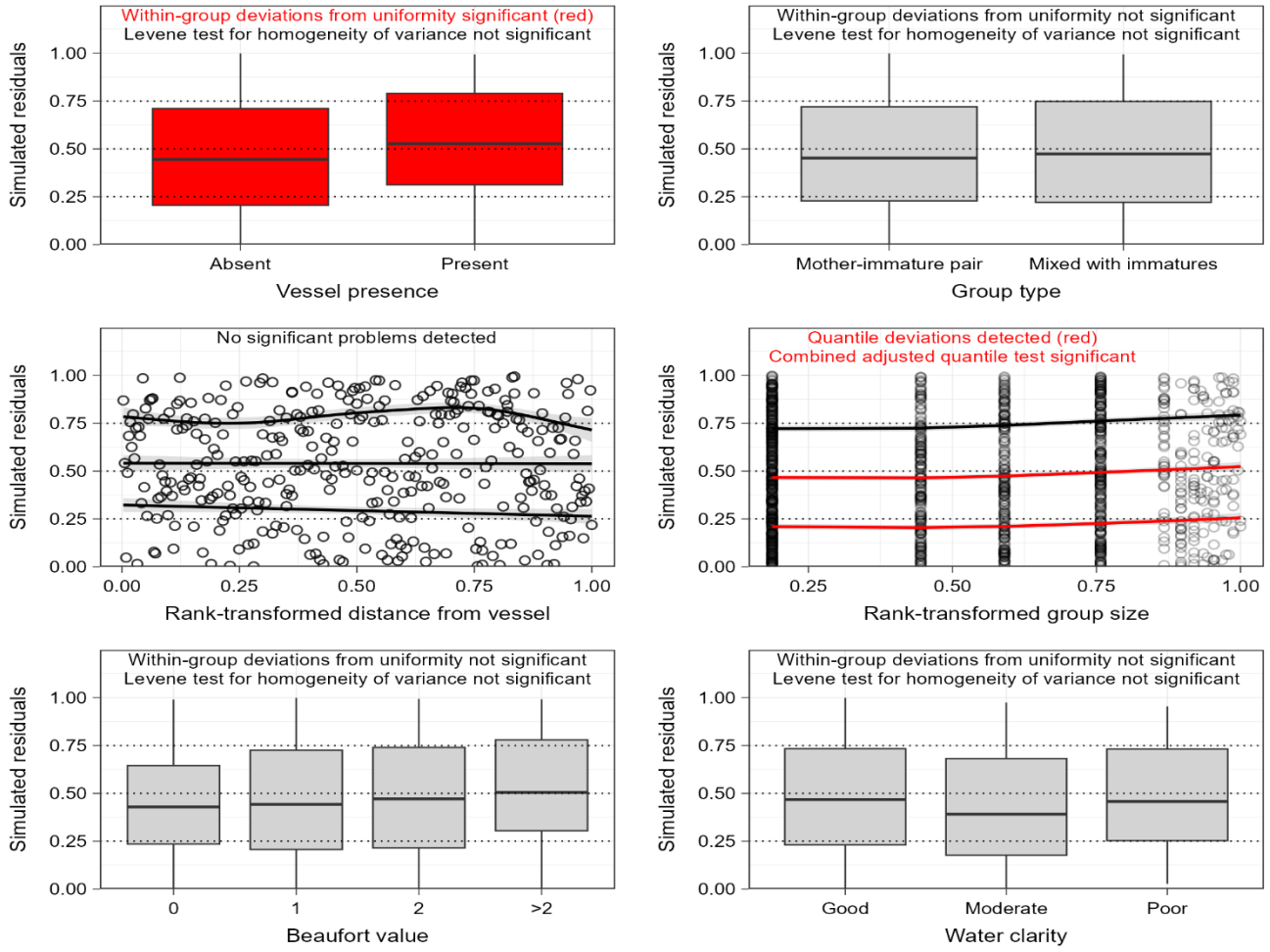


Figure D-15: Residual diagnostics for model of relative position of immature – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

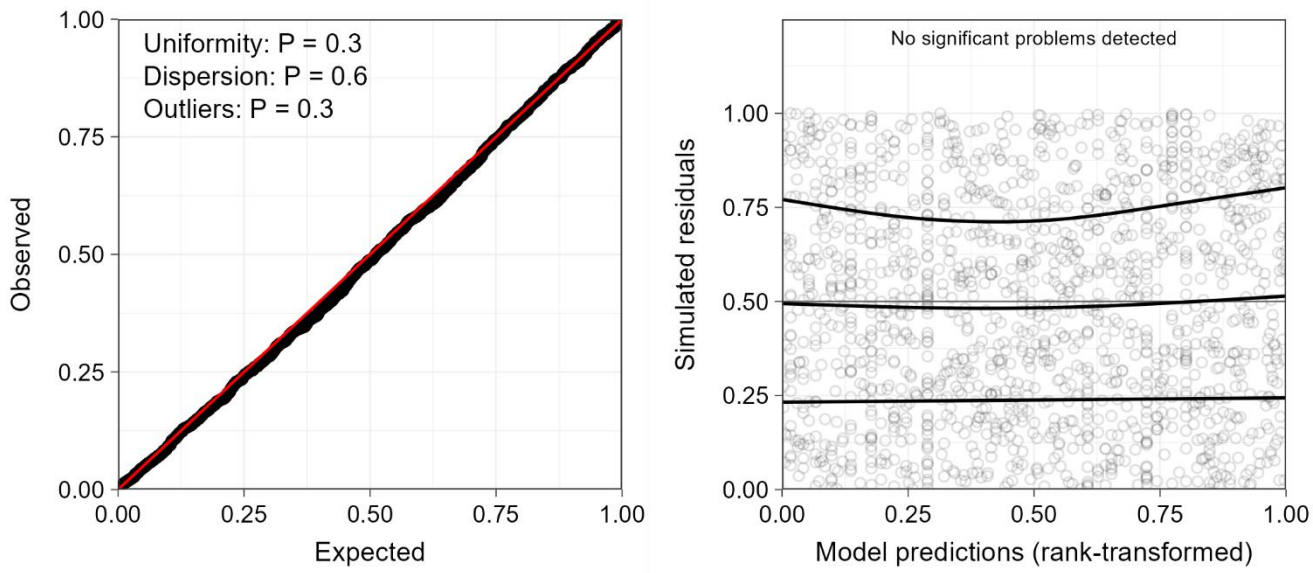


Figure D-16: Residual diagnostics for model of spread between mother and immature – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

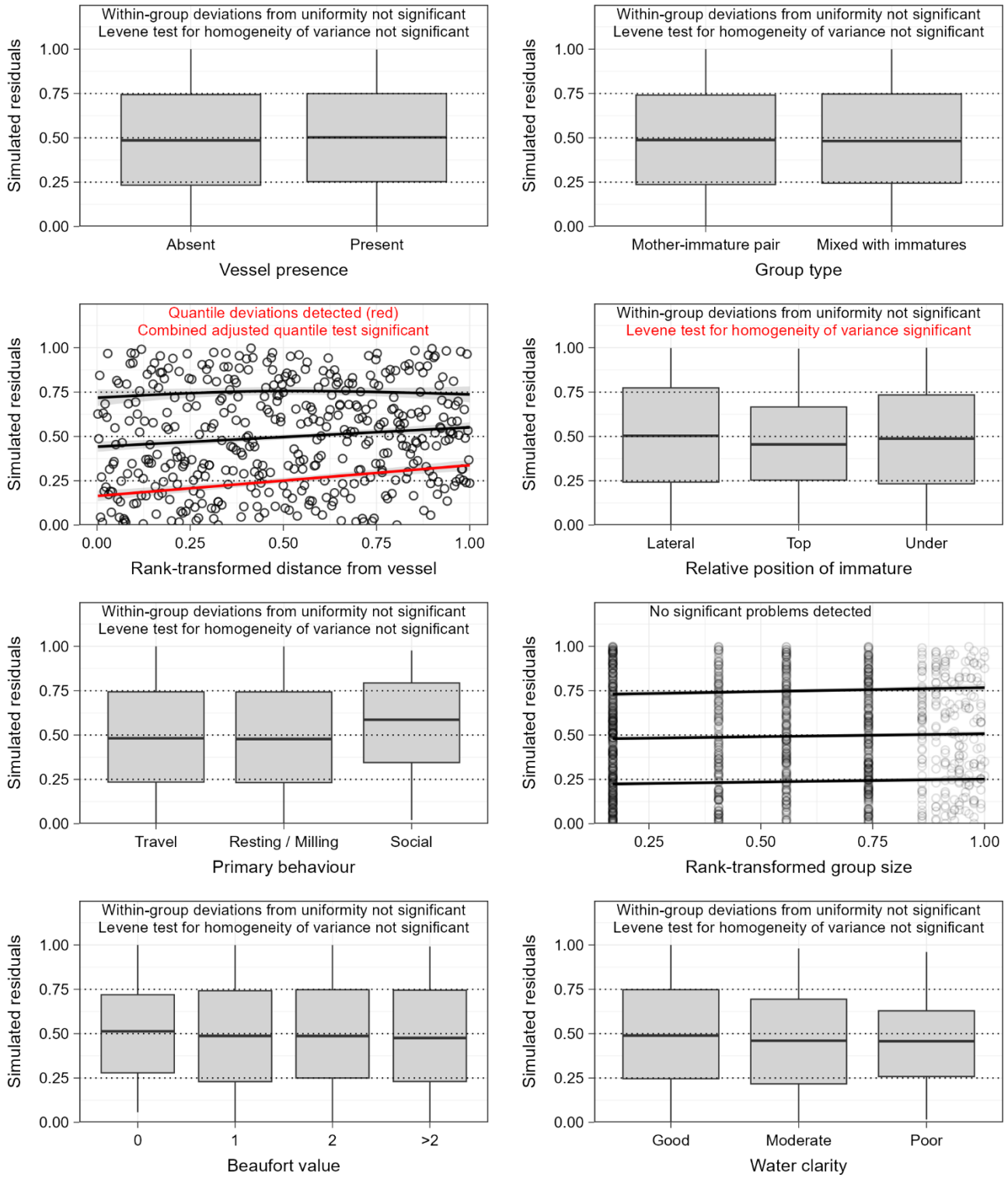


Figure D-17: Residual diagnostics for model of spread between mother and immature – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

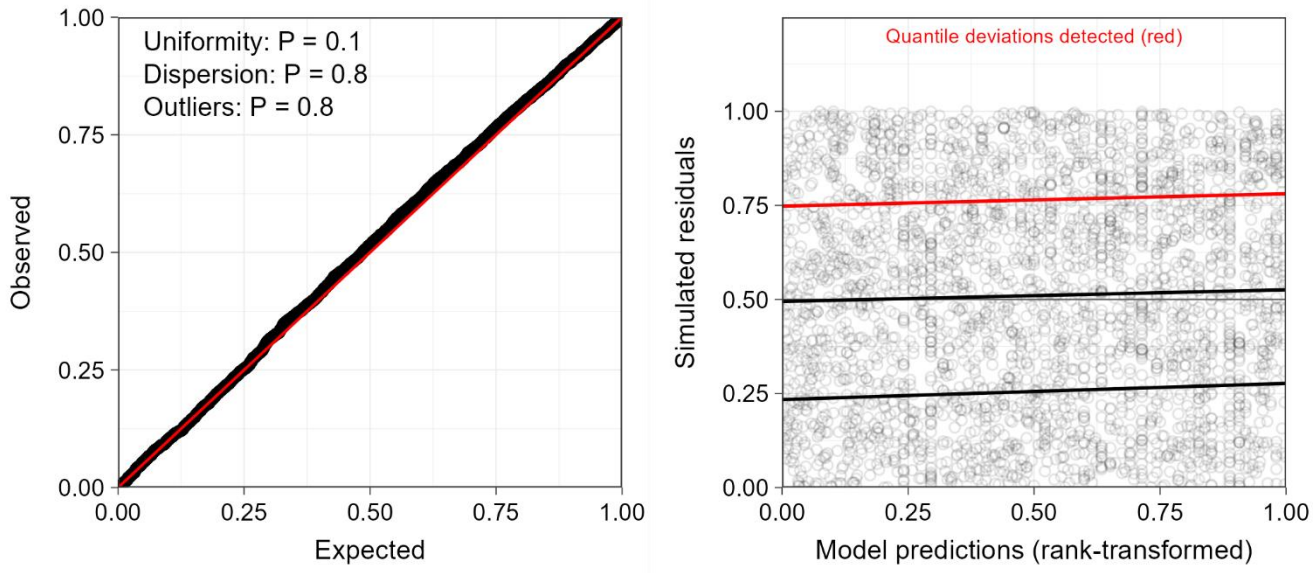


Figure D-18: Residual diagnostics for model of groups observed in non-parallel formation – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

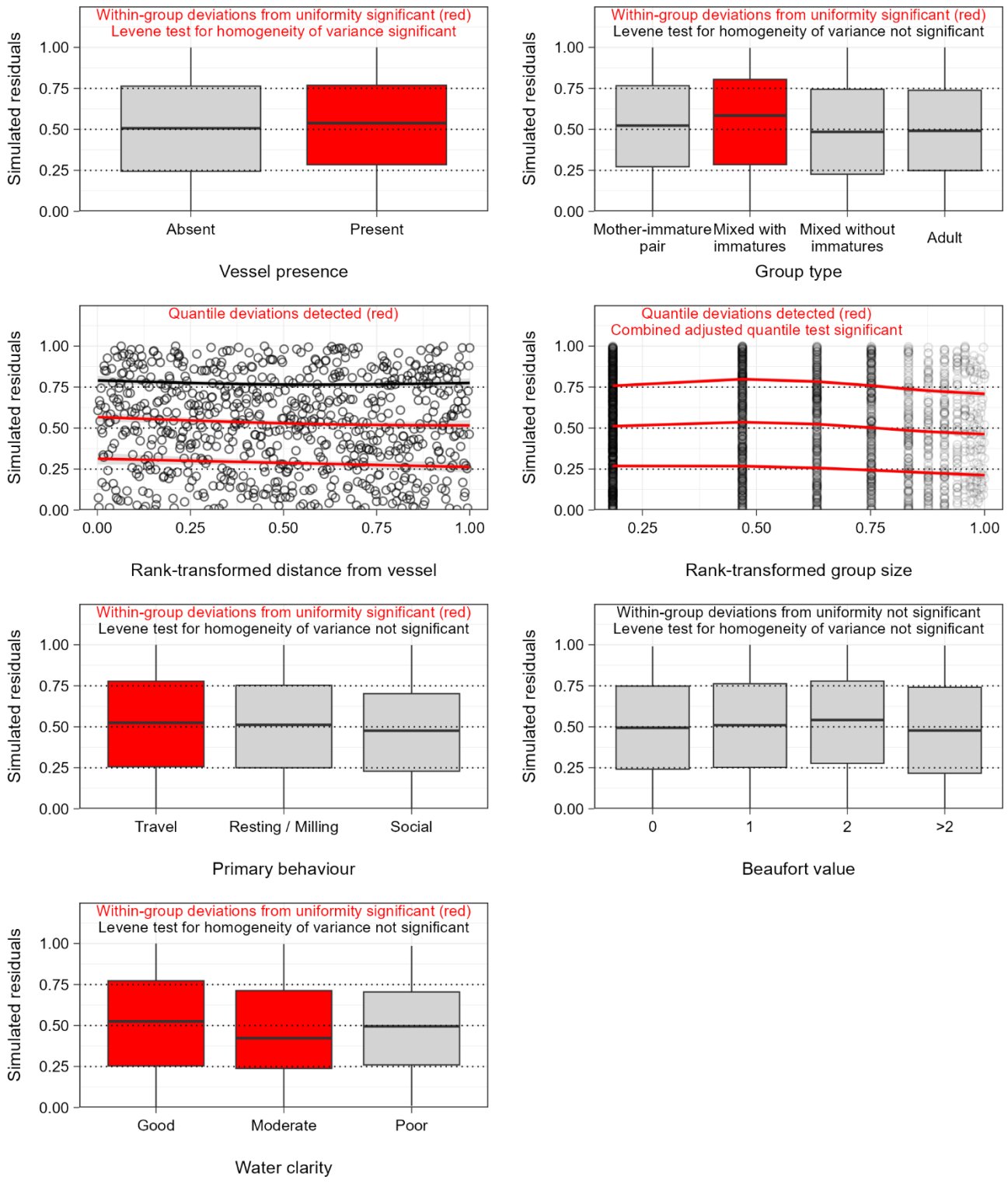


Figure D-19: Residual diagnostics for model of groups observed in non-parallel formation – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

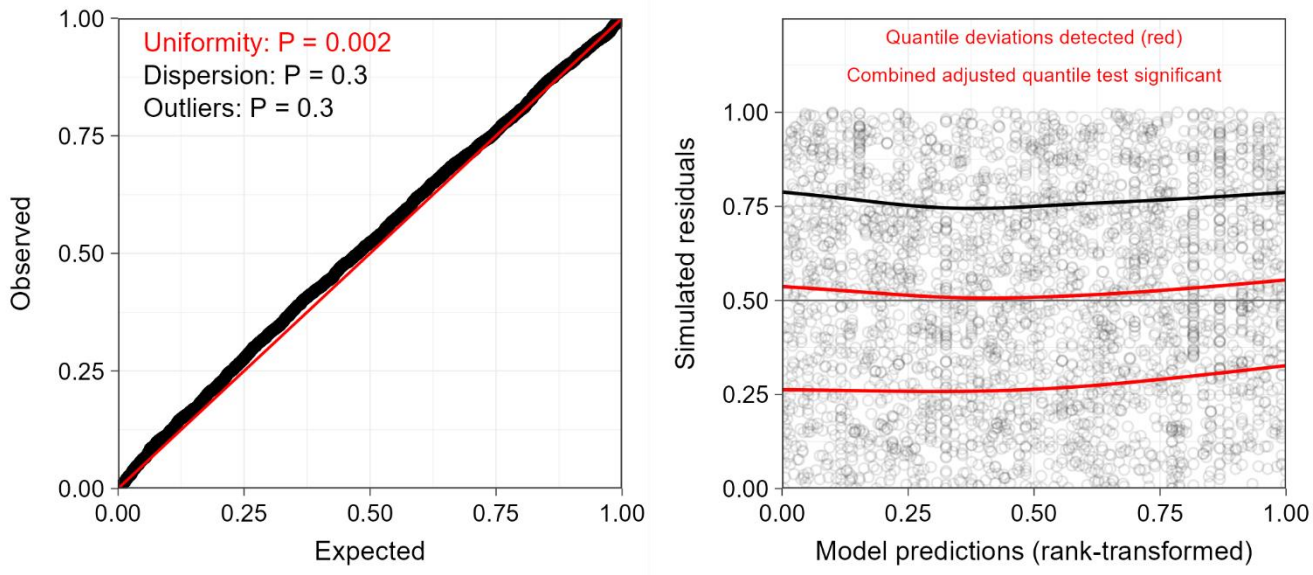


Figure D-20: Residual diagnostics for model of groups observed in a loose (rather than a tight) spread – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

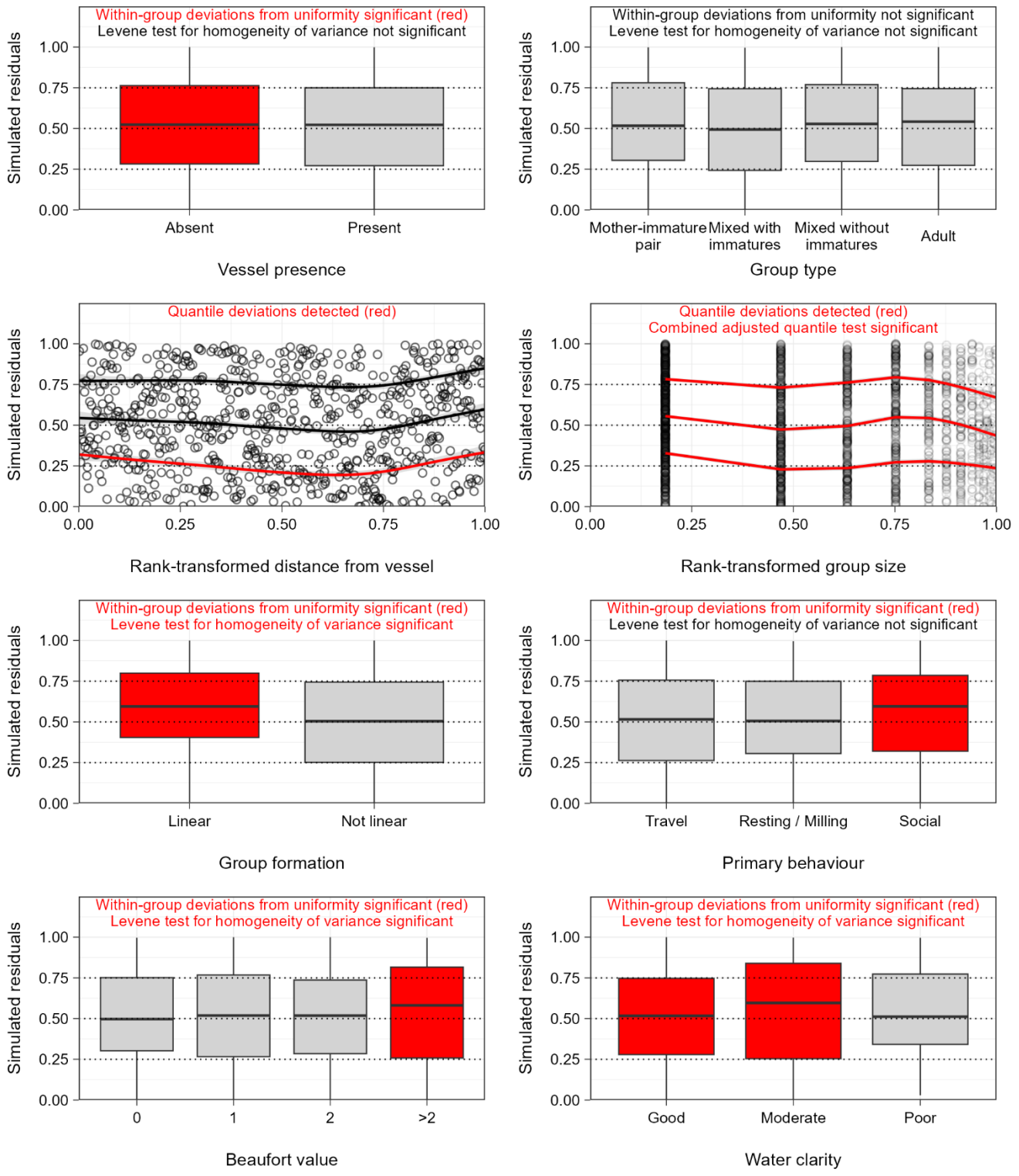


Figure D-21: Residual diagnostics for model of groups observed in a loose (rather than a tight) spread – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

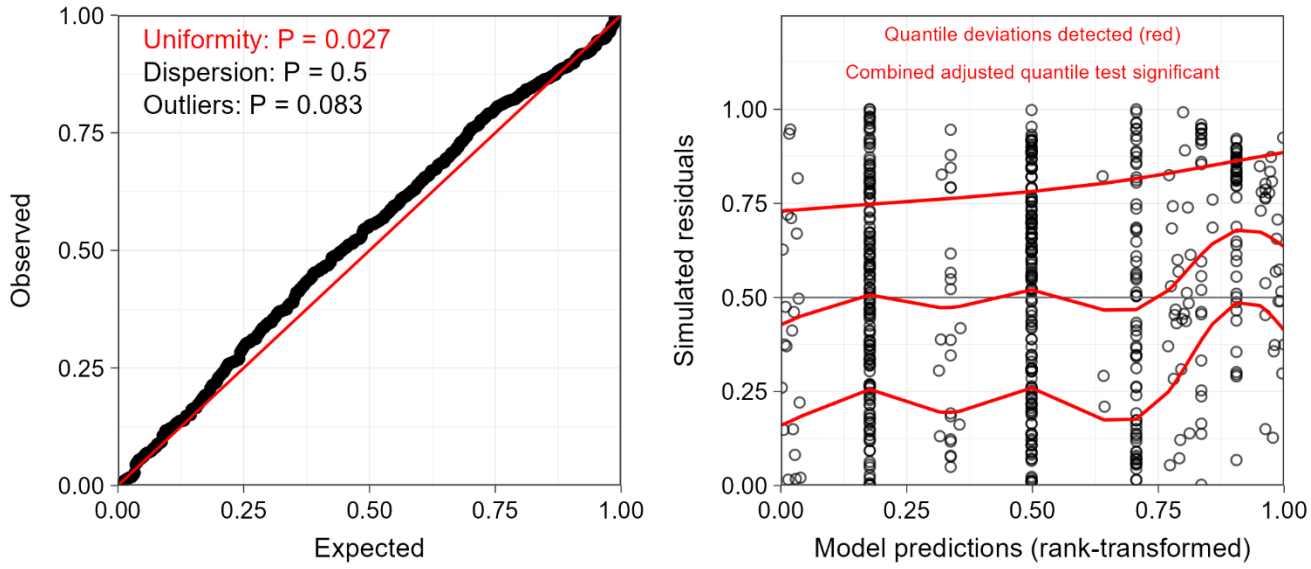


Figure D-22: Residual diagnostics for model of group size for mother-immature pairs – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

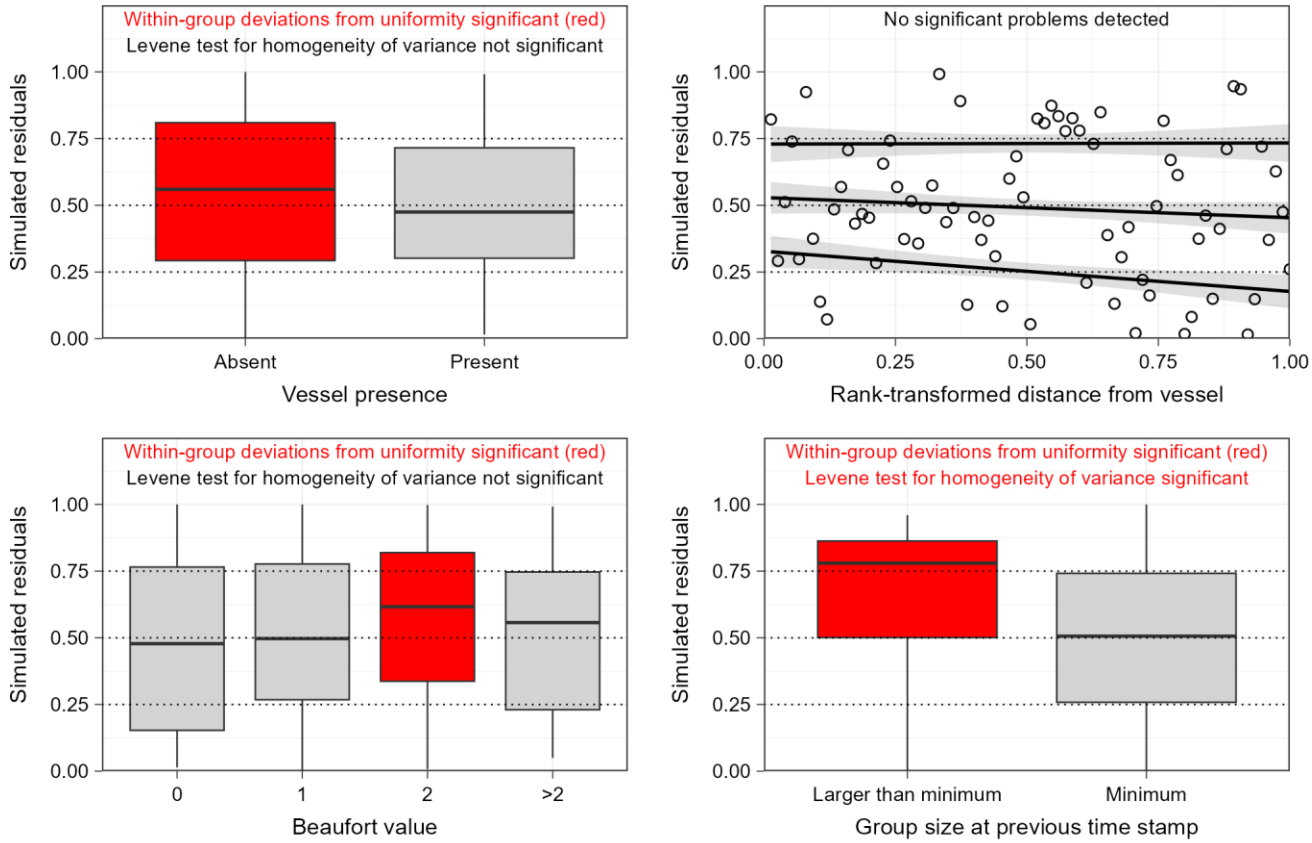


Figure D-23: Residual diagnostics for model of group size for mother-immature pairs – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

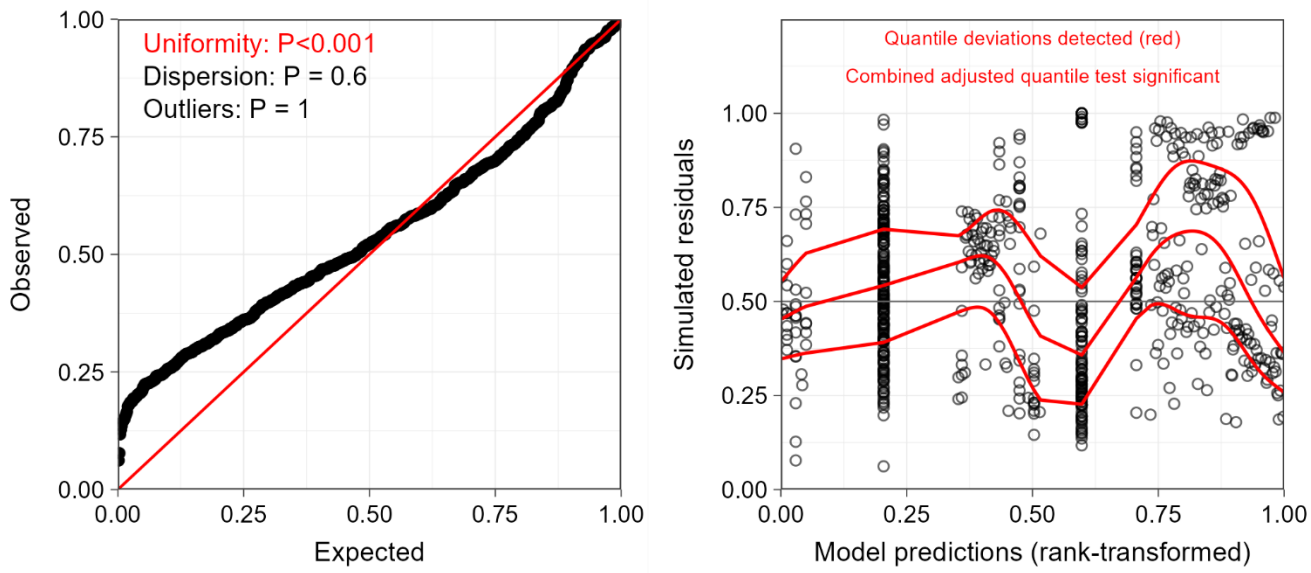


Figure D-24: Residual diagnostics for model of group size for mixed groups with immatures – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

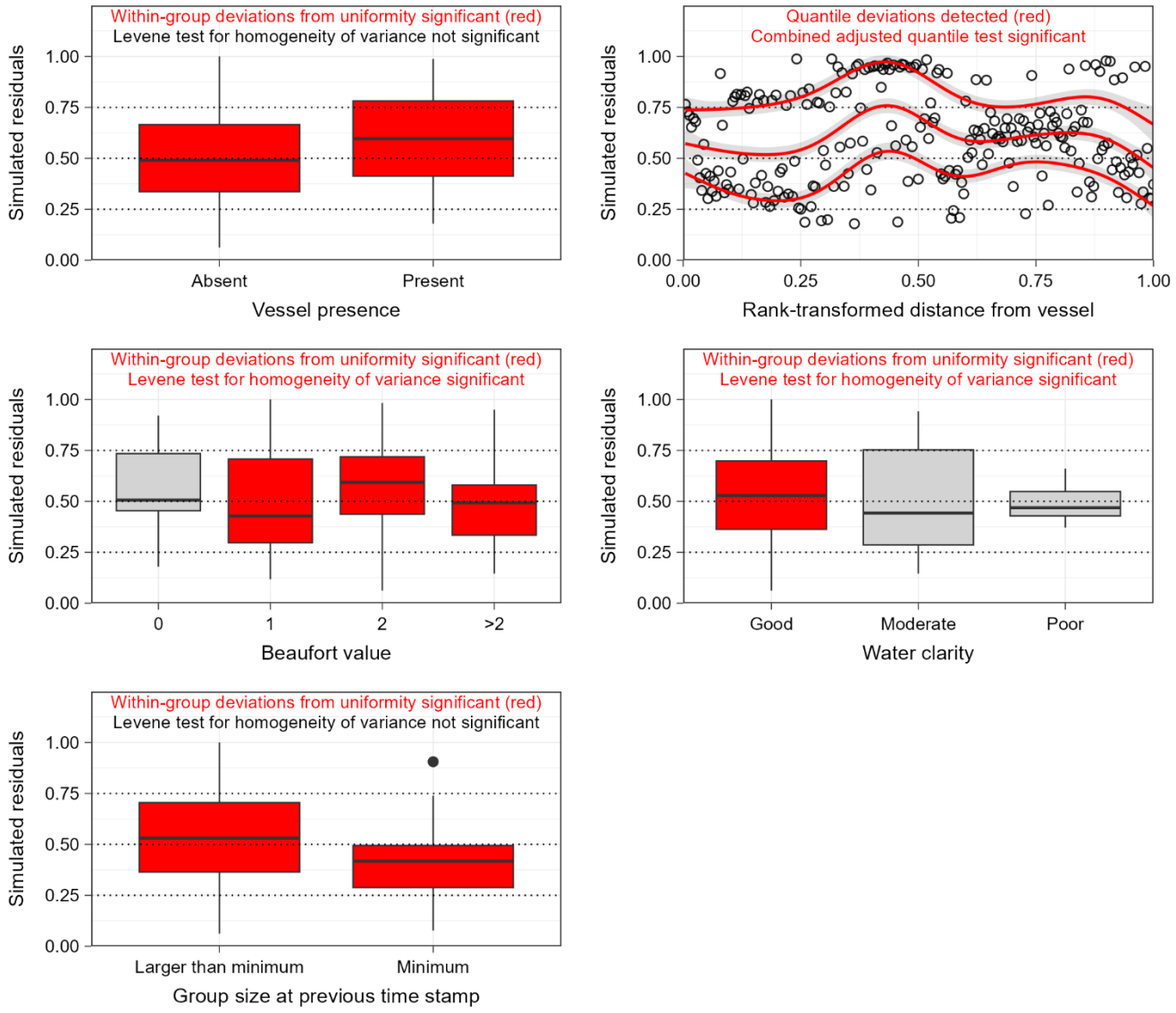


Figure D-25: Residual diagnostics for model of group size of mixed groups with immatures – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

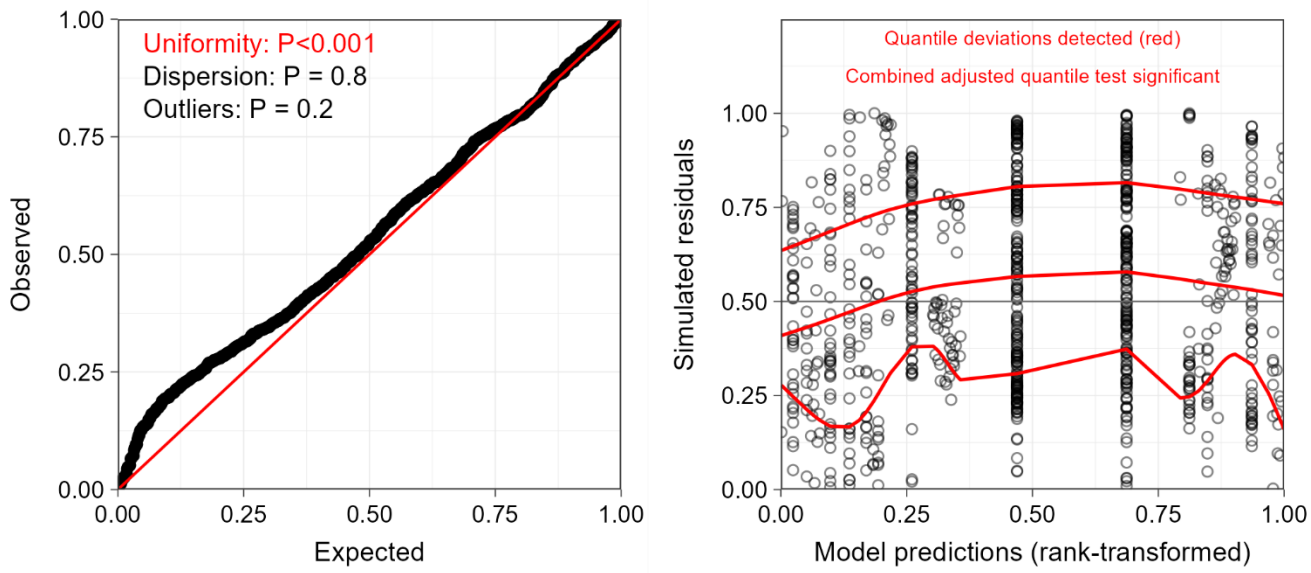


Figure D-26: Residual diagnostics for model of group size of mixed groups without immatures – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

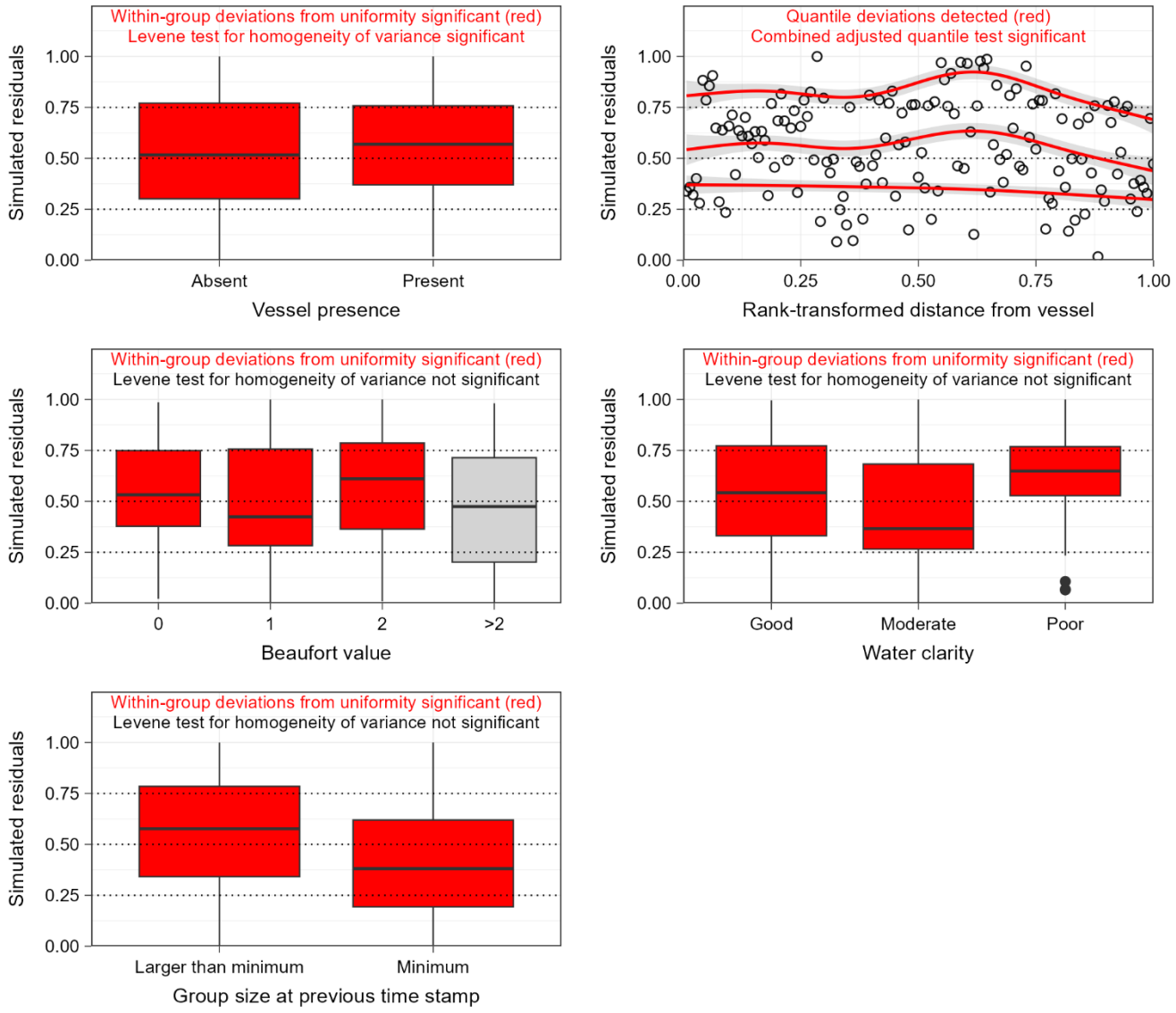


Figure D-27: Residual diagnostics for model of group size of mixed groups without immatures – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

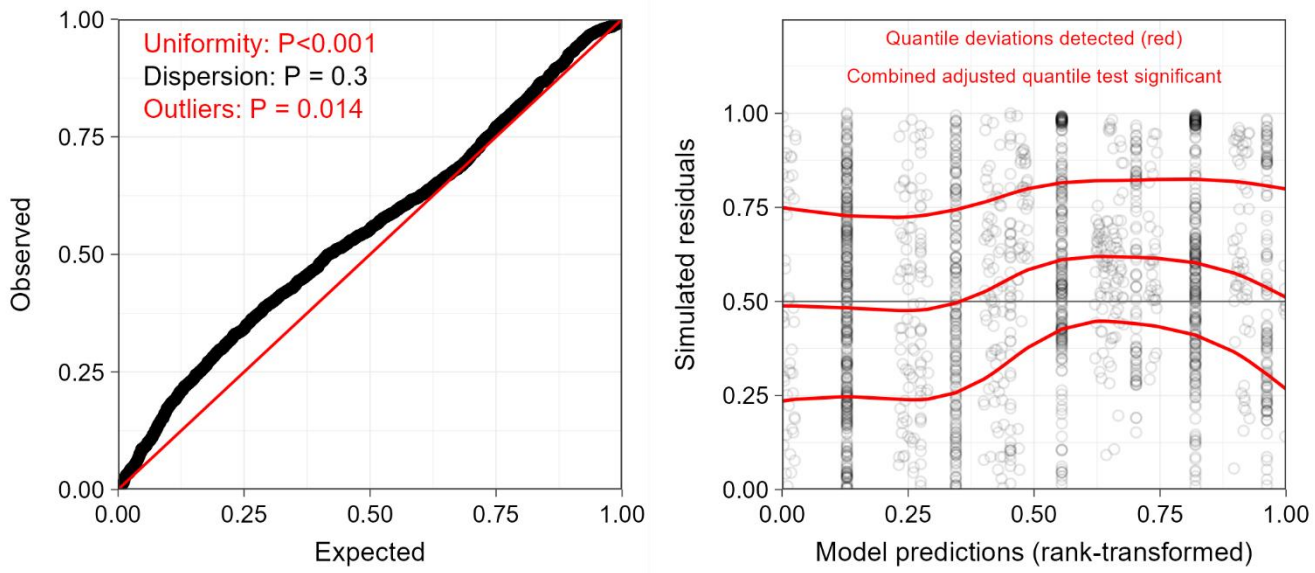


Figure D-28: Residual diagnostics for model of group size for adult groups – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

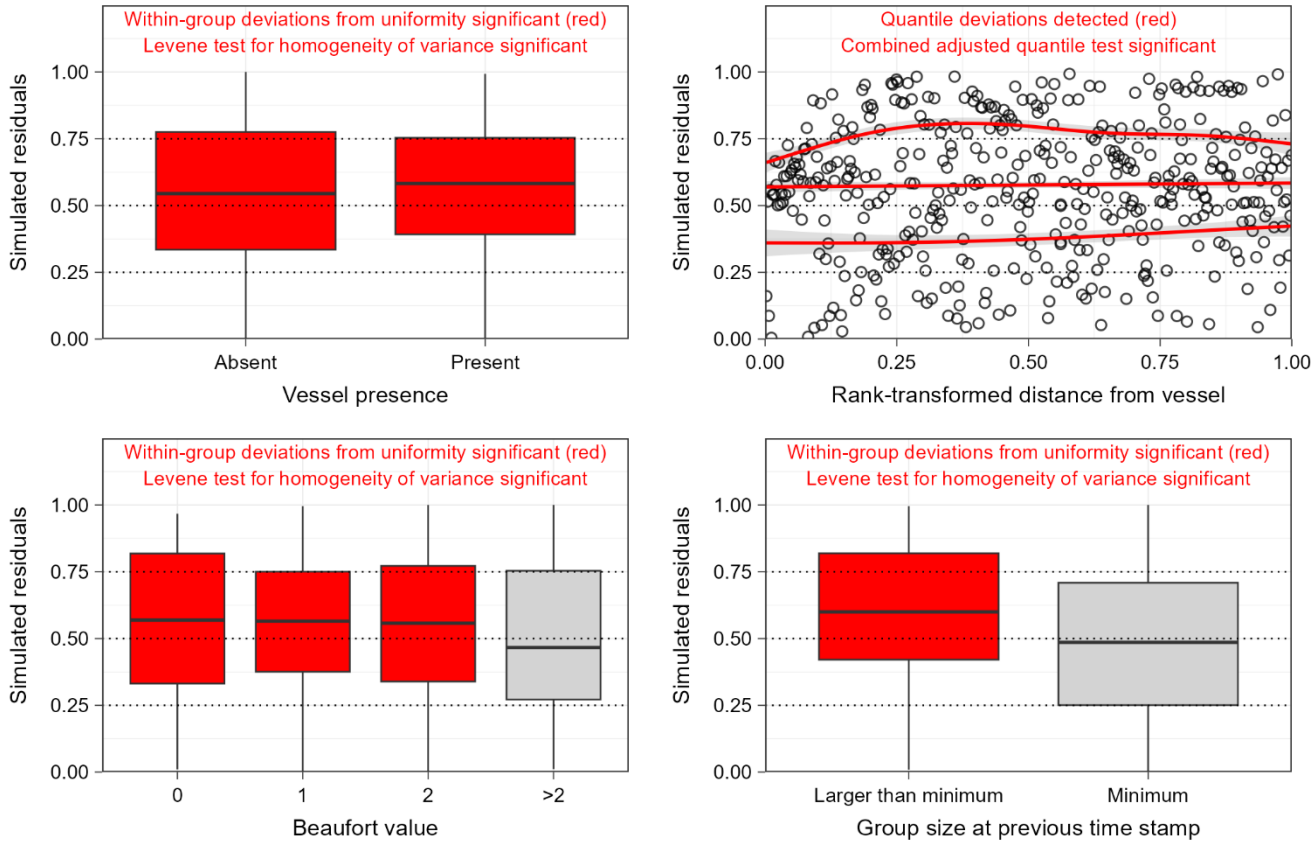


Figure D-29: Residual diagnostics for model of group size for adult groups – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

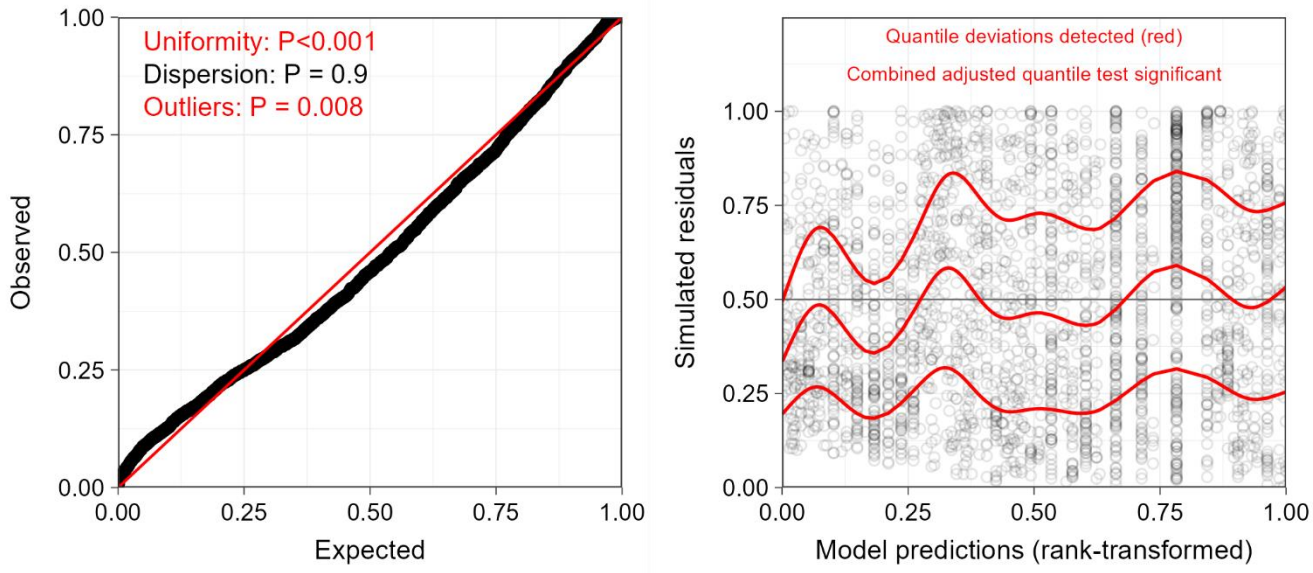


Figure D-30: Residual diagnostics for model of group travel speed – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

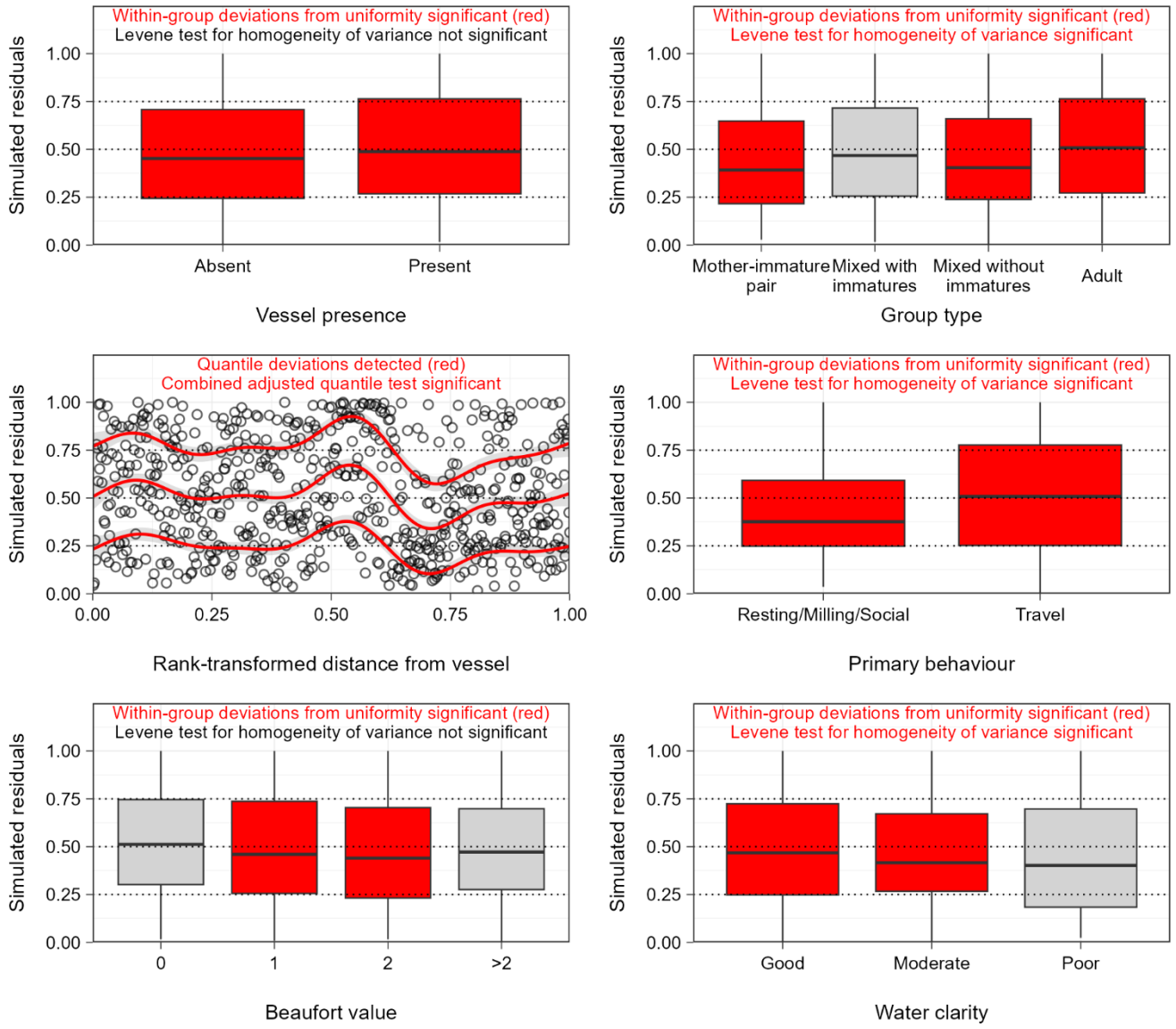
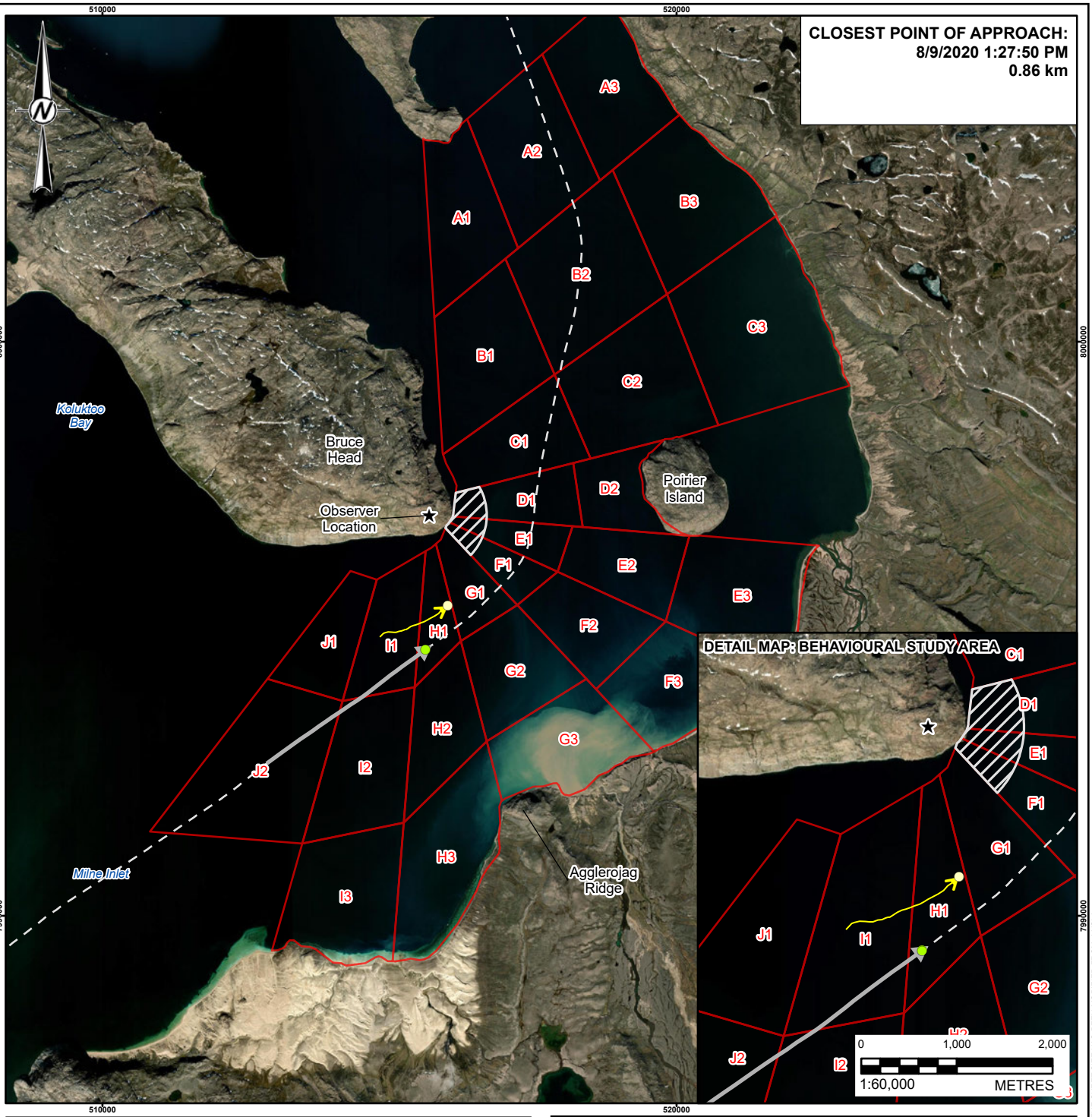


Figure D-31: Residual diagnostics for model of group travel speed – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

APPENDIX E

Focal Follow Survey Tracks Relative to Vessels



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 10 (2020)
- ACTIVE VESSEL TRANSIT (GOLDEN OPPORTUNITY)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN OPPORTUNITY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 10 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-1

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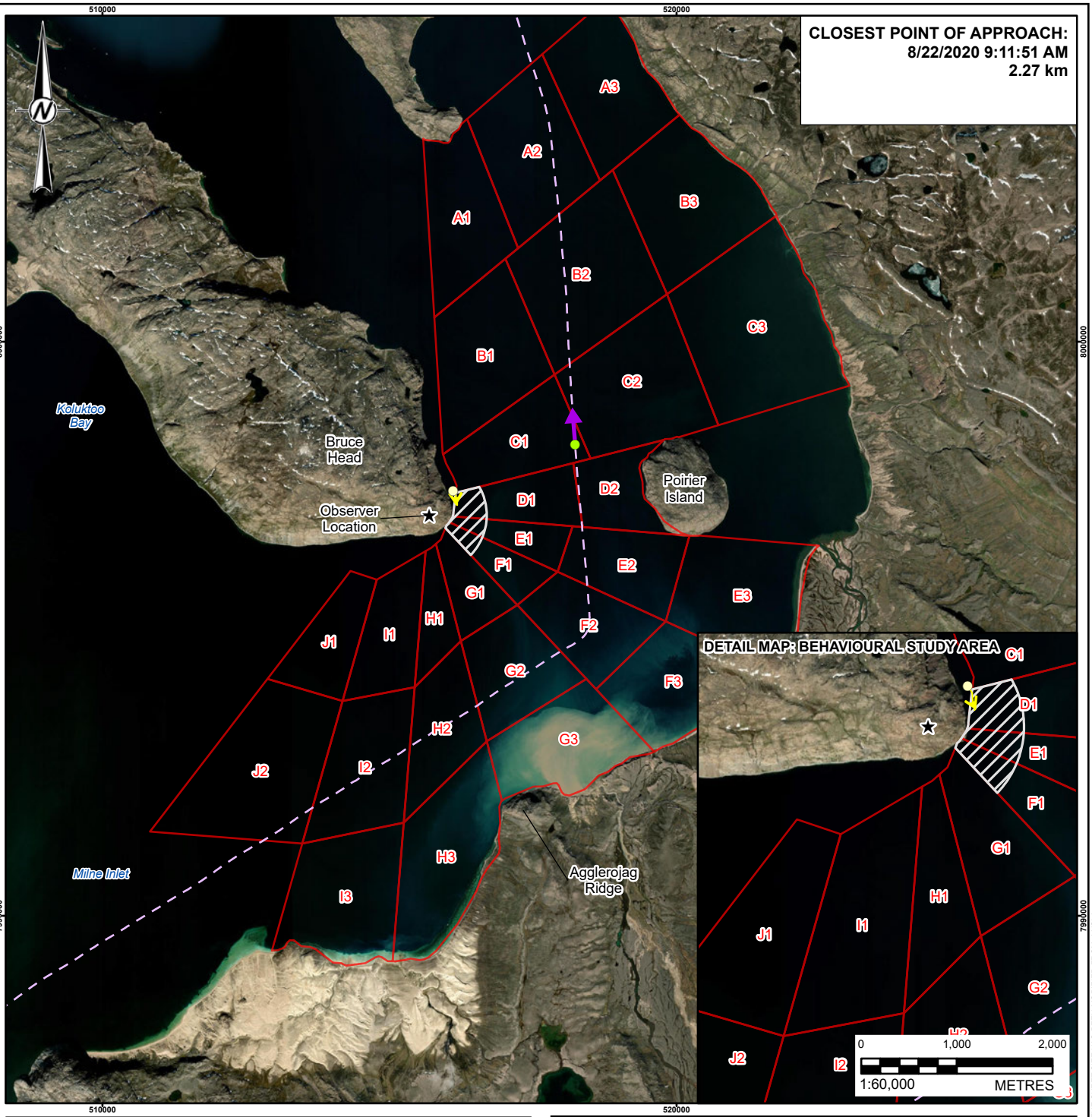

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 56 (2020)
- ACTIVE VESSEL TRANSIT (GEORG OLDENDORFF)
- NON-ACTIVE VESSEL TRANSIT (GEORG OLDENDORFF)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 56 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-2

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

25mm

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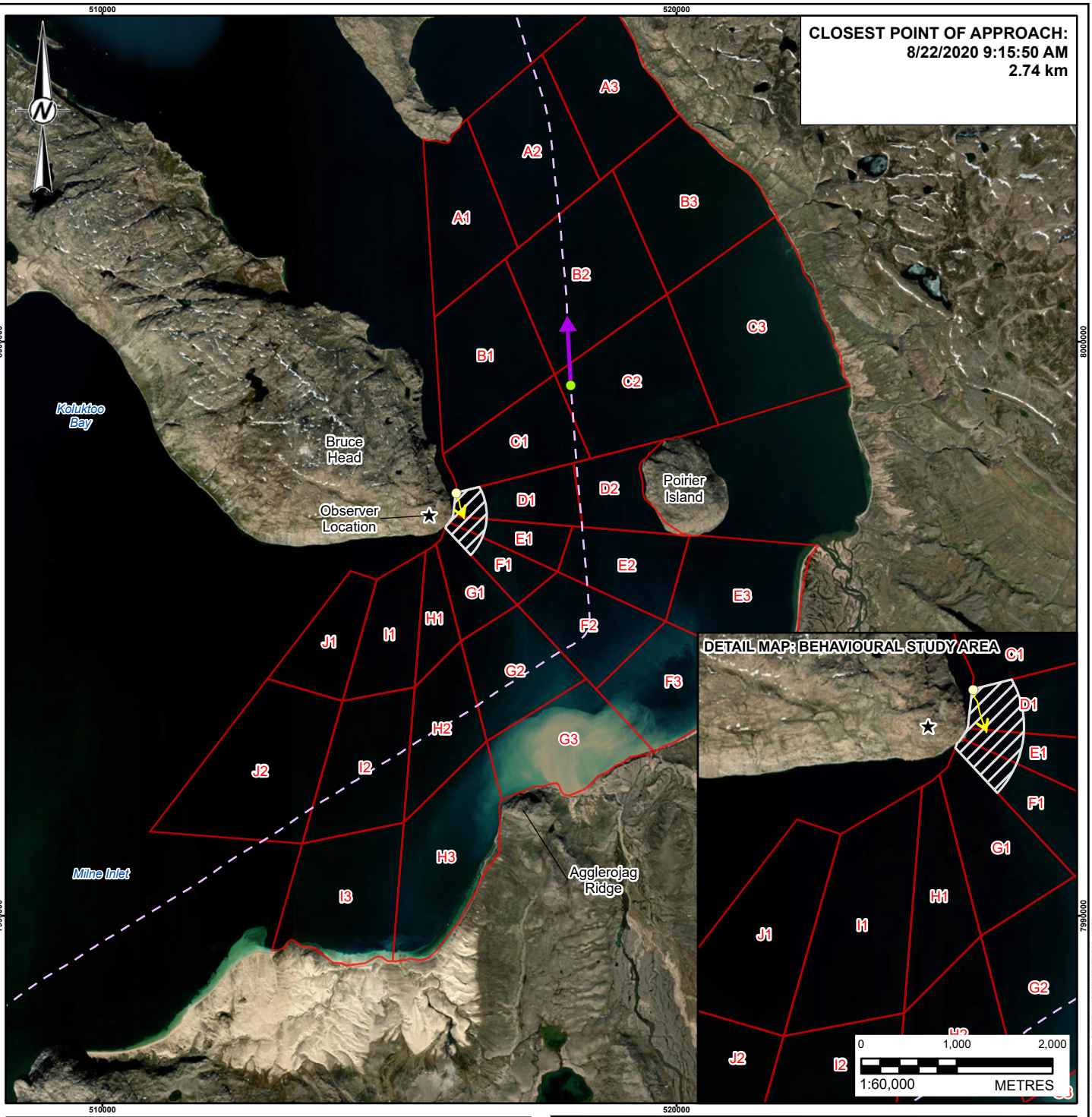

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 57 (2020)
- ACTIVE VESSEL TRANSIT (GEORG OLDENDORFF)
- NON-ACTIVE VESSEL TRANSIT (GEORG OLDENDORFF)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 57 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-3

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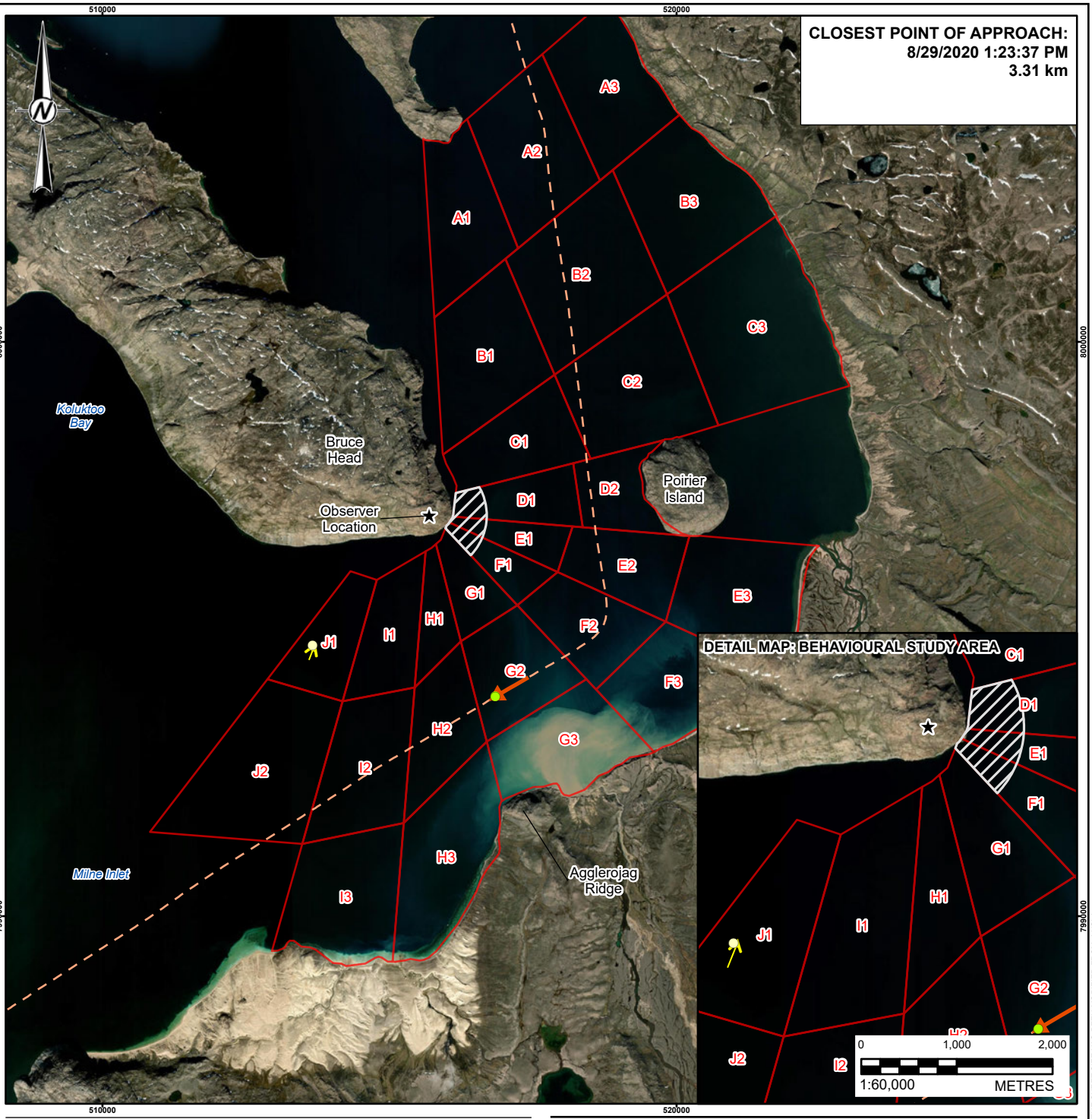

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 62 (2020)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 62 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-4

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

25mm

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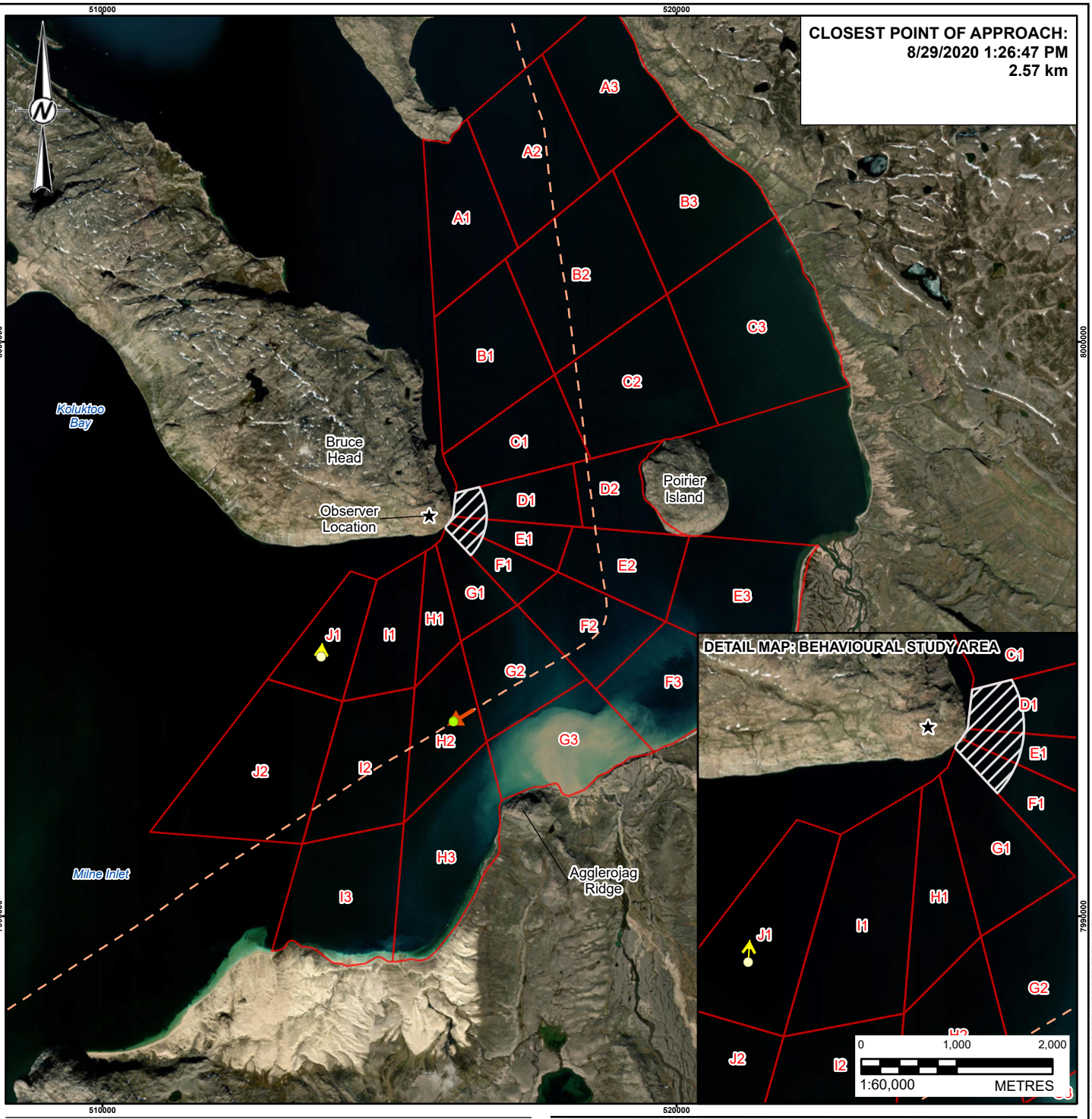

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 63 (2020)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

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BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 63 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-5

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

25mm

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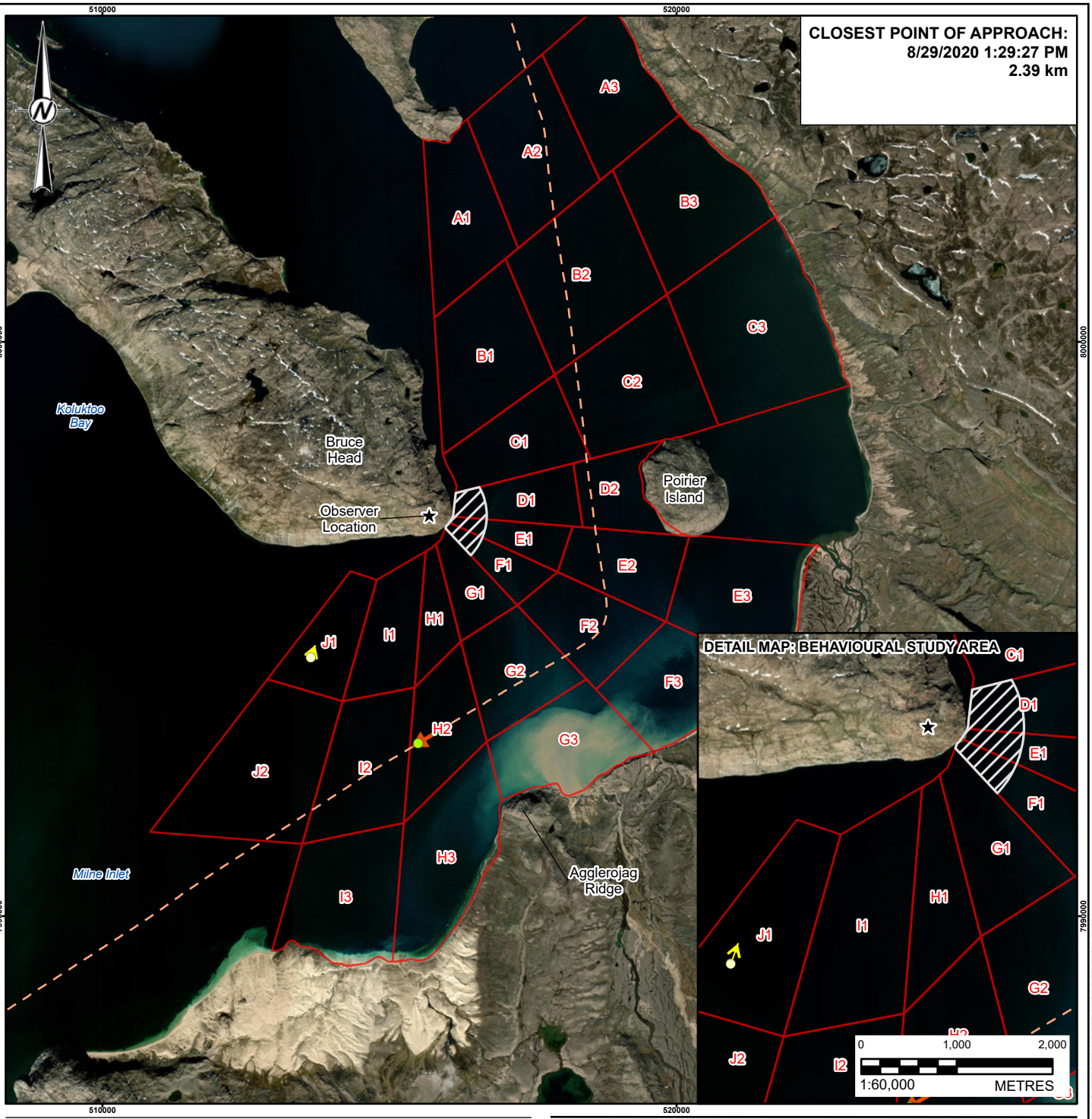

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 64 (2020)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 64 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-6

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

25mm

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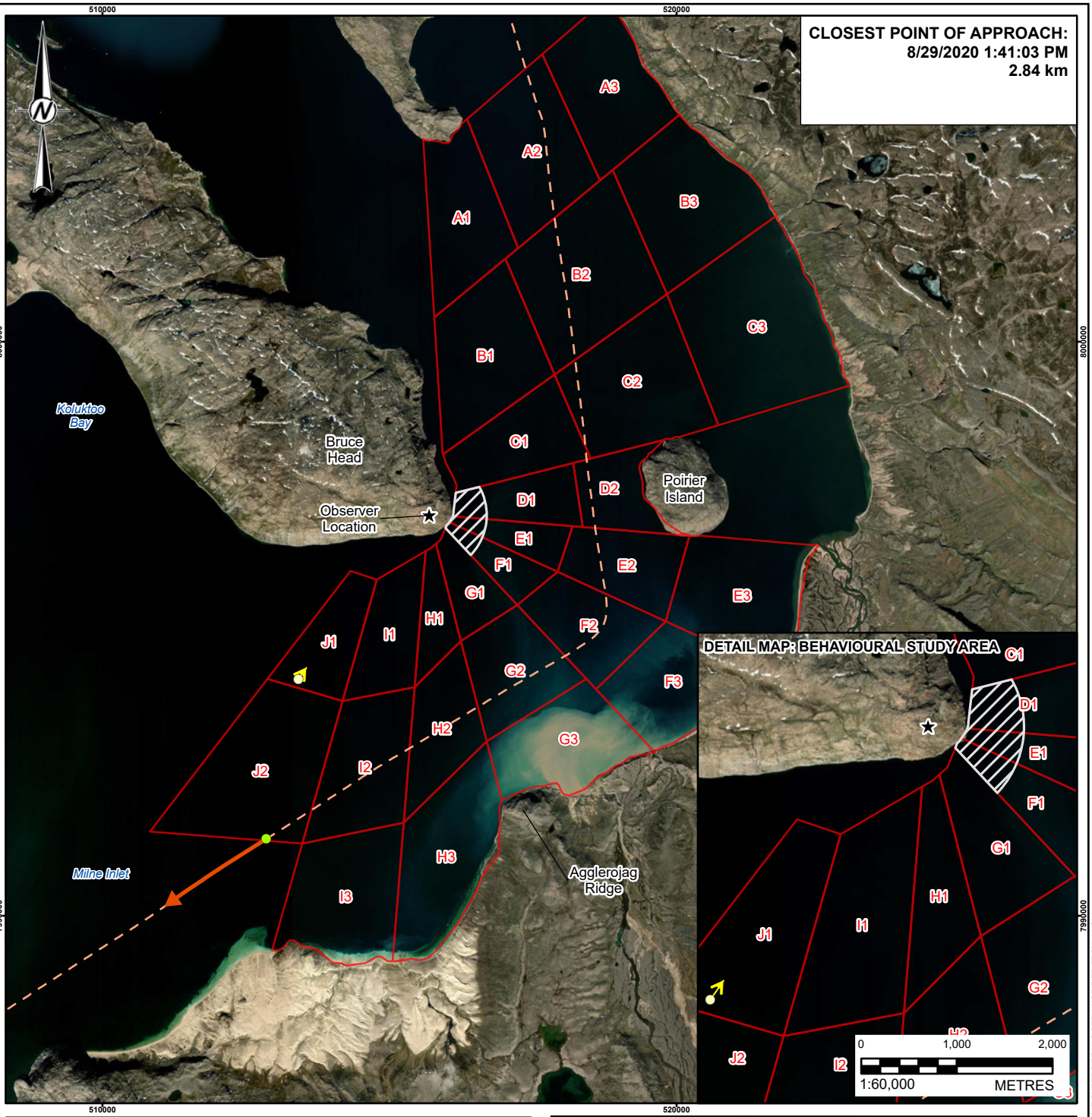

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 65 (2020)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 65 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-7

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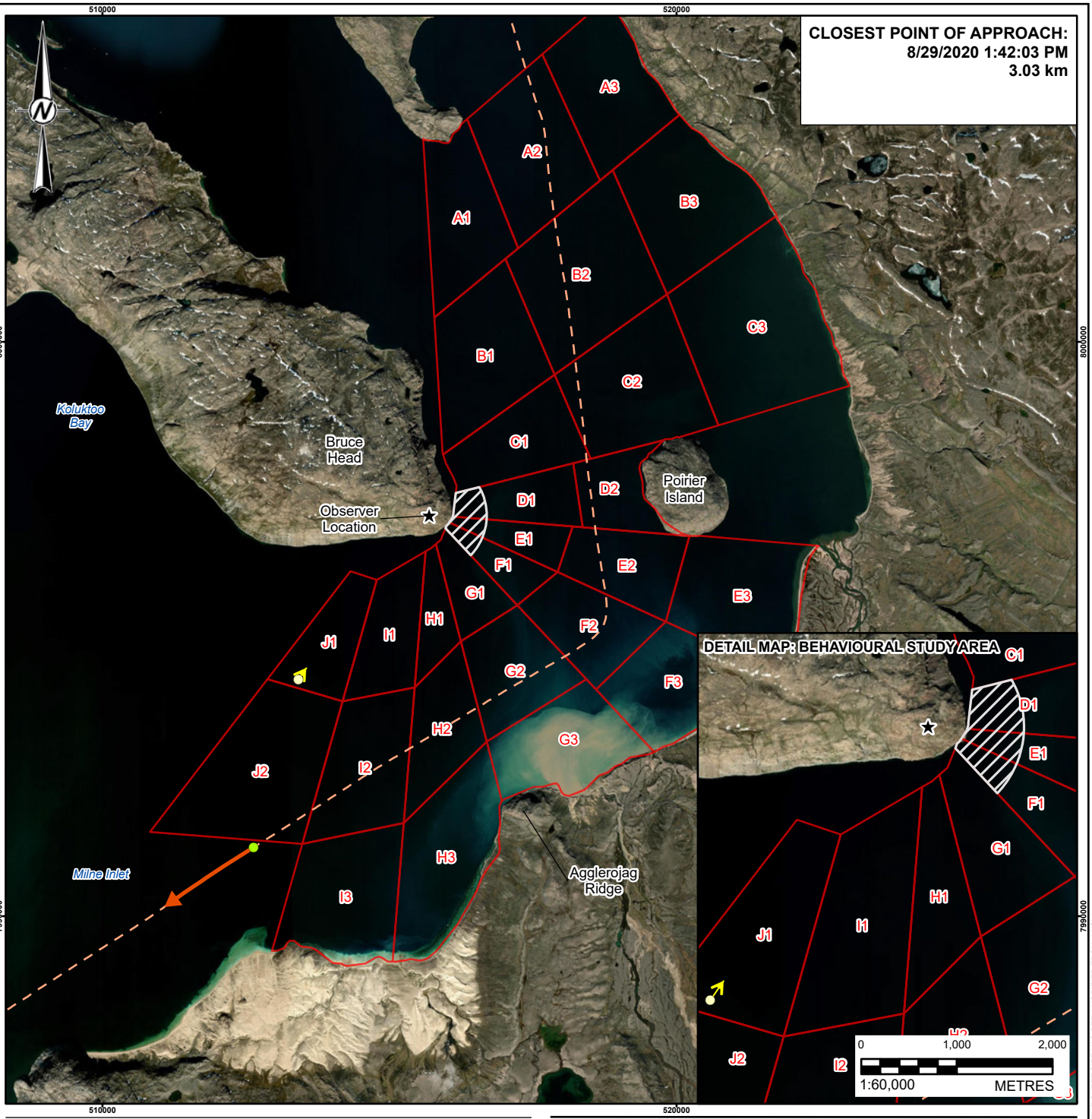

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 66 (2020)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 66 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-8

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

25mm

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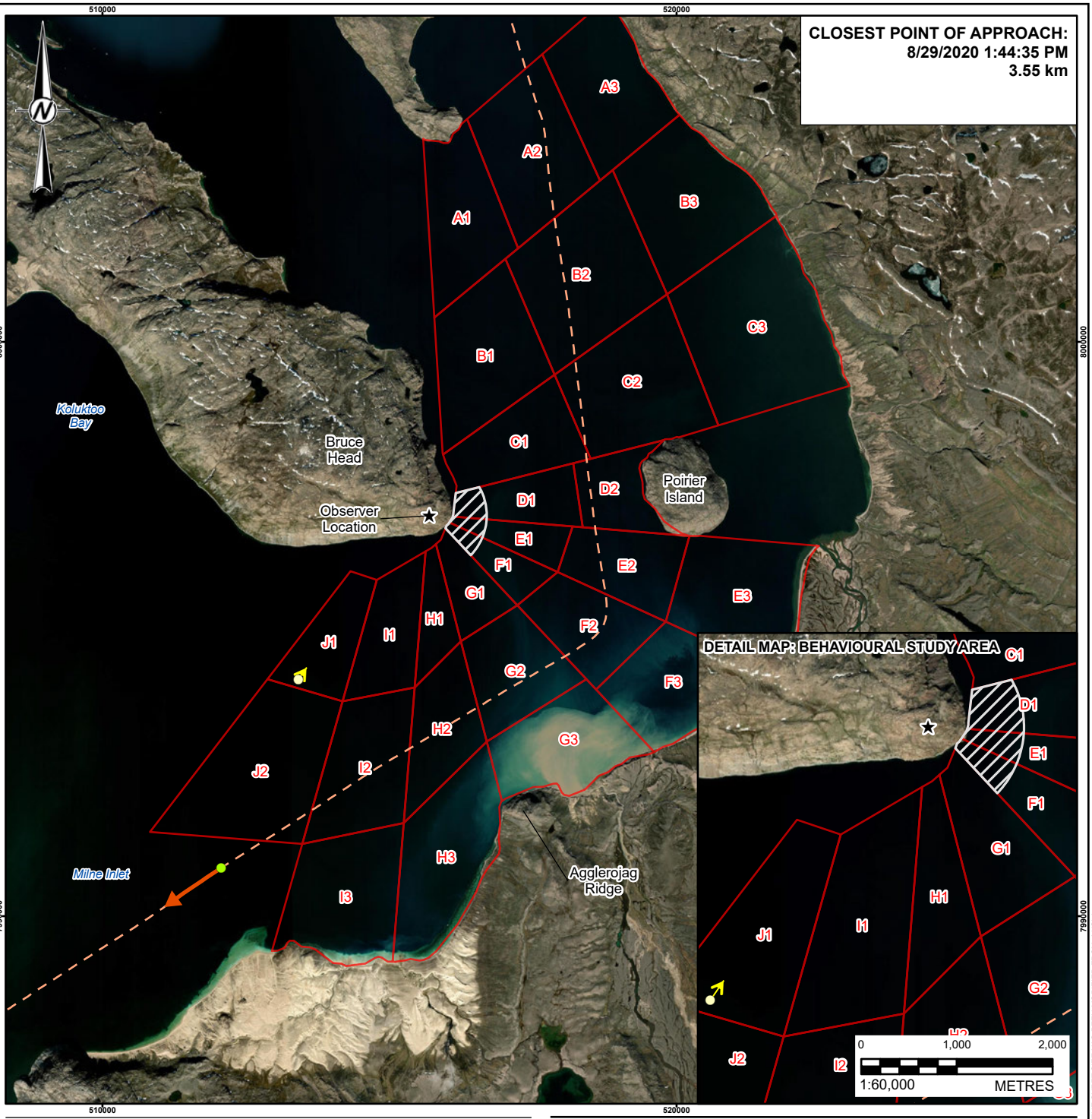

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 67 (2020)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 67 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-9

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

25mm

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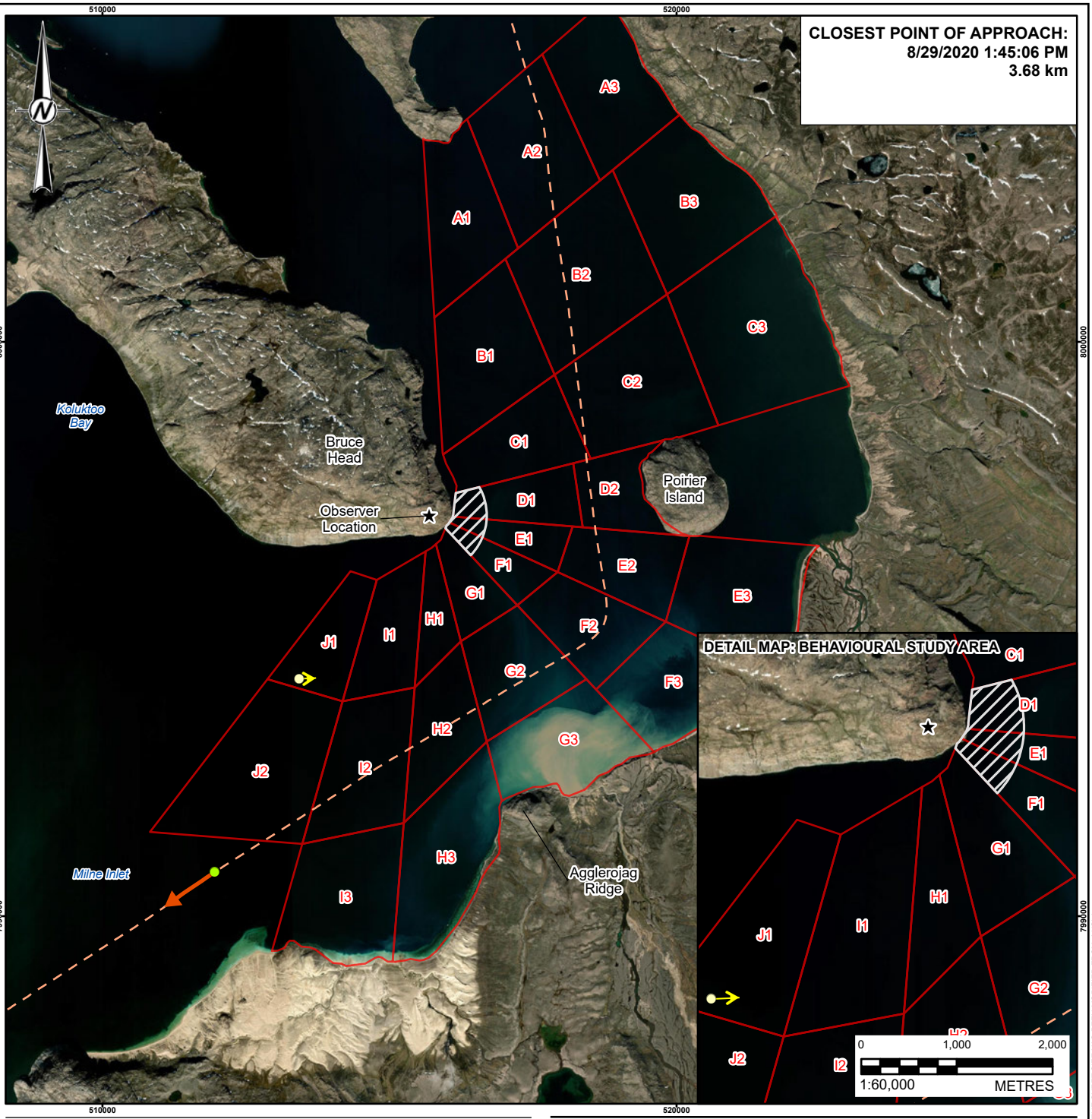

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 68 (2020)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 68 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-10

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

25mm

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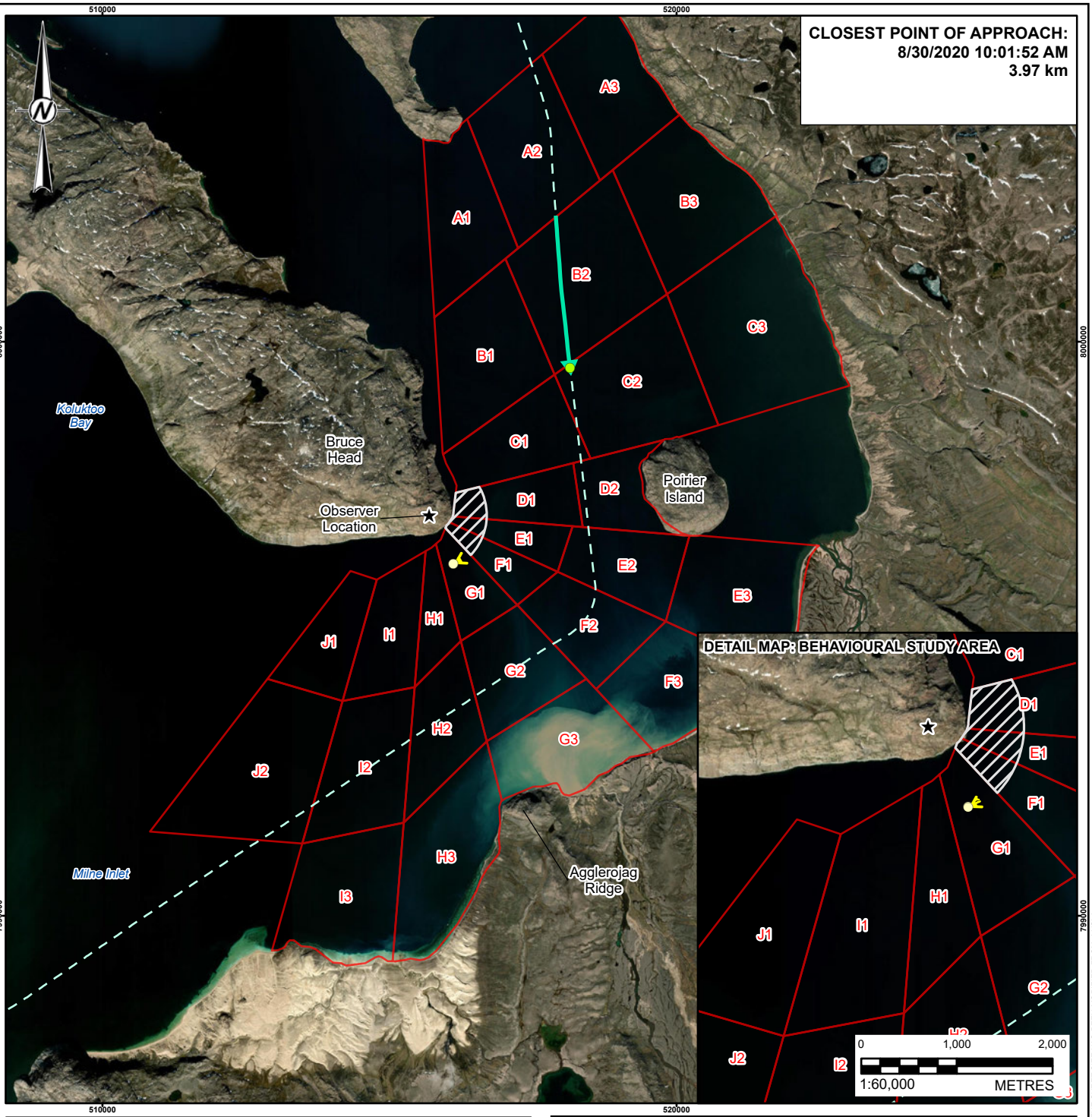

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 83 (2020)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 83 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-11

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

25mm

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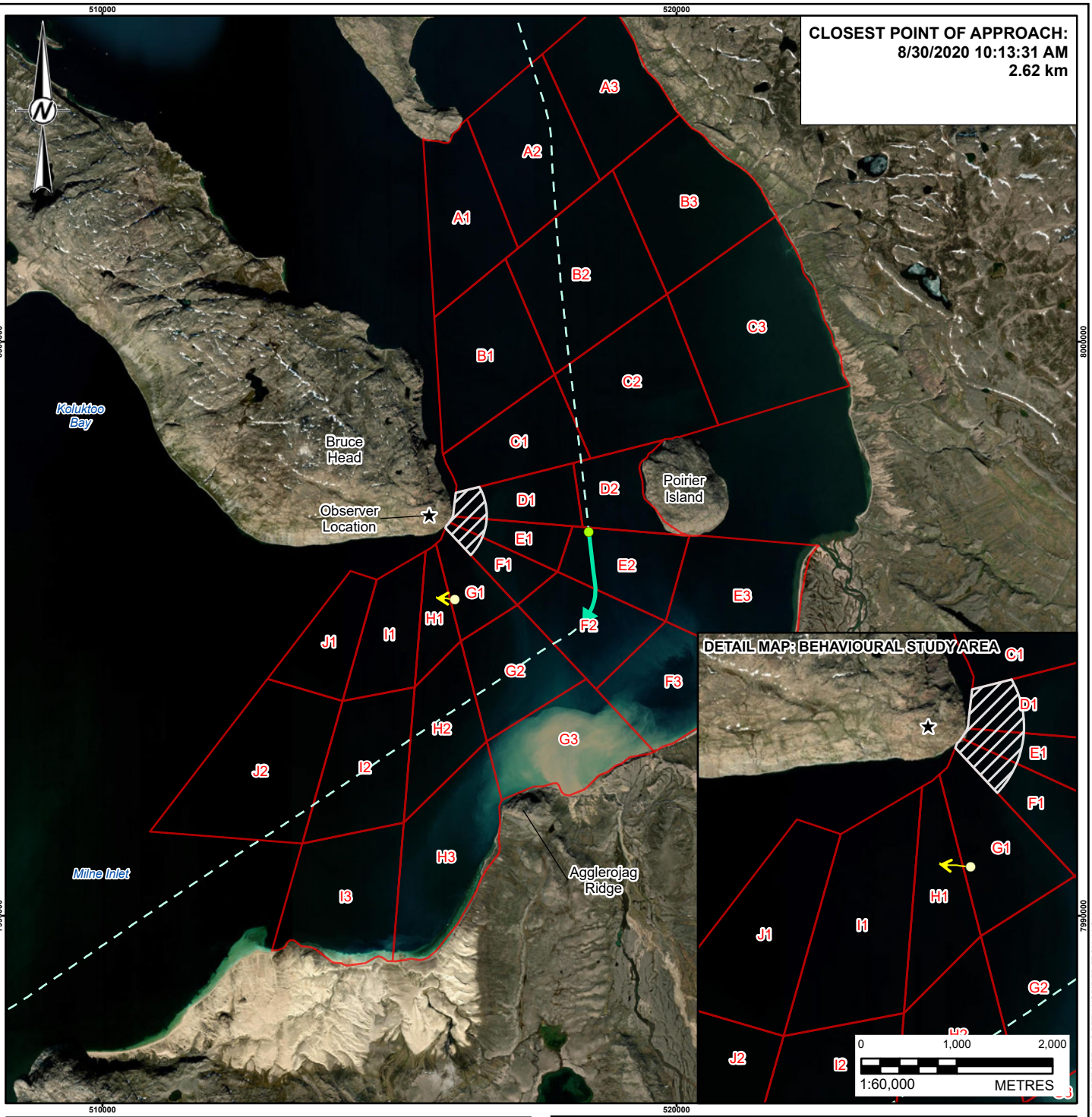

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 84 (2020)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 84 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-12

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

25mm

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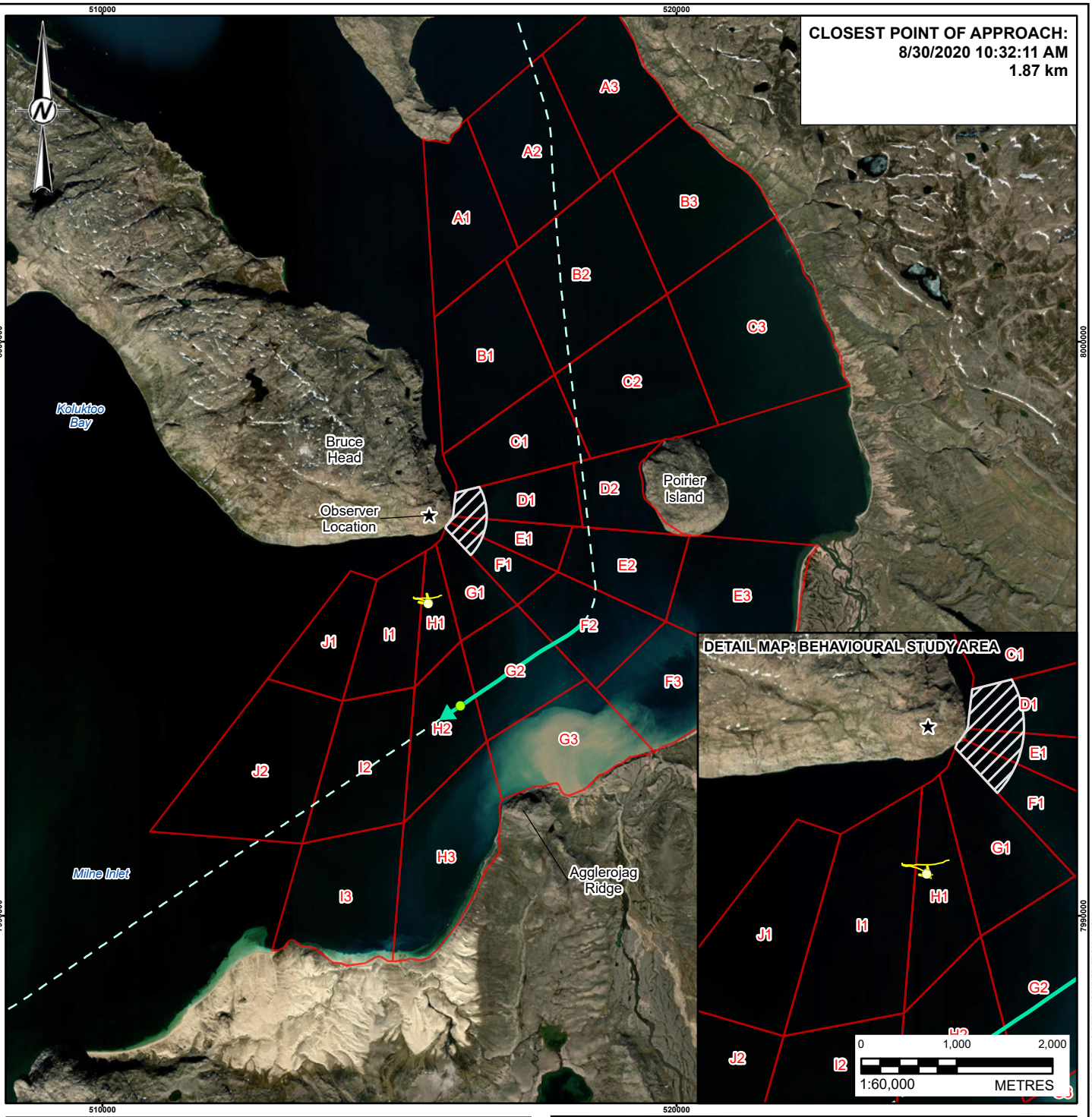

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 85 (2020)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-13

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

25mm

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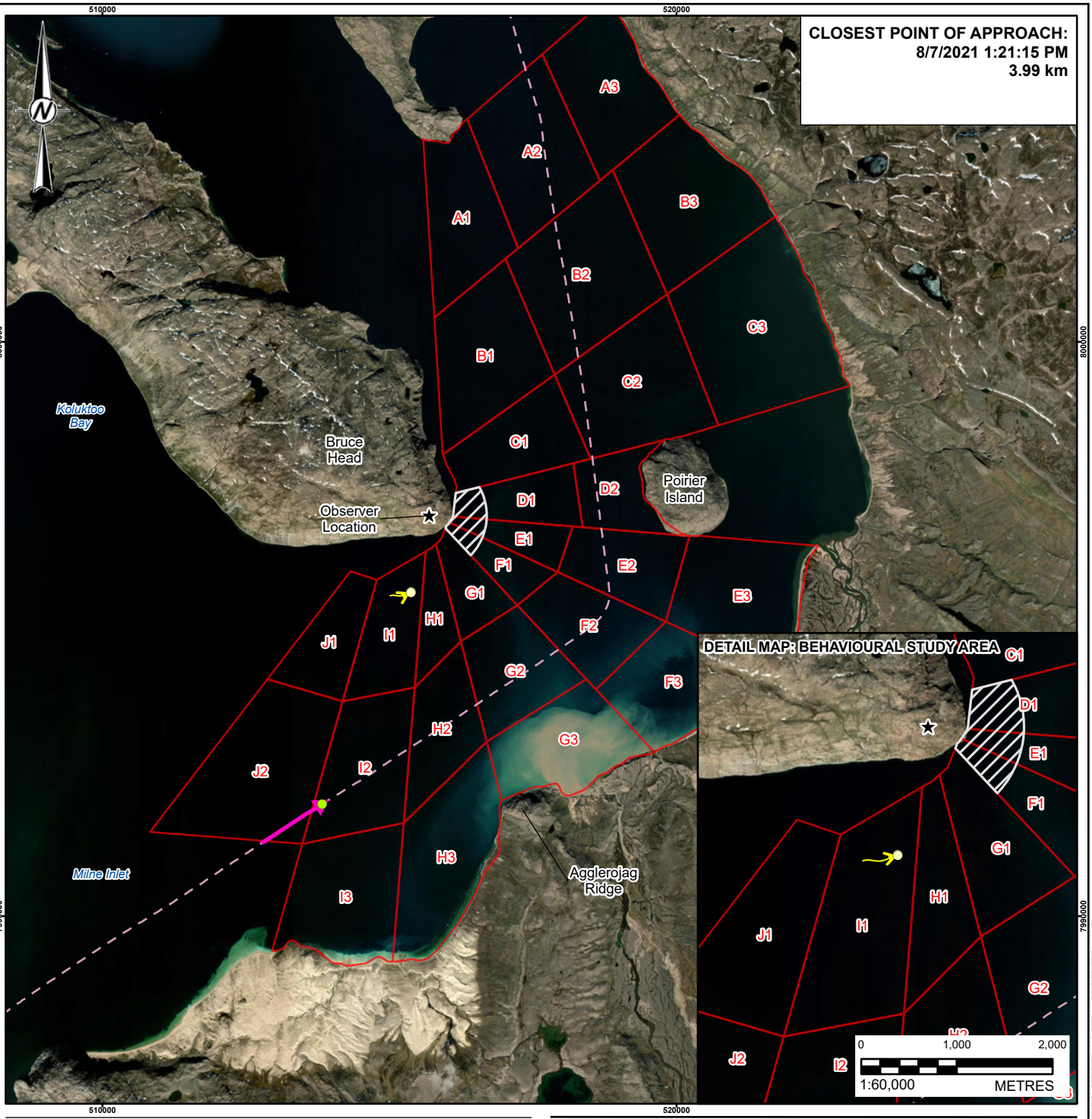

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 33 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 33 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-14

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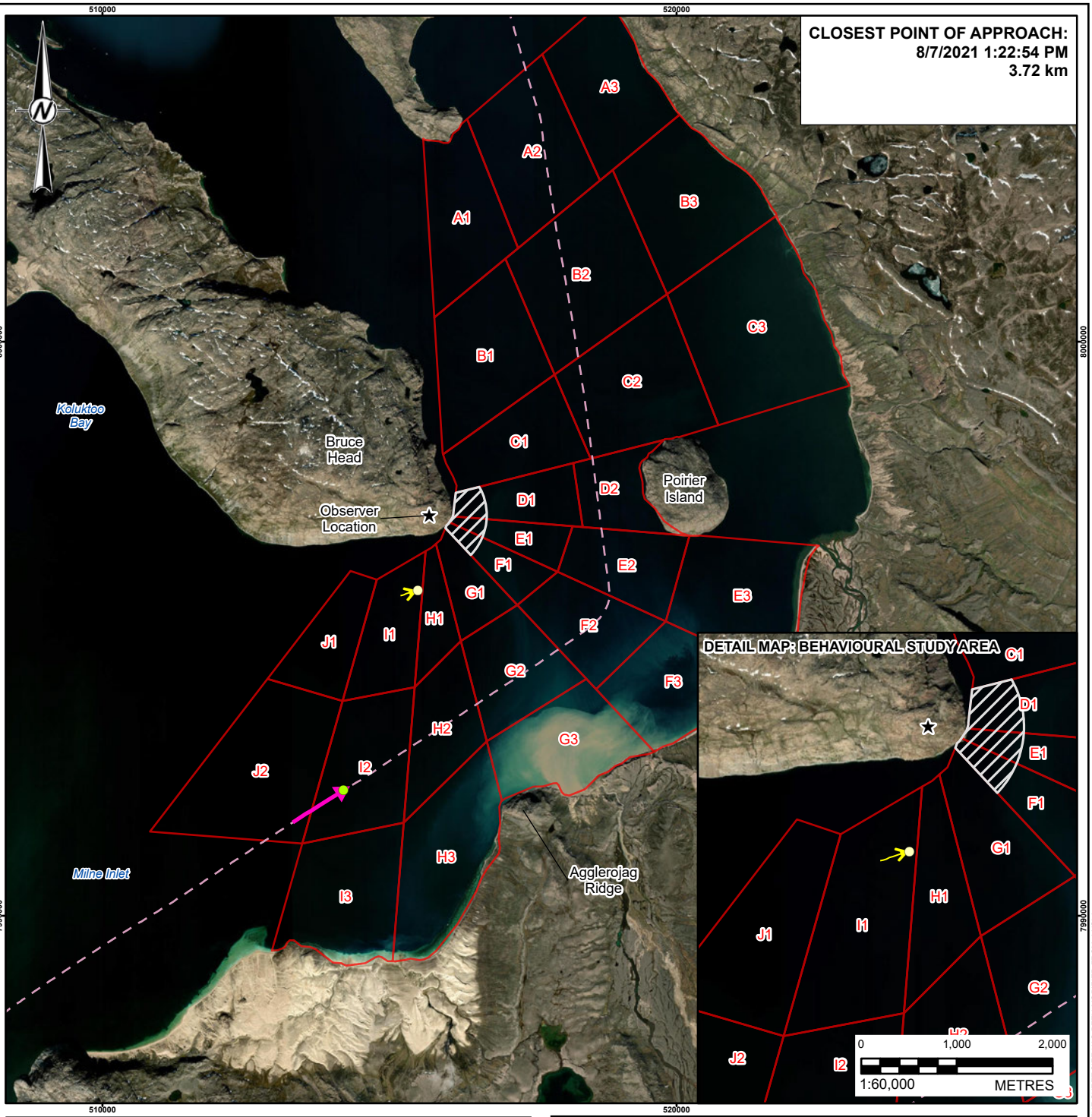

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 34 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 34 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-15

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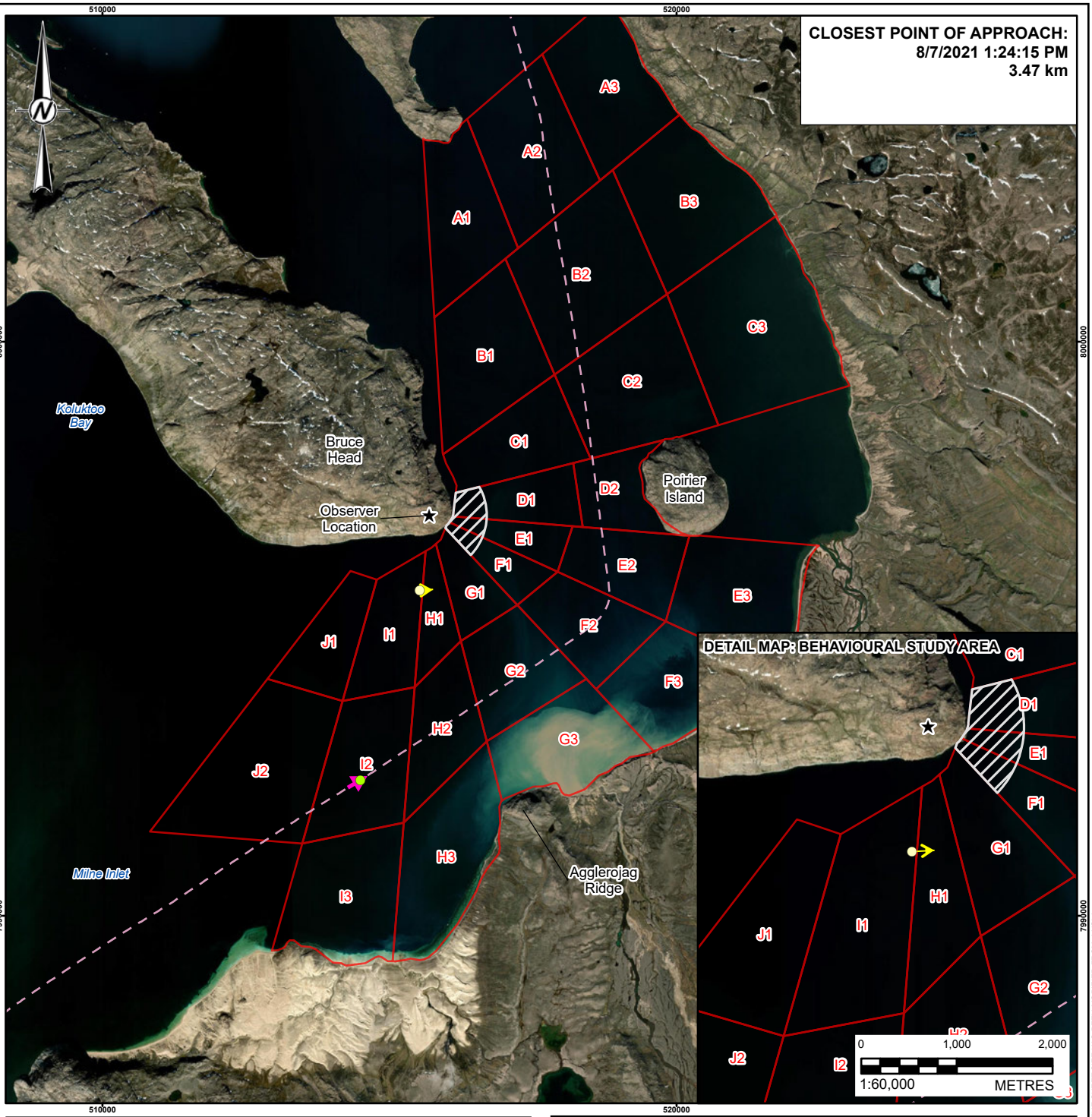

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 35 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 35 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-16

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

25mm

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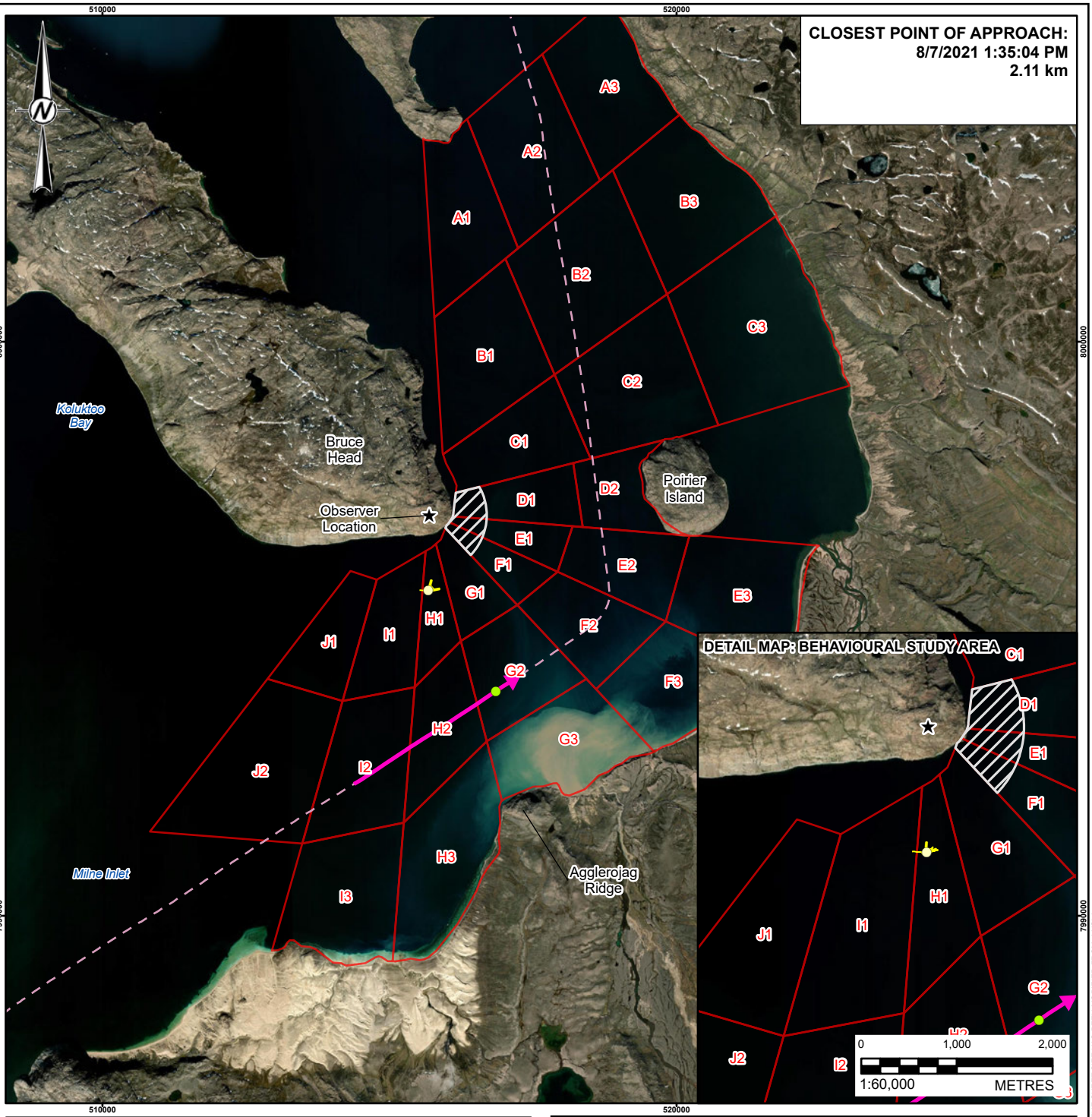

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 36 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 36 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-17

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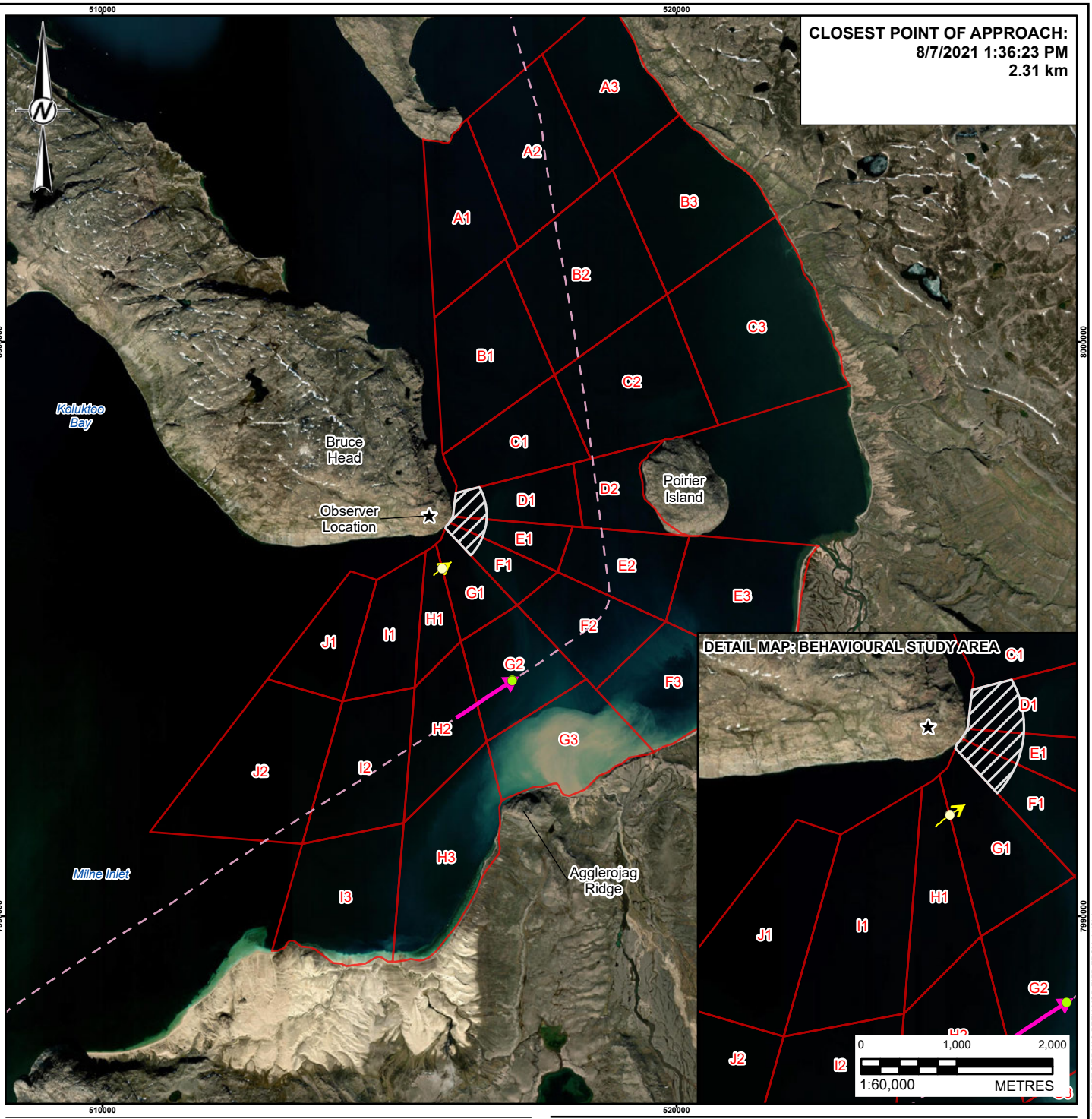

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 37 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

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BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 37 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-18

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

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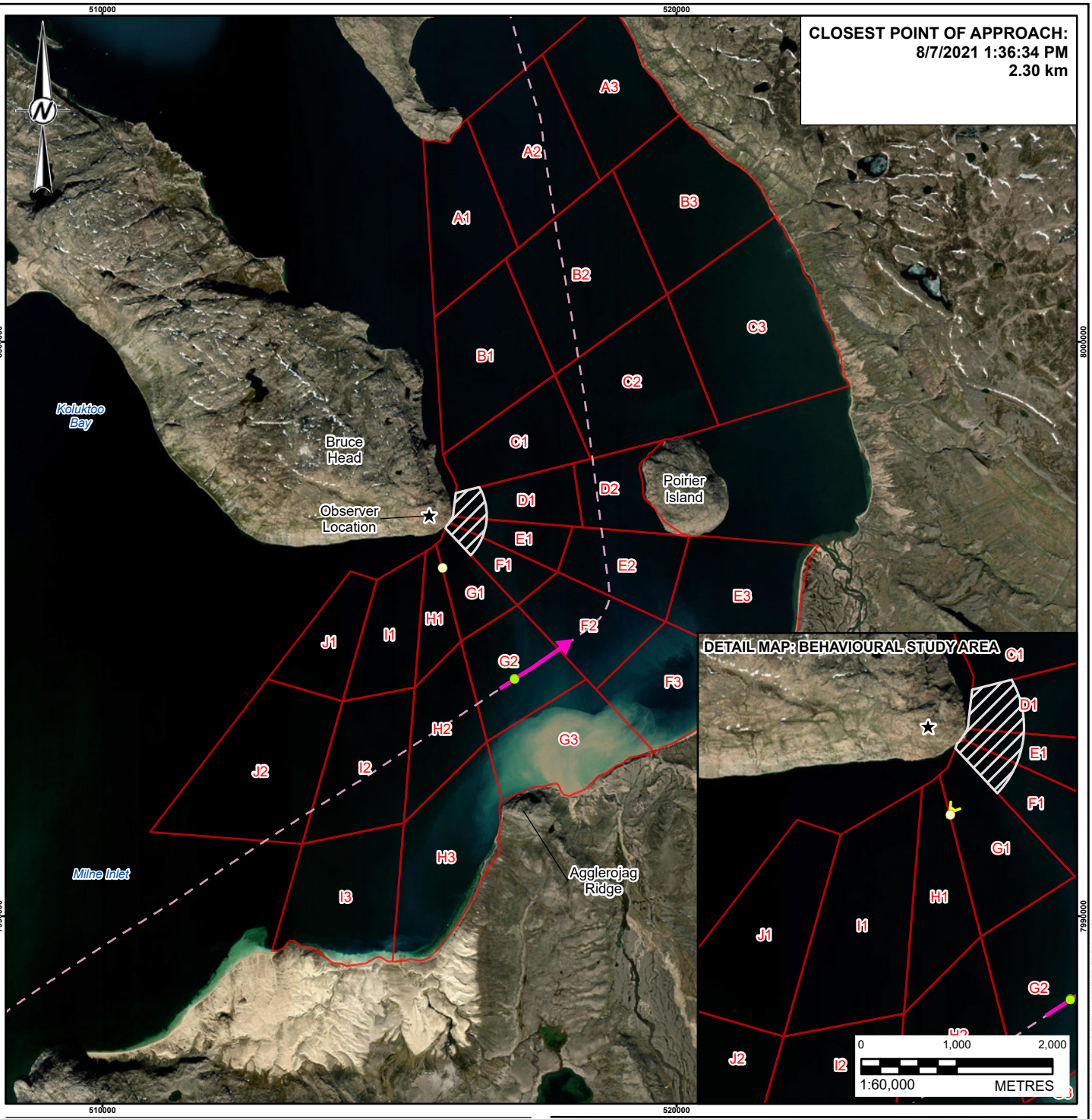

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 38 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 38 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-19

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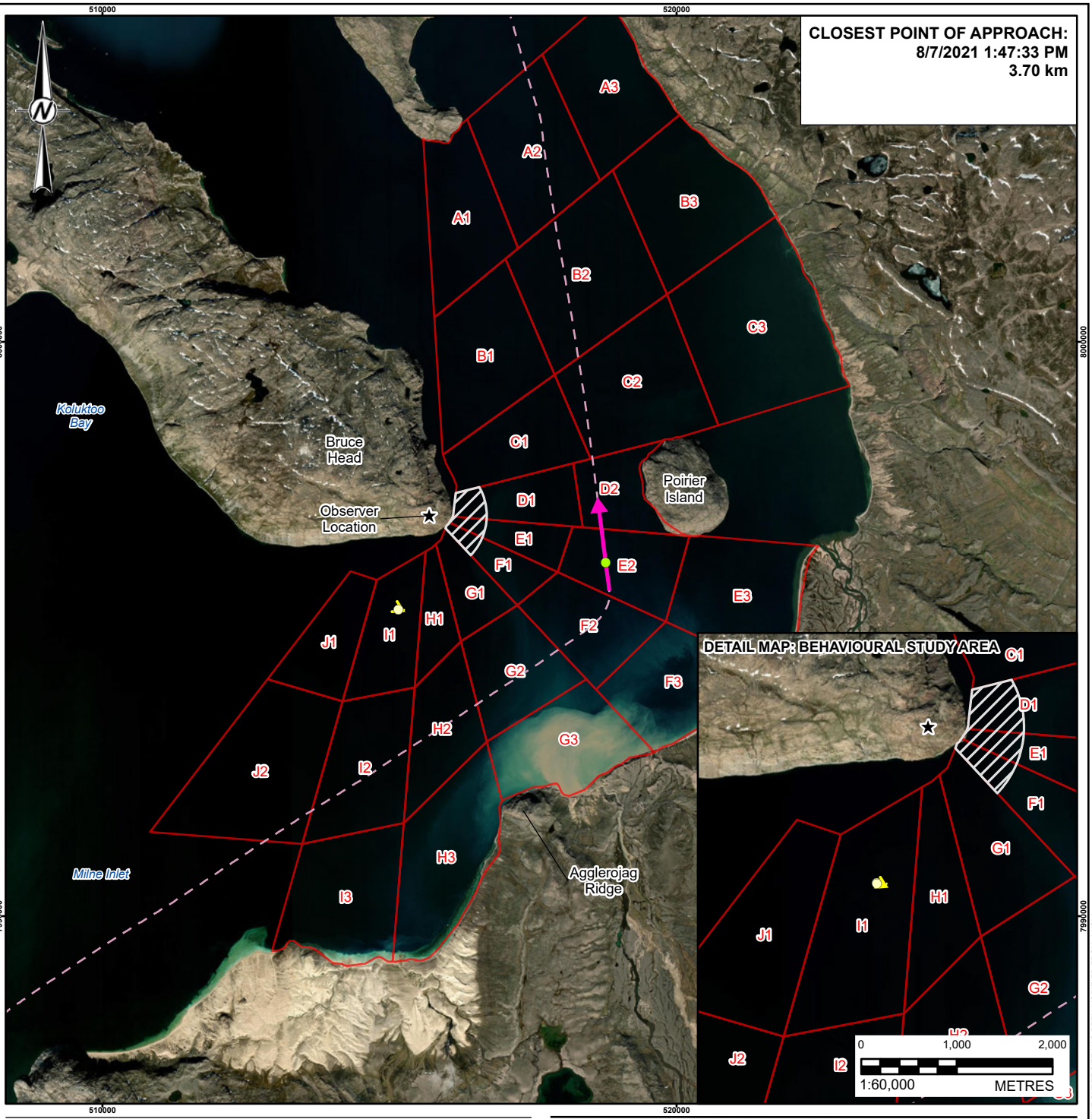

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 39 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 39 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-21

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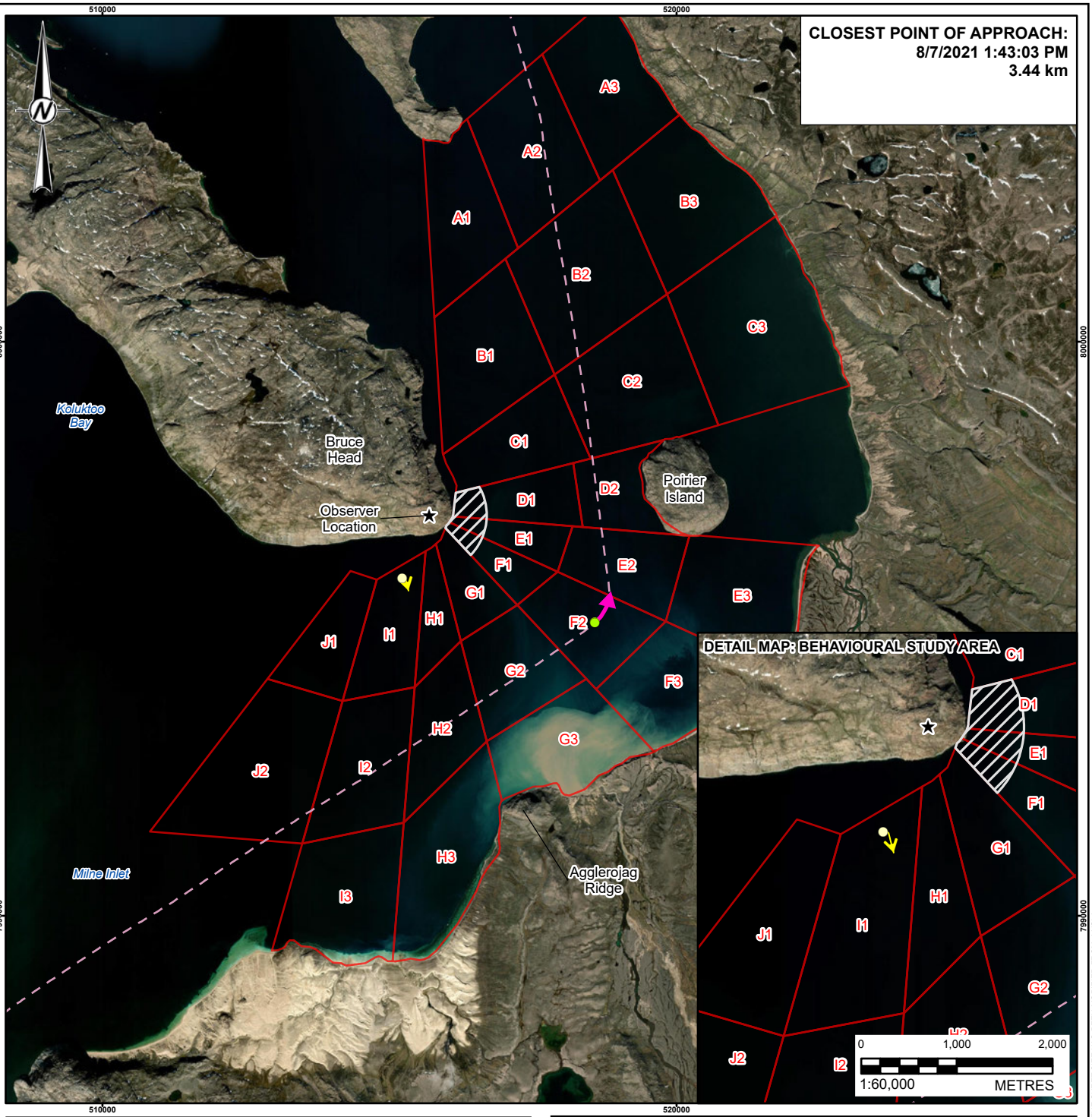

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 40 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 40 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-20

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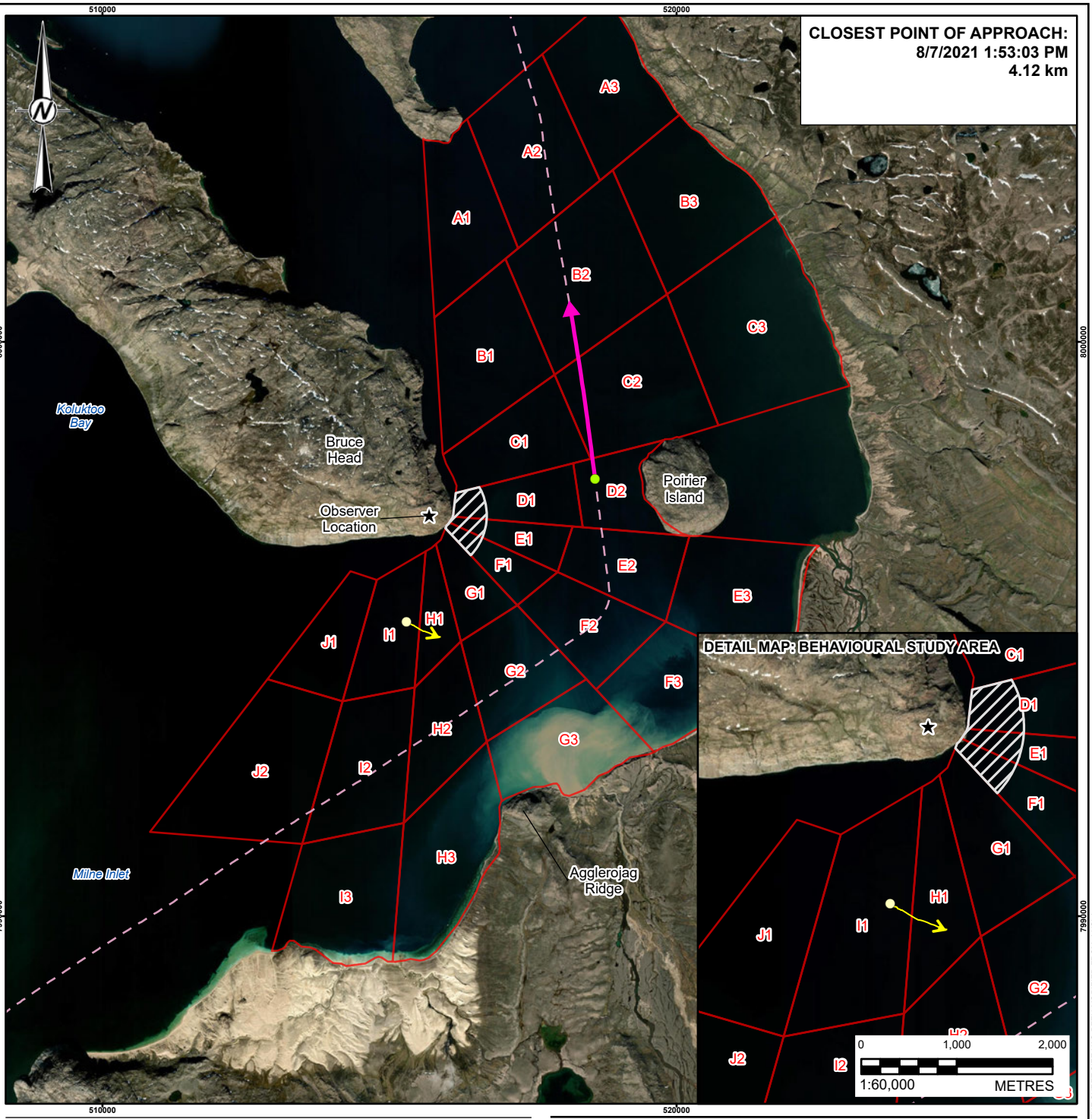

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 41 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 41 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-22

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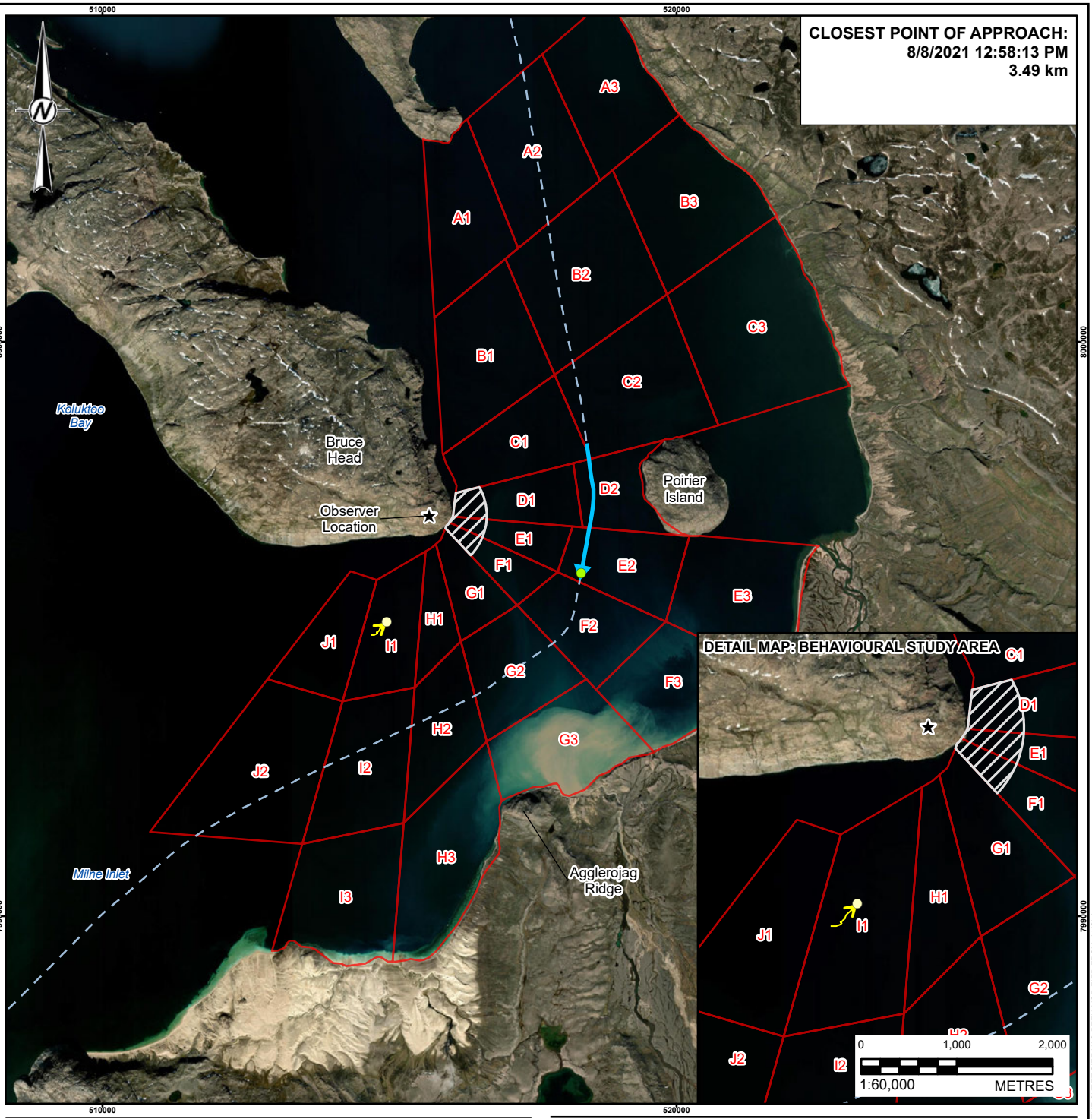

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 47 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN RUBY)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN RUBY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 47 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-23

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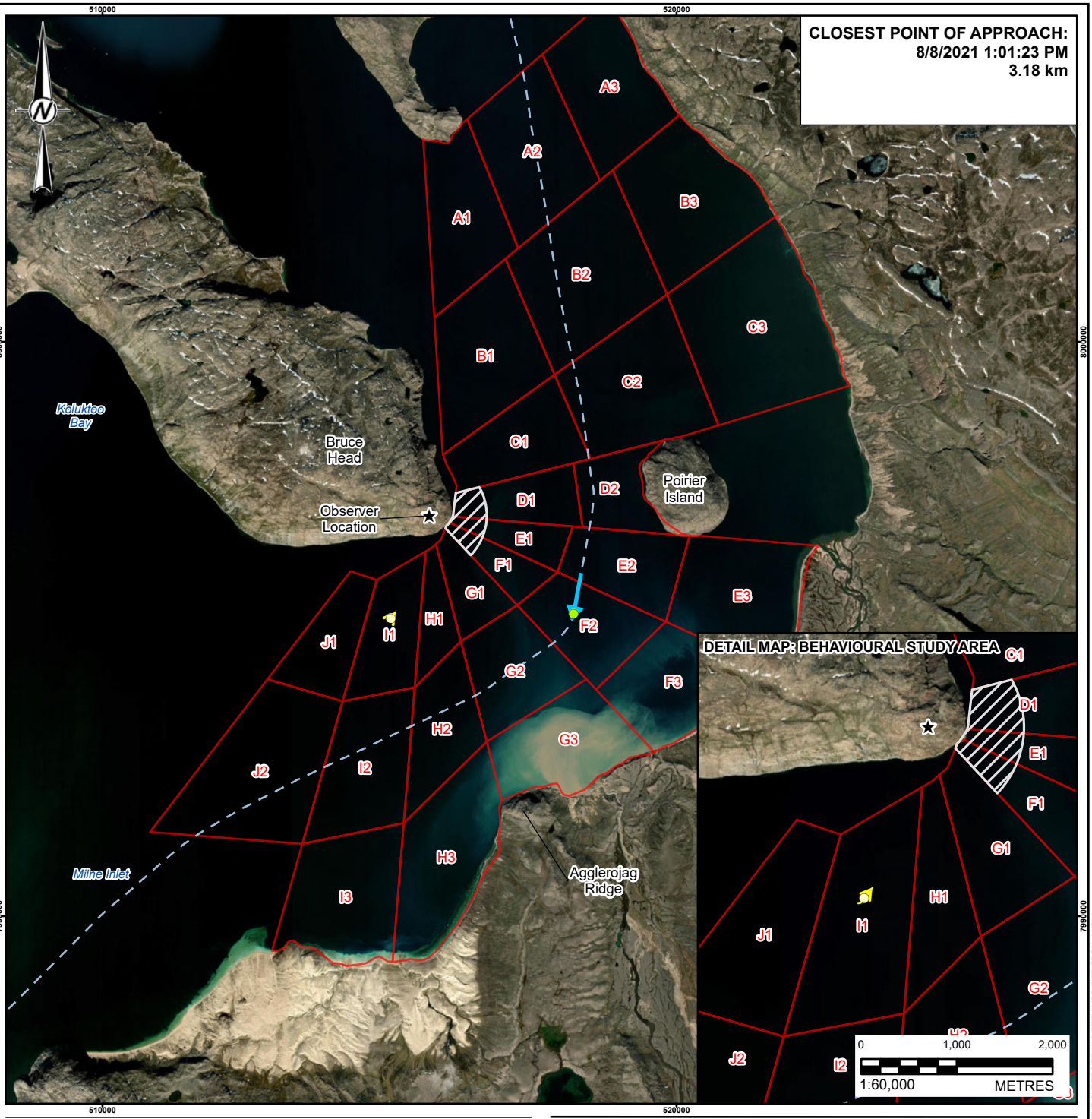
25mm
0



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 48 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN RUBY)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN RUBY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 48 (2021) AND ACTIVE VESSEL TRANSIT

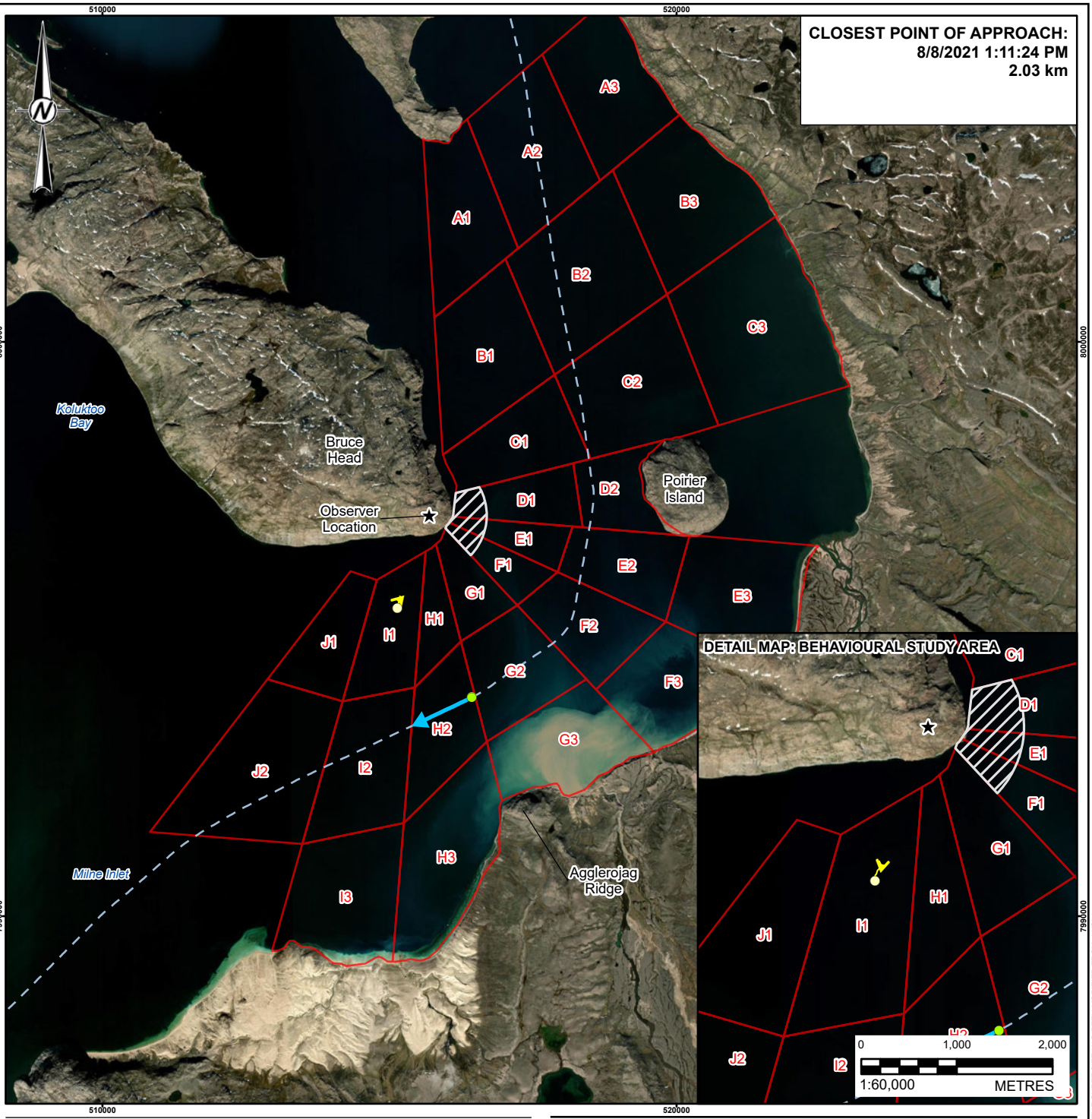
CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-24

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



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 49 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN RUBY)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN RUBY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 49 (2021) AND ACTIVE VESSEL TRANSIT

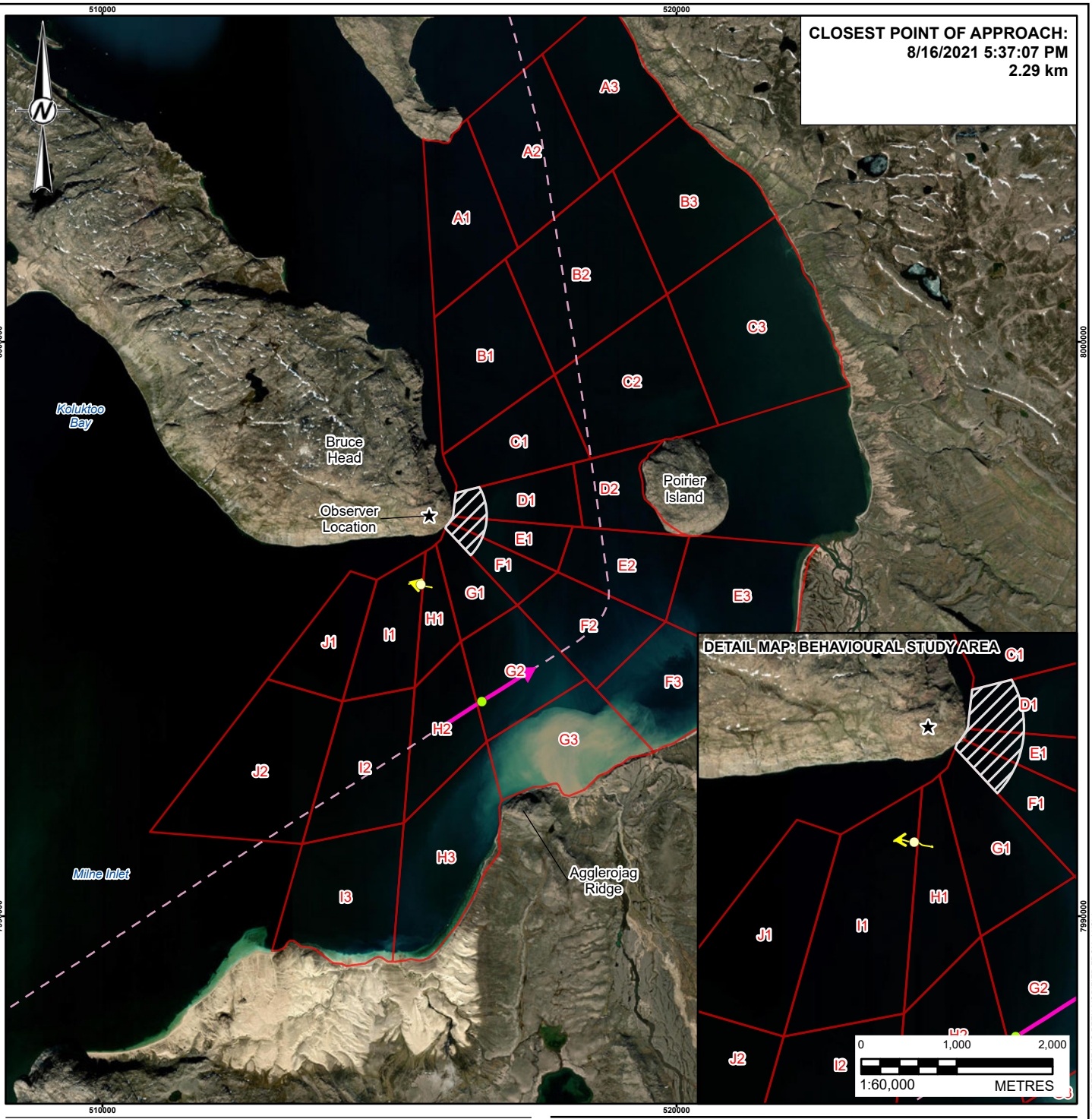
CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-25

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



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 85 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 (2021) AND ACTIVE VESSEL TRANSIT

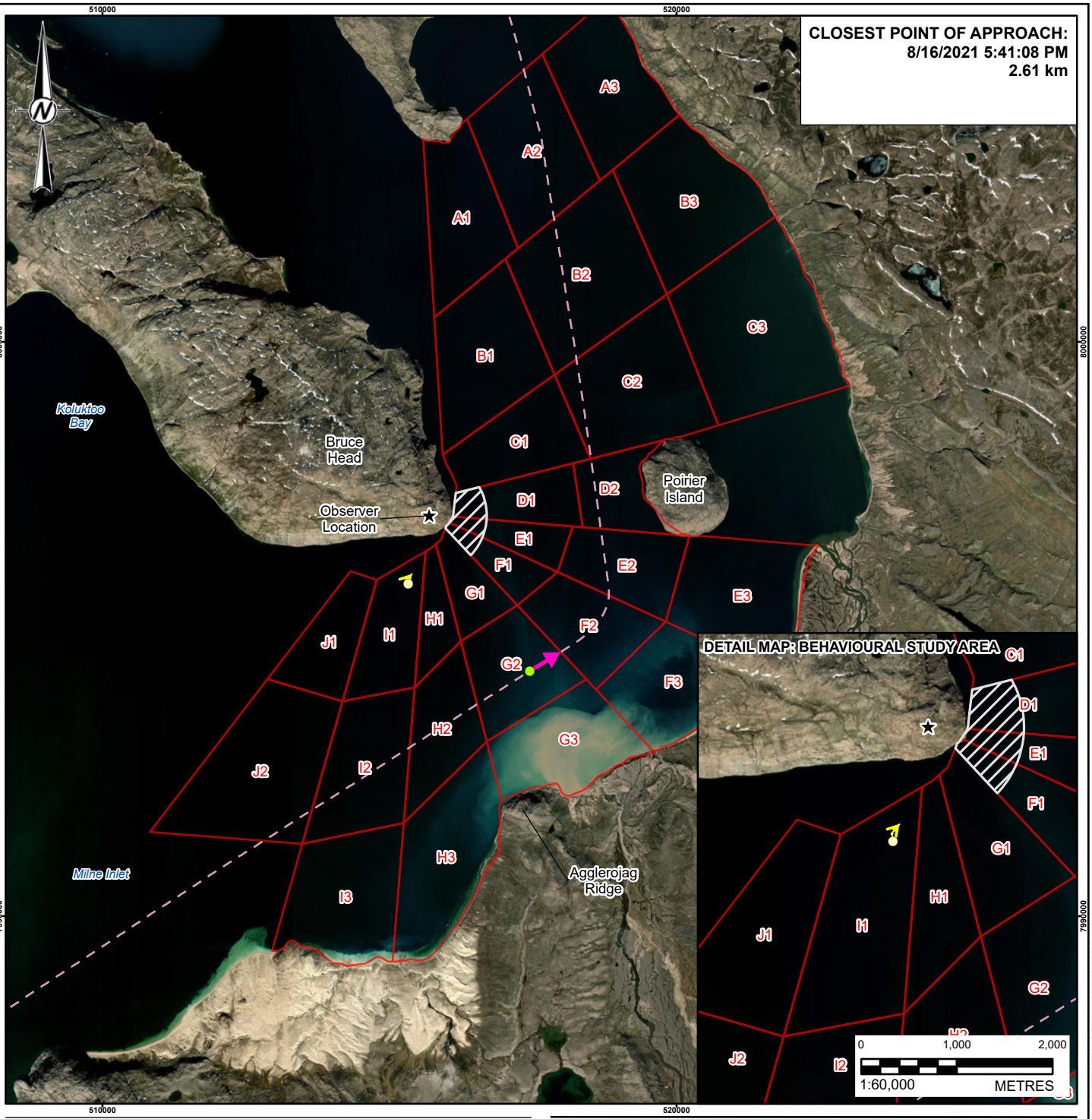
CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-26

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



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 86 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

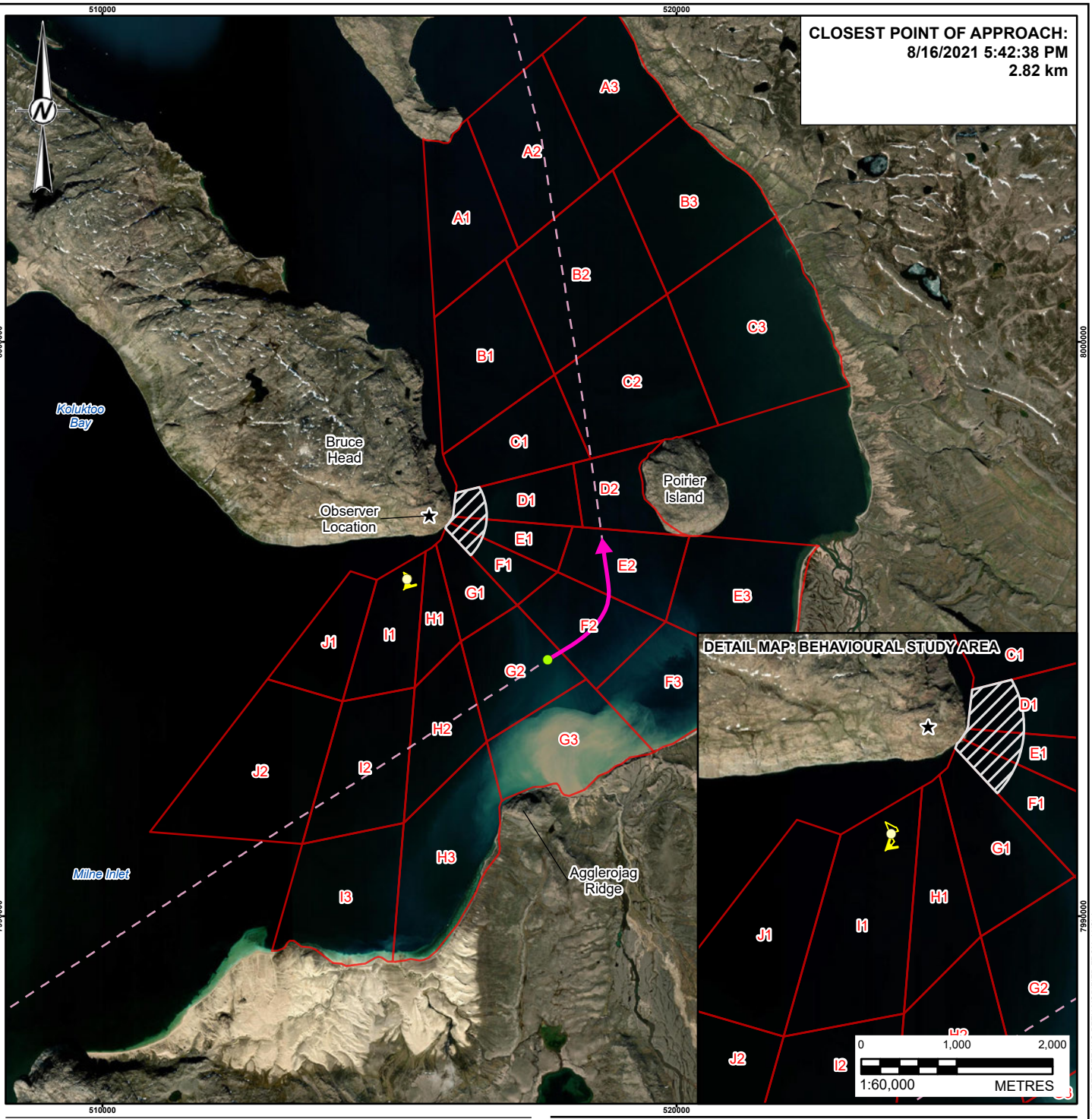
PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-27

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

25mm

0

PATH: I:\2016\166372\4\Mapping\MXD\75000_2023BruceHead\166372402_75000_FigE_14_43_2021FocalFollows_DDP_Rev0.aprx PRINTED ON: AT: 2:07:26 PM



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 87 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-28

PATH: I:\2016\166372A\Mapping\MXD\75000_20240Bruce\Hab\166372402_75000_E-06E_14_43_20241FocalFollows_DNP_Rev0.aprx PRINTED ON: AT 2:07:33 PM
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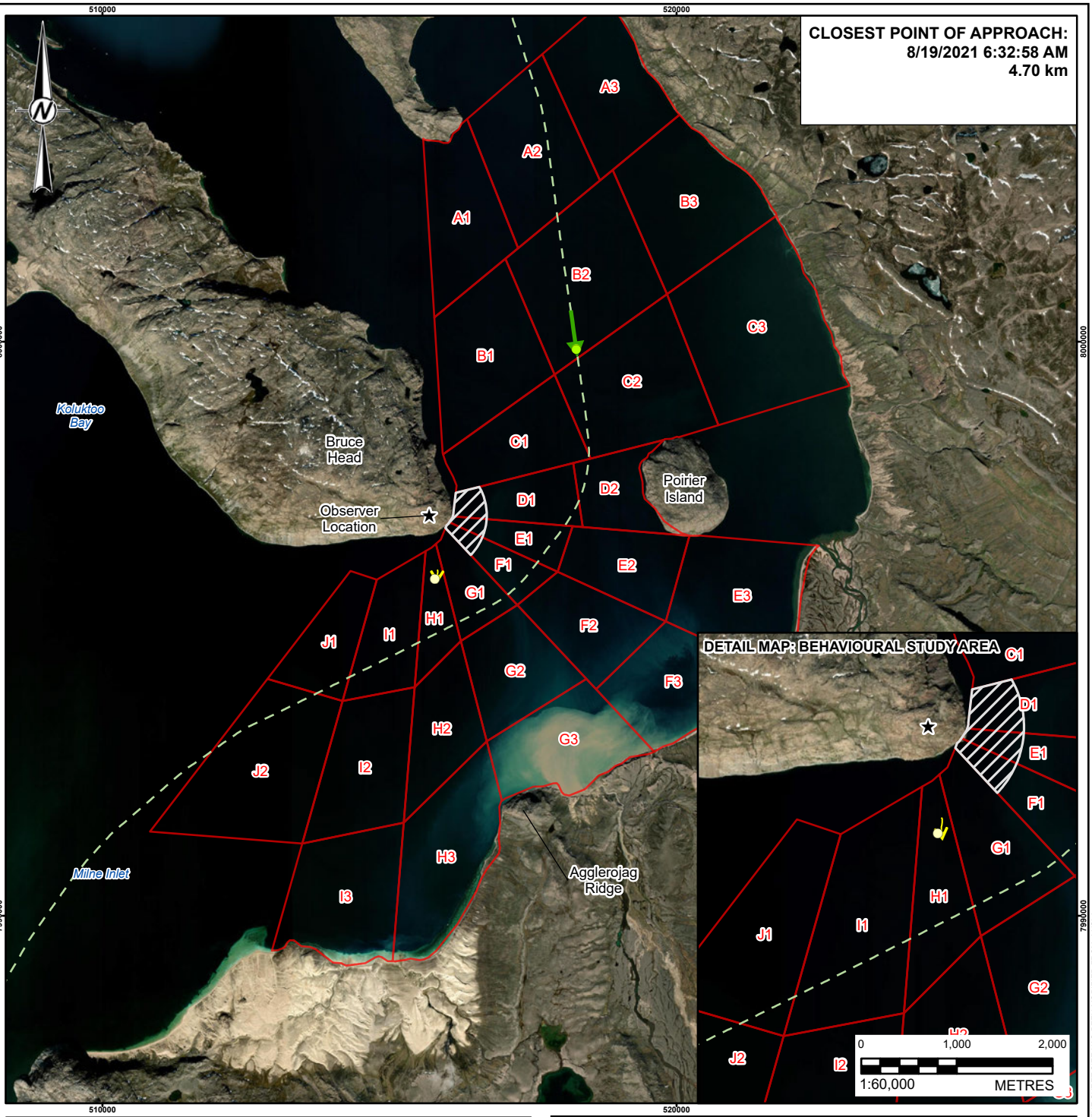
25mm
0



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 114 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 114 (2021) AND ACTIVE VESSEL TRANSIT

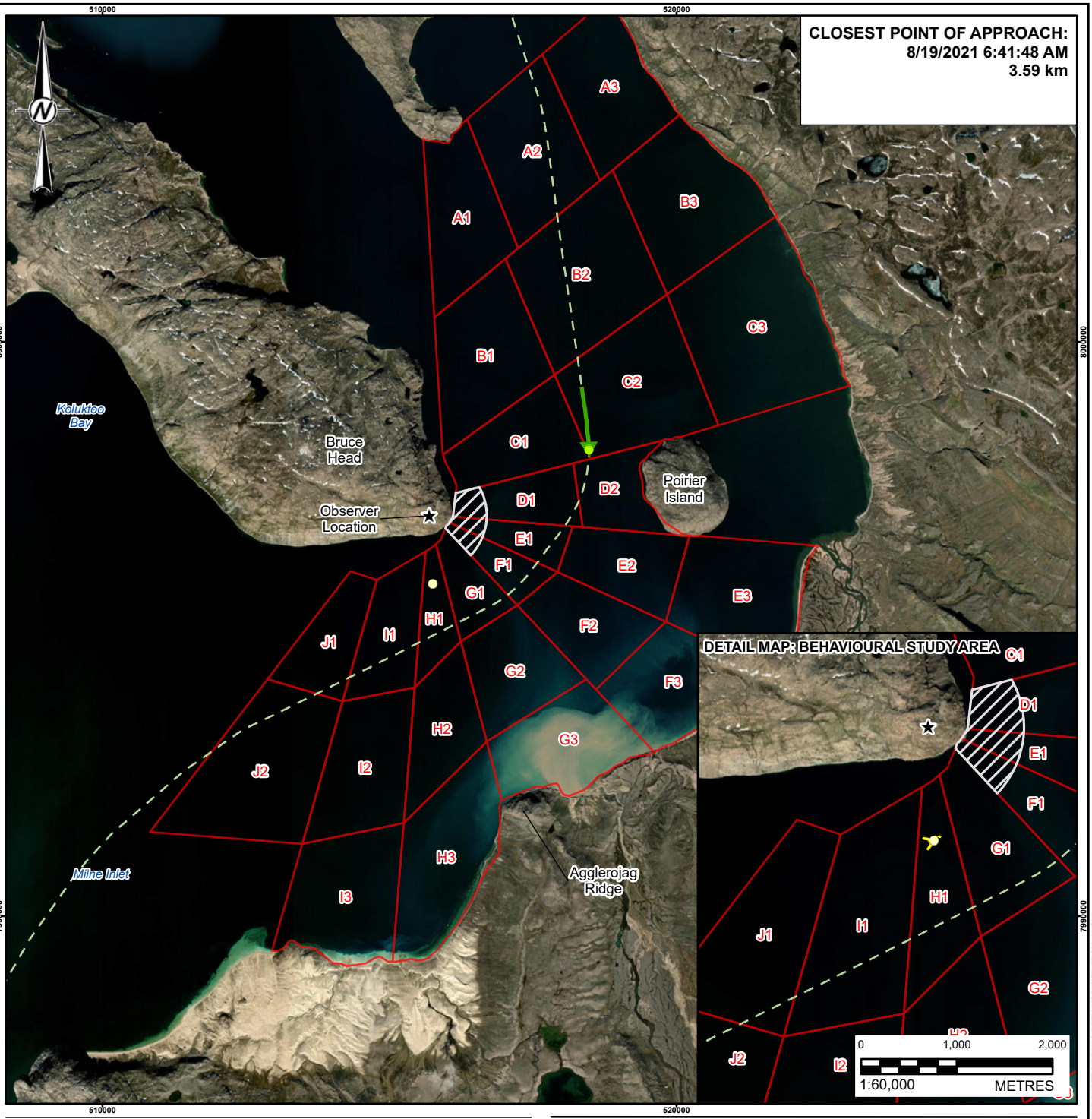
CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-29

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



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 115 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 115 (2021) AND ACTIVE VESSEL TRANSIT

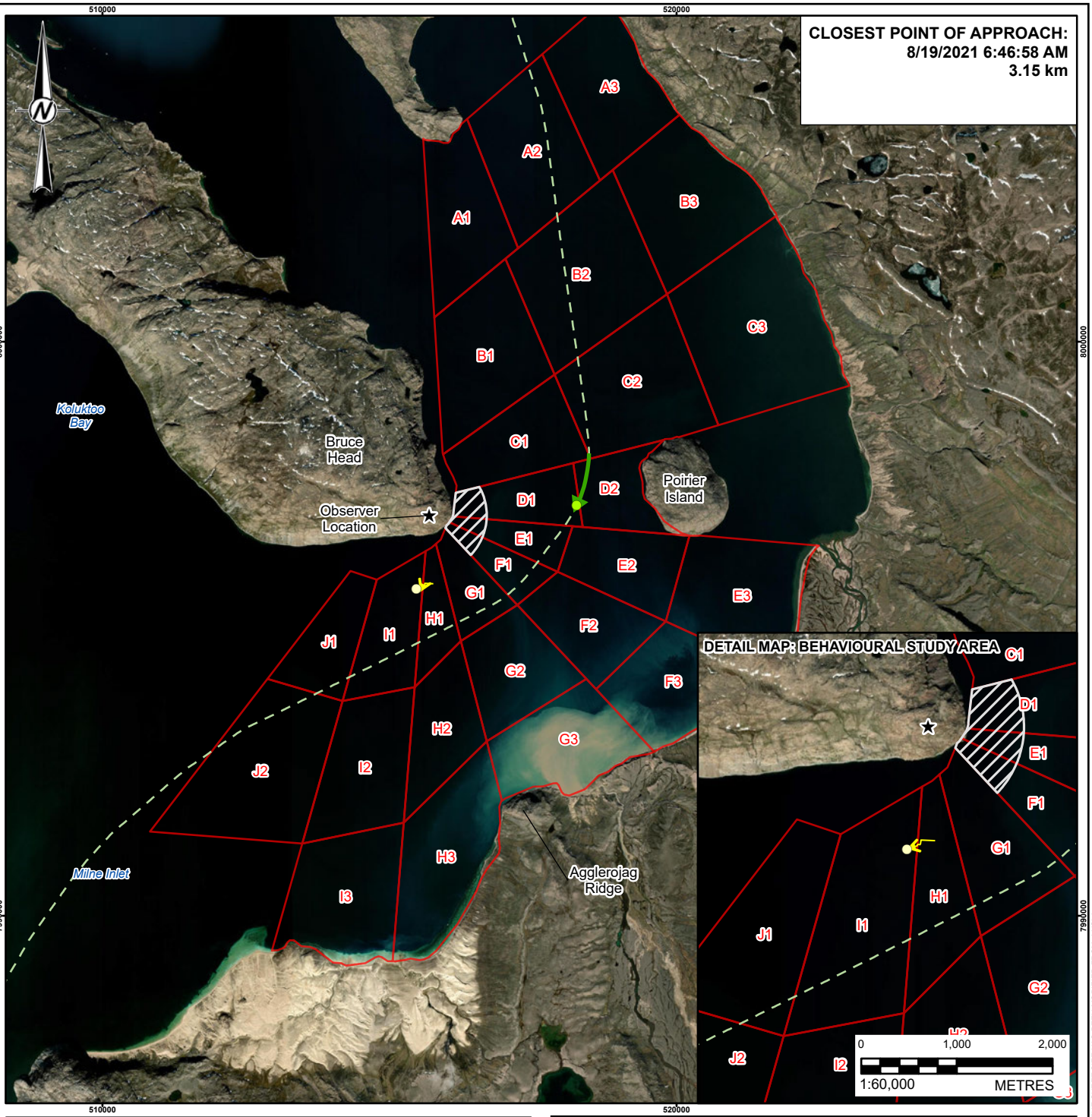
CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-30

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



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 116 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 116 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

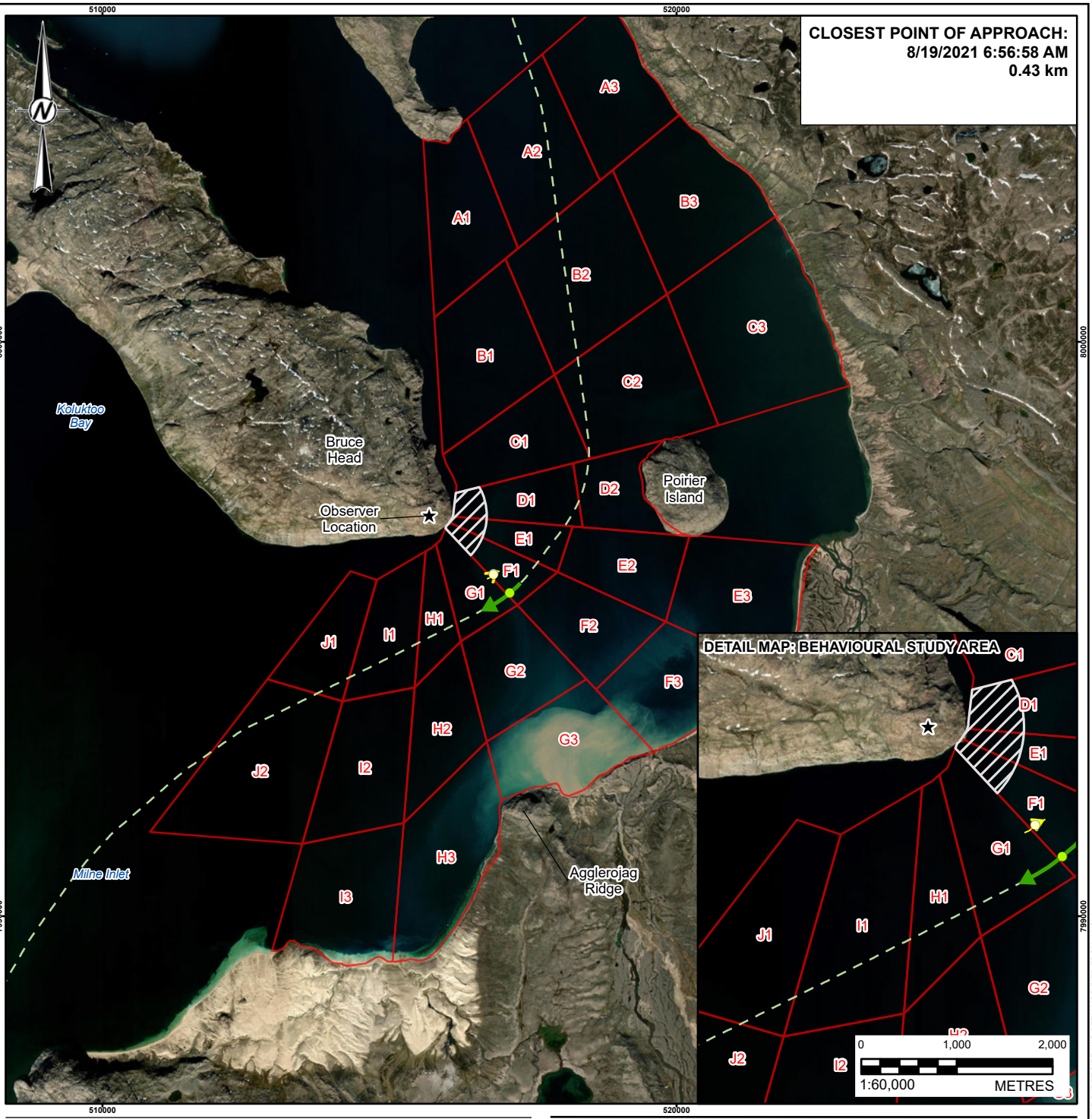
PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-31

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

25mm

0

PATH: I:\2016\166372\4\Mapping\MXD\75000_2023BruceHead\166372402_75000_FigE_14_43_2021FocalFollows_DDP_Rev0.aprx PRINTED ON: AT: 2:07:58 PM



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 117 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

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BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 117 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

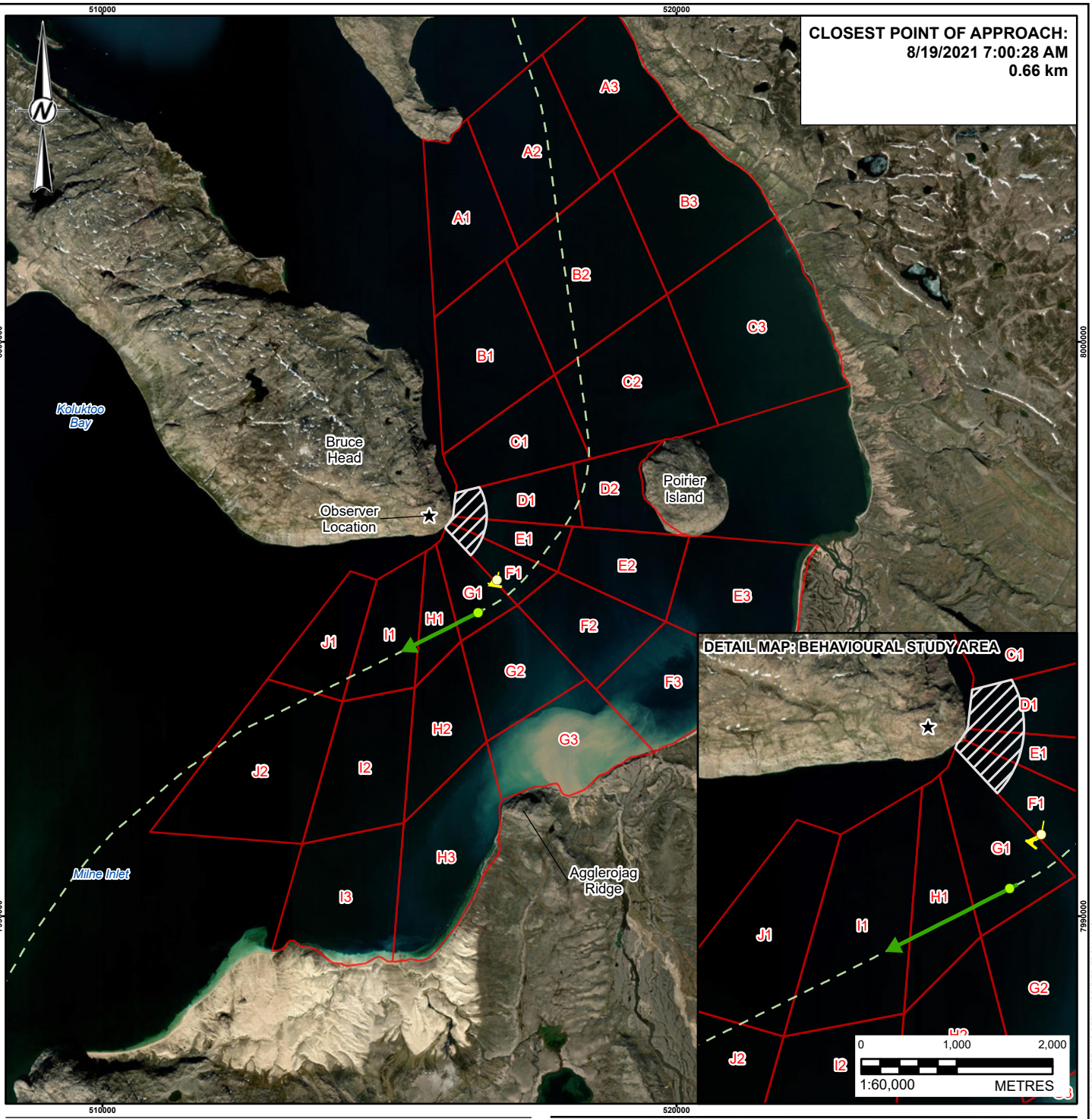
PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-32

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

25mm

0

PATH: I:\2016\166372402\Mapping\MXD\75000_202BruceHead\166372402_75000_E32E_14_43_20210ExpelFollows_DNP_RevA.mxd PRINTED ON: AT 2:08:05 PM



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 118 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 118 (2021) AND ACTIVE VESSEL TRANSIT

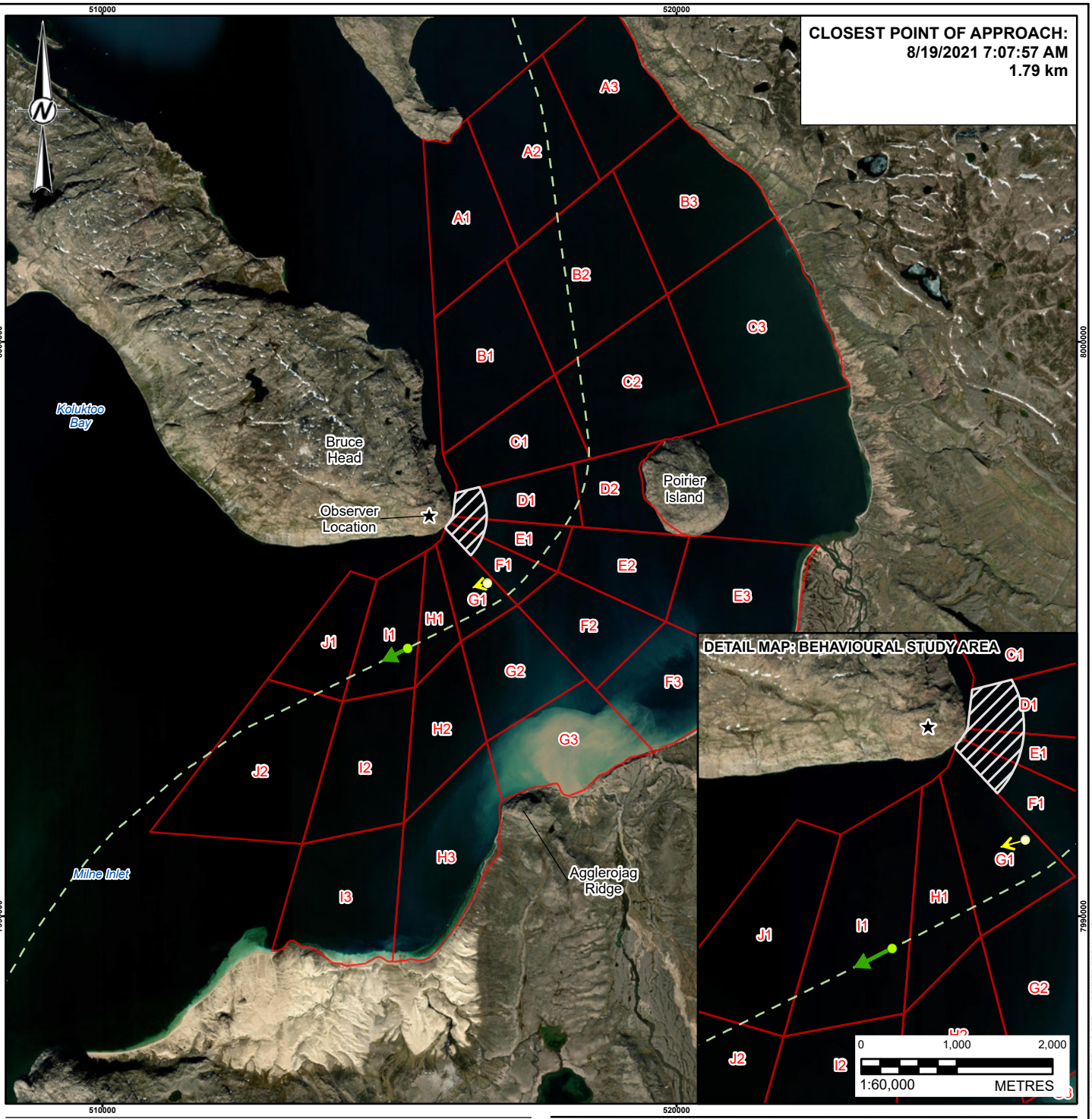
CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-33

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



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 119 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 119 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-34

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

25mm

0

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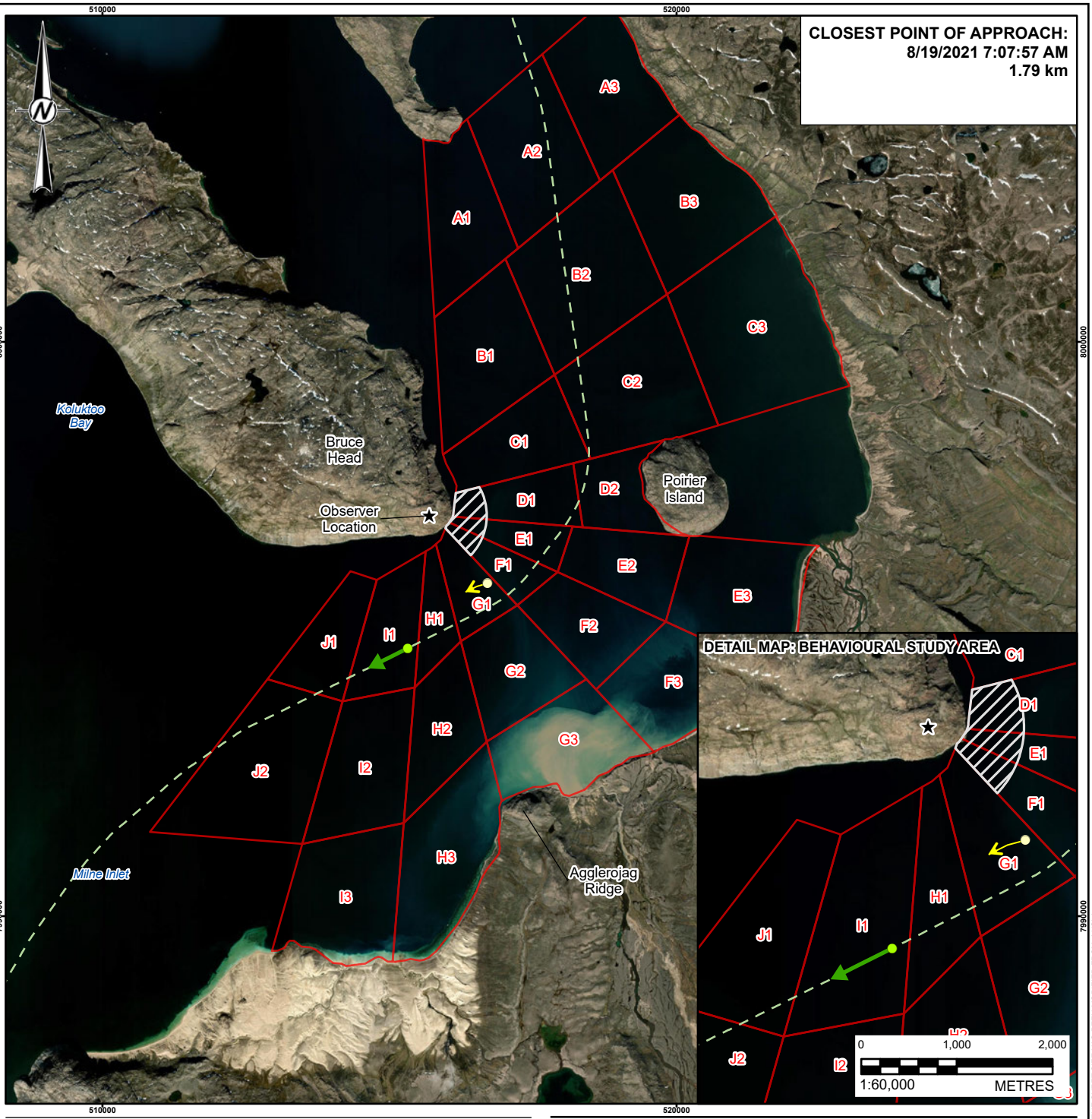


LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 120 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 120 (2021) AND ACTIVE VESSEL TRANSIT

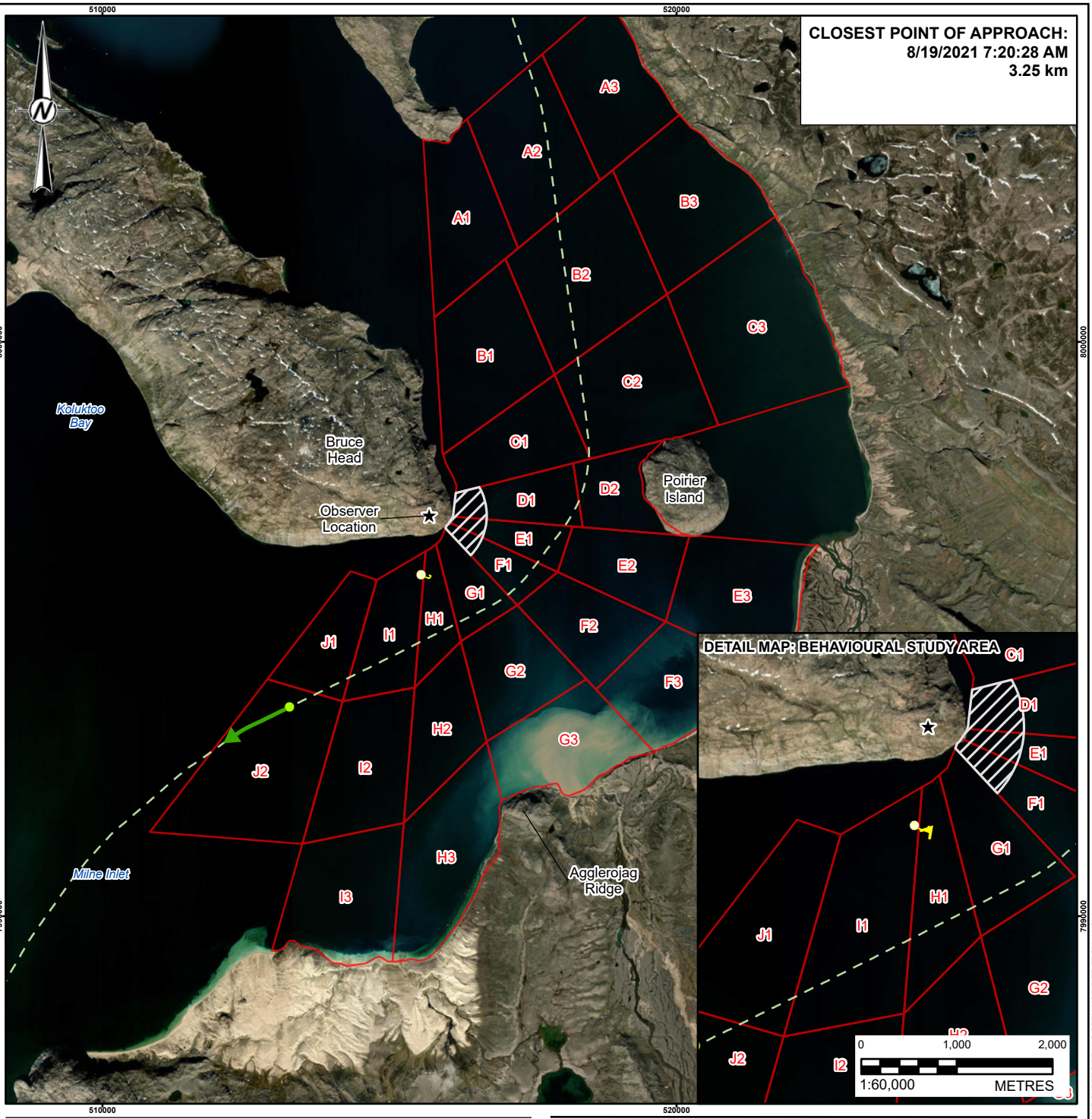
CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-35

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



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 121 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 121 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-36

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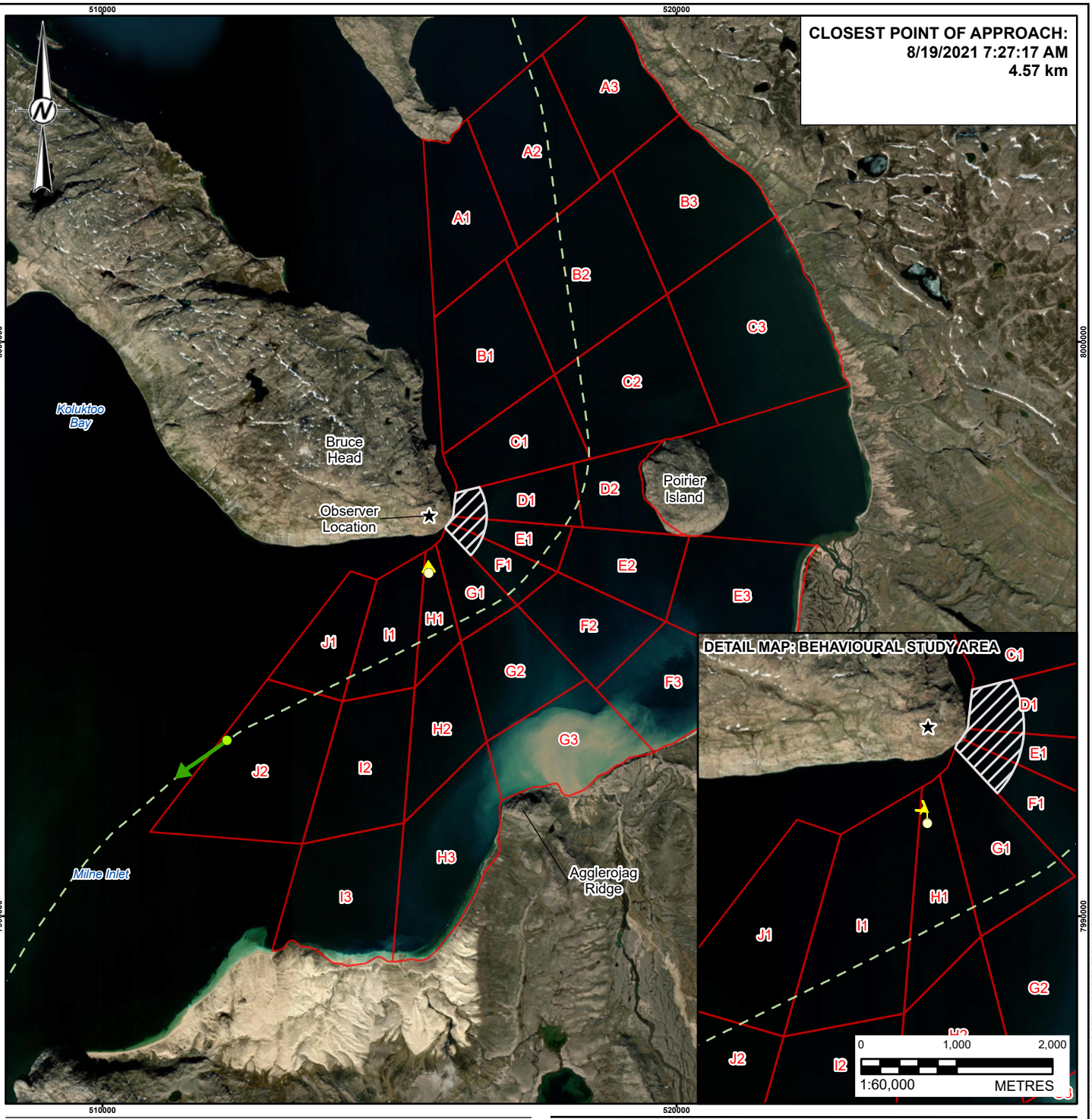

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 122 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 122 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-37

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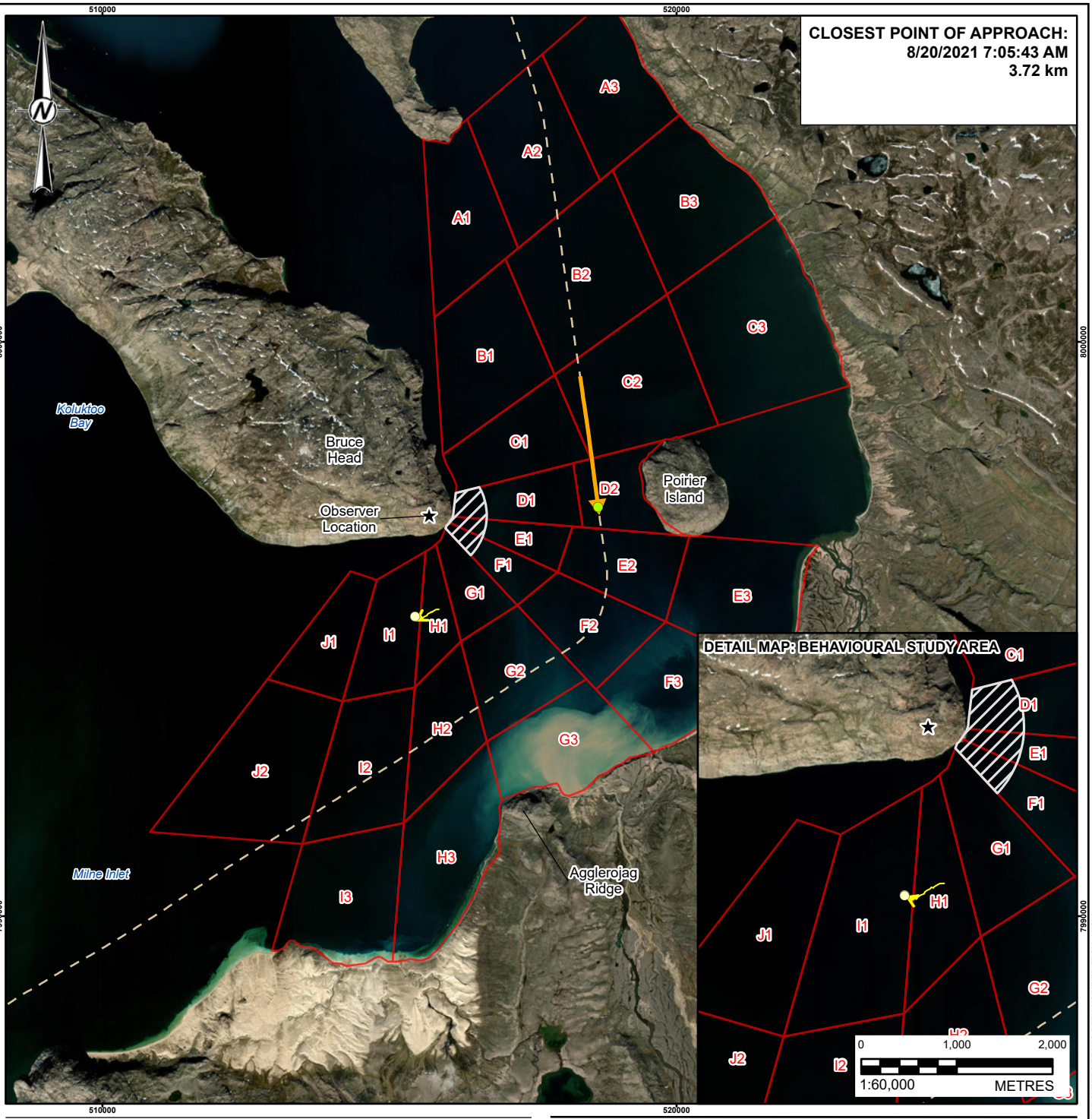

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 139 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 139 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-38

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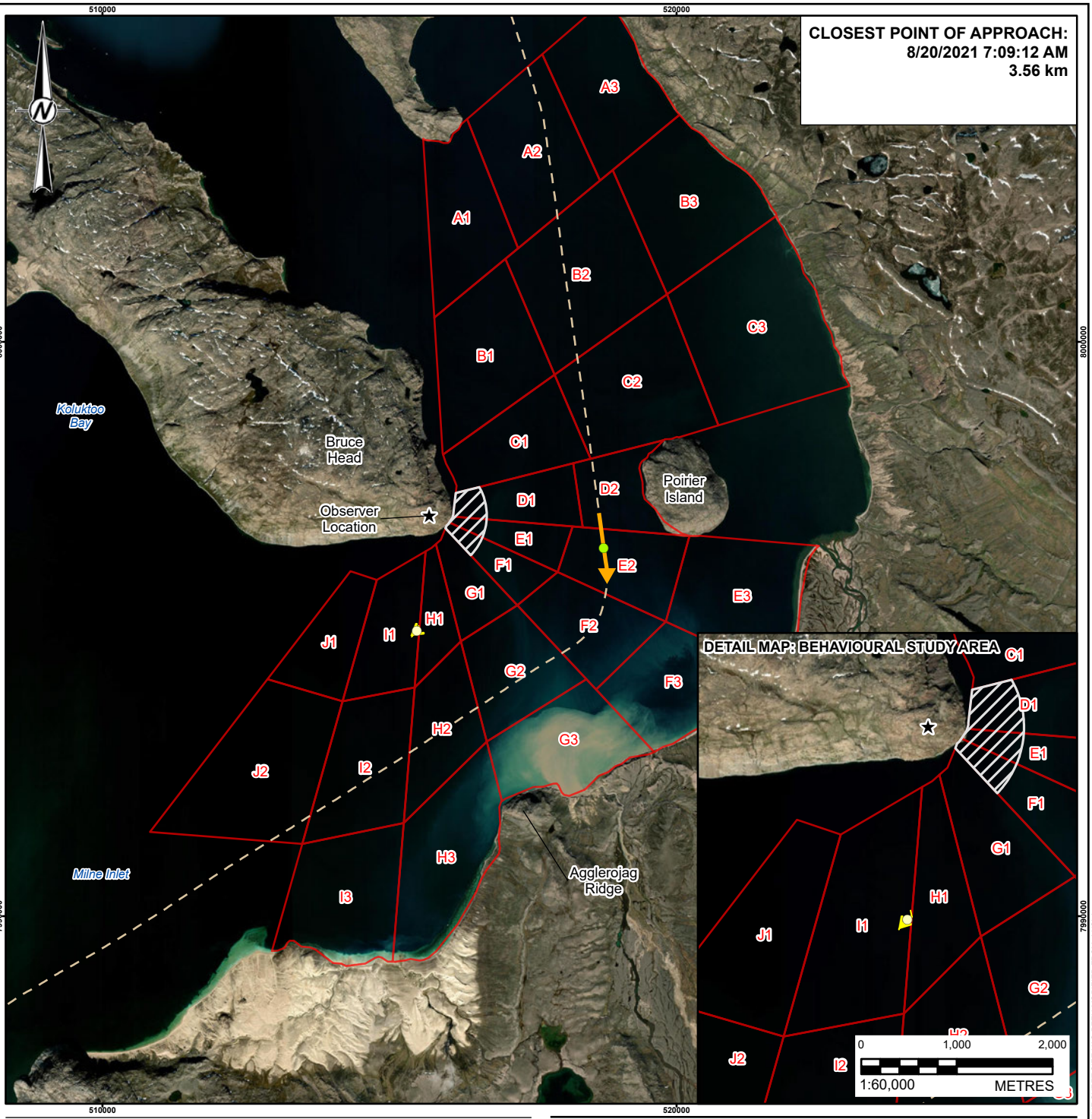

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 140 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 140 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-39

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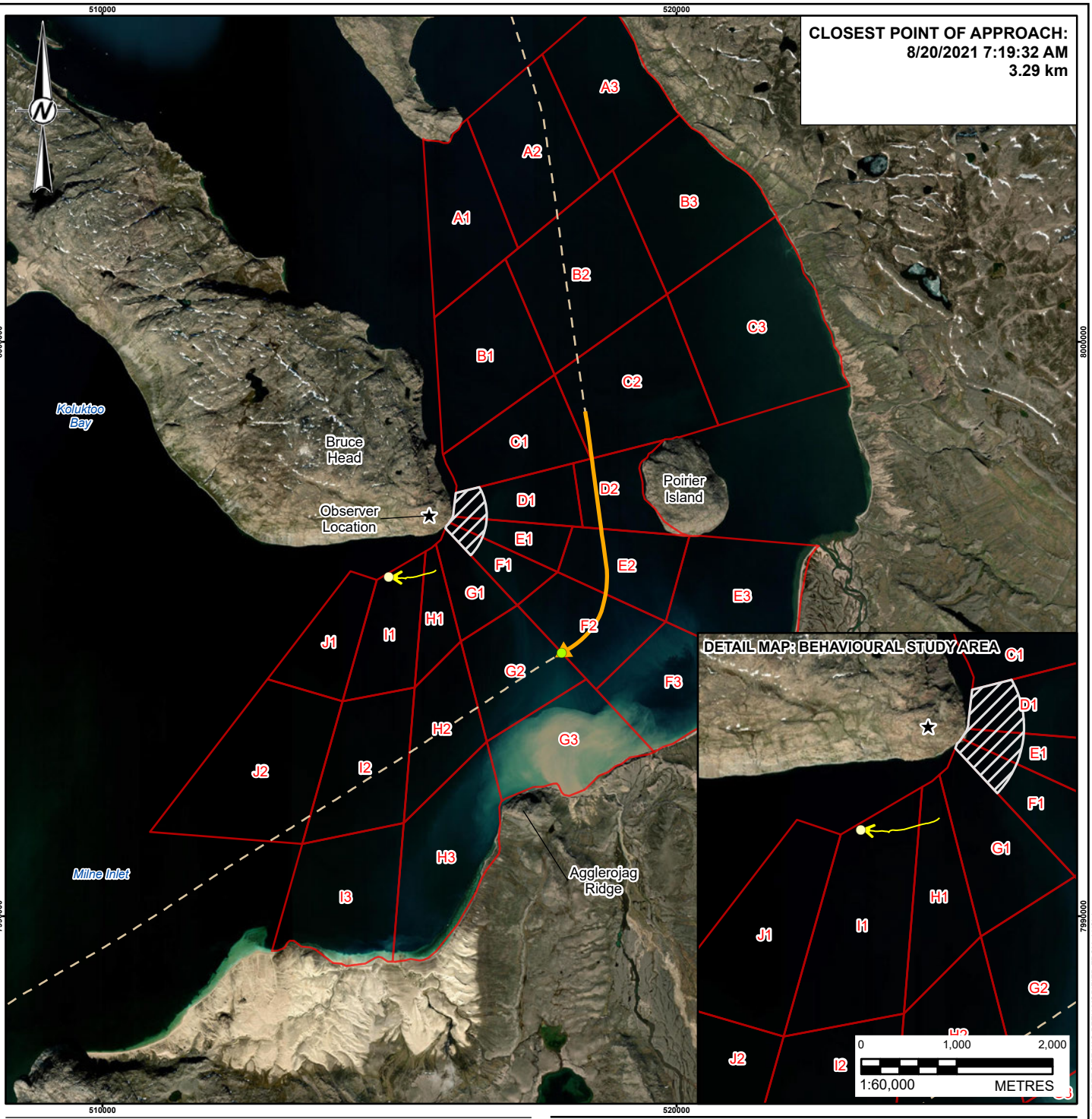


LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 141 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 141 (2021) AND ACTIVE VESSEL TRANSIT

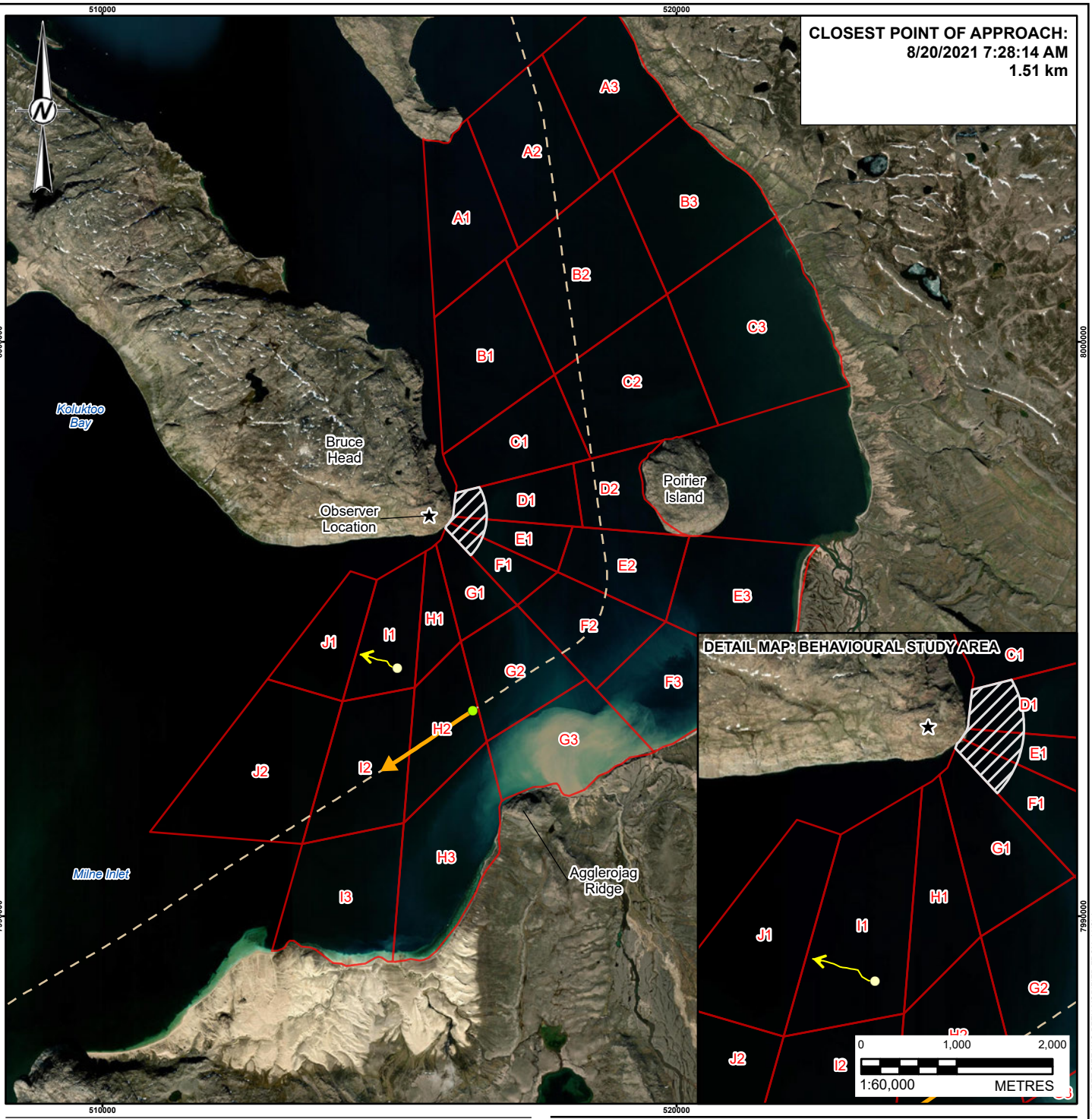
CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-40

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



LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 142 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 142 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-41

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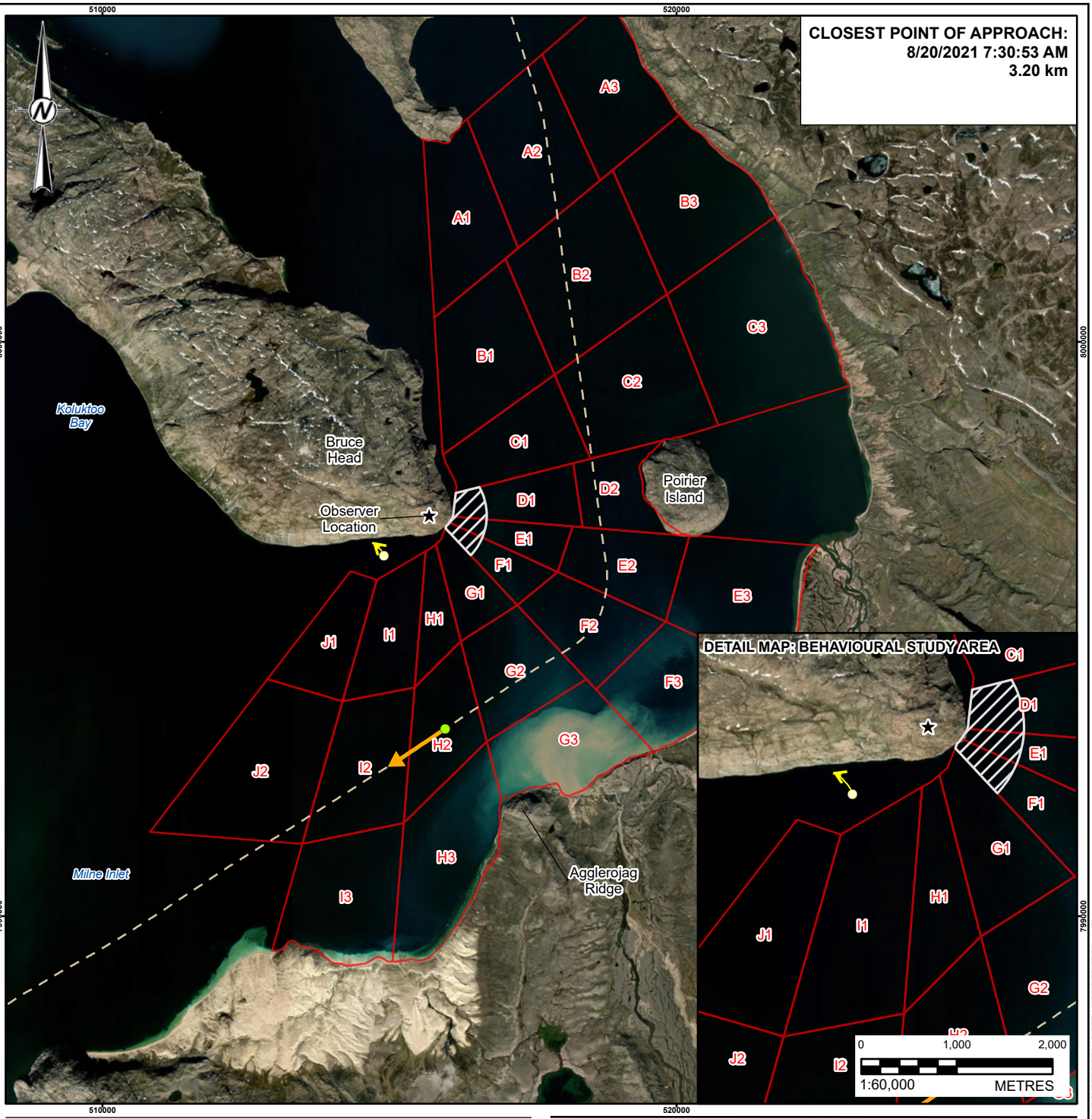

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 143 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 143 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-42

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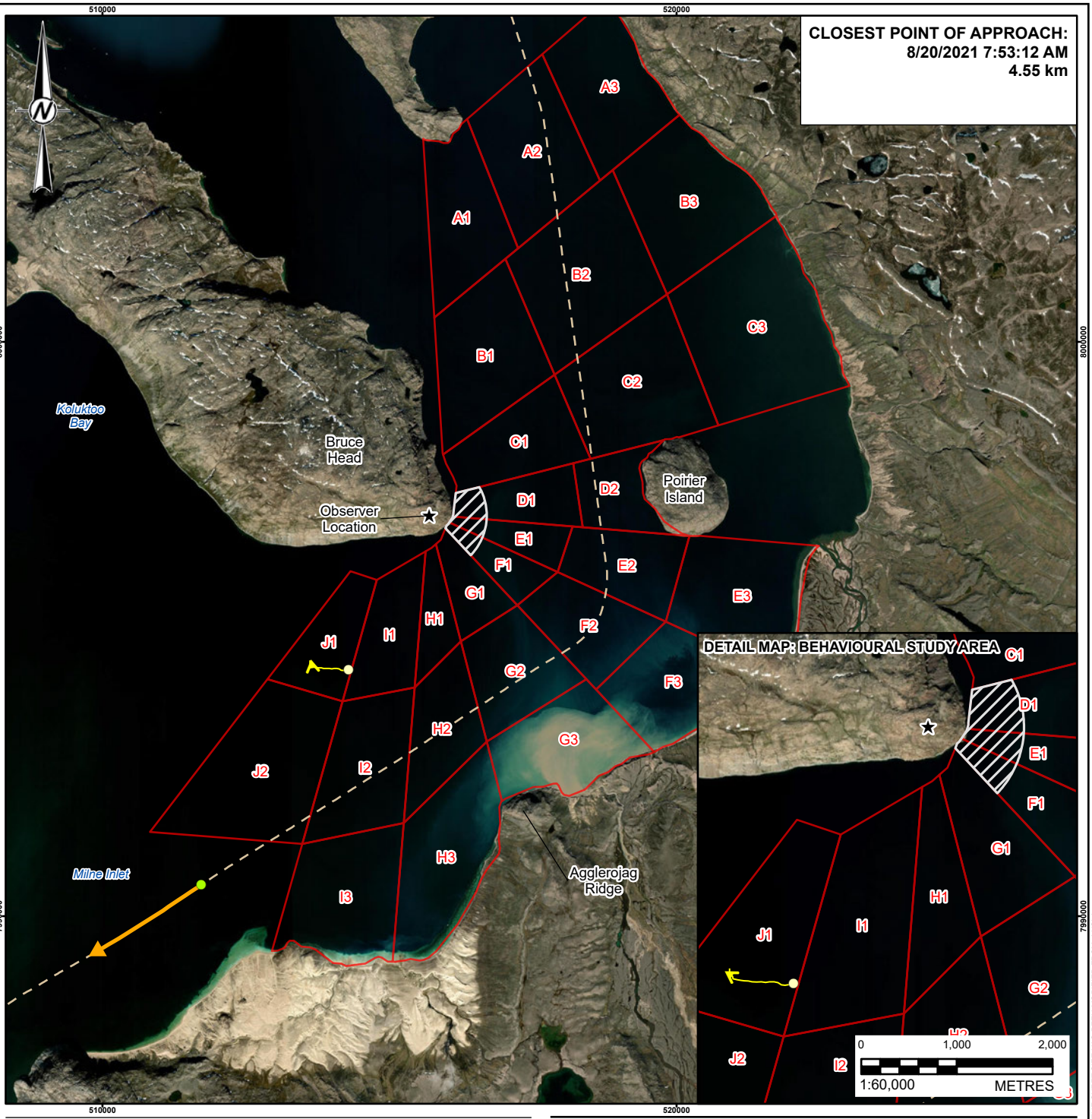

LEGEND

- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 144 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 144 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-43

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

25mm

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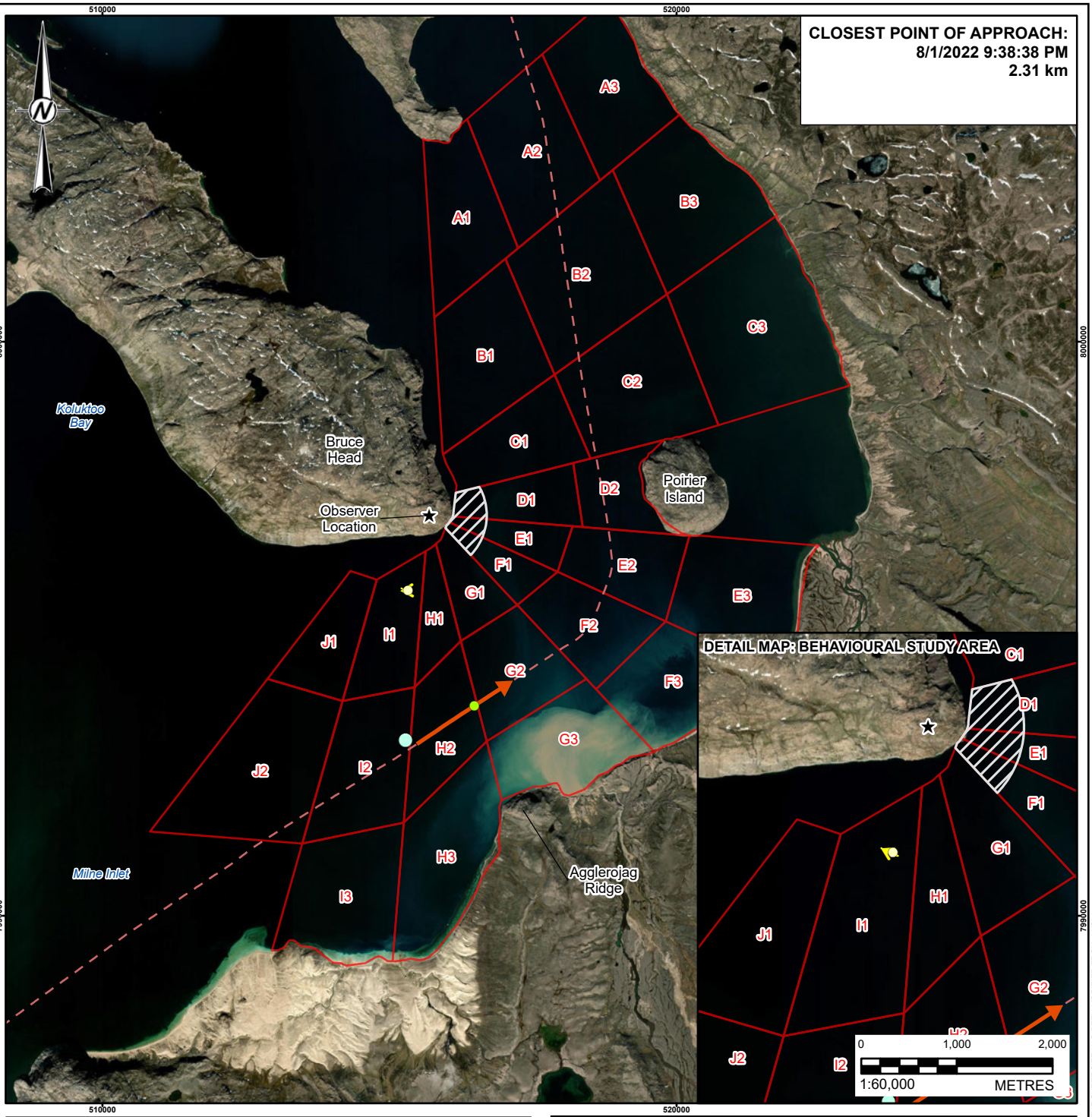

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 16 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 16 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-44

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

25mm

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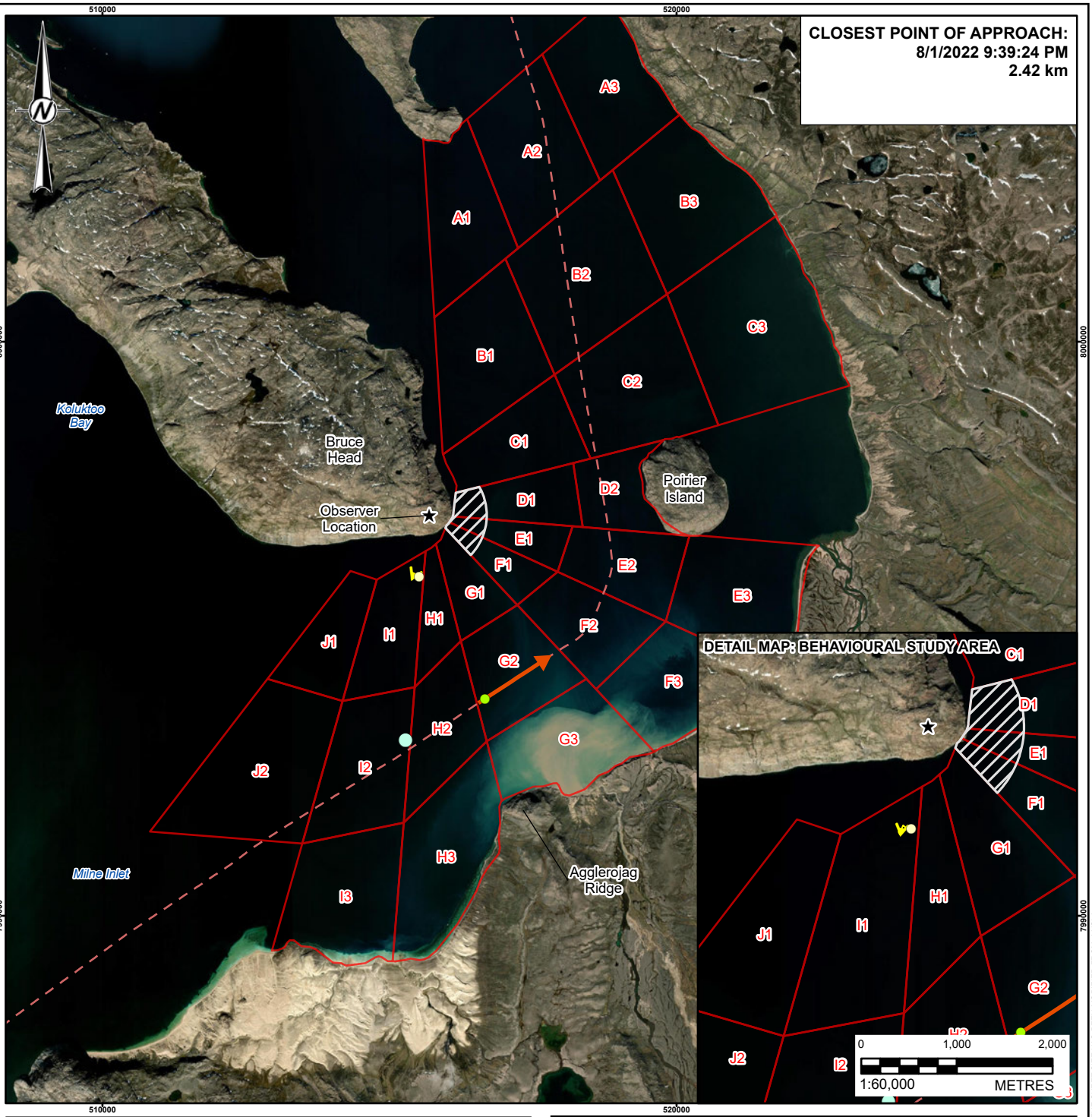

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 17 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 17 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-45

PATH: I:\2016\166372402\Mapping\MXD\75000_202403\Fig_75000_E-45_202403_FocalFollow_DNP_Rev0.mxd PRINTED ON: AT 2:08:13 PM
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25mm
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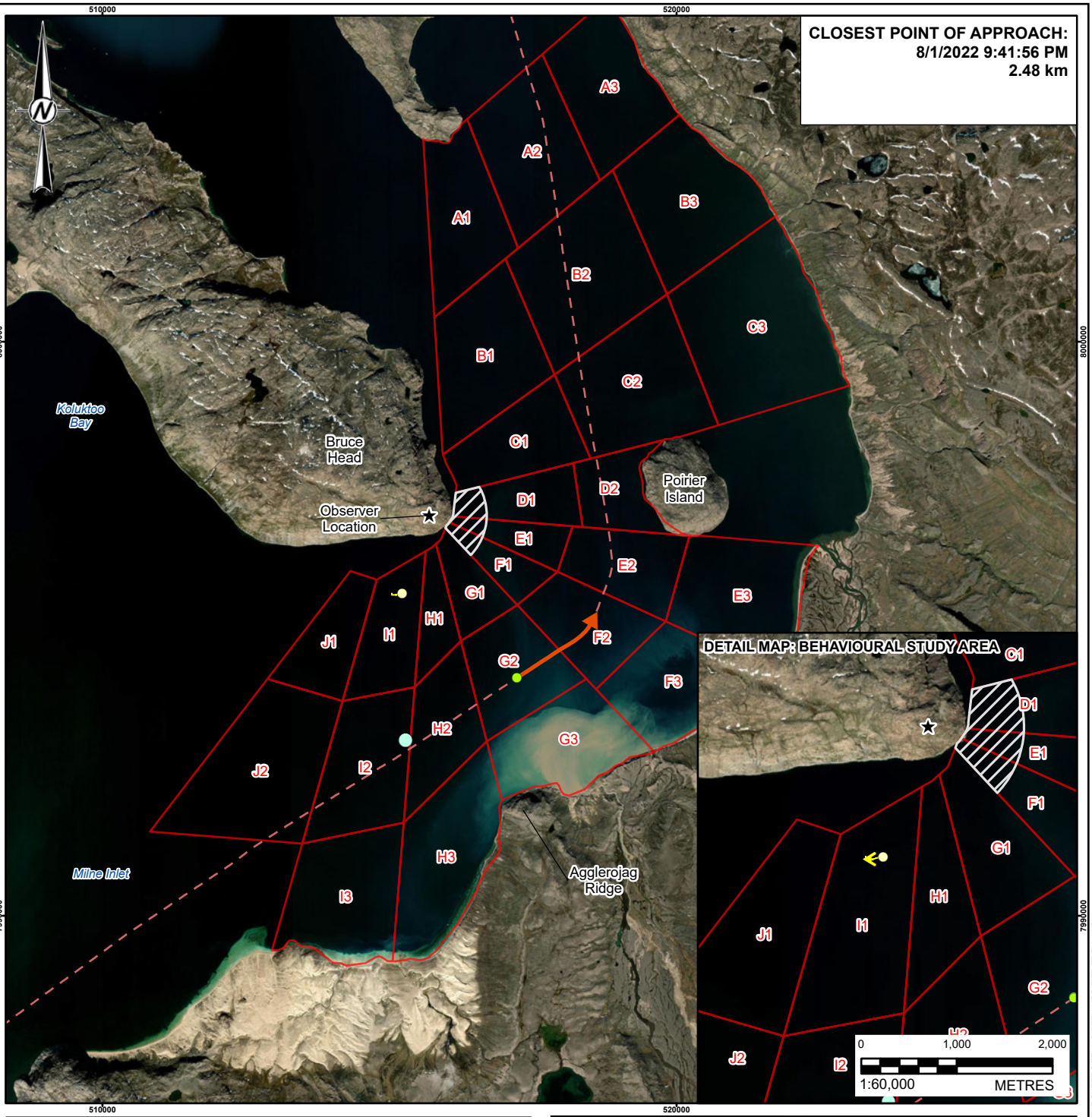

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 18 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 18 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-46

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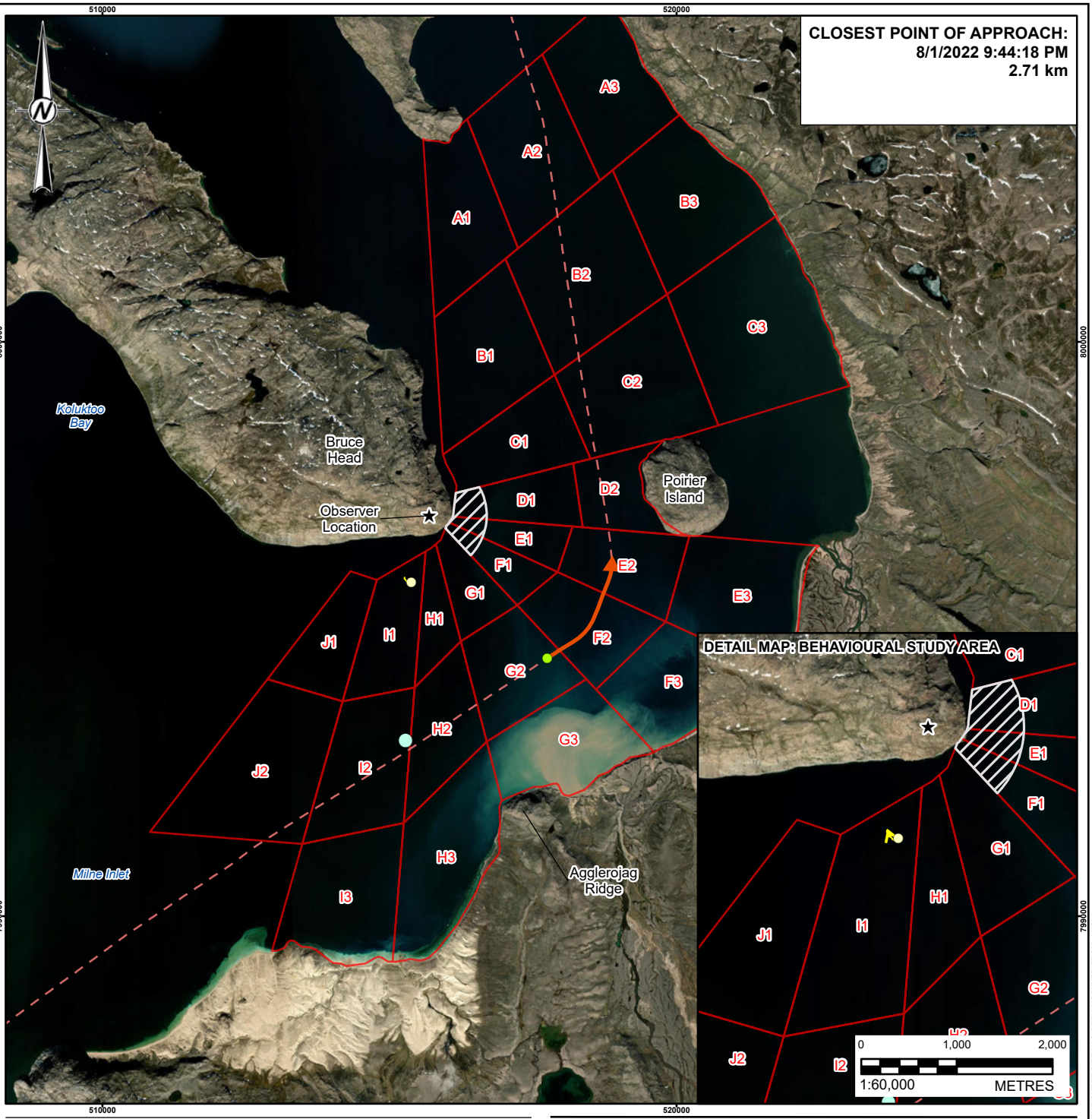

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 19 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 19 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-47

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

25mm

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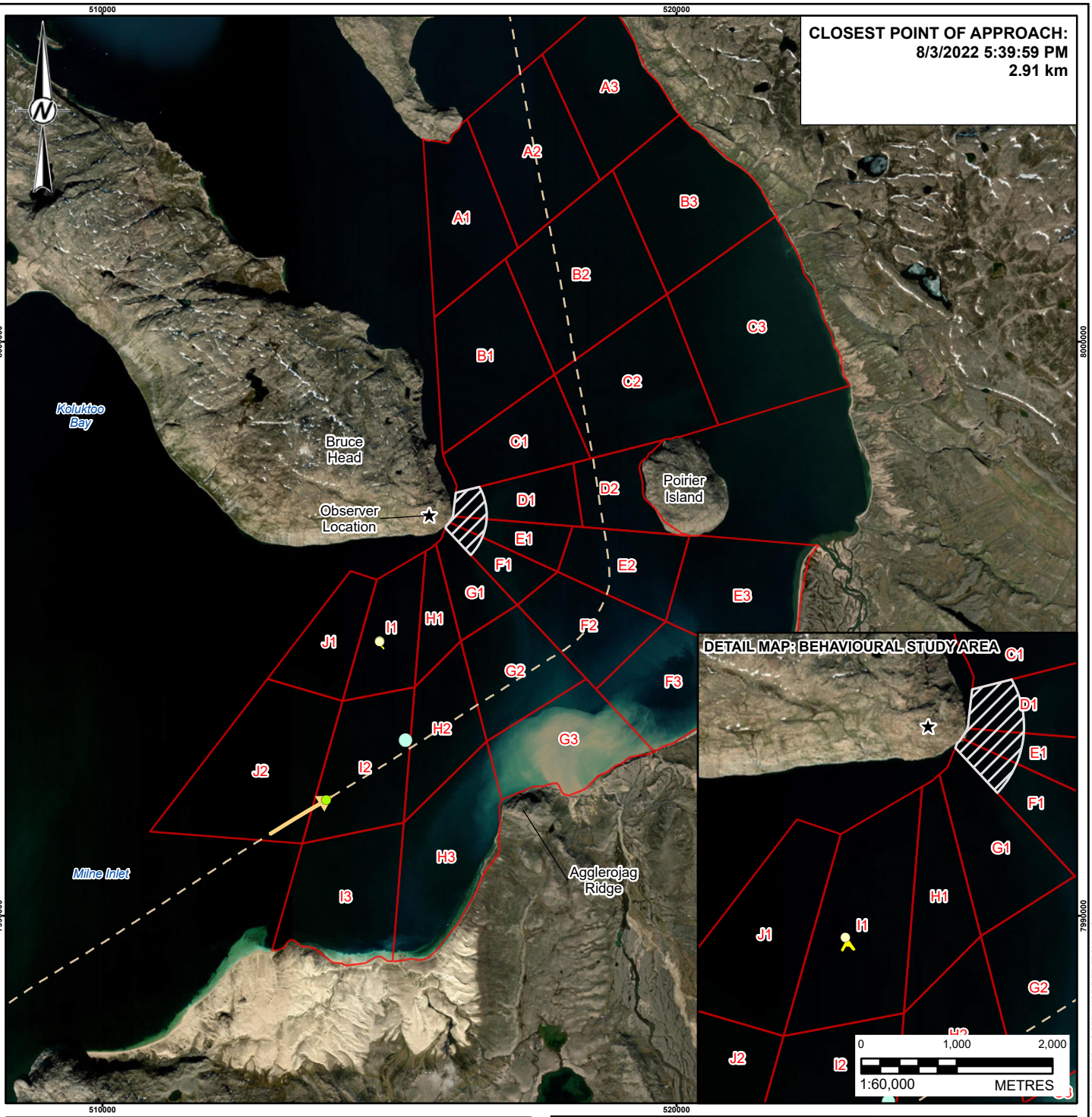

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 25 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC ODIN)
- NON-ACTIVE VESSEL TRANSIT (NORDIC ODIN)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 25 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-48

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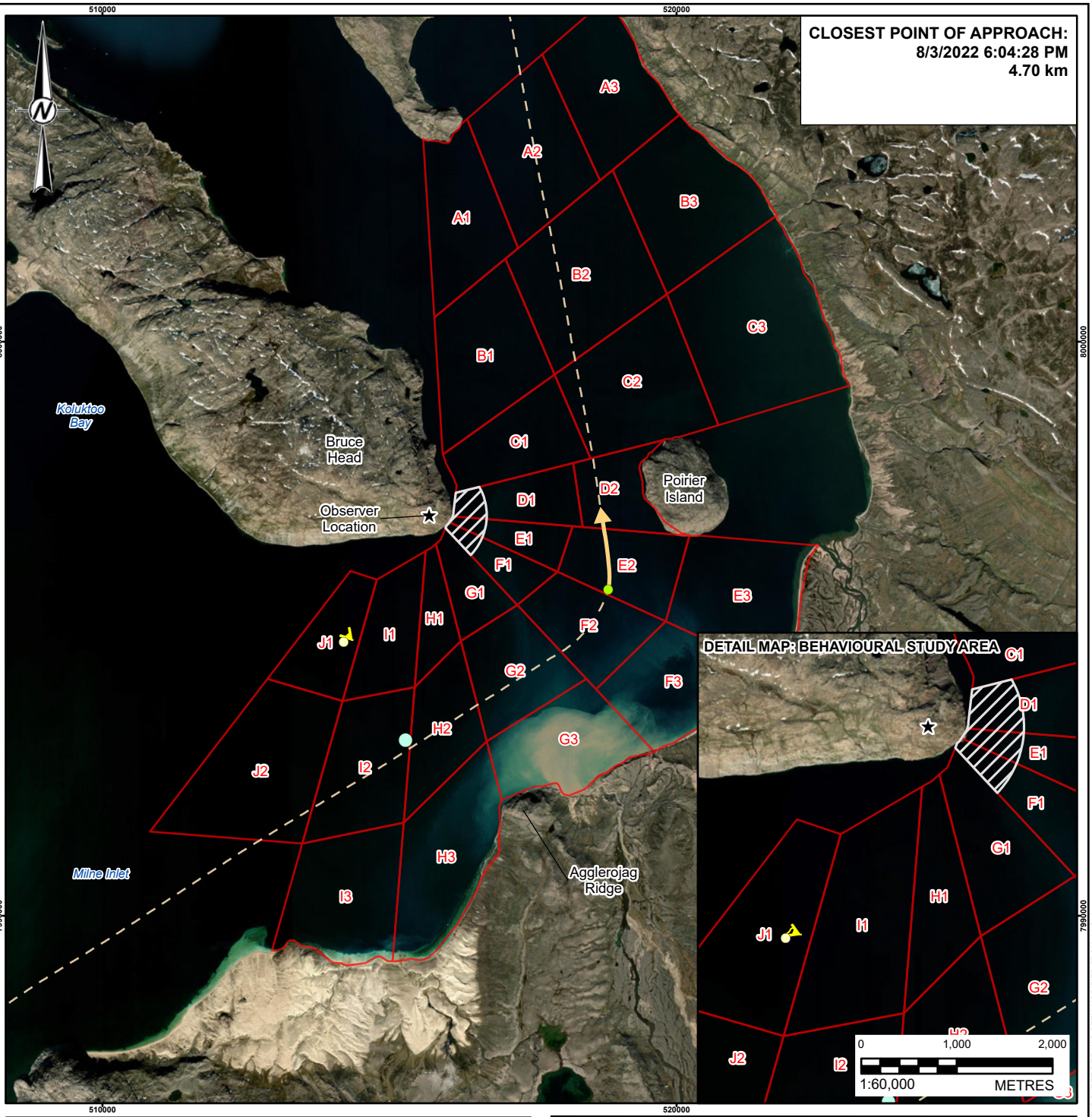


LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 26 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC ODIN)
- NON-ACTIVE VESSEL TRANSIT (NORDIC ODIN)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 26 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

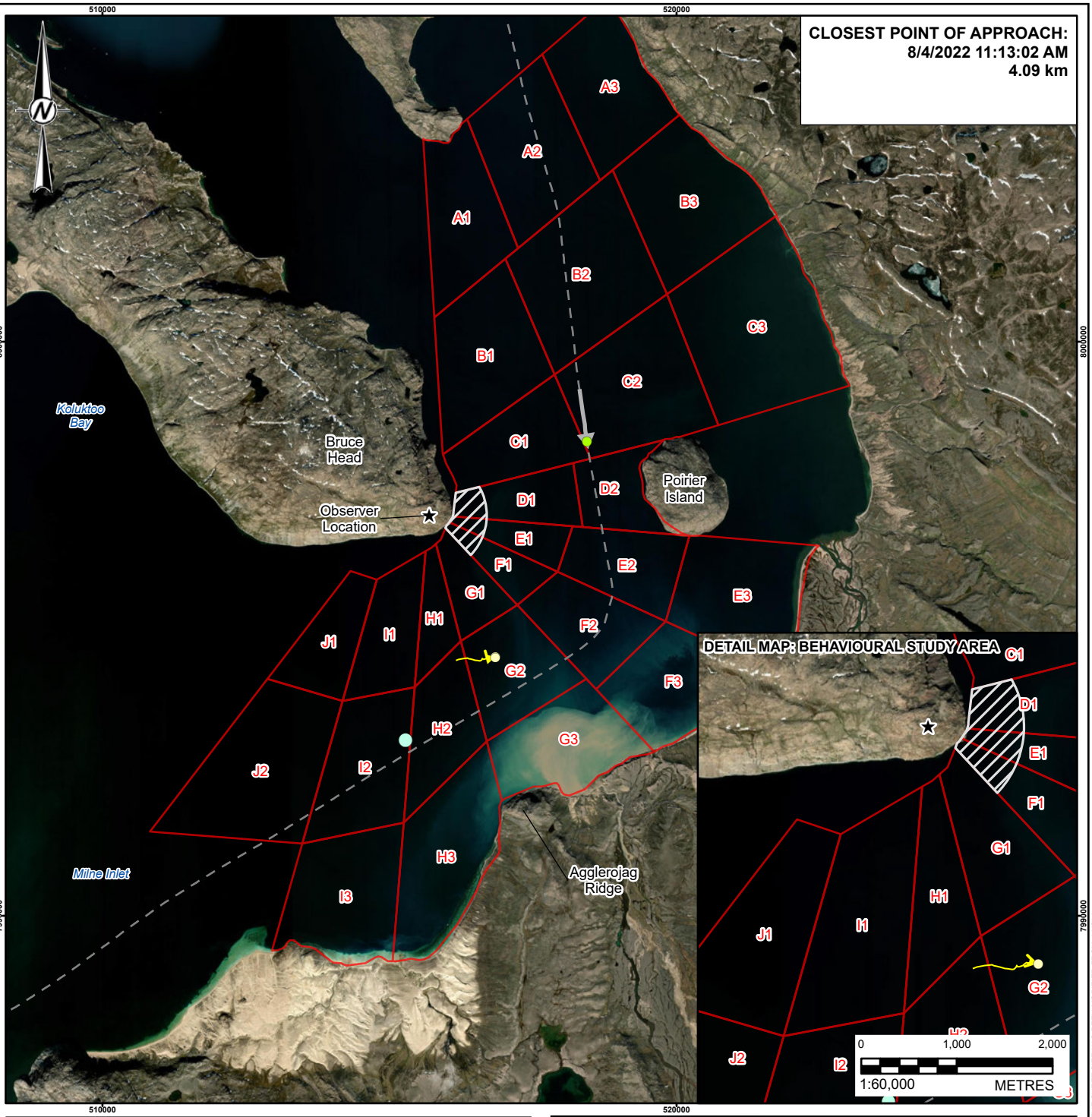
PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-49

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

25mm

0

PATH: I:\2016\166372\4\Mapping\MXD\75000_2023BruceHead\166372402_75000_FigE_44_87_2022FocalFollows_DDP_Rev0.aprx PRINTED ON: AT: 2:06:48 PM



LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 30 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 30 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-50

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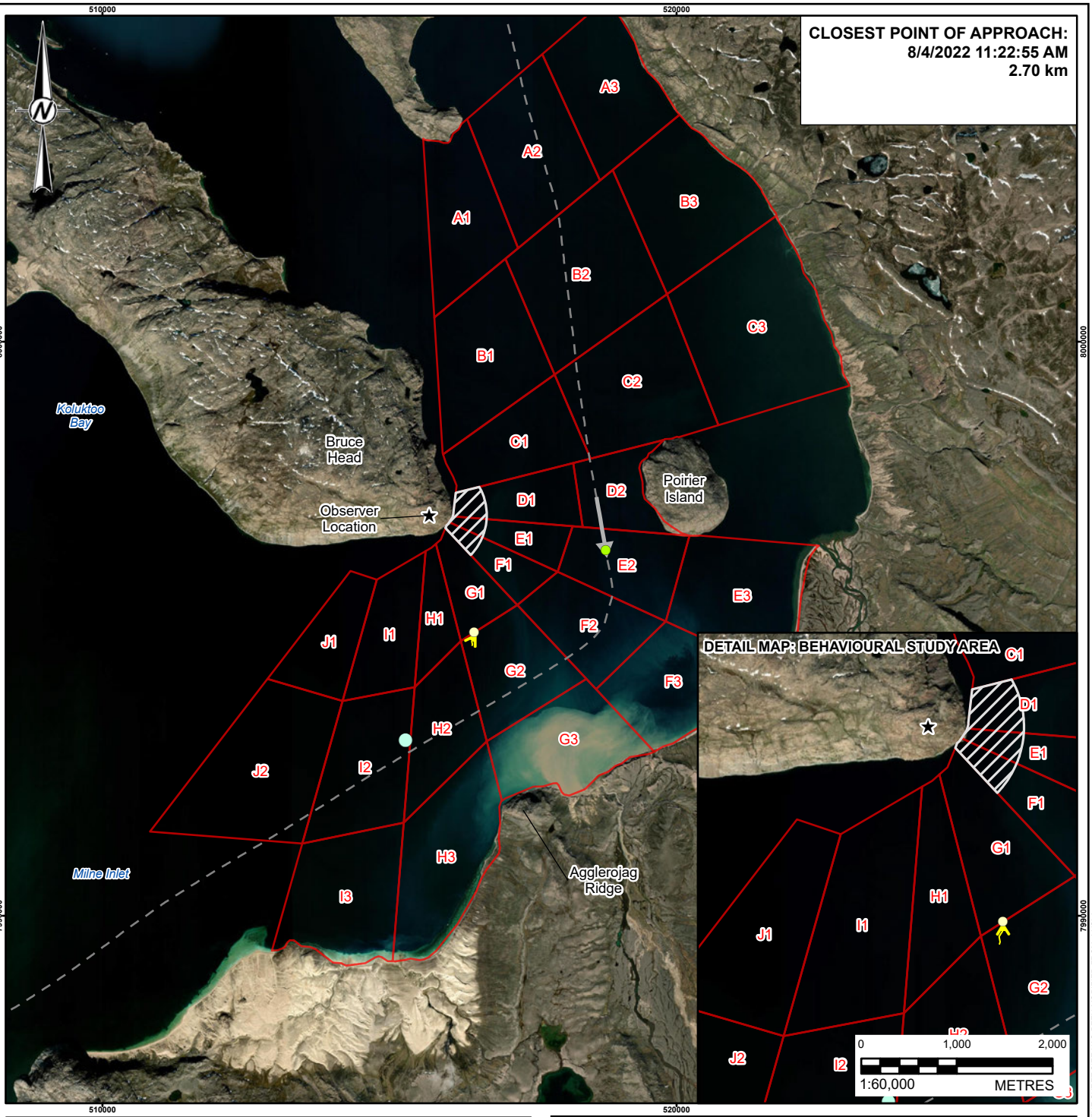

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 31 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 31 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-51

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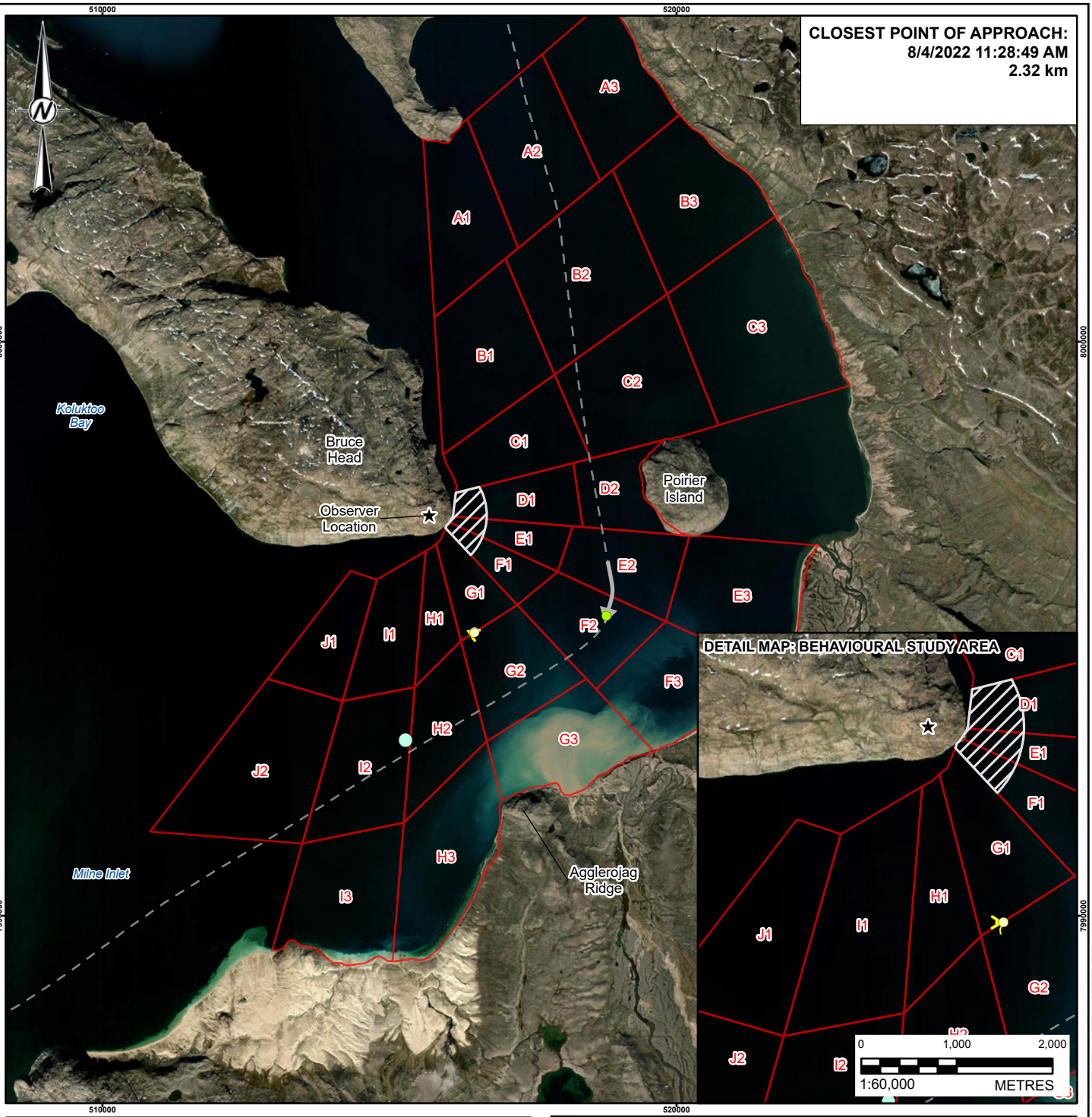

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 32 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 32 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-52

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

25mm

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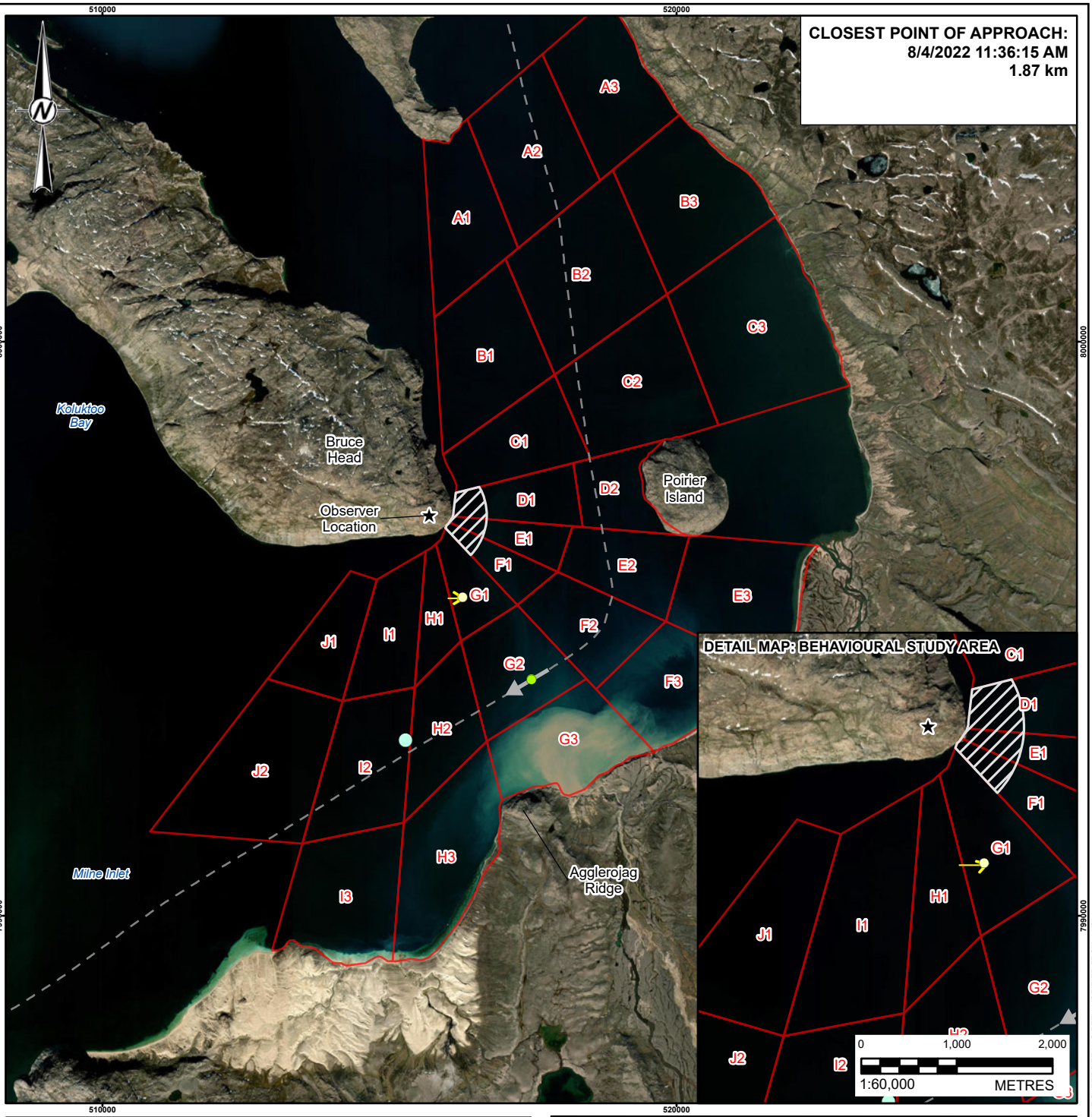
PATH: I:\2016\166372\4\Mapping\MXD\75000_2023BruceHead\166372402_75000_FigE_44_87_2022FocalFollows_DDP_Rev0.aprx PRINTED ON: AT: 2:07:10 PM



LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 33 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 33 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-53

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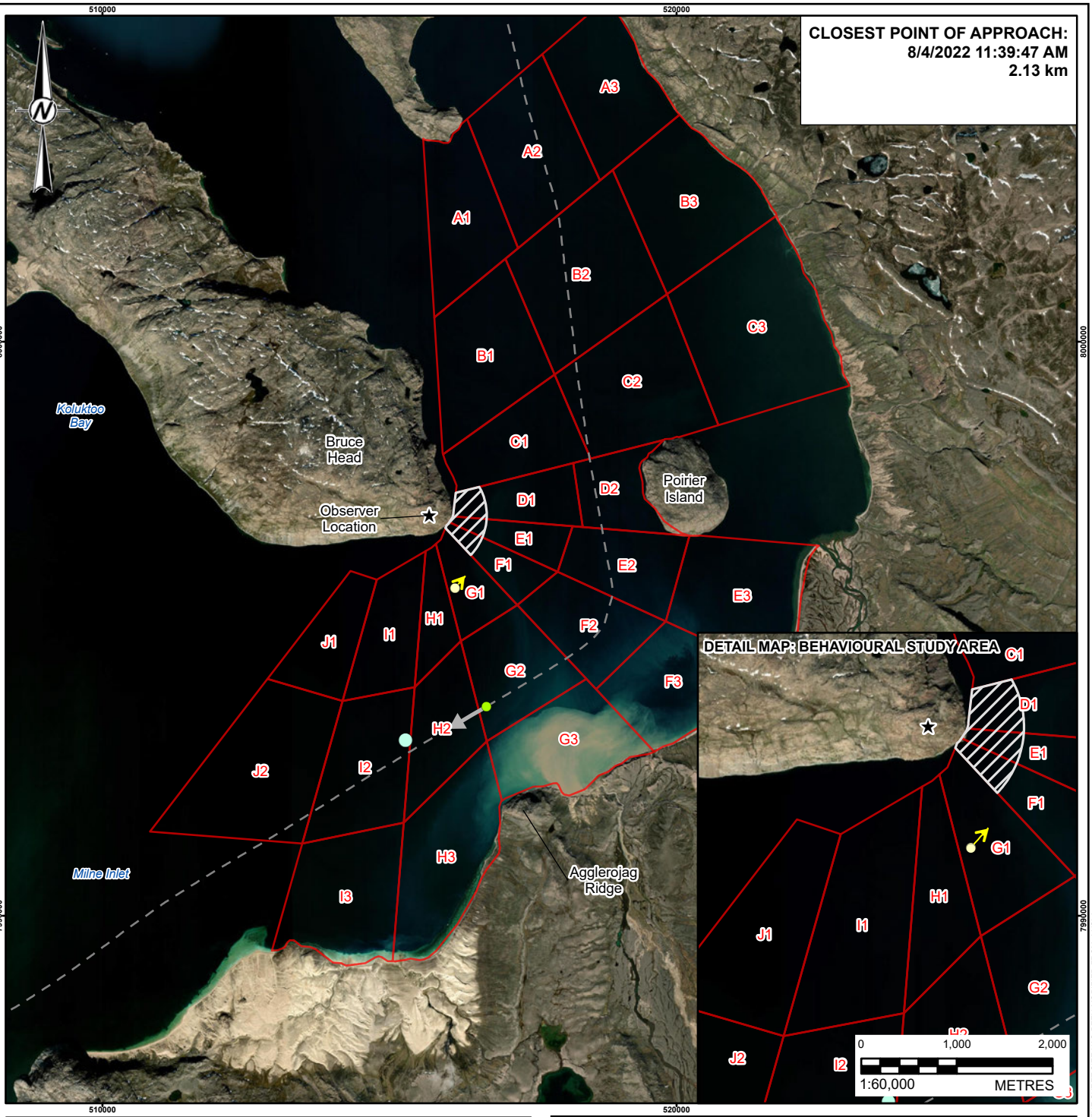

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 34 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 34 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-54

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

25mm

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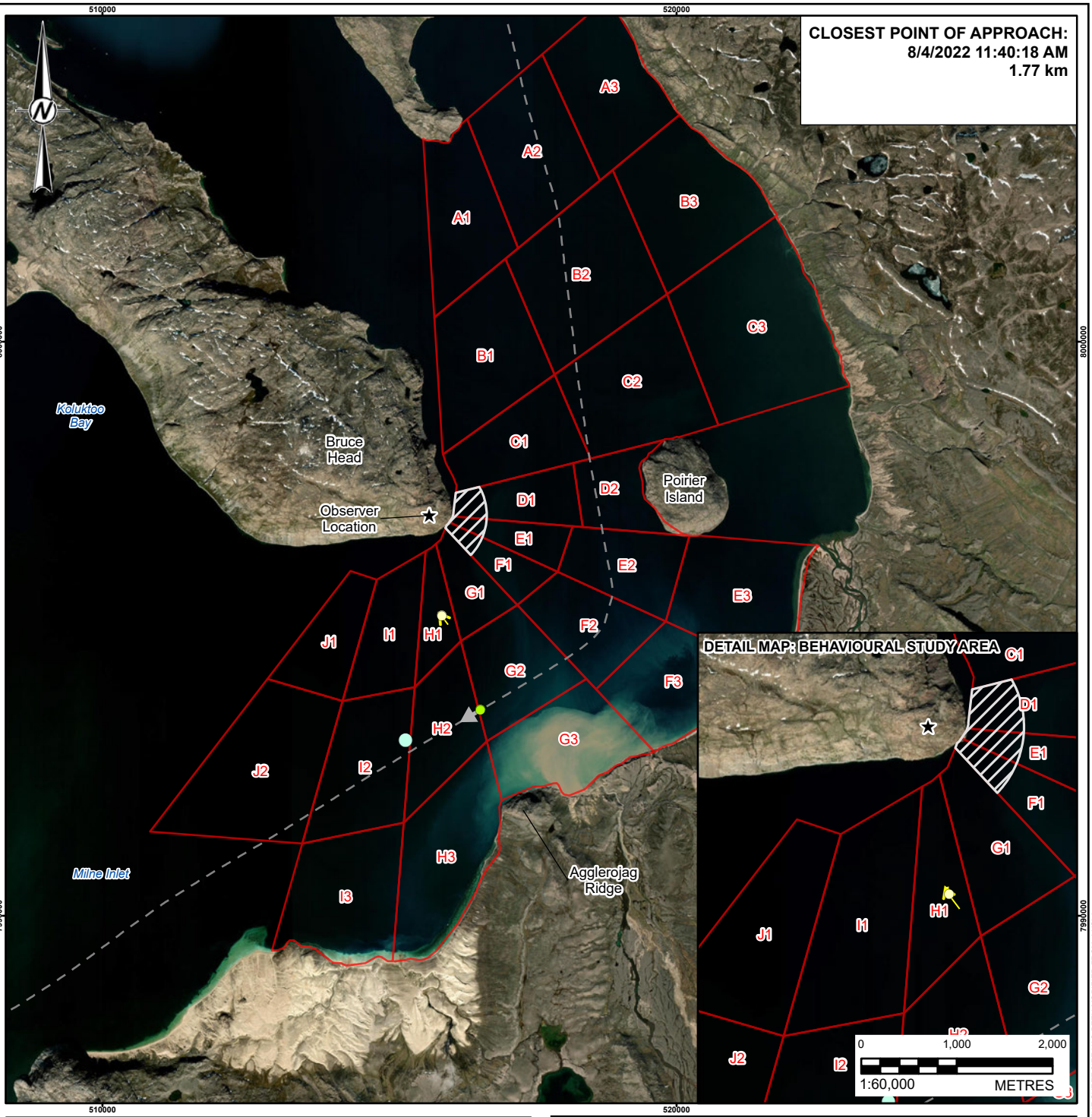

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 35 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 35 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-55

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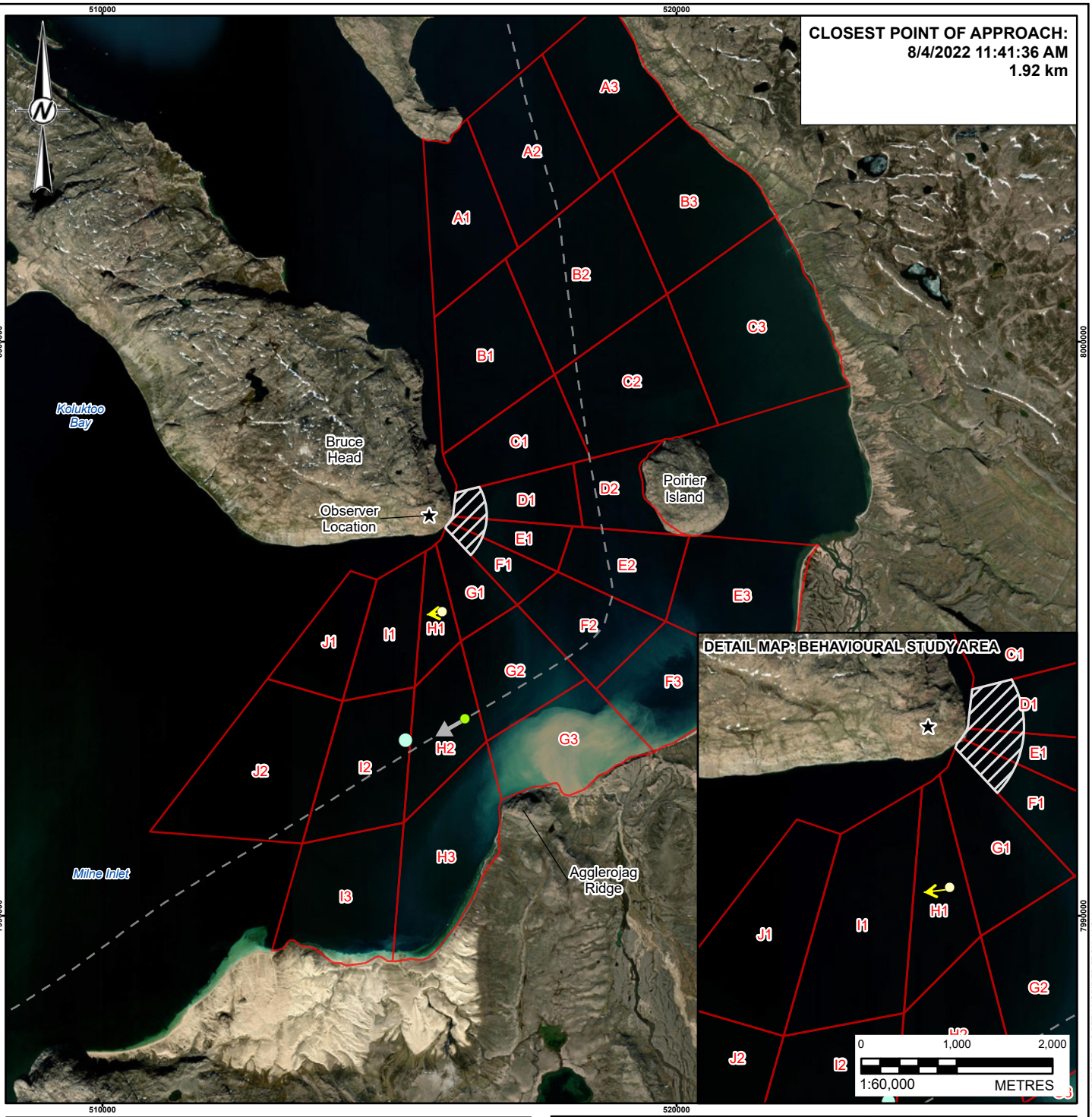


LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 36 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 36 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

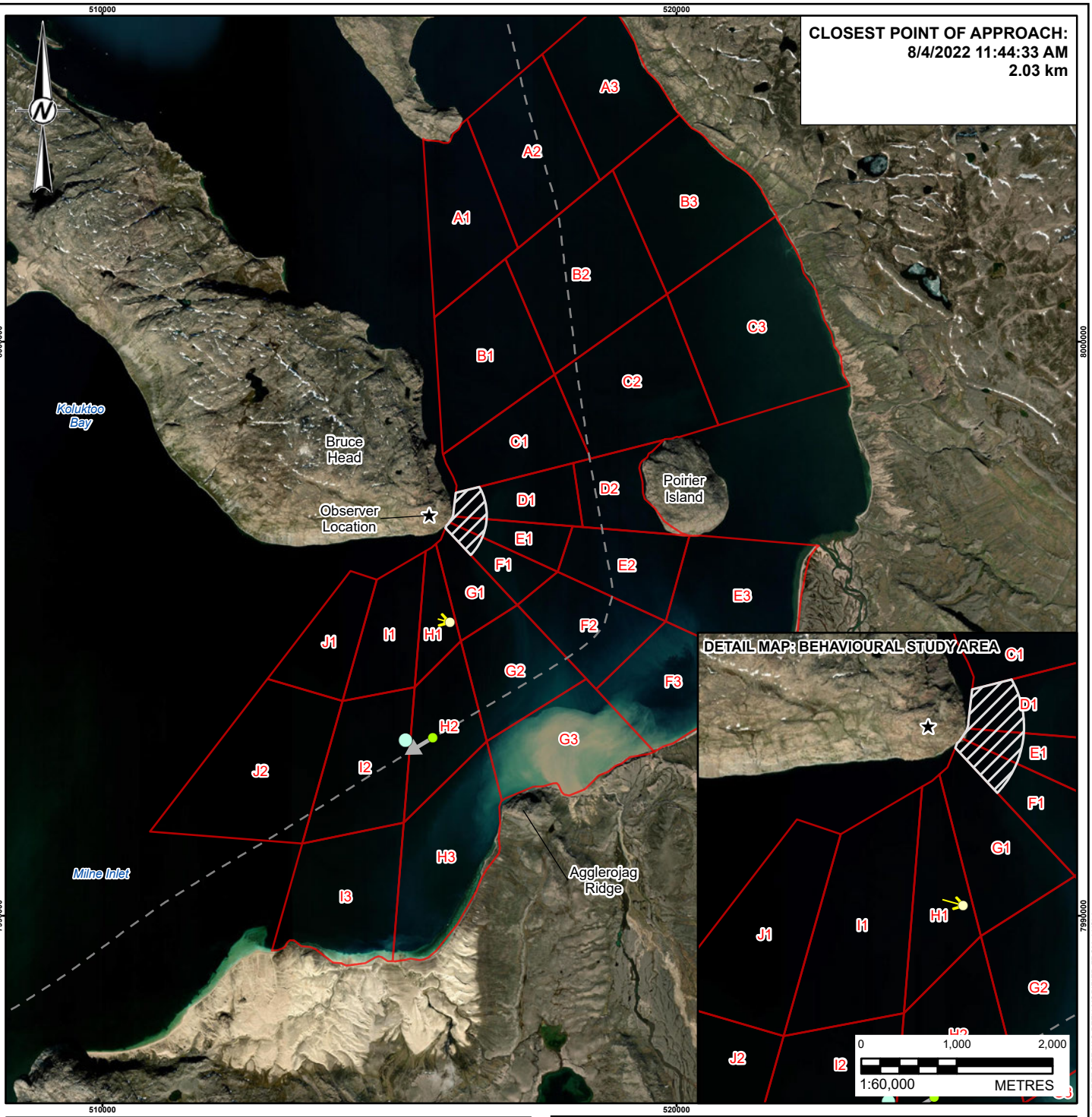
PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-56

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

25mm

0

PATH: I:\2016\166372\4\Mapping\MXD\75000_2023BruceHead\166372402_75000_FigE_44_87_2022FocalFollows_DDP_Rev0.aprx PRINTED ON: AT: 2:07:49 PM



LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 37 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ICE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 37 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

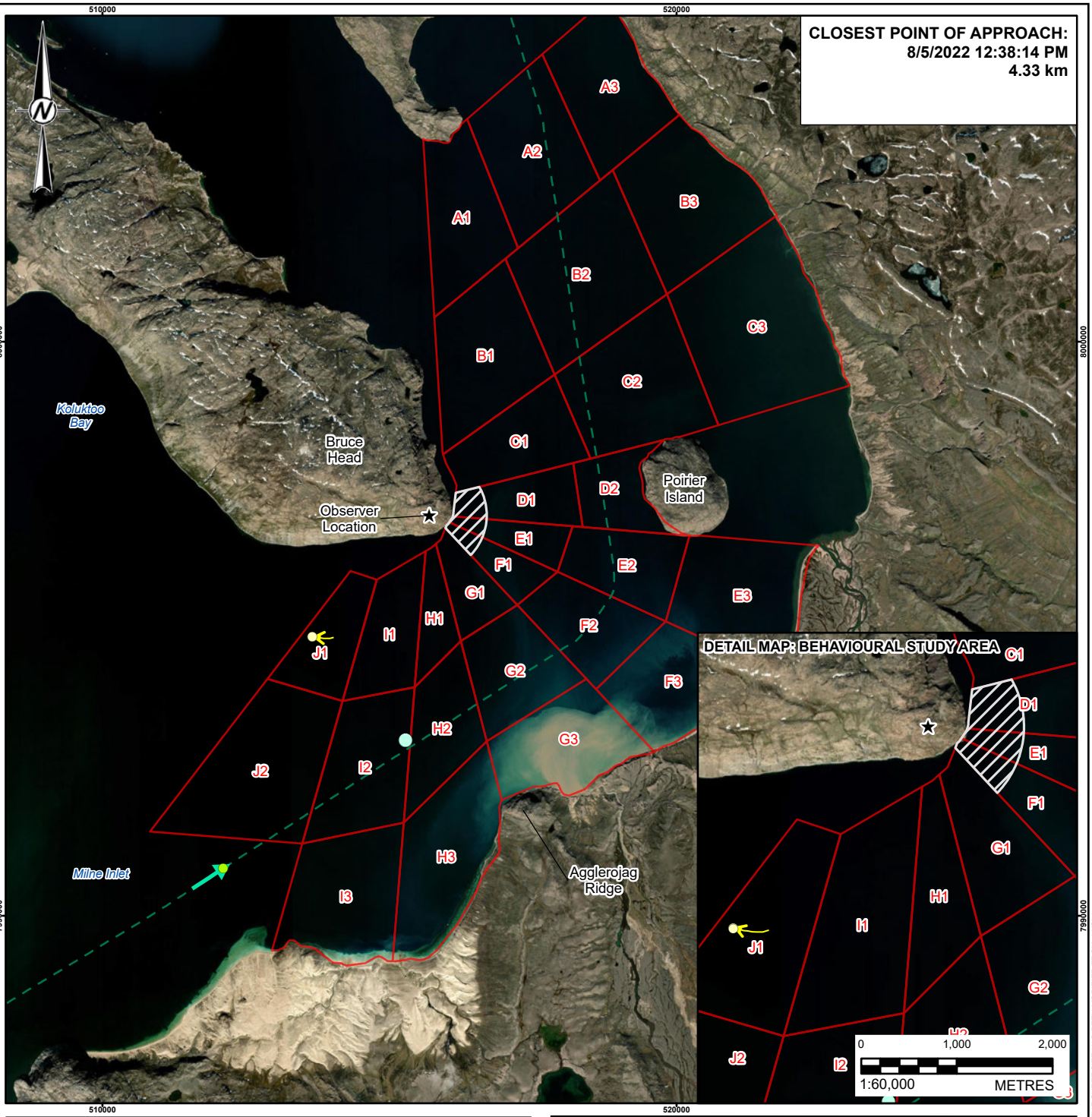
PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-57

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

25mm

0

PATH: I:\2016\166372\4\Mapping\MXD\75000_2023BruceHead\166372402_75000_FigE_44_87_2022FocalFollows_DDP_Rev0.aprx PRINTED ON: AT: 2:07:57 PM



LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 54 (2022)
- ACTIVE VESSEL TRANSIT (ARKADIA)
- NON-ACTIVE VESSEL TRANSIT (ARKADIA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 54 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-58

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

25mm

0

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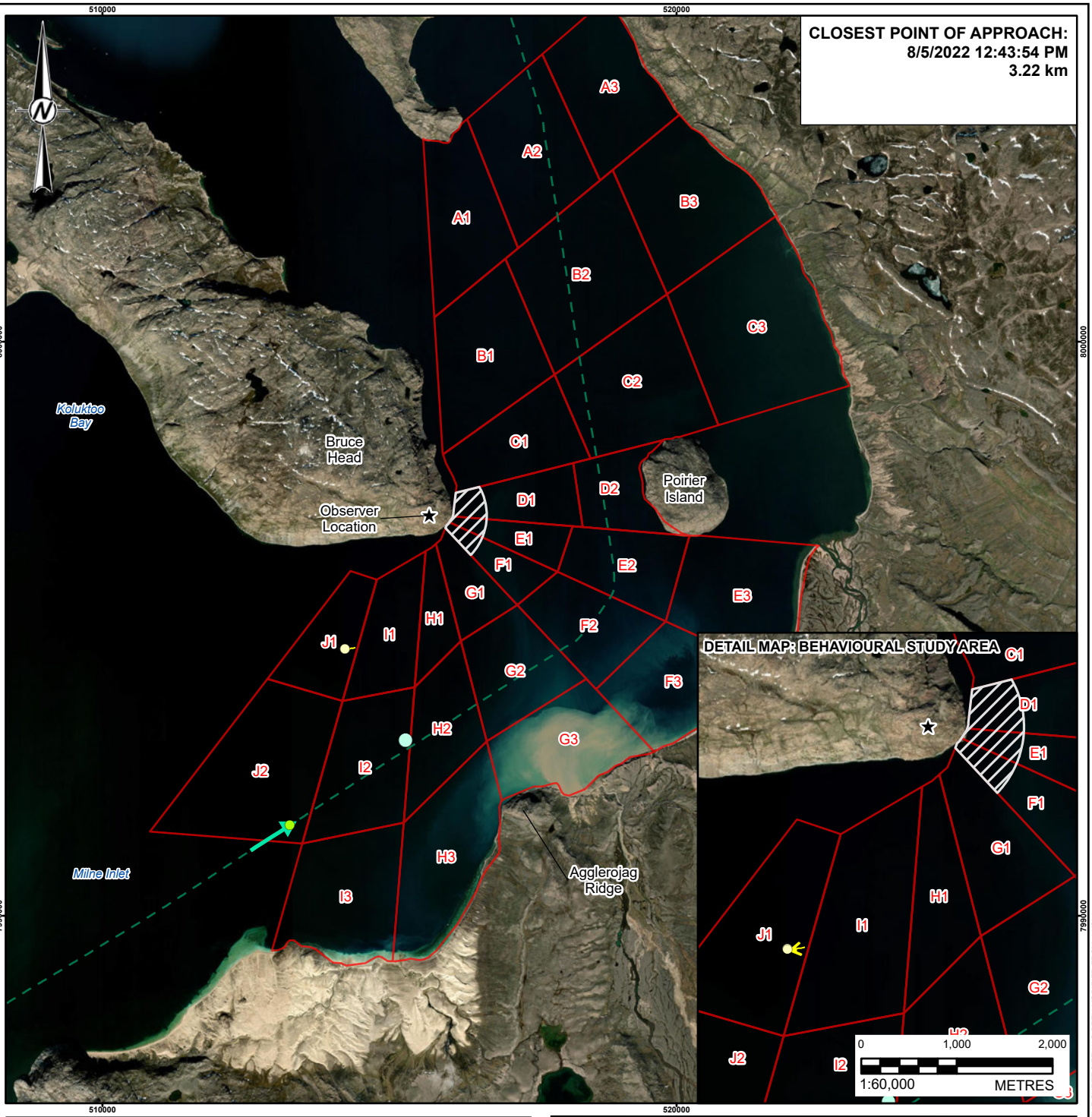

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 55 (2022)
- ACTIVE VESSEL TRANSIT (ARKADIA)
- NON-ACTIVE VESSEL TRANSIT (ARKADIA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 55 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-59

PATH: I:\2016\166372402\Mapping\MXD\75000_202403\Fig E-59 Focal Follow 55 2022 and Active Vessel Transit.mxd PRINTED ON: AT 2:08:12 PM
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25mm
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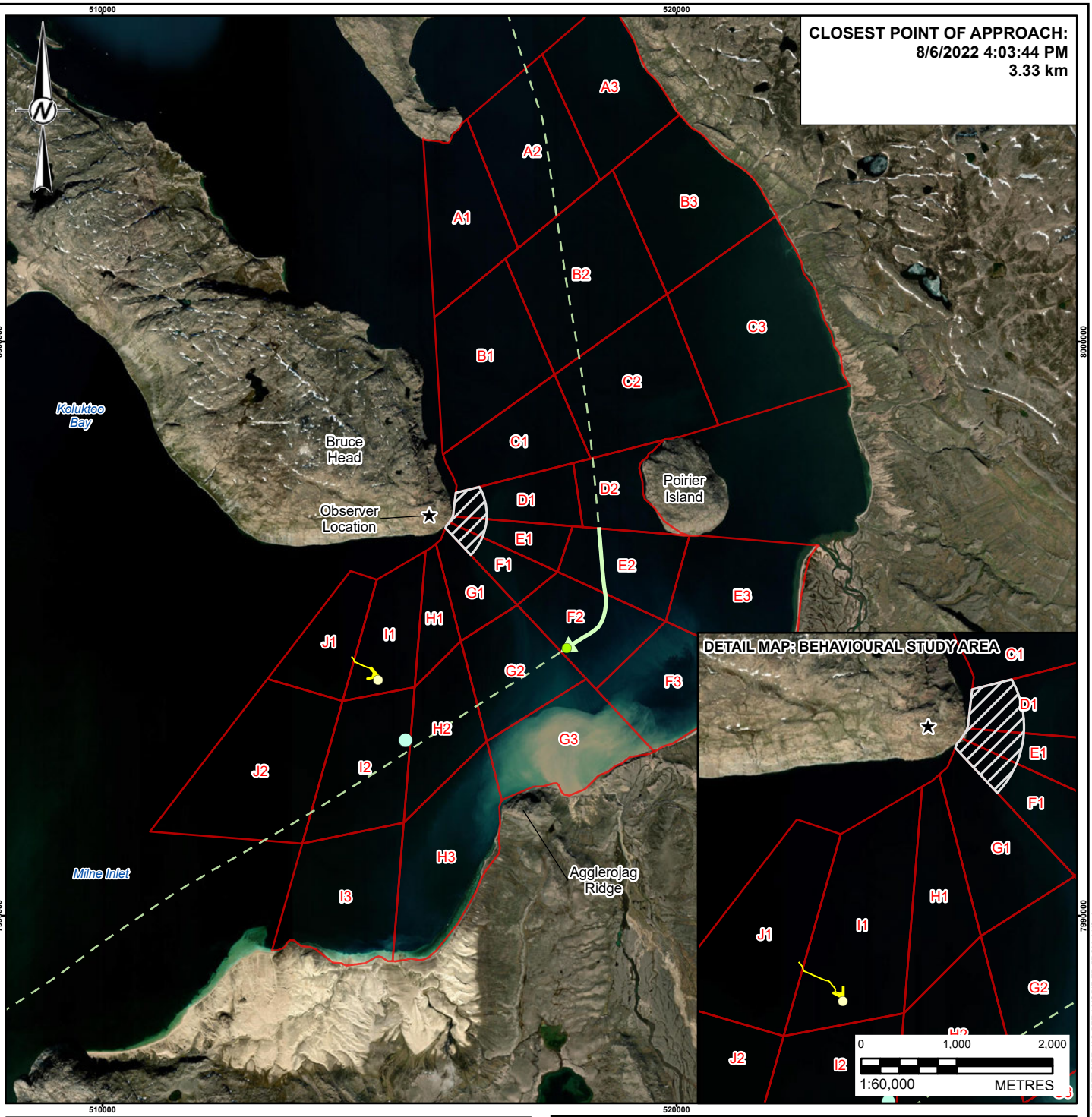

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 63 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC QINNGUA)
- NON-ACTIVE VESSEL TRANSIT (NORDIC QINNGUA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 63 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-60

PATH: I:\2016\166372402\Mapping\MXD\75000_202403\Fig166372402_75000_E-60_44_87_2024FocalFollows_DNP_Rev0.mxd PRINTED ON: AT 2:08:22 PM
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25mm
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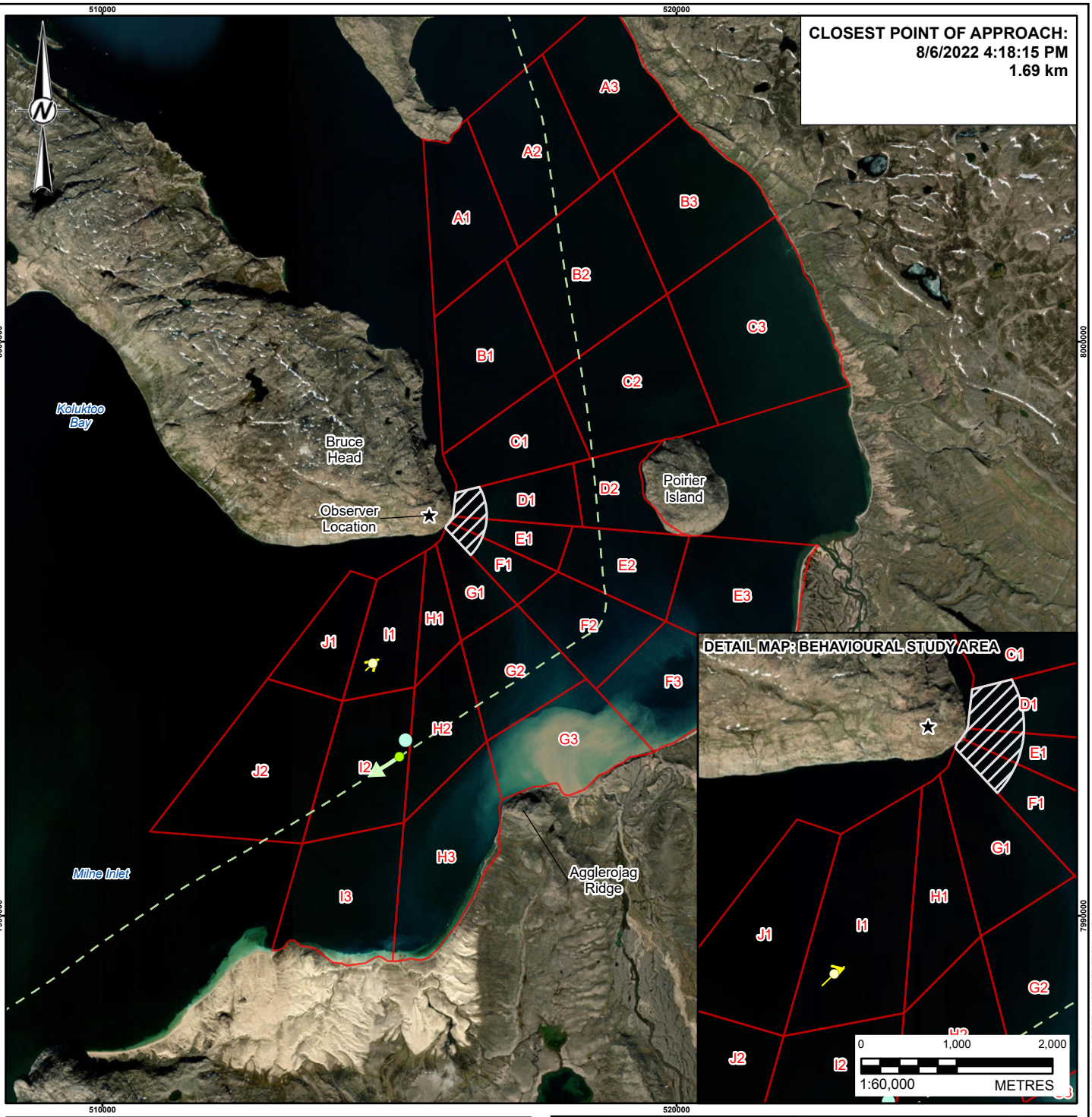


LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 64 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC QINNGUA)
- NON-ACTIVE VESSEL TRANSIT (NORDIC QINNGUA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 64 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

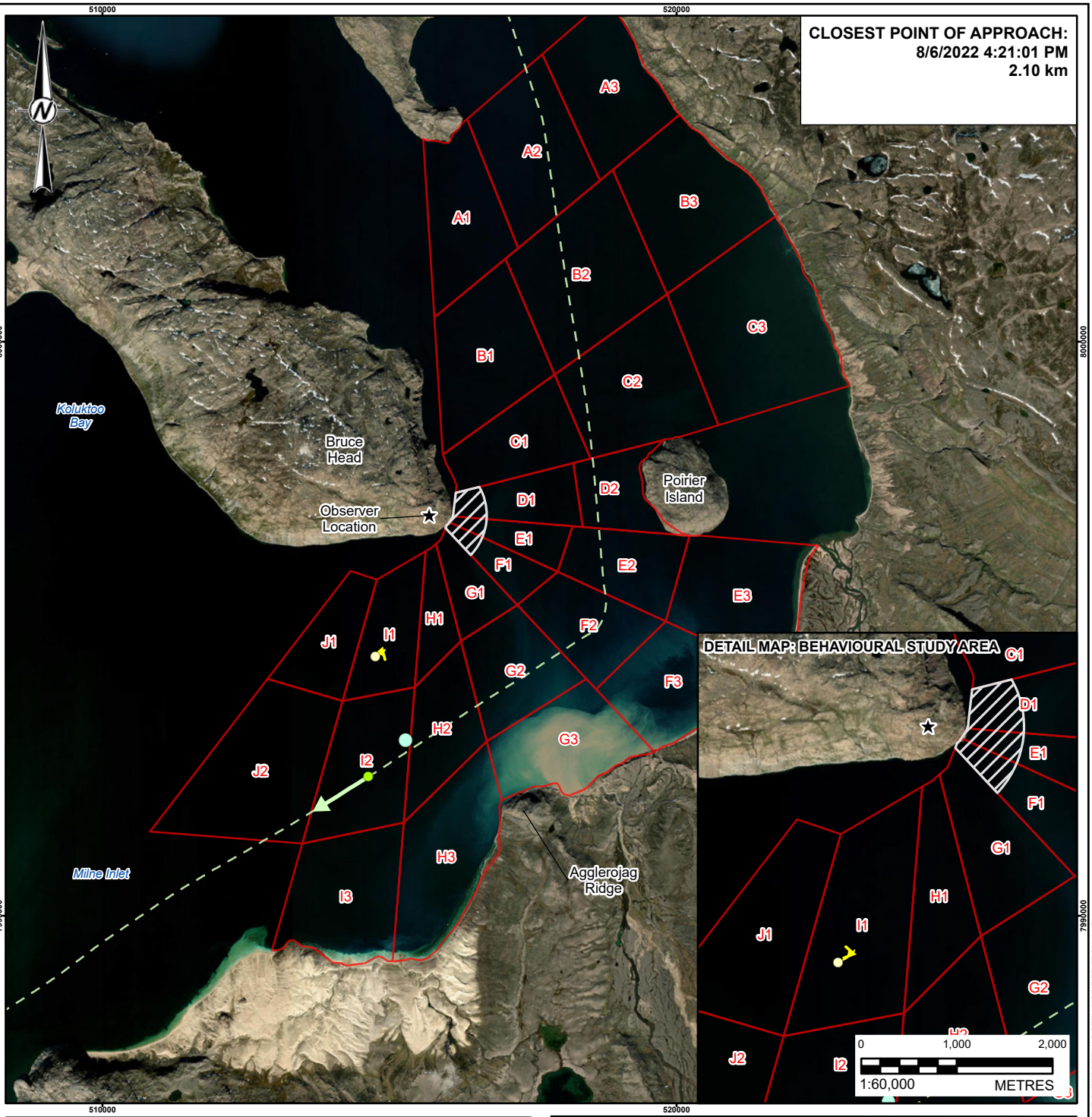
PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-61

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

25mm

0

PATH: I:\2016\166372\4\Mapping\MXD\75000_2023BruceHead\166372402_75000_FigE_44_87_2022FocalFollows_DDP_Rev0.aprx PRINTED ON: AT: 2:08:30 PM



LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 65 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC QINNGUA)
- NON-ACTIVE VESSEL TRANSIT (NORDIC QINNGUA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 65 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-62

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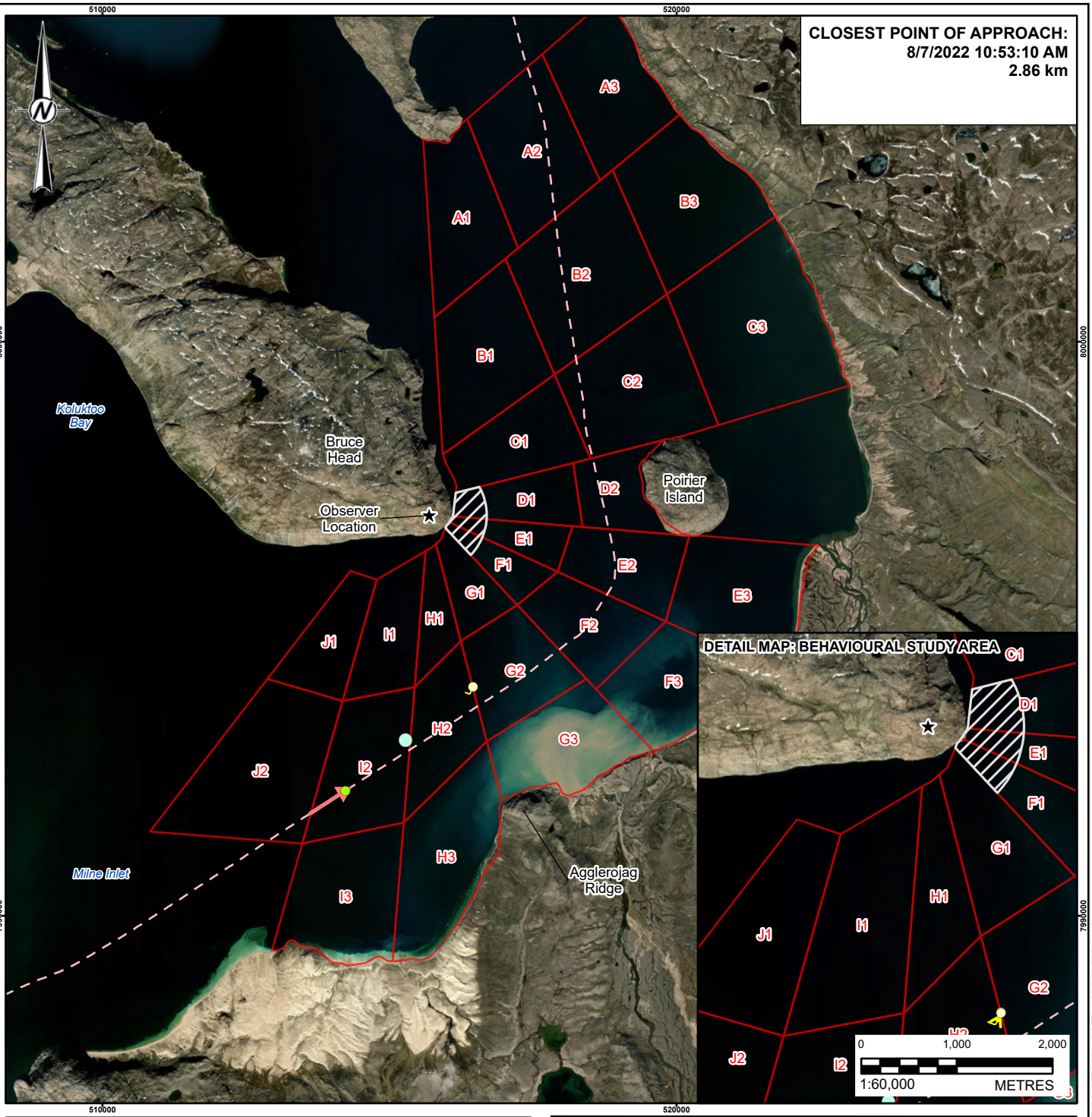

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 70 (2022)
- ACTIVE VESSEL TRANSIT (M.V.GOLDEN BRILLIANT)
- NON-ACTIVE VESSEL TRANSIT (M.V.GOLDEN BRILLIANT)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 70 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-63

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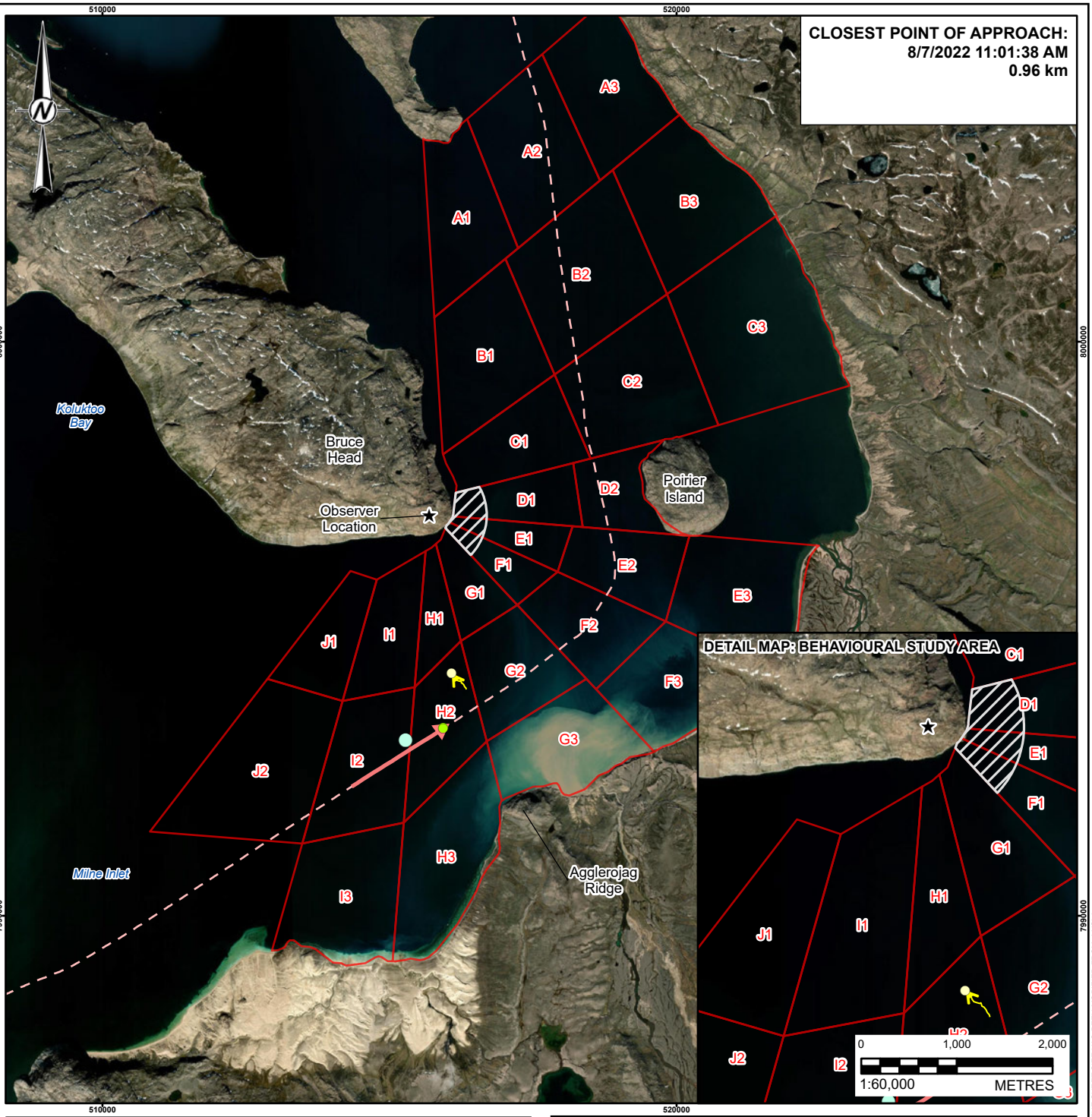

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 71 (2022)
- ACTIVE VESSEL TRANSIT (M.V.GOLDEN BRILLIANT)
- NON-ACTIVE VESSEL TRANSIT (M.V.GOLDEN BRILLIANT)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 71 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-64

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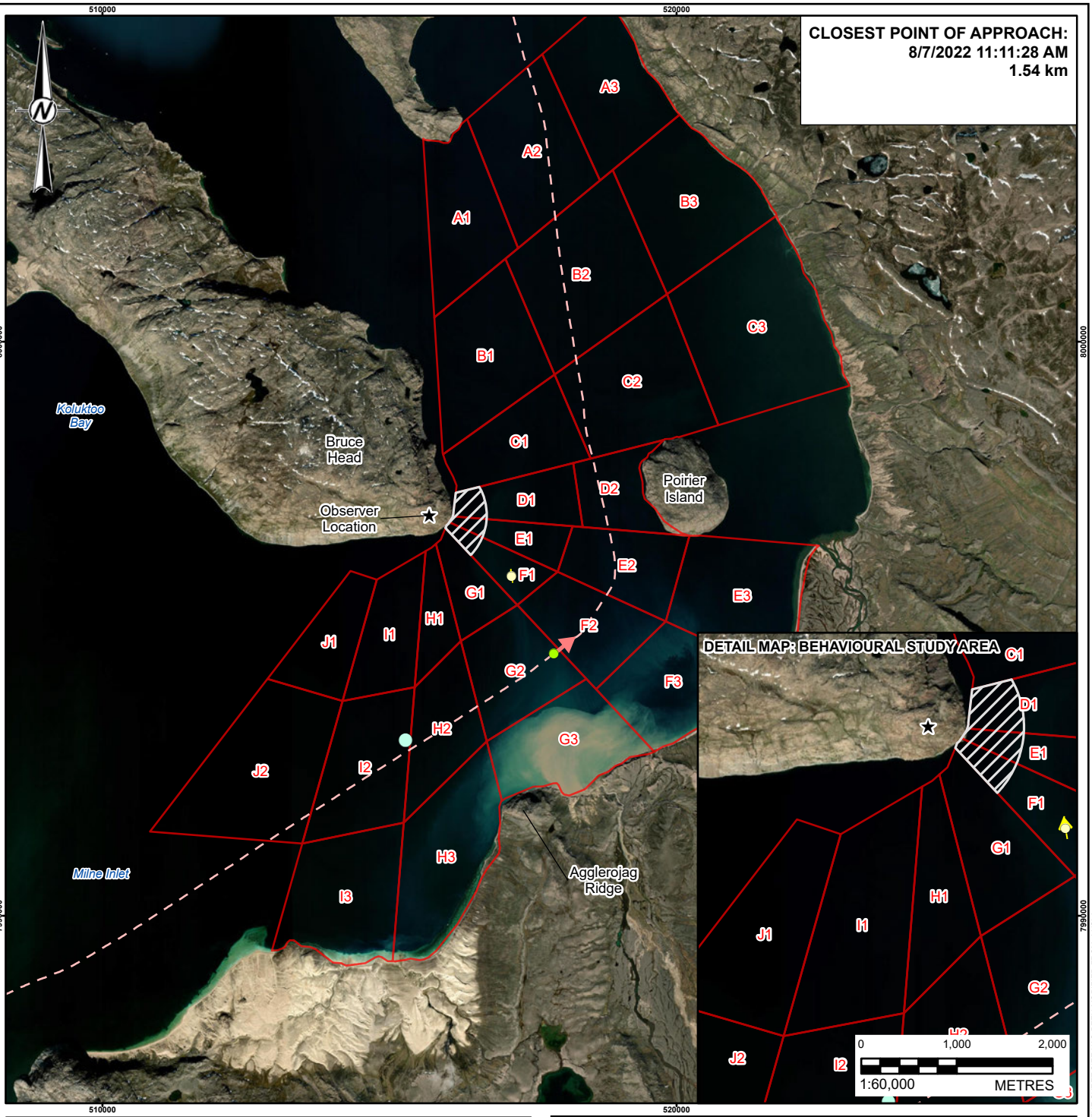

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 72 (2022)
- ACTIVE VESSEL TRANSIT (M.V.GOLDEN BRILLIANT)
- NON-ACTIVE VESSEL TRANSIT (M.V.GOLDEN BRILLIANT)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 72 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-65

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

25mm

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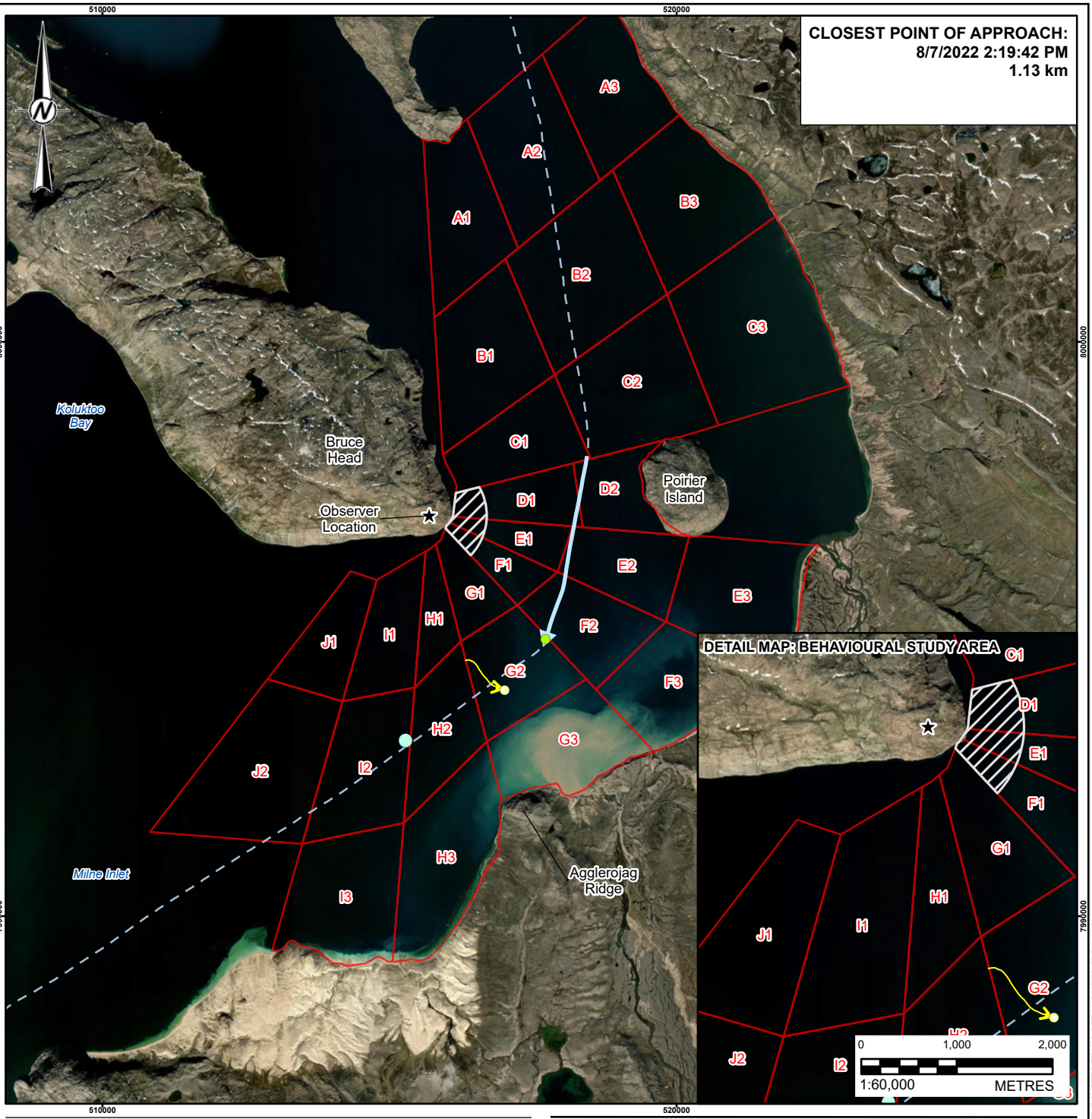

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 74 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC ORION)
- NON-ACTIVE VESSEL TRANSIT (NORDIC ORION)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 74 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-66

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

25mm

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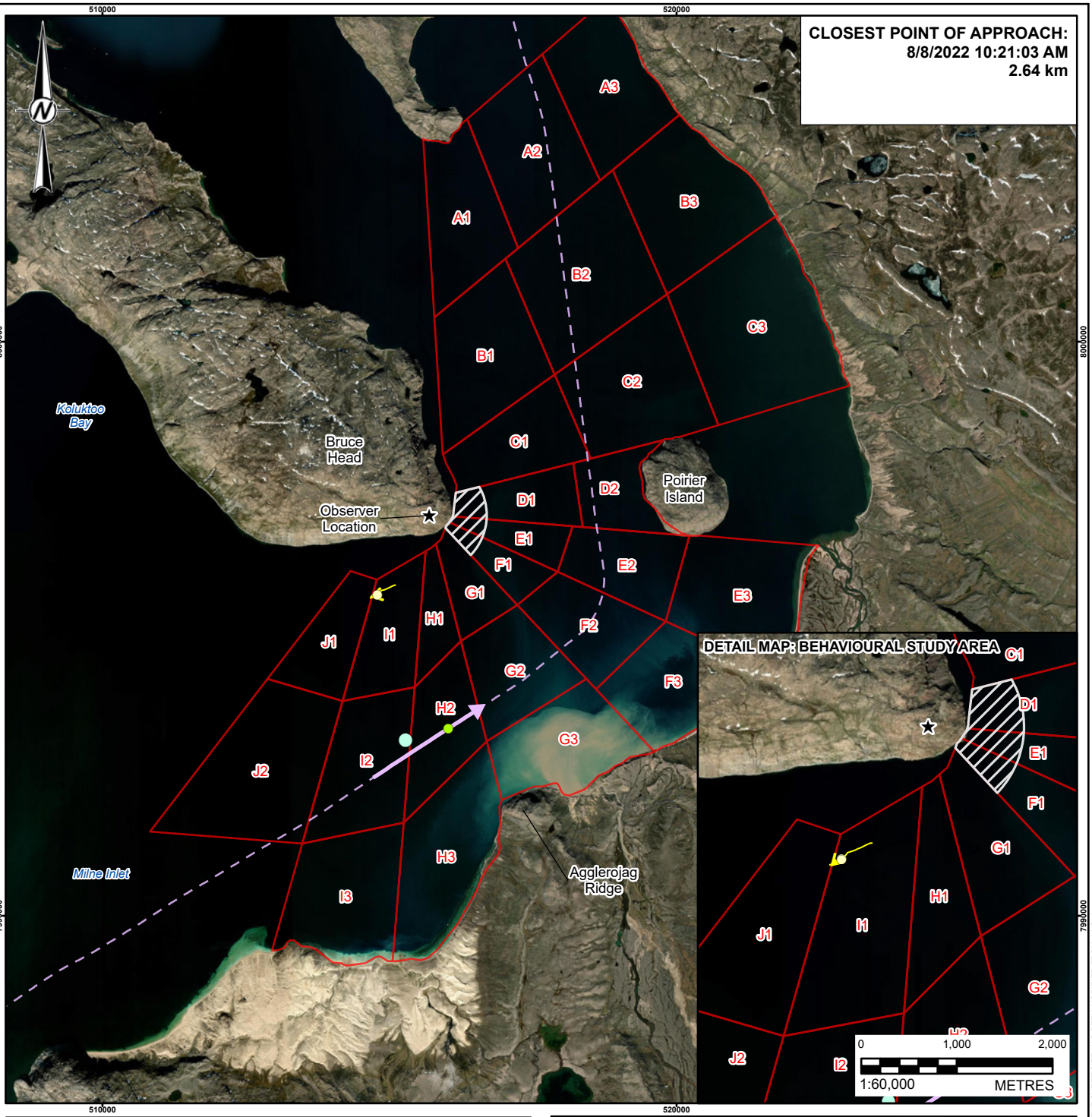

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 78 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC ODYSSEY)
- NON-ACTIVE VESSEL TRANSIT (NORDIC ODYSSEY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-67

PATH: I:\2016\166372402\Mapping\MXD\75000_202403\Bruce Head\166372402_75000_E67_44_87_20240319_Bruce Head.mxd PRINTED ON: AT 2:08:24 PM
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25mm
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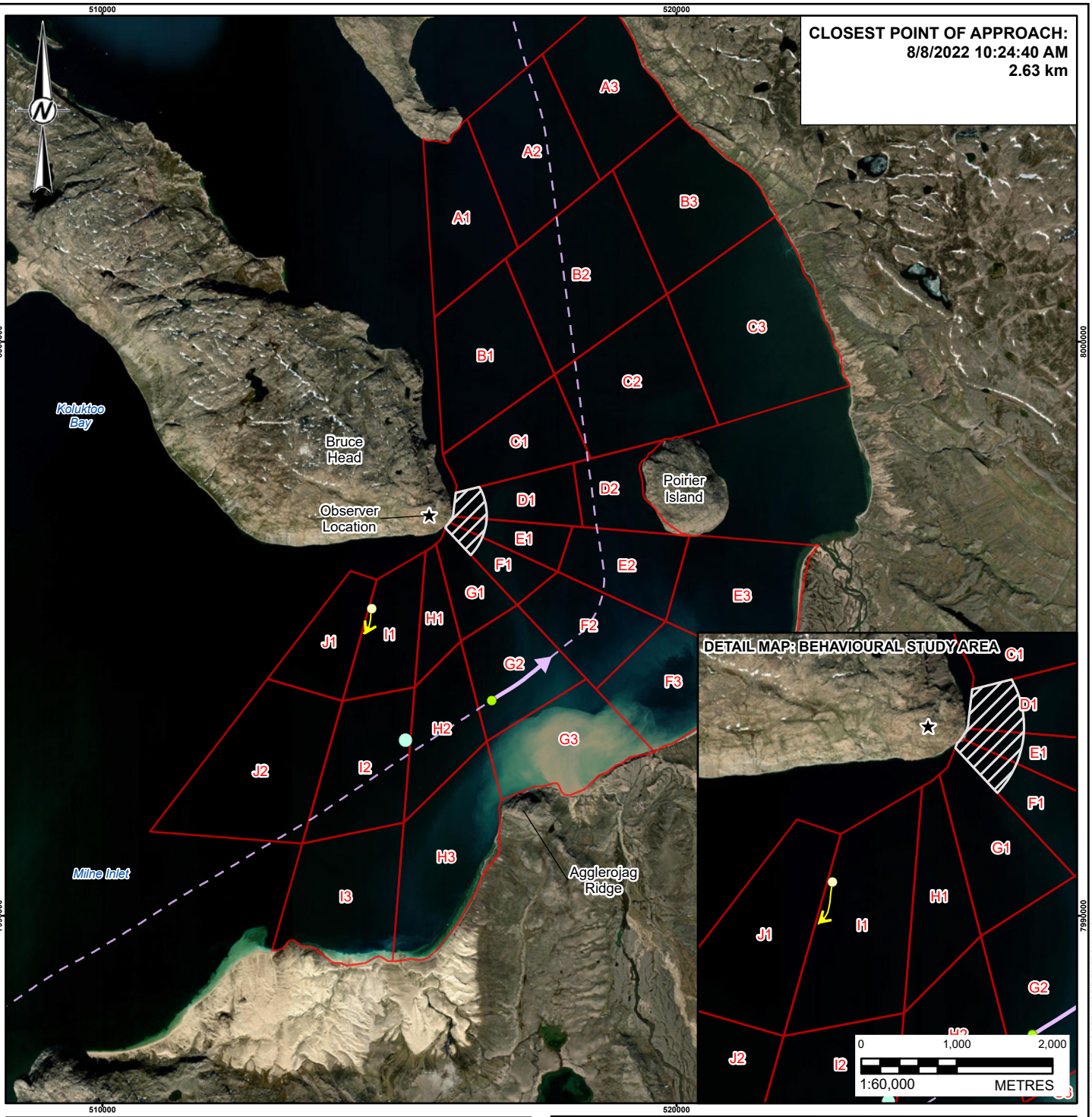

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 79 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC ODYSSEY)
- NON-ACTIVE VESSEL TRANSIT (NORDIC ODYSSEY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-68

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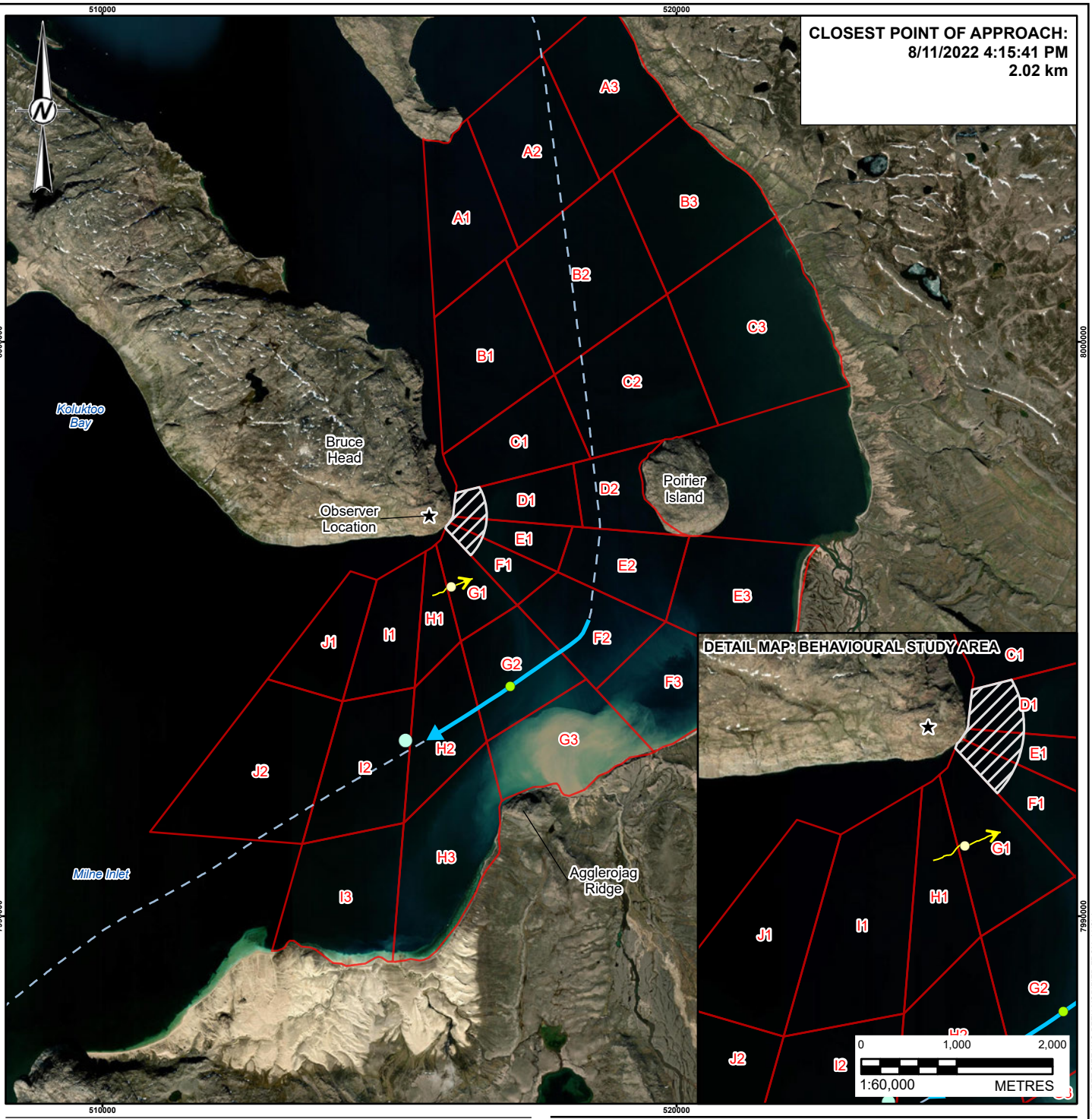

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 98 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN SUEK)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN SUEK)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 98 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-69

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

25mm

0

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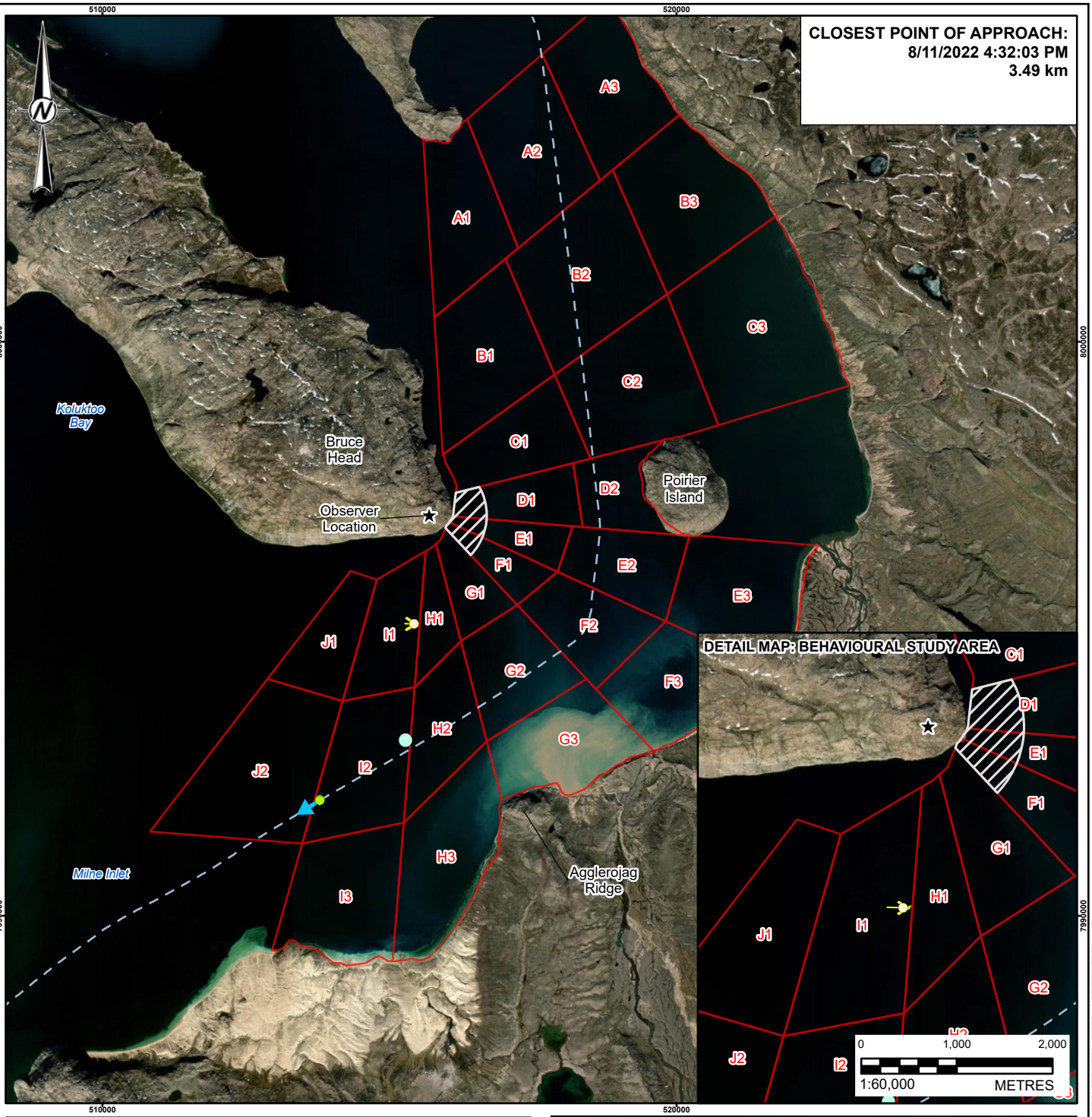

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 99 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN SUEK)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN SUEK)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 99 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-70

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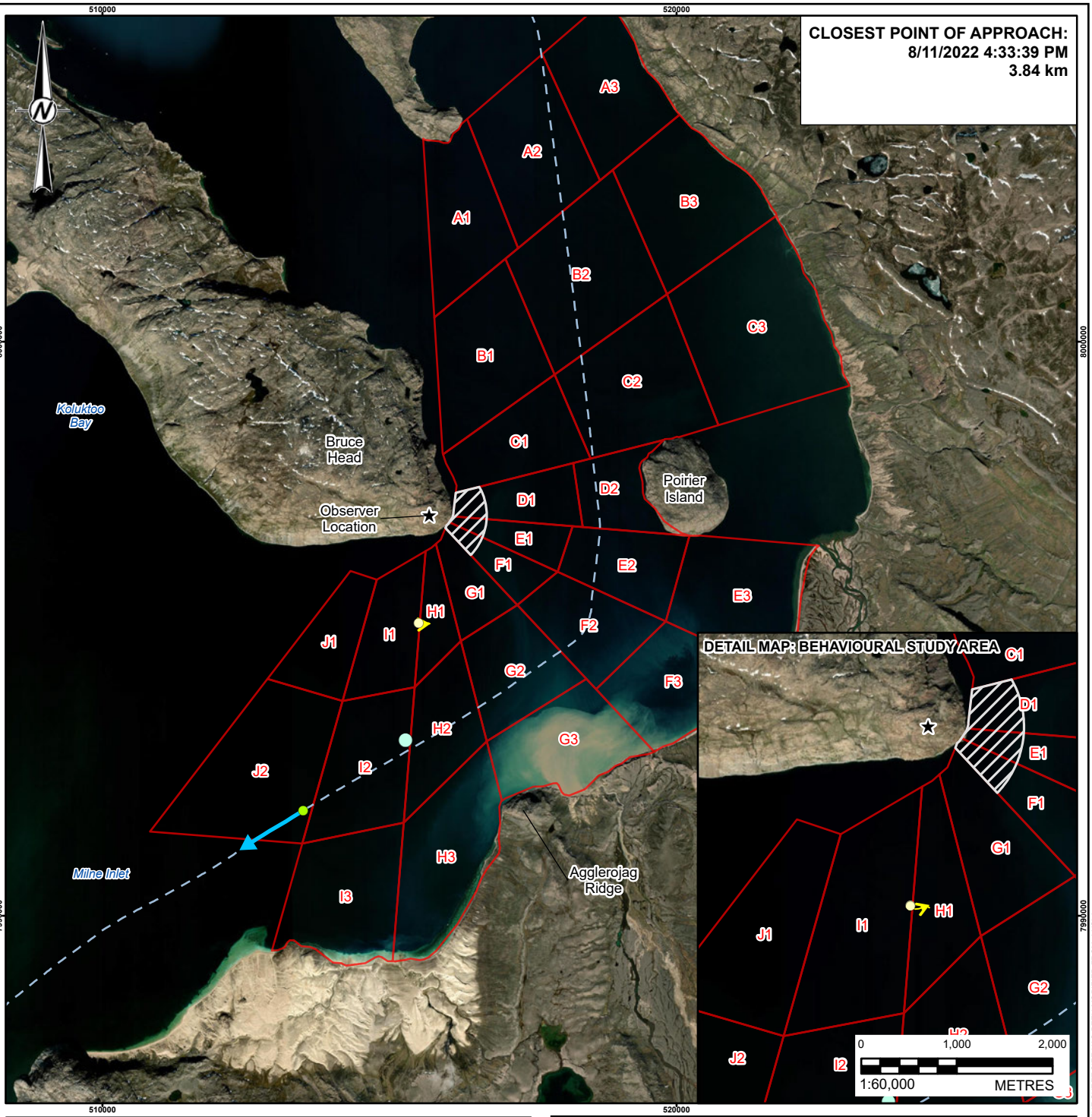

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 100 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN SUEK)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN SUEK)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 100 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-71

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

25mm

0

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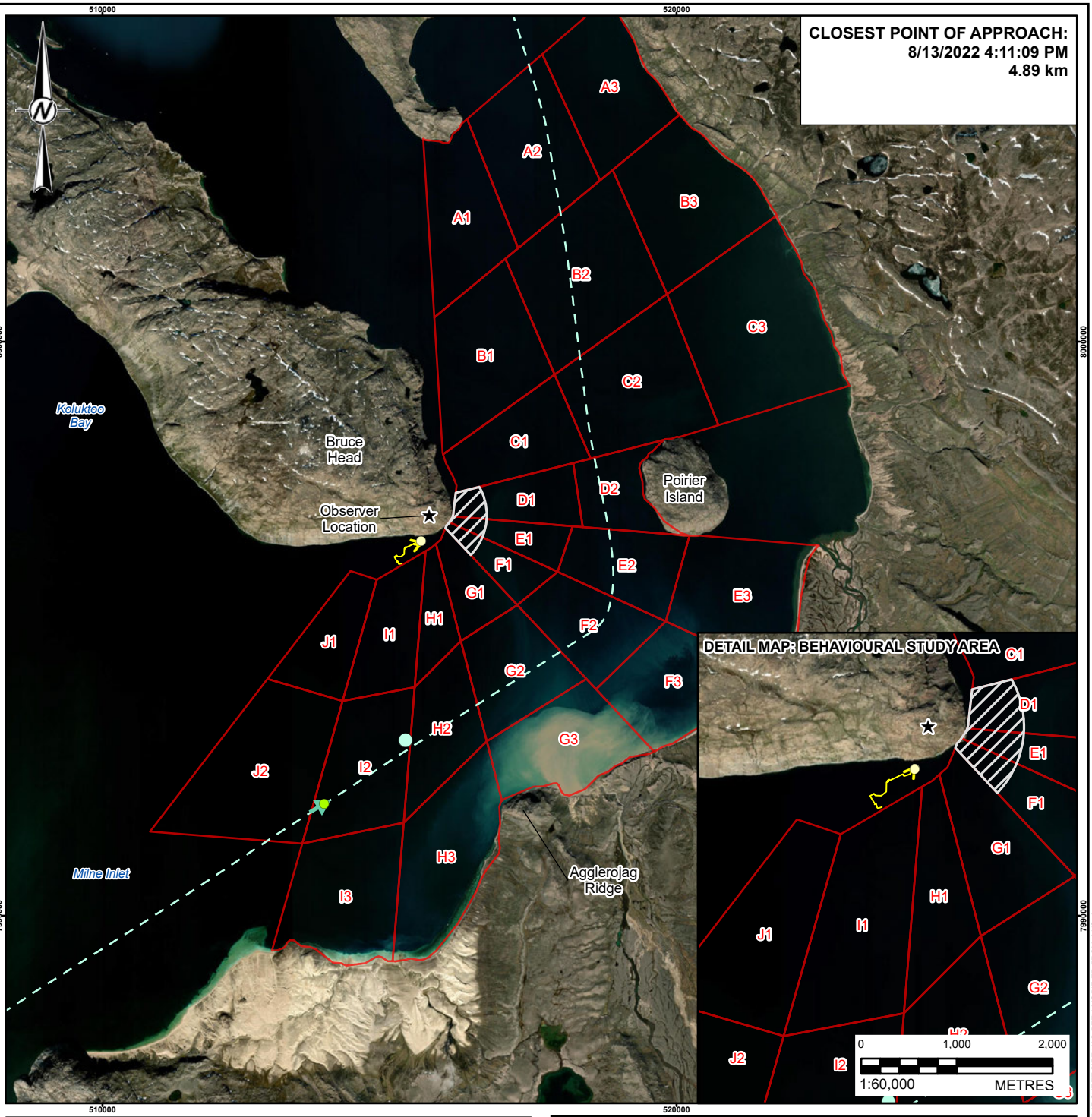

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 107 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC NULUUJAAK)
- NON-ACTIVE VESSEL TRANSIT (NORDIC NULUUJAAK)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 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 107 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-72

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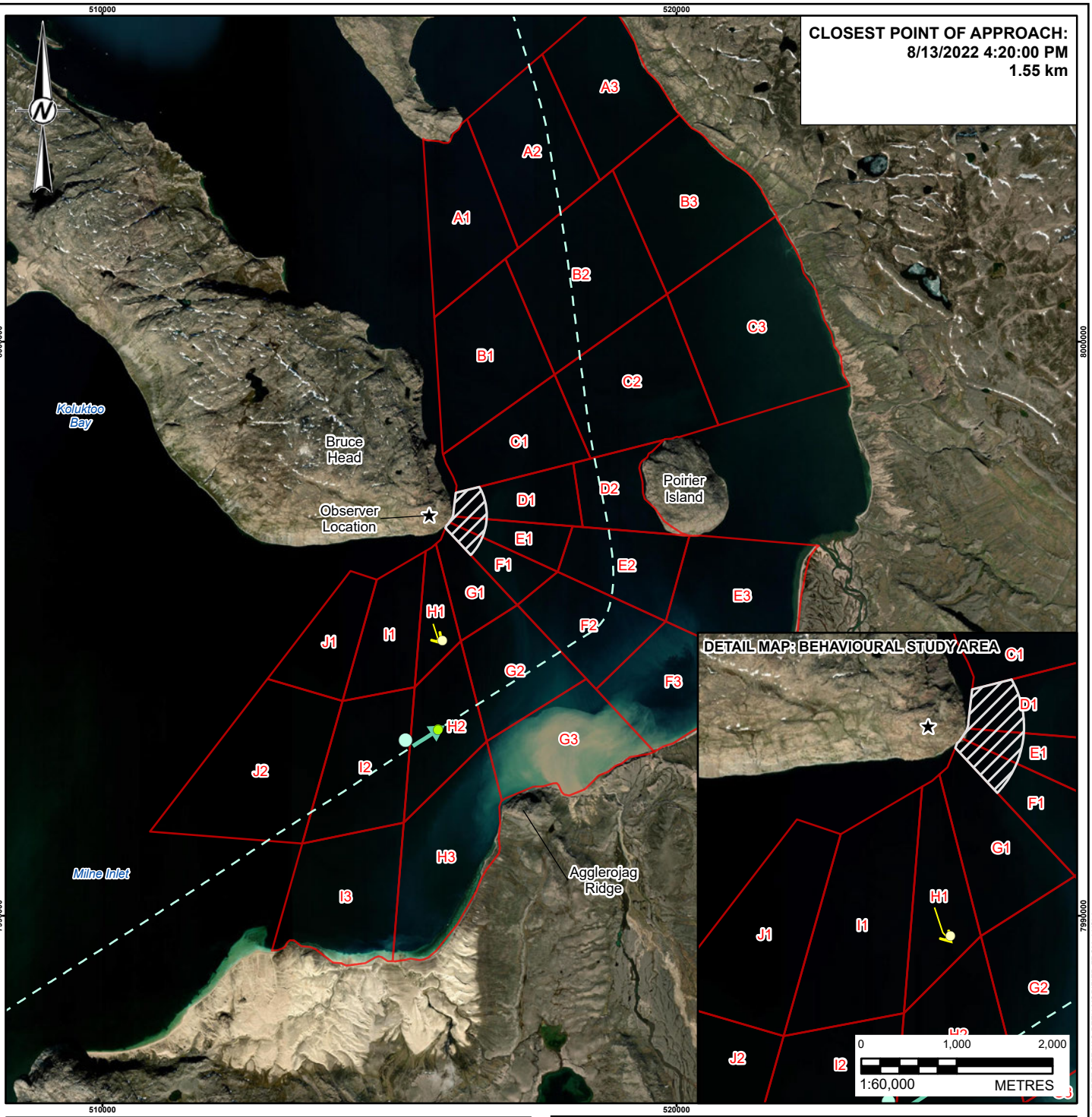

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 108 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC NULUUJAAK)
- NON-ACTIVE VESSEL TRANSIT (NORDIC NULUUJAAK)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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CLIENT
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PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 108 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-73

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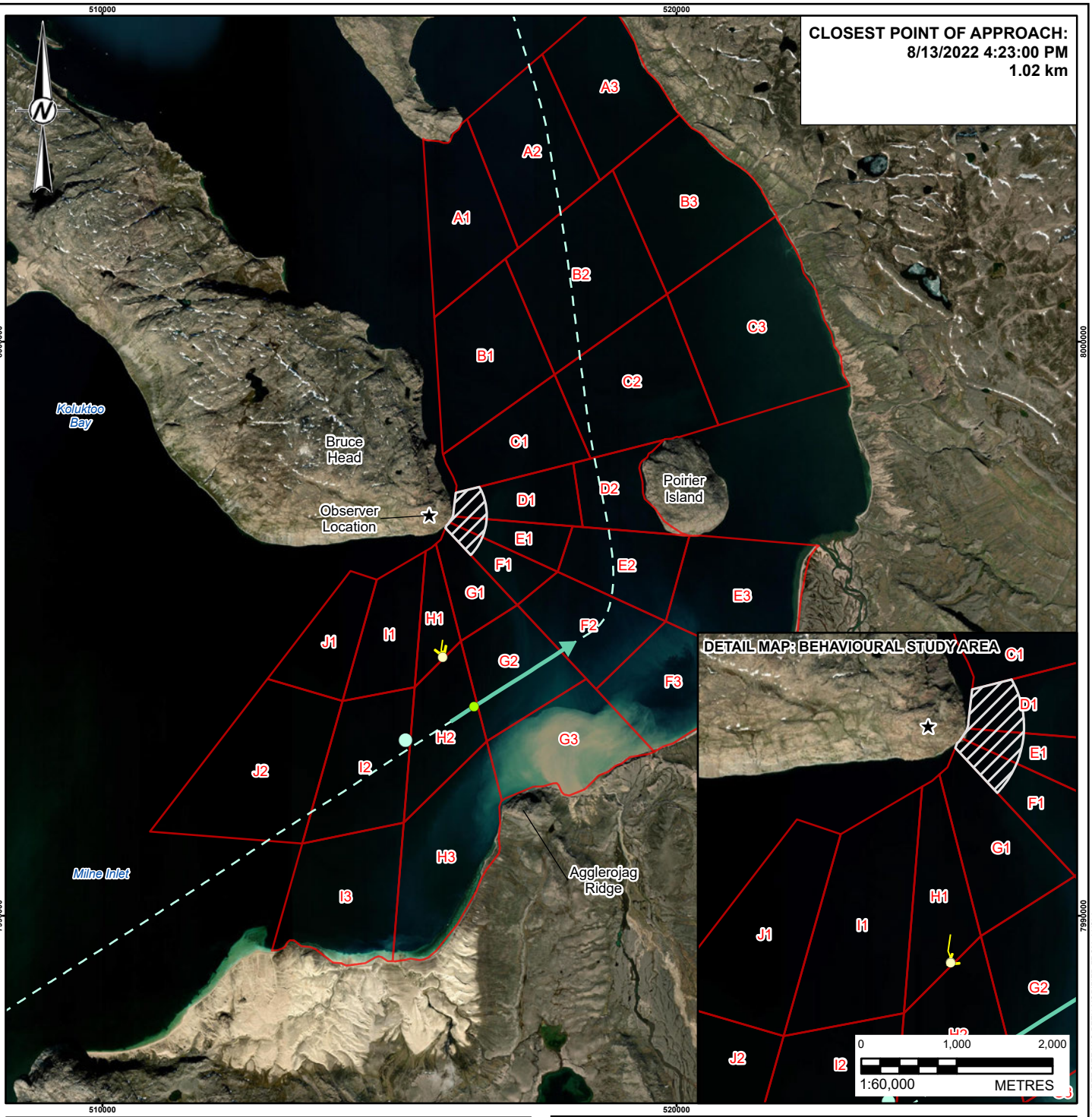

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 109(2022)
- ACTIVE VESSEL TRANSIT (NORDIC NULUUJAAK)
- NON-ACTIVE VESSEL TRANSIT (NORDIC NULUUJAAK)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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CLIENT
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PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 109 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-74

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

25mm

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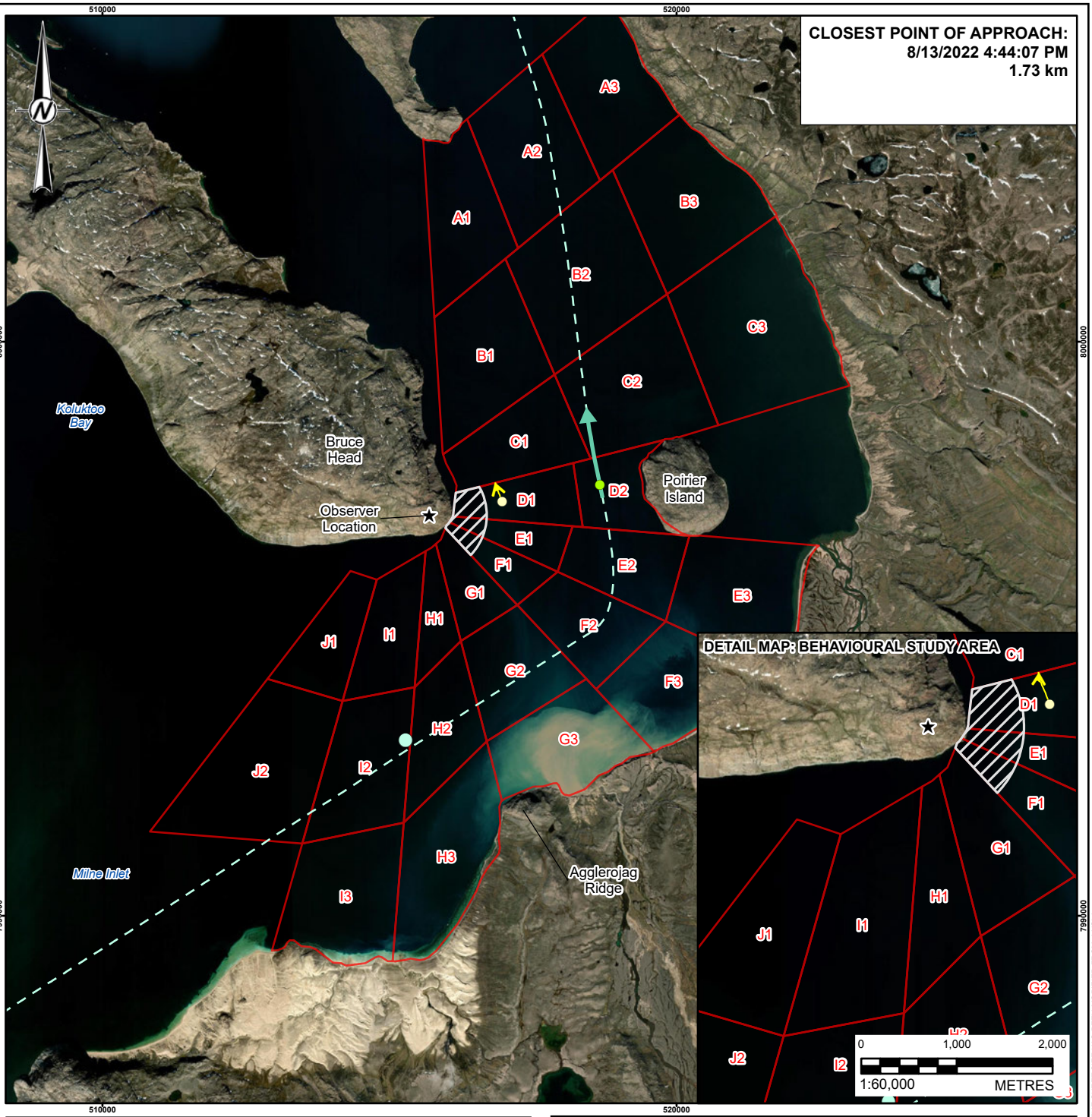

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 110 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC NULUUJAAK)
- NON-ACTIVE VESSEL TRANSIT (NORDIC NULUUJAAK)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
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PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 110 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-75

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25mm
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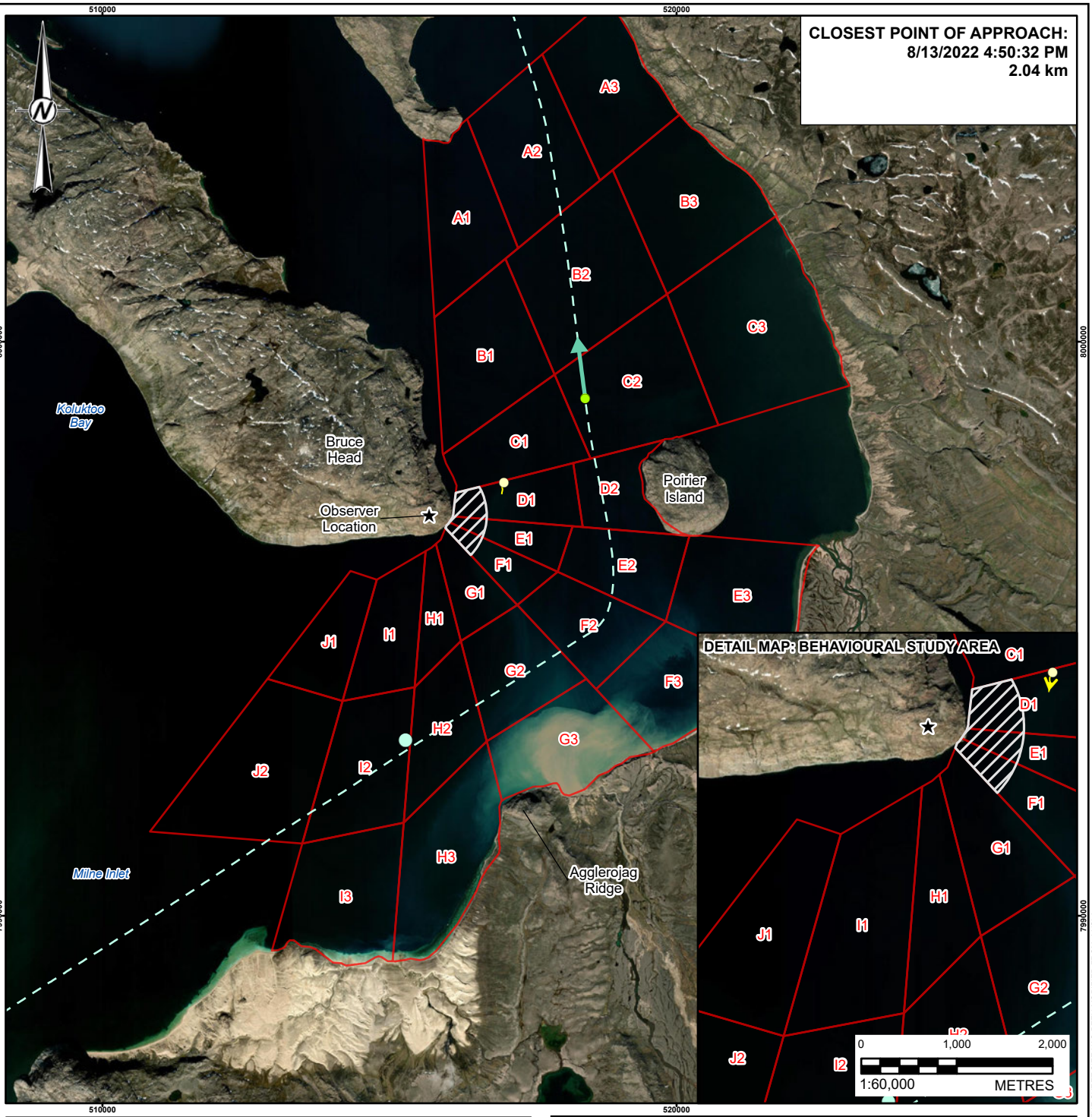

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 111 (2022)
- ACTIVE VESSEL TRANSIT (NORDIC NULUUJAAK)
- NON-ACTIVE VESSEL TRANSIT (NORDIC NULUUJAAK)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 111 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-76

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25mm
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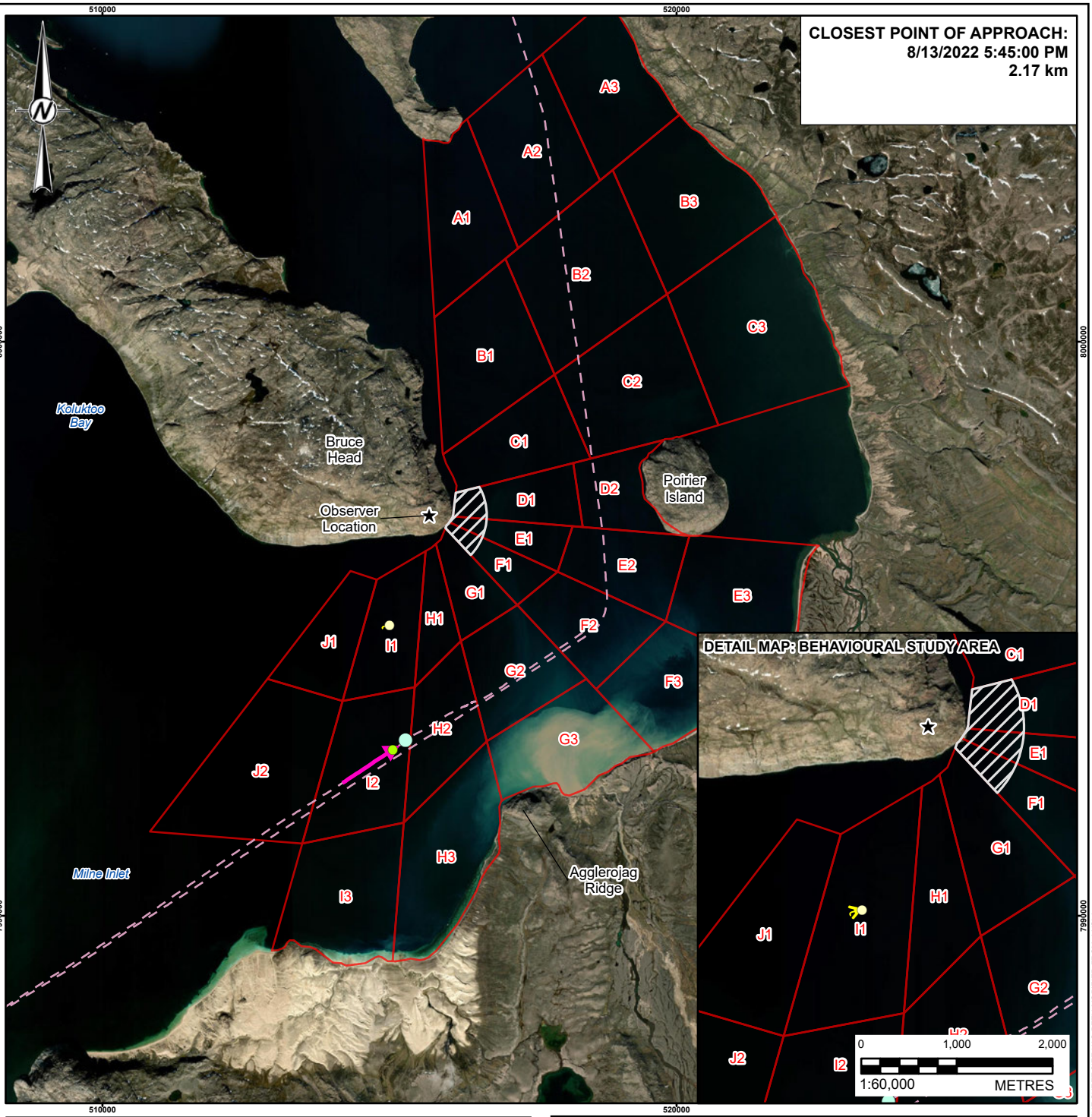

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 112 (2022)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 112 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-77

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

25mm

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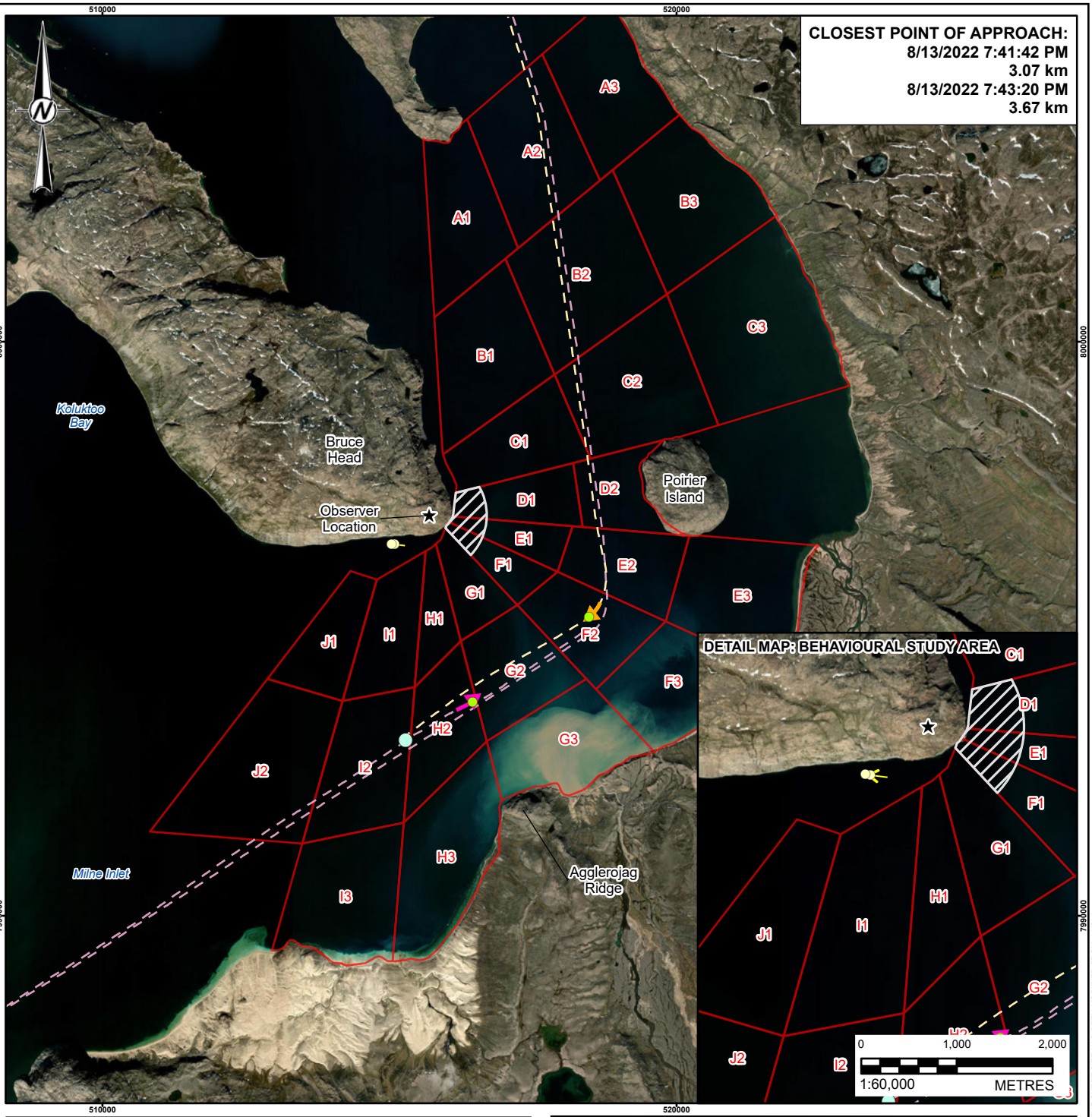

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 113 (2022)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- ACTIVE VESSEL TRANSIT (GOLDEN STRENGTH)

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
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PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 113 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-78

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

25mm

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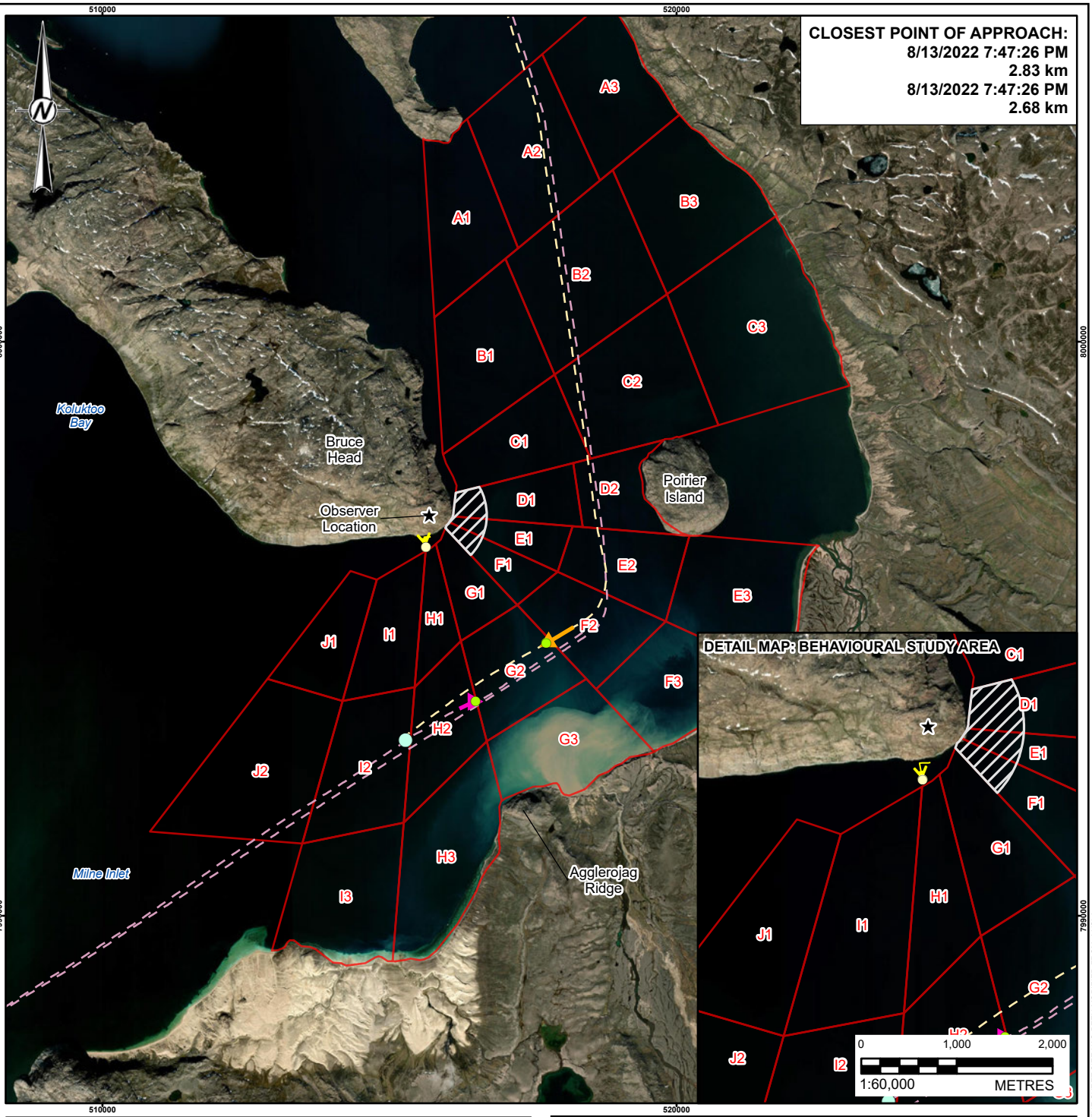

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 114 (2022)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- ACTIVE VESSEL TRANSIT (GOLDEN STRENGTH)

0 2.5 5

1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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CLIENT
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PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 114 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

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DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-79

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

25mm

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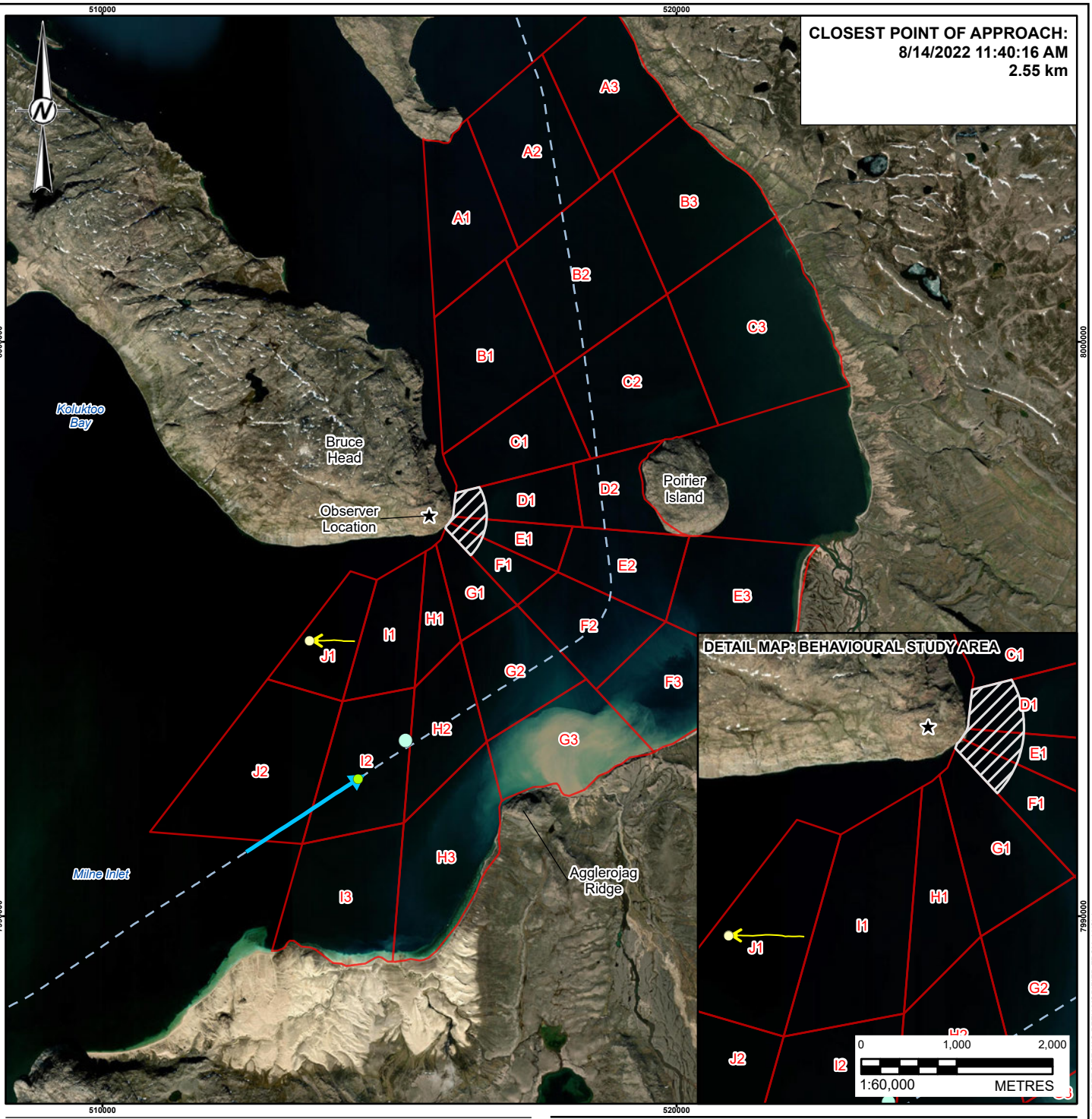

LEGEND

- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 120 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN SUEK)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN SUEK)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 120 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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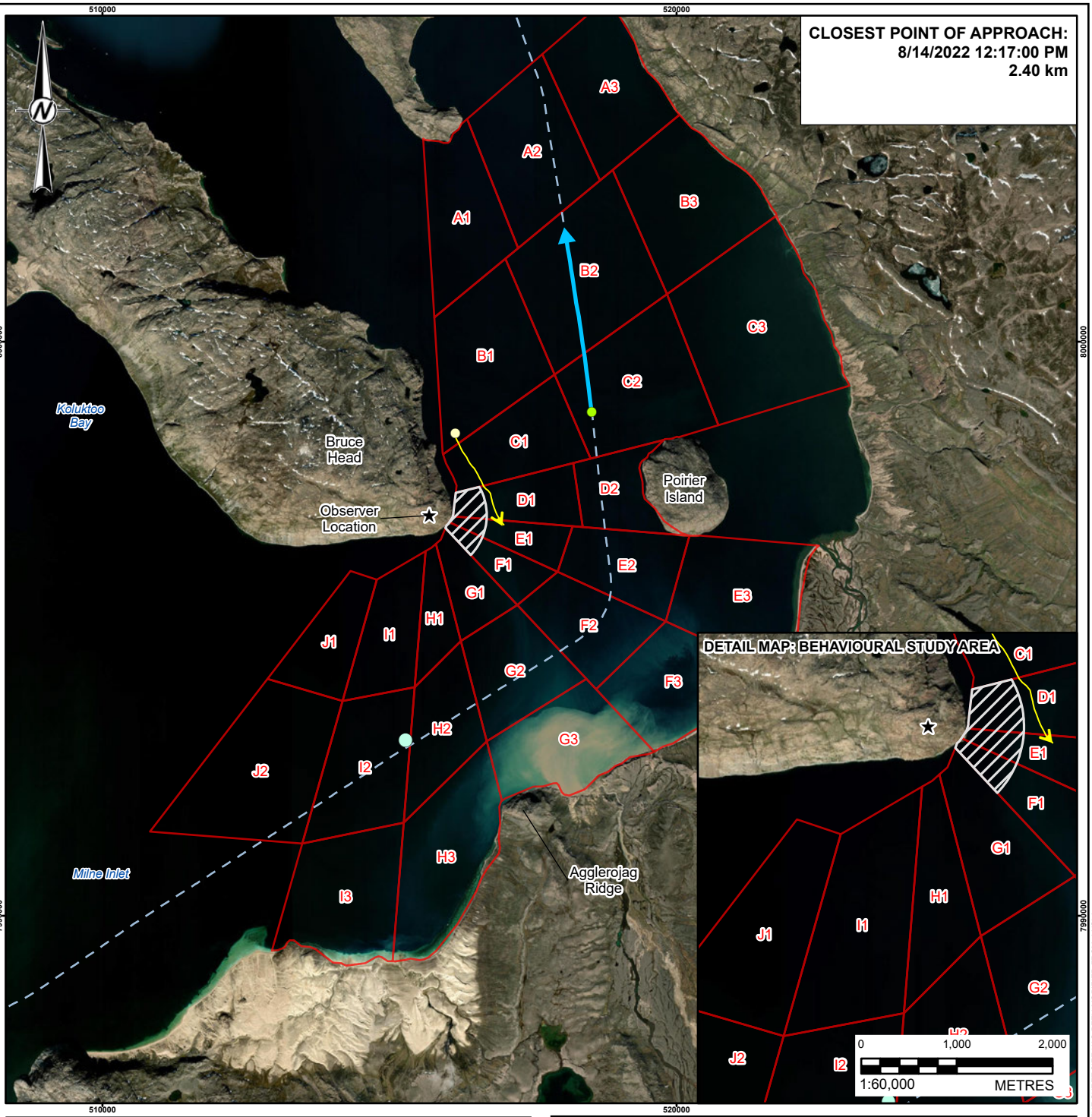

LEGEND

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- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 121 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN SUEK)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN SUEK)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

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1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 121 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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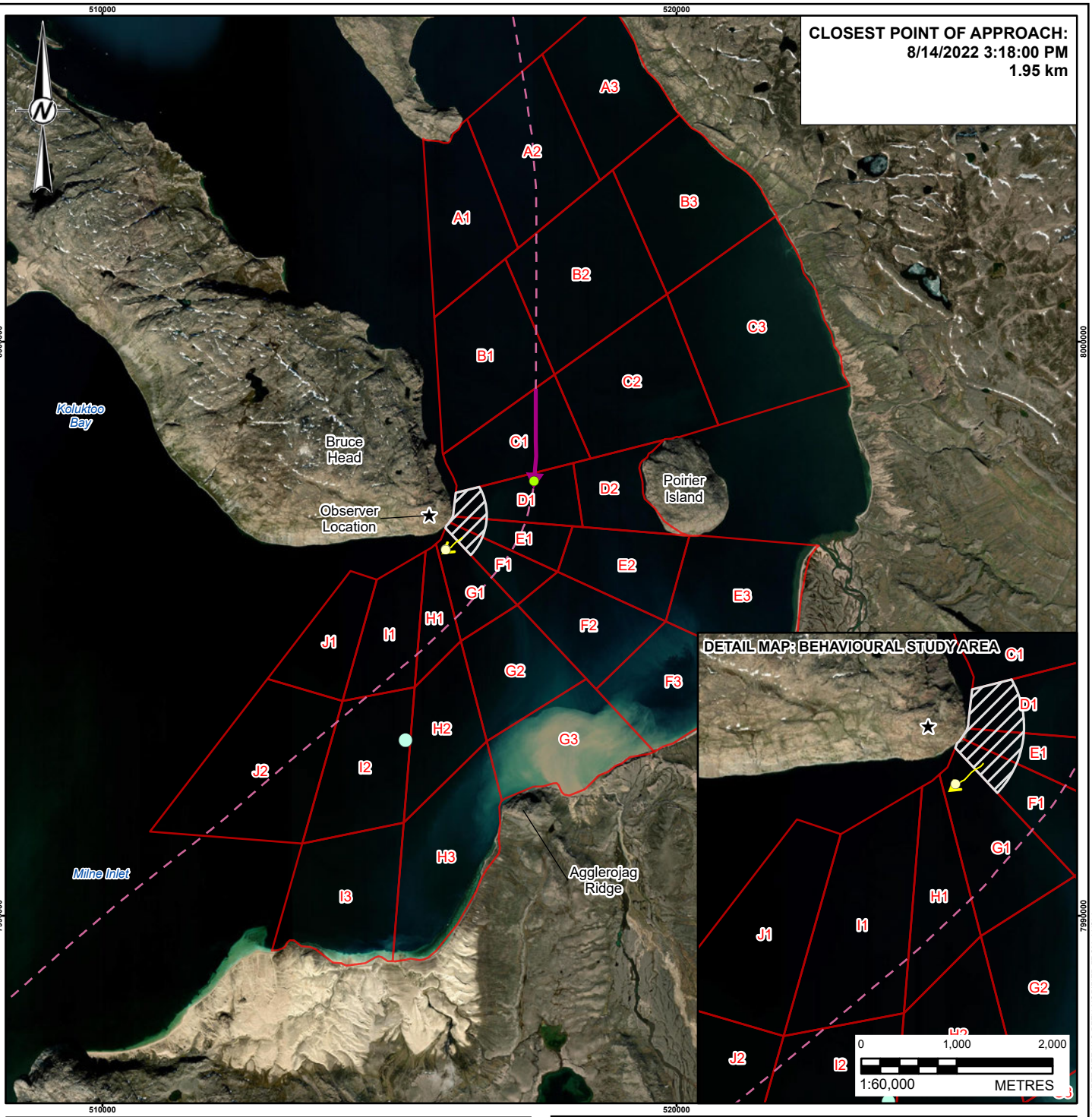

LEGEND

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- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 124 (2022)
- ACTIVE VESSEL TRANSIT (SAGAR SAMRAT)
- NON-ACTIVE VESSEL TRANSIT (SAGAR SAMRAT)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

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1:100,000 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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 124 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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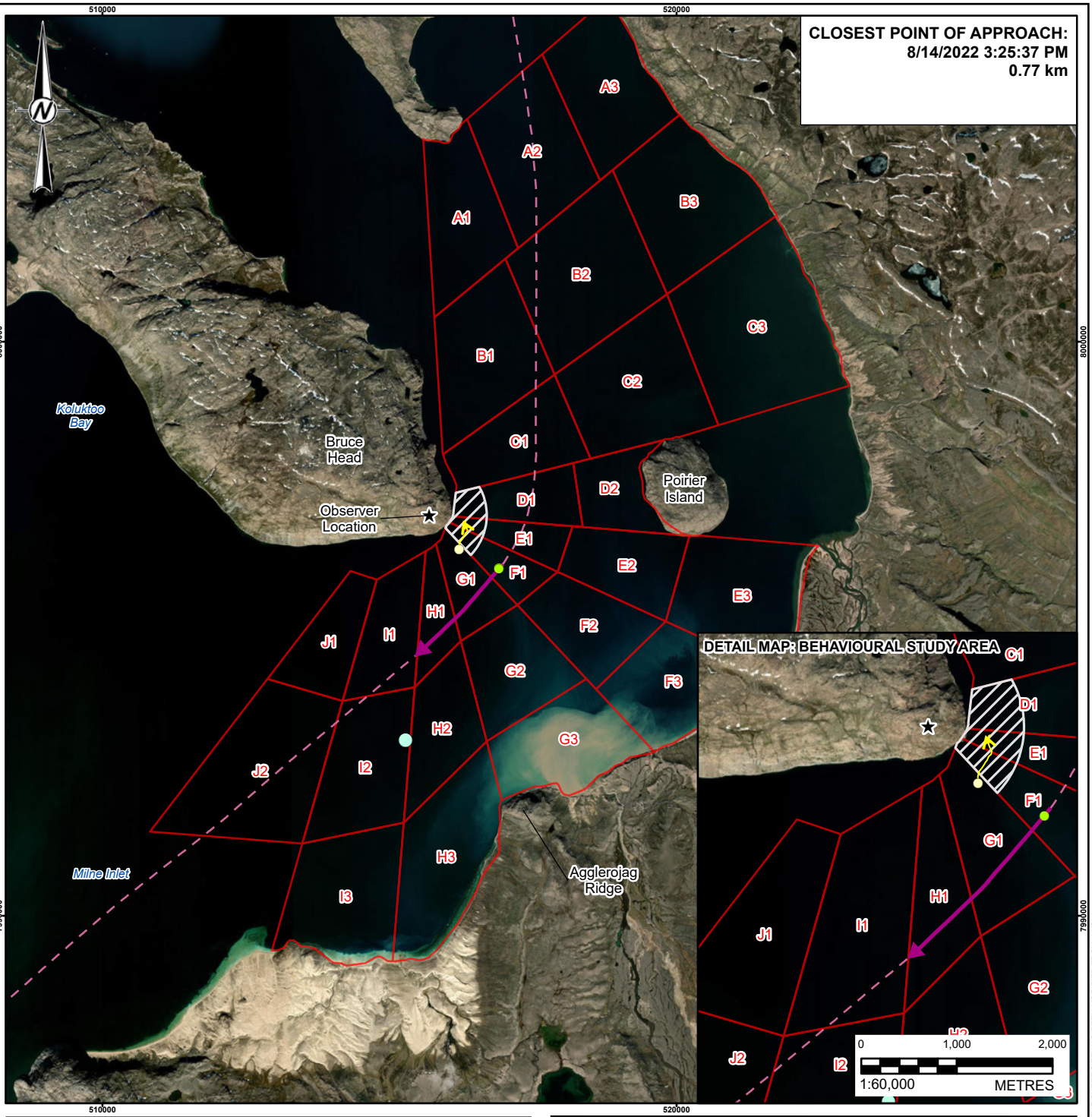

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- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 125 (2022)
- ACTIVE VESSEL TRANSIT (SAGAR SAMRAT)
- NON-ACTIVE VESSEL TRANSIT (SAGAR SAMRAT)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

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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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 125 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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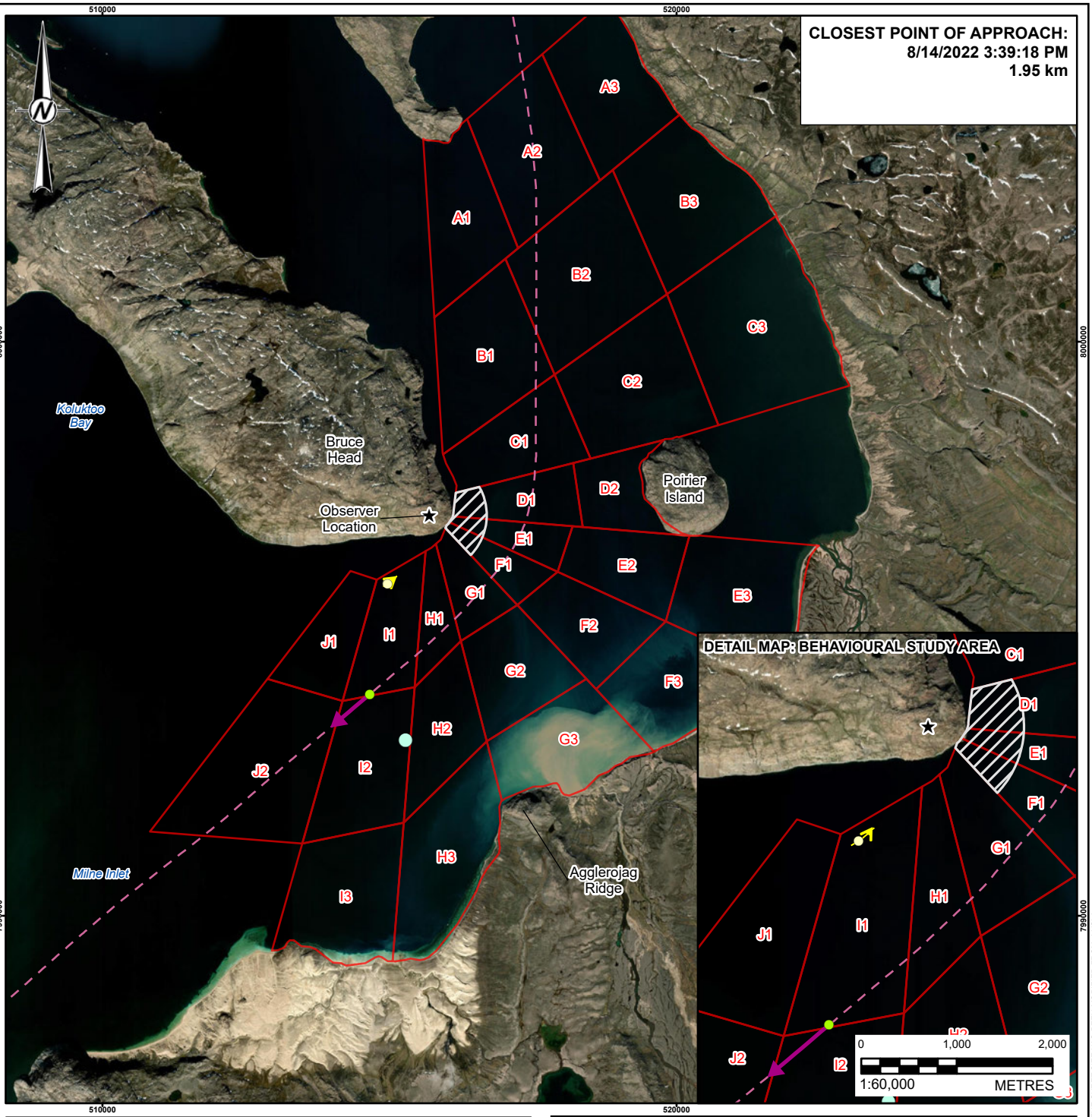

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- ACOUSTIC RECORDER (AMAR) LOCATION
- CLOSEST POINT OF APPROACH (VESSEL)
- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 126 (2022)
- ACTIVE VESSEL TRANSIT (SAGAR SAMRAT)
- NON-ACTIVE VESSEL TRANSIT (SAGAR SAMRAT)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

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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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 126 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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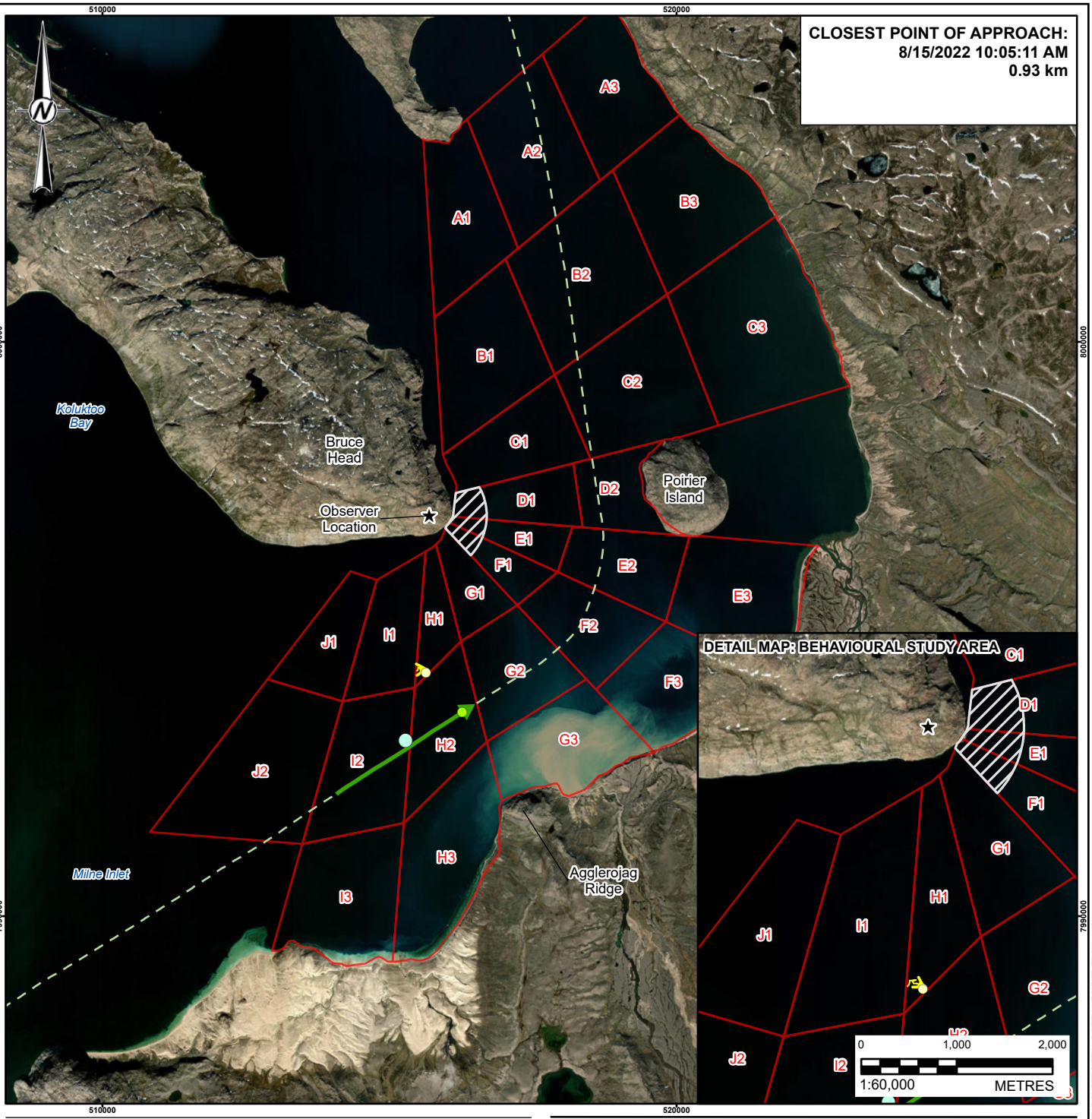

LEGEND

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- CLOSEST POINT OF APPROACH (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 127 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN FAST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FAST)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

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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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 127 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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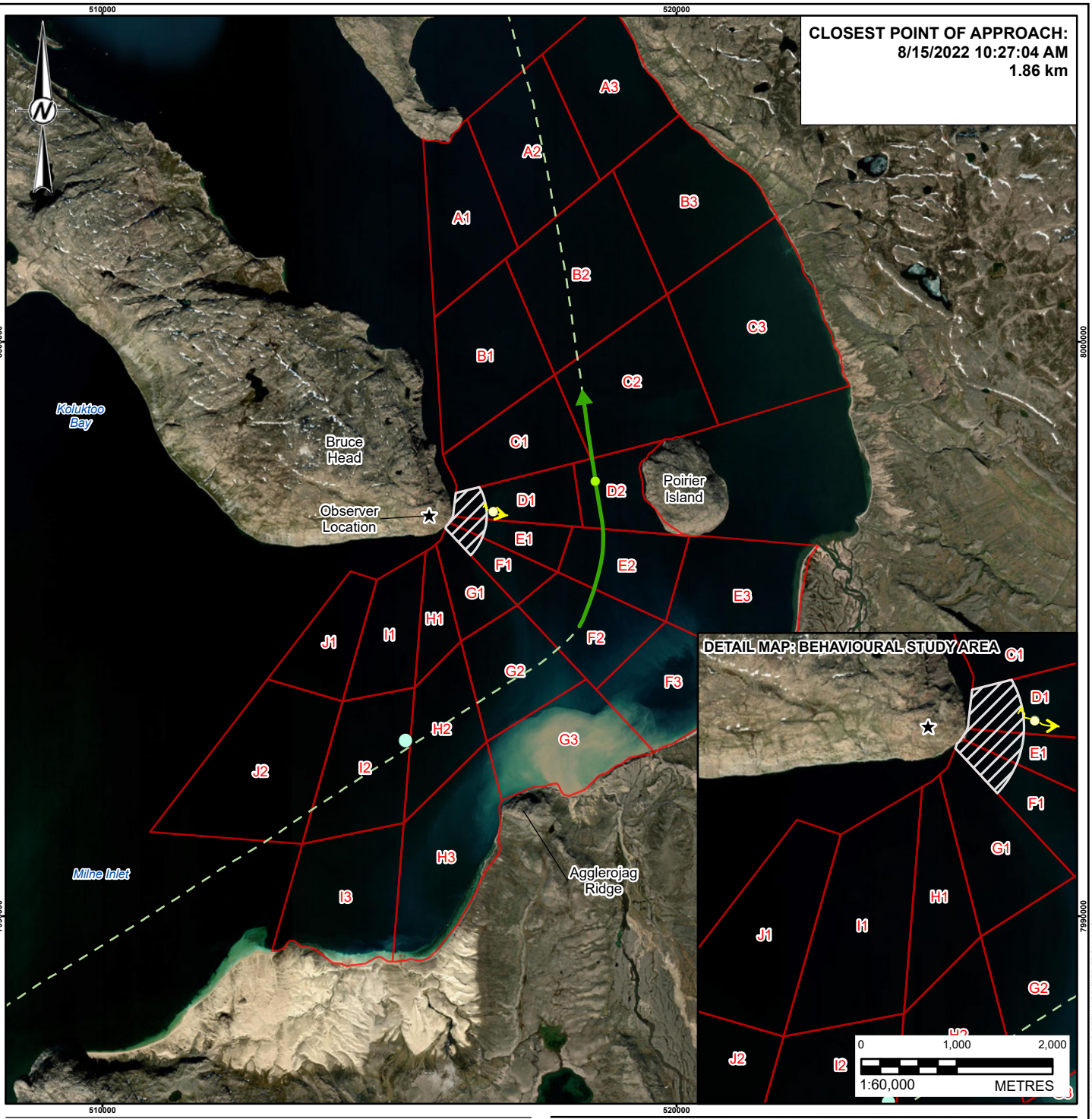

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- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 128 (2022)
- ACTIVE VESSEL TRANSIT (GOLDEN FAST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FAST)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

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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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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PROJECT
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TITLE
FOCAL FOLLOW 128 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

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YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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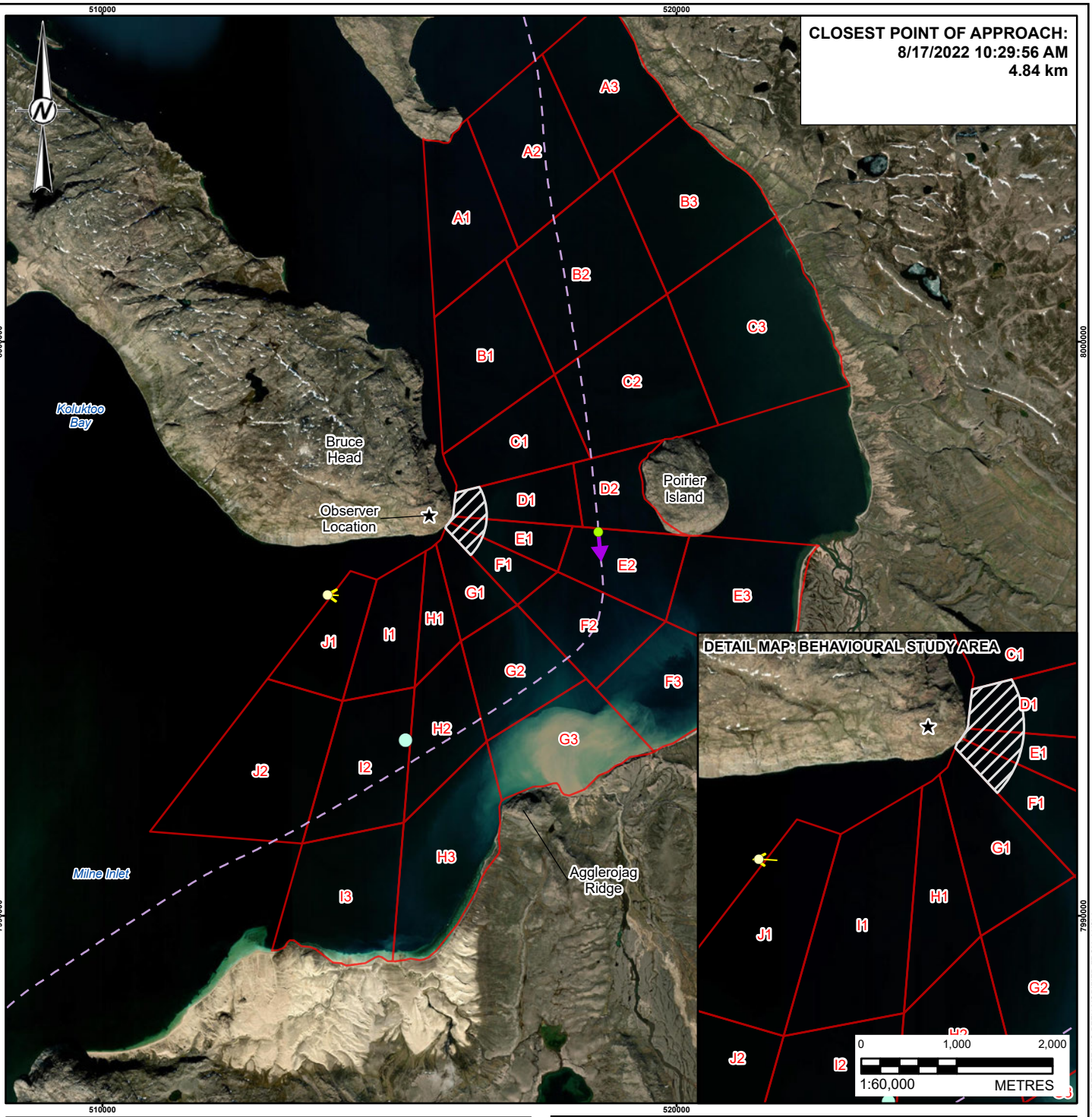

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- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 137 (2022)
- ACTIVE VESSEL TRANSIT (ELENA VE)
- NON-ACTIVE VESSEL TRANSIT (ELENA VE)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5

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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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 137 (2022) AND ACTIVE VESSEL TRANSIT

CONSULTANT

wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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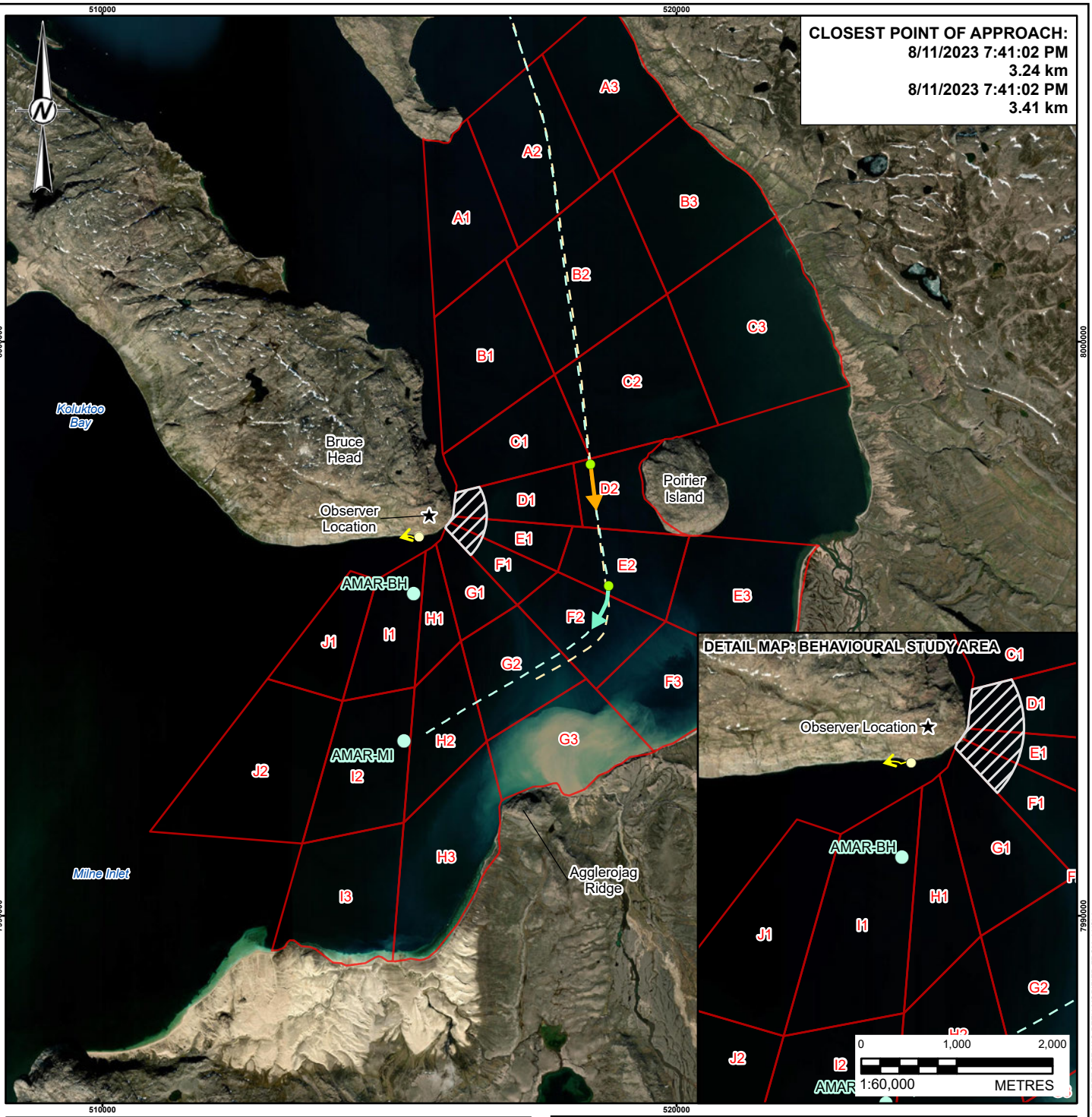

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- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 1 (2023)
- ACTIVE VESSEL TRANSIT (GOLDEN OPAL)
- ACTIVE VESSEL TRANSIT (NORDIC ODYSSEY)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN OPAL)
- NON-ACTIVE VESSEL TRANSIC (NORDIC ODYSSEY)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2.5 5
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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. IMAGERY COPYRIGHT ©20210811 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
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CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 1 (2023) AND ACTIVE VESSEL TRANSIT

CONSULTANT
wsp

YYYY-MM-DD	2024-03-19
DESIGNED	SU
PREPARED	AA
REVIEWED	PA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	75000.04	0	E-88

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APPENDIX F

Focal Follow Survey Descriptions in the Presence of Vessels

Table F-1: Summary of narwhal focal follow surveys conducted within 5 km of vessels in 2020.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
10	9 August / 13:27	12 m 5 s	0.86	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.
56	22 August / 9:11	1 m 59 s	2.27	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.
57	22 August / 9:15	4 m 6 s	2.74	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.
62	29 August / 13:23	1 m 21 s	3.31	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.
63	29 August / 13:26	1 m 10 s	2.57	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.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
64	29 August / 13:29	1 m 30 s	2.39	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.
65	29 August / 13:41	3 m 55 s	2.84	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.
66	29 August / 13:42	3 m 30 s	2.84	1x adult (no tusk)	Non-tusked adult observed resting and milling while oriented eastward. Individual then began travelling slowly eastward before diving out of sight. Nordic Olympic transiting southbound, beyond the southern portion of the SSA. Survey ended due to individual diving deeply and not resurfacing.
67	29 August / 13:44	3 m 30 s	3.55	1x juvenile (tusked)	Juvenile (tusked) observed travelling predominantly eastward while at the surface. Nordic Olympic transiting southbound, beyond the southern portion of the SSA. Survey ended due to individual diving deeply and not resurfacing.
68	29 August / 13:45	3 m 30 s	3.68	1x adult (no tusk)	Non-tusked adult observed travelling predominantly eastward and then resting and milling slowly at the surface. Individual rolls horizontally at end of video. Nordic Olympic transiting southbound, beyond the southern portion of the SSA. Survey ended due to battery.
83	30 August / 10:01	10 m 0 s	3.97	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

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
					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.
84	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.
85	30 August / 10:32	12 m 49 s	1.87	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.

Table F-2: Summary of narwhal focal follow surveys conducted within 5 km of vessels in 2021.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
33	7 August / 13:21	4 m 48 s	3.99	1x adult (tusked) Later joined by: 1x adult (no tusk)	Single adult (tusked) observed travelling eastward, later joined by another adult (no tusk). Adult with tusk dove deeply at 3m 26s, while adult (no tusk) travelled NE. Botnica transiting northbound through stratum J. Survey ended due to animal leaving frame.
34	7 August / 13:22	3 m 24 s	3.72	7x adults (tusked)	Group of tusked adults observed travelling NE in a loose parallel formation. Two individuals separately observed defecating. Group diverges and then dive below the surface at approximately 3 m 24s. Botnica transiting northbound through strata I/J. Survey ended due to the group diving deeply and not resurfacing.
35	7 August / 13:24	51 s	3.47	2x adults (tusked)	Two tusked adults observed travelling eastward in loose linear formation. One individual observed defecating. Botnica transiting northbound through stratum I. Survey ended due to the pair diving deeply and not resurfacing.
36	7 August / 13:35	13 m 0 s	2.11	1x adult (tusked)	Single adult (tusked) observed travelling eastward. Switched direction to westward travel at 4m 30s, then again changed travel direction to orient northward at 7m 30s. Observed milling and frequently changing travel direction for remainder of survey. Hunting vessel observed travelling southbound through stratum B at 13:33. Botnica transiting northbound through strata I/H/G. Survey ended due to battery.
37	7 August / 13:36	4 m 0 s	2.31	2x adults (tusked)	Single adult (tusked) observed milling at surface, joined by another adult with tusk 30s into follow. Pair observed milling and circling one another during first part of survey and then began travelling in northward direction in loose parallel formation. Hunting vessel observed travelling southbound through stratum B at 13:33. Botnica transiting northbound through strata H/G. Survey ended due to the pair diving deeply and not resurfacing.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
38	7 August / 13:36	4 m 31 s	2.30	1x adult (tusked)	Single adult (tusked) observed travelling SW. Individual changed direction of travel to orient northward after 30s, then again changed direction of travel to orient SW at approximately 3m 30s. Hunting vessel observed travelling southbound through stratum B at 13:33. Botnica transiting northbound through stratum G. Survey ended due to the individual diving deeply and not resurfacing.
39	7 August / 13:47	5 m 24 s	3.70	2x adults (tusked)	Two adults (tusked) observed travelling southbound in loose parallel formation. One adult dove at 2:30 and the remaining adult switched to resting behaviour while oriented eastward, until commencing travel again at 5m 0s. Botnica transiting northbound through stratum E. Survey ended due to the individual diving deeply and not resurfacing.
40	7 August / 13:43	1 m 54 s	3.44	1x adult (tusked)	Single adult (tusked) observed milling throughout the duration of the survey. Botnica transiting northbound through stratum F. Survey ended due to battery.
41	7 August / 13:53	10 m 53 s	4.12	3x adults (tusked)	Group of three adults (tusked) observed tightly associated and socializing at depth for the first four minutes of the survey, rolling, rubbing, and engaged in sexual behaviour (genitals of two individuals obvious). Rolling and rubbing behaviour continues throughout the survey as group travels SE in tight cluster formation. Botnica transiting northbound through stratum C. Survey ended due to the group diving deeply and not resurfacing.
47	8 August / 12:58	8m 55s	3.49	1x adult (no tusk) Temporarily joined by: 1x adult (tusked)	Single adult (no tusk) observed alternating between resting, milling, and travel toward the NE. Temporarily joined by another adult (tusked) at 1m 30s which dove shortly after joining. Bulk carrier Golden Ruby transiting southbound through strata D/E. Survey ended due to the individual diving deeply and not resurfacing.
48	8 August / 13:01	2m 32s	3.18	1x adult (tusked)	Single adult (tusked) observed milling at surface for duration of survey. Bulk carrier Golden Ruby transiting southbound through strata E/F. Survey ended due to the group diving deeply and not resurfacing.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
49	8 August / 13:11	2m 43s	2.03	1x adult (no tusk)	Single adult (no tusk) observed travelling generally northward, milling temporarily, then resuming northward travel. Bulk carrier Golden Ruby transiting southbound through stratum H. Survey ended due to the individual diving deeply and not resurfacing.
85	16 August / 17:37	6m 35s	2.29	1x adult (no tusk)	Single adult (no tusk) observed travelling westward throughout the survey and periodically rolling horizontally. Observed milling temporarily at 3m 0s then resumed westward travel. Botnica transiting northbound through strata H/G. Survey ended due to the individual diving deeply and not resurfacing.
86	16 August / 17:41	1m 17s	2.61	1x adult (no tusk) 1x calf	Mother and calf pair observed travelling SW/W while tightly associated. Calf predominantly underneath its mother but no nursing discernible. Botnica transiting northbound through stratum G. Survey ended due to the pair diving deeply and not resurfacing.
87	16 August / 17:42	10m 23s	2.82	1x adult (no tusk) 1x juvenile (no tusk) 1x calf	Group of three narwhal observed milling in loose cluster formation with calf tight to mother. “S scar” observed on mother’s dorsal side (individual resighted during multiple surveys). Group dove deeply at 2m 0s and only calf resurfaced at 4m 30 s, commencing SE/SW travel on its own for duration of survey. Botnica transiting northbound through strata F/E. Survey ended due to battery.
114	19 August / 06:32	1m 53s	4.70	1x adult (tusked) Later joined by: 1x juvenile (tusked)	Single adult (tusked) observed travelling southward. Individual joined by juvenile (tusked) at 0m 30s and the pair continued to travel together in loose linear formation. Golden Frost transiting southbound through stratum B. Survey ended due to the pair diving deeply and not resurfacing.
115	19 August / 06:41	4m 39s	3.59	1x adult (tusked) Later: 1x adult (tusked) 1x adult (no tusk)	Single adult (tusked) observed milling non-directionally. Individual commenced travel westward at 1m 30s, then joined by non tusked adult at 2m, and another tusked adult at 2m 30s. Group then alternated milling and travelling in various directions, occasionally rolling horizontally. Golden Frost transiting southbound through stratum C. Survey ended due to the group diving deeply and not resurfacing.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
116	19 August / 06:46	3m 2s	3.15	1x adult (tusked)	Single adult (tusked) observed travelling southward throughout survey. Golden Frost transiting southbound through stratum D. Survey ended due to the individual diving deeply and not resurfacing.
117	19 August / 06:56	2m 41s	0.43	1x adult (tusked)	Single adult (tusked) observed travelling NE throughout survey. Golden Frost transiting southbound through strata F/G. Survey ended due to the individual diving deeply and not resurfacing.
118	19 August / 07:00	7m 8s	0.66	1x adult (no tusk) 1x yearling	Mother and yearling pair observed travelling northward, with yearling below its mother and tightly associated. Ore carrier is visible within the field of view. The pair is observed to split up and dive below the surface at 1m 30s, with only the yearling resurfacing and resuming travel initially oriented SW, then westward. Yearling is then observed milling temporarily, making short dives below 5 metres depth, and frequently changing direction. The individual is also observed rolling horizontally throughout survey. Golden Frost transiting southbound through strata G/H. Survey ended due to battery.
119	19 August / 07:07	54s	1.79	1x adult (tusked)	Single adult (tusked) observed travelling NW. Golden Frost transiting southbound through stratum I. Survey ended due to the individual diving deeply and not resurfacing.
120	19 August / 07:07	52s	1.79	3x adults (tusked)	Group of three adults (tusked) observed travelling westward in loose cluster. Golden Frost transiting southbound through stratum I. Survey ended due to the group diving deeply and not resurfacing.
121	19 August / 07:20	4m 42s	3.25	1x juvenile (tusked) Later joined by: 1x adult (tusked)	Single juvenile (tusked) observed milling at surface, then joined by adult (tusked). The pair milled together at the surface and rubbed against one another. The pair then travelled northward, followed by westward, with more rubbing observed. Golden Frost transiting southbound through stratum J. Survey ended due to the pair diving deeply and not resurfacing.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
122	19 August / 07:27	3m 14s	4.57	1x adult (no tusk) 1x calf	Mother and calf pair observed travelling northward with the calf tightly associated and to the right of its mother. The pair changed orientation to SW at 1m 30 and began resting, with the calf observed nursing from its mother. Travel then resumed at 2m 30s. Golden Frost transiting southbound through the southern portion of stratum J. Survey ended due to the pair diving deeply and not resurfacing.
139	20 August / 07:05	8m 12s	3.72	1x adult (tusked) 1x adult (no tusk) Later joined by: 1x adult (tusked)	Two adults (one tusked, one not tusked) observed travelling SE, initially in tight parallel formation. Pair became more loosely associated during early part of survey, periodically rolling horizontally. Another adult (tusked) joined group at 1m 30s and more rolling was observed. Group began milling and resting at 6m 0s , and the adult (no tusk) departed the group at 6m 30s. Golden Rose transiting southbound through strata C/D. Survey ended due to the group diving deeply and not resurfacing.
140	20 August / 07:09	5m 21s	3.56	3x adults (tusked)	Three adults (tusked) observed converging into group and socializing. Rubbing and horizontal rolling observed. Group travels SW with intermittent milling. Golden Rose transiting southbound through stratum E. Survey ended due to battery.
141	20 August / 07:19	18m 59s	3.29	1x adult (tusked) 2x adults (no tusk) 2x yearlings	Adult (tusked) with two mother and yearling pairs observed travelling westward in loose parallel formation, with yearlings tightly associated with their mothers. Group maintained course with the tusked adult periodically diving deeply and resurfacing. Rolling observed by all group members, with one instance where all individuals rolled at the same time. No nursing observed throughout the survey. Golden Rose transiting southbound through strata D/E/F. Survey ended due to battery.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
142	20 August / 07:28	8m 4s	1.51	4x adults (no tusk) 1x calf	Four adults (no tusk) with single calf observed travelling westward in loose parallel and loose cluster formation. Calf maintains tight associated with its mother throughout the survey. Group observed travelling at and below surface, with one of the adults periodically rolling horizontally throughout the survey. Golden Rose transiting southbound through strata H/I. Survey ended due to battery.
143	20 August / 07:30	3m 6s	3.20	1x adult (tusked)	Single adult (tusked) observed travelling NW. Golden Rose transiting southbound through strata H/I. Survey ended due to weather.
144	20 August / 07:53	8m 22s	4.55	4x adults (no tusk) 1x calf	Resighting of group in survey #142. Four adults (no tusk) with single calf observed travelling westward in loose parallel formation. Calf maintains tight associated with its mother throughout the survey. Group observed travelling at the surface and at depth (>5m), with one of the adults continuing to roll horizontally throughout the survey. Golden Rose transiting southbound, beyond the southern portion of stratum J. Survey ended due to battery.

Table F-3: Summary of narwhal focal follow surveys conducted within 5 km of vessels in 2022.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
16	01 August / 09:38	5m 24s	2.31	8x Adults (tusk)	Three adults observed stationary with some milling before travelling west. Group loosely associated and in cluster/parallel formation. Joined by five tusked adults at 21:36. Nordic Olympic transiting northbound from substratum I2 to G2. Survey ended due to animals diving and not resurfacing.
17	01 August / 09:39	3m 45s	2.42	1x Adult (tusk) 1x Juvenile (no tusk)	Single adult observed travelling west, met with juvenile and began milling. Juvenile dove and adult travelled west before diving. Group loosely associated without consistent formation. Nordic Olympic transiting northbound through substratum G2. Survey ended due to animals diving and not resurfacing.
18	01 August / 09:41	1m 11s	2.48	5 x Adults (tusks)	Five adults observed travelling west in loose cluster formation. Nordic Olympic transiting Northbound from substratum G2 to F2. Survey ended due to animals diving and not resurfacing.
19	01 August / 09:41	8m 20s	2.71	5 x Adults (no tusks) 1 x Calf	Mother-calf pair plus three adults (no tusks) observed travelling west in loose cluster formation. Later joined by single adult (no tusk). Calf shifted position between under, side, and above its presumed mother, remaining tightly associated. Nursing observed. When mother went to depth, calf associated with another female in group. Mother and calf reunited towards end of survey. Nordic Olympic transiting northbound from substratum G2 to E2. Survey ended due to battery
25	03 August / 17:39	3m 18s	2.91	1 x Adult (no tusk) 1x Yearling	Mother-yearling pair observed travelling northwest. Yearling circled its presumed mother loosely before resuming tight position underneath mother. Nordic Odin transiting northbound from substratum J2 to I2. Survey ended due to animals diving and not resurfacing.
26	03 August / 18:04	5m 45s	4.70	2 x Adult (no tusks) 1 x Calf 1 x yearling	Mother and calf observed travelling northeast in tight parallel formation. Calf remained tightly under its mother. Nursing observed. Nordic Odin transiting northbound from substratum J2 to I2. Survey ended due to animals diving and not resurfacing.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
30	04 August / 11:13	12:56m	4.09	2 x Adult (tusks) 2 x Adult (no tusks) 1 x Calf	Group observed travelling southeast in tight cluster formation, stopping to mill and socialize at depth in non-directional manner. Calf tightly associated with mother throughout survey. Nursing observed. When mother departed group, calf associated with tusked adult before splitting off and diving. Golden Ice transiting southbound through substratum C2. Survey ended due to animals diving and not resurfacing.
31	04 August / 11:22	3m 13s	2.70	3 x Adult (tusks) 1 x Juvenile (tusk) 1 x Calf	Group observed travelling north in loose parallel formation. Calf's presumed mother not apparent in group. Calf split off and dove in first minute of survey. Golden Ice transiting southbound from substrata D2 to E2. Survey ended due to battery.
32	04 August / 11:28	2m 09s	2.32	1 x Adult (no tusk) 1 x Yearling 1 x Calf	Mother-yearling pair and lone calf observed travelling north in loose linear formation. Group spent most of the time at depth with calf swimming ahead of mother-yearling pair. Yearling tightly associated with mother. Golden Ice transiting southbound from substratum E2 to F2. Survey ended due to animals diving and not resurfacing.
33	04 August / 11:36	2m 11s	1.87	1 x Adult (tusk) 1 x Juvenile (tusk)	Group observed milling non-directionally, shifting between loose parallel formation and no formation. Golden Ice transiting southbound through G2. Survey ended due to animals diving and not resurfacing.
34	04 August / 11:39	2m 35s	2.13	1 x Adult (tusk)	Single adult observed travelling north. Golden Ice transiting southbound from substratum G2 to H2. Survey ended due to animal diving and not resurfacing.
35	04 August / 11:40	51s	1.77	1 x Adult (tusk) 1 x Adult (no tusk) 1 x Juvenile (tusk)	Group observed milling in general northwest direction. Golden Ice transiting southbound from substratum G2 to H2. Survey ended due to animals diving and not resurfacing.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
36	04 August / 11:41	47s	1.92	1 x Adult (tusk) 1 x Adult (no tusk) 1 x Juvenile (no tusk) 1 x Calf	Group observed milling in loose cluster formation, moving in general southwest direction. Calf positioned loosely in front and abreast of its presumed mother. Golden Ice transiting southbound through H2. Survey ended due to animals diving and not resurfacing.
37	04 August / 11:44	47s	2.03	1 x Adult (no tusk) 1 x Yearling	Mother-yearling pair observed milling in easterly direction. Yearling positioned tightly beneath its presumed mother. Golden Ice transiting southbound through H2. Survey ended due to animals diving.
54	05 August / 12:38	3m 29s	4.33	2 x Adult (tusks)	Two adults observed travelling west in loose linear formation. Arkadia transiting northbound towards substratum J2. Survey ended due to animals diving and not resurfacing.
55	05 August / 12:43	2m 47s	3.22	2 x Adult (no tusks) 1 x Juvenile (tusk) 1 x Yearling	Mother-yearling pair with adult observed travelling west in loose cluster formation. Joined by juvenile, continued travelling west. Arkadia transiting northbound towards substratum J2. Survey ended due to animals diving and not resurfacing.
63	06 August / 16:03	11m 50s	3.33	5 x Adult (tusks)	Two adults with tusks observed travelling south in loose parallel formation. Three additional adults joined group, stopping briefly to mill and socialize before resuming travel south in loose parallel formation. Nordic Qinngua transiting southbound from substratum D2 to F2. Survey ended due to battery.
64	06 August / 16:18	1m 36s	1.69	1 x Adult (tusk) 1 x Juvenile (tusk)	Group observed travelling east in loose parallel formation. Group later moves to tight formation. Nordic Qinngua transiting southbound through substratum I2. Survey ended due to animals diving and not resurfacing.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
65	06 August / 16:21	3m 15s	2.10	1 x Adult (tusk) 1 x Adult (no tusk) 1 x Calf	Mother-calf pair observed travelling east. Calf positioned tightly beneath presumed mother. Travel interrupted by adult male that appeared to chase mother and calf to depth. Adult male then travelled south. Mother-calf resurface and travelled northeast before diving. Nordic Qinngua transiting southbound through substratum I2. Survey ended due to animals diving and not resurfacing.
70	07 August / 10:53	1m 47s	2.86	1 x Adult (no tusk) 1 x Calf	Mother-calf pair observed milling non-directionally, with calf tightly associated throughout the survey. M.V. Golden Brilliant transiting northbound through substratum I2. Survey ended due to animals diving and not resurfacing.
71	07 August / 10:53	7m 53s	0.96	2 x Adult (no tusk) 1 x Juvenile (tusk) 2 x Juvenile (no tusks) 1 x Yearling	Group (all excluding 1 adult) observed travelling northeast in tight cluster formation. Group loosened and milled temporarily, then travel resumed in westerly direction, shifting between cluster and parallel formations. Yearling positioned tightly above and below its presumed mother. M.V. Golden Brilliant transiting from substratum I2 to H2. Survey ended due to battery.
72	07 August / 11:11	36s	1.54	1 x Adult (no tusk) 1 x Calf	Mother-calf pair observed travelling north in tight parallel formation. Calf tightly associated throughout survey. M.V. Golden Brilliant transiting from substratum G2 to F2. Survey ended due to animals diving and not resurfacing.
74	07 August / 14:19	12m 29s	1.13	3 x Adult (tusks)	Three adults observed socializing and milling non-directionally and in no formation. Nordic Orion transiting southbound from substratum C2 to G2. Survey ended due to battery.
78	08 August / 10:21	7m 55s	2.64	6 x Adult (tusks) 1 x Adult (no tusk) 1 x Juvenile (tusk) 1 x Juvenile (no tusk)	Single juvenile (no tusk) observed travelling west. Later joined by other individuals and all travelled west in tight cluster formation. Group gradually split up and dove. Nordic Odyssey transiting northbound from substratum I2 to H2. Survey ended due to group diving and not resurfacing.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
79	08 August / 10:24	4m 32s	2.63	1 x Adult (tusk) 1 x Juvenile (tusk)	Pair observed travelling south in tight linear formation. Juvenile dove out of sight and adult continued travelling south. Adult (no tusk) joins toward end of survey. Nordic Odyssey transiting northbound through substratum G2. Survey ended due to battery.
98	11 August / 16:15	14m 47s	2.02	3 x Adult (no tusks) 1 x Juvenile (no tusk) 2 x Yearlings	Group observed travelling northeast in loose cluster formation. Group went to depth then resurfaced. Intermittent milling observed. First yearling associated tightly underneath its presumed mother, occasionally to the right or above. Second yearling loosely associated and to the left of presumed mother, later moving tightly below mother. Golden Suek transiting southbound from substratum F2 to H2. Survey ended due to battery.
99	11 August / 16:32	35s	3.49	1 x Adult (tusk)	Single adult observed travelling northeast. Golden Suek transiting southbound from substratum I2 to J2. Survey ended due to animal diving and not resurfacing.
100	11 August / 16:33	6m 29s	3.84	4 x Juvenile (tusks)	Group observed travelling east in tight cluster formation. Group began socializing at depth, though barely visible. Golden Suek transiting southbound through substratum J2. Survey ended due to animals diving and not resurfacing.
107	13 August / 16:11	13m 8s	4.89	3 x Adult (tusks) 3 x Adult (no tusk) 1 x Adult (unknown tusk) 1 x Calf	Group observed milling in westerly direction in loose cluster formation. Adult males appeared unusually interested in calf, as though they were trying to separate it from its presumed mother. The same individuals had been observed conducting this behaviour several hours prior to this survey, during which time no ships were present. Animals were consistently shifting formations, spread and direction throughout survey. Calf was intermittently without its mother but would join her several times to “escape” the other males. Males would eventually catch up and again attempt to separate calf from its mother. Nordic Nuluujak transiting northbound from substratum J2 to I2. Survey ended due to animals diving and not resurfacing.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
108	13 August / 16:20	39s	1.55km	1 x Adult (no tusk) 1 x Yearling 1 x Calf	Three narwhal observed travelling north in loose parallel formation. Calf observed tightly beneath its presumed mother. Yearling is not considered to have mother present. Nordic Nuluujak transiting northbound from substratum I2 to H2. Survey ended due to animals diving and not resurfacing.
109	13 August / 16:23	10m 7s	1.02	4 x Adult (tusks) 1 x Juvenile (tusk)	Group observed socializing at depth tightly without formation. Numerous instances of rubbing, tusking, and rolling. Animals consistently rotating around one another. Nordic Nuluujak transiting northbound from substratum H2 to F2. Survey ended due to battery.
110	13 August / 16:44	5m 50s	1.73	1 x Adult (tusk) 4 x Adult (no tusk) 1 x Juvenile (tusk) 4 x Yearling	Group observed travelling north in tight cluster formation. Group loosened throughout the survey, eventually diving out of sight. Nordic Nuluujak transiting northbound from substratum D2 to C2. Survey ended due to animals diving and not resurfacing.
111	13 August / 16:50	3m 15s	2.04	1 x Juvenile (tusk)	Single juvenile observed travelling southwest. Nordic Nuluujak transiting northbound from substratum C2 to B2. Survey ended due to animals diving and not resurfacing.
112	13 August / 17:45	9m 07s	2.17	3 x Adult (tusks) 1 x Adult (no tusk)	Group observed socializing tightly without formation. Temporarily travelled east, then resumed socializing. Group social behavior similar to FFID 109.
113	13 August / 19:41	31s	3.07	1 x Adult (tusk) 1 x Adult (no tusk)	Group observed travelling west in tight parallel formation. Botnica transiting northbound in H2, Golden strength transiting southbound through F2. Survey ended due to animals diving and not resurfacing.
114	13 August / 19:47	43s	2.71	2 x Adult (tusks) 1 x Juvenile (no tusk)	Group observed travelling west in tight parallel formation. Botnica transiting northbound in H2, Golden strength transiting southbound through F2. Survey ended due to animals diving and not resurfacing.
120	14 August / 11:40	10m 05s	2.55	7 x Adult (tusks)	Group observed travelling west in loose cluster formation. Golden Suek transiting northbound from substratum I3 to I2. Survey ended due to battery.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
121	14 August / 12:17	15m 41s	2.40	9 x Adult (tusks) 5 x Adult (no tusks) 2 x Juvenile (tusks) 3 x Yearling	Large group observed travelling south in tight cluster formation as part of herding event. Group includes three mother-yearling pairs. Golden Suek transiting northbound from substratum C1 to B2. Survey ended due to animals diving and not resurfacing.
124	14 August / 15:17	5m 36s	1.99	2 x Adult (tusks) 1 x Adult (no tusk) 1 x Juvenile (tusk)	Three adults observed travelling west in tight parallel formation, later in loose cluster formation. Sexual display observed my adult male. Sagar Samrat transiting southbound from substratum B1 to D1. Survey ended due to animals diving and not resurfacing.
125	14 August / 15:25	8m 7s	0.75	1 x Adult (tusk) 1 x Juvenile (tusk) 1 x Yearling	Adult and juvenile pair observed travelling north in parallel formation. Lone yearling joins group towards end of follow. Sagar Samrat transiting southbound from substratum F1 to H1. Survey ended due to animals diving and not resurfacing.
126	14 August / 15:39	3m 18s	2.01	8 x Adult (tusks) 6 x Adult (no tusks) 4 x Juvenile (tusks) 3 x Juvenile (no tusks) 1 x Yearling 1 x Calf	Group observed travelling east in cluster formation. Many individuals at depth. Yearling positioned tightly beneath its presumed mother. Calf positioned tightly to the right of its presumed mother. Sagar Samrat transiting southbound from substratum I1 to J2. Survey ended due to animals diving and not resurfacing.
127	15 August / 10:05	10m 8s	0.93	4 x Juvenile (Tusks)	Four juveniles observed socializing in tight parallel formation moving northwest. Golden Fast transiting northbound from substratum I2 to H2. Survey ended due to animals diving and not resurfacing.
128	15 August / 10:22	17m 30s	1.07	4 x Adult (tusks) 6 x Adult (no tusks) 2 x Yearling	Group observed milling loosely and non-directionally. Part of group went down to depth, the rest travelled southeast in loose cluster formation. Golden fast transiting northbound from substratum G1 to C2. Survey ended due to battery.
137	17 August / 10:29	1m 35s	4.84	1 x Adult (no tusk) 1 x Juvenile (tusk)	Pair observed travelling west in tight parallel formation. Elena Ve transiting southbound through substratum E2. Survey ended due to losing radial line of sight to group.

Table F-4: Summary of narwhal focal follow surveys conducted within 5 km of vessels in 2023.

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
1	11 August 2023 19:41	1m 17s	3.24	4 x Adult (no tusk) 5 Juvenile (no tusk) 2 x Yearling	Group of eleven observed travelling west in loose parallel formation. Two southbound ships in area; Golden Opal is closest with CPA of 3.24km and Nordic Odyssey with a CPA of 3.41km. Both yearlings were in tight left position relative to presumed mothers. Part of group including mother yearling pairs dove at 0:44, rest of group changed direction to N towards shoreline before diving. Survey ended due to animals diving and not resurfacing.

APPENDIX G

Ice Conditions in Eclipse Sound and Milne Inlet in Early August 2023

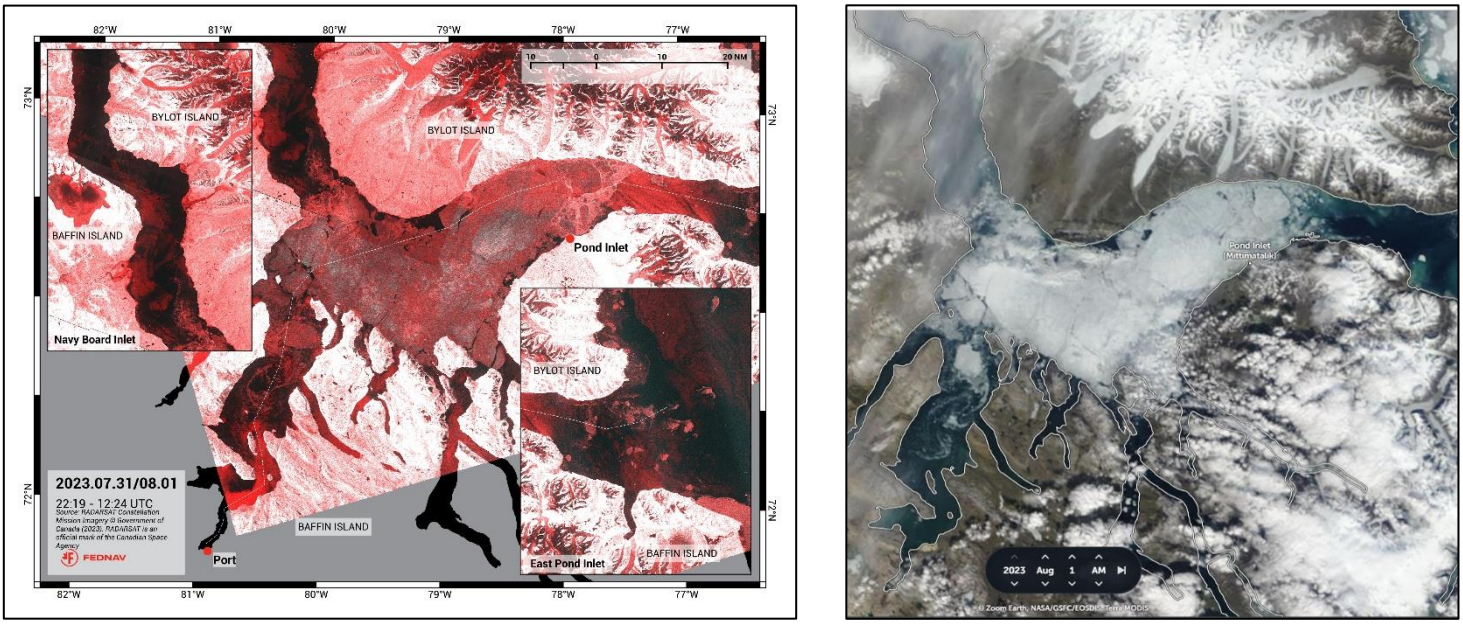

Figure G1: Satellite ice imagery (left) and Zoom Earth™ satellite images (right) showing ice conditions in Eclipse Sound area on 01 August 2023.

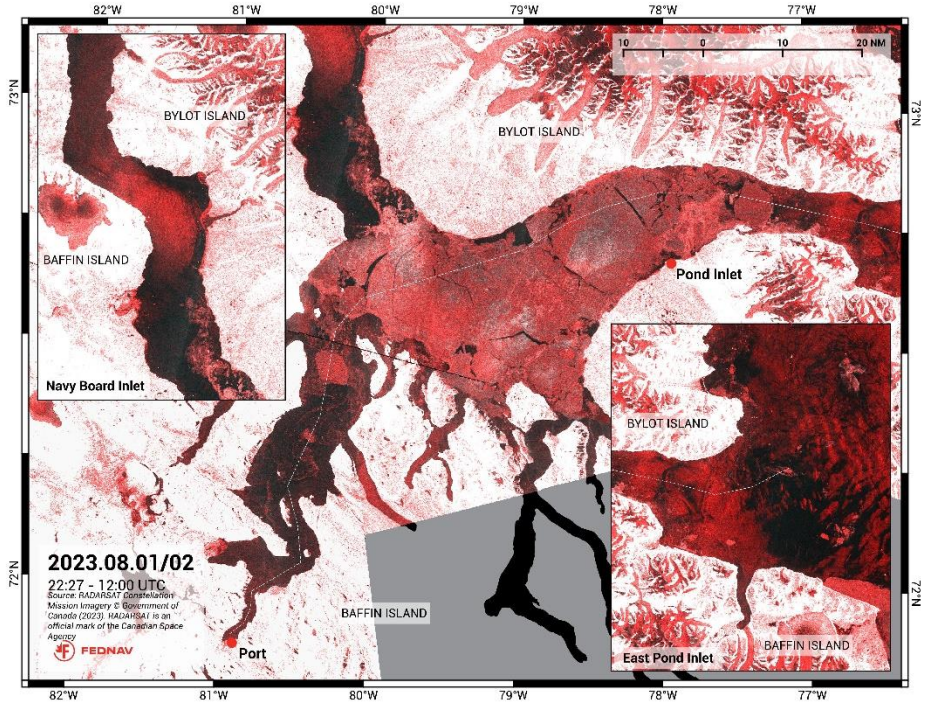

Figure G2: Satellite ice imagery showing ice conditions in Eclipse Sound area on 02 August 2023.

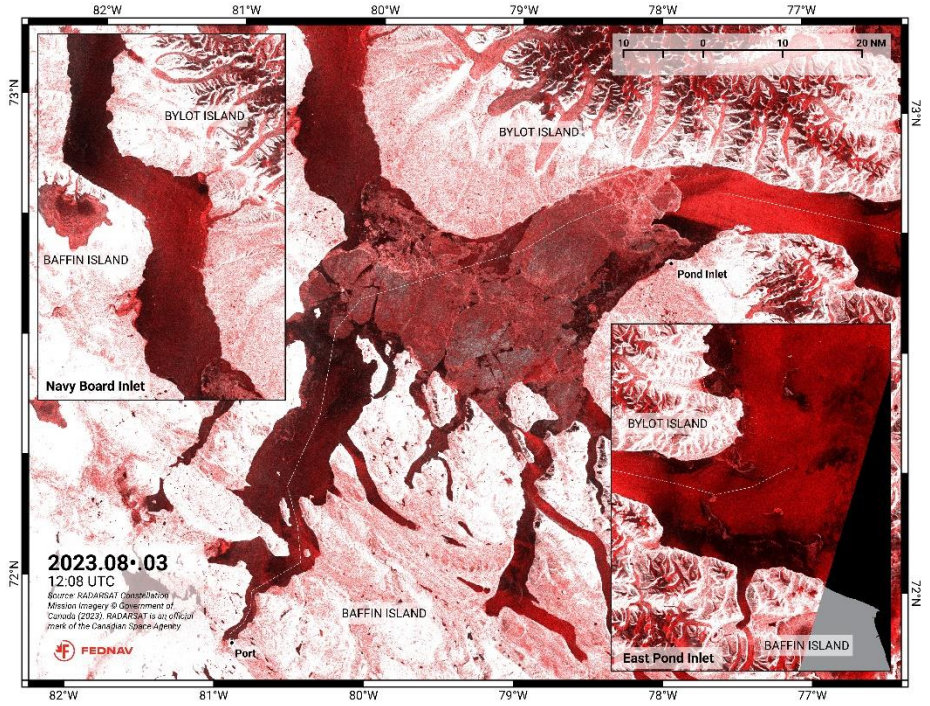

Figure G3: Satellite ice imagery showing ice conditions in Eclipse Sound area on 03 August 2023.

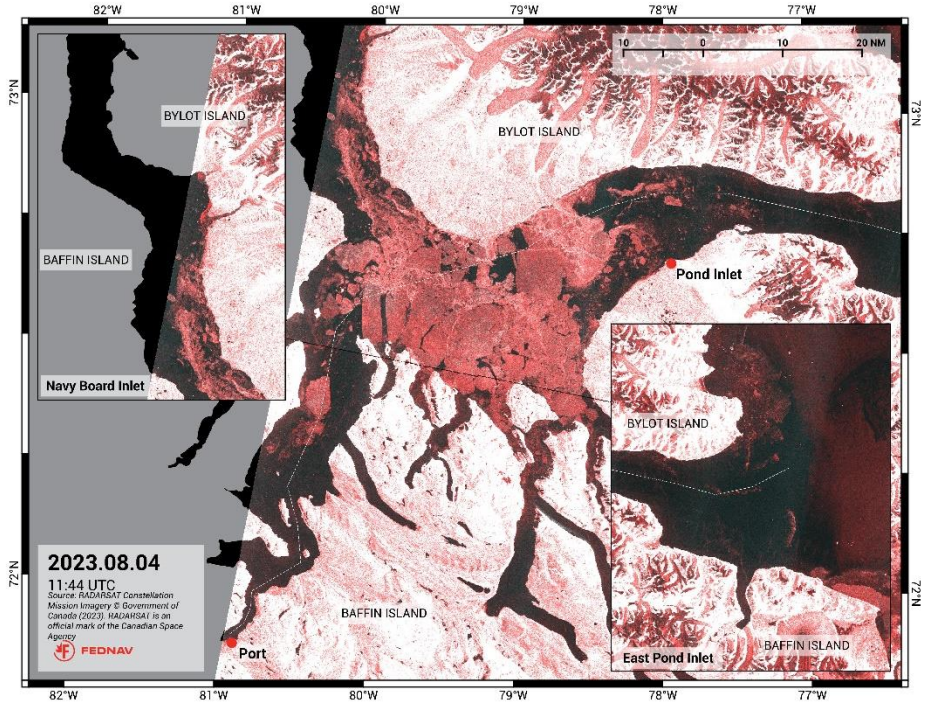

Figure G4: Satellite ice imagery showing ice conditions in Eclipse Sound area on 04 August 2023.

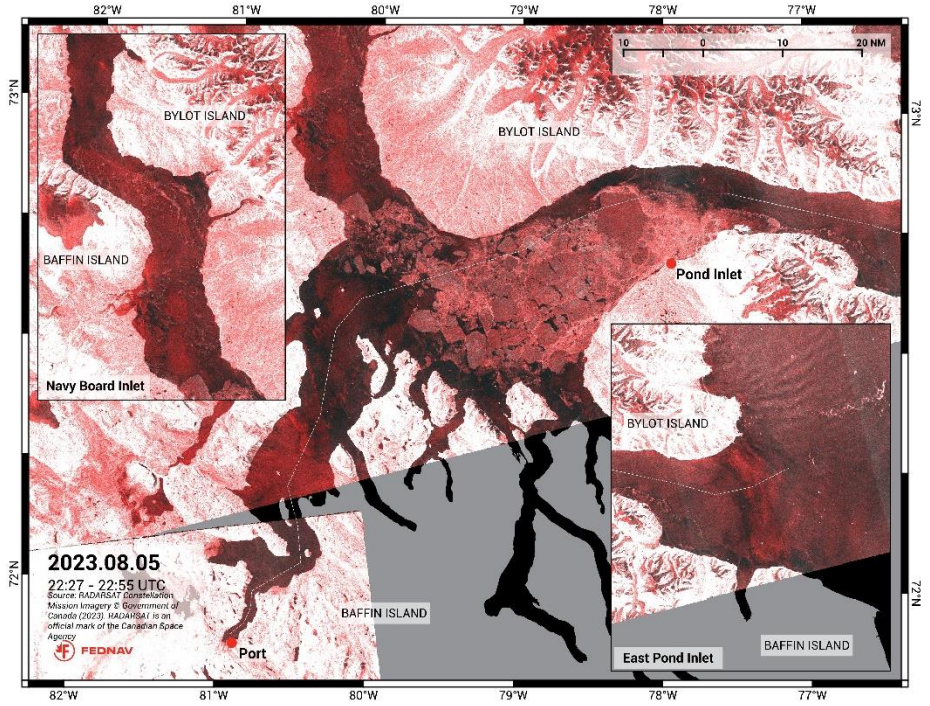

Figure G5: Satellite ice imagery showing ice conditions in Eclipse Sound area on 05 August 2023.

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