FINAL REPORT

Mary River Project

2021 Bruce Head Shore-based Monitoring Program

Submitted to:

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Executive Summary

The Mary River Project (hereafter, “the Project”) is an operating open pit iron ore mine owned by Baffinland Iron Mines Corporation (Baffinland) and located in the Qikiqtani Region of North Baffin Island, Nunavut. To date, Baffinland has been operating in the Early Revenue Phase (ERP) of the Project and is currently authorized to transport 6.0 million tonnes per annum (Mtpa) of iron ore to global markets. The operating mine site is connected to Milne Port, located at the head of Milne Inlet, through which iron ore is transported to chartered ore carrier vessels for open water shipping along the Project’s Northern Shipping Route.

The Project’s Northern Shipping Route encompasses Milne Inlet, Eclipse Sound, Pond Inlet, and adjacent water bodies. This coastal fjord system represents important summering grounds for narwhal (*Monodon monoceros*) in the Canadian Arctic. To investigate narwhal response to shipping activities along the Northern Shipping Route, the Bruce Head Shore-based Monitoring Program (“the Program”) has been conducted annually since 2014 (with the exception of 2018), following a pilot project in 2013. The Program was designed to specifically address Project Certificate (PC) conditions 99c, 101g, 109, and 111, related to evaluating potential disturbance of marine mammals from shipping activities that may result in changes in animal abundance, distribution, and migratory movements within the Project’s Regional Study Area (RSA). The 2021 Bruce Head Shore-based Program represents the seventh year of environmental effects monitoring undertaken at Bruce Head in support of the Project.

This report presents the integrated results of shore-based monitoring of narwhal and vessel traffic in Milne Inlet during the 2014-2017 and the 2019-2021 open-water seasons. Behavioural response of narwhal to Project-related ore carriers and other non-Project-related vessel traffic was investigated by collecting visual survey data from a cliff-based observation platform at Bruce Head, overlooking the Northern Shipping Route. Information was collected on relative abundance and distribution (RAD), group composition, and behaviour of narwhal near Bruce Head. Additional data were collected on environmental conditions and anthropogenic activities (e.g., shipping and hunting activities) to distinguish between the potential effects of Project-related shipping activities and confounding factors that may also influence narwhal behaviour.

Based on analysis of data obtained during previous Bruce Head Shore-based Monitoring Programs, as well as consultation with the various stakeholder groups (i.e., the Marine Environment Working Group or “MEWG”), it was determined that a more in-depth understanding of potential effects of shipping activities to narwhal could be obtained through the integration of an Unmanned Aerial Vehicle (UAV) and by correlating visual observations with concurrent acoustic data. As such, the use of an UAV was incorporated into the 2020 and 2021 Programs to enhance the collection of observational data on narwhal group composition and behaviour.

The following is a summary of key findings pertaining to narwhal behavioural response to vessel traffic based on seven years of shore-based visual survey data collected at Bruce Head between 2014 and 2021.

Relative Abundance and Distribution

- Interannual variation: The relative abundance of narwhal (total number of narwhal corrected for survey effort) in the Stratified Study Area (SSA) was substantially lower in 2020 and 2021 than in previous survey years (2014-2019), including years prior to the start of Baffinland’s iron ore shipping operations in the RSA (i.e., 2014). The observed decrease in local narwhal abundance at Bruce Head in 2021 is consistent with findings from the 2020 and 2021 aerial surveys which indicated that narwhal abundance in Eclipse Sound was statistically lower in 2020 and 2021 than in previous survey years (2013, 2016 and 2019) (Golder 2022). However, the combined narwhal abundance in Eclipse Sound and Admiralty Inlet was shown to be similar in 2020 to that observed in previous survey years (2013 and 2019); and was statistically higher in 2021 than in previous survey years (2013, 2019 and 2020) (Golder 2022). These results suggest a displacement or shift of a portion of the Eclipse Sound stock to the Admiralty Inlet summering ground during the summer of 2021.

Narwhal Density

- Vessel exposure was shown to result in a significant decrease in narwhal density in the SSA compared to when no vessels were present, but only when narwhal were in close proximity to vessels (i.e., within 2 km from a vessel). This was equivalent to a maximum period of 14 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remain 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 (1-26 Aug), there were approximately two vessel transits per day in the SSA (58 one-way transits in SSA over a 24-day period). Therefore, the maximum period per day associated with vessel disturbance on narwhal density was 28 minutes. These findings are consistent with previous years' findings and with behavioural results from the narwhal tagging study (Golder 2020a), indicating that narwhal density in the SSA is influenced by vessel traffic, but this was limited to close distances (i.e., within 2 km of a vessel). 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., up to 14 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

Group Composition and Behaviour

- Group Size: Modelling results from the combined multi-year dataset suggest that narwhal may associate in marginally larger group sizes when in close proximity (<1 km) to vessels. 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 remain stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). The maximum period per day associated with vessel disturbance on narwhal group size was 14 minutes (based on an average of two vessel transits per day in the SSA). A change in group cohesion (e.g., change in group size) by narwhal is consistent with a moderate severity behavioural response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., up to 7 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

- Group Composition:
  - All narwhal life stage categories (adults, juveniles, yearlings, and calves) were recorded in the BSA throughout the seven-year sampling program.

- The mean daily proportion of calves recorded in the BSA (relative to the total number of narwhal observed per day) was higher in 2021 (annual mean of mean daily calf proportions = 14.8%) than all previously estimated annual means, which ranged from 9.5% (2017) to 12.9% (2015). While this may suggest that calving rate (i.e., reproductive success) of the Eclipse Sound summering stock in 2021 was consistent with pre-shipping levels, the finding is likely attributed to the influence of two survey days when narwhal sightings in the BSA were limited to a single mother-calf pair, resulting in a 50% daily calf proportion on those days.
- Presence of Immatures: Consistent with previous years' findings, results based on the combined multi-year dataset suggest that narwhal groups are more likely to include immatures when in close proximity (<2 km) to vessels. This finding is potentially due to groups without calves or yearlings being more capable of diving and moving away, thus inflating the probability of observing groups with calves or yearlings at the surface. The noted response was shown to be short in duration, equivalent to a maximum period of 14 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial exposure (i.e., a temporary effect). The maximum period per day associated with vessel disturbance on narwhal group composition was 28 minutes (based on an average of two vessel transits per day in the SSA). A change in group cohesion and/or a disruption of female and dependant offspring (exceeding baseline case) is consistent with a moderate severity behavioural response. However, given the temporary nature of the effect (i.e., up to 14 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.
- Proportion of Immatures (Early Warning Indicator "EWI"): Findings from the multi-year dataset indicated that the proportion of immature narwhal (i.e., calves and yearlings) in the observed population in 2021 was lower than all previous sampling years. The observed change represented a 24% decrease in the proportion of immatures but was not significantly lower than the 2014/2015 baseline condition, indicating that the EWI threshold was not exceeded. However, the observed effect size and its 95% confidence interval (-55% to +7%) suggest a decrease in the 2021 annual proportion of immatures relative to the observed population, thereby warranting further investigation. Golder has recommended that Baffinland undertake an equivalent EWI analysis of the 2021 aerial survey data (using the dedicated 1000 ft. survey data which was collected for this purpose) to further investigate this finding.

- Group Spread: Modelling results from the combined multi-year dataset suggest that narwhal congregate in more tightly associated groups when in close proximity (i.e., ≤ 2 km) to vessels. The noted response was shown to be short in duration, equivalent to a maximum period of 14 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial exposure (i.e., a temporary effect). The maximum period per day associated with vessel disturbance on narwhal group spread was 28 minutes (based on an average of two vessel transits per day in the SSA). A change in group cohesion (e.g., change in group spread) by narwhal is consistent with a moderate severity behavioural response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., up to 14 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

- Group Formation: Narwhal groups were most often observed in parallel formation under both vessel presence and vessel absence scenarios. Consistent with previous years' findings, results from the combined multi-year dataset suggest that narwhal do not significantly alter their group formation in response to vessel traffic. The lack of response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.
- Group Direction: Narwhal groups were predominantly observed travelling south through the BSA. Consistent with previous years' findings, results from the combined multi-year dataset suggest that narwhal group travel direction is not affected by approaching vessels but that narwhal groups may avoid "following" in the wake of vessels moving away from the Behavioural Study Area (BSA). That is, narwhal tended to move in the opposite direction of vessels that move away from the BSA, regardless of whether the vessel was north- or southbound. The noted response was demonstrated up to a maximum distance of 4-km from the vessel, equivalent to a period of 28 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). The maximum period per day associated with vessel disturbance on narwhal group direction was 56 minutes (based on an average of two vessel transits per day in the SSA). A change in orientation response (e.g., a change in group direction) by narwhal is consistent with a low severity behavioural response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., up to 28 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.
- Travel Speed: Results from the combined multi-year dataset suggest that if narwhal were among other narwhal groups travelling at a medium or fast speed, they were more likely to travel slowly when less than 4 km from a vessel compared to when no vessels were present. For narwhal occurring among other narwhal groups already travelling slowly, no significant change in group travel speed was evident. The noted response was shown to be short in duration (i.e., within 4 km of a vessel) equivalent to a maximum period of 28 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial exposure (i.e., a temporary effect). The maximum period per day associated with vessel disturbance on narwhal group travel speed was 56 minutes (based on an average of two vessel transits per day in the SSA). A change in energy expenditure (e.g., a change in travel speed) by narwhal is consistent with a moderate severity response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., up to 28 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

- Distance from Bruce Head Shoreline: Narwhal groups were observed more often within 300 m of the Bruce Head shoreline under both vessel presence and vessel absence scenarios. Results from the combined multi-year dataset suggest that narwhal may swim closer to shore when in close proximity (≤2 km) to vessels. The noted response was shown to be short in duration, equivalent to a maximum period of 14 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). The maximum period per day associated with vessel disturbance on narwhal distance from shore was 28 minutes (based on an average of two vessel transits per day in the SSA). A minor deviation from typical migratory pathway (e.g., a change in distance from shore) by narwhal is consistent with a low severity response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., up to 14 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

UAV Focal Follow Surveys

- The UAV focal follow surveys differed from the observer-based data collection in the BSA in that emphasis was placed on narwhal groups that comprised immatures (e.g., mother/calf pairs) to better assess potential behavioural responses of narwhal in more vulnerable life stages, including potential vessel effects on nursing behaviour and relative positioning of dependants during vessel interactions.
- A total of 249 unique focal follow surveys have been conducted to date (85 surveys in 2020 and 164 surveys in 2021), providing 23.6 hours of recorded behavioural data of narwhal near Bruce Head. Of the focal follow surveys conducted, 43 surveys coincided with a vessel transiting within 5 km of the focal group, providing a total of 3.9 hours of behavioural data in the presence of vessels (CPA between 0.4 km and 4.7 km). While the additional data collected via UAV focal follow surveys in 2021 is valuable in providing insight into narwhal behaviour, the sample size in close proximity to vessels remains insufficient to conduct a meaningful quantitative analysis of behavioural response variables relative to ‘distance from vessel’, with total time spent within 0 km, 1 km, 2 km, and 3 km of focal groups including only 2.5 min, 11.5 min, 62.0 min, and 60.5 min, respectively. Therefore, results presented below pertaining to the UAV focal follow surveys should be interpreted accordingly.
- Group Formation (UAV-based): The most frequently observed group formation during the focal follow surveys was parallel (42% of time), similar to the predominant formation recorded in the BSA by shore-based observers. This was followed by linear formation (23% of the time) and cluster formation (23% of the time). In the absence of vessels, the proportion of groups in parallel formation was slightly lower (40% of the time) compared to when vessels were present (52%). In contrast, the proportion of groups in linear formation was slightly higher in the absence of vessels (24%) relative to when vessels were present (15%). The proportion of groups in cluster formation was similar when a vessel was absent compared to when a vessel was present (23% and 26%, respectively). No significant effect of vessel presence on group formation was demonstrated.
- Group Spread (UAV-based): Narwhal were shown to spend less time in tightly associated groups when vessels were present (32%) compared to when vessels were absent (44% of the time). This finding is

inconsistent with results obtained from the shore-based monitoring dataset which found that narwhal formed tighter groups in the presence of vessels. A limited sample size in the focal follow surveys at close range to vessels may contribute to observed discrepancy. Vessel presence was shown to have a marginally significant effect on group spread in mother-immature narwhal groups (P=0.071); but not for other group types (P>0.2 for all).

- Primary Behaviour (UAV-based): Narwhal spent the majority of time travelling (71% of the time), followed by resting / milling (22% of the time), and social behaviours (7% of the time). The proportion of time that narwhal spent resting / milling was similar when a vessel was present (19%) compared to when no vessels were present (12%). For groups including life stages that may be more vulnerable to disrupted opportunities to rest (i.e. mother-immature groups), the proportion of time engaged in resting / milling behaviour was 9-67% when a vessel was present (depending on distance from vessel) compared to 35% when no vessels were present. The proportion of time that mixed groups with immatures engaged in resting / milling behaviour was 14% when a vessel was present (sightings limited to 3 km distance form vessel) and 22% when a vessel was absent. No significant effect of vessel presence on primary behaviour was demonstrated.

- Unique Behaviours (UAV-based): 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 in 119 of the total focal follow surveys conducted, including during 23% of the time in the absence of vessels and 19% of the time when vessels were present. Vessel presence was shown to have a marginally significant effect on unique behaviour in adult groups (P=0.052) and lone calves (P=0.066); but not for mother-immature groups (P=0.5) or mixed groups with immatures (P=0.2).

  - Nursing: Nursing of a calf or yearling from its mother was recorded during 24 of the focal follow surveys (12 surveys in 2020 and 12 surveys in 2021; accounting for 14% and 7% of all groups in 2020 and 2021, respectively). During the 24 events where nursing was observed, time spent nursing ranged between 5% and 63% of the focal follow period (mean value of 25% of the time, SD of 17% of the time). Two focal follow surveys coinciding with vessel presence included nursing behaviour. No significant effect of vessel presence on nursing activity was demonstrated.

- Focal Groups with Immatures: Mother-immature pairs were observed in 45 individual focal follow surveys for a total of 170 min (including 21 min in the presence of vessels), while mixed groups with immatures were observed in 27 focal follow surveys for a total of 103 min (including 39 min in the presence of vessels). Calves were observed on their own (i.e., either as a single calf or two calves together without other individuals) in 22 individual focal follow surveys, for a total of 158 min (including 12 min in the presence of vessels).

  - Relative and Distal Association of Immature with Mother: Immatures were most often recorded underneath their presumed mother compared to abreast, behind, or above in both the presence and absence of vessels (40% and 49% of the time, respectively). When an immature was positioned underneath of the presumed mother, it was tightly associated with the adult 99% of the time and the association was not affected by vessel presence (97% in presence of vessel and 99% when no vessels were present). That is, immatures did not appear to change their relative or distal association with their mother in response to vessel presence. No significant effect of vessel presence on the relative position or spread of immatures was demonstrated. In general, the results may have implications for the broader shore-based monitoring program at Bruce Head, suggesting that calves and yearlings passing through the BSA may be disproportionally underrepresented given the reduced ability to sight a smaller animal underneath an accompanying adult.

Future Recommendations

With respect to future monitoring initiatives for the Bruce Head Shore-based Monitoring Program, Golder recommends the following:

- Increase emphasis on the UAV survey component of the program, given the valuable insight this tool provides with respect to monitoring changes in group composition and fine scale behaviours in the presence of shipping (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 or signs of aggression. While the sample size of surveys conducted when ships were ‘present’ remains insufficient to achieve adequate detection power for statistical analysis based on the 2020- 2021 integrated dataset alone, increasing the sample size through future UAV surveys would have the potential to quantitatively evaluate changes in key narwhal behaviours in response to shipping. Furthermore, UAV survey methods allow for increased data collection at the closer vessel approach distances (i.e., 0-2 km range) compared to the BSA study design because focal follows can be undertaken directly on the shipping lane; whereas vessels rarely approach at close distances to the BSA given the location of the shipping lane (which was adjusted further eastward in 2020).
- Undertake additional analysis of the 2021 aerial survey data for specific evaluation of the EWI metric (using the dedicated 1,000 ft survey data which was collected for this purpose) to confirm that this is a reflection of the low samples size and not a pattern of decreasing proportion of immature narwhal in the RSA.
- Undertake dedicated UAV surveys for narwhal group composition as a secondary assessment of the Early Warning Indicator metric (i.e., proportion of immature narwhal relative to the adult population). This would provide for improved detection probability and increased accuracy in animal detection and enumeration, age class determination and gender confirmation compared to the current traditional monitoring method (observer-based data collection). Having a permanent record of the UAV video survey will eliminate observer bias in the data collection phase and allow for a better assessment of variability in the EWI data.

ᐊᐅᓚᑦᑎᔨᓂᖖᒑᖅᑐᑦ ᓇᐃᓈᖅᓯᔪᑦ

ᓄᓘᔮᓐᓂ ᐱᓕᕆᐊᖅ (ᑭᙳᓂᐊᓂ, "ᐱᓕᕆᐊᒃᓴᖅ") ᐊᐅᓚᓂᖃᖅᑐᖅ ᐃᑎᖅᓴᓕᐅᖅᓱᑎᒃ ᓴᕕᒃᓴᓂᒃ ᐅᔭᕋᙵᓂᐊᖅᑐᑦ ᓇᒻᒥᓂᖅᑯᑎᒋᔭᐅᓪᓗᓂ ᐹᕝᕕᓐᓇ ᓴᕕᒃᓴᓂᒃ ᐅᔭᕋᙵᓂᐊᖅᑏᑦ ᑯᐊᐳᕇᓴᙳᑦ (ᐹᕝᕕᓐᓇ) ᐃᓂᐊᖅᑐᑦ ᕿᑭᖅᑕᓂ ᓄᓇᖁᑎᖏᓐᓂ ᐅᐊᖕᓇᖕᖓᓂ ᕿᑭᖅᑖᓗᒃ, ᓄᓇᕗᒻᒥ. ᐅᓪᓗᒥᒧᑦ, ᐹᕝᕕᓐᓇᑯᑦ ᐊᐅᓚᓂᖃᖅᓯᒪᔪᑦ ᐊᑐᖅᓱᓂᕐᔪᒃ ᑮᓇᐅᔾᔭᒃᓴᖃᕐᓂᓇᓯᐊᕐᓂᖅ (ERP) ᐱᓕᕆᐊᒥᒃ ᐊᒻᒪᓗ ᒫᓐᓇ ᐊᖏᖅᑕᐅᓯᒪᓪᓗᑎᒃ ᐊᐅᓪᓚᖅᑎᑦᑎᔪᓐᓇᖅᓱᑎᒃ 6.0 ᒥᓕᐊᓐ ᑕᓐᓯᓂᒃ ᐊᕐᕌᒍᑕᒫᑦ (Mpta) ᓴᕕᒃᓴᓂᒃ ᓄᓇᕐᔪᐊᒥ ᓂᐅᕐᕈᓯᕐᕕᐅᕙᒃᑐᓄᑦ. ᐊᐅᓚᓂᖃᖅᑐᑦ ᐅᔭᕋᙵᓂᐊᕐᕕᒃ ᐊᒃᑐᐊᔪᖅ ᕿᙳᐊᓄᑦ ᑐᓚᒃᑕᕐᕕᖕᒧᑦ, ᐃᓂᖃᖅᑐᑦ ᕿᙳᐊᓂ, ᐊᑐᖅᑕᐅᓪᓗᓂ ᓴᕕᒃᓴᓂᖅ ᐊᐅᔾᓚᖅᑎᑕᐅᕙᒃᑐᑦ ᓵᑕᖅᑕᐅᓯᒪᔪᑎᒍᑦ ᓴᕕᒃᓴᓂᒃ ᐅᓯᔭᓇᖅᑐᓂᒃ ᐅᒥᐊᕐᔪᐊᑦ ᓯᑯᖃᖏᑎᓪᓗᒍ ᐅᓯᔭᐅᓪᓗᑎᒃ ᑕᐅᕙᓇ ᐱᓕᕆᐊᑉ ᐅᑭᐅᖅᑕᖅᑐᒥ ᐊᐅᓪᓚᖅᑎᑦᑎᖃᑦᑕᕐᓂᕐᒧᑦ ᐊᖅᑯᑖᒍᑦ.

ᐱᓕᕆᐊᑉ ᐊᑭᐅᖅᑕᖅᑐᒥ ᐊᐅᓪᓚᖅᑎᑦᑎᖃᑦᑕᕐᓂᕐᒧᑦ ᐊᖅᑯᑖ ᐊᕙᑖᓃᑦᑐᖅ ᕿᙳᐊᓂ, ᑕᓯᐅᔭᕐᒥ, ᒥᑦᑎᒪᑕᓕᖕᒥ, ᐊᒻᒪᓗ ᖃᓂᒋᔭᖏᓐᓂᒃ ᐃᒪᕕᐅᔪᓂᒃ. ᓯᔫᒥᑦᑐᑦ ᑲᖏᖅᖢᑦ ᑭᒡᒐᖅᑐᐃᔪᑦ ᐱᒪᓇᐅᔪᒥᒃ ᐊᐅᔭᒃᑯᑦ ᑑᒑᓕᖕᓂᒃ ᐃᓂᒋᔭᐅᕙᒃᑐᓂᒃ (*Monodon monoceros*) ᑲᓇᑕᐅᑉ ᐅᑭᐅᖅᑕᖅᑐᖓᓂ. ᖃᐅᔨᓴᖅᑕᐅᖁᓪᓗᑎᑦ ᑑᒑᓖᑦ ᐃᓕᖅᑯᓯᓕᕆᓕᖅᐸᒃᑕᖏᑦ ᐊᐅᓪᓚᖅᑎᑦᑎᖃᑦᑕᕐᓂᕐᒥᒃ ᐱᓕᕆᔪᖃᖅᑎᓪᓗᒍ ᑕᐅᕙᓇ ᐅᑭᐅᖅᑕᖅᑐᒥ ᐊᐅᓪᓚᖅᑎᑦᑎᖃᑦᑕᕐᓂᕐᒧᑦ ᐊᖅᑯᑖᓂ, ᐃᓗᕕᓕᖕᒥ ᓯᓪᔭᒥ ᖃᐅᔨᓴᖅᐸᓪᓕᐊᖏᓐᓇᕐᓂᖏᓐᓄᑦ ᐱᓕᕆᐊᖅ ("ᐱᓕᕆᐊᖅ") ᐱᓕᕆᐊᙳᖃᑦᑕᖅᓯᒪᐃᓐᓇᖅᑐᑦ 2014-ᒥᓂᑦ (2018 ᐃᓚᐅᙱᖅᓱᓂ), ᑭᙳᓂᐊᒍᑦ ᓯᕗᓪᓕᖅᐹᒥᒃ ᖃᐅᔨᓴᕐᓂᐅᔪᒥᒃ ᐱᓕᕆᓪᓗᑎᒃ 2013-ᒥ. ᐱᓕᕆᐊᒃᓴᐅᔪᖅ ᐋᖅᑭᒃᓯᒪᓚᐅᖅᑐᑦ ᑖᒃᑯᓂᙵᓪᓚᑦᑖᖅ ᑲᒪᕐᑯᓪᓗᑎᑦ ᐅᕋᓂᐊᕈᓇᑎᒥ (PC) ᒪᓕᒃᑕᐅᔭᕆᐊᖏᑦ 99ᑎ, 101ᓂ, 109, ᐊᒻᒪᓗ 111, ᐊᒃᑐᐊᔪᑦ ᖃᐅᔨᓴᕐᓂᕐᒥᒃ ᐸᒡᕕᓴᖕᓂᐅᑐᐃᓐᓇᕆᐊᓕᖕᓂᒃ ᑕᕆᐅᒥ ᐳᐃᔾᔨᓂᒃ ᐊᐅᓪᓚᖅᑎᑦᑎᖃᑦᑕᕐᓂᕐᒧᑦ ᐱᓕᕆᓂᕐᓂᒃ ᓴᖅᑮᑐᐃᓐᓇᕆᐊᖏᑦ ᐊᓯᔾᔨᐅᑎᓂᒃ ᓂᕐᔪᑏᑦ ᐅᓄᕐᓂᖏᓐᓄᑦ, ᓇᓅᓐᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ ᑎᑭᐸᒃᑐᑦ ᐃᖏᕐᕋᕙᓐᓂᖏᓐᓂᒃ ᐱᓕᕆᐊᒥ ᓄᓇᐃᑦ ᐊᑯᒃᑐᖅᓯᒪᔪᑦ ᖃᐅᔨᓴᕐᕕᖏᓐᓂᒃ (RSA) . 2021 ᐃᓗᕕᓕᖕᒥ ᓯᓪᔭᒦᖕᖓᑎᒃ ᐱᓕᕆᐊᑦ ᑭᒡᒐᖅᑐᐃᔪᑦ 7-ᑭᓕᖅᑕᖕᖓᓂᒃ ᐊᕐᕌᒍᒥᑦ ᐊᕙᑎᓕᕆᓂᕐᒧᑦ ᐊᒃᑐᐃᓂᕐᓂᒃ ᖃᐅᔨᓴᖅᐸᓪᓕᐊᖏᓐᓇᕐᓂᖅ ᐱᓕᕆᐊᙳᖃᑦᑕᖅᓯᒪᔪᖅ ᐃᓗᕕᓕᖕᒥᒃ ᐃᑲᔪᖅᓯᕋᓯᐊᖅᓱᑎᒃ ᐱᓕᕆᐊᒥᒃ.

ᑖᓐᓇ ᐅᓂᒃᑳᖅ ᓴᖅᑭᔮᖅᑎᑦᑎᔪᖅ ᐃᓚᓕᐅᑎᔭᐅᓯᒪᔪᓂᒃ ᖃᐅᔨᓴᐅᔪᓂᒃ ᓯᓪᔭᒦᖕᖓᑎᒃ ᖃᐅᔨᓴᕐᐸᓪᓕᐊᖏᓐᓇᕈᑎᓂᒃ ᑑᒑᓕᖕᓂᒃ ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᓂᕙᒃᑕᖏᓐᓂᒃ ᕿᙳᐊᓂ ᐊᑐᖅᑎᓪᓗᒍ 2014-2017 ᐊᒻᒪᓗ 2019-2021 ᓯᑯᖃᙱᑎᓪᓗᒍ ᐅᒥᐊᕐᔪᐊᖃᕐᓂ. ᐃᓕᖅᑯᓯᓕᕆᔨᖅᐸᒃᑐᑦ ᑑᒑᓕᖕᓂᑦ ᐱᓕᕆᐊᒧᑦ-ᐊᒃᑐᐊᔪᓄᑦ ᓴᕕᒃᓴᓂ ᐅᓯᕙᒃᑐᓄᑦ ᐊᒻᒪᓗ ᐊᓯᖏᑦ ᐱᓕᕆᐊᒥᙳᖏᑦᑐᑦ-ᐊᒃᑐᐊᒧᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᑲᑕᒃᑕᖅᑐᑦ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᑐᑦ ᑲᑎᖅᓯᐃᓪᓗᑎᒃ ᑕᑯᔭᑎᒍᑦ ᖃᐅᔨᓴᕐᓃᑦ ᖃᐅᔨᓴᕈᑎᕕᓂᖏᓐᓂᒃ ᐃᓈᕈᕐᒥᓗᑎᒃ ᓇᐅᑦᑎᖅᓯᖅᓱᑎᒃ ᐃᓗᕕᓕᖕᒥ, ᓵᙱᓪᓗᓂ ᐅᑭᐅᖅᑕᖅᑐᒥ ᐅᓯᑲᖅᑕᕐᓂᖏᓐᓄᑦ ᐊᖅᑯᑖᓂ. ᑐᓴᐅᒪᔾᔪᑏᑦ ᑲᑎᖅᓯᖅᑕᐅᓚᐅᖅᑐᑦ ᐊᒃᑐᐊᔪᑦ ᐱᑕᖃᕐᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ ᓇᓅᖃᑦᑕᕐᓂᖏᓐᓄᑦ (RAD), ᑲᑎᙵᔪᑦ ᖃᓄᐃᓕᖓᓂᖏᑦ, ᐊᒻᒪᓗ ᐃᓕᖅᑯᓯᓕᖅᑕᐅᕙᒃᑐᑦ ᑑᒑᓕᖕᓂᒃ ᖃᓂᒋᔮᓂ ᐃᓗᕕᓕᐅᑉ. ᑎᑎᖅᑲᖁᑎᒃᑲᓐᓂᑦ ᑲᑎᖅᓯᖅᑕᐅᓚᐅᖅᑐᑦ ᐊᕙᑎᓕᕆᓂᕐᓂᕐᒧᑦ ᖃᓄᐃᓕᖓᓂᕐᒧᑦ ᐊᒻᒪᓗ ᐃᓄᐃᑦ ᐃᓕᖅᑯᓯᖏᓐᓂ ᖃᓄᐃᓕᐅᕈᑎᑦ (ᐆᒃᑯ ᐊᒻᒪᓗ ᐊᖏᓇᓱᓐᓂᑦ ᐱᓕᕆᓂᐅᔪᑦ) ᐊᔾᔨᒌᖏᓕᖅᑎᓐᓇᓯᐊᖅᑐᑦ ᐊᒃᑐᐃᓂᐅᑐᐃᓐᓇᕆᐊᖏᑦ ᐱᓕᕆᐊᒧᑦ-ᐊᒃᑐᐊᔪᑦ ᐅᓯᑲᖅᑕᕐᓂᖏᓐᓄᑦ-ᐱᓕᕆᓂᕐᓂᒃ ᐊᒻᒪᓗ ᓇᓗᓇᖅᓯᔭᑦᑐᑦ ᐱᔾᔪᑕᐅᔪᑦ ᐊᒃᑐᐃᑐᐃᓐᓇᕆᐊᓕᒃ ᑑᒑᓖᑦ ᐃᓕᖅᑯᓯᓕᖅᐸᒃᑕᖏᓐᓂᒃ.

ᑐᙵᕕᖃᖅᓱᑎᒃ ᖃᐅᔨᓴᕈᑎᓂᒃ ᑎᑎᖅᑲᖁᑎᓂᒃ ᐱᔭᐅᔪᑦ ᐱᓕᕆᑎᓪᓗᒋᑦ ᐃᓗᕕᓕᖕᒥᒃ ᓯᓪᔭᒦᖕᖓᑎᒃ ᖃᐅᔨᓴᖅᐸᓪᓕᐊᖏᓐᓇᕐᓂᖏᓐᓄᑦ ᐱᓕᕆᐊᒧᑦ, ᐊᒻᒪᓗᑦᑕᐅᖅ ᑐᓴᕋᓱᐊᖃᑦᑕᖅᑎᓪᓗᒋᑦ ᐊᔾᔨᙳᐊᖅᑐᓂᒃ ᓇᒻᒥᓂᖃᖅᑎᐅᔪᓄᑦ ᐃᓚᒋᔭᐅᔪᓂ (ᐆᒃᑯ ᑕᕆᐅᑉ ᐊᕙᑎᖓᓄᑦ ᐱᓕᕆᖃᑎᒌᑦ ᐅᕝᕙᓘᓐᓂᑦ "MEWG"), ᓇᓗᓇᐃᖅᑕᐅᓚᐅᖅᑐᑦ ᑐᑭᓯᓇᑦᑎᐊᒃᑲᓂᕐᓂᖅᓴᐅᓪᓗᑎᒃ ᐊᒃᑐᐃᓂᐅᓇᔭᖅᑐᑦ ᐅᓯᑲᖅᑕᕐᓂᖏᓐᓄᑦ ᐱᓕᕆᓅᑦ ᑑᒑᓕᖕᓄᑦ ᐱᔭᐅᔪᓐᓇᖅᑐᑦ ᐊᑐᕐᓗᑎᒃ ᐃᓚᓕᐅᑎᓯᒪᓗᑎᒃ ᐃᓄᒃᑲᙳᖏᑦᑐᑦ ᖃᖓᑕᔫᓯᖏᑦ ᐊᔾᔨᓕᐅᕈᑎᖏᑦ (UAV) ᐊᒻᒪᓗ ᐊᒃᑐᐊᖅᑲᑎᖏᑦ ᑕᐅᑐᙵᒃᑯᑦ ᐅᔾᔨᕈᓱᖕᓂᑦ ᑭᙵᓪᓕᐅᔪᑦ ᓂᐱᓄᑦ ᑎᑎᖅᑲᑏᑦ, ᑕᐃᒪᐃᓪᒪᑦ, ᐊᑐᖅᓂᖏᑦ ᐃᓄᒃᑲᙳᖏᑦᑐᑦ ᖃᖓᑕᔫᓯᖏᑦ ᐊᔾᔨᓕᐅᕈᑎᖏᑦ (UAV) ᐃᓚᓕᐅᔾᔭᐅᓚᐅᖅᑐᑦ 2020 ᐊᒻᒪᓗ 2021 ᐱᓕᕆᐊᒃᓴᐅᔪᓄᑦ ᐱᐅᓯᕆᐊᖅᑕᐅᖁᓪᓗᑎᑦ ᐅᔾᔨᕈᓱᖕᓂᑦ ᑎᑎᖅᑲᑎᓄᑦ ᑑᒑᓕᑦ ᑲᑎᙵᔪᑦ ᖃᓄᐃᓕᖓᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ ᐃᓕᖅᑯᓯᖏᓐᓄᑦ.

ᑭᙳᓂᐊᒍᑦ ᓇᐃᓈᖅᓯᒪᔪᑦ ᖃᐅᔨᓴᐅᓪᓗᐊᑕᖅᑐᑦ ᐊᒃᑐᐊᒧᑦ ᑑᒑᓖᑦ ᐃᓕᖅᑯᓯᓕᖅᐸᒃᑕᖏᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᖃᑦᑕᕐᓂᖏᑦ ᐱᓪᓗᒋᑦ ᒪᕿᒃᓂᒃ ᐊᕕᓕᖕᓄᑦ ᐊᕐᕌᒍᓄᑦ ᓯᕗᒥ ᑕᑯᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᖃᐅᔨᓴᕐᓂᕐᓂᒃ ᖃᐅᔨᓴᕈᑎᕕᓂᕐᓂᒃ ᑲᑎᖅᓯᖅᑕᐅᔪᑦ ᐃᓗᕕᓕᖕᒥ ᐊᑯᓂᐅᓪᓗᓂ 2021 ᐊᒻᒪᓗ 2021.

ᐅᓄᕐᓂᖅᑎᑦ ᓇᓃᑉᐸᖕᓂᖅᑎᓪᓗ

- ᐊᕐᕌᒍᒥᒃ ᐊᓪᓗᐃᑦᑕᖃᑦᑕᖅᑐᑦ ᐊᔾᔨᒌᙱᔾᔪᑎᖏᑦ: ᐅᓄᕐᓂᖏᓐᓄᑦ ᑑᒑᓘᑦ (ᑲᑎᓗᒃᑖᖅᓱᒋᑦ ᑑᒑᓘᑦ ᐋᖅᑭᐊᖅᑕᐅᓯᒪᒧᑦ ᖃᐅᔨᓴᕐᓂᐅᓇᓱᒃᑐᓄᑦ) ᑕᐃᒃᑯᓂ ᐊᕕᒃᑐᖅᓱᒋᑦ ᐅᓄᙱᓐᓂᖅᓴᐅᓗᑎᒃ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᑦ (SSA) ᐊᒃᐸᓯᙵᓂᖅᓵᕐᔭᐊᖑᓚᐅᖅᑐᑦ 2020-ᒥ ᐊᒻᒪᓗ 2021-ᒥ ᑕᑯᙳᐊᕐᓗᒋᑦ ᖃᐅᔨᕈᑎᕚᓃᑦ ᑭᖑᓂᖑᑦᑎᓐᓂ ᐊᕐᕌᒍᓂ (2014-2019), ᐱᖃᓯᐅᑎᓪᓗᒋᑦ ᐊᕐᕌᒍᐃᑦ ᐱᒋᐊᓚᐅᖅᑳᖅᑎᓇᒋᑦ ᐹᕙᓛᓐᑯᑦ ᓴᕕᒃᓴᓂᒃ ᐊᐅᓪᓚᖅᑎᑦᑎᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᐊᐅᓚᓃᑦ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᓂ (RSA) (ᓃᕐᓗ 2014). ᑕᑯᔭᐅᔪᑦ ᐅᓄᕈᓐᓂᖅᓯᒪᕚᓪᓕᖅᑐᑦ ᓄᓇᓕᐅᔪᓂ ᑑᒑᓕ ᐱᑕᖃᕐᓂᖏᓐᓄᑦ ᐃᓗᕕᓕᖅᒥ 2021-ᒥ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᖃᐅᔨᔭᐅᔪᓂᒃ 2020-ᒥ ᐊᒻᒪᓗ 2021-ᒥ ᖃᖓᑕᓲᒃᑯᑦ ᖃᐅᔨᓴᕐᓂᕐᓂᒃ ᓇᓗᓇᐃᖅᓯᓯᒪᔪᑦ ᑑᒑᓘᑦ ᐱᑕᖃᕐᓂᖏᑦ ᑕᓯᐅᔭᒥ ᓇᐃᓴᐅᑎᑎᒍᑦ ᐊᒃᐸᓯᙵᓂᖅᓴᐅᓚᐅᖅᑐᑦ 2020-ᒥ ᐊᒻᒪᓗ 2021-ᒥᓂᑦ ᑭᖑᓂᖑᑦᑎᓐᓂ ᖃᐅᔨᓴᕐᓂᐅᓚᐅᖅᓯᒪᔪᓂ ᐊᕐᕌᒍᓂ (2013, 2016 ᐊᒻᒪᓗ 2019) (ᒍᑐ 2022). ᑭᓯᐊᓂᓕ, ᑲᑎᓯᒪᔪᑦ ᑑᒑᓘᑦ ᐱᑕᖃᕐᓂᖏᑦ ᑐᓯᐅᔭᒥ ᐃᒃᐱᐊᕐᔫᓪᓗ ᐃᒪᖓᓂ ᓴᖅᑮᔭᖅᑎᑦᑎᓯᒪᔪᑦ ᐊᔾᔨᐸᓗᖏᓐᓂᒃ 2020-ᒥ ᑕᑯᔭᐅᓯᒪᔪᓄᑦ ᑭᖓᓂᖑᑦᑎᓐᓂ ᖃᐅᔨᓴᕐᓂᐅᓚᐅᖅᑐᓂ ᐊᕐᖄᒍᓂ (2013 ᐊᒻᒪᓗ 2019); ᐊᒻᒪᓗ ᓇᐃᓴᐅᑎᑎᒍᑦ ᖁᕝᕙᓯᙵᓂᖅᓴᐅᓪᓗᑎᒃ 2021-ᒥ ᑕᑯᓗᒋᑦ ᑭᖑᓂᖑᑦᑎᓐᓂ ᖃᐅᔨᓴᕐᓂᐅᓚᐅᖅᑐᓂ ᐊᕌᒎᔪᓂ (2013, 2019 ᐊᒻᒪᓗ 2020) (ᒍᑐ 2022). ᑕᒪᒃᑯᐊ ᖃᐅᔨᔭᐅᔪᑦ ᐃᒪᐃᓕᖓᖅᑯᔨᔪᑦ ᓅᓯᒪᓂᖅᑎᑦ ᓴᖑᓯᒪᓂᖅᑎᓪᓘᓐᓃᑦ ᐃᓚᖏᑦ ᑕᓯᐅᔭᒥ ᐱᑕᖃᕐᕕᐅᔪᑦ ᑕᐃᑯᖓ ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓᓄᑦ ᐊᐅᔭᒃᑯᑦ ᓇᔪᖅᑕᐅᕝᕕᒃᑐᒥ 2021-ᖑᑎᓪᓗᒍ.

ᑑᒑᓘᑦ ᐊᒥᓈᓂᖏᑦ

ᐅᒥᐊᕐᔪᐊᖃᖃᑦᑕᕐᓂᖓ ᓴᖅᑭᑕᐅᓚᐅᖅᑐᑦ ᖃᐅᔨᔭᐅᔾᔪᑕᐅᓪᓗᓂ ᐅᓄᕈᓐᓃᕐᔪᐊᕐᓂᖏᓐᓄᑦ ᑑᒑᓘᑦ ᐊᒥᓈᓂᖏᓐᓄᑦ ᑕᐅᕙᓂ ᐊᕕᒃᑐᖅᓱᒋᑦ ᐅᓄᙱᓐᓂᖅᓴᐅᓗᑎᒃ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᑦ (SSA) ᖃᓄᐃᓐᓂᖅᓴᐅᓂᖏᑦ ᑕᑯᓪᓗᒋᑦ ᑖᒃᑯᓄᖓ ᐅᒥᐊᕐᓇᐊᖅᑲᑦᑕᙱᑎᓪᓗᒍ, ᑭᓯᐊᓂᓕ ᑑᒑᓘᑦ ᖃᓂᑦᑐᒦᓕᕌᖓᑕ ᑭᓯᐊᓂᓕ ᐅᒥᐊᕐᔪᐊᓄᑦ (ᓃᕐᓗ 2 ᑭᓛᒥᑕᑦ ᖃᓂᒌᔭᓂ ᐅᒥᐊᕐᔪᐊᑦ). ᑖᓐᓇ ᓇᓕᒧᐸᓗᒃᑐᖅ ᐊᑯᓂᐅᓛᖑᔪᓐᓇᖅᑐᑦ 14 ᒥᓇᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᓂᖏᑦ (ᑐᙵᕕᖃᖅᓱᑎᒃ 9 ᓈᑦᓂᒃ ᐃᖏᕐᕋᓂᖃᖅᓱᑎᒃ, ᐃᓱᒪᒋᓗᒋᑦ ᑑᒑᓘᑦ ᓱᓕ ᐊᓯᔾᔨᖃᑦᑕᙱᑎᑦᑐᑦ ᑐᓴᒪᓗᐊᖅᑎᓪᓗᒋᑦ), ᓂᕐᔫᑎᑦ ᐅᑎᖅᐸᒃᓱᑎᒃ ᐃᓕᖅᑯᓯᕆᓚᐅᖅᑕᒥᖕᓄᑦ ᐊᓂᒍᓕᓵᖅᑎᓪᓗᒍ ᓯᕗᓪᓕᖅᐹᖅ ᑐᓵᕝᕕᒋᔭᖓᑦ (ᓃᕐᓗ ᕿᓚᒥᐅᓚᐅᒃᑐᖅ ᐊᒃᑐᐃᓂᖅ). ᐱᓕᕆᑎᓪᓗᒋᑦ ᐱᓕᕆᐊᒥᒃ (1-26 ᐋᒻᒋᓯ), ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᓚᐅᖅᑐᑦ ᒪᕐᕉᒃ ᐅᒥᐊᕐᔪᐊᒃ ᐅᑎᖅᑕᖅᐸᒡᓗᑎᒃ ᖃᐅᑕᒫᑦ ᐊᕕᒃᑐᖅᓱᒋᑦ ᐅᓄᙱᓐᓂᖅᓴᐅᓗᑎᒃ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᑦ (SSA) (58 ᐅᖓᒡᒧᑐᐊᖅ ᐊᖏᕐᕋᓗᓂ ᑕᐅᓲᓇ ᐊᕕᒃᑐᖅᓱᒋᑦ ᐅᓄᙱᓐᓂᖅᓴᐅᓗᑎᒃ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᑦ (SSA) ᐊᑐᖅᑎᓪᓗᒍ 24-ᓄᑦ ᐅᓪᓗᓄᑦ). ᑕᐃᒪᐃᒻᒪᑦ, ᐅᓄᓛᖑᔪᓐᓇᖅᑐᑦ ᖃᐅᑕᒫᑦ ᐊᒃᑐᐊᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐸᑦᕕᓴᐃᖃᑦᑕᕐᓂᖏᓐᓂᒃ ᑑᒑᓕᖕᓂᒃ ᐱᑕᖃᕐᕕᐅᓂᐅᔪᓂᒃ 28 ᒥᓇᑦᖑᓚᐅᖅᑐᑦ. ᑕᒪᒃᑯᐊ ᖃᐅᔨᔭᐅᔪᑦ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᖀᖏᖅᑐᓂ ᐊᕐᕌᒍᓂ ᖃᐅᔨᔭᐅᓯᒪᔪᓂ ᐊᒻᒪᓗ ᐃᓕᖅᑯᓯᐅᓕᖅᐸᒃᑐᑦ ᓴᖅᑭᑦᑐᑦ ᑑᒑᓘᑦ ᓂᕕᖓᑖᓕᖅᑕᐅᓂᖏᓐᓄᑦ ᖃᐅᔨᓴᕐᓂᕐᒥᒃ (ᒍᑐ 2020ᐃ), ᓇᓗᓇᐃᖅᓯᓚᐅᖅᑐᑦ ᑑᒑᓕᖕᓂᒃ ᐱᑕᖃᕐᕕᐅᓪᓚᕆᒃᑐᑦ ᐊᕕᒃᑐᖅᓱᒋᑦ ᐅᓄᙱᓐᓂᖅᓴᐅᓗᑎᒃ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ (SSA) ᐊᒃᑐᖅᑕᐅᓯᒪᖕᒪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᑕᐅᕗᓇ, ᑭᓯᐊᓂᓕ ᑕᒪᓐᓇ ᑭᒡᓕᖃᖅᑐᑦ ᖃᓂᑦᑐᓄᑐᐊᖅ (ᓃᕐᓗ 2 ᑭᓛᒥᑕᒥᒃ ᖃᓂᒃᓴᕐᓗᓂ ᐅᒥᐊᕐᔪᐊᖅ). ᓄᓇᐅᔪᒥ ᓂᐱᖃᖅᑎᑦᑎᑦᑕᐃᓕᒪᓃᑦ (ᓃᕐᓗ ᐅᒥᐊᕐᔪᐊᓂᒃ) ᑑᒑᓕᖕᓄᑦ ᒪᓕᐃᑐᐃᓐᓇᖅᑐᑦ ᐊᒃᓯᐊᖑᙱᑦᑐᒥᒃ ᐃᓕᖅᑯᓯᖃᓕᖃᑦᑕᕐᓂᖏᓐᓄᑦ (ᓴᐅᑦᐋ ᐊᑕᖏᖅᓱᑎᒃ 2021). ᑭᓯᐊᓂᓕ ᐱᔾᔪᑕᐅᓪᓗᑎᒃ ᕿᓚᐅᒻᒥᐅᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᐊᒃᑐᐃᓃᑦ (ᓃᕐᓗ, ᑎᑭᖢᒍ 14 ᒥᓇᑦ ᐊᑐᓂ ᐅᒥᐊᕐᔪᐊᖅ ᐃᖏᕐᕋᑎᓪᓗᒍ) ᑕᒪᓐᓇ ᐃᓱᒪᒋᖃᓯᐅᔾᔮᙱᑦᑐᖅ ᑎᒥᖏᑦᑎᒍᑦ ᐊᖏᔪᒥ ᐃᖅᑯᓯᐅᓕᕐᓗᓂ ᐊᒻᒪᓗ ᓂᕆᐅᕆᔭᐅᓇᓂ ᓴᖅᑮᔾᔭᕋᓱᕆᔭᐅᙱᖢᓂ ᐊᓯᔾᔨᕐᔪᐊᕈᑎᒥᒃ ᐃᓕᖅᑯᓯᓇᐅᔭᖅᑕᖏᓐᓄᑦ ᖃᓄᐃᓕᖓᓂᐅᕝᕒᑐᓄᑦ ᑑᒑᓘᑦ ᑕᐅᕙᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ (RSA) ᐅᕝᕙᓘᓐᓃᑦ ᐸᕝᕕᓴᖕᓃᑦ ᖃᐅᑕᒦᖅᓯᐅᑎᖏᓐᓄᑦ. ᒪᓕᒃᓱᒋᑦ ᐊᒃᑐᐃᓃᑦ ᓂᕆᐅᕆᔭᐅᙱᑦᑐᑦ ᐊᑐᓂ ᖃᓄᐃᙱᓐᓂᑦᐊᕐᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ/ᐅᕝᕙᓘᓐᓃᑦ ᑎᒥᖏᑕ ᐆᒃᑲᓕᓂᖏᑦ ᑑᒑᓘᑦ ᑕᐅᕙᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ (RSA) ᐊᒃᑐᐃᓪᓚᕆᓚᔭᖅᑐᒃᓴᐅᔪᖅ ᐅᓄᕐᓂᖏᓐᓄᑦ ᑭᒡᓕᐅᕝᕕᒃᑐᓂᒃ. ᑕᒪᓐᓇ ᖃᓄᐃᓕᖓᓕᕐᓂᐅᔪᖅ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᓂᒃ ᑕᐃᑲᓂ ᑭᖑᓪᓕᖅᐹᒥᒃ ᐊᕙᑎᒧᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᐅᓂᒃᑳᓂᒃ (FEIS) ᑕᒪᑐᒧᖓ ᑮᓇᐅᔾᔭᒃᓵᓕᓇᓱᖕᓂᕐᒧᑦ (ERP), ᑕᐃᑲᓂᓗ ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖏᑦ ᐊᒃᑐᐃᓇᔭᖅᑐᑦ ᑑᒑᓕᖕᓂᒃ ᓂᕆᐅᒋᔭᐅᔪᑦ ᑭᒡᓕᖃᕐᓗᑎᒃ ᕿᓚᒻᒥᐅᔪᒥᒃ, ᖃᓂᒌᔭᓂᑐᐊᖅ ᑕᑯᑦᑕᐅᑎᑦᑕᐃᓕᒪᓂᕐᒧᑐᐊᖅ ᐃᓕᖅᑯᓯᐅᓗᓂ.

ᑲᑎᙵᔪᑦ ᖃᓄᐃᓕᖓᓂᖏᑦ ᐃᓕᖅᑯᓯᖏᓪᓗ

- ᑲᑎᙵᔪᑦ ᐊᖏᓂᖏᑦ: ᐋᖅᑭᙳᐊᖅᑕᐅᓯᒪᔪᑦ ᖃᐅᔨᔭᐅᔪᓂᑦ ᑲᑎᑕᐅᓯᒪᔪᓂ ᐊᕐᕌᒍᒐᓚᖓᓄᑦ ᖃᐅᔨᓴᕈᑎᕕᓂᕐᓂᒃ ᐃᒪᐃᓐᓇᓯᒋᓈᔪᑦ ᑖᒃᑯᐊ ᑑᒑᓘᑦ ᐊᒃᑐᐊᓂᖃᑐᐃᓐᓇᕈᓘᑦ ᐅᓄᕐᓂᖅᓴᒪᓇᖕᓄᑦ ᑲᑎᙵᔪᓄᑦ ᖃᓂᒋᔭᐅᔪᕐᒥᑎᓪᓗᒋᑦ (<1 ᑭᓛᒥᑕᑦ) ᐅᒥᐊᕐᔪᐊᓄᑦ. ᓇᓗᓇᕐᓗᒍ ᖃᓄᐃᓕᖓᓕᕐᓂᖏᑦ ᓴᖅᑮᔭᓚᐅᖅᑐᑦ ᕿᓚᒥᐅᓪᓗᑎᒃ, ᓇᓕᒧᑦᑐᑦ ᐊᑯᓂᐅᓛᖑᔪᓐᓇᖅᑐᒧᑦ 7 ᒥᓇᓂᒃ ᐊᑐᓂ ᐅᒥᐊᕐᔪᐊᖅ ᐃᖏᕐᕋᑎᓪᓗᒍ (ᑐᙵᕕᖃᖅᓱᑎᒃ 9 ᓈᑦᓂᒃ ᓱᒃᑲᓕᓂᖃᖅᓱᒃ, ᐃᓱᒪᒋᓪᓗᒋᑦ ᑑᒑᓘᑦ ᑕᒪᐃᓕᖓᐃᓐᓇᖃᑦᑕᕐᓂᖏᓐᓂᒃ ᑐᓴᑎᓪᓗᒋᑦ),

ᓂᕐᔪᑮᓪᓗ ᐅᑎᖅᐸᒃᓱᑎᒃ ᖃᓄᐃᓕᖓᓕᖅᑳᖅᑎᓐᓇᒋᑦ ᐃᓕᖅᑯᓯᕗᑦᑕᕐᓂᐅᓄᑦ ᑭᖑᓂᐊᒍᑦ ᐅᒥᐊᕐᔪᐊᒥᒃ ᑐᓵᖃᓚᐅᖅᑎᓪᓗᒋᑦ (ᓃᕐᓗ ᕿᓚᒥᐅᔪᖅ ᐊᒃᑐᐃᓂᖅ). ᐊᑯᓂᐅᓛᖑᔪᓐᓇᖅᑐᖅ ᐊᑐᓂ ᐅᓪᓗᕐᒧᑦ ᐊᒃᑐᐊᒧᖅ ᐅᒥᐊᕐᔪᐊᑦ ᐸᒃᕕᓴᐃᓂᖅᑎᑦ ᑑᓚᖓᑦ ᑲᑎᙵᔪᑦ ᐊᖏᓂᖏᓐᓄᑦ 14 ᒥᓇᑦᖑᓚᐅᖅᑐᑦ (ᑐᙵᕕᑦᓗᒋᑦ ᒪᕐᕈᓚᔪᒃᑐᑦ ᐅᒥᐊᕐᔪᐊᑎᑦ ᐃᖏᕐᕋᖃᑦᑕᕐᓂᖏᑦ ᐊᑐᓂ ᐅᓪᓗᒧᑦ ᑕᐅᕗᓂ ᐊᕕᒃᑐᖅᓱᒋᑦ ᐅᓄᙱᓐᓂᖅᓴᐅᓗᑎᒃ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᑦ (SSA)). ᐊᓯᔾᔨᖅᑐᖅ ᑲᑎᙵᔪᑦ ᑲᑎᙵᐃᓐᓇᕐᓂᖏᑦ (ᓃᕐᓗ ᐊᓯᔾᔨᖅᑐᖅ ᑲᑎᙵᔪᑦ ᐅᓄᕐᓂᖏᑦ) ᑖᑉᓱᖓ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᒃᓯᐊᓘᐸᓗᒃᑐᓄᑦ ᐃᓕᖅᑯᓯᕆᔭᐅᓕᖅᐸᒃᑐᓄᑦ (ᓴᐅᑦᐋ ᐊᑕᖏᖅᓱᑎᒃ 2021). ᑭᓯᐊᓂᓕ ᐱᔾᔪᑕᐅᓪᓗᑎᒃ ᑭᓚᒥᐅᓂᖏᓐᓄᑦ ᐊᒃᑐᐃᓃᑦ (ᓃᕐᓗ ᑎᑭᓪᓗᒍ 7 ᒥᓇᑦ ᐊᑐᓂ ᐊᒥᕐᔪᐊᖅ ᐃᖏᕋᑎᓪᓗᒍ), ᑕᒪᓐᓇ ᐃᓱᒪᒋᖃᓯᐅᔾᔮᖏᑦᑐᖅ ᑎᒥᖏᑦᑎᒍᑦ ᐊᖏᔪᒥ ᐃᖅᑯᓯᐅᓕᕐᓗᓂ ᐊᒻᒪᓗ ᓂᕆᐅᒋᔭᐅᖏᑦᑐᑦ ᓴᖅᑮᔾᕋᓯᒋᔭᐅᙱᓪᓗᓂ ᐊᓯᔾᔩᕐᔪᐊᕈᑎᒥᒃ ᐃᓕᖅᑯᓯᓈᓇᐅᔭᖅᑕᖏᓐᓄᑦ ᖃᓄᐃᓕᖓᓂᐅᑉᑐᓄᑦ ᑑᓚᖕᒧᑦ ᑕᐅᕗᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥ (RSA) ᐸᒃᕕᓴᐃᙱᓪᓗᑎᒃᓗ ᖃᐅᑕᒫᖅᓯᐅᑎᖏᓐᓂ. ᒪᓕᒃᓱᒋᑦ ᐊᒃᑐᐃᓃᑦ ᓂᕆᐅᒋᔭᐅᙱᑦᑐᑦ ᐊᑐᓂ ᖃᓄᐃᙱᓐᓂᑦᐊᕐᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ/ᐅᕝᕙᓘᓃᑦ ᑎᒥᖏᑕ ᓱᒃᑲᓂᖏᑦ ᑑᓚᖓᑦ ᑕᐅᕗᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥ (RSA) ᐊᒃᑐᐃᓪᓚᕆᒐᓚᖅᑐᖅᓴᐅᔪᖅ ᐅᓄᕐᓂᖏᓐᓄᑦ ᑭᒡᓕᐅᕙᒃᑐᓂᒃ. ᑕᒪᓐᓇ ᖃᓄᐃᓕᖓᓕᕐᓂᐅᔪᖅ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᓂᒃ ᑕᐃᑲᓂ ᑭᖑᓪᓕᖅᐹᒥᒃ ᐊᕙᑎᒧᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᐅᓂᒃᑳᓂᒃ (FEIS) ᑕᒪᑐᒧᖓ ᑮᓇᐅᔾᔭᒃᓭᓕᓇᓱᖕᓂᕐᒧᑦ (ERP), ᑕᐃᑲᓂᓗ ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖏᑦ ᐊᒃᑐᐃᓇᔭᖅᑐᑦ ᑑᓚᖕᓂᒃ ᓂᕆᐅᒋᔭᐅᔪᑦ ᑭᒡᓕᖃᕐᓱᑎᒃ ᕿᓚᒻᒥᐅᔪᒥᒃ, ᖃᓂᒌᔭᓂᑐᐊᖅ ᑕᑯᑦᑕᐅᑎᑦᑕᐃᓕᒪᓂᕐᒧᑐᐊᖅ ᐃᓕᖅᑯᓯᐅᓗᓂ

ᑕᒪᓐᓇ ᖃᓄᐃᓕᖓᓕᕐᓂᐅᔪᖅ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᓂᒃ ᑕᐃᑲᓂ ᑭᖑᓪᓕᖅᐹᒥᒃ ᐊᕙᑎᒧᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᐅᓂᒃᑳᓂᒃ (FEIS) ᑕᒪᑐᒧᖓ ᑮᓇᐅᔾᔭᒃᓭᓕᓇᓱᖕᓂᕐᒧᑦ (ERP), ᑕᐃᑲᓂᓗ ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖏᑦ ᐊᒃᑐᐃᓇᔭᖅᑐᑦ ᑑᓚᖕᓂᒃ ᓂᕆᐅᒋᔭᐅᔪᑦ ᑭᒡᓕᖃᕐᓱᑎᒃ ᕿᓚᒻᒥᐅᔪᒥᒃ, ᖃᓂᒌᔭᓂᑐᐊᖅ ᑕᑯᑦᑕᐅᑎᑦᑕᐃᓕᒪᓂᕐᒧᑐᐊᖅ ᐃᓕᖅᑯᓯᐅᓗᓂ

- ᑲᑎᙵᔪᑦ ᖃᓄᐃᓕᖓᓂᖏᑦ:
  - ᑑᓚᓪᓗᒃᑖᑦ ᐃᓅᓯᖏᓐᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᑦ (ᑎᒻᒪᐃᑦ, ᑎᕿᑐᕋᐃᑦ, ᐋᕐᕋᓂᓴᑦ, ᐊᒻᒪᓗ ᐅᑭᐊᑦ) ᑎᑎᕋᖅᑕᐅᓚᐅᖅᑐᑦ ᐃᓕᖅᑯᓯᕆᔭᐅᓕᖅᐸᒃᑐᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐃᓂᐅᔪᖅ (BSA) ᐱᓕᕆᐊᓗᒃᑖᓂ ᒫᕐᕉᖓᓂᒃ ᐊᕐᕕᓃᖓᓄᑦ-ᐊᕐᕋᒍᓄᑦ ᖃᐅᔨᓴᒃᓴᓕᐅᕐᓂᕐᒧᑦ ᐱᓕᕆᐊᓂ.
  - ᖃᐅᑕᒫᑦ ᓇᐃᓴᐅᑎᐅᓚᐅᒃᑐᖅ ᐅᓄᕐᓂᖏᓐᓄᑦ ᐅᑭᐊᑦ ᑎᑎᕋᖅᑕᐅᓯᒪᔪᑦ ᐃᓕᖅᑯᓯᕆᔭᐅᓕᖅᐸᒃᑐᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐃᓂᐅᔪᒥ (BSA) (ᐊᒃᑐᐊᔪᑦ ᑲᑎᓪᓗᒃᑖᕐᓱᒋᑦ ᓇᐃᓴᐅᑎᖏᑦ ᑑᓚᖓᑦ ᑕᑯᔭᐅᔪᑦ ᐅᓪᓗᑕᒫᑦ) ᖁᕝᕙᓯᖕᓂᖅᓴᐅᓚᐅᖅᑐᑦ 2021-ᒥ (ᐊᕐᕌᒍᑕᒫᑦ ᓇᐃᓴᐅᑎᖑᒐᔪᒃᑐᖅ ᓇᐃᓴᐅᑐᑎᓄᑦ ᐅᑭᐊᖃᑦ = 14.8%) ᑖᒃᑯᓇᓂ ᐊᑕᖏᖅᓱᒋᑦ ᑭᖑᓂᖓᑦᑎᓐᓂ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᑦ ᐊᕐᕌᒍᑕᒫᖅᓯᐅᑏᑦ ᓇᐃᓴᐅᑎᓂᒃ, ᐊᔾᔨᒌᙱᑦᑎᕈᓘᔭᓚᐅᖅᑐᑦ ᑕᕝᕙᖕᒐᑦ 9.5%-ᒥᑦ (2017) 12.9%-ᒧᑦ (2015). ᑕᒪᓐᓇ ᐃᒪᐃᑎᑦᑎᕐᑰᔨᒐᓗᐊᖅᓱᓂ ᐅᑭᐊᖃᖃᑦᑕᕐᓂᖏᑦᑕ ᓇᐃᓴᐅᑎᖏᑦ (ᓃᕐᓗ ᕿᑐᖕᖏᐅᑦᑎᐊᕐᓂᖏᓐᓄᑦ) ᑕᓯᐅᔭᒥ ᐊᐅᔾᔭᑯᑦ ᐱᑕᖃᕐᑯᐅᕝᑐᒥ 2021-ᒥ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐅᒥᐊᕐᔪᐊᖃᖃᑦᑕᖅᑳᖅᑎᓐᓇᒍ ᖁᕝᕙᓯᓕᕆᓄᑦ ᓇᐃᓴᐅᑎᓄᑦ, ᖃᐅᔨᔭᐅᔪᑦ ᐃᓚᓕᐅᑎᔾᑕᐅᔪᖅ ᐊᒃᑐᐃᓂᕐᓄᑦ ᒫᕐᕉᖕᓄᑦ ᖃᐅᔨᓴᕐᓂᕐᓄᑦ ᐅᓪᓗᓄᑦ ᑑᓚᖓᑦ ᑕᑯᔭᐅᖃᑦᑕᓚᐅᖅᑎᓪᓗᒋᑦ ᑕᐅᕗᓂ ᐃᓕᖅᑯᓯᕆᔭᐅᓕᖅᐸᒃᑐᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐃᓂᐅᔪᒥ (BSA) ᐅᓄᓚᐅᙱᑐᑦ ᐃᓄᑐᐊᖅ ᐋᓇᒌᒃ–ᐅᑭᐊᕆᒃ, ᓴᖅᑮᓪᓗᓂ 50%-ᒥᒃ ᖃᐅᑕᒫᖅᓯᐅᑎᑦ ᐅᑭᐊᓖᑦ ᑕᐃᑯᓇᓂ ᐅᓪᓗᓂ.

- ᐱᑕᖅᑕᕐᓂᖏᑦ ᐃᓄᑭᙱᑦᑐᑦ ᓯᓚ: ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᕐᕋᒎᓚᐅᖅᑐᓂ ᖃᐅᔨᔭᐅᔪᓂ, ᑲᑎᑕᐅᓯᒪᔪᓂ ᐊᕐᕋᒍᑉᓚᖕᓄᑦ ᖃᐅᔨᓴᕈᑎᕕᓂᕐᓂᒃ ᐃᒪᐃᖅᑰᔨᓇᓱᒋᓈᔪᑦ ᑖᒃᑯᐊ ᑑᓚᖓᑦ ᑲᑎᙵᔪᑦ ᐃᓚᐅᑎᑦᑎᔪᒃᓴᐅᔪᑦ ᐃᓄᑭᖅᓯᒪᙱᑦᑐᒃ ᓯᓚ ᖃᓂᒋᔭᐅᑎᓪᓗᒋᑦ (<2 ᑭᓛᒥᑕᑦ) ᐅᒥᐊᕐᔪᐊᓄᑦ. ᑕᒪᓐᓇ ᖃᐅᔨᔭᐅᔪᖅ ᐱᔾᔪᑕᐅᑐᐃᓐᓇᕆᐊᓕᒃ ᑲᑎᙵᔪᑦ ᐅᒥᐊᖕᖏᑦᑐᑦ ᐅᕝᕙᓘᓃᑦ ᐊᕐᕋᓂᓴᖅᑕᖅᖏᑦᑐᑦ ᐊᖅᑲᕋᔭᖅᑐᒃᓴᐅᓂᖏᓐᓂᒃ ᐊᒻᒪᓗ ᕿᒫᓗᑎᒃ, ᑕᒪᓐᓇ ᐅᓄᖅᓯᒋᐊᖅᓯᓗᓂ ᑕᐃᒪᐃᑐᐃᓐᓇᕆᐊᖃᕐᓂᖏᓐᓂᒃ ᑕᑯᔭᐅᓗᑎᒃ ᑲᑎᙵᔪᑦ ᐅᒥᐊᓖᑦ ᐊᕐᕋᓂᓴᓖᓪᓘᓃᑦ >ᐃᑭᓯᓗᑎᒃ. ᑎᑎᕋᖅᑕᐅᓯᒪᔪᖅ ᖃᓄᐃᓕᖓᕐᓂᐅᕙᒃᑐᑦ ᓴᖅᑭᔮᖅᑎᑦᑎᔪᖅ ᕿᓚᒥᐅᓪᓗᓂ, ᒪᓕᑐᐃᓐᓇᖅᑐᒧᑦ ᐊᑯᓂᐅᓛᖑᔪᓐᓇᖅᑐᒧᑦ 14 ᒥᓇᑦ ᐊᑐᓂ ᐅᒥᐊᕐᔪᐊᒧᑦ ᐃᖏᕐᕋᓂᐅᔪᖅ (ᑐᙵᕕᖅᓱᑎᒃ 9 ᓈᑦᓂᒃ ᓱᒃᑲᓂᖅᖢᑎᒃ, ᐃᓱᒪᒋᓪᓗᒋᑦ ᑑᓚᖓᑦ ᑕᒪᐃᓕᖓᐃᓐᓇᖃᑦᑕᕐᓂᖏᓐᓂᒃ ᑐᓵᑎᓪᓗᒋᑦ, 28 ᒥᓇᑦᖑᓚᐅᖅᑐᖅ (ᑐᙵᕕᒋᓪᓗᒋᑦ ᐊᑐᖅᑕᐅᓚᐅᒃᑐᑦ ᒫᕐᕉᒃ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔪᑦ ᖃᐅᑕᒫᑦ ᑕᐅᕗᔭᓂ ᐊᕕᒃᑐᖅᓱᒋᑦ ᐅᓄᙱᓐᓂᖅᓴᐅᓗᑎᒃ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᑦ (SSA)). ᐊᓯᔾᔨᕐᓂᖏᑦ ᑲᑎᙵᔪᑦ ᒪᓕᒃᑐᖅ ᐊᒻᒪᓗ/ᐅᕝᕙᓘᓃᑦ ᐅᓚᕕᓴᖅᑕᐅᓂᖏᑦ ᐊᕐᓇᐃᑦ ᐊᒻᒪᓗ ᕿᑐᙵᖏᑦ (ᐅᖓᑕᐅᔾᔨᓯᒪᔪᑦ ᐱᒋᐊᕈᑕᐅᔪᓂᒃ ᖃᐅᔨᓴᕈᑎᓄᑦ ᐋᖅᑭᒃᑕᐅᓯᒪᔪᓂᒃ) ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐱᓗᐊᕈᕚᔭᖅᑐᒥᒃ ᐃᓕᖅᑯᓯᖃᓕᖃᑦᑕᕐᓂᖏᓐᓄᑦ. ᑭᓯᐊᓂᓕ ᐱᔾᔪᑕᐅᓪᓗᑎᒃ ᕿᓚᐅᒥᐅᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᐊᒃᑐᐃᓃᑦ (ᓃᕐᓗ, ᑎᑭᓪᓗᒍ 14 ᒥᓇᑦ ᐊᑐᓂ ᐅᒥᐊᕐᔪᐊᖅ ᐃᖏᕋᑎᓪᓗᒍ) ᑕᒪᓐᓇ ᐃᓱᒪᒋᖃᓯᐅᔾᔮᖏᑦᑐᖅ ᑎᒥᖏᑦᑎᒍᑦ ᐊᖏᔪᒥ ᐃᖅᑯᓯᐅᓕᕐᓗᓂ ᐊᒻᒪᓗ ᓂᕆᐅᒋᔭᐅᓇᓂ ᓴᖅᑮᔾᕋᓯᒋᔭᐅᙱᓪᓗᓂ ᐊᓯᔾᔩᕐᔪᐊᕈᑎᒥᒃ ᐃᓕᖅᑯᓯᓈᓇᐅᔭᖅᑕᖏᓐᓄᑦ ᖃᓄᐃᓕᖓᓂᐅᑉᑐᓄᑦ ᑑᓚᖕᒧᑦ ᑕᐅᕗᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥ (RSA) ᐅᕝᕙᓘᓃᑦ

ᐸᒃᕕᓴᖅᓃᑦ ᖃᐅᑕᒫᖅᓯᐅᑎᖏᓐᓄᑦ. ᒪᓕᒃᑯᓯᑦ ᐊᒃᑐᐃᓂᑦ ᓂᕈᐅᒋᔭᐅᙱᑦᑐᑦ ᐊᑐᓂ ᖃᓄᐃᙱᓐᓂᑦᐊᕐᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ/ᐅᕝᕙᓘᓐᓃᑦ ᑎᒥᖏᑕ ᓱᖃᓕᓂᖏᑦ ᑑᒃᓖᑦ ᑕᐅᕗᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ (RSA) ᐊᒃᑐᐃᓪᓚᕆᖃᔭᖅᑐᒃᓴᐅᔪᖅ ᐅᓄᕐᓂᖏᓐᓄᑦ ᑮᓕᐅᕝᑐᓂᒃ. ᑕᒪᓐᓇ ᖃᓄᐃᓕᖓᓕᕐᓂᐅᔪᖅ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᒥᒃᓴᐅᓭᑕᐅᓯᒪᔪᓂᒃ ᑕᐃᑲᓂ ᑭᖑᓪᓕᖅᐹᒥᒃ ᐊᕙᑎᒧᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᐅᓂᒃᑳᓂᒃ (FEIS) ᑕᒪᑐᒪᖓ ᑰᓇᐅᔾᔭᒃᓵᓕᓇᓱᖕᓂᕐᒧᑦ (ERP), ᑕᐃᑲᓂᑯ ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖏᑦ ᐊᒃᑐᐃᓇᔭᖅᑐᑦ ᑑᒃᓕᖕᓂᒃ ᓂᕈᐅᒋᔭᐅᔪᑦ ᑮᓕᖃᕐᑯᑎᒃ ᕿᓚᒻᒥᐅᔪᒥᒃ, ᖃᓂᒋᔮᓂᑐᐊᖅ ᑕᑯᑦᑕᐅᑎᑦᑕᐃᓕᒪᓂᕐᒧᑐᐊᖅ ᐃᓕᖅᑯᓯᐅᑯᓂ.

- ᐃᓚᒋᔭᐅᔪᑦ ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ (ᖃᐅᔮᓭᓕᓯᒪᔭᖃᕆᐊᓕᑦ ᓇᑯᓇᐃᖅᓯᔾᔪᑎᑦ "EWI"): ᖃᐅᔮᔭᐅᔪᑦ ᐊᕐᕌᒍᓖᓐᓄᑦ ᑎᑎᖅᑲᖁᑎᓃᑦᑐᑦ ᓇᑯᓇᐃᖅᓯᔪᑦ ᑕᒪᒃᑯᐊ ᐃᓚᖏᑦ ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ ᑑᒃᓖᑦ (ᓲᕐᓗ ᐅᒋᐊᑦ ᐊᒻᒪᓗ ᐊᕐᕌᓂᓴᑦ) ᓇᐅᑦᑎᖅᓱᖅᑕᐅᔪᓂ ᐃᓄᕐᓂᖏᓐᓂ 2021-ᒥ ᐊᒃᐸᓱᖕᓂᖅᓴᐅᓚᐅᖅᑐᑦ ᐊᑕᖏᖅᑯᓯᑦ ᑭᖑᓂᖕᖔᑦᑎᓐᓂ ᖃᐅᔨᓴᓚᒃᓴᓕᐅᕐᓂᕐᒧᑦ ᐊᕐᕌᒎᔪᓂ. ᐅᔾᔨᕆᔭᐅᔪᑦ ᐊᓯᔾᔨᐅᑏᑦ ᑭᒡᓚᖅᓱᐃᔪᑦ 24%-ᒥᒃ ᐅᓄᕈᓃᖅᐸᓕᖅᑐᑦ ᐃᓚᖏᓐᓂ ᐃᓐᓇᕈᖅᓯᓖᓂᙱᑦᑐᓂᒃ ᑭᓯᐊᓂᓕ ᐊᖏᔫᙱᓐᓂᖅᓴᐅᔪᑦ ᐊᒃᐸᓱᖕᓂᖅᓴᐅᔪᓂ ᑖᒃᑯᓇᓂ 2014/2015 ᐱᒋᐊᕈᑕᐅᔪᓂ ᖃᐅᔨᓴᕐᓂᕐᓂ ᖃᓄᐃᓕᖓᓂᐅᔪᓂ, ᓇᑯᓇᐃᖅᓯᓪᓗᑎᒃ ᖃᐅᔮᓭᓕᓯᒪᔭᖃᕆᐊᓕᑦ ᓇᑯᓇᐃᖅᓯᔾᔪᑎᓄᑦ (EWI) ᖃᓄᐃᓪᓕᔪᖃᖅᑳᖅᑎᓐᓇᒍ ᑮᓕᐅᔪᓂᒃ ᐅᖓᑕᐅᔾᔨᓯᒪᓚᐅᙱᒻᒪᑦ. ᑭᓯᐊᓂᓕ, ᐅᔾᔨᕆᔭᐅᔪᑦ ᐊᒃᑐᐃᓂᕐᒧᑦ ᐊᖏᓂᖏᑦ ᐊᒻᒪᓗ 95%-ᖑᔪᑦ ᐅᒃᐱᕆᔭᐅᓪᓚᕆᒃᑐᑦ ᐊᑯᓕᕇᑦ (-55%-ᒥᑦ +7%-ᒧᑦ) ᐃᒪᐃᓐᓇᓱᒋᓐᓈᔪᑦ ᐅᓄᕈᓐᓂᕐᓂᖏᑦ 2021-ᒥ ᐊᕐᕌᒍᑕᒫᑦ ᐃᓚᒋᔭᐅᔪᑦ ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᓄᑦ ᐊᒃᑐᐊᖅ ᐅᔾᔨᕆᔭᐅᔪᓂᒃ ᐅᓄᕐᓂᖏᓐᓄᑦ, ᑕᐃᒪᐃᓐᓂᖓᓄᑦ ᓱᓕᔫᓇᓱᒋᓐᓈᔪᑦ ᖃᐅᔨᓴᖅᑕᐅᒃᑲᓐᓂᕆᐊᖃᕐᓂᖏᓐᓂᒃ. ᒫᑐᒃᑯᑦ ᐊᑐᓕᕐᑯᔮᔪᑦ ᐸᕝᕕᓐᓃᑯᑦ ᐱᓕᕿᐊᖃᕐᓗᑎᒃ ᓇᓕᒧᑦᑐᓂᒃ ᖃᐅᔮᓭᓕᓯᒪᔭᖃᕆᐊᓕᑦ ᓇᑯᓇᐃᖅᓯᔾᔪᑎᓄᑦ (EWI) ᖃᐅᔨᓴᕈᑏᑦ 2021-ᒥ ᖃᖓᑕᓲᒃᑯᑦ ᖃᐅᔨᓴᕈᑎᕕᓃᑦ (ᐊᑐᖅᑕᐅᓪᓗᑎᒃ 1,000 ᐃᓯᒐᓂᒃ ᖁᑦᑎᖕᓂᓛᑦ ᖃᐅᔨᓴᕈᑏᑦ ᑲᑎᖅᓱᖅᑕᐅᓚᐅᖅᑐᑦ ᑕᒪᓐᓇ ᐱᓪᓗᒍ) ᖃᐅᔨᓴᖅᑕᐅᒃᑲᓐᓂᕐᑯᔭᐅᓪᓗᑎᒃ ᑕᒪᒃᑯᐊ ᖃᐅᔮᔭᐅᔪᑦ.

- ᑲᑎᙵᔪᑦ ᓯᐊᒻᒪᒃᓯᒪᓂᖏᑦ: ᐋᖅᑭᙳᐊᖅᑕᐅᓯᒪᔪᓂ ᖃᐅᔮᔭᐅᔪᑦ ᑖᒃᑯᓇᙵᑦ ᑲᑎᑕᐅᓯᒪᔪᓂ ᐊᕐᕌᒍᓖᓐᓄᑦ ᖃᐅᔨᓴᕈᑎᕕᓂᕐᓂᒃ ᐃᒪᐃᖅᑰᔮᓇᓱᒋᓐᓈᔪᑦ ᑖᒃᑯᐊ ᑑᒃᓖᑦ ᑲᑎᖃᑦᑕᖅᑐᑦ ᖃᓂᑮᖕᓂᖅᓴᐅᓪᓗᑎᒃ ᐊᒃᑐᐊᔪᓄᑦ ᑲᑎᙵᔪᓄᑦ ᖃᓂᑭᒃᑎᓪᓗᑎᑦ (ᓲᕐᓗ ≤ 2 ᑭᓛᒥᑕᑦ) ᐅᒥᐊᕐᔪᐊᓄᑦ. ᑎᑎᕋᖅᑕᐅᓯᒪᔪᖅ ᐃᓕᖅᑯᓯᕆᐅᓕᖅᐸᒃᑐᓄᑦ ᓴᖅᑮᔾᔪᖅᑎᑕᐅᓚᐅᖅᑐᖅ ᕿᓚᒻᒥᐅᓪᓗᓂ, ᓇᓕᒧᐸᓪᓕᓪᓗᓂᐅᒃ ᐊᑯᓂᐅᓛᖑᔪᓐᓇᖅᑐᒧᑦ 14 ᒥᓇᑦ ᐊᑐᓂ ᐅᒥᐊᕐᔪᐊᖅ ᐃᖏᕐᕋᑎᓪᓗᒧᑦ (ᑐᙵᕕᖃᕐᑯᑎᒃ 9 ᓈᑦᓂᒃ ᐃᖏᕐᕋᓂᖃᕐᑯᑎᒃ, ᐃᓱᒪᒋᓪᓗᒋᑦ ᑑᒃᓖᑦ ᓱᓕ ᐊᓯᔾᔨᖃᑦᑕᙱᑦᑐᑦ ᑐᓴᓗᐊᖅᑎᓪᓗᒋᑦ), ᓂᕐᔫᑦ ᐅᑎᖅᑎᓪᓗᒋᑦ ᐃᓕᖅᑯᓯᕆᓚᐅᖅᑕᖏᓐᓄᑦ ᑭᖑᓂᑦᑎᐊᖓᓗᑦ ᓯᕗᓪᓕᖅᐹᒥᒃ ᑐᓴᓚᐅᖅᑎᓪᓗᒋᑦ (ᓲᕐᓗ ᐊᒃᑐᐃᓂᐅᓚᐅᑲᑐᐃᓐᓇᖅᑐᖅ). ᐊᑯᓂᐅᓂᖅᐹᕆᔭᖓ ᐊᑐᓂ ᐅᓪᓗᕐᒥ ᐊᒃᑐᐊᔪᑦ ᐅᒥᐊᕐᔪᐊᓂᒃ ᐸᒃᕕᓴᐃᓃᑦ ᑑᒃᓕᖓᓄᑦ ᑲᑎᙵᔪᓄᑦ ᓯᐊᒻᒪᒃᓯᒪᔪᖅ 28 ᒥᓇᑦᓄᑦ (ᑐᙵᕕᒋᔭᐅᓪᓗᑎᒃ ᐊᑐᖅᑕᐅᖓᔪᒃᑑᒃ ᒪᕐᕉᒃ ᐅᒥᐊᕐᔪᐊᒃ ᐃᖏᕐᕋᔫᒃ ᐊᑐᓂ ᐅᓪᓗᕐᒥ ᐊᕕᒃᑐᖅᑯᓯᑦ ᐅᓄᙱᓐᓂᖅᓴᐅᓗᑎᒃ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᑦ (SSA)). ᐊᓯᔾᔨᖅᑐᖅᑲᖅᐸᒃ ᑲᑎᙵᔪᓂ ᑲᑎᑎᓪᓗᒋᑦ (ᓲᕐᓗ ᐊᓯᔾᔨᕐᓂᖏᑦ ᑲᑎᖓᔪᑦ ᓯᐊᒻᒪᒃᓯᒪᓂᖏᑦ) ᑑᒃᓕᖕᓂᑦ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐱᓗᐊᕈᔫᔭᖅᑐᒥᒃ ᐃᓕᖅᑯᓯᖃᓕᖃᑦᑕᕐᓂᖏᓐᓄᑦ (ᓴᐅᑦᐋᓪ ᐊᑕᖏᖅᑯᑎᒃ 2021). ᑭᓯᐊᓂᓕ ᐱᔾᔪᑕᐅᓪᓗᑎᒃ ᕿᓚᐅᒻᒥᐅᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᐊᒃᑐᐃᓂᑦ (ᓲᕐᓗ, ᑎᑭᑯᒎ 14 ᒥᓇᑦ ᐊᑐᓂ ᐅᒥᐊᕐᔪᐊᖅ ᐃᖏᕐᕋᑎᓪᓗᒍ) ᑕᒪᓐᓇ ᐃᓱᒪᒋᖃᓯᐅᔾᔮᙱᑦᑐᖅ ᑎᒥᖏᑦᑎᒍᑦ ᐊᖏᔪᒥ ᐃᖅᑯᓯᐅᓕᕐᑯᓂ ᐊᒻᒪᓗ ᓂᕈᐅᒋᔭᐅᓇᓂ ᓴᖅᑮᔾᔨᕋᓱᒋᔭᐅᙱᑯᓂ ᐊᓯᔾᔩᕐᔪᐊᕈᑎᒥᒃ ᐃᓕᖅᑯᓯᓈᓇᐅᔭᖅᑕᖏᓐᓄᑦ ᖃᓄᐃᓕᖓᓂᐅᕝᑐᓄᑦ ᑑᒃᓖᑦ ᑕᐅᕗᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ (RSA) ᐅᕝᕙᓘᓐᓃᑦ ᐸᒃᕕᓴᖅᓃᑦ ᖃᐅᑕᒫᖅᓯᐅᑎᖏᓐᓄᑦ. ᒪᓕᒃᑯᓯᑦ ᐊᒃᑐᐃᓂᑦ ᓂᕈᐅᒋᔭᐅᙱᑦᑐᑦ ᐊᑐᓂ ᖃᓄᐃᙱᓐᓂᑦᐊᕐᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ/ᐅᕝᕙᓘᓐᓃᑦ ᑎᒥᖏᑕ ᓱᖃᓕᓂᖏᑦ ᑑᒃᓖᑦ ᑕᐅᕗᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ (RSA) ᐊᒃᑐᐃᓪᓚᕆᖃᔭᖅᑐᒃᓴᐅᔪᖅ ᐅᓄᕐᓂᖏᓐᓄᑦ ᑮᓕᐅᕝᑐᓂᒃ. ᑕᒪᓐᓇ ᖃᓄᐃᓕᖓᓕᕐᓂᐅᔪᖅ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᒥᒃᓴᐅᓭᑕᐅᓯᒪᔪᓂᒃ ᑕᐃᑲᓂ ᑭᖑᓪᓕᖅᐹᒥᒃ ᐊᕙᑎᒧᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᐅᓂᒃᑳᓂᒃ (FEIS) ᑕᒪᑐᒪᖓ ᑰᓇᐅᔾᔭᒃᓵᓕᓇᓱᖕᓂᕐᒧᑦ (ERP), ᑕᐃᑲᓂᑯ ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖏᑦ ᐊᒃᑐᐃᓇᔭᖅᑐᑦ ᑑᒃᓕᖕᓂᒃ ᓂᕈᐅᒋᔭᐅᔪᑦ ᑮᓕᖃᕐᑯᑎᒃ ᕿᓚᒻᒥᐅᔪᒥᒃ, ᖃᓂᒋᔮᓂᑐᐊᖅ ᑕᑯᑦᑕᐅᑎᑦᑕᐃᓕᒪᓂᕐᒧᑐᐊᖅ ᐃᓕᖅᑯᓯᐅᑯᓂ

- ᑲᑎᙵᔪᑦ ᐋᖅᑭᒃᐸᓪᓕᐊᓂᖏᑦ: ᑑᒃᓖᑦ ᑲᑎᙵᔪᑦ ᑕᑯᔭᐅᓚᔪᓚᐅᖅᑐᑦ ᓴᓂᓕᕇᒃᑯᑎᒃ ᐋᖅᑭᒃᓯᒪᓪᓗᑎᒃ ᑕᒪᑮᖕᓂᒃ ᐅᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒋ ᐱᑕᖃᙱᑎᓪᓗᒋᓪᓗ. ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᕐᕌᒍᓂ ᖄᖏᖅᑐᓂᑦ ᖃᐅᔮᔭᐅᔪᓂᒃ, ᖃᐅᔮᔭᐅᔪᑦ ᑲᑎᑕᐅᓯᒪᔪᓂ ᐊᕐᕌᒍᓖᓐᓄᑦ ᖃᐅᔨᓴᕈᑎᕕᓂᕐᓂᒃ ᐃᒪᐃᓐᓇᓱᒋᓐᓈᔪᑦ ᑖᒃᑯᐊ ᑑᒃᓖᑦ ᐊᓯᔾᔩᕐᔪᐊᔾᔮᙱᑦᑐᑦ ᑲᑎᙵᔪᑦ ᐋᖅᑭᒃᐸᓪᓕᐊᕝᕕᓂᖏᓐᓂᒃ ᐃᓕᖅᑯᓯᕆᓕᕐᔪᓂᓪᓚᒃ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᖃᑦᑕᕐᓂᖏᓐᓄᑦ. ᐱᑕᖃᑦᑎᐊᖏᓐᓂᖓᓄᑦ ᐃᓕᖅᑯᓯᐅᓕᖅᐸᒃᑐᓄᑦ ᐃᑯᔪᖅᓯᕋᔭᖅᑐᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᒥᒃᓴᐅᓭᑕᐅᓯᒪᔪᓂ ᑕᐃᑲᓂ ᑭᖑᓪᓕᖅᐹᒥᒃ ᐊᕙᑎᒧᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᐅᓂᒃᑳᓂᒃ (FEIS) ᑕᒪᑐᒪᖓ

ᑭᓇᐅᔾᔭᒃᓵᓕᓇᓱᖕᓂᕐᒧᑦ (ERP), ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖏᓐᓄᑦ ᐊᒃᑐᐃᓃᑦ ᓂᕆᐅᒋᔭᐅᔪᑦ ᖃᓂᒌᔭᓂᑐᐊᖅ ᑕᑯᑦᑕᐅᑎᑦᑕᐃᓕᒪᓂᕐᒧᑐᐊᖅ ᐃᓕᖅᑯᓯᐅᓗᓂᓂᕆᐅᒋᔭᐅᔪᑦ ᑭᒡᓕᖃᕐᓗᑎᒃ ᕿᓚᒻᒥᐅᔪᒥᒃ, ᖃᓂᒌᔭᓂᑐᐊᖅ ᑕᑯᑦᑕᐅᑎᑦᑕᐃᓕᒪᓂᕐᒧᑐᐊᖅ ᐃᓕᖅᑯᓯᐅᓗᓂ.

- ᑲᑎᙵᔪᑦ ᓇᒨᕙᐅᖃᑦᑲᕐᓂᖏᑦ: ᑑᒐᓖᑦ ᑲᑎᙵᔪᑦ ᑕᑯᔭᐅᕙᔫᒃᑐᑦ ᓅᐸᓪᓕᐊᑎᓪᓗᒋᑦ ᓂᒋᐊᓄᑦ ᐃᓕᖅᑯᓯᕆᔭᐅᓕᖅᐸᒃᑐᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐃᓂᐅᔪᒥ (BSA). ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᓂᒍᖅᓯᒪᔪᓂ ᐊᕐᕌᒍᓂ ᖃᐅᔨᔭᐅᓚᐅᖅᑐᓂ, ᖃᐅᔨᔭᐅᔪᑦ ᑲᑎᑕᐅᓯᒪᔪᓂ ᐊᕐᕌᒍᒐᓚᖕᓄᑦ ᖃᐅᔨᓴᕈᑎᕕᓂᕐᓂᒃ ᐃᒪᐃᖅᑰᔨᓇᓱᒋᓐᓈᔪᑦ ᑑᒐᓖᑦ ᑲᑎᙵᔪᑦ ᓅᐸᓪᓕᐊᔪᑦ ᓇᒨᕙᐅᓂᖏᑦ ᐊᒃᑐᖅᑕᐅᓯᒪᙱᑦᑐᑦ ᑎᑭᐸᓪᓕᐊᔪᓄᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ ᑭᓯᐊᓂᓕ ᑖᒃᑯᐊ ᑑᒐᓖᑦ ᑲᑎᙵᔪᑦ ᐊᑐᖅᑕᐃᓕᒪᑐᐃᓐᓇᕆᐊᓖᑦ "ᒪᓕᙱᓪᓗᑎᒃ" ᐅᒥᐊᖅᑭᕐᔪᐊᓂᒃ ᓅᐸᓪᓕᐊᔪᑦ ᐃᓕᖅᑯᓯᕆᔭᐅᓕᖅᐸᒃᑐᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐃᓂᐅᔪᒥ (BSA). ᐃᒪᐃᑦᑑᓪᓗᓂ, ᑑᒐᓖᑦ ᓅᓐᓂᖅᓴᐅᖃᑦᑕᓚᐅᖅᑐᑦ ᐃᒡᓗᐊᓄᙳᖅ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᕝᕕᒋᔭᙵᓄᑦ ᕿᓖᓪᓗᑎᒃ ᐃᓕᖅᑯᓯᕆᔭᐅᓕᖅᐸᒃᑐᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐃᓂᐅᔪᒥ (BSA), ᑕᐃᒪᐃᒃᑲᓗᐊᖅᑎᓪᓗᒍ ᐃᒪᐃᙱᒃᑲᓗᐊᕐᒪᖑᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐅᐊᖕᓇᖓᓃᒃᑲᓗᐊᖅᐸᑕ - ᓂᒋᐊᓄᙵᐅᓚᓗᐊᖅᐊᑕ. ᓇᓗᓇᐃᕐᓗᒍ ᐃᓕᖅᑯᓯᐅᓕᖅᐸᒃᑐᖅ ᓴᖅᑮᔭᖅᑎᑦᑎᔪᖅ ᐅᖓᓯᒌᖑᔪᓐᓇᖅᑐᑦ 4-ᑭᓛᒥᑕᑦ ᐅᒥᐊᕐᔪᐊᒥᑦ, ᓇᓕᒧᑦᑐᖅ ᐊᑯᓂᐅᓂᖓ 28 ᒥᓇᑦ ᐊᑐᓂ ᐅᒥᐊᕐᔪᐊᖅ ᐃᖏᕐᕋᑎᓪᓗᒍ (ᑐᙵᕕᖃᖅᑲᑎᒃ 9-ᓈᑦᓂᒃ ᓱᒃᑲᓕᓂᖃᖅᑎᓪᓗᒋᑦ, ᐃᓱᒪᒋᓪᓗᒋᑦ ᑑᒐᓖᑦ ᑕᒪᐃᓕᖓᐃᓐᓇᖃᑦᑕᕐᓂᖏᓐᓂᒃ ᑐᓵᑎᓪᓗᒋᑦ), ᓂᕐᔩᑏᓪᓗ ᐅᑎᖅᐸᒃᑲᑎᒃ ᖃᓄᐃᓕᖓᓕᖅᑳᖅᑎᓇᒋᑦ ᐃᓕᖅᑯᓯᕙᒃᑕᖏᓐᓄᑦ ᑭᖑᓂᐊᒍᑦ ᐅᒥᐊᕐᔪᐊᒥᒃ ᑐᓭᑲᓚᐅᖅᑎᓪᓗᒋᑦ (ᓃᕐᓗ ᕿᓚᒥᐅᔪᖅ ᐊᒃᑐᐃᓂᖅ). ᐊᑯᓂᐅᓛᖑᔪᓐᓇᖅᑐᑦ ᐅᓪᓗᑕᓖᑦ ᐊᒃᑐᐊᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐸᒡᕕᓴᐃᓂᖏᑦ ᑑᒐᓖᑦ ᑲᑎᙵᔪᑦ ᓇᒨᕙᐅᖃᑦᑕᕐᓂᖏᑦ 56 ᒥᓇᑦᑰᓚᐅᖅᑐᑦ (ᑐᙵᕕᒋᔭᐅᓪᓗᑎᒃ ᒪᕉᓚᔫᒃᑑᒃ ᐅᒥᐊᕐᔪᐊᒃ ᐅᖏᕐᕋᔪᑦ ᐊᑐᓂ ᓗᕐᒧᑦ ᐊᕕᒃᑐᖅᑲᓕᑦ ᐅᓄᙱᓐᓂᖅᓴᐅᓗᑎᒃ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᑦ (SSA). ᐊᓯᔾᔨᐅᑏᑦ ᖃᓄᓕᐃᓐᓂᖏᓐᓄᑦ ᐃᓕᖅᑯᓯᕆᔭᐅᕙᒃᑐᑦ (ᓰᕐᓗ ᐊᓯᔾᔨᕐᓂᖏᑦ ᑲᑎᙵᔪᑦ ᓇᒨᕙᐅᓂᖏᑦ) ᑖᒃᑯᓇᓂ ᑑᒐᓕᖕᓂ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐱᓗᐊᕋᔭᖏᓐᓂᖏᓐᓂᒃ ᐃᓕᖅᑯᓯᕆᔭᐅᓕᖅᐸᒃᑐᑦ (ᓴᐅᑦᐋ ᐊᑕᖏᖅᓱᑎᒃ 2021). ᑭᓯᐊᓂᓕ, ᐱᔾᔪᑕᐅᓗᓂ ᕿᓚᒻᒥᐅᖃᑦᑕᕐᓂᖓ ᐊᒃᑐᐃᓂᖅ (ᓰᕐᓗ 28 ᒥᓇᑦ ᐊᑐᓂ ᐅᒥᐊᕐᔪᐊᖅ ᐃᖏᕐᕋᑎᓪᓗᒍ), ᑕᒪᓐᓇ ᐃᓱᒪᒋᖃᓯᐅᔾᔮᙱᑦᑐᖅ ᑎᒥᖏᑦᑎᒍᑦ ᐊᖏᔪᒥ ᐃᖅᑯᓯᐅᓕᕐᓗᓂ ᐊᒻᒪᓗ ᓂᕆᐅᒋᔭᐅᓇᓂ ᓴᖅᑮᔾᔭᕋᓱᒋᔭᐅᙱᕐᓗᓂ ᐊᓯᔾᔩᕐᔪᐊᕈᑐᑎᒥᒃ ᐃᓕᖅᑯᓰᓐᓇᐅᔭᖅᑕᖏᓐᓄᑦ ᖃᓄᐃᓕᖓᓂᐅᕙᒃᑐᓄᑦ ᑑᒐᓖᑦ ᑕᐅᕙᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ (RSA), ᐅᕙᔫᓐᓃᑦ ᐸᒡᕕᓴᐃᓇᔭᙱᑦᑐᖅ ᖃᐅᑕᒫᖅᓯᐅᑎᖏᓐᓂᒃ. ᒪᓕᒃᑲᑎᑦ ᐊᒃᑐᐃᓃᑦ ᓂᕆᐅᒋᔭᐅᙱᑦᑐᑦ ᐊᑐᓂ ᖃᓄᐃᙱᓐᓂᑦᐊᕐᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ/ᐅᕙᔫᓐᓃᑦ ᑎᒥᖏᑕ ᓱᒃᑲᓂᖏᑦ ᑑᒐᓖᑦ ᑕᐅᕙᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ (RSA) ᐊᒃᑐᐃᓕᕆᓚᔭᖅᑐᒃᓴᐅᔪᖅ ᐅᓄᕐᓂᖏᓐᓄᑦ ᑭᒡᓕᐅᕙᒃᑐᓂᒃ. ᑕᒪᓇ ᖃᓄᐃᓕᖓᓕᕐᓂᐅᔪᖅ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᒥᒃᓴᐅᓵᑕᐅᓯᒪᔪᓂᒃ ᑕᐃᑲᓂ ᑭᖑᓕᖅᐹᒥᒃ ᐊᕙᑎᒧᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᐅᓂᒃᑳᓂᒃ (FEIS) ᑕᒪᑐᒧᖓ ᑭᓇᐅᔾᔭᒃᓵᓕᓇᓱᖕᓂᕐᒧᑦ (ERP), ᑕᐃᑲᓂᓗ ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖏᑦ ᐊᒃᑐᐃᓇᔭᖅᑐᑦ ᑑᒐᓕᖕᓂᒃ ᓂᕆᐅᒋᔭᐅᔪᑦ ᑭᒡᓕᖃᕐᓗᑎᒃ ᕿᓚᒻᒥᐅᔪᒥᒃ, ᖃᓂᒌᔭᓂᑐᐊᖅ ᑕᑯᑦᑕᐅᑎᑦᑕᐃᓕᒪᓂᕐᒧᑐᐊᖅ ᐃᓕᖅᑯᓯᐅᓗᓂ

- ᐃᖏᕐᕋᓂᖏᑕ ᓱᒃᑲᓂᖏᑦ: ᖃᐅᔨᔭᐅᔪᑦ ᑖᒃᑯᓇᙵᑦ ᑲᑎᑕᐅᓯᒪᔪᓂ ᐊᕐᕌᒍᓚᖕᓄᑦ ᖃᐅᔨᓴᕈᑎᕕᓂᕐᓂᒃ ᐃᒪᐃᖅᑰᔨᓇᓱᒋᓐᓈᔪᑦ ᑖᒃᑯᐊ ᑑᒐᓖᑦ ᐃᓚᒋᔭᐅᒃᐸᑕ ᐊᓯᖏᓐᓄᑦ ᑑᒐᓕᖕᓄᑦ ᑲᑎᙵᔪᓂᑦ ᐃᖏᕐᕋᕙᓪᓕᐊᔪᓂᒃ ᓱᒃᑲᓗᐊᙱᑎᓪᓗᒋᑦ ᓱᒃᑲᑎᓪᓗᒋᓘᓐᓃᑦ, ᐃᖏᕋᕋᔾᔭᕐᓂᖅᓴᐅᓇᔭᖅᑐᑦ ᑐᖑᓂ 4 ᑭᓛᒥᑕᒥᒃ ᐅᒥᐊᕐᔪᐊᓂᑦ ᖃᓄᐃᓐᓂᖅᓴᐅᓇᔭᖅᓂᖏᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ. ᑑᒐᓖᑦ ᐱᑕᖃᖅᑐᑦ ᐊᓯᖏᓐᓂ ᑲᑎᙵᔪᓂ ᑑᒐᓕᖕᓂ ᐃᖏᕐᕋᓂᒃᑯᑦ ᓱᒃᑲᐃᕗᑎᒃ, ᐊᓯᔾᔨᐅᑎᕐᔪᐊᓂᒃ ᑲᑎᙵᔪᓂᒃ ᐃᖏᕐᕋᓂᖏᓐᓄᑦ ᓱᒃᑲᓕᑎᓪᓗᒋᑦ ᓇᓗᓇᓚᐅᙱᑦᑐᑦ. ᓇᓗᓇᐃᖅᑕᐅᓯᒪᔪᑦ ᐃᓕᖅᑯᓯᐅᕙᒃᑐᑦ ᓴᖅᑮᔭᖅᑐᑦ ᕿᓚᒥᐅᓪᓗᑎᒃ (ᓰᕐᓗ 4 ᑭᓛᒥᑕᑦ ᖃᓂᒌᔭᓂ ᐅᒥᐊᕐᔪᐊᑦ) ᓇᓕᒧᑦᑐᖅ ᐊᑯᓂᐅᓛᖑᔪᓐᓇᖅᑎᓪᓗᒍ 28 ᒥᓇᑦ ᐊᑐᓂ ᐅᒥᐊᕐᔪᐊᖅ ᐃᖏᕐᕋᔪᖅ (ᑐᙵᕕᖃᖅᑲᑎᒃ 9 ᓈᑦᓂᒃ ᐃᖏᕐᕋᓂᖃᖅᑲᑎᒃ, ᐃᓱᒪᒋᓗᒋᑦ ᑑᒐᓖᑦ ᓯᓕ ᐊᓯᔾᔨᖃᑦᑕᙱᑦᑐᑦ ᑐᓴᓗᐊᖅᑎᓪᓗᒋᑦ), ᐆᒪᔪᑦ ᐅᑎᖅᐸᒃᑲᑎᒃ ᐃᓕᖅᑯᓯᕆᓚᐅᖅᑕᒥᖕᓄᑦ ᑭᖑᓂᑦᑎᐊᖕᖓᒍᑦ ᑐᓭᑲᓚᐅᖅᑎᓪᓗᒋᑦ (ᓰᕐᓗ ᕿᓚᒻᒥᐊᔪᖅ ᐊᒃᑐᐃᓂᖅ). ᐅᓄᖑᔪᓐᓇᖅᑐᑦ ᐊᑐᓂ ᐅᓪᓗᕐᒧᑦ ᐊᒃᑐᐊᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐸᒡᕕᓴᐃᓂᖏᑦ ᑑᒐᓕᖕᓂᒃ ᑲᑎᙵᔪᑦ ᓱᒃᑲᓕᓂᖏᓐᓂᒃ ᐃᒪᐃᓐᓇᑎᒌᓚᐅᖅᑐᑦ 56 ᒥᓇᑦ (ᑐᙵᕕᒋᓪᓗᒋᑦ ᒪᕉᓚᔫᒃᑐᑦ ᐅᒥᐊᕐᔪᐊᑎᑦ ᐃᖏᕐᕋᖃᑦᑕᕐᓂᖏᑦ ᐊᑐᓂ ᐅᓪᓗᒧᑦ ᑕᐅᕙᓂ ᐊᕕᒃᑐᖅᑲᓕᑦ ᐅᓄᙱᓐᓂᖅᓴᐅᓗᑎᒃ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᑦ (SSA)). ᐊᓯᔾᔨᐅᑎ ᐱᕋᖓᖏᓐᓂᕐᒧᑦ ᐊᑐᖅᑕᐅᔪᑦ (ᓰᕐᓗ ᐊᓯᔾᔨᕐᓂᖏᑦ ᐃᖏᕐᕋᓂᖏᓐᓄᑦ ᓱᒃᑲᓂᖏᑦ) ᑑᒐᓕᖕᓂᒃ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐱᓗᐊᕌᖏᓐᓇᑎᒃ ᐃᓕᖅᑯᓯᕆᓕᖅᐸᒃᑕᖏᑦ (ᓴᐅᑦᐋᓪ ᐊᑕᖏᖅᓱᑎᒃ 2021). ᑭᓯᐊᓂᓕ, ᐱᔾᔪᑕᐅᓗᑎᒃ ᐊᖏᔪᑦ ᐃᓕᖅᑯᓯᕆᔭᐅᓕᖅᐸᒃᑐᑦ ᐊᒻᒪᓗ ᓂᕆᐅᓇᙱᓐᓗᑎᒃ ᓴᖅᑭᓛᕐᓂᖏᓐᓂᒃ ᐋᓯᔾᔨᕐᓗᑎᒃ ᐃᓕᖅᑯᓰᓐᓇᐅᔭᖅᑕᖏᓐᓄᑦ ᖃᓄᐃᓕᖓᓕᕐᓂᐅᕙᒃᑐᑦ ᑑᒐᓕᖕᓄᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᓄᓇᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᓂ (RSA) ᐅᕙᔫᓐᓃᑦ ᐸᒡᕕᓴᐃᓂᖅ ᖃᐅᑕᒫᖅᓯᐅᑎᖏᓐᓂᑦ. ᑕᐃᒪᐃᓐᓂᖓᓄᑦ, ᐊᒃᑐᐃᓂᖅᑕᖃᙱᑦᑐᑦ ᓂᕆᐅᒋᔭᐅᙱᑦᑐᑦ ᒪᓕᒃᑲᑎᑦ ᐊᒃᑐᐃᓃᑦ ᓂᕆᐅᒋᔭᐅᙱᑦᑐᑦ ᐊᑐᓂ ᖃᓄᐃᙱᓐᓂᑦᐊᕐᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ/ᐅᕙᔫᓐᓃᑦ ᑎᒥᖏᑕ ᓱᒃᑲᓂᖏᑦ ᑑᒐᓖᑦ ᑕᐅᕙᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ (RSA) ᐊᒃᑐᐃᓕᕆᓚᔭᖅᑐᒃᓴᐅᔪᖅ ᐅᓄᕐᓂᖏᓐᓄᑦ ᑭᒡᓕᐅᕙᒃᑐᓂᒃ. ᑕᒪᓇ ᖃᓄᐃᓕᖓᓕᕐᓂᐅᔪᖅ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᒥᒃᓴᐅᓵᑕᐅᓯᒪᔪᓂᒃ ᑕᐃᑲᓂ ᑭᖑᓕᖅᐹᒥᒃ ᐊᕙᑎᒧᑦ ᐊᒃᑐᐃᓂᕐᓄᑦ ᐅᓂᒃᑳᓂᒃ (FEIS) ᑕᒪᑐᒧᖓ

ᑮᓇᐅᔾᔭᖅᓵᓕᓇᓱᖕᓂᕐᒧᑦ (ERP), ᑕᐃᑲᓂᓗ ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖕᒋᑦ ᐊᑦᑐᐃᓇᔭᖅᑐᑦ ᑑᓚᓕᖕᓂᒃ ᓂᕆᐅᒋᔭᐅᔪᑦ ᑭᒡᓕᖃᕐᓗᑎᒃ ᖁᓚᒻᒥᐅᔪᒥᒃ, ᖃᓂᒋᔮᓂᑐᐊᖅ ᑕᑯᑦᑕᐅᑎᑦᑕᐃᓕᒪᓂᕐᒧᑐᐊᖅ ᐃᓕᖅᑯᓯᐅᓗᓂ.

- ᓇᓕᒧᑦᑐᑦ ᐊᑯᓂᐅᓛᖑᔪᓐᓇᖅᑐᒧᑦ 7 ᒥᓇᓂᒃ ᐊᑐᓂ ᐅᒥᐊᕐᔪᐊᖅ ᐃᖏᕐᕋᑎᓪᓗᒍ (ᑐᙵᕕᖃᖅᓗᑎᒃ 9 ᓈᑦᓂᒃ ᓱᒃᑲᓕᓂᖃᖅᓗᒃ, ᐃᓱᒪᒋᓪᓗᒋᑦ ᑑᓚᓖᑦ ᑕᒪᐃᓕᖕᓚᐃᓐᓇᖃᑦᑕᕐᓂᖏᓐᓂᒃ ᑐᓵᑎᓪᓗᒋᑦ), ᓂᕐᔪᑏᓪᓗ ᐅᑎᖅᐸᒃᓗᑎᒃ ᖃᓄᐃᓕᖕᓕᖅᑳᖅᑎᓐᓇᒋᑦ ᐃᓕᖅᑯᓯᕙᒃᑕᖏᓐᓄᑦ ᑭᖑᓂᐊᒍᑦ ᐅᒥᐊᕐᔪᐊᒥᒃ ᑐᓵᖃᓚᐅᖅᑎᓪᓗᒋᑦ (ᓲᕐᓗ ᕿᓚᒥᐅᔪᖅ ᐊᑦᑐᐃᓂᖅ). ᐊᑯᓂᐅᓛᖑᔪᓐᓇᖅᑐᖅ ᐊᑐᓂ ᐅᓪᓗᕐᒧᑦ ᐊᑦᑐᐊᒧᖅ ᐅᒥᐊᕐᔪᐊᑦ ᐸᒡᕕᓴᐃᓂᕐᒋᑦ ᑑᓚᓖᑦ ᑲᑎᙵᔪᑦ ᐊᕐᒋᓂᕐᒋᓐᓄᑦ 14 ᒥᓇᑦᖑᓚᐅᖅᑐᑦ (ᑐᙵᕕᒋᓪᓗᒋᑦ ᒪᕐᕿᓚᔪᒃᑐᑦ ᐅᒥᐊᕐᔪᐊᑎᑦ ᐃᖏᕐᕋᑲᑦᑕᕐᓂᕐᒋᑦ ᐊᑐᓂ ᐅᓪᓗᒧᑦ ᑕᐅᕙᓂ ᐊᕕᒃᑐᖅᓱᒋᑦ ᐅᓄᙱᓐᓂᖅᓴᐅᓗᑎᒃ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᑦ (SSA)). ᐊᓯᔾᔨᖅᑐᖅ ᑲᑎᙵᔪᑦ ᑲᑎᙵᐃᓐᓇᕐᓂᕐᒋᑦ (ᓲᕐᓗ ᐊᓯᔾᔨᖅᑐᑦ ᑲᑎᙵᔪᑦ ᐅᓄᕐᓂᕐᒋᑦ) ᑖᓚᖕᓂᑦ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᒃᓱᐊᕈᐸᓗᒃᑐᓄᑦ ᐃᓕᖅᑯᓯᓇᔭᐅᓕᖅᐸᒃᑐᓄᑦ (ᓴᐅᑦᐋ ᐊᑕᕐᒋᖅᓗᑎᒃ 2021). ᑭᓯᐊᓂᓕ ᐱᔾᔪᑕᐅᓪᓗᑎᒃ ᑭᓚᒻᒥᐅᓂᕐᒋᓐᓄᑦ ᐊᑦᑐᐃᓐᓂᑦ (ᓲᕐᓗ ᑎᒃᓗᒍ 7 ᒥᓇᑦ ᐊᑐᓂ ᐊᒥᕐᐊᔪᐊᖅ ᐃᖏᕐᕋᑎᓪᓗᒍ), ᑕᒪᓐᓇ ᐃᓱᒪᒋᖃᓯᐅᔾᔭᐃᙱᑦᑐᑦ ᑎᒥᖏᑦᑎᒍᑦ ᐊᖏᔪᒥᒃ ᐃᓕᖅᑯᓯᓇᓕᖅᑕᐅᖃᑦᑕᕐᓗᓂ ᐊᒻᒪᓗ ᓂᕆᐅᒋᔭᐅᙱᑦᑐᑦ ᓴᖅᑮᓂᐊᕐᓂᖕᓚᓂᒃ ᐊᓯᔾᔨᕐᔪᐊᕈᑎᓂᒃ ᐃᓕᖅᑯᓰᓐᓇᐅᔭᖅᑕᕐᒋᓐᓄᑦ ᖃᓄᐃᓕᖕᓚᓂᐅᕙᒃᑐᑦ ᑑᓚᓖᑦ ᑕᐃᕙᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ (RSA) ᐅᕝᕙᓘᓐᓃᑦ ᐸᒡᕕᓴᐃᓗᑎᒃ ᖃᐅᑕᒫᖅᓯᐅᑎᖏᓐᓂ. ᒪᓕᒃᓱᒋᑦ ᐊᑦᑐᐃᓐᓂᑦ ᓂᕆᐅᒋᔭᐅᙱᑦᑐᑦ ᐊᑐᓂ ᖃᓄᐃᙱᓐᓂᑦᐊᕐᓂᕐᒋᓐᓄᑦ ᐊᒻᒪᓗ/ᐅᕝᕙᓘᓐᓃᑦ ᑎᒥᖏᑕ ᓱᒃᑲᓂᕐᒋᑦ ᑑᓚᓖᑦ ᑕᐅᕙᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ (RSA) ᐊᑦᑐᐃᓪᓚᓇᓚᔭᖅᑐᒃᓴᐅᔪᖅ ᐅᓄᕐᓂᕐᒋᓐᓄᑦ ᑭᒡᓕᐅᕙᒃᑐᓂᒃ. ᑕᒪᓐᓇ ᖃᓄᐃᓕᖕᓕᕐᓂᐅᔪᖅ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐊᑦᑐᐃᓂᕐᓄᑦ ᒥᒃᓴᐅᓭᑕᐅᓯᒪᔪᓂᒃ ᑕᐃᑲᓂ ᑭᖑᓪᓕᖅᐹᒥᒃ ᐊᕙᑎᒧᑦ ᐊᑦᑐᐃᓂᕐᓄᑦ ᐅᓂᒃᑳᓂᒃ (FEIS) ᑕᒪᑐᒧᖓ ᑮᓇᐅᔾᔭᖅᓵᓕᓇᓱᖕᓂᕐᒧᑦ (ERP), ᑕᐃᑲᓂᓗ ᐅᒥᐊᕐᔪᐊᑦ ᓂᐱᖕᒋᑦ ᐊᑦᑐᐃᓇᔭᖅᑐᑦ ᑑᓚᓕᖕᓂᒃ ᓂᕆᐅᒋᔭᐅᔪᑦ ᑭᒡᓕᖃᕐᓗᑎᒃ ᖁᓚᒻᒥᐅᔪᒥᒃ, ᖃᓂᒋᔮᓂᑐᐊᖅ ᑕᑯᑦᑕᐅᑎᑦᑕᐃᓕᒪᓂᕐᒧᑐᐊᖅ ᐃᓕᖅᑯᓯᐅᓗᓂ.

ᐃᓄᖃᙱᑦᑐᑦ ᖃᖓᑕᓲᖃᕐᓛᑦ ᐊᔾᔨᓕᐅᕈᑎᓖᑦ (UAV) ᓂᕐᔪᑎᓂᒃ ᒪᓕᒡᓗᑎᒃ ᖃᐅᔨᓴᕐᓃᑦ

- ᐃᓄᖃᙱᑦᑐᑦ ᖃᖓᑕᓲᖃᕐᓛᑦ ᐊᔾᔨᓕᐅᕈᑎᓖᑦ (UAV) ᓂᕐᔪᑎᓂᒃ ᒪᓕᒡᓗᑎᒃ ᐊᔾᔨᒌᙱᑦᑕᕐᒋᑦ ᑕᑯᖃᑦᑕᖅᑐᓄᑦ–ᑐᙵᕖᑦ ᖃᐅᔨᓴᕈᑎᖏᓐᓂᒃ ᑲᑎᖅᓱᐃᓂᖅ ᑕᐅᕙᓂ ᐃᓕᖅᑯᓯᓇᔭᐅᓕᖅᐸᒃᑐᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐃᓂᐅᔪᒥ (BSA) ᐊᒃᓱᕈᐊᓇᔭᐅᓕᖅᓱᓂᓗ ᑑᓚᓖᑦ ᑲᑎᙵᔪᑦ ᐃᓗᓕᖃᖅᑐᑦ ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᓂᒃ (ᓲᕐᓗ ᐊᓈᓇᒌᒃ/ᐅᒋᐊᓃᑦ ᐱᖃᑎᒌᒃᑐᑦ) ᖃᐅᔨᓴᖅᑕᐅᑦᑎᐊᒃᑲᓐᓂᕐᓗᑎᒃ ᐃᓕᖅᑯᓯᓇᓕᑐᐃᓐᓇᓇᐊᖅᑲᖅᑕᕐᒋᓐᓄᑦ ᑑᓚᓖᑦ ᐊᒃᑐᖅᑕᐅᓴᕋᐃᓐᓂᖅᓴᐅᓂᕐᒋᓐᓄᑦ ᐃᓅᓯᕐᒋᓐᓂ ᓇᓃᒪᖕᖁᕐᒋᑦ ᒪᓕᒃᓱᒋᑦ, ᐱᖃᓯᐅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᒥ ᐊᑦᑐᐃᓂᐅᑐᐃᓐᓇᓇᐊᓖᑦ ᐊᒫᒪᒃᑎᑦᑎᖃᑦᑕᖅᑎᓪᓗᒋᑦ ᐃᓕᖅᑯᓯᕐᒋᑦ ᐊᒻᒪᓗ ᐊᑦᑐᐊᔪᑦ ᓇᒦᖃᑦᑕᒪᖕᖁᑕ ᐸᖅᑭᔭᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᓂᒃ ᑕᑯᖃᑦᑕᐅᑎᖃᑦᑕᖅᑎᓪᓗᒋᑦ.

- ᑲᑎᓗᒃᑖᖅᓱᒋᑦ 249 ᐊᔾᔨᐅᙱᑦᑐᑦ ᓂᕐᔪᓂᒃ ᒪᓕᒃᓱᑎᒃ ᖃᐅᔨᓴᕐᓃᑦ ᐱᓕᕆᐊᖑᓯᒪᔪᑦ ᐅᓪᓗᒥᒧᑦ (85 ᖃᐅᔨᓴᕐᓃᑦ 2020-ᒥ ᐊᒻᒪᓗ 164 ᖃᐅᔨᓴᕐᓃᑦ 2021-ᒥ), ᐱᑕᖃᖅᓱᓂ 23.6 ᐃᑲᕐᕋᑦ ᑎᑎᕋᖅᑕᐅᓯᒪᔪᑦ ᐃᓕᖅᑯᓯᓇᔭᐅᕙᒃᑐᓄᑦ ᖃᐅᔨᓴᕈᑎᕙᓃᑦ ᑑᓚᓕᖕᓄᑦ ᐃᓗᕕᓕᐅᑉ ᖃᓂᒋᔮ. ᑖᒃᑯᓇᓂ ᓂᕐᔪᑎᓂᒃ ᒪᓕᒡᓗᑎᒃ ᖃᐅᔨᓴᕐᓃᑦ ᐱᓕᕆᐊᖑᓯᒪᔪᑦ, 43 ᖃᐅᔨᓴᖅᑕᐅᔪᑦ ᒪᓕᒃᑐᑦ ᐃᒥᐊᕐᔪᐊᑦ ᑕᐅᑦᑐᙵᖅᐸᓪᓕᐊᑎᓪᓗᒋᑦ ᐃᓗᐊᓂ 5 ᑭᓛᒥᑕᑦ ᒪᓕᒃᑕᐅᔪᓂ ᑲᑎᙵᔪᓂ, ᐱᑕᖃᓕᖅᓱᓂ 3.9 ᐃᑲᕐᕋᑦ ᐃᓕᖅᑯᓯᓇᔭᖏᓐᓄᑦ ᖃᐅᔨᓴᕈᑏᑦ ᐱᑕᖅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ (CPA ᐊᑯᓐᓂᖓᓂ 0.4 ᑭᓛᒥᑕᑦ ᐊᒻᒪᓗ 4.7 ᑭᓛᒥᑕᑦ). ᖃᐅᔨᓴᕈᑎᒃᑲᓐᓂᑦ ᑲᑎᑕᐅᓚᓗᐊᖅᑎᓪᓗᒋᑦ ᐊᑐᖅᑕᐅᓪᓗᑎᒃ ᐃᓄᖃᙱᑦᑐᑦ ᖃᖓᑕᓲᖃᕐᓛᑦ ᐊᔾᔨᓕᐅᕈᑎᓖᑦ (UAV) ᓂᕐᔪᑎᓂᒃ ᒪᓕᒡᓗᑎᒃ 2021-ᒥ ᐱᒻᒪᕆᐅᔪᑦ ᐊᑐᐃᓐᓇᕈᐃᑎᓪᓗᒋᑦ ᑐᑭᓯᓂᕐᒥᒃ ᑑᓚᓖᑦ ᐃᓕᖅᑯᓯᖏᓐᓄᑦ, ᖃᐅᔨᓴᓚᒃᓴᐃᑦ ᐊᕐᒋᓂᕐᒋᑦ ᖃᓂᒋᔭᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ ᓱᓕ ᓈᒻᒪᓂᙱᒃᑲᓗᐊᓗᐃᑎᓪᓗᒋᑦ ᐱᓕᕆᑦᑎᐊᕐᓂᕐᒧᑦ ᐅᓄᖅᑐᓂᒃ ᖃᐅᔨᓴᕈᑎᓂᒃ ᐃᓕᖅᑯᓯᓇᔭᐅᓕᖅᐸᒃᑐᓄᑦ ᐊᑦᑐᐊᔪᑦ 'ᐅᖓᓯᖕᓂᖓᓄᑦ ᐅᒥᐊᕐᔪᐊᒥ', ᑲᑎᓗᒃᑖᖅᓱᒍ ᐱᓕᕆᐊᖑᓯᒪᔪᑦ ᐃᓗᐊᓂ 0 ᑭᓛᒥᑕᑦ, 1 ᑭᓛᒥᑕᑦ, 2 ᕿᓛᒥᑕᑦ ᐊᒻᒪᓗ 3 ᕿᓛᒥᑕᑦ ᒪᓕᒃᑕᐅᔪᑦ ᑲᑎᙵᔪᑦ ᐱᖃᓯᐅᑎᓪᓗᒋᑦ ᑖᒃᑯᐊᑐᐊᖅ 2.5 ᒥᓇᑦ, 11 ᒥᓇᑦ, 62.0 ᒥᓇᑦ ᐊᒻᒪᓗ 60.5 ᒥᓇᑦ, ᐱᔾᔪᑎᒋᓪᓗᒋᑦ. ᑕᐃᒪᐃᒻᒪᑦ ᖃᐅᔨᔭᐅᔪᑦ ᓴᖅᑭᑕᐅᔪᑦ ᐊᑦᑐᐊᒧᑦ ᑖᒃᑯᓄᖓ ᐃᓄᖃᙱᑦᑐᑦ ᖃᖓᑕᓲᖃᕐᓛᑦ ᐊᔾᔨᓕᐅᕈᑎᓖᑦ (UAV) ᓂᕐᔪᑎᓂᒃ ᒪᓕᒡᓗᑎᒃ ᖃᐅᔨᓴᕐᓃᑦ ᑐᑭᓯᔭᐅᓪᓗᐊᖅᑐᑦ ᑕᐃᒪᐃᓐᓂᖏᓐᓄᑦ.

- ᑲᑎᙵᔪᑦ ᑲᑎᖃᑦᑕᕐᓂᕐᒋᑦ (ᐃᓄᖃᙱᑦᑐᑦ ᖃᖓᑕᓲᖃᕐᓛᑦ ᐊᔾᔨᓕᐅᕈᑎᓕᖕᓂᒃ (UAV)-ᐊᑐᖅᓗᑎᒃ): ᑕᑯᔭᐅᓚᔪᓚᐅᖅᑐᑦ ᑲᑎᙵᔪᑦ ᐱᓕᕆᑎᓪᓗᒋᑦ ᓂᕐᔪᑎᓂᒃ ᒪᓕᒡᓗᑎᒃ ᖃᐅᔨᓴᕐᓂᕐᓂᒃ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ (42% ᐱᕕᖃᕐᓂᕐᒧᑦ), ᐊᔾᔨᐸᓗᒋᓪᓗᓂᐅᒃ ᐊᑐᖅᑕᐅᓪᓗᐊᑕᖅᑐᖅ ᐋᖅᑭᒃᓯᒪᓂᕐᒋᓐᓄᑦ ᑎᑎᕋᖅᑕᐅᓚᐅᖅᑐᑦ ᑕᐃᑲᓂ ᐃᓕᖅᑯᓯᓇᔭᐅᓕᖅᐸᒃᑐᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐃᓂᐅᔪᒥ (BSA) ᓱᓪᔮᒥᒡᓗᑎᒃ ᓇᐅᑦᑎᖅᓱᖅᑎᓄᑦ. ᑕᒪᓐᓇ ᑭᖑᓂᖓᒍᑦ ᑐᑭᓕᐊᖅᑐᒥᒃ ᐋᖅᑭᒃᓯᒪᓃᑦ (23% ᐱᕕᖃᕐᓂᕐᒧᑦ) ᐊᒻᒪᓗ ᐊᕕᒃᑐᓚᒃᓯᒪᔪᑦ ᐋᖅᑭᒃᓯᒪᓃᑦ (23% ᐱᕕᖃᕐᓂᕐᒧᑦ). ᐱᑕᖃᙱᓐᓂᕐᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ, ᐃᓚᖏᑦ ᑲᑎᙵᔪᑦ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐋᖅᑭᒃᓯᒪᓂᕐᓄᑦ ᐊᒃᐸᓯᖕᓂᖅᓴᐅᓚᐅᖅᑐᑦ (40% ᐱᕕᖃᕐᓂᕐᒧᑦ), ᑕᑯᓗᒋᑦ ᖃᓄᐃᓐᓂᖅᓴᐅᓂᕐᒋᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ (52%). ᐊᔾᔨᒌᙱᑦᑕᖓ,

ᐃᓚᖏᑦ ᑲᑎᙵᔪᑦ ᑐᑭᓕᕇᓂᒃ ᐋᖅᑭᒃᓯᒪᔪᑦ ᖁᕝᕙᓯᖕᓂᖅᓴᕐᔪᓚᐅᖅᑐᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ (24%) ᐊᒃᑐᐊᔪᑦ ᐅᒥᕐᐊᔪᐊᖅᑕᖅᑎᓪᓗᒍ (15%). ᐃᓚᖏᑦ ᑲᑎᙵᔪᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᐋᖅᑭᓯᒪᔪᑦ ᐊᔾᔨᐸᓗᒋᓚᐅᖅᑕᖓ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ ᑕᕝᓗᒋᑦ ᖃᓄᐃᓐᓂᖅᓵᐅᖕᒪᖔᑕ ᐅᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ (23% ᐊᒻᒪᓗ 26%, ᐱᔾᔪᒋᑦ). ᐊᒃᑐᐃᓂᕐᔪᐊᖅᑕᖃᓚᐅᙱᑦᑐᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ ᑲᑎᙵᔪᑦ ᐋᖅᑭᒃᓯᒪᓂᖏᓐᓄᑦ ᓴᖅᑭᔮᖅᑐᒥᒃ.

■ ᑲᑎᙵᔪᑦ ᓯᐊᒻᒪᒃᓯᒪᓂᖏᑦ (ᐃᓄᖃᙱᑦᑐᑦ ᖃᖓᑕᓲᖁᑦ ᐊᔾᔨᓕᐅᕈᑎᓕᖕᓂᒃ (UAV)-ᐊᑐᖅᖢᑎᒃ): ᑑᒐᓘᑦ ᓴᖅᑭᔮᖅᑎᑦᑎᓚᐅᖅᑐᑦ ᐱᕙᖃᙱᓐᓂᖅᓴᐅᓂᖏᓐᓂᒃ ᖃᓂᒡᔪᐊᖅᑐᓂᒃ ᐊᒃᑐᐊᒍᓂᒃ ᑲᑎᙵᔪᓂᒃ ᐅᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ (32%) ᑕᕝᓗᒋᑦ ᖃᓄᐃᓐᓂᖅᓵᐅᖕᒪᖔᑕ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ (44% ᐱᕙᖃᕐᓂᕐᒧᑦ). ᑕᒪᓐᓇ ᖃᐅᔨᓴᐅᔪᖅ ᒪᓕᙱᑦᑐᑦ ᖃᐅᔨᓴᐅᔪᓂᒃ ᐱᓴᐅᓯᒪᔪᓂᒃ ᓯᓚᐦᔾᔫᑎᑦ ᖃᐅᔨᓴᖅᐸᓪᓕᐊᖏᓐᓇᕐᓂᕐᓂ ᑎᑎᖅᑯᖁᑎᓂᒃ ᖃᐅᔨᓚᐅᖅᑐᑦ ᑖᒃᑯᐊ ᑑᒐᓘᑦ ᖃᓂᒌᖕᓂᖅᓴᐅᓪᓗᑎᒃ ᑲᑎᙵᔪᑦ ᐱᑕᖃᖅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ. ᐅᓄᙱᑦᑐᑦ ᖃᐅᔨᓴᖅᓴᐃᑦ ᓂᕐᔪᑎᓂᒃ ᒪᓕᒃᖢᑎᒃ ᖃᐅᔨᓴᕐᓂᕐᓂᒃ ᖃᓂᒋᔭᖏᓐᓂ ᐅᒥᐊᕐᔪᑦ ᐃᓚᓕᐅᑎᑐᐃᓐᓇᕆᐊᓕᒃ ᑕᕝᔭᐅᔪᓂᑦ ᐊᔾᔨᕌᖏᓐᓂᖓᓄᑦ. ᐃᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ ᓴᖅᑭᔮᖅᑎᑦᑎᓯᒪᔪᖅ ᐊᖏᓂᖅᓴᓚᕈᐅᔪᒥᒃ ᐊᒃᑐᐃᓂᖃᕐᓂᐊᖓᓂᒃ ᑲᑎᙵᔪᑦ ᓯᐊᒻᒪᒃᓯᒪᓂᖏᓐᓂᒃ ᑖᒃᑯᓇᓂ ᐊᓈᓇᐅᔪᑦ–ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ ᑑᒐᓘᑦ ᑲᑎᔪᔪᓂ (P=0.071); ᑭᓯᐊᓂᓕ ᑖᒃᑯᓄᖓᐅᙱᑦᑐᑦ ᐊᓯᖏᓐᓄᑦ ᑲᑎᙵᔪᑦ ᖃᓄᐃᑦᑑᓂᖏᓐᓄᑦ (P>0.2 ᑕᒪᕐᒥᓗᒃᑖᓄᑦ).

■ ᐃᓕᖅᑯᓯᓪᓗᐊᑕᐅᕙᒃᑐᑦ ᐃᓄᖃᙱᑦᑐᑦ ᖃᖓᑕᓲᖁᑦ ᐊᔾᔨᓕᐅᕈᑎᓕᖕᓂᒃ (UAV)-ᐊᑐᖅᖢᑎᒃ: ᑑᒐᓘᑦ ᐱᕕᓪᓗᐊᑕᖃᑦᑕᖅᑐᑦ ᐃᖏᕐᕋᓪᓗᑎᒃ (71% ᐱᕙᖃᕐᓂᕐᒧᑦ), ᑭᙳᓂᐊᒍᑦ ᓄᖅᑲᖖᒋᖅᖢᑎᒃ / ᓂᒪᑐᐃᓐᓇᖅᖢᑎᒃ (22% ᐱᕙᖃᕐᓂᕐᒧᑦ), ᐊᒻᒪᓗ ᓂᕐᔪᑎᐅᖃᑎᒌᖕᓂᕐᒧᑦ ᐃᓕᖅᑯᓯᖏᑦ (7% ᐱᕙᖃᕐᓂᕐᒧᑦ). ᐃᓚᖓ ᐱᕙᖃᕐᓂᕐᒧᑦ ᑕᒪᒃᑯᐊ ᑑᒐᓘᑦ ᓄᖅᑲᖓᑎᓪᓗᒋᑦ / ᓂᒪᑎᓪᓗᒋᑦ ᐊᔾᔨᐸᓗᒋᓚᐅᖅᑕᖓ ᐅᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ (19%) ᖃᓄᐃᓐᓂᖅᓵᐅᖕᒪᖔᑕ ᑕᕝᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ (12%). ᑲᑎᙵᔪᓄᑦ ᐱᖅᓯᐅᑎᓪᓗᒋᑦ ᐃᓄᓲᕐᒥ ᓇᒦᒻᒪᖔᑦ ᐊᒃᑐᖅᑕᐅᓴᕆᐊᓂᖅᓴᐅᔭᓇᖅᑐᑦ ᐸᕝᕕᓴᒃᑕᐅᓂᕐᒧᑦ ᑕᖃᐃᓯᕋᓱᒃᑎᓪᓗᒋᑦ (ᓱᕐᓗ ᐊᓇᓈᕆᒃ/ᐃᓐᓇᕈᑎᓯᒪᙱᑦᑐᑦ ᑲᑎᙵᔪᑦ), ᐃᓚᖓ ᐱᕙᖃᕐᓂᕐᓂᐅᔪᖅ ᐊᑐᖅᑕᐅᓚᐅᖅᑐᑦ ᑕᖃᐃᖅᓯᖅᑎᓪᓗᒋᑦ / ᓂᒪᑎᓂᓪᓗᒋᑦ ᐃᓕᖅᑯᓯᐅᔪᖅ 9-67% ᐅᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ (ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐅᖓᓯᖕᓂᖏᓐᓂᒃ ᐅᒥᐊᕐᔪᐊᒥᑦ) ᖃᓄᐃᓐᓂᖅᓵᐅᖕᒪᖔᑕ ᑕᕝᓗᒋᑦ 35% ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ. ᐃᓚᖏᑦ ᐱᕙᖃᕐᓂᐅᔪᑦ ᑲᑎᖅᓴᐱᐅᑎᓪᓗᒋᑦ ᑲᑎᙵᔪᑦ ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ ᐃᓚᐅᑎᓪᓗᒋᑦ ᓄᖅᑲᖓᑎᓪᓗᒋᑦ / ᓂᒪᑎᓪᓗᒋᑦ ᐃᓕᖅᑯᓯᐅᔪᑦ 14%-ᖑᓚᐅᖅᑐᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ (ᑕᕝᔭᐅᔪᑦ ᑭᒡᓕᖃᖅᑐᑦ 3 ᑭᓛᒥᑕᓄᑦ ᐅᖓᓯᒃᖢᑎᒃ ᐅᒥᐊᕐᔪᐊᒥᑦ) ᐊᒻᒪᓗ 22% ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ. ᐊᒃᑐᐃᓂᕐᔪᐊᓂᒃ ᐅᒥᐊᕐᔪᐊᖅᑕᖅᓂᖓᓄᑦ ᐃᓕᖅᑯᓯᓪᓗᐊᑕᐅᕝᑐᒥᒃ ᓴᖅᑭᔮᖅᑐᖃᓚᐅᙱᑦᑐᖅ.

■ ᐊᔾᔨᐅᙱᑦᑐᑦ ᐃᓕᖅᑯᓰᑦ ᐃᓄᖃᙱᑦᑐᑦ ᖃᖓᑕᓲᖁᑦ ᐊᔾᔨᓕᐅᕈᑎᓕᖕᓂ (UAV)- ᐊᑐᖅᖢᑎᒃ: ᐊᔾᔨᐅᙱᑦᑐᑦ ᐃᓕᖅᑯᓰᑦ ᓂᕆᐅᒋᔭᐅᙱᑎᑦᑐᑦ ᐃᓯᒫᓗᒃᑎᓪᓗᒍ, ᓱᕐᓗ ᐊᒫᒪᒃᑎᑦᑎᑎᓪᓗᒋᑦ, ᕿᓚᓗᒐᐅᖅᑲᑎᑏᑦ ᐊᒃᑐᐊᖃᑎᑏᖕᓃᑦ, ᓄᓕᐊᕋᓯᖕᓂᕐᒧᑦ ᐅᔾᔨᖅᓇᖅᑐᑦ, ᐱᙳᐊᖅᑎᓪᓗᒋᑦ (>ᐃᑲᑕᒃᑎᓪᓗᒋᑦ ᐃᒫᓂ ᐅᕝᕙᓗᓐᓃᑦ ᓴᓂᒨᑲᑕᒃᑎᓪᓗᒋᑦ) ᑎᑎᕋᖅᑕᐅᓚᐅᖅᑐᑦ 119–ᓂ ᑲᑎᓗᒃᑖᖅᖢᒋᑦ ᓂᕐᔪᑎᓂᒃ ᒪᓕᒃᖢᑎᒃ ᖃᐅᔨᓴᕐᓂᕐᓂᒃ ᐱᓕᕆᐊᖑᓯᒪᔪᑦ ᐱᖅᓯᐅᑎᓪᓗᒋᑦ 23%-ᓂᒃ ᐱᕙᖃᖅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓪᓗᒍ ᐊᒻᒪᓗᓗ 18% ᐅᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ ᓴᖅᑭᔮᖅᑎᑕᐅᓚᐅᖅᑐᑦ ᐊᒃᑐᐃᓂᖅᓵᕐᔪᓗᓂ ᐊᔾᔨᐅᙱᑦᑐᓄᑦ ᐃᓕᖅᑯᓯᐅᕝᑐᓄᑦ ᐃᓐᓇᕐᓂᑦ ᑲᑎᙵᔪᓂ (P=0.052) ᐊᒻᒪᓗ ᐅᒥᐊᑦ ᐃᓄᑑᑎᓪᓗᒋᑦ (P=0.066); ᑭᓯᐊᓂᓕ ᐊᓈᓇᕆᒃ–ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᓄᑦ ᑲᑎᙵᔪᑦ (P=0.5) ᐅᕝᕙᓗᓐᓃᑦ ᑲᑎᖅᓴᐲᑦ ᑲᑎᙵᔪᑦ ᐃᓐᓇᕈᖅᓯᒪᔪᖃᙱᑦᑐᓂᒃ ᐃᓚᖃᖅᖢᑎᒃ (P=0.2).

- ᐊᒫᒪᒃᑎᑦᑎᓂᖅ: ᐊᒫᒪᒃᑎᑦᑎᓂᖅ ᐅᒥᐊᒥᒃ ᐅᕝᕙᓗᓐᓃᑦ ᐊᕐᕌᓂᓴᒥᒃ ᐊᓈᓇᖓᓂᑦ ᑎᑎᕋᖅᑕᐅᓯᒪᖃᑕᐅᓚᐅᖅᑐᑦ ᐱᓕᕆᑎᓪᓗᒋᑦ 24-ᓂᒃ ᓂᕐᔪᓂᒃ ᒪᓕᒃᖢᑎᒃ ᖃᐅᔨᓴᕐᓂᕐᓂᒃ (12 ᖃᐅᔨᓴᕐᓃᑦ 2020-ᒥ, 12 ᖃᐅᔨᓴᕐᓃᑦ 2021-ᒥ; ᐃᒪᐃᓕᖓᓕᖅᖢᑎᒃ 14%-ᓂᒃ ᐊᒻᒪᓗ 7%-ᖑᓗᑎᒃ ᐊᑕᖏᖅᖢᒋᑦ ᑲᑎᙵᔪᓂ 2020-ᒥ ᐊᒻᒪᓗ 20221-ᒥ, ᐱᔪᒋᑦ). ᐱᓕᕆᐊᖑᑎᓪᓗᒋᑦ 24-ᖑᔪᑦ ᐱᓕᕆᐊᖑᔪᑦ ᐊᒫᒪᒃᑎᑦᑎᓃᑦ ᑕᕝᔭᓚᐅᖅᑐᓂ, ᐱᕙᖃᕐᓂᖏᑦ ᐊᒫᒪᒃᑎᑦᑎᓂᕐᒧᑦ ᐊᔾᔨᓕᐅᙱᑦᑐᑦ ᐊᑯᓐᓂᖏᓐᓂᒃ 5% ᐊᒻᒪᓗ 63% ᑖᒃᑯᓇᓂ ᓂᕐᔪᑏᑦ ᒪᓕᒃᑕᐅᓗᑎᒃ ᐱᓕᕆᕝᕕᐅᔪᓂᒃ (ᑐᑭᖃᓖᑦᑐᑦ ᓇᐃᓴᐅᑎᖅᑎᑕᐅᓗᑎᒃ 25% ᐱᕙᖅᑎᓪᓗᒋᑦ, SD 17%-ᖑᓗᓂ ᐱᕙᖅᑎᓪᓗᒋᑦ). ᒪᕐᕉᒃ ᓂᕐᔪᑎᓂᒃ ᒪᓕᒃᖢᑎᒃ ᖃᐅᔨᓴᕐᓂᕐᓂᒃ ᒪᓕᑐᐃᓐᓇᖅᑐᑦ ᐅᒥᐊᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ ᐱᖅᑯᓯᐅᔾᔨᓯᒪᔪᑦ ᐊᒫᒪᒃᑎᑦᑎᓂᓪᓗᒋᑦ ᐃᓕᖅᑯᓯᖏᓐᓂ. ᐊᒃᑐᐃᓂᕐᔪᐊᖅᑕᖃᓚᐅᙱᑦᑐᑦ ᐅᒥᐊᕿᔪᐊᖅᑕᖅᑎᓪᓗᒍ ᐊᒫᒪᒃᑎᑦᑎᖃᑦᑕᕐᓂᕐᒧᑦ ᓴᖅᑭᔮᖅᑐᓂᒃ.

■ ᓂᕐᔪᑏᑦ ᑲᑎᙵᔪᑦ ᐃᓐᓇᕈᑎᓯᒪᙱᑦᑐᓂᒃ ᐱᑕᖅᑎᓪᓗᒍ: ᐊᓈᓇᕆᒃ–ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ ᐱᖃᑎᕆᑦ ᑕᕝᔭᐅᓚᐅᖅᑐᑦ 45-ᓂᒃ ᐃᓄᑐᐊᓂᒃ ᓂᕐᔪᑎᑦ ᒪᓕᒃᑕᐅᓗᑎᒃ ᖃᐅᔨᓴᕐᓂᕐᓂᒃ ᑲᑎᓗᒃᑖᖅᖢᒋᑦ 170 ᒥᓇᑦ (ᐱᖃᓯᐅᑎᓪᓗᒋᑦ 21 ᒥᓇᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ), ᐃᒪᐃᒃᑲᓗᐊᖅᑎᓪᓗᒍ ᑲᑎᖅᓴᐲᑦ ᑲᑎᙵᔪᑦ ᐃᓐᓇᐅᙱᑦᑐᖅᑕᖅᑐᑦ ᑕᕝᔭᐅᓚᐅᖅᑐᑦ 27-ᓂᒃ ᓂᕐᔪᑎᓂᒃ ᒪᓕᒃᖢᑎᒃ ᖃᐅᔨᓴᕐᓂᕐᓂᒃ ᑲᑎᓗᒃᑖᖅᖢᒋᑦ 103 ᒥᓇᑦᓂᒃ (ᐱᖃᓯᐅᑎᓪᓗᒋᑦ 39 ᒥᓇᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖅᑎᓪᓗᒍ). ᐅᒥᐊᑦ ᑕᕝᔭᐅᓚᐅᖅᑐᑦ ᐃᓄᑐᐊᖑᓗᑎᒃ

(ᓃᕐᓗ ᐃᓄᑐᐊᕐᒍᓚᓗᑎᒃ ᐃᖃᑎᖃᕐᓗᑎᒡᓘᓐᓃᑦ ᐅᒋᐊᕐᒎᖃᑎᒥᓂᒃ ᐊᓯᐊᓂᒃ ᐱᑕᖃᒃᑲᓐᓂᙵᑎᓚᓗᒍ) 22-ᓂᒃ ᐃᓄᑐᐊᓂᒃ ᓂᕐᔪᑎᓂᒃ ᒪᓕᒃᓘᑎᒃ ᖃᐅᔨᓴᕐᓂᕐᓂᒃ, ᑲᑎᓗᒃᑖᖕᓘᒋᑦ 158 ᒥᓇᑦ (ᐱᖃᓯᐅᑎᓚᓗᒋᑦ 12 ᒥᓇᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓚᓗᒍ).

- ᐊᒃᑐᐊᔪᑦ ᐊᒻᒪᓗ ᐊᒃᑐᐊᖃᑎᖏᑦ ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ ᐊᓈᓇᖏᓐᓄᑦ: ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ ᑎᑎᕋᖅᑕᐅᓯᒪᓛᕐᒍᓚᐅᖅᑐᑦ ᐊᑖᓃᑎᓚᓗᒋᑦ ᐃᓱᒪᒋᔭᐅᔪᓄᑦ ᐊᓈᓇᖏᓐᓄᑦ ᖃᓄᐃᓐᓂᖕᓴᐅᙱᓚᙱᑕ ᑕᑯᓚᓗᒋᑦ ᓯᕗᓂᐊᓂ, ᑭᖑᓂᐊᓂ, ᐅᕝᕙᓘᓐᓃᑦ ᖁᓚᓂ ᑕᒪᕐᒥᖏᓂᒃ ᐱᑕᖃᖅᑎᓚᓗᒋ ᐊᒻᒪᓗ ᐱᑕᖃᙱᑎᓚᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ (40% ᐊᒻᒪᓗ 49% ᐱᕙᖃᖅᑎᓚᓗᒋᑦ, ᐱᓚᓗᒋᑦ). ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ ᐊᑖᓃᑎᓚᓗᒋᑦ ᐊᓈᓇᒋᔭᐅᓇᓯᒋᔭᒧᑦ, ᐊᒃᑐᐊᓚᓗᓇᓗᐅᖅᑐᑦ ᐃᓐᓇᕐᒧᑦ 99% ᐱᕙᖃᖅᑎᓚᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᙱᑎᓚᓗᒍ). ᑕᒪᐃᓐᓂᖓᓄᑦ, ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ ᐊᓯᔾᔨᖅᑰᔨᓯᒪᖃᑦᑕᓗᐅᙱᑦᑐᑦ ᐊᒃᑐᐊᔪᑦ ᐊᒻᒪᓗ ᐊᒃᑐᐊᖃᑎᖏᑦ ᐊᓈᓇᒥᖕᓄᑦ ᐃᓕᖅᑯᓯᓇᔭᕐᒋᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓚᓗᒋᑦ. ᐊᒃᑐᐃᓂᕐᔪᐊᖅᑕᖃᙱᑦᑐᑦ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓚᓗᒋᑦ ᐃᒪᐃᓐᓇᓯᒋᔭᐅᔪᑦ ᐊᕐᒥᓂᖕᓴᑦ ᓯᓪᔭᒥᓘᑎᒃ ᖃᐅᔨᓴᖕᐸᓚᓕᐊᓂᕐᓂᒃ ᐱᓕᕆᐊᓂ ᐃᓗᕙᓕᕐᒥ, ᐃᒪᐃᓐᓇᓯᒋᓐᓈᓚᓗᑎᒃ ᐅᒋᐊᑦ ᐊᒻᒪᓗ ᐊᕐᕋᓂᓴᑦ ᖃᕐᒋᖅᓯᕙᓕᐊᔪᑦ ᑕᐃᑯᓇ ᐃᓕᖅᑯᓯᓇᔭᐅᓕᖅᐸᒃᑐᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐃᓂᐅᔪᒥᒃ (BSA) ᐅᓄᙳᒋᓗᐊᖅᑎᓯᒪᔪᑦ ᐃᑉᔪᑎᒋᓚᓗᒋᑦ ᑕᑯᔭᕐᓂᕐᒋᓐᓂᖕᓴᐅᓂᕐᒋᓐᓂᓄᑦ ᒥᑭᓐᓂᖕᓴᓂ ᐆᒪᔪᓂ ᐊᑖᓃᑎᓚᓗᒋᑦ ᒪᓕᒃᑕᐅᓚᓗᑎᒃ ᐃᓐᓇᕐᒧᑦ.

ᓯᓃᓂᒃᓴᒥ ᐊᑐᓕᖁᔭᐅᔪᑦ

ᐱᔾᔪᑎᒋᓚᓗᒋᑦ ᓯᓃᓂᒃᓴᒥ ᖃᐅᔨᓴᖅᐸᓚᓕᐊᕐᒋᓐᓇᕈᑏᑦ ᐱᒋᐊᖅᑕᐅᔪᒪᔪᑦ ᐃᓗᕙᓕᕐᒥ ᓯᓪᔭᒦᓚᓗᑎᒃ ᖃᐅᔨᓴᖅᐸᓚᓕᐊᕐᒋᓐᓇᕐᓂᕐᒧᑦ ᐱᓕᕆᐊᑦ, ᒨᑐᒃᑯᑦ ᐃᒪᓐᓇ ᐅᑐᓕᖁᔨᔪᑦ ᐅᑯᓂᙵ:

- ᐊᑐᖅᑕᐅᓂᖕᓴᐅᓕᕐᓗᑎᒃ ᐃᓄᒃᑲᙱᑦᑐᑦ ᖃᙵᑕᓲᕋᕐᓛᑦ ᐊᔾᔨᓕᐅᕈᑎᓛᑦ (UAV) ᖃᐅᔨᓴᕐᓃᑦ ᐃᓗᓕᕐᒋᑦ ᐱᓕᕿᐊᒥᑦ, ᐱᔾᔪᑕᐅᓚᓗᑎᒃ ᐱᒻᒪᐱᐅᔪᑦ ᑐᑭᓯᑎᑦᑎᔾᔪᑏᑦ ᑖᔅᓯᒪ ᐱᓕᐱᔾᔪᓯᐅᑉ ᐊᑐᐃᓐᓇᕈᖅᑕᕐᒋᑦ ᐃᔾᔪᒋᑦ ᖃᐅᔨᓴᖅᐸᓚᓕᐊᕐᒋᓐᓇᕐᓂᕐᒧᑦ ᐊᓯᔾᔨᐅᑏᑦ ᑲᑎᙵᔪᓂ ᐋᖅᑭᒃᓯᒪᖃᑦᑕᕐᓂᕐᒋᑦ ᐋᖅᑭᑦᑎᐊᓇᐊᓚᓪᓗᒋᑦ ᐊᕐᒋᓐᕐᒋᓐᓄᑦ ᐃᓕᖅᑯᓯᐅᕙᒃᑐᑦ ᐃᑕᖃᖅᑎᓚᓗᒋᑦ ᐊᐅᓚᖅᑎᑦᑎᓃᑦ (ᐆᑯ ᐊᑕᕐᒋᖕᓘᑎᒃ 2019). ᐃᓄᒃᑲᙱᑦᑐᑦ ᖃᙵᑕᓲᕋᕐᓛᑦ ᐊᔾᔨᓕᐅᕈᑎᓛᑦ (UAV) ᖃᐅᔨᕈᑏᑦ ᐊᑐᐃᓐᓇᕈᐃᓲᕐᒍᕐᒪᑦ ᓇᓗᓇᐃᔭᑦᑎᐊᖅᓯᒪᔪᓂᒃ ᑎᑎᖅᑲᕐᑯᑎᓚᑦᑖᓇᔭᐅᓚᖅᑐᓂᒃ ᐱᓗᐊᑕᕐᓂᒃ ᑑᓖᓛᑦ ᐃᓕᖅᑯᓯᕐᒋᓐᓄᑦ (ᓃᕐᓗ ᐊᒫᒪᒃᑎᑦᑎᑎᓚᓗᒋᑦ, ᓄᖅᑲᖓᕐᖅᑎᓚᓗᒋᑦ, ᓄᓇᕐᑯᑎᕐᒋᓐᓂ ᐃᓕᖅᑯᓯᕐᒋᑦ) ᐅᓄᖅᓯᑎᑕᐅᔪᓐᓇᕋᔭᙱᑦᑐᑦ ᓯᔮᒥᓚᓗᑎᒃ ᑕᑯᖃᑦᑕᕐᓂᕐᒧᑦ ᐱᓕᕆᔾᔪᓯᒥ. ᓃᕐᓗ, ᐃᓚᙵᑦ ᐱᕚᓕᕈᑕᐅᔪᖅ ᓂᕐᔪᑎᓂᒃ ᒪᓕᒃᓘᑎᒃ ᖃᐅᔨᓴᕐᓃᑦ ᐱᐅᓯᒋᐊᖅᑕᐅᓯᒪᔪᖅ ᖃᐅᔨᓴᖅᐸᓚᓕᐊᔪᓐᓇᕐᓂᕐᒧᑦ ᕿᑎᖃᖅᓯᒪᔪᓂᒃ ᖁᕝᕙᓯᒃᑐᒻᒪᕆᙵᓂᓘᓐᓃᑦ ᐃᓕᖅᑯᓯᕆᓚᖅᑕᐅᕙᒃᑐᑦ ᓃᕐᓗ ᐊᓯᔾᔨᕐᓃᑦ ᐊᒫᒪᒃᑎᑦᑎᖃᑦᑕᕐᓂᕐᒧᑦ ᐅᕝᕙᓘᓐᓃᑦ ᐃᖅᓯᓇᕋᓱᒃᑎᓚᓗᒋᑦ. ᖃᐅᔨᓴᕆᒃᓴᓕᐊᑦ ᐊᕐᒥᓂᕐᒋᑦ ᐱᓕᕆᐊᕐᒍᔪᑦ ᐅᒥᐊᕐᔪᐊ 'ᐱᑕᖃᖅᑎᓚᓗᒋ' ᓱᓕ ᓈᓪᓕᒍᓂᙵᒃᑲᓗᐊᖅᑎᓚᓗᒍ ᓈᒪᒃᓯᓯᒪᓛᓂᒃ ᖃᐅᔨᔪᓐᓇᐅᑎᓂᒃ ᓇᐃᓴᐅᑎᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᑐᙵᕙᒋᓚᓗᒋᑦ 2020-2021 ᑲᑎᖕᓴᐋᑦ ᖃᐅᔨᓴᕈᑎᕙᓃᑦ ᑖᒃᑯᐊᑐᐊᕐᒍᓗᑎᒃ, ᐅᓄᖅᓯᒋᐊᕐᓂᕐᒋᑦ ᖃᐅᔨᓴᕆᒃᓴᑦ ᐊᕐᒥᓂᕐᒋᑦ ᐊᑐᖅᑕᐅᓗᑎᒃ ᓯᓃᓂᒃᓴᒥ ᐃᓄᒃᑲᙱᑦᑐᑦ ᖃᙵᑕᓲᕋᕐᓛᑦ ᐊᔾᔨᓕᐅᕈᑎᓛᑦ (UAV) ᖃᐅᔨᕈᑏᑦ ᐅᓄᖅᓯᒋᐊᖅᓯᓂᖕᓴᐅᔪᓐᓇᖅᑐᒃᓴᐅᔪᑦ ᖃᐅᔨᓴᕐᓂᒥ ᐊᓯᔾᔨᖅᑐᓂᒃ ᑑᑯᓄᕐᒐᓗᐊᑕᖅ ᑑᓖᓛᑦ ᐃᓕᖅᑯᓯᕐᒋᓐᓄᑦ ᐃᓕᖅᑯᓯᓇᓕᖅᐸᒃᑕᕐᒋᑦ ᐅᒥᐊᕐᔪᐊᖃᖃᑦᑕᖅᑎᓚᓗᒍ. ᓱᓕᒃᑲᓂᖅ, ᐃᓄᒃᑲᙱᑦᑐᑦ ᖃᙵᑕᓲᕋᕐᓛᑦ ᐊᔾᔨᓕᐅᕈᑎᓛᑦ (UAV) ᖃᐅᔨᕈᑏᑦ ᐱᓕᕆᔾᔪᓯᕐᒋᑦ ᐅᓄᕐᓂᖕᓴᓂᒃ ᑎᑎᖅᑲᕐᑎᓂᒃ ᑲᑎᓯᐃᑎᑦᑎᓇᔭᖅᑐᑦ ᖃᓂᓐᓂᖕᓴᐅᑎᓚᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐅᙱᓯᖕᓂᕐᒋᑦ (ᓃᕐᓗ 0-2 ᑭᓲᒥᑕᓂ ᐅᙱᓂᖕᓂᖃᕐᓘᑎᒃ) ᖃᓄᐃᓐᓂᖕᓴᐅᓂᕐᒋᑦ ᑕᑯᓗᒋᑦ ᑕᐅᕙᓂ ᐃᓕᖅᑯᓯᓇᔭᐅᓕᖅᐸᒃᑐᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐃᓂᐅᔪᒥ (BSA) ᖃᐅᔨᓴᕐᕙᐅᔪᒥ ᐋᖅᑭᒃᑕᐅᓯᒪᔪᑦ ᓃᖃᐃᒻᒪ ᓂᕐᔪᑐᑎᓂᒃ ᒪᓕᒃᑎᓚᓗᒋᑦ ᐱᓕᕆᐊᕐᒍᓚᓚᑦᑖᕈᓐᓇᕐᓂᕐᒋᓐᓂᒃ ᐅᒥᐊᕐᔪᐊᑦ ᐊᖅᑯᑎᖏᓐᓂ; ᐃᒪᐃᑎᓚᓗᒍᓚ ᐅᒥᐊᕐᔪᐊᑦ ᐅᐊᒍᓐᓇᓗᐊᙵᓪᒪᑕ ᖃᓂᒋᔭᕐᒋᓐᓄᑦ ᐃᓕᖅᑯᓯᓇᔭᐅᓕᖅᐸᒃᑐᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐃᓂᐅᔪᖅ (BSA) ᐱᔾᔪᑎᒋᓚᓗᒋᑦ ᐃᓂᖓ ᐅᒥᐊᕐᔪᐊᑦ ᐊᖅᑯᑖ (ᐋᖅᑭᒋᐊᖅᑕᐅᓚᐅᖅᑐᖅ ᑲᓇᕐᓇᖅᐸᓯᕐᒧᑦ 2020–ᒥ).

- ᐱᓕᕆᒃᑲᓐᓂᕐᓗᑎᒃ ᖃᐅᔨᓴᕈᑎᒃᑲᓐᓂᕐᓂᒃ 2021-ᒥ ᖃᙵᑕᓲᒃᑯᑦ ᖃᐅᔨᓴᕈᑎᕙᓂᕐᓂᒃ ᑖᒃᑯᓄᙵᓚᓪᓚᑖᖅ ᖃᐅᔨᓴᖅᑕᐅᖁᓚᓗᒋᑦ ᖃᐅᔩᓴᓕᓯᒪᔭᖃᓇᐊᓕᑦ ᓇᓗᓇᐃᖅᓯᔾᔪᑎᑦ (EWI) ᖃᐅᔨᓴᕈᑏᑦ (ᐊᑐᕐᓗᒋᑦ ᑖᒃᑯᓄᙵᓚᓪᓚᑖᖅ 1,000 ᐃᓯᙵᓂ ᖃᐅᔨᓴᕈᑏᑦ ᑎᑎᖅᑲᕐᑯᑎᖏᑦ ᑲᑎᑕᐅᓚᐅᖅᑐᑦ ᑕᒪᑐᒧᙵ) ᓇᓗᓇᐃᖅᑕᐅᖁᓚᓗᒍ ᓴᖅᑮᖅᑎᑦᑎᓂᕐᒋᑦ ᐅᓄᙳᒋᑦᑐᒻᒪᕆᙵᓂᒃ ᖃᐅᔨᓴᕆᒃᓴᑦ ᐊᕐᒥᓂᕐᒋᓐᓂᒃ ᐊᒻᒪᓗ ᖃᓄᐃᓕᙵᓂᐅᕙᒃᑐᑦ ᐅᓄᕈᓐᓂᖅᐸᓚᓕᐊᑎᓚᓗᒋᑦ ᐃᓚᕐᒋᑦ ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ ᑑᓖᓛᑦ ᑕᐅᕙᓂ ᓄᓇᓂ ᐊᕙᑦᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕙᐅᔪᓂ (RSA).

- ᐱᓕᕆᐊᖃᕐᓗᑎᒃ ᑖᒃᑯᓄᙵᓚᓪᓚᑖᖅ ᐃᓄᒃᑲᙱᑦᑐᑦ ᖃᙵᑕᓲᕋᕐᓛᑦ ᐊᔾᔨᓕᐅᕈᑎᓛᑦ (UAV) ᖃᐅᔨᓴᕈᑎᓂᒃ ᑑᓖᓚᙵᓄᑦ ᑲᑎᙵᔪᑦ ᖃᓄᐃᓕᙵᓂᕐᒋᓐᓄᑦ ᑭᙳᓚᐅᓗᑎᒃ ᖃᐅᔨᓴᖅᑕᐅᓗᑎᒃ ᑕᒪᒃᑯᓄᙵ ᖃᐅᔩᓴᓕᓯᒪᔭᖃᓇᐊᓕᑦ ᓇᓗᓇᐃᖅᓯᔾᔪᑎᑦ (EWI) ᖃᐅᔨᓴᕈᑏᑦ (ᓃᕐᓗ ᐃᓚᕐᒋᑦ ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ ᑑᓖᓛᑦ ᐊᒃᑐᐊᔪᑦ ᐃᓐᓇᐃᑦ ᐅᓄᕐᓂᕐᒋᓐᓄᑦ). ᑕᒪᓐᓇ ᐊᑐᐃᓐᓇᕈᐃᔪᓐᓇᖅᑐᑦ ᖃᐅᔨᔭᐅᑎᐊᕈᓐᓇᕐᓂᖅᓴᐅᓗᑎᒃ ᐱᑕᖃᑐᐃᓐᓇᓇᐊᖃᕐᓂᕐᒋᓐᓄᑦ ᐊᒻᒪᓗ ᑕᒻᒪᖅᓯᒪᙱᓐᓂᖅᓴᐅᓕᕐᓗᑎᒃ ᓂᕐᔪᑏᑦ ᑕᑯᔭᐅᔪᑦ ᐊᒻᒪᓗ

ᓇᐃᓭᖅᑕᐅᓂᖏᑦ, ᐅᑭᐅᖏᓐᓄᑦ ᓇᓗᓇᐃᔭᐅᑏᑦ ᐊᒻᒪᓗ ᑭᓲᓂᖏᓐᓄᑦ ᓇᓗᓇᐃᖅᓯᔾᔪᑏᑦ ᖃᓄᐃᓐᓂᖅᓴᐅᓂᖏᑦ ᑕᑯᓗᒋᑦ ᒫᓐᓇ ᐱᖅᑯᓯᐅᒐᔪᒃᑐᑦ ᖃᐅᔨᓴᖅᐸᓪᓕᐊᖏᓐᓇᕐᓂᕐᒧᑦ ᐱᓕᕆᔾᔪᑏᑦ (ᓇᐅᑦᑎᖅᓱᖅᑎᓪᓗᒋᑦ ᑎᑎᖅᑲᖁᑎᓂᒃ ᑲᑎᖅᓱᐃᓂᖅ). ᑎᑎᖅᑲᖁᑎᖃᓪᓚᑦᑖᕐᓂᒃ ᐃᓄᖃᙱᑦᑐᑦ ᖃᖓᑕᔫᕋᓛᑦ ᐊᔾᔨᓕᐅᕆᑎᓖᑦ (UAV) ᑕᕐᓇᔭᐅᓯᐅᖅᓯᒪᔪᓂᒃ ᖃᐅᔨᓴᕈᑎᓂᒃ ᐲᖅᓯᓇᔭᖅᑐᑦ ᓇᐅᑦᑎᖅᓱᖅᑐᑦ ᐃᓚᐃᓐᓈᖅᓯᖃᑦᑕᕐᓂᖏᓐᓂᒃ ᑎᑎᖅᑲᖁᑏᑦ ᑲᑎᖅᓱᖅᑕᐅᕙᓪᓕᐊᑎᓪᓗᒋᑦ ᐊᒻᒪᓗ ᖃᐅᔨᓴᑦᑎᐊᕐᓂᖅᓴᐅᓗᑎᒃ ᐊᔾᔨᒌᖃᑦᑕᙱᑦᑐᓂᒃ ᖃᐅᔨᓵᓕᓯᒪᔭᖃᓚᐊᓕᑦ ᓇᓗᓇᐃᖅᓯᔾᔪᑎᑦ (EWI) ᖃᐅᔨᓴᕈᑎᕕᓂᖏᓐᓂᒃ.

Study Limitations

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Acronyms / Abbreviations

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

Glossary of Terms

Term	Definition
ambient sound	Sound that would be present in the absence of a specified activity, usually a composite of sound from many sources near and far, e.g., shipping vessels, seismic activity, precipitation, sea ice movement, wave action, and biological activity.
broadband level	The total level measured over a specified frequency range.
ceteacean	Any animal in the order Cetacea. These are aquatic species and include whales, dolphins, and porpoises.
Continuous sound	A sound whose sound pressure level remains above ambient sound during the observation period. A sound that gradually varies in intensity with time, for example, sound from a marine vessel.
decibel (dB)	Unit of level used to express the ratio of one value of a power quantity to another on a logarithmic scale. Unit: dB.
frequency	The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: f. 1 Hz is equal to 1 cycle per second.
hearing group	Category of animal species when classified according to their hearing sensitivity and to the susceptibility to sound. Examples for marine mammals include very low-frequency (VLF) cetaceans, low-frequency (LF) cetaceans, mid-frequency (MF) cetaceans, high-frequency (HF) cetaceans, very high-frequency (VHF) cetaceans, otariid pinnipeds in water (OPW), phocid pinnipeds in water (PPW), sirenians (SI), other marine carnivores in air (OCA), and other marine carnivores in water (OCW) (NMFS 2018, Southall et al. 2019). See auditory frequency weighting functions, which are often applied to these groups.
hearing threshold	The sound pressure level for any frequency of the hearing group that is barely audible for a given individual for specified background noise during a specific percentage of experimental trials
high-frequency (HF) cetacean	See hearing group
impulsive sound	Qualitative term meaning sounds that are typically transient, brief (less than 1 second), broadband, with rapid rise time and rapid decay. They can occur in repetition or as a single event. Examples of impulsive sound sources include explosives, seismic airguns, and impact pile drivers.
low-frequency (LF) cetacean	See hearing group
masking	Obscuring of sounds of interest by sounds at similar frequencies.
median	The 50th percentile of a statistical distribution.
mid-frequency (MF) cetacean	See hearing group
odontocete	odontocete

Term	Definition
phocid	A common term used to describe all members of the family Phocidae. These true/earless seals are more adapted to in-water life than are otariids, which have more terrestrial adaptations. Phocids use their hind flippers to propel themselves. Phocids are one of the three main groups in the superfamily Pinnipedia; the other two groups are otariids and walrus.
pinniped	A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus
phocid pinnipeds in water (PPW)	See hearing group
received level	The level measured (or that would be measured) at a defined location. The type of level should be specified.
acoustic disturbance threshold	Based on best available science and the practical need to adopt a threshold based on a factor that is both predictable and measurable for most activities, the National Marine Fisheries Service (NMFS) applies a generalized acoustic disturbance threshold for marine mammals based on received sound level to estimate the onset of behavioral harassment. NMFS predicts that marine mammals are likely to be behaviorally harassed in a manner categorized as 'Level B harassment' when exposed to underwater anthropogenic noise above received levels of 120 dB re 1 micropascal (μPa) (rms) for continuous (e.g., vibratory pile-driving, drilling, vessel noise) and above 160 dB re 1 μPa (rms) for non-explosive impulsive (e.g., seismic airguns, impact pile driving) or intermittent (e.g., scientific sonar) sources. This threshold estimation includes disruption of behavioral patterns resulting directly in response to noise exposure (e.g., avoidance), as well as that resulting indirectly from associated impacts such as temporary threshold shift (TTS) in hearing or masking.
acoustic disturbance distance	Distance or range from the sound source over which the emitted sound would exceed the established acoustic disturbance threshold of 120 dB re 1 μPa (rms) for continuous sound sources and 160 dB re 1 μPa (rms) for non-continuous or impulsive sound sources
acoustic disturbance period	period of time an animal would be exposed to sound above the established acoustic disturbance threshold of 120 dB re 1 μPa (rms) for continuous sound sources and 160 dB re 1 μPa (rms) for non-continuous or impulsive sound sources
narwhal-vessel disturbance distance	Maximum distance from a Project vessel associated with the onset of narwhal behavioural responses to an approaching vessel or the conclusion of narwhal behavioural responses to a departing vessel (note: term defined exclusively for the present study based on existing narwhal behavioural response data collected for the Project).
vessel disturbance period	The maximum time period (per vessel transit) a narwhal would demonstrate a measurable behavioural response during a direct interaction with a vessel, assuming the most extreme exposure condition (i.e., a narwhal remaining stationary on the shipping lane during exposure) and based on a vessel transit speed of 9 knots.
daily vessel disturbance period	The sum of all 'vessel disturbance periods' incurred on a narwhal over a 24-hour period, assuming the most extreme exposure condition (i.e., the exposed narwhal remained stationary on the shipping lane during all vessel exposures that day), and based on a vessel transit speed of 9 knots and the 2021 frequency of ship transits in the RSA (i.e., two transits per day on average).

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TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

This report presents the integrated results of a seven-year shore-based monitoring study of narwhal (*Monodon monoceros*) conducted near Bruce Head on North Baffin Island, Nunavut. During the open-water seasons of 2014-2017 and 2019-2021, visual survey data were collected from a cliff-based observation platform overlooking an established shipping corridor to investigate potential narwhal response to shipping activities, with information collected on narwhal relative abundance and distribution (RAD), group composition, and behaviour. Additional data were collected on environmental conditions and anthropogenic activities (e.g., shipping and hunting activities) to distinguish between the potential effects of Project-related shipping activities and potential confounding factors that may also influence narwhal behaviour.

1.1 Project Background

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

To date, Baffinland has been operating in the Early Revenue Phase (ERP) of the Project and is authorized to transport 4.2 Mtpa of ore by truck to Milne Port for shipping through the Northern Shipping Route using chartered ore carrier vessels. A production increase to ship 6.0 Mtpa from Milne Port was approved for 2018-2021 and shipping is expected to continue for the life of the Project (20+ years). During the first year of ERP operations in 2015, Baffinland shipped ~900,000 tonnes of iron ore from Milne Port involving 13 return ore carrier voyages. In 2016, the total volume of ore shipped out of Milne Port reached 2.6 million tonnes involving 37 return ore carrier voyages. In 2017, the total volume of ore shipped out of Milne Port reached 4.2 million tonnes involving 56 return ore carrier voyages. Following approval to increase production to 6.0 Mtpa, a total of 5.4 Mtpa of ore was shipped via 71 return voyages in 2018, 5.9 Mtpa of ore was shipped via 81 return voyages in 2019, and 5.5 Mtpa was shipped via 72 return voyages in 2020. In 2021, a total of 5.6 Mtpa of iron ore was shipped via 73 return voyages with the first inbound transit of the season occurring on 27 July and the last outbound transit of the season occurring on 31 October 2021. One additional vessel was called to Milne Port in 2021, but not loaded due to timing constraints at the end of the shipping season.

1.2 Program Objective

The Bruce Head Shore-based Monitoring Program (the Program) represents one of several environmental effects monitoring (EEM) programs for marine mammals. The Program was designed to specifically address Project Certificate (PC) conditions related to evaluating potential disturbance of marine mammals from shipping activities that may result in changes to animal distribution, relative abundance, and migratory movements in the Project's Regional Study Area (RSA; Figure 1-1).

LEGEND

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

0 125 250
1:5,000,000 KILOMETRES

REFERENCE(S)
BASE MAP: © ESRI DATA AND MAPS (ONLINE) (2016). REDLANDS, CA: ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
PROJECT LOCATION

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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Specifically, the Program contributes to the following PC conditions:

- Condition No. 99c and 101g – “Shore-based observations of pre-Project narwhal and bowhead whale behaviour in Milne Inlet that continues at an appropriate frequency throughout the Early Revenue Phase and for not less than three consecutive years”.
- Condition No. 109 (for Milne Inlet specifically) – “The Proponent shall conduct a monitoring program to confirm the predictions in the FEIS with respect to disturbance effects from ships noise on the distribution and occurrence of marine mammals. The survey shall be designed to address effects during the shipping seasons, and include locations in Hudson Strait and Foxe Basin, Milne Inlet, Eclipse Sound, and Pond Inlet. The survey shall continue over a sufficiently lengthy period to determine the extent to which habituation occurs for narwhal, beluga, bowhead and walrus”.
- Condition No. 110 – “The Proponent shall immediately develop a monitoring protocol that includes, but is not limited to, acoustical monitoring, to facilitate assessment of the potential short term, long term, and cumulative effects of vessel noise on marine mammals and marine mammal populations. The Proponent is expected to work with the Marine Environment Working Group to determine appropriate early warning indicator(s) that will ensure rapid identification of negative impacts along the southern and northern shipping routes.”
- Condition No. 111 – “The Proponent shall develop clear thresholds for determining if negative impacts as a result of vessel noise are occurring.
- Condition No. 112 – “Prior to commercial shipping of iron ore, the Proponent, in conjunction with the Marine Environment Working Group, shall develop a monitoring protocol that includes, but is not limited to, acoustical monitoring that provides an assessment of the negative effects (short and long term cumulative) of vessel noise on marine mammals. Monitoring protocols will need to carefully consider the early warning indicator(s) that will be best examined to ensure rapid identification of negative impacts. Thresholds shall be developed to determine if negative impacts as a result of vessel noise are occurring. Mitigation and adaptive management practices shall be developed to restrict negative impacts as a result of vessel noise.”

The specific objectives of the Bruce Head Shore-based Monitoring Program are to investigate and characterize narwhal behavioural responses to shipping along the Northern Shipping Route in Milne Inlet, with data collected on relative abundance and distribution (RAD), group composition, and behaviour. Additionally, data are collected on environmental conditions and anthropogenic activities (e.g., shipping and hunting activities) to distinguish between the potential effects of Project-related shipping activities and confounding factors that may also influence narwhal behaviour.

1.3 Early Warning Indicators (EWIs)

Adverse effects of the Project on narwhal may be promptly identified and mitigated through the development of appropriate EWIs. Therefore, in accordance with requirements outlined in PC Condition No. 110 and 112, Baffinland worked with members of the Marine Environment Working Group (MEWG) to develop an early warning indicator (EWI) that is able to rapidly identify adverse impacts on narwhal along the Northern Shipping Route. A description of the EWI selection process, including engagement with the MEWG, is provided in Golder (2020d).

The EWI selected for the Project was a ‘change in the proportion of immature narwhal in the population’. This indicator was originally proposed by Fisheries and Oceans Canada (DFO) and was confirmed as being of high importance by the Mittimatalik Hunters and Trappers Organization (MHTO) (Golder 2020d).

The data for monitoring this EWI would originate from the Bruce Head Shore-based Monitoring Program, and specifically from narwhal group composition data collected in the Behavioural Study Area (BSA). The threshold selected for this EWI was originally assessed as a 10% decrease in the proportion of immatures (i.e., calves and yearlings) observed at Bruce Head relative to the lowest available baseline value (i.e., 0.152 recorded in 2014). If the proportion of immature narwhal recorded at Bruce Head would have dropped below the EWI threshold of 0.137 (i.e., a 10% decrease from 0.152), adaptive management practices may be triggered as per the protocol summarized in Section 1.4.

In recent MEWG engagements, 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 2021a). 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. 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 1-1). A set of planned contrasts was constructed, 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 ANOVA 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 is deemed to have been exceeded if a statistically significant difference is observed between each year’s least squares mean and the average of 2014–2015 least squares mean values.

Table 1-1: 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

1.4 Adaptive Management Protocol

Adaptive management is a planned and systematic process for continuously improving environmental management practices by learning about their outcomes (CEAA 2016). 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 has developed a draft Adaptive Management Plan (AMP) which provides a framework for how adaptive management is incorporated into Project operations (Baffinland 2020). As part of this process, a Marine Mammal Trigger Action Response Plan (TARP) was developed for the Project to identify a number of indicators and tiered thresholds that are used to evaluate and respond to potential Project effects on narwhal (and other marine mammal species in the Project area; Baffinland 2021b). The TARP shares the same objective as the EWI identified above, although uses a broader range of effect indicators that are measured against a series of tiered thresholds (i.e., low, moderate and high risk thresholds) that are designed to guide short-term and long-term adaptive management strategies. The TARP also identifies pre-defined actions (commensurate responses) that would be implemented by Baffinland 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. On 22 March 2021, Baffinland released the most current version of the Marine Mammal TARP and Action Toolkits as part of its responses to Post-Hearing Questions related to Phase 2 (Baffinland 2021b). A summary of the tiered thresholds for narwhal is provided below.

1.4.1 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:

- Moderate severity behavioural responses (Severity Score 5 and 6)[1] that do not persist for a prolonged period (i.e., for several hours) following vessel exposure period as described in Section 3.0.

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 'Low Risk' response would be triggered (Baffinland 2021b).

[1] 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).

1.4.2 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 vessel exposure period as described in Section 3.0.

AND

- >10.0% decrease in the proportion of immatures relative to pre-Phase 2 shipping (2014/2015 baseline levels).

In the event that these threshold criteria are exceeded, a commensurate 'Moderate Risk' response would be triggered (Baffinland 2021b).

1.4.3 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[2] Moderate severity behavioural responses (Severity Score 5 and 6) that persist for a prolonged period (i.e., for several hours) following vessel exposure period as described in Section 3.0.

AND/OR

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

AND

- >25.0% decrease in calving rate (proportion of immatures) relative to pre-Phase 2 shipping (2014 baseline levels).

AND/OR

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

In the event that these threshold criteria are exceeded, a pre-determined 'High Risk' response would be triggered, as defined in Baffinland (2021b).

1.5 Study Area

The Bruce Head Shore-based Monitoring Program is based at Bruce Head, a high rocky peninsula on the western shore of Milne Inlet, Nunavut, overlooking the Project's Northern Shipping Route. The observation platform, renovated in 2019, is located on a cliff at Bruce Head, approximately 215 m above sea level (N 72° 4' 17.76",

[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.

W 80° 32’35.52”) and approximately 40 km from Milne Port. From the observation platform, Marine Mammal Observers (MMOs) are provided with a mostly unobstructed view of Milne Inlet from the southern tip of Stephens Island to the north, to the embayment south of Agglerojaq Ridge to the south, with the mouth of Koluktoo Bay visible to the south of the peninsula, and Poirier Island visible to the east (directly offshore of the survey platform).

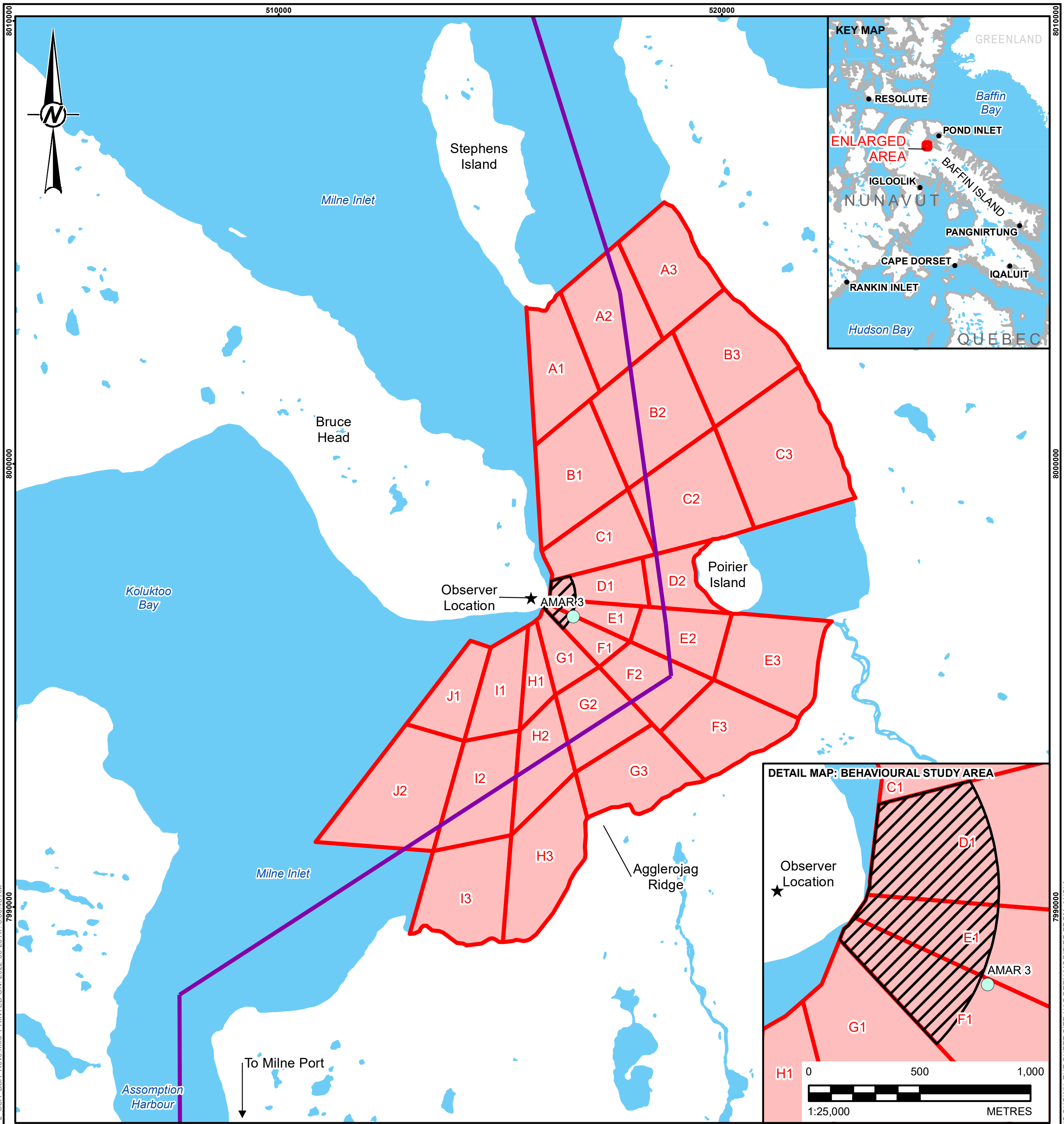
Consistent with previous years, two study areas were used for the 2021 shore-based study depending on the applicable data collection protocol. These areas included a broader Stratified Study Area (SSA) and a smaller Behavioural Study Area (BSA) nested within the SSA (Figure 1-2).

1.5.1 Stratified Study Area

The stratified study area (SSA) covers a total area of 90.5 km^2 and was designed to collect narwhal relative abundance and distribution data (RAD). The SSA is stratified into strata A (northernmost stratum) through J (southernmost stratum; added in 2019) and further separated into substrata 1 through 3 (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 stratum D and J are comprised of only two substrata, 1 and 2. These substrata boundaries are visually defined in the field using definitive landmarks on the far shore of Milne inlet and nearby islands.

1.5.2 Behavioural Study Area

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



LEGEND

- AMAR LOCATION
- COMMUNITY
- OBSERVER LOCATION
- APPROXIMATE SHIPPING ROUTE
- BEHAVIOURAL STUDY AREA (BSA)
- 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
STRATIFIED STUDY AREA (SSA) WITH BEHAVIORAL STUDY AREA (BSA) NESTED WITHIN

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000-04	0	1-2

2.0 SPECIES BACKGROUND

2.1 Population Status and Abundance

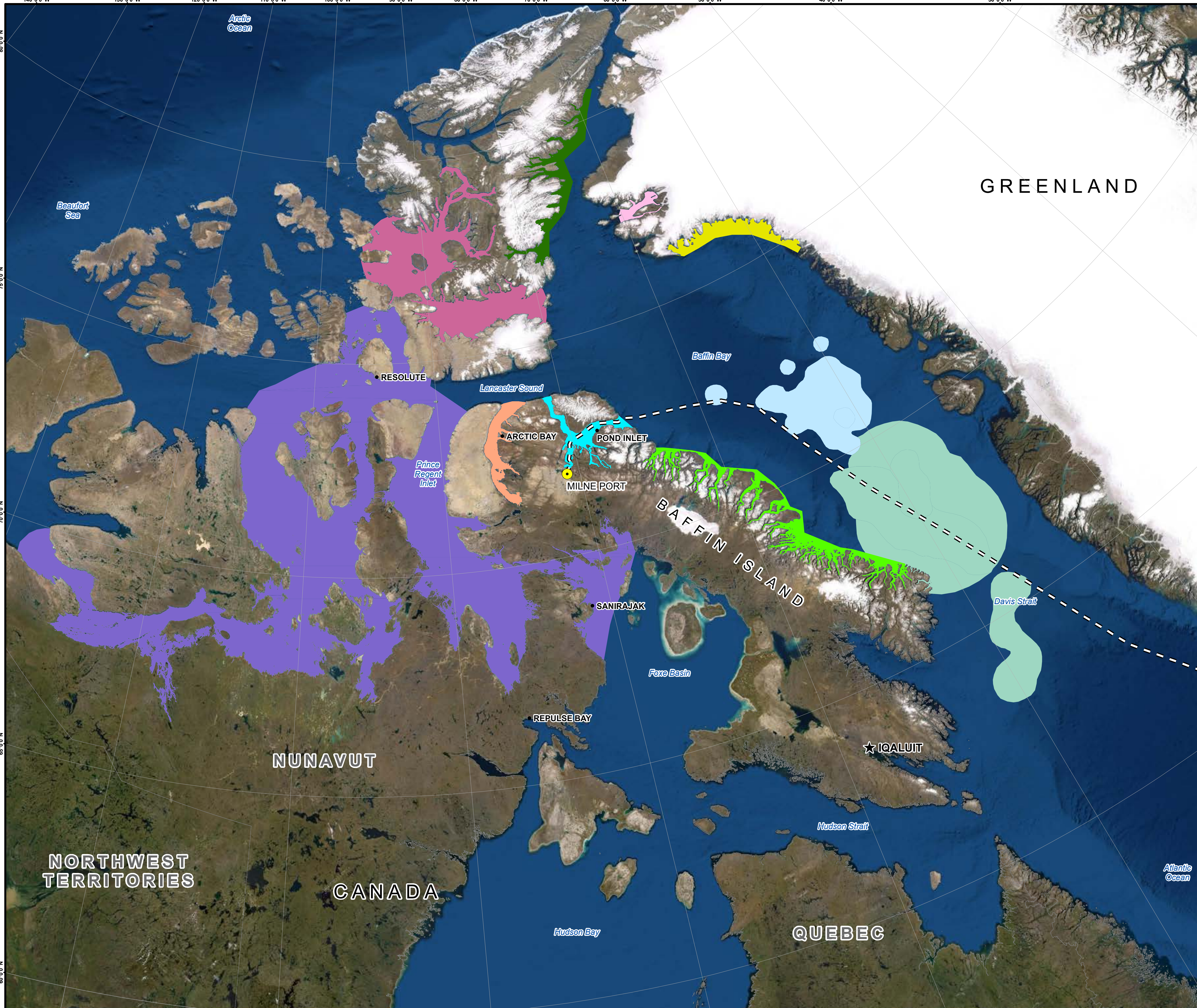
Narwhal are endemic to the Arctic, occurring primarily in Baffin Bay, the eastern Canadian Arctic, and the Greenland Sea (Reeves et al. 2012). Seldom present south of 61º N latitude (COSEWIC 2004), two populations are recognized in Canadian waters; the Baffin Bay (BB) population and the northern Hudson Bay (NHB) population (Watt et al. 2017). Of these, only the Baffin Bay population occurs seasonally along the Northern Shipping Route for the Project (Koski and Davis 1994; Dietz et al. 2001; Richard et al. 2010). A third recognized population of narwhal occurs in East Greenland and is not thought to enter Canadian waters (COSEWIC 2004). The populations are distinguished by their summering distributions, as well as a significant difference in nuclear microsatellite markers indicating limited mixing of the populations (DFO 2011).

For management purposes, DFO has defined seven narwhal stocks (i.e., resource units subject to hunting) in Nunavut: Jones Sound, Smith Sound, Somerset Island, Admiralty Inlet, Eclipse Sound, East Baffin Island, and Northern Hudson Bay (Doniol-Valcroze et al. 2015) (Figure 2-1). These stocks were selected based on satellite tracking data indicating geographic segregation in summer (year-round segregation from the others in the case of the northern Hudson Bay stock) and also on evidence from genetic and contaminants studies that supported this stock partitioning. Subdividing the management units was recommended as a precautionary approach that would reduce the risk of over-exploitation of a segregated unit with site fidelity in summer (Richard et al. 2010). While the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) considers narwhal a species of special concern, narwhal populations in Canada are not presently listed under the federal *Species at Risk Act* (*SARA*).

The Canadian High Arctic Cetacean Survey conducted by DFO in August 2013 represents the most complete 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 (CV by stock = 0.2 to 0.65; Doniol-Valcroze et al. 2015).

Although narwhal stocks are thought to 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 Golder in 2021 indicated an abundance estimate of 75,177 narwhal for the combined Eclipse Sound and Admiralty Inlet stocks (Coefficient of Variation (CV) = 0.08, 95% confidence interval CI = 63,795 – 88,590; Golder 2022). Previously, 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 (Coefficient of Variation (CV) = 0.12, 95% confidence interval 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 narwhals, CV=0.33, CI = 22,440–92,384; Doniol-Valcroze et al. 2015). For the Eclipse Sound stock alone, the 2021 abundance estimate was 2,595 narwhal (CV = 0.33, 95% CI = 1,369 – 4,919; Golder 2022). The 2020 abundance estimate was 5,018 narwhal (CV = 0.03, 95% CI = 4,736–5,317; Golder 2021a) which fell below the 95% confidence interval of all previous DFO abundance estimates for the Eclipse Sound stock, including the last aerial survey undertaken in 2016 (12,093 narwhal, CV = 0.23, CI = 7,768–18,660; Marcoux et al. 2019).



LEGEND

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

SUMMER AGGREGATION AREA

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

WINTER AGGREGATION AREA

- NORTHERN WINTERING AREA
- SOUTHERN WINTERING AREA

0 200 400

1:10,000,000 KILOMETRES

REFERENCE(S)

NARWHAL POPULATION RANGES DIGITIZED FROM DFO FIGURE 1 'MAP OF HIGH ARCTIC NARWHAL SUMMER AGGREGATIONS' (SOURCE: AMMCO/SC/21-JCNB/SWG/14-05). NARWHAL WINTERING AREAS DIGITIZED FROM RICHARD ET AL. (2014) FIGURE 3 PUBLISHED WINTER HOME RANGES OF TRACKED BAFFIN BAY NARWHAL. SHYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. COUNTRY BASE DATA © ESRI AND ITS LICENSORS. USED UNDER LICENSE, ALL RIGHTS RESERVED. SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY
PROJECTION: CANADA ALBERS EQUAL AREA CONIC DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
NARWHAL SUMMERING AND WINTERING AREAS – BAFFIN BAY POPULATION

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000-04	0	2-1

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 1000 m (Dietz and Heide-Jørgensen 1995). Narwhal generally arrive at their wintering grounds in Baffin Bay and Davis Strait during November (Heide-Jørgensen et al. 2003) where they associate closely with heavy pack ice comprised of 90 to 99% ice cover (Koski and Davis 1994). Elders have indicated that while the majority of narwhal overwinter in Baffin Bay, some animals remain along the floe edges at Pond Inlet and Navy Board Inlet. Narwhal tracking data have identified two distinct wintering areas for the Baffin Bay population (Richard et al. 2010, Laidre and Heide-Jørgensen 2005). One wintering area is located in northern Davis Strait / southern Baffin Bay (referred to as the southern wintering area) and is frequented by Canadian narwhal summering stocks from Admiralty Inlet and Eclipse Sound, and the Greenland narwhal stock from Melville Bay. The second wintering area is located in central Baffin Bay (referred to as the northern wintering area) and is used by narwhal from the Somerset Island summering stock (Laidre and Heide-Jørgensen 2005).

2.3 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 and at the floe edge east of Pond Inlet and at the north end of Navy Board Inlet. Eclipse Sound, Tremblay Sound, Milne Inlet, and Koluktoo Bay have also been reported as mating areas (Remnant and Thomas 1992). Conception typically occurs between late March and late May, although mating has been observed in June at the Admiralty Inlet floe edge and in August in western Admiralty Inlet (Stewart 2001). At least one presumed mating event was observed from the Bruce Head observation platform in southern Milne Inlet during the 2016 open-water season (Smith et al. 2017) and multiple sexual displays were observed via Unmanned Aerial Vehicle (UAV; i.e., drone) focal follow 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 to 170 cm in length, approximately 1/3 to 1/2 the body length of an adult female (Charry et al. 2018). Typically, newborn calves travel less than one body length away from their mother and in larger group sizes while in Eclipse Sound (mean group size = 5) compared to smaller group sizes along the east coast of Baffin Island (mean group size = 2; Charry et al. 2018). Calves are generally weaned at 1–2 years of age (COSEWIC 2004).

2.4 Diet

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

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

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

2.5 Locomotive Behaviour

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

2.5.1 Surface Movements

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

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

Narwhal are highly gregarious and are closely associated with one another by nature (Marcoux et al. 2009). Although knowledge regarding the context and function (if any) of narwhal aggregations is incomplete (Marcoux et al. 2009), they have been observed throughout Milne Inlet and Koluktoo Bay in small groups or clusters[3] averaging 3.5 individuals (range: 1 to 25), and in herds[4] 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 1 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).

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

Based on findings from the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a), narwhal were shown to alter their surface behaviour in response to vessel traffic by turning back on their own track at distances up to 4 km of a transiting vessel, corresponding to a total exposure period of 29 min per vessel transit (based on a 9 knot travel speed). Tagged narwhal were also shown to change their travel orientation relative to transiting vessels at distances up to 5 km of an approaching vessel and up to 10 km of a departing vessel, corresponding to a total exposure period of 54 min per vessel transit (based on a 9 knot travel speed). For both response variables, animals returned to their pre-response behaviour following the vessel exposure period (i.e., a temporary effect). Given that vessels were within 4 to 10 km of a tagged narwhal for <2% to <7% of the GPS datapoints collected in

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

[4] Herd = an aggregation of clusters.

the RSA respectively, the frequency of occurrence of these effects was considered intermittent. Finally, a gap in narwhal distribution evident in close proximity to transiting vessels (0.5 km of a vessel's port and starboard and 1 km of a vessel's bow and stern) suggested movement away from the vessel by narwhal (i.e., avoidance), however this finding may have also been a function of low-resolution data available in close proximity to vessels.

2.5.2 Dive Behaviour

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

During the summer months, narwhal spend a large proportion of time near the surface, milling and socially interacting with one another (Pilleri 1983; Heide-Jørgensen et al. 2001). Narwhal (n = 23) tagged near Baffin Island between 2009 and 2012 were estimated to spend approximately 31.4% of their time within 2 m of the surface during the month of August (Watt et al. 2015). Innes et al. (2002) reported a similar value of 38% of time that narwhal spend within 2 m of the surface based on aerial surveys. The proportion of time that narwhal spend within 5 m of the surface is slightly greater; Heide-Jørgensen et al. (2001) reported narwhal (n = 21) spend approximately 45.6% of time within the top five metres of the water column, while Laidre et al. (2002) reported a range of 30-53% of time that narwhal (n = 4) 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, mean dive rate of all narwhal outfitted with tags during the month of August was 7.4 dives/hour below 8 m depth, with narwhal from Tremblay Sound having a significantly lower dive rate overall (7.2 dives/hour) compared to animals tagged in Melville Bay (8.6 dives/hour). No diurnal difference was found in narwhal dive rate from either tagging site (Heide-Jørgensen et al. 2001). Furthermore, increasing number of dives (dive rate) had no effect on narwhal surfacing times (0-5 m). Laidre et al. (2002) reported similar dive rates for two narwhal tagged in Tremblay Sound, ranging from 6.0 dives/hour to 10.9 dives/hour.

In regard to descent and ascent speeds, one study conducted by Laidre et al. (2002) determined that a typical dive profile for two narwhal tagged in Tremblay Sound consisted of a steep descent, followed by a short bottom interval, a gradual ascent, and a relatively slow approach to the surface. The two narwhal in this study exhibited mean descent rates of 0.8 m/s and 1.3 m/s and mean ascent rates of 0.7 m/s and 1.5 m/s, respectively (Laidre et al. 2002). According to an older study that tracked the dive behaviour of three narwhal tagged in Tremblay Sound (Martin et al. 1994), the maximum rates of ascent and descent for each dive ≥ 20 m depth were positively correlated to the depth and duration of the dive. This finding was supported by the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a) in which mean descent rates were strongly correlated with destination depth. A recent study reported dive profiles similar to those reported by Laidre et al. (2002) where tagged narwhal (n=13) had steeper descents than ascents. Dives were described as either V- or U-dives and narwhal were recorded spending more time on V-dives. V-dives were on average, longer lasting (8.7 min vs 6.9 min respectively), deeper (257 m vs 123 m) and had shorter bottom times (4.1 min vs 5.0 min) than U-dives (Tervo et al. 2021). The tagged narwhal also utilized prolonged gliding during descent, active fluke stroking during ascent, and demonstrated spinning behaviour (rolling along their longitudinal axis) typically during descents and during the bottom phase of a dive, particularly during presumed foraging (Tervo et al. 2021).

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

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

2.6 Acoustic Behaviour

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

2.6.1 Vocalizations

Narwhal are a highly vocal species that produce a combination of pulsed calls, clicks, and whistles (Ford and Fisher 1978; Marcoux et al. 2011a). Pulsed calls are the predominant form of narwhal vocalization and are comprised of pulsed tones and click series (Ford and Fisher 1978). Pulsed tones emitted by narwhal possess pulsed repetition rates that have distinct tonal properties and are generally concentrated between 500 Hz and 5 kHz (Ford and Fisher 1978; Shapiro 2006). Click series are broadband and are concentrated between 12 and 24 kHz, though many click series with low repetition rates are concentrated at lower frequencies between 500 Hz and 5 kHz (Ford and Fisher 1978). High frequency broadband echolocation clicks emitted by narwhal extend up to and beyond 150 kHz (Miller et al. 1995; Rasmussen et al. 2015). Finally, whistles are typically emitted between 300 Hz and 10 kHz, though some whistles have been found to reach frequencies as high as 18 kHz (Ford and Fisher 1978; Marcoux et al. 2011a). More recent studies that include recordings at higher sampling rates or that have incorporated novel techniques of data collection/analysis have allowed for more complete descriptions of narwhal vocalizations (Rasmussen et al. 2015; Koblitz et al. 2016; Walmsley et al. 2020; Podolskiy and Sugiyama 2020; Ames et al. 2021; Zahn et al. 2021).

2.6.2 Hearing

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

2.6.3 Narwhal and Vessel Noise

Behavioural responses of marine mammals exposed to vessel traffic and associated noise have been documented for several species, however limited information is available for cetaceans inhabiting Arctic waters and for narwhal specifically. Vessel disturbance may elicit several different behavioural responses in cetaceans, including a shift in travel speed or dive rate, freeze or flight (avoidance) response, and short- or long-term displacement from optimal habitat, all of which have the potential to affect subpopulation viability. Of note, narwhal have been shown to react at relatively low received sound levels to distant icebreaking vessels actively breaking ice (Finley et al. 1990; Cosens and Dueck 1993). 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: $1µPa^2 \cdot s$). Sound pressure level (SPL_{rms}) refers to the average of the squared sound pressure over some duration, while sound exposure level (SEL) is a cumulative measure of sound energy that takes into account the duration of exposure (Southall et al. 2007; NMFS 2018; Southall et al. 2019). It is generally accepted that cetaceans exposed to received sound levels above 120 dB re: 1µPa (SPL_{rms}) will begin to demonstrate behavioural disturbance, though the specific behavioural responses exhibited are highly variable depending on the context of the exposure, the receiving environment, the familiarity of the animal with the sound, and the behaviour of the animal during the exposure event (Southall et al. 2007, 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 SELs never exceeded the thresholds for acoustic injury[5] (i.e., temporary or permanent hearing loss) at any of the recording sites in the RSA. Assessed relative to the behavioural disturbance SPL threshold of 120 dB re 1 µPa[6] for continuous-type sounds such as vessel noise, ship noise exceeded the disturbance threshold for <1 hour per day. The results demonstrate that while noise from Project vessels is detectable in the underwater soundscape, vessel noise exposure is 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.

[5] 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).

[6] 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 response 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. 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 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[7]. Therefore, any further discussion of severity scaling is specific to those responses that may be detectable through (or informed by) the shore-based observer and/or drone-based components of the Bruce Head Program.

[7] 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.

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 are listed below. Table 3-1 provides a summary of these responses as they relate to the specific response variables assessed through the Bruce Head Program, segregated by categorical track.

- No response
- Identifiable, sustained and/or multiple vigilance responses including interruption of resting behaviour, change in orientation response, and minor deviation from typical migratory pathway
- Individual startle response
- Behavioural state changes from advertisement and courtship to other behaviour

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: - Change in orientation - Interruption of resting - Minor deviation from typical migratory pathway • As detected by changes in group direction (BSA), changes in primary behaviors (UAV), and changes in distance from shore (BSA), respectively.	-	Detectable interruption of advertisement and courtship behaviour • As detected by changes in unique behaviors, namely sexual displays (UAV)
2	Sustained or multiple vigilance responses • As detected by changes in group direction (BSA), changes in primary behaviors (UAV), and changes in distance from shore (BSA; see row above).		
3	-	-	Behavioural state changes from advertisement and courtship to other behaviour • As detected by changes in unique behaviors, 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 and species characteristics such as body size, feeding strategy, and behavioural state at the time of the exposure. In general, a response would be considered ‘long-duration’ if it lasted up to several hours, or enough time to significantly disrupt an animal’s daily routine. For the derivation of behavioural criteria in this study, a long duration was defined as a response that 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 are listed below. Table 3-2 provides a summary of these responses as they relate to the specific response variables assessed through the Bruce Head Program, segregated by categorical track.

- 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: 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	Reduction in variance of heading • As detected by changes in group direction (BSA) Change in group cohesion • As detected by changes in group spread, group formation, and/or group size (BSA, UAV)	Detectable elevation in energy expenditure • As detected by an increase in travel speed (BSA) and changes in primary behaviour (BSA)	Non-reproductive (advertisement and courtship) state longer than typical • As detected by changes in unique behaviors, namely sexual displays (UAV)

Response score	Behavioural changes affecting survival	Behavioural changes affecting feeding	Behavioural changes affecting reproduction
5	Onset of avoidance behaviour (e.g., heading away and/or increasing range from source) • As detected by changes in group direction (BSA) and 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 behaviors, nursing behaviour (UAV)	-
6	Individual aggressive behaviour, including movement potentially directed at conspecifics • As detected by changes in unique behaviors, namely "jousting[8]" (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 behaviors, namely "jousting" (UAV)	Sustained disruption of nursing behaviour • As detected by changes in unique behaviors, nursing behaviour (UAV)	Reduction of advertisement and courtship behaviours potentially sufficient to reduce reproductive success • As detected by changes in unique behaviors, 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)

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

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 are listed below. Table 3-3 provides a summary of these responses as they relate to the specific response variables assessed through the Bruce Head Program, segregated by categorical track.

- 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[9]
- Stranding

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 distance from shore (BSA) and 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 behaviors, namely social behavior and sexual displays (UAV)

[9] 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'.

Response score	Behavioural changes affecting survival	Behavioural changes affecting feeding	Behavioural changes affecting reproduction
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 behaviors, namely social behaviors 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 (BSA) and/or nursing behaviour	

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 SELECTION OF BEHAVIOURAL RESPONSE VARIABLES

The response variables defined by LGL (2014-2016) were carried forward in the present study to maintain consistency among sampling years. This section discusses each response variable's relevance for assessing behavioural response of narwhal to vessel traffic, in addition to other natural and anthropogenic stressors occurring in the RSA.

4.1 Group Size

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

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

4.2 Group Composition

Changes in the group composition of cetaceans in response to disturbance may occur over the short-term, as group membership changes in the immediate presence of a disturbance (Bejder et al. 2006a), and over the long-term as a result of reduced reproductive success (Mann et al. 2000; Bejder 2005) leading to changes in population structure. In a study by Bejder et al. (2006a) in which the behavioural responses of Indo-Pacific bottlenose dolphins to vessel approaches were tested, dolphin groups had higher rates of change in group membership during vessel approaches, compared to before and after vessel approaches. Bejder et al. (2006a) concluded that strong social interdependence may be important in reducing vulnerability of dolphins to other stressors such as predation from sharks. Group separation has also been reported to enable predators to prey on unprotected offspring for a variety of terrestrial animals (e.g., Dall sheep: Nette et al. 1984; mountain goats: Côté & Beaudoin 1997; numerous species of water birds: Carney & Sydeman 1999). Therefore, social interdependence is considered important in reducing the vulnerability of cetaceans to predation and a primary determinant in the evolution of cetacean grouping behaviour (Norris & Dohl 1980; Wells et al. 1980; Norris et al. 1994). Prolonged changes in group composition in response to vessel activity and other stressors, especially if mutually reliant group members are separated, has the potential to escalate predation risk and increase individual stress levels.

It is acknowledged that the demographic characteristics of a population are strongly correlated with the population's status and may therefore be used as EWI of future changes in abundance (Booth et al. 2020). In Booth et al. (2020), the sensitivity of two vital rates were assessed, including the ratio of calves/pups to mature females and the proportion of immature animals in a population. Both characteristics were shown to be sensitive to changes in fertility and calf survival. Based on PCoD (population consequences of disturbance) models, Booth et al. (2020) also confirmed that demographic characteristics, including the proportion of immature animals in a population, can be used as an EWI of population decline. This conclusion has been supported by other studies that investigated the potential effects of disturbance on reproductive success where disturbance resulted in a large reduction in the proportion of calves reaching weaning age in North Atlantic long-finned pilot whales (Hin et al. 2019) and Blaineville's beaked whales (*Mesoplodon densirostris*) (Moretti et al. 2019). These studies suggest that the EWI identified for the Project (i.e., a decline in the proportion of immatures) is appropriate for early identification of population decline in the Eclipse Sound narwhal stock, which could be due to the Project, or alternatively could indicate the presence of an external stressor on the population (i.e., a non-Project impact). Early detection of a decline in the EWI, in combination 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.

4.3 Group Spread

Cetaceans have been shown to form tight groups in situations of perceived threat or when surprised (Johnson and Norris 1986; Cosens and Dueck 1988, 1991, 1993; Finley et al. 1990; Nowacek et al. 2001; Visser et al. 2016; Golder 2021a), potentially as a mechanism to provide increased protection for individuals within the group. Cetaceans have also been shown to form tight pods in the presence of vessels (Irvine et al. 1981; Au and Perryman 1982; Finley et al. 1990; Blane and Jaakson 1994; Bejder et al. 1999, 2006a; Nowacek et al. 2001) and when exposed to navy sonar activity (Visser et al. 2016). There is 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 are not considered avoidance responses directly, it is acknowledged that disruptions to normal behaviour can lead to increased energetic challenges with the potential for population level consequences, particularly to small or vulnerable populations (Lusseau and Bejdger 2007).

In the Eastern Canadian High Arctic, narwhal have been observed forming tight groups in response to killer whales (Steltner et al. 1984; Laidre et al. 2006; Breed et al. 2017; Golder 2021a) and vessel traffic (Cosens and Dueck 1988, 1993; Finley et al. 1990). These results fit with the majority of findings that suggest cetaceans form tighter groups in situations of perceived threat (e.g., as an anti-predator response). Finley et al. (1990) conducted aerial surveys of beluga and narwhal 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 “ardlinayuk”, fear of killer whales, which describes the behaviours of beluga and narwhal in response to killer whales. During aerial surveys conducted by Golder Associates in 2020, a large group of killer whales was observed herding 150-200 narwhal into Fairweather Bay near Milne Inlet (Golder 2021a). The killer whales travelled quickly into the bay swimming abreast of each other in two lines as the narwhal swam in tight groups and clustered near the shoreline. As the killer whales neared the narwhal, the killer whales dispersed into smaller groups and were observed killing two narwhal calves and two adults, including an adult male that was observed floating motionless near shore and one probable adult female, potentially the mother to one of the killed calves (Golder 2021a).

4.4 Group Formation

Previous studies have shown that cetaceans react to disturbances by changing group formation (Irvine et al. 1981; Au and Perryman 1982). In one study, 47 bottlenose dolphins were captured, tagged, and released ninety times, revealing that many of the previously caught dolphins seemed to recognize the capture boat and fled in a tight group, often in a line-abreast formation (Irvine et al. 1981). In another study, data on the behavioural response to a survey ship was collected on eight separate groups of spotted dolphin (*Stenella attenuata*), spinner dolphin, and striped dolphin (*Stenella coeruleoalba*) from a helicopter (Au and Perryman 1982). Dolphin group formations were often observed changing as the vessel approached, with groups scattering, orienting in lines abreast, and forming arcs, oval-shaped groups, or compact ranks. During one observation, a group of spotted dolphins was observed scattering when the vessel approached within 3.0 miles, then congregated to form a large arc (with some animals scattered on the sides when the vessel was 2.5 miles away, and finally scattering again when the vessel was 1.6 miles away). During another observation, a group of spotted and spinner dolphins formed compact ranks at the rear of the group when the vessel was 3.3 miles away, then swam in various directions in an oval-shaped group when the vessel was 2.2 miles away. The dolphin groups were described as swimming “in an almost amoeboid” fashion in the presence of the vessel and, when the vessel was within 2 miles, the groups were increasingly oriented in lines abreast (Au and Perryman 1982).

4.5 Group Direction

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

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

4.6 Travel Speed

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

4.7 Distance from Shore

A recent study by Heide-Jørgenson et al. (2021) conducted trials in which narwhal were exposed to seismic airguns and vessel noise and found that the propensity of narwhal to move toward the shore increased with shorter distance to vessels. Various studies conducted in the Eastern Canadian Arctic have also documented narwhal moving closer to shore in the presence of killer whales (Steltner et al. 1984 in Marcoux 2011b; Laidre et al. 2006; Ferguson et al. 2012; Breed et al. 2017; Golder 2021a). For example, satellite tagging data collected in Admiralty Inlet in August 2005 revealed obvious, short-term responses of narwhal to killer whales, with narwhal moving close to shore and into shallow water (< 2 m) when within 2-4 km of this apex predator (Laidre et al. 2006). Following an attack of narwhal by killer whales, narwhal were then observed resuming normal behaviour within an hour of killer whales leaving the area (Laidre et al. 2006). Breed et al. (2017) reported similar observations of narwhal behaviour when killer whales were present in Admiralty Inlet in August 2009. In the study by Breed et al. (2017), one killer whale and seven narwhal were tagged to assess narwhal movements in the presence of killer whales. With the narwhal and a group of 12-20 killer whales both occupying the Inlet over a ten-day period, the authors were able to assess narwhal habitat use in both the presence and absence of killer whales. Of note, narwhal habitat use was shown to differ between the two periods significantly, with narwhal remaining within 500 m of the shore when in the presence of killer whales until killer whales left the area at which point narwhal moved further offshore (i.e., 4-10 km from shore). Marcoux (2011b) also reported observing narwhal swimming very close to shore a few hours after killer whales departed Koluktoo Bay. Unlike the other studies, where narwhal resumed normal distances from shore shortly after killer whales left the area, the narwhal remained close to shore for many hours after the killer whales departed (Marcoux et al. 2011b). Narwhal were also observed swimming in tight groups near shore when a large group of killer whales was observed herding ~150-200 narwhal into Fairweather Bay, Milne Inlet during aerial surveys in 2021 (Golder 2021a).

5.0 METHODS

5.1 Study Team and Training

The 2021 field program took place between 1 and 26 August 2021 and consisted of 16 hours of daily monitoring effort (weather permitting), undertaken by two teams comprised of five individuals each, alternating at 4 h observation intervals. Study teams consisted of Golder biologists with previous arctic marine mammal survey experience, qualified Marine Mammal Observer (MMO) subcontractors, and local Inuit Researchers from Pond Inlet and Arctic Bay (**Photograph 5.1**). The drone operations team, comprised of two individuals from InDro Robotics Inc., worked closely with Golder biologists to plan and execute the focal follow surveysl.

Upon arrival to the Bruce Head camp on 31 July 2021, 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 including rifle use storage and expectations while in camp, polar bear awareness, communication procedures, and identification of general hazards in and around camp. All relevant health and safety policies and regulations by Golder and Baffinland were reviewed and discussed.

The study team also participated in a comprehensive training session led by the 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 (Appendix A). 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

Photograph 5.1: Field team members of the 2021 Bruce Head Shore-based Monitoring Program.

5.2 Data Collection

Understanding the context and function (if any) of narwhal aggregations and spatial use patterns is important in assessing behavioural response to a potential perceived threat (e.g., vessel traffic). Narwhal are a highly gregarious species (Marcoux et al. 2009; Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b) and are known to alter their spatial use patterns in the presence of predators (Campbell et al. 1988; Cosens and Dueck 1991; Laidre et al. 2006; Breed et al. 2017). In drawing from accounts of predator-induced behavioural responses by narwhal, the following metrics were selected to be examined to assess behavioural response to other potential perceived threats such as vessel traffic: relative abundance and distribution, group size, group composition, group spread, group formation, group direction, travel speed, and distance from shore.

Visual survey data collected during the Program included information on: (1) narwhal relative abundance and distribution (RAD); (2) narwhal group composition and behaviour; and (3) other anthropogenic activities, such as hunting activity. During each monitoring shift, the study team was split into two separate survey groups. The first group, composed of two MMOs, was exclusively responsible for collecting RAD data in the SSA. The second group, composed of three MMOs, was responsible for collecting data on group composition and behaviour in the BSA, as well as tracking vessels and recording anthropogenic activities in the SSA. Both teams also collected data on environmental conditions during their respective survey efforts. To minimize potential observer fatigue, study team members rotated between observer and recorder roles throughout each monitoring shift.

During the 2021 Program, the drone operations team coordinated survey effort with the MMOs, though worked primarily independently (see section 5.2.6). Detailed descriptions of data collection and survey methods employed during the annual programs are provided in the respective annual reports (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b).

5.2.1 Relative Abundance and Distribution

Consistent with previous years' data collection techniques, RAD surveys were conducted throughout the SSA in 2021. Observations were made using survey and scan observation (Mann 1999), where the observer surveyed each stratum for a minimum of three minutes to identify narwhal groups, group size (solitary narwhal were considered a group of one), and travel direction. Once all narwhal present within each substratum were counted and their direction of travel was recorded, the observer moved on to the next substratum. Where the majority of narwhal were travelling in one direction (e.g., north → south), the observer would begin counting strata from the opposite direction (e.g., south → north) to minimize the potential of double-counting groups. RAD surveys were conducted in the SSA throughout the daily monitoring period, every hour, on the hour. In addition, RAD surveys were conducted continuously as a vessel approached the SSA, throughout the time that a vessel transited through the SSA, and once again after the vessel had exited the SSA. During vessel transits through the SSA, counting commenced in the stratum closest to the incoming vessel.

5.2.2 Group Composition and Behaviour

Group composition and nearshore behavioural data were collected for all narwhal observed within the BSA (< 1 km from shore). Survey and scan sampling protocols (Mann 1999) were used to record group-specific data (Table 5-1, Table 5-2, Table 5-3). Observations were made using a combination of Big Eye binoculars (25 x 100), 10 x 42 and 7 x 50 binoculars, and the naked eye. When large herding events took place and RAD team members were not conducting a RAD count, they assisted in collecting group composition data in the BSA. The data collection protocols were similar across all years of sampling. A detailed description of group composition and behavioural data collected is provided in the Training Manual (Appendix A).

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

Recorded Data	Description
Time of sighting	Time of initial observation within the BSA
Sighting number	A sighting number was used as a unique identifier for each single whale or group of whales
Marine mammal species	All marine species observed were recorded as a separate sighting
Group size[1]	Number of narwhal within one body length of one another
Number of narwhal by tusk classification	■ Number of narwhal with tusks ■ Number of narwhal without tusks ■ Number of narwhal with unknown tusks (i.e., head not visible)
Number of narwhal by age category	Adult, juvenile, yearling, calf, unknown life stage (Table 5-2)
Spread of group	■ Tight: narwhal ≤ 1 body width apart ■ Loose: narwhal >1 body width apart
Group formation	Linear, parallel, cluster, non-directional line, no formation (Table 5-3)
Direction of travel	North, South, East, West
Speed of travel	■ Fast / Porpoising ■ Medium ■ Slow ■ Not travelling / Milling
Distance away from shore	■ Inner: <300 m ■ Outer: >300 m
Primary behaviour	See Table 8 (Behavioural Data) in the Training Manual (Appendix A) for lists of behaviours recorded

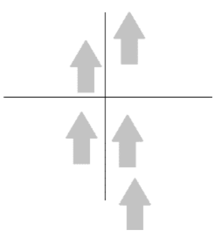
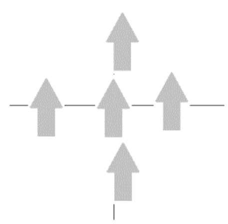
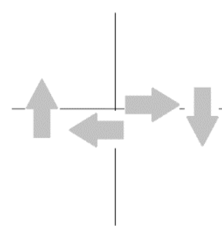
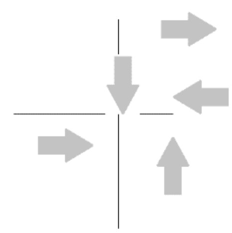
Notes:

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

Table 5-2: Life stages of narwhal

	Adult	Juvenile	Yearling	Calf
Length	4.2 – 4.7 m	80-85% the length of adult	2/3 the length of accompanying female	1/3 to 1/2 the length of accompanying female, usually in “baby” or “echelon” position close to mother.
Coloration	Black and white spotting on their back, or mostly white (generally old whales)	Dark grey; no or only light spotting on their back	Light to uniformly dark grey	White or uniformly light (slate) grey, or brownish-grey

Table 5-3: Group formation categories

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

5.2.3 Vessel Transits

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

The study teams also visually recorded vessel traffic in the SSA during each survey period. Vessels were classified by size (small <50 m, medium 50-100 m, and large >100 m in length), type of vessel, and general travel direction. In previous years of analysis (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b), small vessels were modelled as either total count present during each RAD count or as present/absent. In the current analysis, only medium and large vessels were included, while small vessel presence was omitted from analysis due to concerns of small vessels being detected disproportionately between different substrata and between different levels of narwhal activity in the BSA.

5.2.4 Non-vessel Anthropogenic Activity

The rocky shoreline below the Bruce Head observation platform serves intermittently as a hunting camp for local Inuit. Over the course of the seven-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 5.2**). 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 5.2: Two SM4 acoustic recorders mounted back-to-back on a fiberglass pole. The shoreline location of the Inuit hunting camp is visible in the background.

5.2.5 Environmental Conditions

Environmental conditions were recorded at the start of the monitoring period, every hour, and whenever conditions changed. For the entire SSA, cloud cover (percent [%]), precipitation, and ice cover (%) were recorded. Beaufort level, sun glare, and an overall assessment of sightability were recorded for each substratum within the SSA and also in the BSA. In all years, modelled tidal data for Bruce Head were obtained from WebTide Tidal Prediction Model (v 0.7.1). These tidal data were provided as tide height (m) relative to chart datum. A derivative variable of elevation change (as cm/5 min) was calculated by subtracting each data point from the previous recorded tide height point. New to the 2021 Program, a Davis Vantage Pro 2 weather station was set up at the observation platform to provide the team with real-time updates of changing weather conditions, including wind speed and wind direction.

5.2.6 Focal Follow (UAV) Surveys

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, InDro Robotics Inc. was contracted to complete aerial photography of the SSA and surrounding area for the duration of the 2020 and 2021 Programs. The Drone Operations team worked closely with Golder biologists to carry out focal follow surveys of narwhal using a selection of UAV units, primarily the EVO 2 by Autel Robotics. The EVO 2 is a compact UAV unit that includes a powerful camera on a 3-axis stabilized gimbal, capable of recording video at 8k resolution up to 25 frames per second and capturing 48 megapixel stills. 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 field season in an effort to increase sample size. All survey footage was recorded at 4k or higher. To conduct this work, a Special Flight Operations Certificate (SFOC) was obtained from Transport Canada to perform Beyond Visual Line of Sight (BVLOS) operations (SFOC #930030).

During the 2020 and 2021 Programs, a dedicated team of two to three individuals conducted the focal follow surveys, including the primary Beyond Visual Line of Sight (BVLOS) Pilot in Command and a Golder biologist who directed the survey and acted as the Ground Supervisor/Visual Observer. For each survey, the drone was flown to a predetermined, randomized starting point either within the SSA or slightly to the south, toward Koluktoo Bay. Once at the starting point, the drone was oriented north (to facilitate data entry and analysis later) and flown until the first group of narwhal was encountered. Important to note is that emphasis was placed on following groups with immatures in 2021 to inform behavioural responses of animals in vulnerable life stages to vessel traffic. The UAV team then followed the focal group for as long as it was visible and terminated the survey only 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 Pilot increased the altitude of the drone, attempting to stay with the focal group for as long as possible.

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

5.3 Data Management

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

At the end of each daily monitoring period, study team members reviewed the BSA field data sheets and the Access databases (for RAD, environmental, and anthropogenic data) as a means for quality control. Any discrepancies/omissions in the data were addressed immediately while the study team maintained a memory of the day's events. All data sheets were photographed and saved as a digital record on both the laptop and an external hard drive, and original data sheets were filed in a binder at the Bruce Head camp. Every day, the group composition and behaviour data were entered into an Access database, and the full data suite (RAD, group composition and behaviour, environmental, and anthropogenic data) was reviewed and quality checked a second time. Any missing and/or incorrectly entered fields, as well as discrepancies, were corrected by cross referencing with field notes taken during each monitoring period.

5.4 Data Analysis

5.4.1 Data Preparation for Analysis

5.4.1.1 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 seven-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 minutes following a shooting event were significantly different from number of narwhal recorded during no hunting activity (P values of <0.009 for all) and that narwhal group sizes were significantly different up to 70 minutes following a shooting event when compared to group sizes when no hunting occurred (Golder 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 minutes, and narwhal recorded more than 70 minutes following a shooting event were considered as "no hunting" observations.

5.4.1.2 Data Integration between Sampling Years

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

For the 2014 RAD surveys, the time stamp associated with each substratum survey was identical (i.e., only the timing of start of the overall RAD count was recorded, not the timing of each stratum or substratum survey). As vessel passage and anthropogenic activity are tied to RAD data via time stamps, individual substratum-specific start times have since been incorporated into the analysis. To calculate these for 2014 RAD surveys, it was assumed that a full RAD survey required 27 min (i.e., three minutes per stratum × nine strata surveyed in 2014).

Each stratum was then allocated three minutes (i.e., one minute per substratum), and time stamps were allocated to each substratum.

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

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

5.4.1.3 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 2021 from the shore-based AIS station at Bruce Head had a mean of 0.2 min between positions (range of 0.02-2.9 min, median of 0.20 min, SD of 0.06 min). The distances between positions ranged from 0.0 km to 0.63 km (mean of 0.04 km, median of 0.04 km, and SD of 0.01 km). Positioning data from the AIS satellite only (i.e., with removed Bruce Head antenna data) had a mean of 0.7 minutes between positions (range of 0.02-2.95 min, median of 0.33 min, SD of 0.66 min). The distances between positions ranged from 0.0 km to 0.9 km (mean of 0.16 km, median of 0.08 km, and SD of 0.16 km).

AIS data were subsequently filtered to only include data collected during active RAD/BSA survey periods at the platform. In AIS positioning data filtered to the temporal extent of RAD/BSA sampling, only 2.5% of the AIS data were contributed by satellite data. The combined shore-based and satellite-based AIS dataset had a mean of 0.2 minutes between positions (range of 0-2.40 min, median of 0.20 min, SD of 0.14 min). The distances between positions ranged from 0.0 km to 0.7 km (mean of 0.05 km, median of 0.04 km, and SD of 0.04 km). The resulting dataset was used to interpolate the AIS data to 1 min resolution, to create a high temporal resolution, necessary to relate vessel positions to narwhal sightings and behaviour.

Each point in the compiled AIS dataset was used to calculate the distance and angle between the ship’s position and each centroid of the 28 SSA substrata (Figure 5-1). The resulting distances were used as continuous predictors of narwhal response to vessel traffic. To account for the orientation of the vessel relative to the substrata, vessels that were nearing the substrata (angles >270º and <90º) were classified as “Toward the substratum”, whereas vessels that were moving away from the substrata (90º< angles <270º) were classified as “Away from the substratum”. The interpretation of a vessel moving toward or moving away is therefore not that it departs the actual substratum, but that it is moving away from the substratum, acknowledging that an animal’s response to a transiting vessel may vary depending on whether it is being approached by the vessel or is facing the stern of a departing vessel where the majority of radiated noise is generated. The AIS data preparation was repeated in an identical way for the behavioural and composition dataset, using the BSA centroid as the reference point.

The potential effects of the vessel were assessed up to 15 km from the SSA substrata or from the centroid of the BSA following the collection of data in 2017 (Golder 2019) and up to 10 km following the collection of data in 2019 (Golder 2020b). However, based on narwhal movement data collected as part of the 2017-2018 narwhal tagging study (Golder 2020a), narwhal behavioural responses to shipping were generally limited to distances up to 5 km from the vessel. That is, narwhal behaviour was generally found to return to non-exposure levels once vessels were 5 km or farther from the narwhal. In addition, shipping sound levels recorded as part of JASCO's passive acoustic monitoring program indicated that vessel noise, 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 ≤ 4.64km; 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 aimed to reduce potential noise in the data at farther distances, which would allow to better quantify the effects at closer distances, where effects are likely to be stronger.

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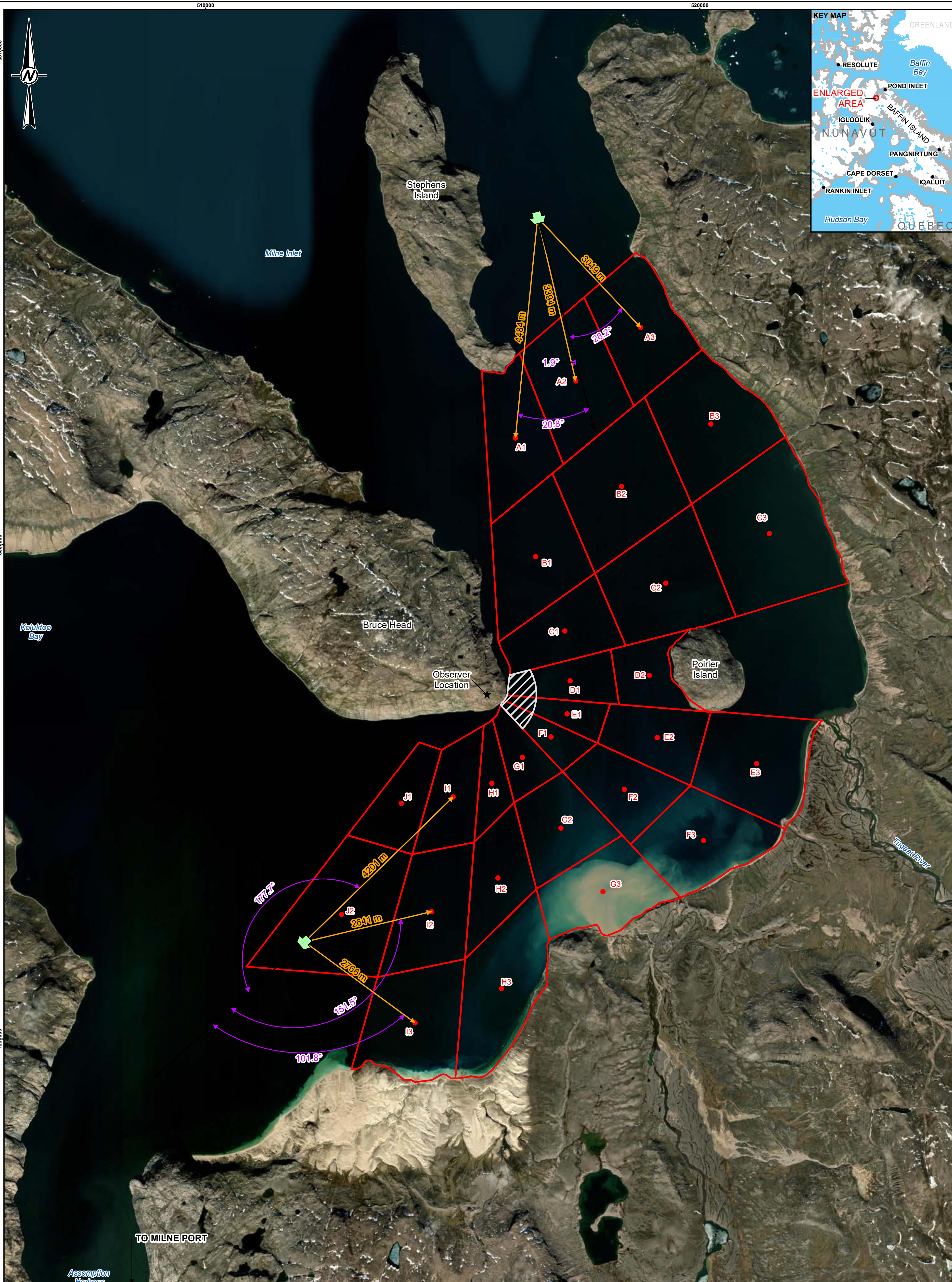

LEGEND

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

0 2 4

1:75,000 KILOMETRES

REFERENCE(S)

SUBSTRATA LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. IMAGERY COPYRIGHT ©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

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

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5.4.1.4 Relative Abundance and Distribution (RAD) Data

For each RAD count within a given substratum, AIS data were retrieved for each vessel present in the study area, including information on course, heading, and distance, and whether the vessel was moving toward or away from the substratum's centroid (recorded to the nearest time stamp). The data were then filtered using a temporal criterion: vessels with GPS positions recorded more than 15 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 corresponds 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.

5.4.1.5 Group Composition and Behavioural Data

Similar to the process described above to calculate vessel distance and angle relative to SSA centroids, group composition and behavioural data were also allocated vessel distance and angle, using the centroid of the BSA instead of the SSA centroids. Note that the BSA centroid used for 2014-2016 data differed from the centroid used for 2017 and 2019-2021 data, as detailed in Section 5.4.1.1.

5.4.1.6 Environmental Data

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

5.4.1.7 Data Filtering

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

- Data collected during periods of 'impossible' sightability and cases with Beaufort level 6 or higher (1,347 cases representing 3.1% of total individual substratum surveys). These accounted for a combination of high sea state, glare, fog, or ice cover, and therefore had to be removed from the modelling dataset.
- Data collected on days when killer whales were known to be present within southern Milne Inlet (1,386 cases, representing 3.3% of total individual substratum surveys). Killer whales were present on four days of the combined 2014-2020 dataset: 12 August 2015, 18 August 2019, 26-27 August 2020, and 10 August 2021. These cases were removed, since narwhal behaviour and distribution are strongly affected by the presence of killer whales.
- Cases with narwhal density of ≥200 narwhal/km² (2 cases, <0.01% of total individual substratum surveys) – these were removed to resolve model convergence issues.

Note that some of these cases overlapped. For example, in 34 substratum surveys, sightability was “impossible” and Beaufort level was 6 or higher. Data omitted from the multi-year analysis of group composition and behaviour data included the following:

- Observations collected during periods of ‘impossible’ sightability (27 observations representing <0.5% of total observations).
- Cases where group size was >20 narwhal (20 cases overall representing 0.3% of total observations). Group sizes of >20 narwhal were very rare, observed only twenty times since the start of the Program. Group size was used as a continuous covariate in the analysis of group composition, spread, formation, direction, speed, and distance from shore. These large group sizes resulted in there being influential cases, skewing model results. Therefore, the 20 cases associated with group sizes > 20 narwhal were removed from the analysis to better capture patterns of the overall dataset.
- Sightings collected on days when killer whales were present in southern Milne Inlet (161 cases, representing 2.6% of the data). Killer whales were recorded in the study area on five days of the combined 2014-2021 dataset: 12 August 2015, 18 August 2019, 26-27 August 2020, and 10 August 2021. The 161 cases associated with killer whale occurrences were removed from the analysis, since narwhal behaviour is known to be strongly influenced by the presence of killer whales.
- For the analysis of presence of immatures (i.e., calves and yearlings), groups without calves or yearlings but with at least one narwhal of an unknown life stage were removed from the data. Since the unidentified life stages may have been calves or yearlings, the inclusion of these groups in the data as groups without offspring would potentially skew the results.

5.4.2 Statistical Models

5.4.2.1 Updates to Analytical Approach

The following changes were made to the analytical approach used in 2020 (Golder 2021b) and were applied to the entire seven-year dataset to not affect the ability to assess differences between sampling years:

- The effect of ‘distance from vessel’ was modified in the model. Where possible, a simple, positive, non-directional distance was used in the updated 2021 model, 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. In variables where previous work identified significant effects of vessel’s direction within Milne Inlet, the variable was retained in the model, to correctly account for differences in shipping effect as function of vessel direction. In 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 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 allows for an increase in power where possible, while accounting for the effects of shipping on each response variable.

- Vessel effects were considered when vessels were within 5 km from SSA and BSA centroids (i.e., exposure zone <5 km), as opposed to the 7 km spatial extent that was used previously, as detailed in Section 5.4.1.1 (Golder 2021b).
- Small vessel effects – In the current analysis, the presence/absence of small vessels in the SSA was included in the models, to account for potential effects. This is consistent with analyses performed prior to 2020 (Golder 2018, 2019, 2020b).
- The analytical framework used for behaviour and composition data was changed from mixed models with autocorrelation structures to generalized linear models with a predictor that accounts for the response variable of the previous group recorded on the same observation day. For example, in analysis of group distance from shore, the model included a predictor of whether the previous group recorded on the same day was seen close to shore (<300 m) or offshore (>300 m). This allowed for sufficient control of the temporal autocorrelation (as evaluated by partial autocorrelation plots before and after the addition of this variable). In some cases, the interaction between this variable and distance from vessels was added to the models, where narwhal responses to shipping differed based on the behaviour of previously recorded groups.
- Effect size – In the current analysis, effect sizes are described as small (≥0.10), medium (≥0.25), and large (≥0.50), similar to that used in other marine mammal behavioural response studies related to vessel exposure (Cohen 1988; Richter 2006; Zapetis et al. 2017). In taking a conservative approach to detect behavioural changes of narwhal to vessels, responses with medium effect size may be biologically significant and are considered to warrant further investigation. However, caution should be exercised with interpretation of results at close approach distances to vessels given the small sample size of narwhal observations collected at these distances, and particularly for group composition and behaviour data.

5.4.2.2 Fixed Effect Predictors

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

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

1) Glare (within SSA strata or BSA, as applicable) — categorical variable with the following categories: None (N), Low (L), Moderate (M), and Severe (S).
2) Beaufort level (within SSA strata or BSA, as applicable) — for the RAD, it was used as categorical variable, with categories ranging from 0 to 5. For the BSA, Beaufort values of 4 of greater were combined into a single bin of “4+”. These accounted for 559 cases in the dataset following removal of impossible sightability and days when killer whales were present in southern Milne Inlet (9.5%).

3) Tide – categorical variable with the following categories: "low slack", "flood", "high slack", and "ebb", as detailed in Section 5.4.1.6.

4) Distance from vessel — continuous variable (in km) calculated between vessel location and each of the SSA substratum (and BSA) centroids. Where directional distance was used, the values are negative when the vessel is heading toward the centroid and positive when the vessel is heading away from centroid.

5) Vessel direction within Milne Inlet — categorical variable with two categories: ‘northbound’ and ‘southbound’, used for RAD analysis, as well as in analysis of group direction.

6) Interaction between vessel distance and vessel direction.

Where possible based on previous findings, effects 4-6 were simplified to an effect of absolute distance from a vessel, to increase statistical power and to simplify interpretation of modeling results.

7) Vessel presence within the exposure zone (≤ 5 km) from the substratum/BSA centroid — 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 5.4.2.1).

8) Whether hunting occurred within a pre-defined window prior to a sighting — categorical variable with two categories: ‘hunting occurred’ and ‘no hunting occurred’. For both RAD and behaviour and composition analyses, 70 minutes was selected as the pre-sighting cut-off limit for a hunting activity, as detailed in Section 5.4.1.1.

9) Year — categorical variable with seven categories: 2014, 2015, 2016, 2017, 2019, 2020, and 2021.

10) Day of year — continuous variable, where January 1 of each year is assigned a value of 1. Only used for RAD analysis, since preliminary visual data assessments did not identify relationships between group composition and behaviour response variables and day of year.

11) Stratum – categorical variable (A to J), only used for RAD analysis.

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

13) Presence or absence of small vessels within the SSA when each observation was made.

14) Previous group’s composition and behaviour, only used for group composition and behaviour analysis. For example, in analysis of distance from shore, this variable would account for the distance from shore of the previous group recorded on that survey day. In some cases, an interaction between this variable and distance from vessel was also included, where narwhal responses to shipping differed based on the behaviour of previously recorded groups.

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

5.4.2.3 Narwhal Density Modelling

Narwhal RAD data collected in the SSA were analyzed as the total density of narwhal observed in each substratum during each RAD survey completed across seven years of sampling. The generalized mixed linear model with a zero-inflation component evaluated how the density of narwhal (accounting for the areas of individual substrata) was affected by the various predictor variables; the model contained an offset term of natural log-transformed substratum area, which allowed for the analysis of RAD data as a density, rather than simply analyzing numbers of narwhal per substratum. Predictor variables used for this analysis are listed in Section 5.4.2.2.

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

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

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

The following predictor values were used to visualize model predictions: stratum F, substratum 2, Beaufort level of 2, survey year 2017, day of year 227 (15 August), tide level ‘flood’, and glare value ‘N’.

If significant effects of distance from vessel were found, multiple comparisons (with Dunnett-adjusted *P* values) were performed to estimate at which distance the estimated response values became significantly different from values predicted when no vessels were present within 5 km. All comparisons were made using the package emmeans (Lenth 2020) in R v. 4.0.3 (R 2020).

All analyses were performed using the package glmmTMB (Brooks et al. 2017) in the statistical package R v. 4.0.4 (R 2021). Model fit was assessed via diagnostic and residual plots using the DHARMa package (Hartig 2019) in R v. 4.0.4 (R Core Team 2021).

5.4.2.4 Group Composition and Behaviour

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

5.4.2.4.1 Group Size

The analysis of group size included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship, and since this relationship would not generally be expected). A generalized mixed linear model was used to estimate the effect of the various fixed variables on group size. Group size was assumed to have a truncated Poisson distribution (where truncation was necessary, since no zeroes were possible in the data), and was analyzed using a zero-truncated model from the package “countreg” in R (Zeilis et al. 2008). Distance from vessel was modeled using a non-directional distance variable; that is, neither direction of vessel within Milne Inlet nor vessel position relative to the BSA were included, to increase sample size and model power.

5.4.2.4.2 Group Composition

5.4.2.4.2.1 Presence of Calves or Yearlings

The analysis of presence of calves or yearlings in observed groups included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Distance from vessel was modeled using a non-directional distance variable; that is, neither direction of vessel within Milne Inlet nor vessel position relative to the BSA were included, to increase sample size and model power. An autocorrelative variable (i.e., whether the previously recorded group had calves or yearlings) was not required, since temporal autocorrelation was low, with only 5% of survey days exhibiting significant autocorrelation. Group size was used as a covariate in the model. A generalized linear model with a logit link (for binomial data) was used to estimate the effect of the various variables on presence of calves or yearlings in the observed groups.

5.4.2.4.3 Group Spread

The analysis of group spread (loose vs tight groups) included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Distance from vessel was modeled using a non-directional distance variable; that is, neither direction of vessel within Milne Inlet nor vessel position relative to the BSA were included, to increase sample size and model power. Group size was also used as a covariate; however it was changed from a continuous variable (number of individuals in a group) to a categorical variable – whether the group size was 2 individuals or >2 individuals. This change was made because groups of two individuals were often mom-calf pairs that were in a tight spread, and an increase from a group size of two individuals to a group size of three individuals resulted in a marked increase in the proportion of loose groups. On the other hand, further increases in group size did not have an effect on the proportion of groups in a loose formation. The group spread recorded for the previous group on the same survey day was also used as a covariate, to reduce temporal autocorrelation within the dataset. A generalized linear model with a logit link (for binomial data) was used to estimate the effect of the various variables on group spread.

5.4.2.4.4 Group Formation

The analysis of group formation was simplified to a logistic regression by analysing whether the observed group formation was parallel or not (rather than analysing each individual observed formation). Since parallel formation was most commonly observed under both vessel exposure and non-exposure scenarios (63% of all data), it was assumed to be the baseline formation. Therefore, the logistic analysis will provide insight into the effect of the predictor variables and deviations from the baseline parallel formation.

The analysis of group formation included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Distance from vessel was modeled using a non-directional distance variable; that is, neither direction of vessel within Milne Inlet nor vessel position relative to the BSA were included, to increase sample size and model power. Group size was also used as a covariate. An autocorrelative variable (i.e., the formation of the previously recorded group) was not required, since temporal autocorrelation was low, with only 4% of survey days exhibiting significant autocorrelation. A generalized linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group formation.

5.4.2.4.5 Group Direction

The analysis of group direction was simplified to a logistic regression by removing cases of west- or east-travelling groups, as well as groups that were not travelling (i.e., a total of 185 groups representing 3% of the data). The resulting dataset contained only north- or south-travelling groups. The analysis of group direction included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship) and the effect of year, since it was not deemed likely that group travel directions would change between years. Distance from vessel was modeled using a non-directional distance variable; that is, neither direction of vessel within Milne Inlet nor vessel position relative to the BSA were included, to increase sample size and model power. A covariate of group travel direction was added a predictor, to account for the propensity of south-travelling groups to pass close to shore. The travel direction recorded for the previous group on the same survey day was also used as a covariate, to reduce temporal autocorrelation within the dataset. Group size was also used as a covariate. A generalized linear model with a logit link (for binomial data) was used to estimate the effect of the various predictor variables on group direction.

5.4.2.4.6 Travel Speed

The analysis of travel speed was performed using a logistic model of slow vs medium speeds. Medium travel speeds were assumed to be the baseline values since medium travel speeds were the most common (57% of the data). The analysis of travel speed included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship), in addition to group size that was used as a covariate. Distance from vessel was modeled using a directional distance variable, with an interaction with vessel direction within Milne Inlet. That is, both direction of vessel within Milne Inlet and vessel position relative to the BSA were included in the model, given the difference in narwhal response in previous analysis (Golder 2021b). The travel speed recorded for the previous group on the same survey day was also used as a covariate, to reduce temporal autocorrelation within the dataset. An interaction between this autocorrelative variable and the distance from vessel was also included, to assess whether changes in travel speed in relation to distance from vessels depend on the prevalent travel speed. A generalized linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group travel speed.

5.4.2.4.7 Distance from Bruce Head Shore

The analysis of whether narwhal groups were close to shore (<300 m) or far from shore (>300 m) included all predictor variables listed in Section 5.4.2.2, except for the effect of day of year (since preliminary data visualization indicated no relationship). Group size, group travel direction, and distance from shore recorded for the previous group on the same survey day were also used as covariates. Distance from vessel was modeled using a non-directional distance variable; that is, neither direction of vessel within Milne Inlet nor vessel position relative to the BSA were included, to increase sample size and model power. A covariate of group travel direction was added a predictor, to account for the propensity of south-travelling groups to pass close to shore. A generalized linear model with a logit link (for binomial data) was used to estimate the effect of the various variables on group distance from shore.

5.4.2.5 Power Analysis

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

5.4.3 Focal Follow (UAV) Analysis

Group composition and behavioural data collected for each focal follow survey conducted during the 2020 and 2021 field seasons were entered into an integrated database in 30-second segments. Similar to the group composition and behavioural data collected by shore-based observers in the BSA, response variables considered in the focal follow analysis included group composition, group spread, group formation, and primary behaviour (i.e., travelling, milling, resting, and social behaviour). In addition, the orientation of the focal group was documented, as well as the relative and distal position of all immatures (i.e., calves and yearlings) in relation to the adult female (i.e., presumed mother) with which they were associated. One of the motivating factors in assessing position of immatures relative to the adult female was to assess whether certain positions may be utilized more readily in response to a perceived threat (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 are displayed less often in the presence of vessels.

In 2020, the sample size of focal follow surveys conducted in the presence of shipping was insufficient to carry out a meaningful statistical analysis of behavioural response to vessel traffic. Therefore, analysis of the focal follow data in 2020 was qualitative only, with data summarized using plots and summary statistics. While the additional data collected via UAV surveys in 2021 is valuable in providing insight into narwhal behaviour, the sample size of focal groups in close proximity to vessels remains insufficient to conduct a meaningful statistical analysis of narwhal behavioural response relative to distance from vessels. Specifically, of the 23.6 hours of observational data collected via UAV, the total time spent with focal groups (relative to distance from vessel) was 2.5 min at 0 km, 11.5 min at 1 km, 62 min at 2 km, and 60.5 min at 3 km (distances rounded to nearest integer; Figure 6-46). As such, narwhal behavioural responses were analyzed in relation to vessel presence/absence only.

The analytical approach used was adapted from a recent UAV-based study by Arranz et al. (2021) in which the proportion of time that specific behaviours were observed was assessed relative to vessel traffic. Similar to Arranz et al. (2021), special attention was paid to assessing the behaviour of mothers with immatures (i.e., calves or yearlings) relative to vessel traffic, with a focus on examining the presence of nursing behaviour, as well as the relative and distal positioning of immatures to their mother.

Focal groups were divided into five categories based on composition: 1) mother-immature pairs (includes strictly mothers with calves or yearlings), 2) mixed groups with immatures (dependents include calves or yearlings with the addition of other adults or juveniles in the group), 3) mixed groups without immatures (groups comprised of adults and juveniles or only juveniles, with no dependents including calves or yearlings), 4) strictly adult groups, and 5) lone immatures (in the current integrated dataset, only calves were ever observed on their own).

Statistical analysis of data collected via drone footage was performed for all assessed variables – group size, group composition, group formation, group spread, primary behaviour, unique behaviour, relative position of immatures, distal position of immatures, and presence of nursing behaviour. The analyses were performed using mixed models fitted in the package “brms” (Bürkner 2017) in R (R 2021). 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. Group spread, unique behaviour, presence of nursing behaviour, and the relative/distal position of immature-mother pairs were analyzed using mixed logistic models, since each response variable only included two categories. Group size was analyzed using a truncated Poisson model, since groups of size 0 are not possible. Group composition was analyzed as a multivariate mixed model with an underlying Poisson distribution for each of the three response counts – count of adult, juvenile, and calf or yearling individuals within each group. Primary behaviour, group composition, group formation, and relative position of immatures were analyzed as a multinomial model.

6.0 RESULTS

6.1 Observational Effort and Environmental Conditions

Each annual monitoring campaign at Bruce Head (2014–2017 and 2019-2021) was timed to extend over an approximate four-week period, coinciding with the open-water season (Table 6-1; Figure 6-1). In general, the study area was ice-free during each annual program, with occasional presence of drifting ice floes in the SSA. Survey effort varied between years (Table 6-1), largely due to changing weather conditions and the number of monitoring shifts used each year. For example, survey effort was lower in 2017 than in previous years due to only having a single 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 and 2021.

Table 6-1: 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	
Shipping season extent	08 Aug– 03 Sep	03 Aug– 04 Sep	28 Jul– 03 Sep	02 Aug–17 Oct	18 Jul– 30 Oct	05 Jul– 15 Oct		-
Survey dates	03 Aug– 05 Sep	29 July–05 Sep	30 July–30 Aug	31 July–29 Aug	06 Aug– 01 Sep	07 Aug– 01 Sep	01 Aug – 26 Aug	-
No. of active survey days	23	29	27	26	26	26	24 (BSA), 22 (RAD)	181
No. of survey days lost to weather	14	9	11	2	3	0	4	43
No. of observer hours (total)	79.6	148.7	159.3	97.3	151.5	193.0	163.0	992.5
Average daily survey effort (h)	7.8	10.8	11.9	6.1	11.1	13.6	13.2	10.6
No. of attempted RAD surveys	179	314	321	160(1)	288	353	290	1,905
No. of complete RAD surveys	166	313	311	109	169	206	188	1,462
Number of RAD surveys with 0 narwhal counts(2)	75	164	127	35	71	236	197	905
No. of narwhal (total)	10,463	14,599	28,309	11,862	19,210	9,047	4,762	98,252
No. of narwhal excluding ‘impossible’ sightability	10,463	14,599	28,309	11,831	19,200	9,047	4,762	98,211
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	99.4[4]
No. of vessel transits during RAD effort	7	11(3)	21(3)	22	32(3)	42	31	166
No. of RAD surveys with >1 vessel transiting	2	0	2	3	5	5	4	21

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

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

(3) = counts of vessel transits differ from those presented in Table 6-2 due to transits occurring outside of a RAD count or the vessel being farther than 5 km from relevant substrata during the RAD count.

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

Figure 6-1: Observer effort (h) by survey day, presented by year; lines extend from first to last observations made within each day.

Across the seven-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 6-2). 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 1,870 rows of RAD data (3.7% of the total 2014–2017 and 2019-2021 dataset).

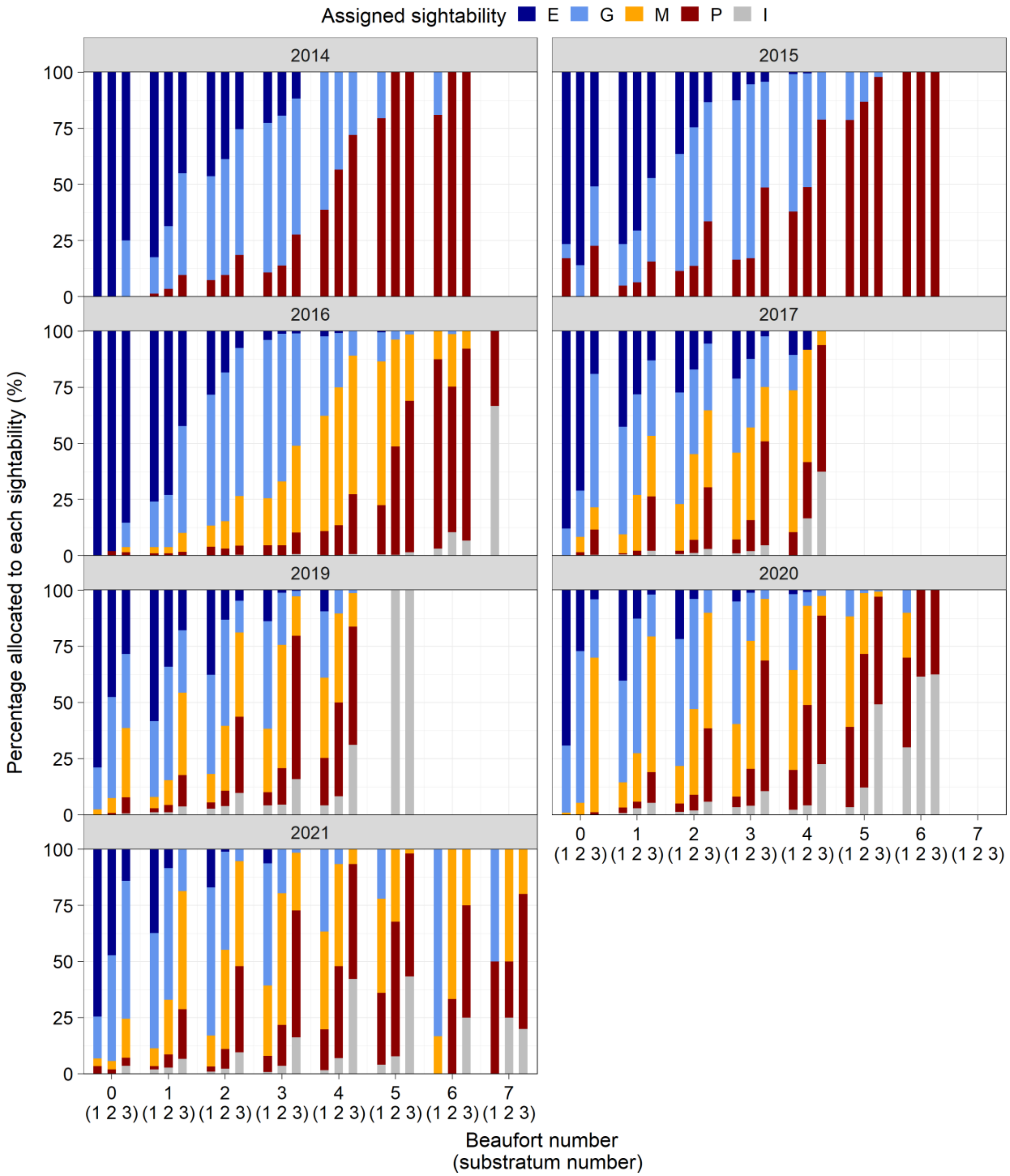


Figure 6-2: Sightability conditions during RAD surveys in the SSA based on Beaufort wind scale, glare, and substratum location (plotted by year): (E) Excellent, (G) Good, (M) Moderate, (P) Poor, (I) Impossible.

6.2 Vessel Transits and Other Anthropogenic Activity

6.2.1 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 6-2 and Figure 6-3. In 2021, sightings data were recorded during 62% of all vessel transits that occurred during the study period. Large vessel traffic in the SSA consisted primarily of Project-related bulk (ore) carriers (28 unique vessels, 50 one-way transits; Table 6-2; APPENDIX B), accounting for 59%, 77%, 73%, 83%, 80%, and 86% of total one-way transits in 2015, 2016, 2017, 2019, 2020, and 2021, respectively (no ore carriers were present in 2014). Other large Project-related vessels included general cargo vessels and fuel tankers. No passenger vessels were recorded in the SSA in 2021. Recorded tracklines of all vessel transits through the SSA during the full extent of all shipping seasons combined are presented in Figure 6-4. Recorded tracklines of vessel transits occurring during the 2021 survey period specifically are presented in Figure 6-5.

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

Survey Year	No. of 1-way Transits in SSA (No. of Project-related Transits)		No. and (%) of 1-way Transits Recorded by Observers during Bruce Head Survey Period
	Full Shipping Season	Bruce Head Survey Period	
2014	13 (5)	13 (5)	7 (54%)
2015	22 (20)	22 (20)	13 (59%)
2016	56 (49)	47 (40)	24 (51%)
2017	154 (150)	59 (55)	22 (37%)
2019	240 (238)	75 (73)	41 (55%)
2020	188 (188)	56 (56)	42 (75%)
2021	175 (175)	58 (58)	36 (62%)
Total	848 (825)	330 (307)	227 (69%)

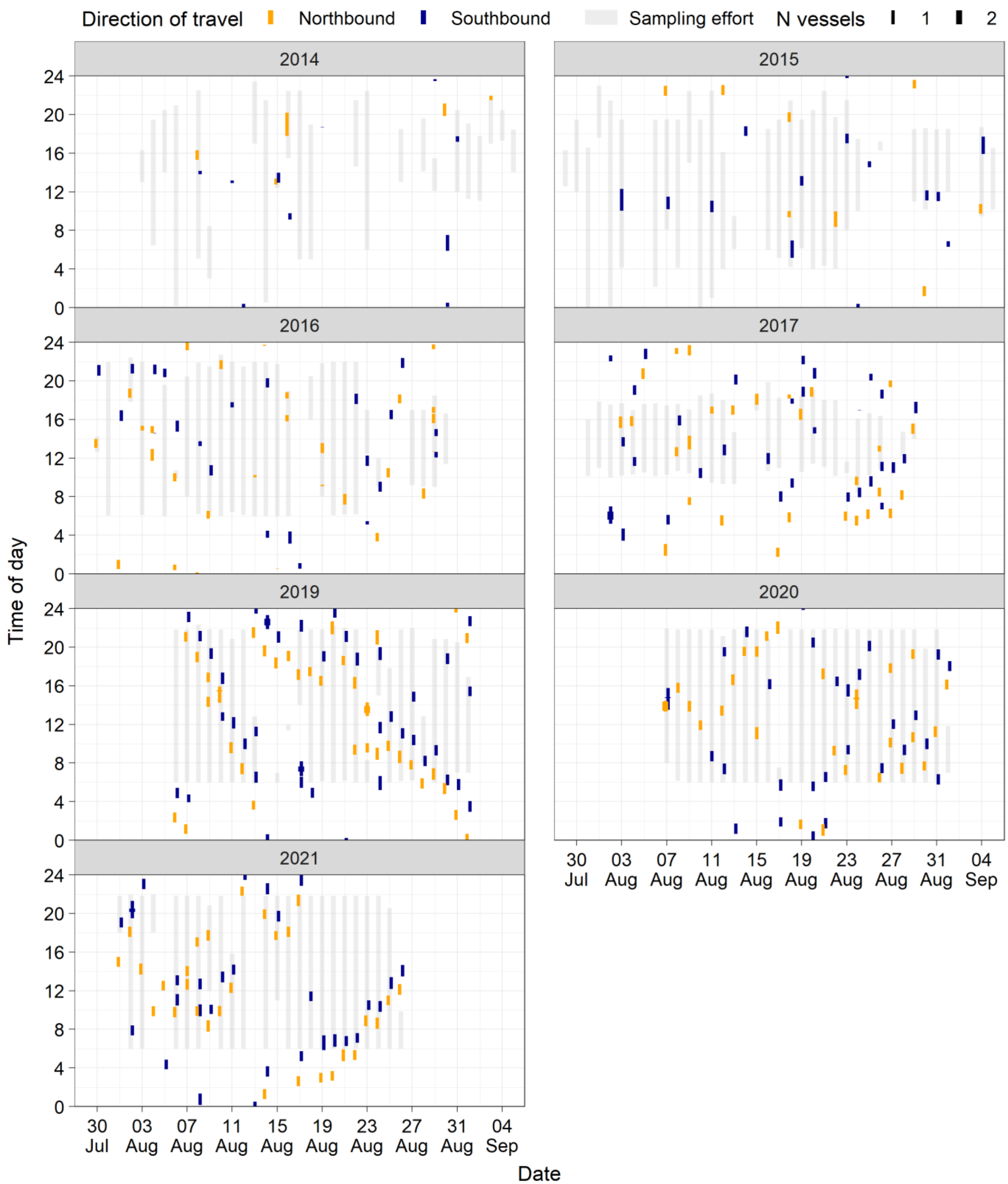


Figure 6-3: Daily summary of vessel transits in SSA with associated survey effort. Grey boxes indicate daily monitoring periods and correspond to observer survey effort shown in Figure 6-1; grey boxes extend from first to last observations made within each day.

LEGEND

VESSEL TRANSIT ROUTES BY LENGTH AND CLASS

LARGE VESSELS

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

MEDIUM VESSELS

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

BEHAVIOURAL STUDY AREA (BSA)

STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 5 10

1:200,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. SUBSTRATA DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. GEOGRAPHIC NAMES, HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

MARY RIVER PROJECT

CONSULTANT

GOLDER

MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

TITLE

TRACKLINES OF LARGE AND MEDIUM VESSEL TRANSITS IN SSA (2014-2017, 2019, 2020 AND 2021) DURING FULL SEASON SHIPPING

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000-04	0	6-4A

LEGEND

VESSEL TRANSIT ROUTES BY LENGTH AND CLASS

LARGE VESSELS

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

MEDIUM VESSELS

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

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

0 5 10

1:200,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. SUBSTRATA DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. GEOGRAPHIC NAMES, HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

MARY RIVER PROJECT

CONSULTANT

GOLDER MEMBER OF WSP

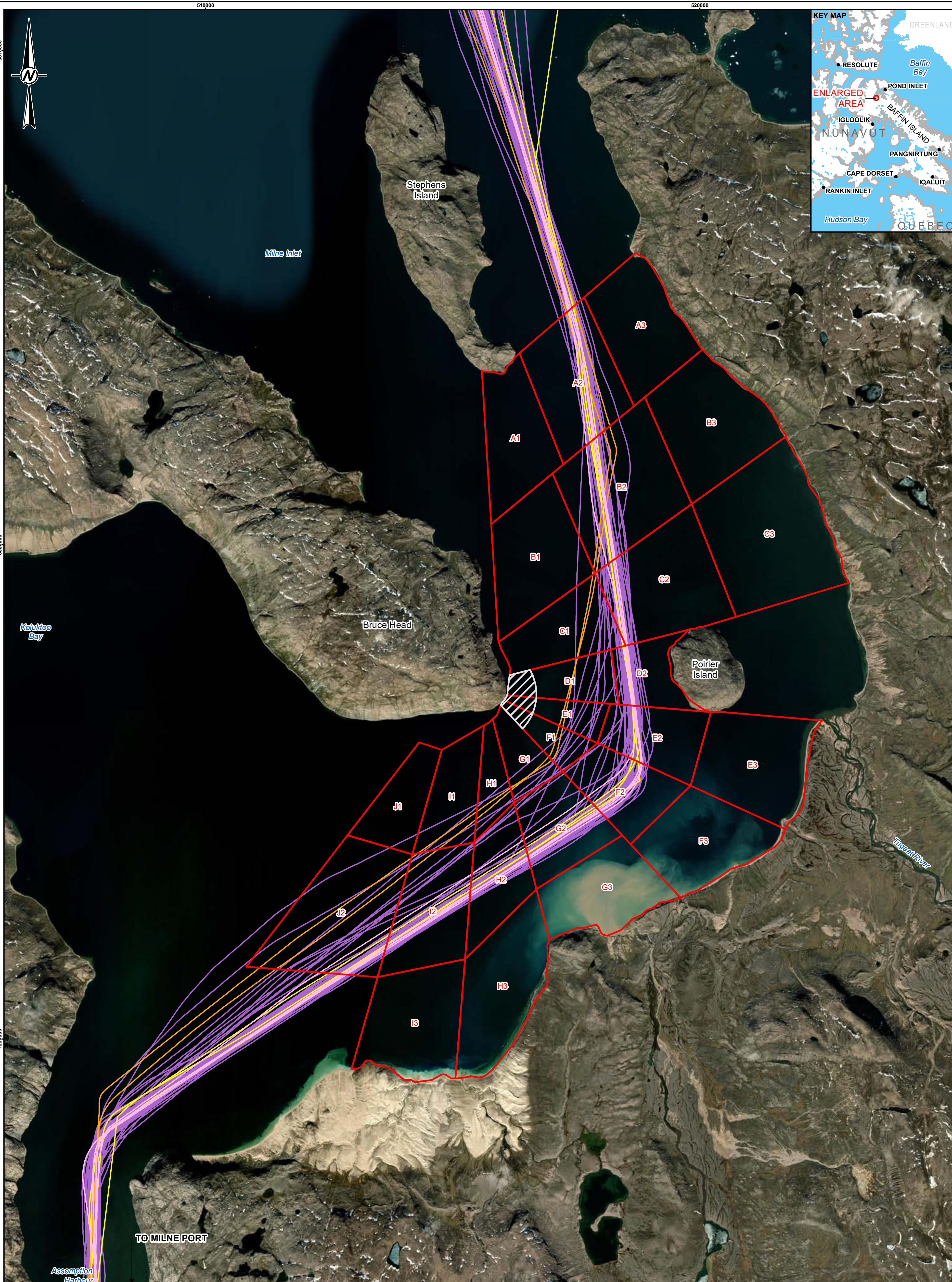
YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

TITLE

TRACKLINES OF LARGE AND MEDIUM VESSEL TRANSITS IN SSA (2014-2017, 2019, 2020 AND 2021) DURING FULL SEASON SHIPPING

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000-04	0	6-4B

PATH: I:\2016\1663724\Mapping\MXD\43000_2021BruceheadProgram\1663724_43000_04_Fig6_05_2021Vessels_SamplingPeriod_Rev0.mxd PRINTED ON: 2022-06-23 AT: 9:30:13 AM



LEGEND

WATERCOURSE

LARGE VESSELS

BULK (ORE) CARRIER

CARGO CARRIER

FUEL TANKER

MEDIUM VESSELS

ICE BREAKER

BEHAVIOURAL STUDY AREA (BSA)

STRATIFIED STUDY AREA (SSA) SUBSTRATA

WATERBODY

0 2 4

1:75,000 KILOMETRES

REFERENCE(S)

SUBSTRATA LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

MARY RIVER PROJECT

TITLE

TRACKLINES OF LARGE AND MEDIUM VESSEL TRANSITS IN SSA DURING 2021 SURVEY (1-31 AUG 2021)

CONSULTANT

GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000-04	0	6-5

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25mm

Vessel speeds were plotted by vessel type for each year (Figure 6-6). As part of Baffinland's vessel management practices, a maximum vessel speed limit of nine knots along the Northern Shipping Route is enforced. Vessel speeds ≥9 knots were recorded during six of the 50 ore carrier transits that occurred in the SSA during the 2021 survey period. No ore carriers exceeded 10 knots in the SSA during 2021.

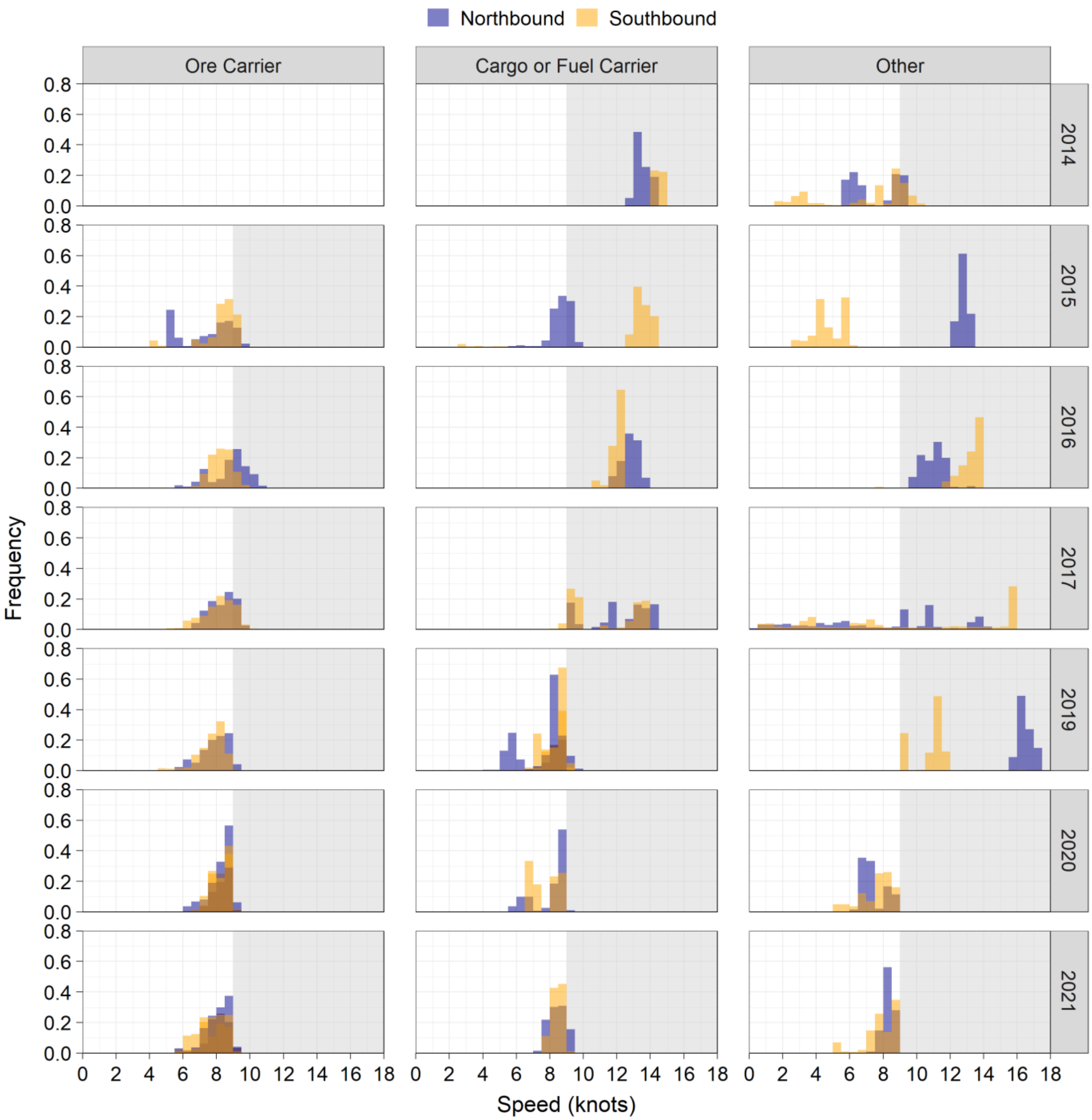

Figure 6-6: Travel speed (knots) of all vessels in the SSA presented by survey year. Shaded area represents speeds >9 knots.

6.2.2 Other Anthropogenic Activities

The shoreline directly below the observation platform at Bruce Head is an established narwhal hunting site commonly used by local community members. Inuit were often observed camping with tents at the site for multiple days at a time, though others only stopped for several minutes to several hours. During the 2021 field program specifically, the hunting camp was visited or occupied by local hunters for a portion of the study period.

The majority of RAD surveys were performed more than 70 min after the last shooting event (81-96% of surveys; Figure 6-7). Where hunting occurred within 70 min prior to surveys, 2-16% 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.

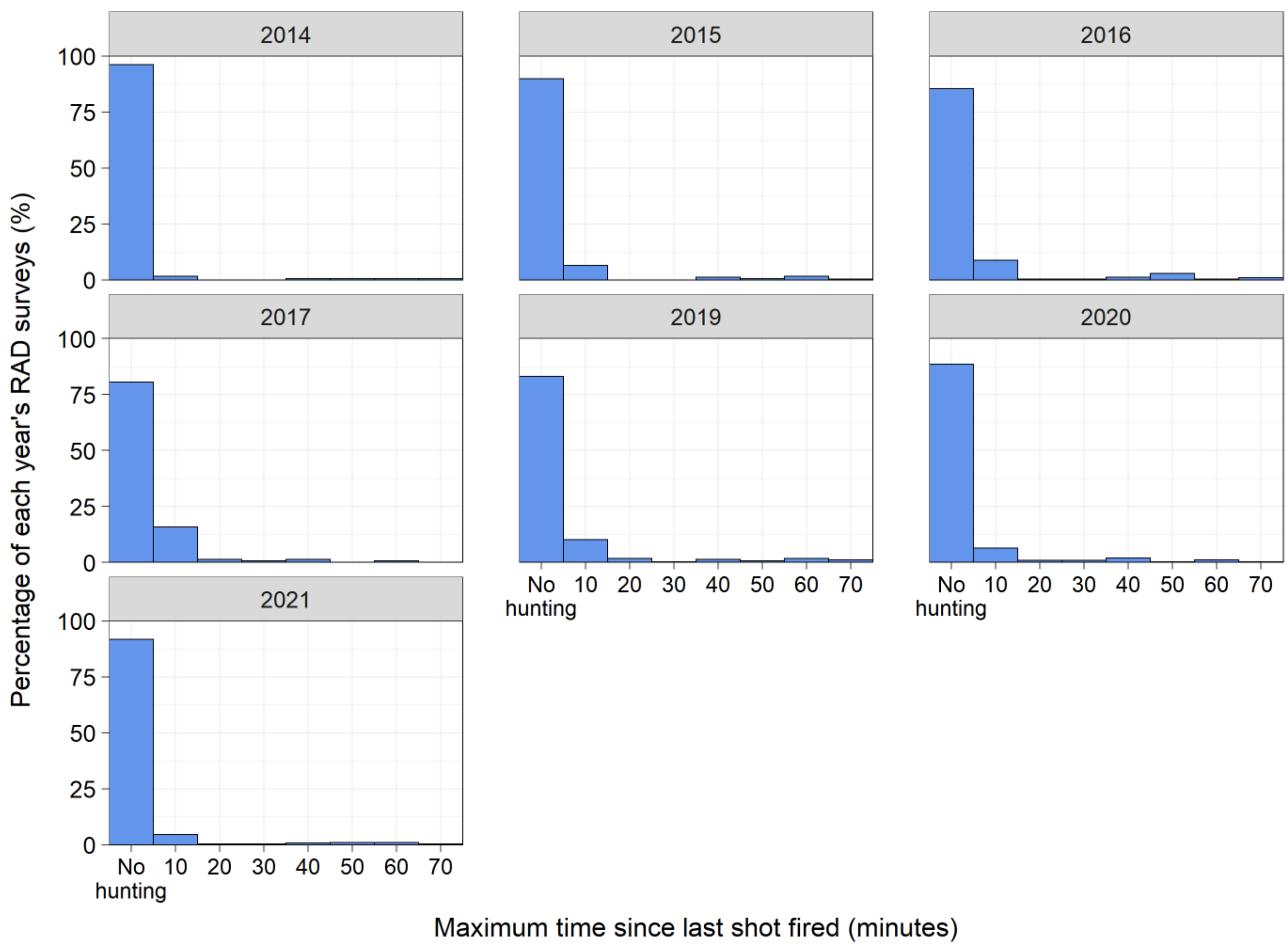

Figure 6-7: Relative proportion of hunting activity at Bruce Head presented by sampling year showing 'maximum time since shooting occurred' breakdown.

6.3 Relative Abundance and Distribution

A total of 290 RAD surveys were completed over the course of 26 days between 1-26 August 2021. A summary of the 2021 RAD data, compared to that collected from 2014 to 2020, is presented in Table 6-1. Similar to previous years, narwhal were the most common cetacean species recorded at Bruce Head in 2021. Less common cetacean sightings recorded in the SSA during 2021 included killer whale (n=4), bowhead whale (two individual sightings) and beluga (n=1). The total number of narwhal recorded (corrected for effort) in 2021 was lower than all previous survey years (Table 6-1; Golder 2021b).

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

A total of 98,252 narwhal were recorded in the SSA over seven years of data collection (Table 6-1). Annual numbers of narwhal recorded ranged from 4,762 (2021) 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 29.0 narwhal/h in 2021 to 156.4 narwhal/h in 2016 (Figure 6-8). Annual median standardized counts ranged from 3.3 narwhal/h in 2021 to 106 narwhal/h in 2017.

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

In all monitoring years, numerous RAD surveys were conducted where no narwhal were observed (see Table 6-1). 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, and 68% in 2021. This variation strongly affected annual mean values. Median daily standardized numbers of narwhal ranged from 3.3 narwhal/h in 2021 to 106.0 narwhal/h in 2017 (Figure 6-8).

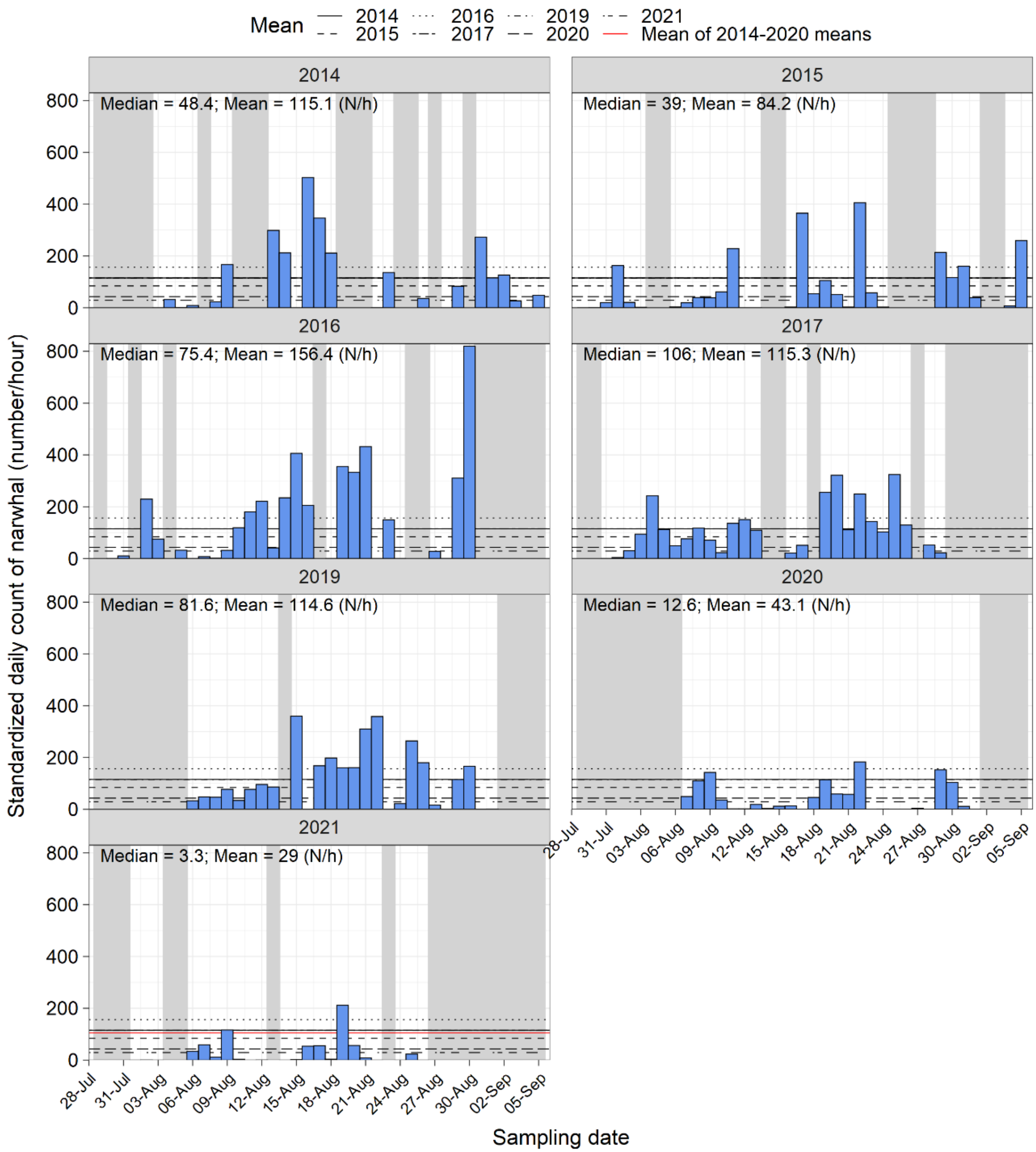

Figure 6-8: Standardized daily numbers of narwhal recorded in the SSA from 2014–2021. Shaded area represents days where no data was collected.

In general, higher numbers of narwhal were recorded in the southern strata (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b). In each survey year, strata G, H, and I possessed the highest proportion of narwhal (Figure 6-9), accounting for 62–72% of total narwhal recorded in 2014–2017, and 47-57% of total narwhal recorded in 2019-2021, respectively (influenced by the introduction of new stratum J in 2019). Stratum J accounted for 23-28% of the total narwhal recorded 2019-2021. In comparison, strata A, B, and C only accounted for 4–11% of total narwhal recorded in 2014-2021. Number of narwhal recorded also varied with substratum distance from the observation platform (Figure 6-9). Each year, substratum ‘2’ (i.e., the mid-channel substrata) had the highest proportion of total narwhal recorded, accounting for 48–56% of total annual narwhal observations.

In addition to stratum and substratum, sightability also affected number of narwhal recorded (Figure 6-9). Number of narwhal recorded per RAD survey were considerably higher during periods when sightability was considered ‘excellent’ and ‘good’, with number of narwhal recorded during ‘excellent’ sightability ranging between 2 narwhal/survey in 2021 and 63 narwhal/survey in 2016 and number of narwhal recorded during ‘good’ sightability ranging from 10 narwhal/survey in 2021 to 42 narwhal/survey in 2016. In comparison, number of narwhal recorded during ‘moderate’ sightability ranged from five narwhal/survey in 2021 to 23 narwhal/survey in 2017 (‘moderate’ sightability was not recorded before 2016) and, during ‘poor’ sightability conditions, from one narwhal/survey in 2020 and 2021 to 19 narwhal/survey in 2014 (before ‘moderate’ sightability was used and thus when ‘poor’ sightability also likely included some ‘moderate’ conditions).

The proportion of narwhal observed in the presence of at least one vessel (i.e., vessel present within 5 km of the substratum centroids) increased from 0.4% in 2014 to 1.4% in 2015, 3.2% in 2016, 11.6% in 2017, 9.1% in 2019, 6.2% in 2020, and 8.9% in 2021. 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%, and 55% in 2014, 2016, 2017 and 2020-2021, respectively), with the exception of 2015 and 2019, in which 33% and 47% 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 = 44,095 surveys of individual substrata, with 94,032 individuals counted), with a mean of 2.1 narwhal per substratum and a mean density of 0.9 narwhal/km² (Figure 6-10).

During periods of single vessel exposure (single vessel ≤5 km), a total of 3,300 surveys of individual substrata were conducted, with a total of 5,018 individuals recorded (mean count of 1.5 narwhal per substratum and mean density of 0.7 narwhal/km²). In 2021, the mean number of narwhal per substratum during periods of single vessel exposure was 0.6 individuals, with a mean density of 0.3 narwhal/km².

During periods of multiple vessel exposure (two or more vessels ≤5 km), a total of 45 surveys of individual substrata were conducted, with a total of 23 narwhal recorded (mean count of 0.5 narwhal per substratum and mean density of 0.1 narwhal/km²). In 2021, no narwhal were observed during the six surveys of individual substrata (during a single RAD survey) that coincided with exposure to multiple vessels.

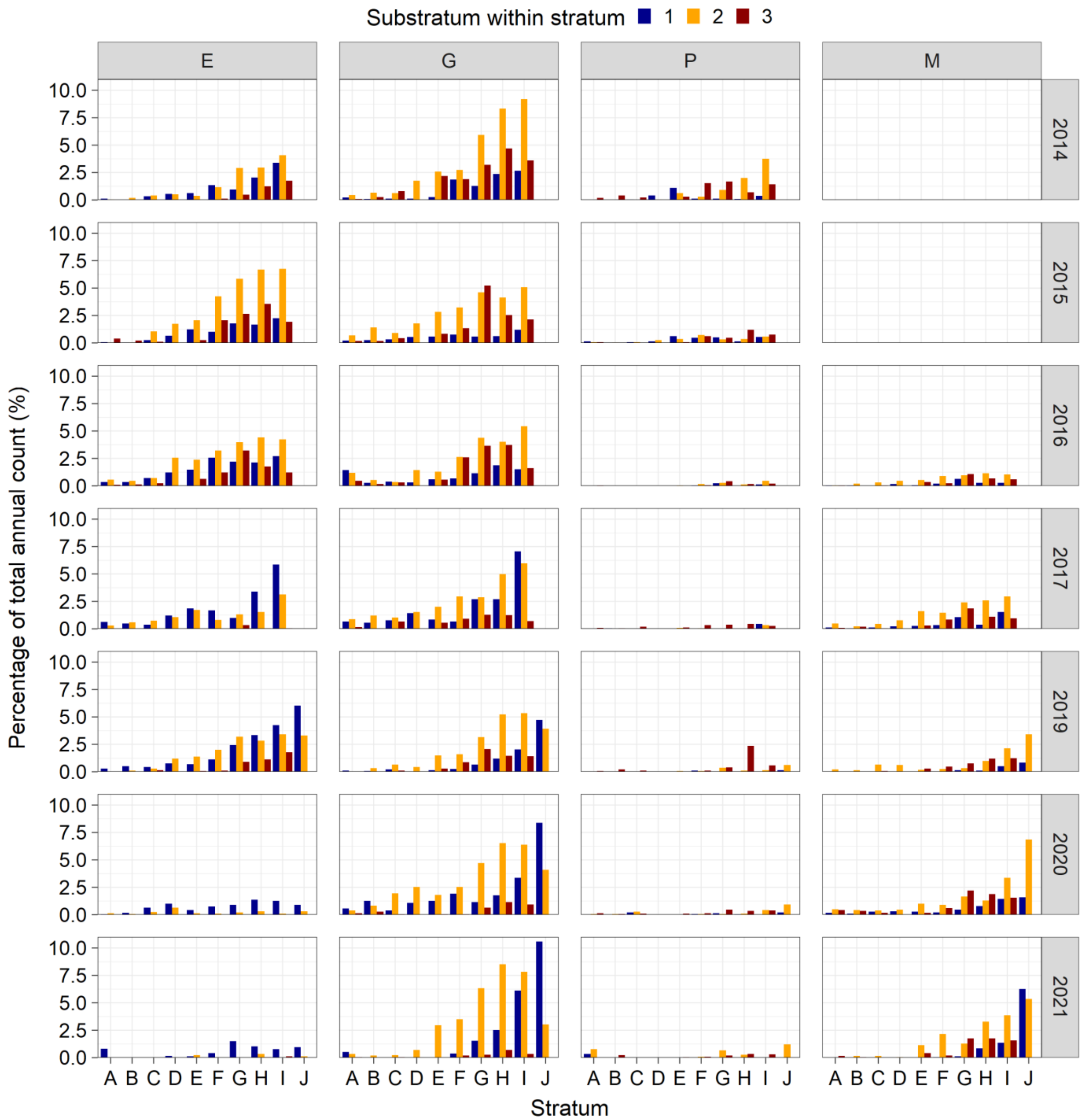

Figure 6-9: Relative proportion of narwhal counts in each substratum as a function of sampling year and sightability (relative to total narwhal counts). Sightability categories: E = excellent, G = good, M = moderate, P = poor.

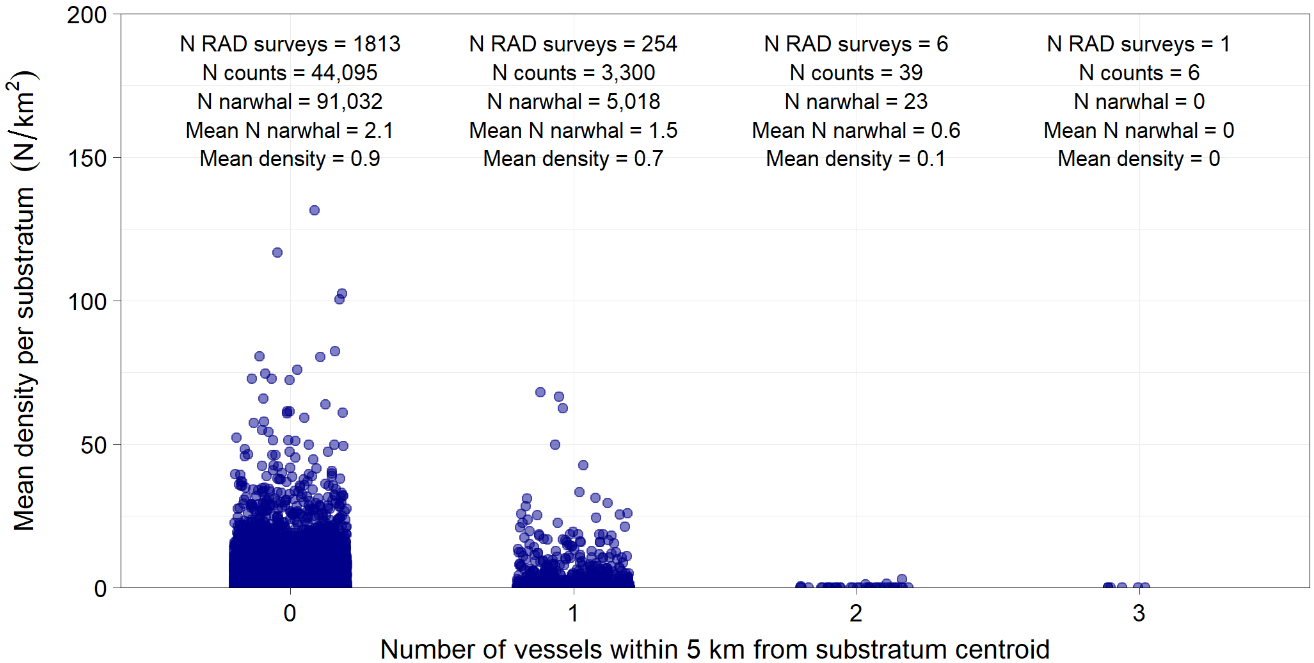

Figure 6-10: Summary of surveys conducted in the SSA relative to vessel exposure level (no exposure, single vessel, and multiple vessels within 5 km); data exclude impossible sightability, cases with Beaufort levels of 6 or higher, and days with killer whales.

In summary, the relative abundance of narwhal (total number of narwhal corrected for survey effort) in the SSA was substantially lower in 2020 and 2021 than in previous survey years (2014-2017 and 2019), including years prior to the start of Baffinland's iron ore shipping operations in the RSA (i.e., 2014). If the decrease in relative narwhal abundance in the SSA is determined to be a result of Project activities, this would be consistent with a high severity response as discussed in Section 3.0 and would be considered a significant alteration of natural behavioural patterns of narwhal in the RSA and/or disruption to their daily routine. This finding would be contrary to 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. A more detailed evaluation of this finding is provided in Section 7.1.

6.4 Narwhal Density

Of the total 47,440 RAD surveys undertaken of individual substrata (excluding “impossible” sightability conditions, cases with Beaufort levels of 6 or higher, and days when killer whales were present in south Milne Inlet), 3,300 surveys (7.0%) were associated with a single vessel exposure event and 45 surveys (0.1%) were associated with a multiple vessel exposure event.

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

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 stratum, substratum, sampling year, and Beaufort level. All four variables were significant predictors in the zero-inflation component of the model ($P<0.001$; APPENDIX C, Table D-1). This indicates that these three fixed effect predictors affect not only narwhal density, but also the probability of recording narwhal presence – whether due to sighting conditions (Beaufort level and distance of the substratum), inter-annual variability (year effect) or spatial (stratum) 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 the BSA, and sampling year (i.e., response variables associated with statistically significant changes), is presented in Figure 6-12. Note that the orange line represents the predicted mean group size for a specific set of predictor values (Section 5.4.2) whereas the blue bars summarize the entirety of the observed data. This leads to some visual discrepancies between the observed and predicted values.

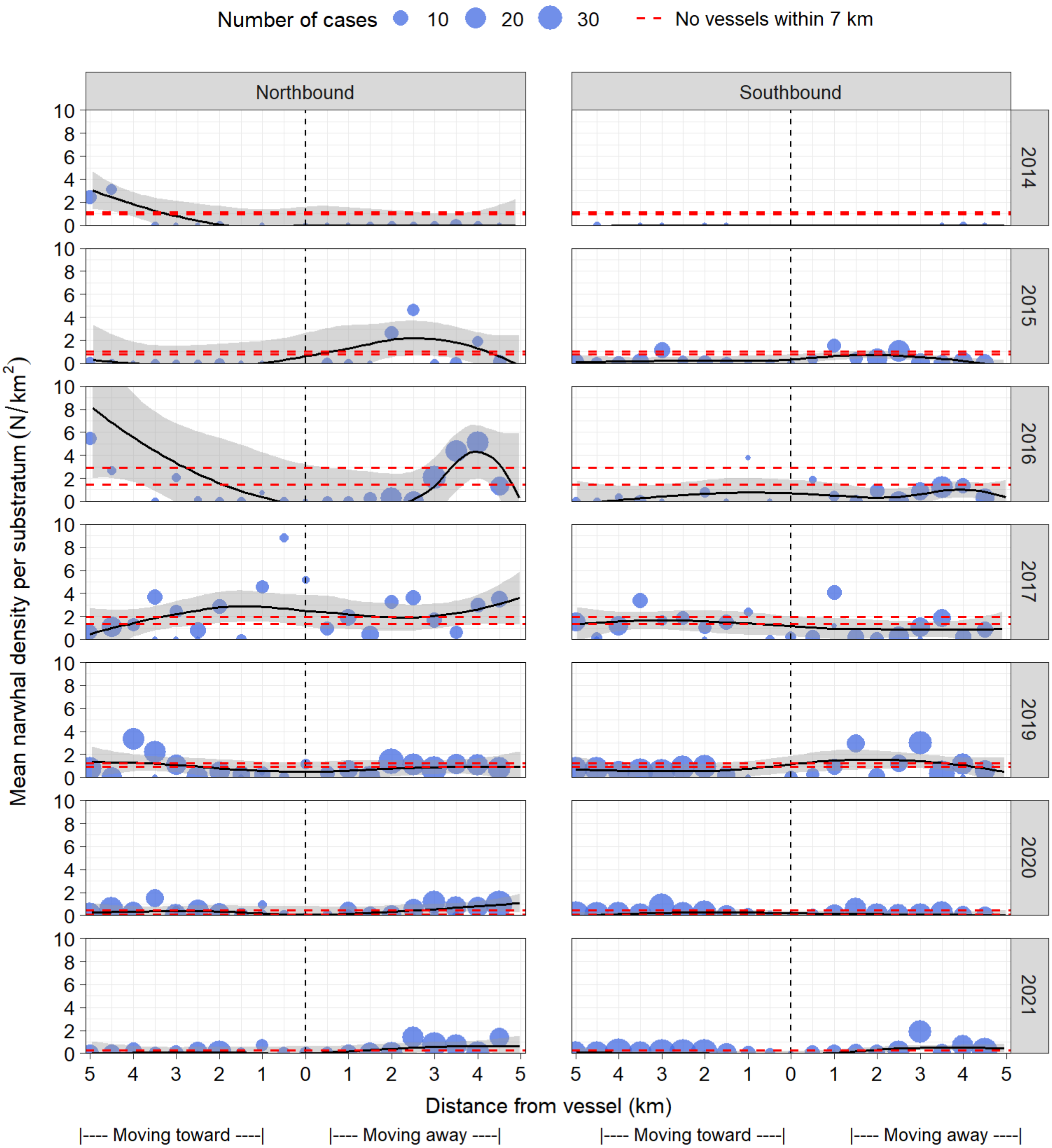

Figure 6-11: Mean narwhal density per substratum as a function of distance from vessel (rounded to 1 km), vessel travel direction, vessel orientation relative to substratum, and sampling year. Size of circle represents relative sample size. Horizontal lines depict mean density of narwhal per substratum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

In the model of narwhal density, the interaction between vessel direction and the effect of distance from vessel was significant (*P*=0.044; Appendix D, Table D-1). During exposure to northbound vessels, modeling results suggested that narwhal densities tended to significantly decrease as the vessel moved closer toward the substratum (slope significance of <0.001), followed by a significant increase in density as the vessel moved further away from the substratum (slope significance of 0.001; Figure 6-12). During exposure to southbound vessels, modeling results suggested that narwhal densities remained generally stable as the vessel moved both toward the substratum and away from the substratum (slope significance >0.7 for both). Mean narwhal densities were significantly lower in the presence of a northbound vessel (for both approaching and departing vessels) at distances within 2 km from a substratum when compared to mean narwhal densities during vessel non-exposure periods (≥ 5 km; Table 6-3). In comparison, in the presence of southbound vessels (both approaching or departing), narwhal densities were not significantly different from those recorded during vessel non-exposure periods. Effect sizes at 0 km were -58% and -23% for a northbound and a southbound vessel, respectively. Effect sizes at 1 km were -48 to -49% for a northbound vessel and -21 to -23% for a southbound vessel. The effect sizes of northbound vessels decreased below ±20% within 4 km (effect sizes at 4 km were +3% for a vessel moving toward the substratum and -3% for a vessel moving away). For a southbound vessel, the effect size at 4 km was -16% for a vessel moving away from the substratum and -26% for a vessel moving toward the substratum. These findings suggest that there may be a moderate biologically significant effect (i.e., >25% change in density – as per Section 5.4.2) up to a distance of 2 km from both northbound and southbound vessels. However, the statistical power to estimate the observed effect at 0 km was shown to be low (Appendix B). That is, the observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥ 0.80) so caution should be exercised with interpretation of this finding. The model had sufficient power (≥0.8) to detect a -68% or +110% effect size in the test of the overall effect of distance from vessel (APPENDIX A).

Other variables that were statistically significant predictors of narwhal density included day of year, year, stratum, substratum, glare, Beaufort level, tide, and hunting (*P*<0.001 for all; APPENDIX C, Table D-1). The effect of presence of small vessels in the SSA was not significant (*P*=0.9). Statistically significant variables that were not related to shipping were further tested using pairwise comparisons. In addition to the significant effect of shipping, the effect of survey year was also significant (*P*<0.001). A significant effect of survey year may indicate a long-term change in narwhal density. Narwhal density was significantly lower in 2021 when compared to 2015 (*P*=0.013), 2016 (*P*=0.002), 2017 (*P*=0.002), and 2019 (*P*=0.005). No other significant comparisons were found (*P*>0.2 for all).

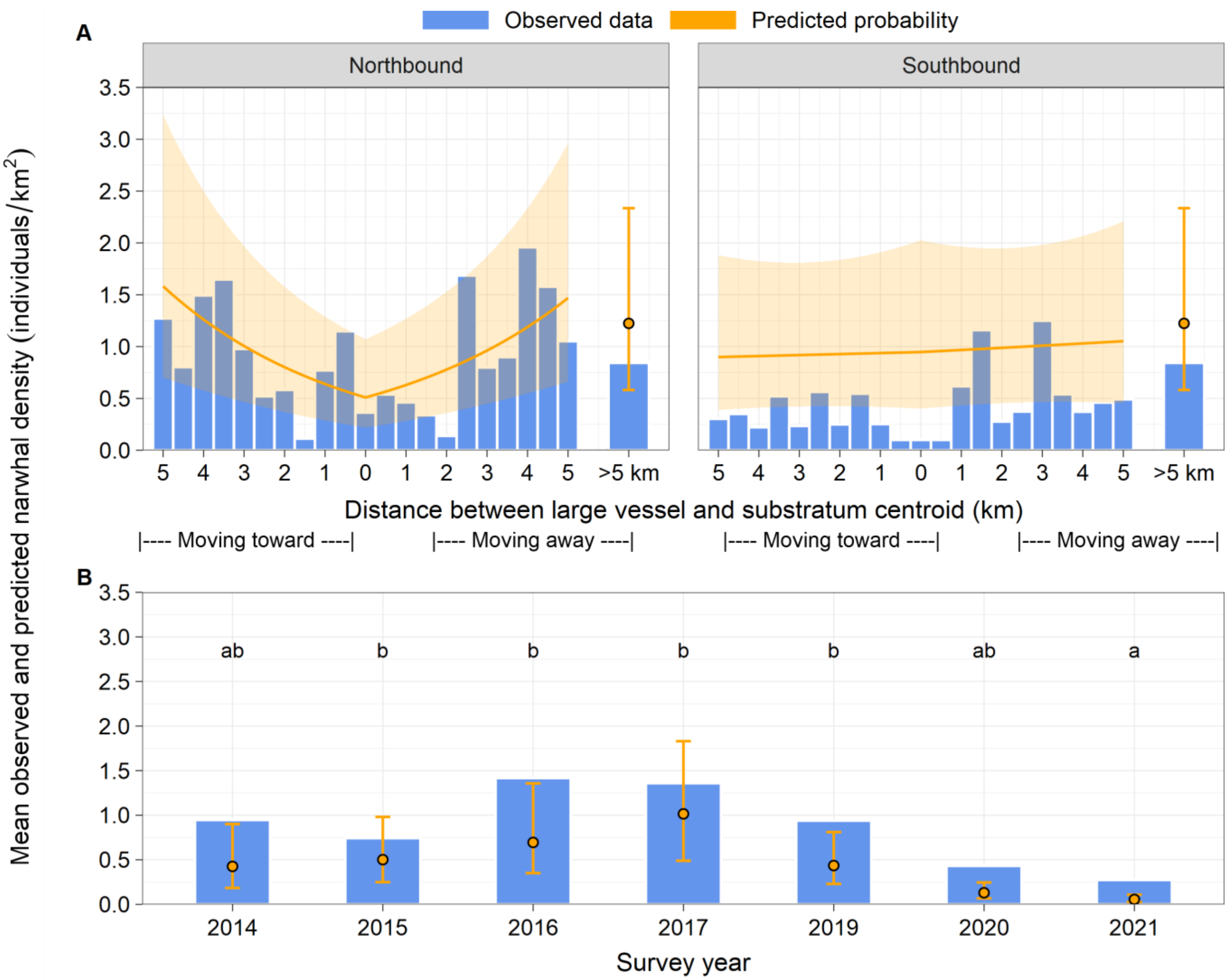

Figure 6-12: Mean narwhal density (individual/km²) as a function of distance from vessel, vessel travel direction, vessel orientation relative to substratum (combined 7-year dataset; Panel A) and survey year (Panel B).

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 6-3: 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 – Least-squares Means with *P* values in Brackets			
	Northbound vessel, toward substratum	Northbound vessel, away from substratum	Southbound vessel, toward substratum	Southbound vessel, away from substratum
0	**0.5 (<0.001)**	**0.5 (<0.001)**	0.9 (0.814)	0.9 (0.814)
1	**0.6 (<0.001)**	**0.6 (<0.001)**	0.9 (0.535)	1.0 (0.638)
2	**0.8 (0.002)**	**0.8 (<0.001)**	0.9 (0.192)	1.0 (0.399)
3	1.0 (0.359)	1.0 (0.067)	0.9 (0.110)	1.0 (0.444)
4	1.3 (1.000)	1.2 (0.999)	0.9 (0.281)	1.0 (0.801)
5	1.6 (0.621)	1.5 (0.792)	0.9 (0.574)	1.1 (0.959)

Narwhal density was generally significantly lower in the northern strata than in the southern strata; that is, narwhal density had a spatial, north-south gradient, with densities generally increasing with every subsequent stratum southward. Narwhal density was significantly lower in substratum “3” when compared to either substratum “1” or substratum “2” (*P*<0.001 for both). Similarly, narwhal density in substratum “2” was significantly lower than substratum “1” (*P*=0.003). Narwhal density was significantly higher when a hunting event occurred within the preceding 70 min (*P*<0.001). This is likely an artefact of the association between narwhal density and hunting, since hunting is more likely to take place when narwhal are present in larger numbers. Narwhal density was estimated to be significantly higher during low slack conditions than during flood, high slack, or ebb conditions (*P*<0.001); also, density was significantly lower during high slack conditions compared to ebb or low slack conditions (*P*<0.001). Densities were found to be significantly lower under severe glare conditions than during normal or no-glare conditions (*P*<0.001 for both), and significantly higher under low-glare conditions when compared to either normal or severe-glare conditions (*P*<0.001 for both). Narwhal densities were found to be significantly higher during lower Beaufort conditions compared to higher Beaufort conditions, except for comparisons between Beaufort values of 0 and 1 (*P*=1.0), and all comparisons between Beaufort values of 3, 4, and 5 (*P*>0.08 for all).

In summary, vessel exposure was shown to result in a significant decrease in narwhal density in the SSA compared to when no vessels were present, but only when narwhal were in close proximity to vessels (within 2 km from a vessel). This would be equivalent to a total disturbance period of 14 min per vessel transit (based on a 9 knot vessel transit speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behaviour following the exposure period (i.e., a temporary effect). During the 2021 Bruce Head program (1 - 26 Aug), there were approximately two transits per day in the SSA (58 one-way transits in SSA over a 24-day period). The daily disturbance period associated with a change in narwhal density was therefore equivalent to approximately 28 min. These findings are consistent with previous years’ findings and with behavioural results from the narwhal tagging study (Golder 2020a), indicating that narwhal density in the SSA is influenced by vessel traffic at close distances (i.e., within 2 km of a vessel). Localized avoidance of the sound source (i.e., the vessel) by narwhal is consistent with a low severity behavioural response, as described in Section 3.0. Given the temporary nature of the effect (i.e., less than the duration of the vessel exposure), this would not be considered a 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

6.5 Group Composition and Behaviour

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 2021, data were collected in the BSA on 24 days, of which killer whales were present on one day, resulting in 23 days of useable date (Table 6-4).

The majority of narwhal groups in the BSA were recorded during 'excellent' sightability conditions in all sampling years except for 2016, 2020, and 2021, during which the majority of narwhal groups were recorded during 'good' sightability conditions (Figure 6-13). The proportion of narwhal groups recorded during 'poor' sightability conditions was relatively high in 2015 (21%). This was an artefact of the 'moderate' sightability category not being used during the first two years of the program, therefore inflating the number of sightings assigned to 'poor' by default. A total of 27 groups were recorded under 'impossible' sightability conditions (8 and 19 groups in 2017 and 2020, respectively) and were excluded from further analyses.

The number of narwhal groups observed in the BSA in 2021 were the lowest recorded since the start of the seven-year study period, with only 80 narwhal groups (comprising 263 individuals) recorded in the BSA in 2021, representing a 68% decrease in sample size compared to the next closest year in 2014 (250 groups comprising 1,086 individuals) (Table 6-4), and representing a 91% decrease relative to the previous sampling year (878 groups in 2020 comprising 2,847 individuals).

Table 6-4: Number of narwhal groups and individuals (i.e., absolute counts) recorded in BSA presented by sampling year.

Survey Year	# Sampling Days	# Narwhal Groups	# Narwhal
2014	11	250	1,086
2015	16	268	1,479
2016	27	761	2,476
2017	27	2,416	8,913
2019	25	1,301	4,986
2020	24	878	2,847
2021	23	80	263

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.

In the combined multi-year dataset, when data associated with “impossible” sightability and killer whale presence were removed, most narwhal sightings in the BSA occurred during vessel non-exposure periods (n = 5,497 cases; 92.3%). A total of 457 sightings occurred during single vessel exposure periods (7.7%). No sightings occurred when multiple vessels were present within 5 km. Annually, the percentage of sightings that occurred when no vessels were present within the BSA ranged from 88% (in 2015) to 100% (in 2014). In 2021, 95% of the sightings occurred when no vessels were present. The percentage of observations when a single vessel was present within 5 km of BSA ranged from 5% (in 2021) to 12% (in 2015).

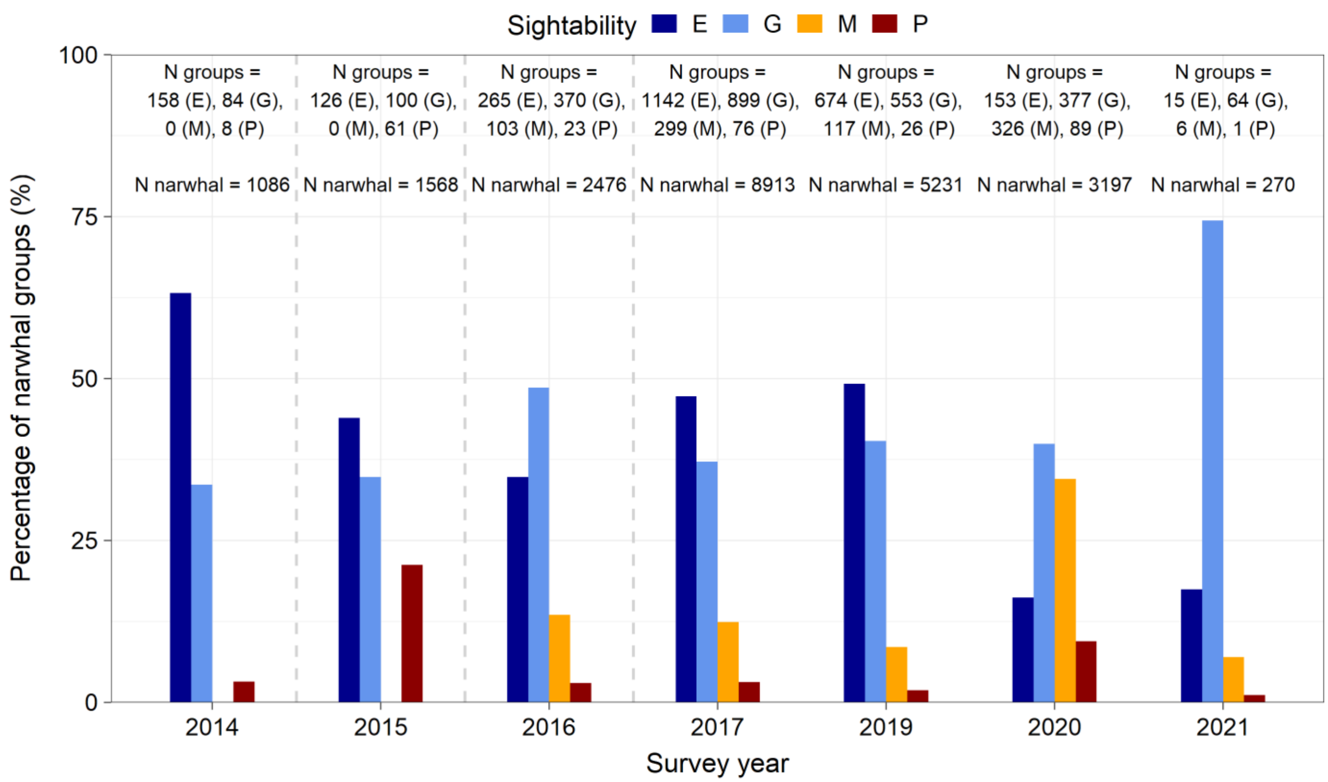

Figure 6-13: Relative proportion of narwhal groups in the BSA as a function of sightability category and sampling year.

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).

6.5.1 Group Size

Throughout the seven-year study, the number of narwhal observed per group was relatively low, generally between one and five individuals (Figure 6-14). Mean group size in the BSA was 4.3 in 2014, 5.5 in 2015, 3.3 in 2016, 3.7 in 2017, 3.8 in 2019, 3.4 in 2020, and 3.0 in 2021. Groups larger than 25 individuals were only recorded once in 2014, three times in 2015 (with group sizes up to 45 individuals), and five times in 2019 (with group sizes up to 35 individuals). The largest group recorded in 2021 was comprised of 13 individuals.

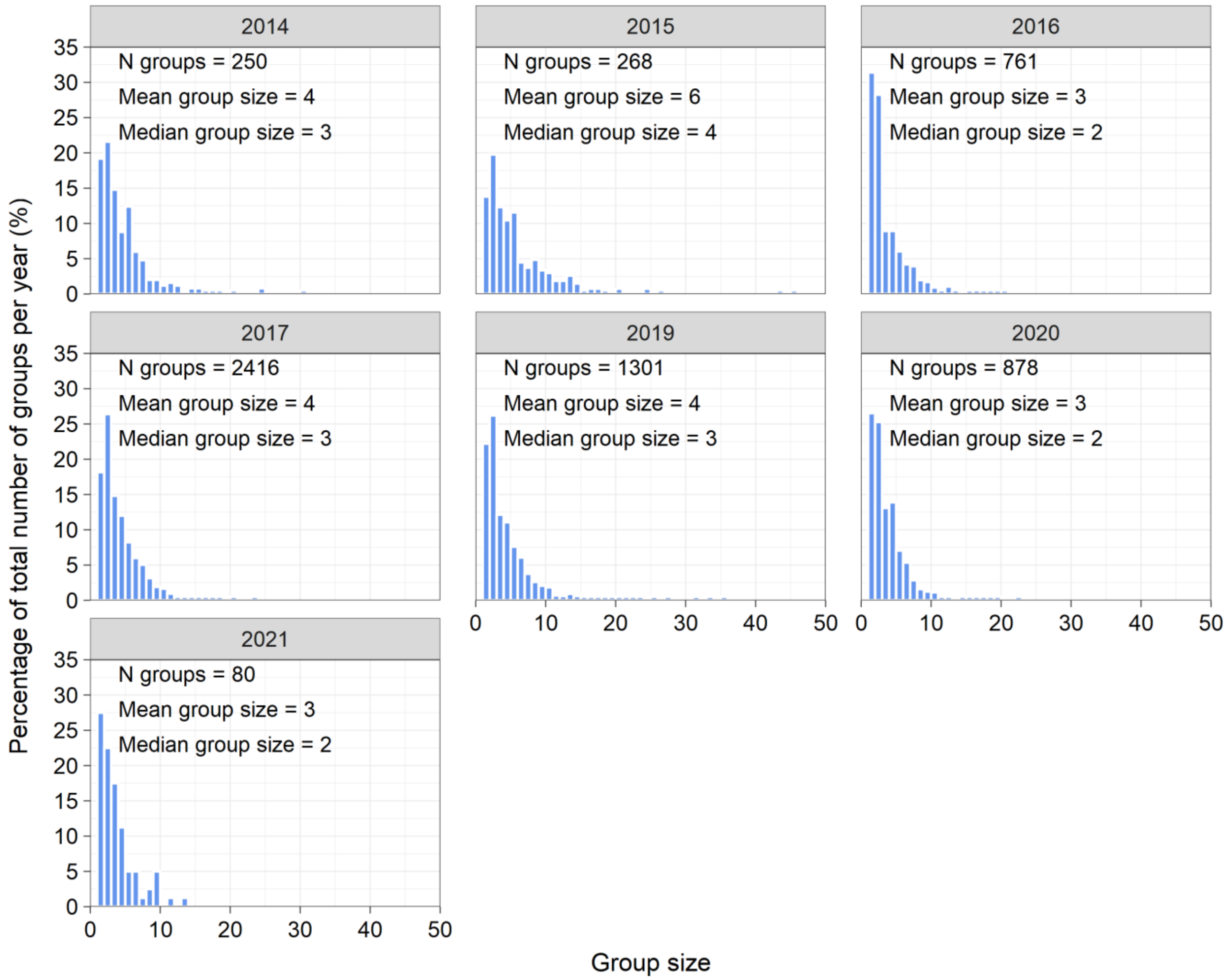

Figure 6-14: Narwhal group size observed in the BSA presented by sampling year.

During vessel non-exposure periods, a total of 5,497 narwhal groups were sighted in the BSA with a mean group size of 3.7 individuals (SD = 3.3 individuals; Figure 6-15). During vessel exposure periods, a total of 457 narwhal groups were sighted in the BSA with a mean group size of 3.6 individuals (SD = 2.9 individuals). There was an apparent trend of a slightly increased group size at the closest vessel exposure distances, with mean group size increasing to 3.9 individuals when vessels were within 1 km of the BSA centroid. Sample sizes were low at the closest approach distances, with observations limited to 28 and 153 narwhal groups within the 1 km and 2 km exposure distances, respectively (out of 457 total observations during ‘vessel exposure’).

Of the 457 observations when vessels were present, 128 and 158 groups were recorded when a northbound vessel was heading toward and away from the BSA, respectively; and 70 and 101 cases were recorded when a southbound vessel was heading toward and away from the BSA, respectively. Mean group size of narwhal observed under these four vessel passage scenarios ranged from 1.9 (northbound vessel heading toward the BSA) to 4.1 individuals (southbound vessel heading toward the BSA; Figure 6-15).

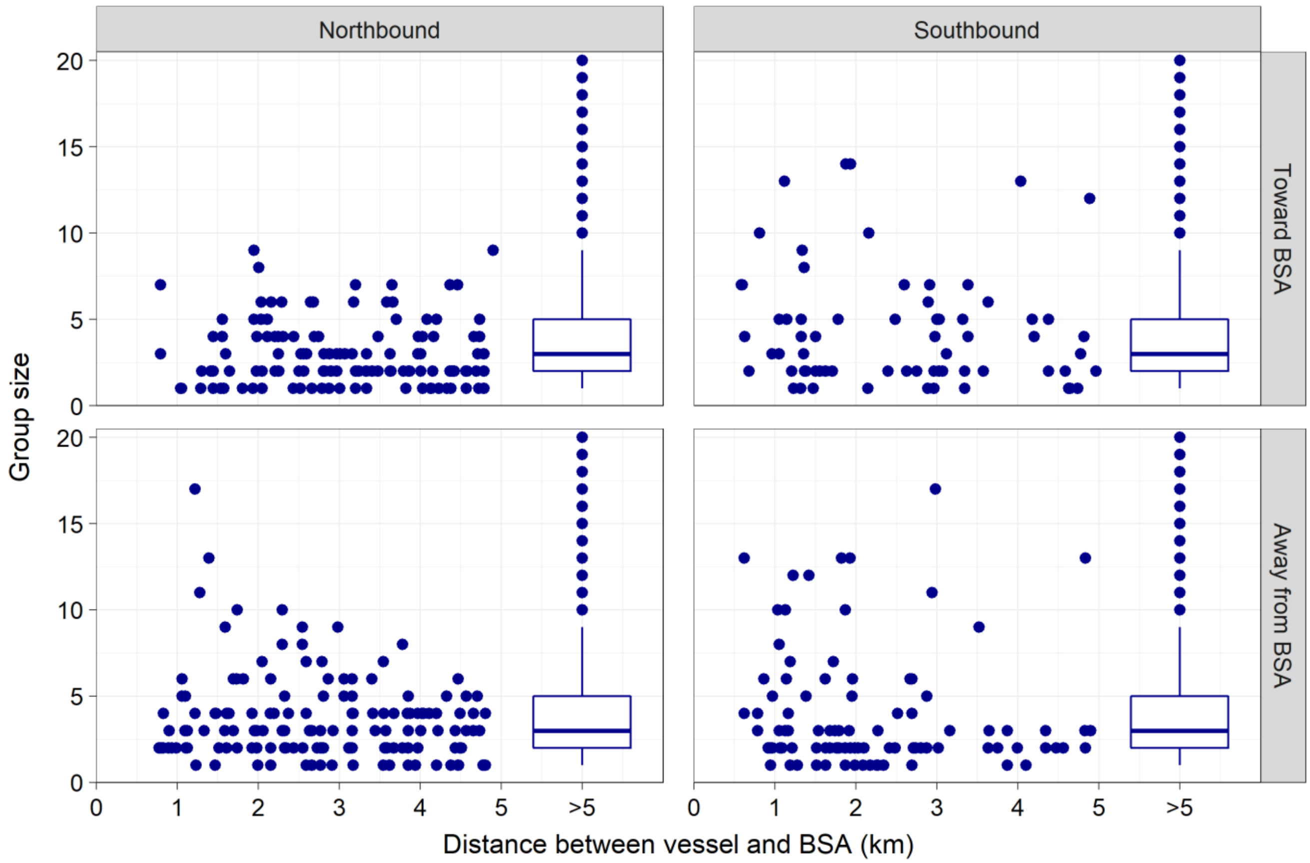

Figure 6-15: Narwhal group size observed in BSA as a function of distance from vessel, vessel direction and vessel position relative to the BSA (combined 7-year dataset).

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

A comparison between the observed data and model predictions for group size, as a function of distance from vessel and sampling year, is presented in Figure 6-16. Note that the orange line represents the predicted mean group size for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars summarize the entirety of the observed data. This leads to some visual discrepancies between the observed and predicted values.

The effect of sampling year on narwhal group size was significant (P<0.001; APPENDIX C, Table D-3). Multiple comparisons between survey years indicated that mean group size was similar between 2014 and 2015 (P=0.7), then decreased significantly (P<0.001) in 2016. Mean group size in 2021 was marginally different from 2015 (P=0.066), but not from other sampling years (P>0.5 for all). While the predicted group size of narwhal decreased after the first two sampling years, group size was generally similar during all subsequent years (Figure 6-16).

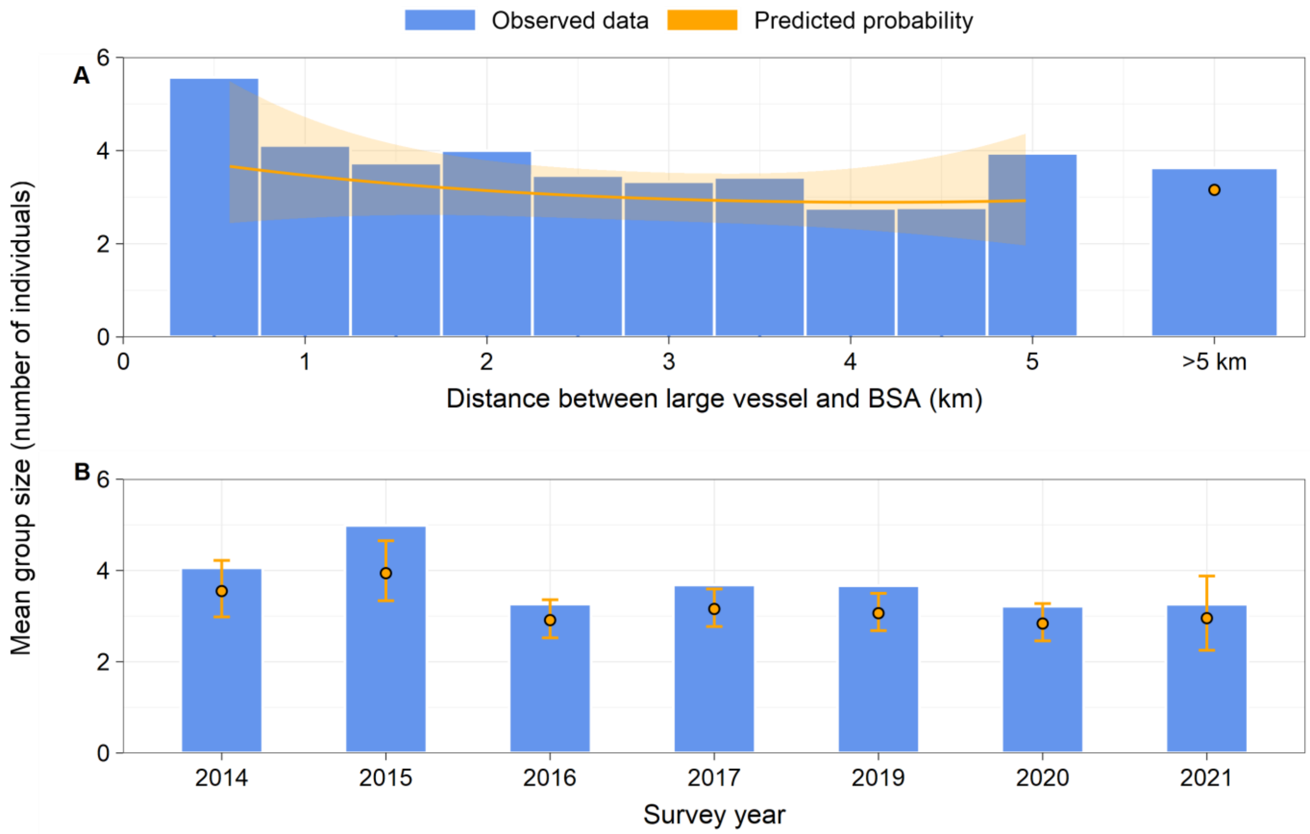

Figure 6-16: Mean narwhal group size as a function of distance (summarized to nearest 0.5 km value) from vessel (Panel A - combined seven-year dataset) and survey year (Panel B).

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

Although both 'distance from vessel' and 'presence of vessel' were not shown to have a significant effect on group size (Appendix D, Table D-3), modelling results predicted an increase in group size at the closest vessel exposure distances (Figure 6-16), with mean group size increasing from 3.2 narwhal during non-exposure periods to 4.0 narwhal when a vessel was at 0 km from the BSA centroid. Estimated effect sizes for a vessel at 0 km, 1 km, and 2 km distance from the BSA were +27%, +10%, and -0.4%, respectively. The effect size of 27% at 0 km suggests that a moderate biologically significant effect (i.e., >25% change in group size – as per Section 5.4.2) may exist at distances less than 1 km from a vessel. The statistical power to estimate the observed effect at 0 km was shown to be low (<0.3; Appendix B). 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 a -47% or a +70% effect size in the test of the overall effect of distance from vessel (Appendix B).

Other variables that were statistically significant predictors of group size included group size of the previous group (P<0.001), Beaufort level (P<0.001), tide (P=0.002), and the occurrence of hunting in the previous 70 min (P<0.001; APPENDIX C, Table D-3). These variables were further tested using pairwise comparisons. Group size was shown to increase during higher Beaufort conditions (3.7-3.9 individuals at Beaufort levels of 0-2, and 4.4 and 4.2 at Beaufort levels 3 and 4 or higher, respectively). However, only the comparisons between Beaufort level 3 and Beaufort levels 0, 1, or 2 were significant (P=0.005, P<0.001, and P=0.007, respectively). Multiple comparisons among tide levels indicated that groups were significantly larger at ebb tide conditions than during flood conditions (P<0.001), but no other significant differences in group size related to tide conditions were identified. Narwhal groups were significantly larger during hunting events (categorized as when hunting occurred in the 70 min prior to the observation event) compared to periods of 'no hunting' (*P*<0.001). This is likely a reverse cause and effect (i.e., hunting is more likely to occur when larger groups pass by the hunting camp). In addition, this finding is likely an artefact of the association between group size and distance from shore (i.e., larger groups are more likely to travel close to shore, as discussed in Section 6.5.7, and hunting is more likely to occur when narwhal are close to shore than when animals are offshore, resulting in an association between hunting events and group size).

In summary, findings based on the combined multi-year dataset suggest that narwhal may associate in marginally larger group sizes when in close proximity (<1 km) to vessels. The noted response was shown to be short in duration (total disturbance period of 7 min per vessel transit based on a 9 knot vessel transit speed) with animals returning to their pre-response behaviour shortly following the initial exposure. During the 2021 Bruce Head Program (1 - 26 Aug), there were approximately two transits per day in the SSA (58 one-way transits in SSA over a 24-day period). The daily disturbance period associated with a change in group size was therefore equivalent to approximately 14 min. As discussed in Section 3.0, a change in group cohesion (e.g., change in group size) by narwhal is consistent with a moderate severity behavioural response. Given the temporary nature of the effect, this would not be considered a 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

6.5.2 Group Composition

A qualitative assessment of group composition by life stage in 2021 indicated an overall similar group composition to previous years, with the majority of the sightings consisting of adult narwhal, followed by juveniles, calves, and yearlings (Figure 6-17). Note that 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, with only five days (1, 6, 10, 17, and 20 August 2021) when no calves were recorded out of the 12 days with narwhal in the BSA. In 2021, the daily proportion of calves (relative to total narwhal counts) ranged between 0% (on 1, 6, 10, 17, and 20 August) and 50% (12 and 21 August 2021- sightings in the BSA on each of these days was limited to a single mother/calf pair). In 2021, yearlings were observed on three of the 12 days with recorded narwhal in the BSA, whereas in previous years the number of days in which yearlings were observed ranged from 14 days (2019 and 2020) to 20 days (2017). For the three days in 2021 when yearlings were recorded, the daily proportion of yearlings (relative to total narwhal counts) was 2% (2 August), 5% (17 August), and 12% (19 August, when only 17 narwhal were recorded in the BSA). The life stage of seven narwhal (2.7% of all narwhal recorded in the BSA in 2021) was unknown, due to either visibility restrictions or logistical challenges of accurately documenting all individuals during periods of high activity.

In previous years, the mean daily proportion of calves ranged between 0% (observed in all sampling years) and 23-50% (23% in 2014 and 50% in 2017). The annual mean of daily proportion of calves[10] was higher in 2021 (14.8%) than all previous sampling years, which ranged from 9.5% (2017) to 12.9% (2015). Note that these proportions were calculated out of all observed animals, including narwhal of unknown life stages, hence mean values differ from those presented for Early Warning Indicators in Section 6.5.2.2. Although this suggests that the current calving rate (i.e., reproductive success) of the Eclipse Sound summering stock is consistent with pre-shipping conditions, this finding should be interpreted with caution as the 2021 annual mean of daily calf proportions is based on a small sample size that is largely influenced by the two sampling days in which only a mother-calf pair was observed in the BSA (i.e., resulting in a daily calf proportion of 50%).

[10] Annual mean of daily calf proportion = the sum of the mean daily calf proportions divided by the number of sampling days in a given year.

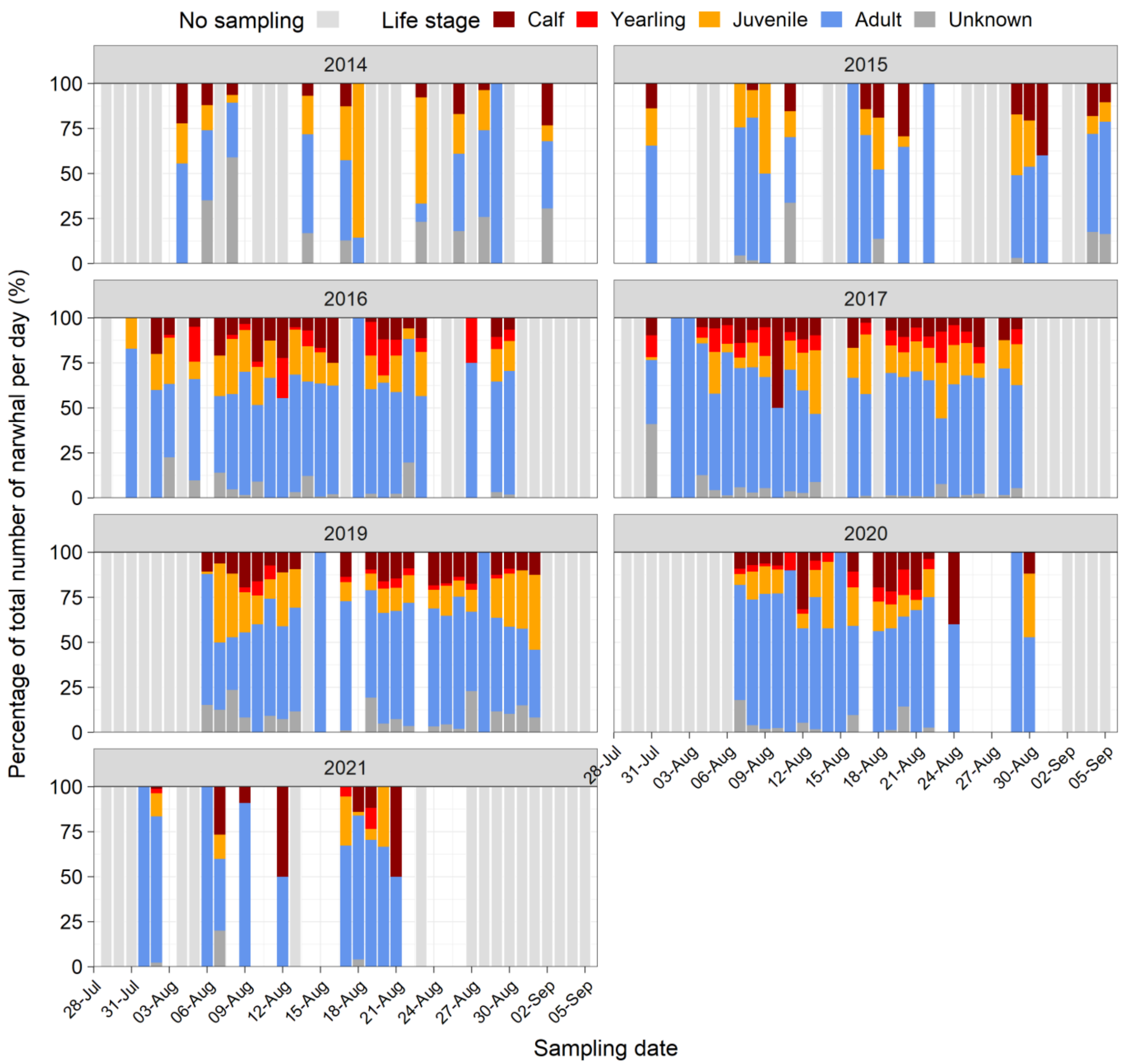

Figure 6-17: Relative daily proportion of narwhal life stages observed in the BSA presented by survey year.

The most common group composition recorded during the seven-year study period was groups composed exclusively of adult narwhal (Figure 6-18), accounting for 36% of all observed narwhal groups with known composition. Mixed groups with and without immatures accounted for 26% and 24% of all observed groups with known composition, respectively, while mother-immature pairs accounted for 14% of all observed groups with known composition.

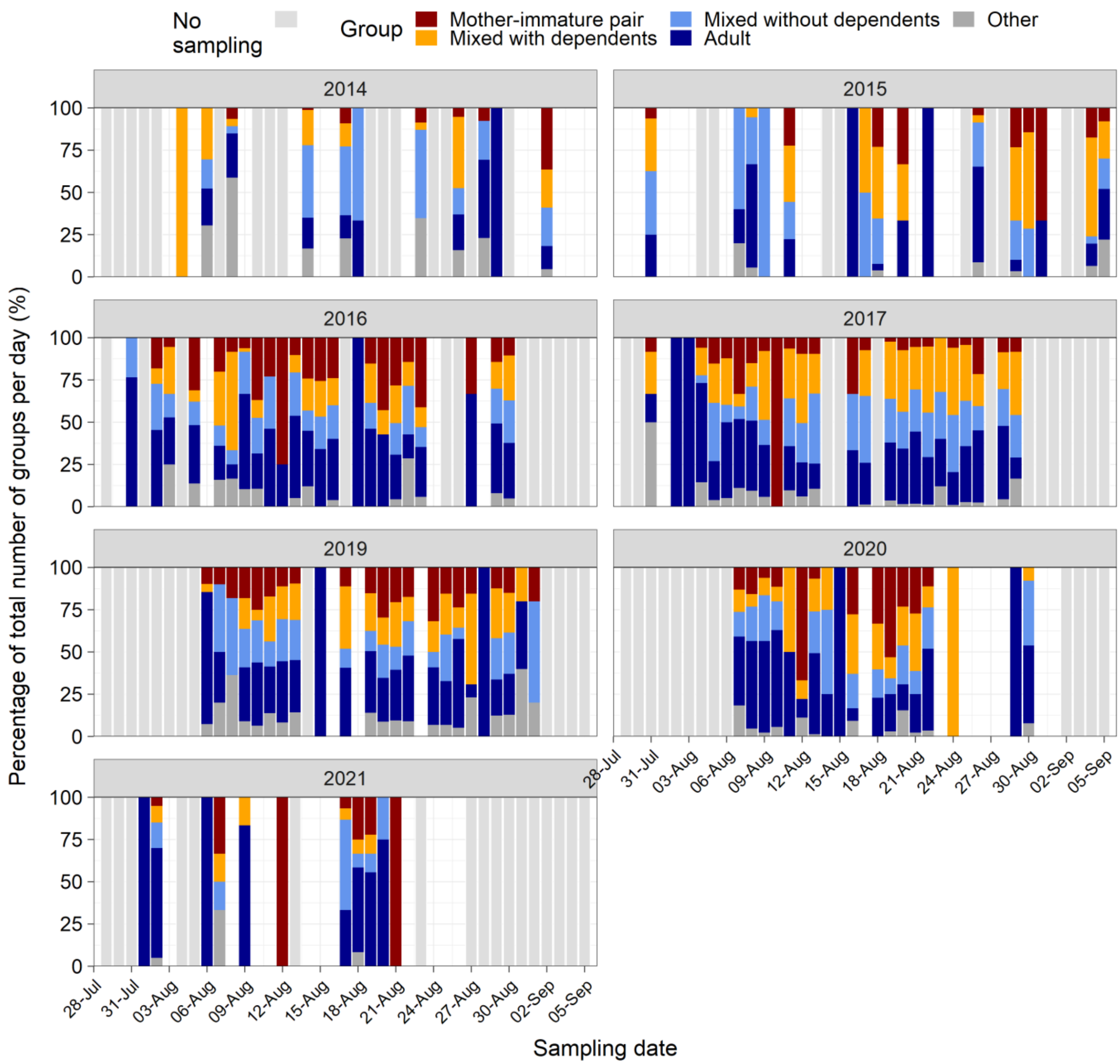

Figure 6-18: Relative daily proportion of narwhal group composition categories observed in the BSA presented by survey year.

6.5.2.1 Presence of Immatures

In addition to the analysis undertaken to evaluate potential changes in the proportion of immatures (i.e., calves and yearlings) in the BSA relative to the adult population (i.e., the EWI selected for the Project as described in Section 6.4.2.2), a separate analysis was conducted to evaluate for potential shipping-induced changes in the presence of immatures in narwhal groups using a generalized linear model as outlined in Section 5.4.2. As part of this analysis, groups that consisted of a single narwhal were removed to avoid skewing the analysis as lone calves or yearlings are not typically observed in the BSA. For the combined seven-year dataset, the majority of observations associated with a group size of ≥2 individuals (with a known group composition) were recorded during vessel non-exposure periods (n = 4,049), of which 51% had immatures (mean annual proportion of immatures ranged from 30% in 2021 to 59% in 2016). Mean narwhal group size was similar for groups with and without calves or yearlings (4.3-4.4 individuals for both; Figure 6-19). Note that the discrepancy in values presented here relative to those presented in the EWI analysis in Section 6.4.2.2 is due to the removal of single and unknown narwhal from the analysis.

During vessel exposure periods, a total of 348 groups with and without immatures were recorded. The proportion of groups with immatures ranged from 42% when northbound vessels were moving toward the BSA to 68% when a southbound vessel was moving away from the BSA; in the remaining two shipping scenarios (i.e., northbound vessels moving away and southbound vessels moving toward), the values were intermediate – 50-54%. Similar to vessel non-exposure periods, groups sizes were comparable for groups with and without observed immatures (mean of 4.2 individuals for both).

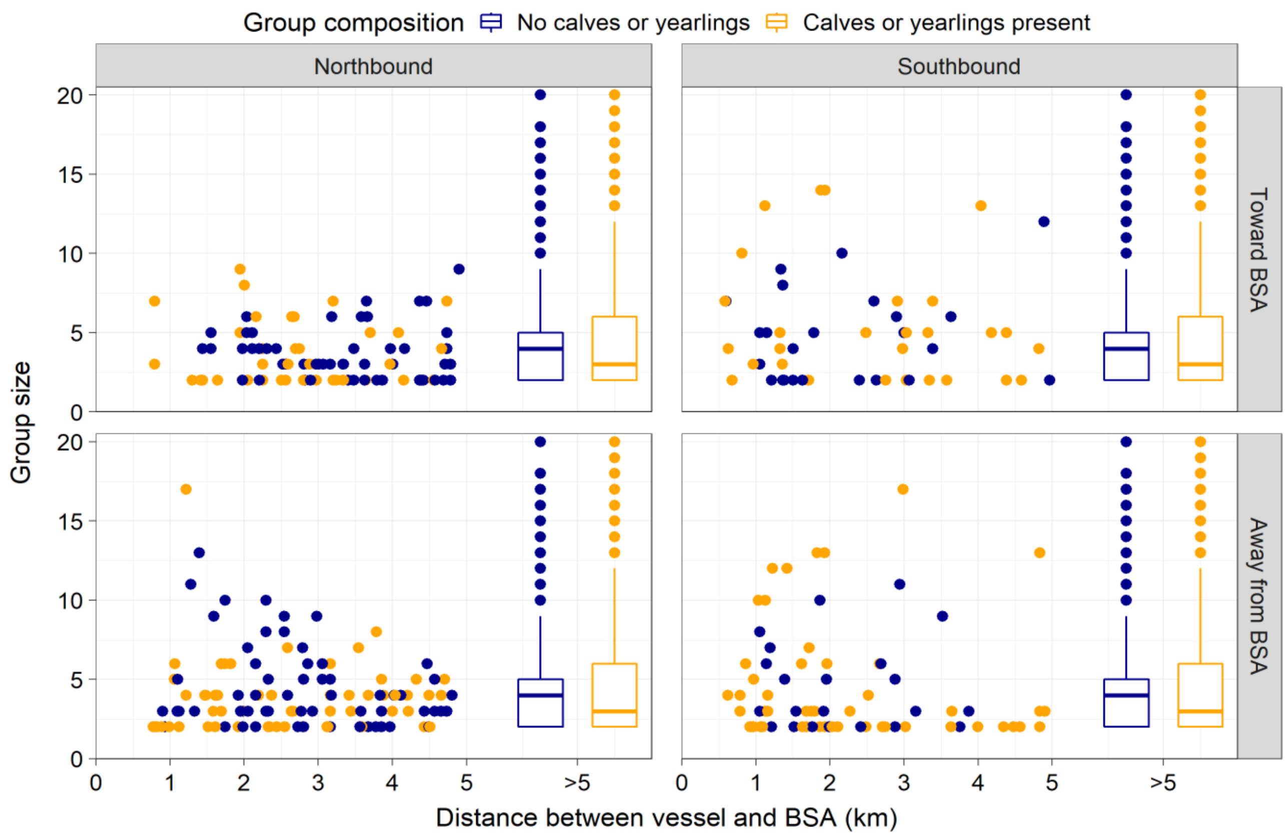

Figure 6-19: Comparison of group size between narwhal groups with and without immatures (i.e., calves or yearlings) relative to distance from vessel, vessel direction, and vessel position relative to BSA (combined 7-year dataset).

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

A comparison between the observed data and model predictions for the proportion of narwhal groups with immatures, as a function of distance from vessel and sampling year (the two response variables associated with statistically significant and marginally significant changes), is presented in Figure 6-20. Note that the orange line represents the predicted proportion of groups in loose formation for a specific set of predictor values (Section

5.4.2.4), whereas the blue bars summarize the entirety of the observed data. This leads to some visual discrepancies between the observed and predicted values.

The effect of ‘distance from vessel’ on the proportion of immature narwhal in a group was significant (P=0.023; APPENDIX C, Table C-5). When vessels were present within 5 km from the BSA, modeling results suggested that the probability of observing a group with immatures was highest when a vessel was close to the BSA (Figure 6-20), with probabilities of 0.800 and 0.625 at a distance of 0 km and 1 km, respectively, compared to 0.474 when no vessel was present within 5 km of the BSA centroid. In the multiple comparison analysis of presence of immatures between vessel exposure (i.e., 0–5 km) and non-exposure (i.e., >5 km) periods, none of the comparisons were significant at the 0.05 level (Table 6-5). That is, when vessels were in close proximity to the BSA, groups were more likely to have immatures when vessels were in proximity to the BSA (<2 km), but the difference was not significant at the 0.05 level. Estimated effect sizes for a vessel at 0 km, 1 km, and 2 km from the BSA were +342%, +84%, and +4%, respectively, suggesting that a moderate biologically significant effect (i.e., >25% change – as per Section 5.4.2) may exist, with a spatial extent of less than 2 km from a vessel. The statistical power to estimate the observed effect at 0 km was 0.74 (Appendix B). That is, the observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model had sufficient statistical power (≥0.8) to detect effect sizes of -85% or +390% in the test of the overall effect of distance from vessel (Appendix B).

In addition to the significant effect of shipping, the effect of survey year was also significant (P<0.001). A significant effect of survey year may indicate a long-term change in the proportion of groups with immatures. Multiple comparisons between survey years indicated that the proportion of groups with immatures increased significantly between 2014 and 2016 (Figure 6-20). While the estimated probabilities of groups with immatures in both 2020 (0.452) and 2021 (0.294) were significantly lower than 2016 (0.582 - the year with the highest recorded proportion of immatures, they were not significantly different from other survey years, including 2014 (0.428; Figure 6-20) prior to the start of shipping operations. Other variables that were statistically significant predictors of the proportion of groups with immatures included group size (P<0.001), glare (P<0.001), and Beaufort level (P=0.047), while hunting and presence of small vessels within the SSA were not statistically significant (P>0.2 for both; APPENDIX C, Table C-5).

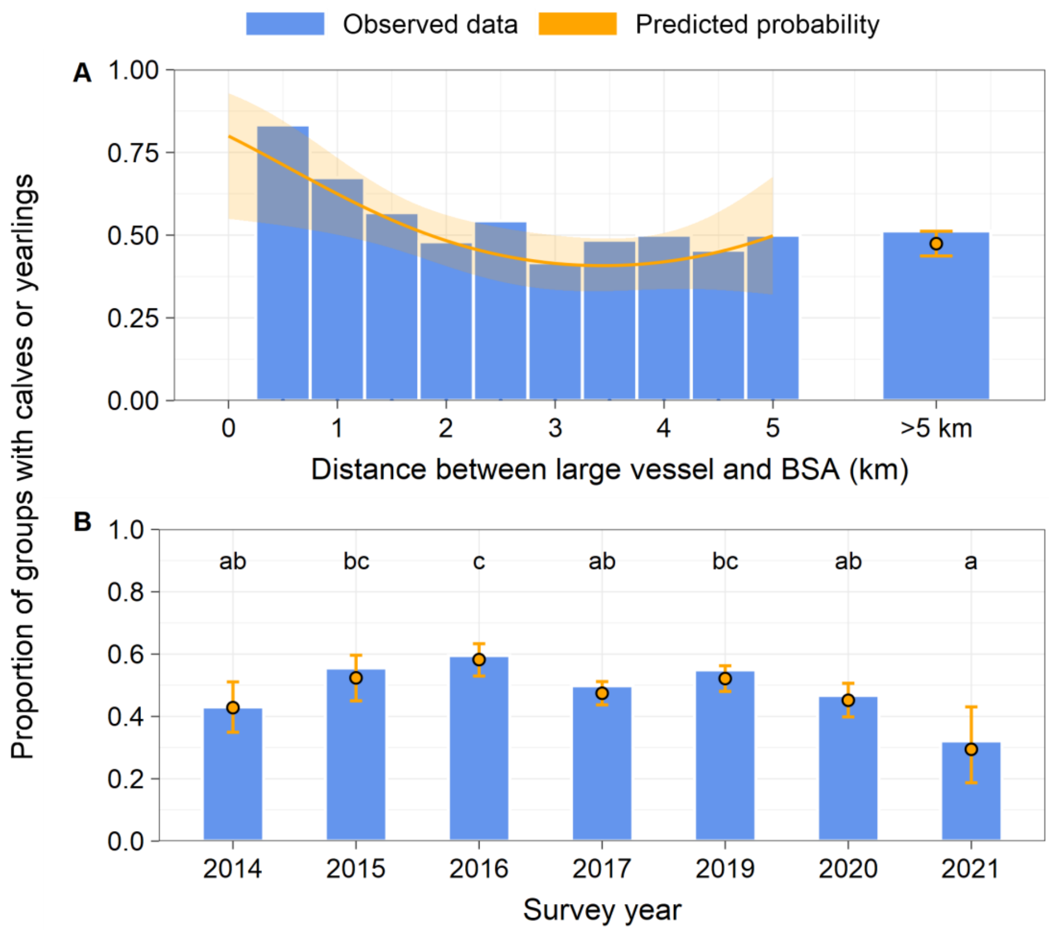

Figure 6-20: Proportion of narwhal groups with immatures as a function of distance (summarized to nearest 0.5 km value) from vessel (Panel A; combined 7-year dataset) and sampling year (Panel B).

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

Table 6-5: Proportion of narwhal groups with immatures - multiple comparison analysis between vessel exposure (0 to 5 km) and non-exposure (≥5 km) periods. Statistically significant values shown in bold.

Distance from Vessel (km)	Multiple Comparisons to No-exposure	
	Least-squares Mean	*P* value
0	0.791	0.059
1	0.619	0.060
2	0.480	0.997
3	0.410	0.391
4	0.409	0.409
5	0.477	1.000

Statistically significant categorical variables that were not related to shipping were further tested using pairwise comparisons. The probability of observing a group with immatures was significantly lower during severe glare (value of 0.339) when compared to either conditions of no glare or low glare (values of 0.467 and 0.473, respectively; $P<0.001$ for both). No significant difference was found between conditions of no glare and low glare ($P=0.9$). This suggests that detection of immatures was more difficult in decreased sightability. While the effect of Beaufort level was significant, none of the multiple comparisons were significant (all $P>0.08$); that is, glare had a stronger effect on observers' ability to detect immatures than sea state.

In summary, consistent with previous years' findings, results based on the combined multi-year dataset suggest that narwhal groups are more likely to include immatures when in close proximity (<2 km) to vessels. The noted response was shown to be short in duration (total disturbance period of 14 min per vessel transit based on a 9 knot vessel transit speed) with animals returning to their pre-response behaviour shortly following the initial exposure. During the 2021 Bruce Head Program (1 - 26 Aug), there were approximately two transits per day in the SSA (58 one-way transits in SSA over a 24-day period). The maximum daily disturbance period associated with a change in the presence of immatures was therefore equivalent to approximately 28 min. This finding is potentially due to groups without calves or yearlings being more capable of diving and moving away, thus inflating the probability of observing groups with calves or yearlings at the surface. As discussed in Section 3.0, a change in group cohesion and/or a disruption of female and dependant offspring (exceeding baseline case) is consistent with a moderate severity behavioural response. Given the temporary nature of the effect, this would not be considered a 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

6.5.2.2 Proportion of Immatures – Early Warning Indicator

Adverse effects of the Project on narwhal may be promptly identified and mitigated through the development of appropriate Early Warning Indicators (EWIs). In 2020, Baffinland worked in collaboration with the Marine Environmental Working Group (MEWG) to develop an EWI that was able to rapidly identify adverse impacts on narwhal along the Northern Shipping Route, consistent with requirements outlined in Project Certificate (PC) Condition No. 110 and 112. A description of the EWI selection process, including engagement with the MEWG, is provided in Golder (2020d).

As a result of this EWI selection process, the EWI selected for narwhal was a decrease in the proportion of immature narwhal (defined as calves and yearlings) relative to all observed narwhal in the RSA (Golder 2020d). The data source identified to support EWI monitoring objectives was the Bruce Head Shore-based Monitoring Program, and specifically from narwhal group composition data collected in the BSA. The EWI was to be compared against historical data reflective of baseline conditions (prior to the start of iron ore shipping operations in the RSA). The threshold value that would trigger the need to apply adaptive management practices was identified as 'a 10% decrease in the proportion of immature individuals in the population relative to the lowest natural variability baseline value available'.

To date, the EWI has been calculated based on the total number of immatures (i.e., calves and yearlings) recorded over the annual study period divided by the total number of narwhals recorded over that same period - referred to hereafter as the ‘combined annual proportion of immatures’. The annual mean of the daily proportions of immatures[11] is also presented in concert with the EWI to demonstrate variability across sampling years, although this metric does not inform the EWI threshold directly.

In recent engagements with the MEWG, 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 2021c). 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 is a statistically significant difference between a year’s least squares mean and the average of 2014–2015 least squares mean values. Table 6-6 includes a summary of the combined annual proportion of immature narwhal recorded during seven years of monitoring at Bruce Head, 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 2021, a total of 80 narwhal groups (comprising 263 individuals) were observed in the BSA, including 19 calves and 7 yearlings. The combined annual proportion of immatures relative to the total number of narwhal observed in 2021 was 0.102. This was lower than all previous sampling years, representing a 24% decrease from the 2014–2015 baseline. However, the observed change was not statistically significant from the baseline condition (p=0.13; Figure 6-21 and Table 6-7). The model had sufficient statistical power (≥0.8) to detect effect sizes of -55% or +55% in the comparison of 2021 data relative to baseline (2014-2015 data; Appendix B). However, the observed effect size and its 95% confidence interval (-55% to +7%) suggest a decrease in the 2021 annual proportion of immatures relative to the observed population, thereby warranting further investigation.

Although the 2021 EWI (i.e., combined annual proportion of immatures) did not exceed the EWI threshold, it did exceed one of the two ‘Moderate Risk’ triggers identified in the Marine Mammal TARP as outlined in Section 1.4 (>10.0% decrease in the proportion of immatures relative to 2014/2015 baseline levels). Overall, the results suggest a decreasing trend in the annual proportion of immatures relative to the observed population that warrants further investigation, as further discussed in Section 7.3, including recommendations moving forward.

In summary, the relative proportion of immature narwhal in the BSA was lower in 2021 than in previous sampling years, including years prior to the start of Baffinland’s iron ore shipping operations in the RSA. While the relative decrease observed in 2021 was not statistically significant from the 2014/2015 baseline condition, the effect size and its 95% CI (-55% to +7%) suggest a decrease in the 2021 annual proportion of immature narwhal relative to the observed population, thereby warranting further investigation. If the decrease is determined to be a result of Project activities, this would be consistent with a high severity response (e.g., disruption of breeding behaviour sufficient to compromise reproductive success as discussed in Section 3.0) and would be considered a significant alteration of natural behavioural patterns of narwhal in the RSA and/or disruption to their daily routine. This finding would be contrary to 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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[11] Annual mean of daily proportions of immatures = the sum of the mean daily proportions of immatures divided by the number of sampling days in a given year.

Table 6-6: Combined annual proportion and mean annual proportion of immatures (i.e., calves and yearlings) relative to the observed adult population at Bruce Head (combined 7-year dataset)

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

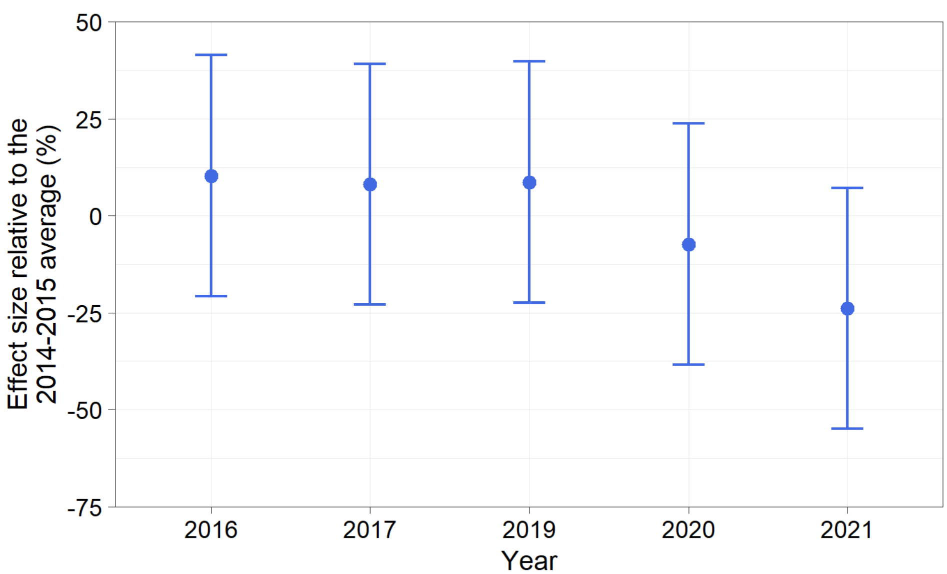


Figure 6-21: Relative change in the proportion of immature narwhal compared to the 2014–2015 baseline condition, based on analysis of annual group composition data, grouped into 10 bins per year. Error bars are 95% confidence intervals.

Table 6-7: 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	0.508	10.4	-20.7 to +41.5
2017	0.602	8.1	-23.0 to +39.2
2018	N/A	N/A	N/A
2019	0.578	8.7	-22.4 to +39.8
2020	0.641	-7.3	-38.4 to +23.8
2021	0.130	-23.9	-55.0 to +7.2

6.5.3 Group Spread

Based on reports suggesting that narwhal form tight groups as an anti-predator response to killer whale presence (Steltner et al.1984; Laidre et al. 2006; Breed et al. 2017), it was predicted that narwhal may form tight groups in response to other potential perceived threats such as vessel traffic. Therefore, narwhal groups of two or more individuals were classified as tight (i.e., individuals ≤1 body width apart) or loose (i.e., individuals >1 body width apart) based on the physical proximity of individuals to one another. In 2021, group spread was successfully recorded for all groups. Throughout the seven years of sampling, narwhal were more often observed in tightly associated groups than in loosely associated groups (Figure 6-22), regardless of whether individuals were exposed to anthropogenic activity or not (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b).

In the combined multi-year dataset, the majority of observations of narwhal group spread were recorded during vessel non-exposure periods (n = 4,090), of which 36% were in loosely associated groups (annual proportion ranged from 23% in 2014 to 57% in 2021). Mean group size was larger for loosely associated groups than for tightly associated groups (i.e., 4.7 and 4.2 individuals, respectively; Figure 6-23).

During vessel exposure periods, 357 groups with a known spread were recorded. Group spread was overall similar between the four vessel transit scenarios, ranging from 33% of groups being loosely associated when a southbound vessel headed away from the BSA to 39% when a northbound vessel headed toward the BSA. Similar to the non-exposure periods, loosely associated groups were on average larger (mean of 4.9 individuals) than tightly associated groups (mean of 3.8 individuals).

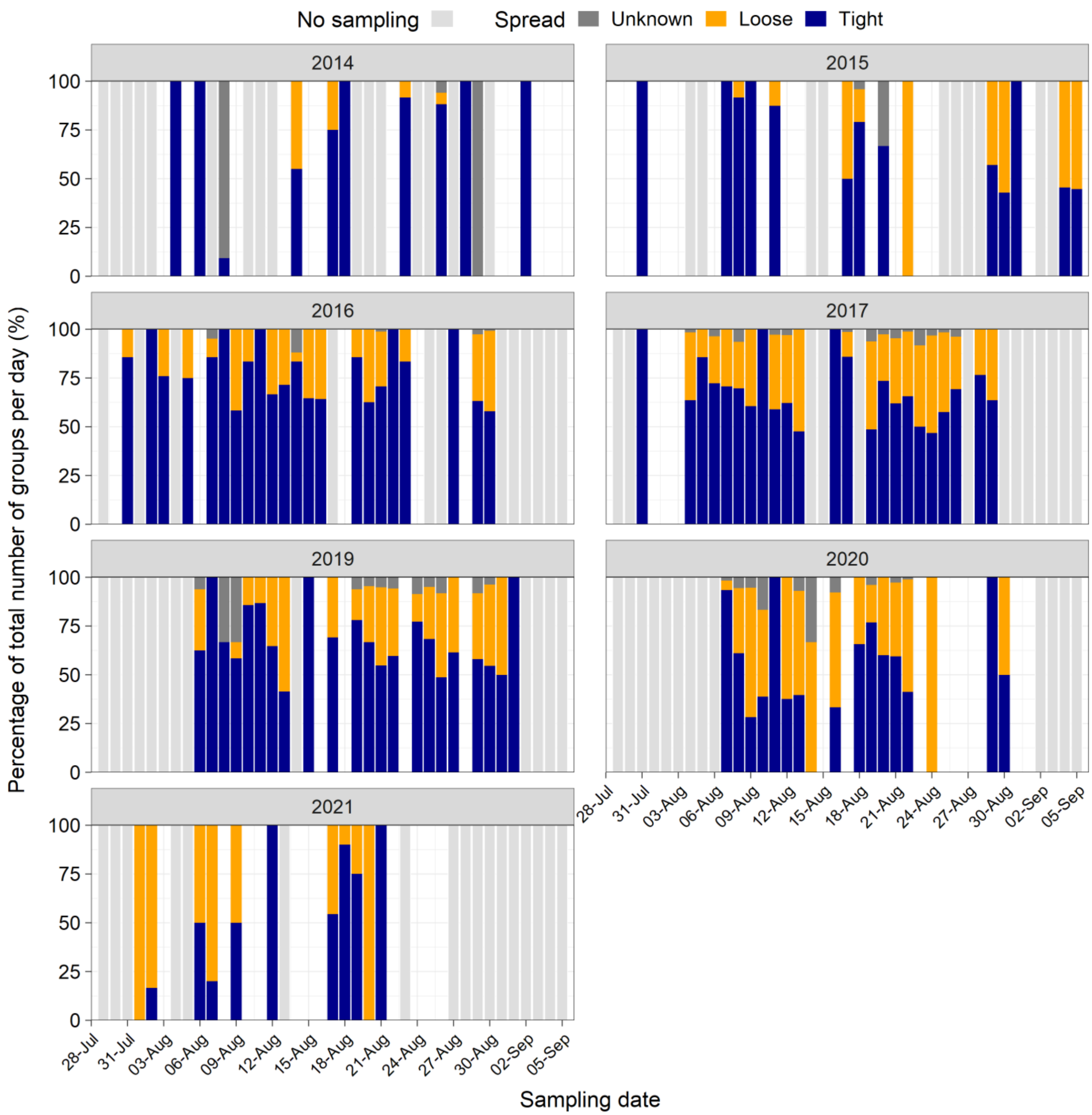


Figure 6-22: Relative daily proportion of narwhal group spread categories observed in the BSA (combined 7-year dataset).

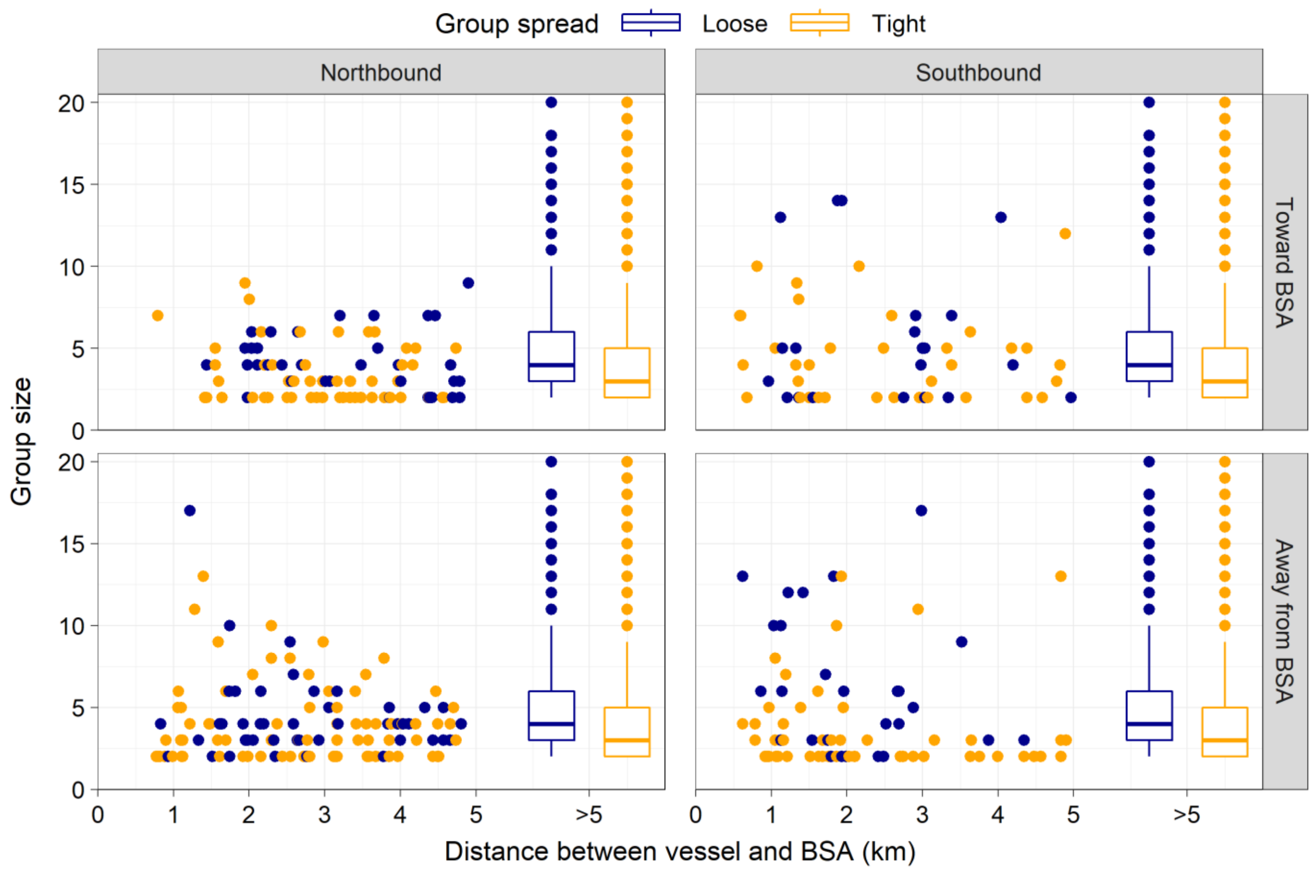


Figure 6-23: Comparison of group size between tightly associated and loosely associated group spread categories relative to distance from vessel, vessel direction, and vessel position relative to BSA (combined seven-year dataset).

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

A comparison between the observed data and model predictions for group spread, as a function of distance from vessel and sampling year (the two response variables associated with statistically significant changes), is presented in Figure 6-24. Note that the orange line represents the predicted proportion of groups in loose formation for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars summarize the entirety of the observed data. This leads to some visual discrepancies between the observed and predicted values.

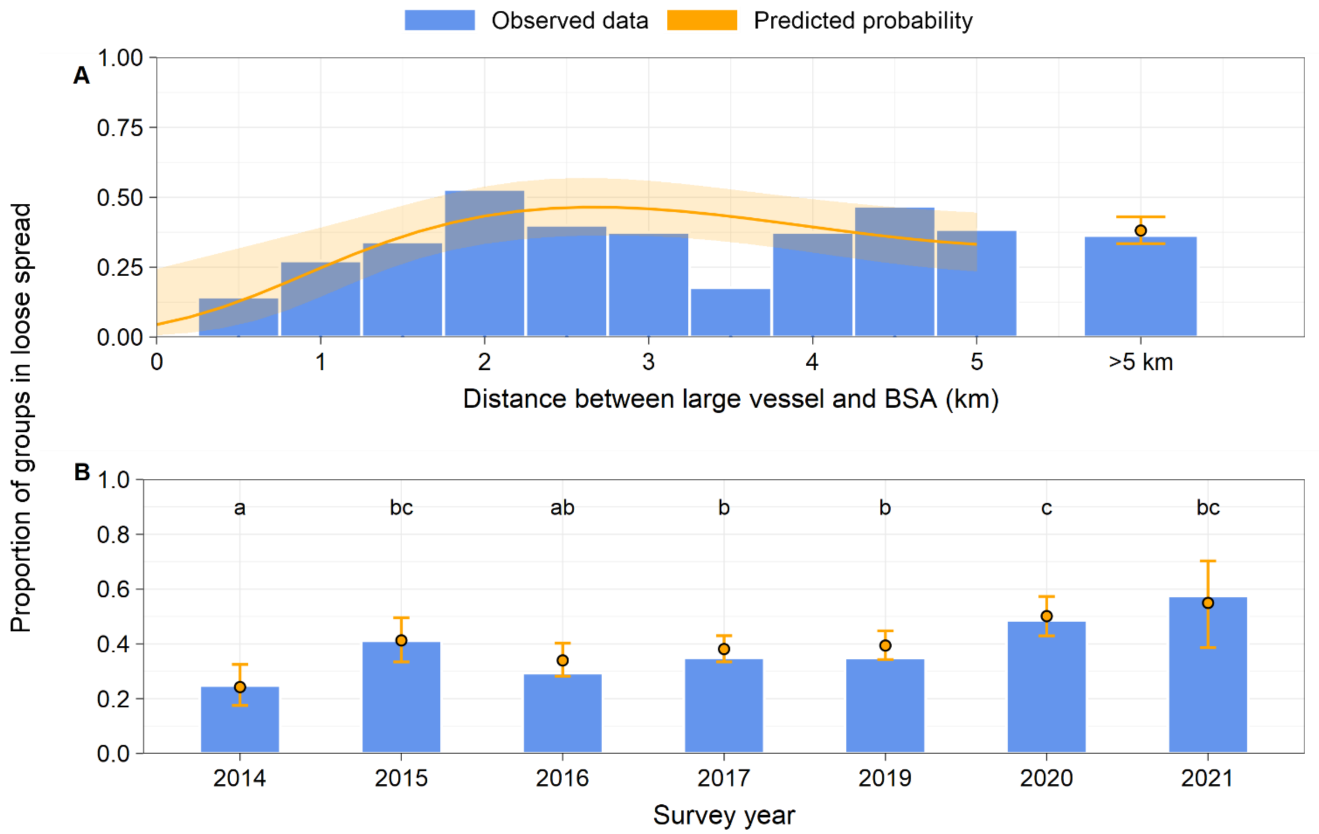


Figure 6-24: Proportion of narwhal groups observed in a loose spread (rather than tight spread) as a function of distance (summarized to nearest 0.5 km value) from vessel (Panel A; combined 7-year dataset) and survey year (Panel B).

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

Table 6-8: Proportion of narwhal groups in loose spread (rather than in tight spread) - multiple comparison analysis between vessel exposure (0 to 5 km distances) and non-exposure (≥5 km) periods. Statistically significant values shown in bold.

Distance from Vessel (km)	Multiple Comparisons to No-exposure	
	Least-squares Mean	*P* value
0	0.045	**0.044**
1	0.247	0.243
2	0.433	0.714
3	0.459	0.317
4	0.394	0.993
5	0.332	0.804

The effect of distance from vessel on narwhal group spread was significant (*P*=0.043; APPENDIX C, Table C-7). During vessel exposure periods (<5 km), modeling results suggested a dome-shaped relationship (Figure 6-24), with the predicted probability of observing loosely associated groups peaking at a value of 0.459 when a vessel was 3 km away from the BSA centroid. When a vessel was in close proximity (i.e., 0 km from BSA centroid), groups were least likely to be loosely associated (probability of 0.045). In the multiple comparison analysis of group spread between vessel exposure (i.e., 0–5 km) and non-exposure (i.e., >5 km) periods, groups were significantly less likely to be loosely associated when a vessel was at 0 km from the BSA centroid (*P*=0.044; Table 6-8). That is, when vessels were at the BSA centroid, narwhal tended to congregate into tightly associated groups. Estimated effect sizes for a vessel at 0 km, 1 km, and 2 km distance from the BSA were -92%, -47% and 24%, respectively. The effect sizes suggest that a moderate biologically significant effect (i.e., >25% change in group spread – as per Section 5.4.2) may exist, with a spatial extent of less than 2 km from a vessel. This finding was in agreement with the hypothesis that narwhal form tighter groups in response to perceived threats such as vessel traffic. The statistical power to estimate the observed effect at 0 km was 0.72 (Appendix B). 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 a -96% or a +420% effect size in the test of the overall effect of distance from vessel (Appendix B).

The effect of sampling year on narwhal group spread was significant (*P*<0.001; Appendix D, Table D-9). A significant effect of survey year may indicate a long-term change in group spread. Multiple comparisons between survey years indicated that group spread generally increased between 2014 and 2021 (Figure 6-24), with narwhal in 2014 occurring in significantly tighter groups in 2014 (pre-operational shipping) than in 2015, 2017, 2019, 2020, and 2021 (*P*=0.026, 0.028, 0.016, <0.001, and 0.001, respectively). This finding was in disagreement with the hypothesis that narwhal form tight groups in response to perceived threats such as vessel traffic, given that shipping operations generally increased over the 7-year study period.

Other variables that were statistically significant predictors of group spread included survey year (*P*<0.001), group size (categorical variable of whether group size was 2 narwhal or >2 narwhal; *P*<0.001), spread of previous group recorded on the same day (*P*<0.001), and whether hunting occurred in the previous 70 min (*P*<0.001). The effects of glare, Beaufort level, tide, and presence of small vessels within the SSA were not statistically significant (*P*≥0.1 for all; APPENDIX C, Table D-7).

Statistically significant variables that were not related to shipping were further tested using pairwise comparisons. Groups where the previous group was also loosely associated were significantly more likely to be loosely associated, compared to groups where the previous group was tightly associated (*P*<0.001). Groups were significantly more likely to be loosely associated when group size was >2 narwhal compared to groups of two narwhal (*P*<0.001), reflecting the tightly associated nature of mother-offspring pairs, which account for a large proportion of all narwhal pair groupings (53% of groups comprised of 2 narwhal had one calf or yearling). Narwhal groups were also significantly less likely to be loosely associated when hunting took place in the previous 70 min than when no hunting occurred (*P*<0.001). This was likely a reversal of cause and effect (i.e., hunting is more likely to occur when groups are tightly associated, potentially making them easier targets).

In summary, findings based on the combined multi-year dataset suggest that narwhal congregate in more tightly associated groups when in close proximity (i.e., ≤ 2 km) to vessels. The noted response was shown to be short in duration (total disturbance period of 14 min per vessel transit based on a 9 knot vessel transit speed) with animals returning to their pre-response behaviour shortly following the initial exposure. During the 2021 Bruce Head Program (1 - 26 Aug), there were approximately two transits per day in the SSA (58 one-way transits in SSA over a 24-day period). The daily disturbance period associated with a change in group spread was therefore equivalent to approximately 28 min. As discussed in Section

3.0, a change in group cohesion (e.g., change in group spread) by narwhal is consistent with a moderate severity behavioural response. Given the temporary nature of the effect, this would not be considered a 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

6.5.4 Group Formation

Monitoring of narwhal group formation is warranted to better understand whether a given formation is indicative of a potential response to a perceived threat (i.e., a transiting vessel). Throughout the seven-year monitoring program, narwhal groups comprised of two or more individuals observed in the BSA were classified as either linear, parallel, cluster, non-directional line, or no formation. The majority of narwhal groups recorded occurred in parallel formation, followed by cluster formation (Figure 6-25), regardless of whether individuals were exposed to anthropogenic activity or not (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b). Parallel groups represented a daily minimum of 12%, 34%, 33%, 49%, 23%, 22%, and 33% of all group formations recorded during each of the seven years of data collection, respectively. The daily minimum proportion of cluster formation groups ranged from 7% to 19%, depending on year. The daily minimum proportion of linear formation groups ranged from 10 to 33%, with the exception of a single day in 2015 with 100% linear formation, where only one group of narwhal in linear formation was recorded in the BSA).

In the combined dataset, the majority of group formation observations were recorded during non-exposure periods (n = 4,111), of which 38% were in non-parallel formation (annual proportion ranged from 20% in 2014 to 46% in 2020). Mean narwhal group size was larger for non-parallel groups than for groups in parallel formation (5.9 and 3.7 individuals, respectively; Figure 6-26).

During vessel exposure periods, 356 groups with a known formation were recorded. The lowest proportion of groups in non-parallel formation was recorded during the passage of southbound vessels, when vessels were heading away from BSA (24%). The highest proportion was recorded during the passage of northbound vessels when vessels were heading away from the BSA (39%). The proportion of groups travelling in non-parallel formation were similar between northbound and southbound vessels that were heading toward the BSA (28% and 36%, respectively). Similar to non-exposure periods, non-parallel groups were on average larger (mean of 6.1 individuals) than groups in parallel formation (mean of 3.4 individuals).

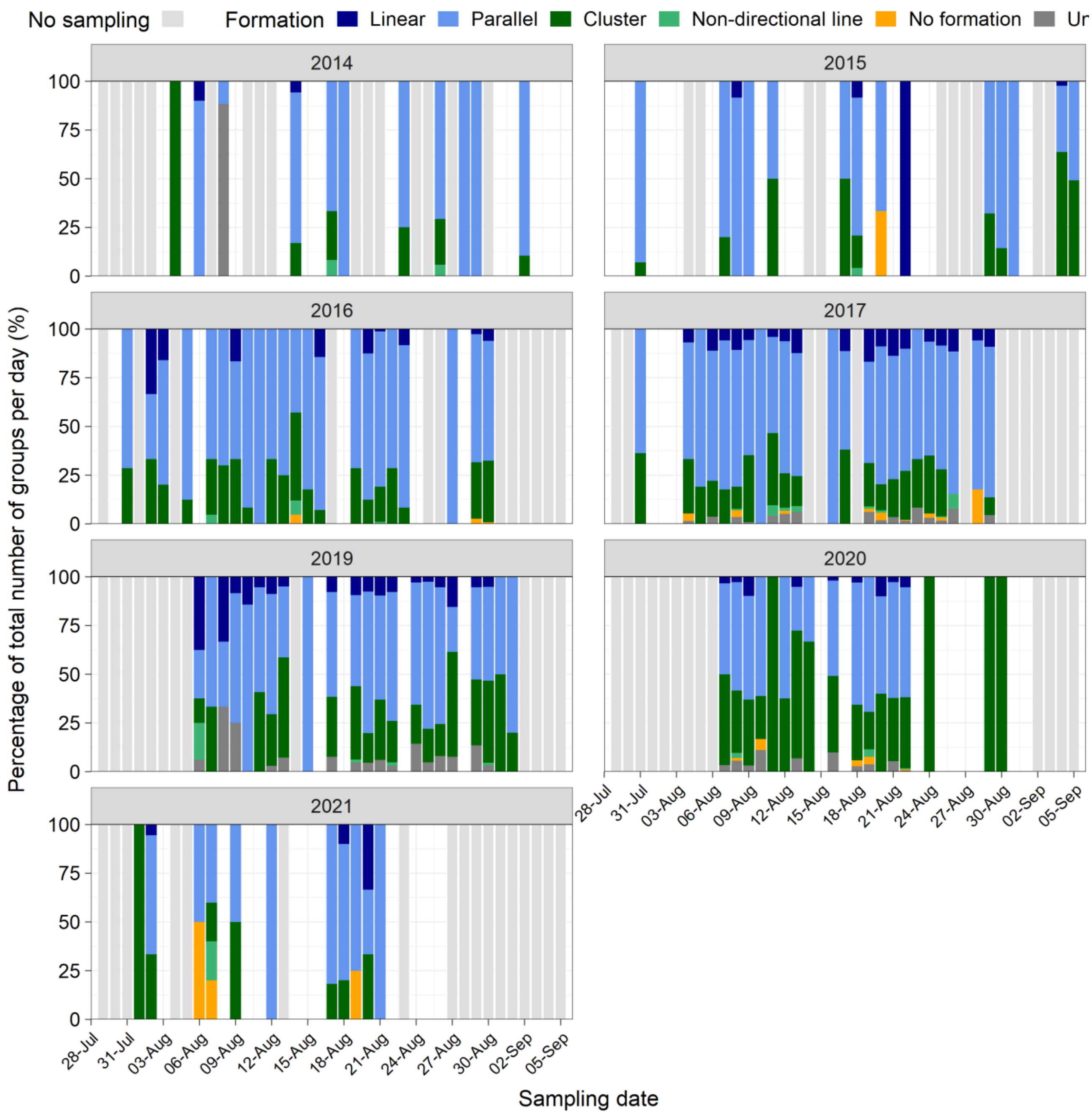


Figure 6-25: Relative daily proportion of narwhal group formation categories observed in the BSA (combined 7-year dataset).

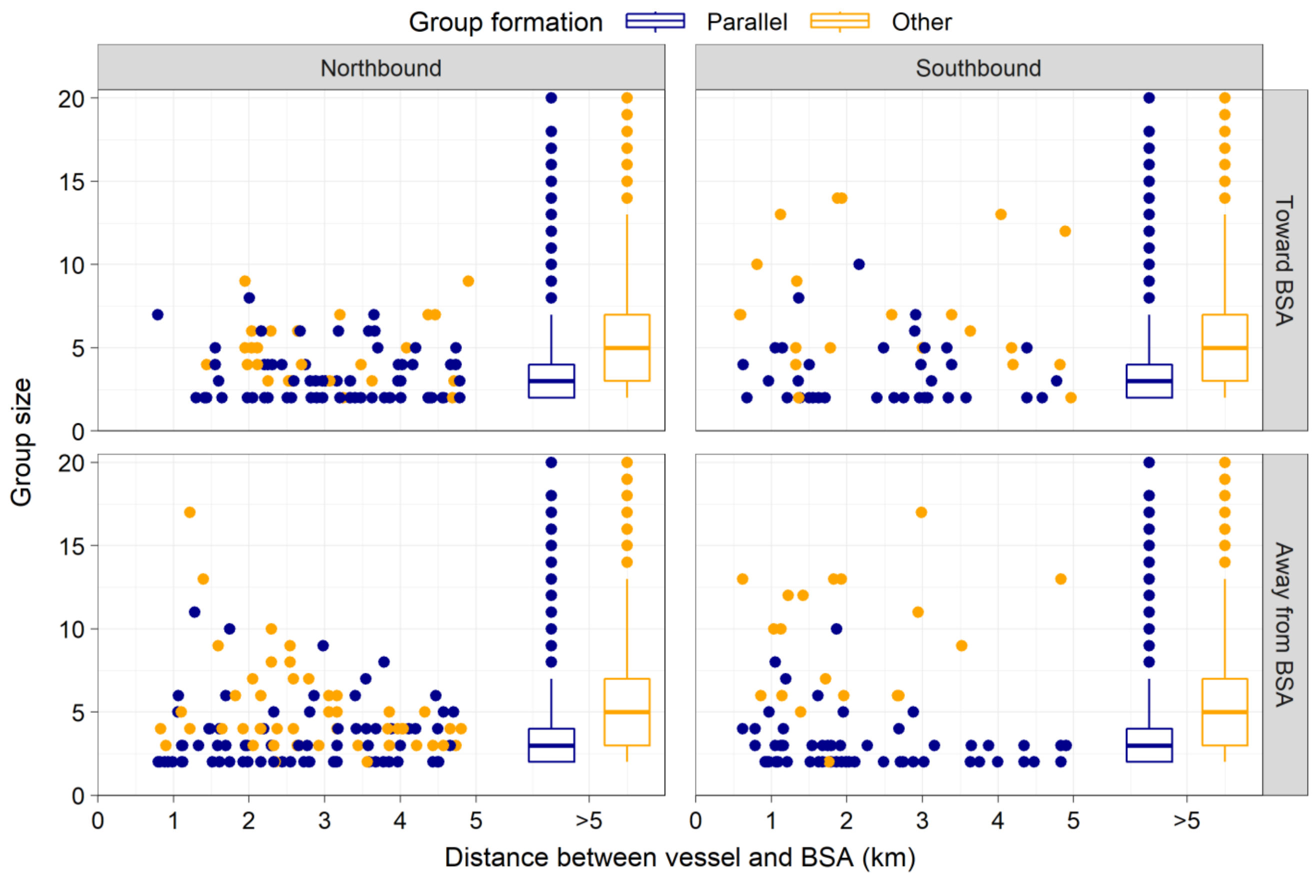


Figure 6-26: Comparison of group size between narwhal groups in parallel formation vs. non-parallel formation relative to distance from vessel, vessel direction, and vessel position relative to BSA (combined seven-year dataset).

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

A comparison between the observed data and model predictions for group formation, as a function of distance from vessel and sampling year (the two response variables associated with statistically significant changes), is presented in Figure 6-27. Note that the orange line represents the predicted proportion of groups in non-parallel formation for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars summarize the entirety of the observed data. This leads to some visual discrepancies between the observed and predicted values.

In the model of group formation, the effect of distance from vessel was not significant (*P*=0.9), whereas the overall effect of presence of vessel was significant (*P*=0.037), suggesting a possible effect of shipping on group formation APPENDIX C, Table C-9). Modeling results suggested a slight decrease in the probability of a group being in non-parallel formation from 0.261 when no vessels were present within 5 km to 0.212 when vessels were within 0 km of the BSA (Figure 6-27). Multiple comparisons between vessel absence and vessel presence at various distances were not conducted since the overall effect of distance was not significant. The estimated effect size for a vessel at 0 km from the BSA was -24%. The model had low power to detect the observed effect sizes, and an effect size of -92% or +350% would be required to achieve sufficient statistical power in the model (APPENDIX A).

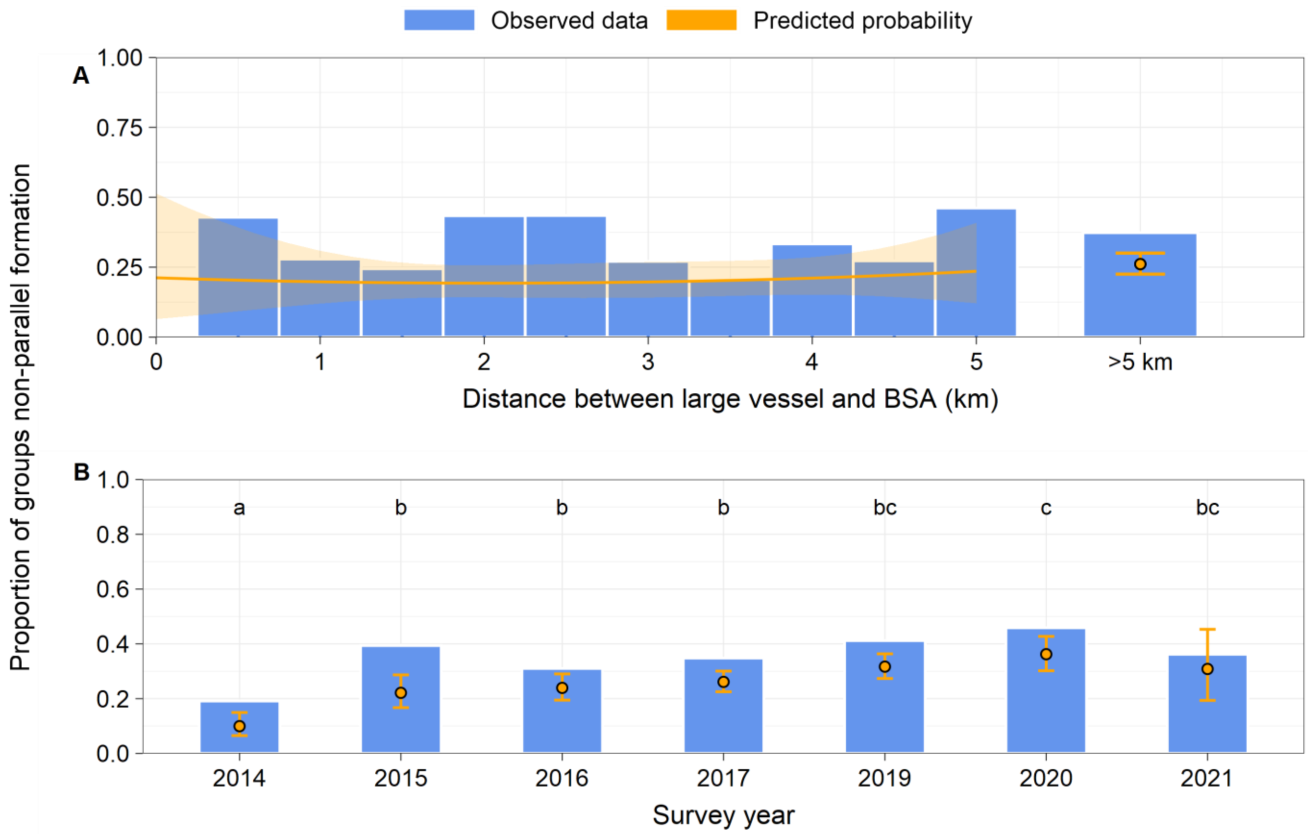


Figure 6-27: Proportion of narwhal groups observed in non-parallel formation as a function of distance (summarized to nearest 0.5 km value) from vessel (Panel A; combined seven-year dataset) and survey year (Panel B).

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

The effect of survey year was significant (P<0.001). A significant effect of survey year may indicate a long-term change in group formation within the BSA. Multiple comparisons between survey years indicated that groups were significantly more likely to be in non-parallel formation in 2015 compared to 2014 (Figure 6-27). The 2021 probability of non-parallel formation was not significantly different from any previous survey year, except for 2014 (P=0.004), and the assessment of the overall 2014-2021 estimates did not suggest a long-term change in group formation (Figure 6-27).

Other variables that were statistically significant predictors of group formation were group size (P<0.001), glare (P=0.003), and tide (P=0.017; APPENDIX C, Table D-7). Statistically significant categorical variables that were not related to shipping were further tested using pairwise comparisons. The probability of observing a group in a non-parallel formation was significantly lower under conditions of no glare or low glare, compared to severe glare (P<0.001 for both comparisons). This may suggest that detection of groups in parallel formation was more difficult when glare is severe, resulting in an inflation in the rate of detection of non-parallel groups. The effect of Beaufort level, however, was not significant (P=0.17); that is, glare had a stronger effect on observers' ability to detect group formation than sea state. Multiple comparisons between tide conditions indicated that group were significantly more likely to be in non-parallel formation under low slack conditions than high slack conditions (*P*=0.028), and more likely to be in non-parallel formation under low slack conditions than ebb conditions (*P*=0.003), although the biological significance of these results is not known.

In summary, findings based on the combined multi-year dataset suggest that narwhal do not significantly alter their group formation in response to vessel traffic. 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, though no such change was evident. The lack of response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

6.5.5 Group Direction

The majority of narwhal groups observed in the BSA during the seven-year study were shown to travel in a southerly direction (Figure 6-28) toward Koluktoo Bay and Milne Port, with the mean annual relative proportion of south-travelling narwhal groups ranging from 46% in 2020 to 91% in 2015. In 2021, the mean annual proportion of south-travelling groups was 58%. The mean annual relative proportion of north-travelling groups ranged from 9% in 2015 to 41% in 2020. In 2021, the mean annual proportion of north-travelling groups was 30%. Both east and west travel directions were rare, with mean annual relative proportion of these travel directions ranging from 0% to 5%, depending on direction and sampling year.

Narwhal group travel direction through the BSA in relation to vessel traffic may inform whether animals actively move away from, or potentially avoid, vessels transiting along the Northern Shipping Route.

In the combined dataset, the majority of group travel direction observations (filtered to north/south travel only) were recorded during vessel non-exposure periods (n = 5,071; 92%), of which 65% of narwhal groups travelled south and 35% of narwhal groups travelled north. The annual proportion of south-travelling groups ranged from 38% in 2021 to 80% in 2014. Mean group size was larger for south-travelling groups than for north-travelling groups (4.3 and 2.8 individuals, respectively; Figure 6-29).

During vessel exposure periods, 419 groups with a known travel direction were recorded. South-travelling narwhal groups were least common when southbound vessels were headed away from the BSA (55%) compared to when vessels were moving toward the BSA (78% and 82% for southbound and northbound vessels, respectively). South-travelling groups were most prevalent when northbound vessels were moving away from the BSA (95%). Similar to vessel non-exposure periods, narwhal group size was larger for south-travelling groups (mean of 3.8 individuals) than for north-travelling groups (mean of 3.1 individuals).

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

A comparison between the observed data and model predictions for group direction, as a function of distance from vessel, vessel direction and vessel orientation relative to the BSA, is presented in Figure 6-30. Note that the orange line represents the predicted proportion of groups in non-parallel formation for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars summarize the entirety of the observed data. This leads to some visual discrepancies between the observed and predicted values.

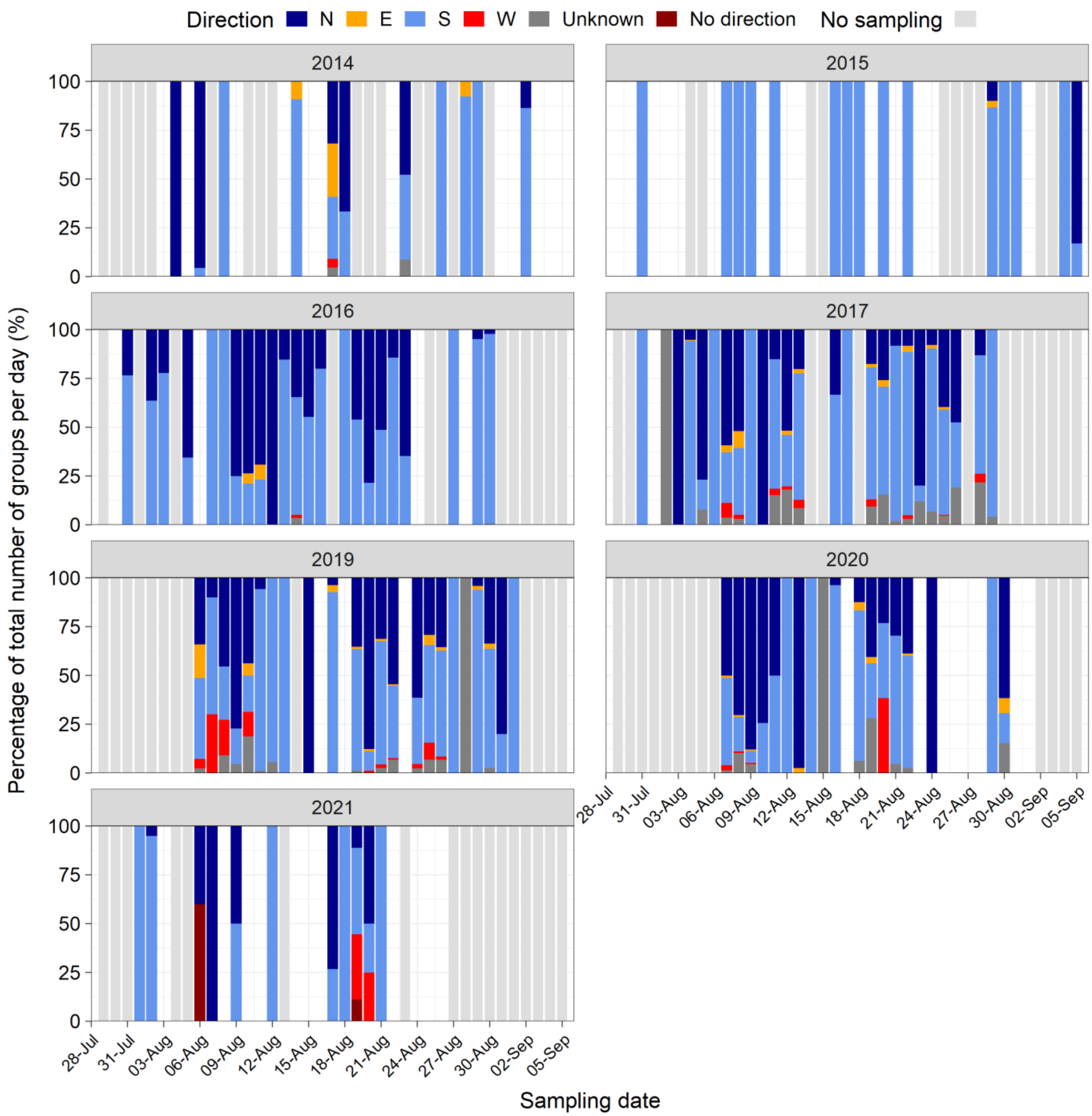


Figure 6-28: Relative daily proportion of group travel direction categories observed in the BSA (combined seven-year dataset).

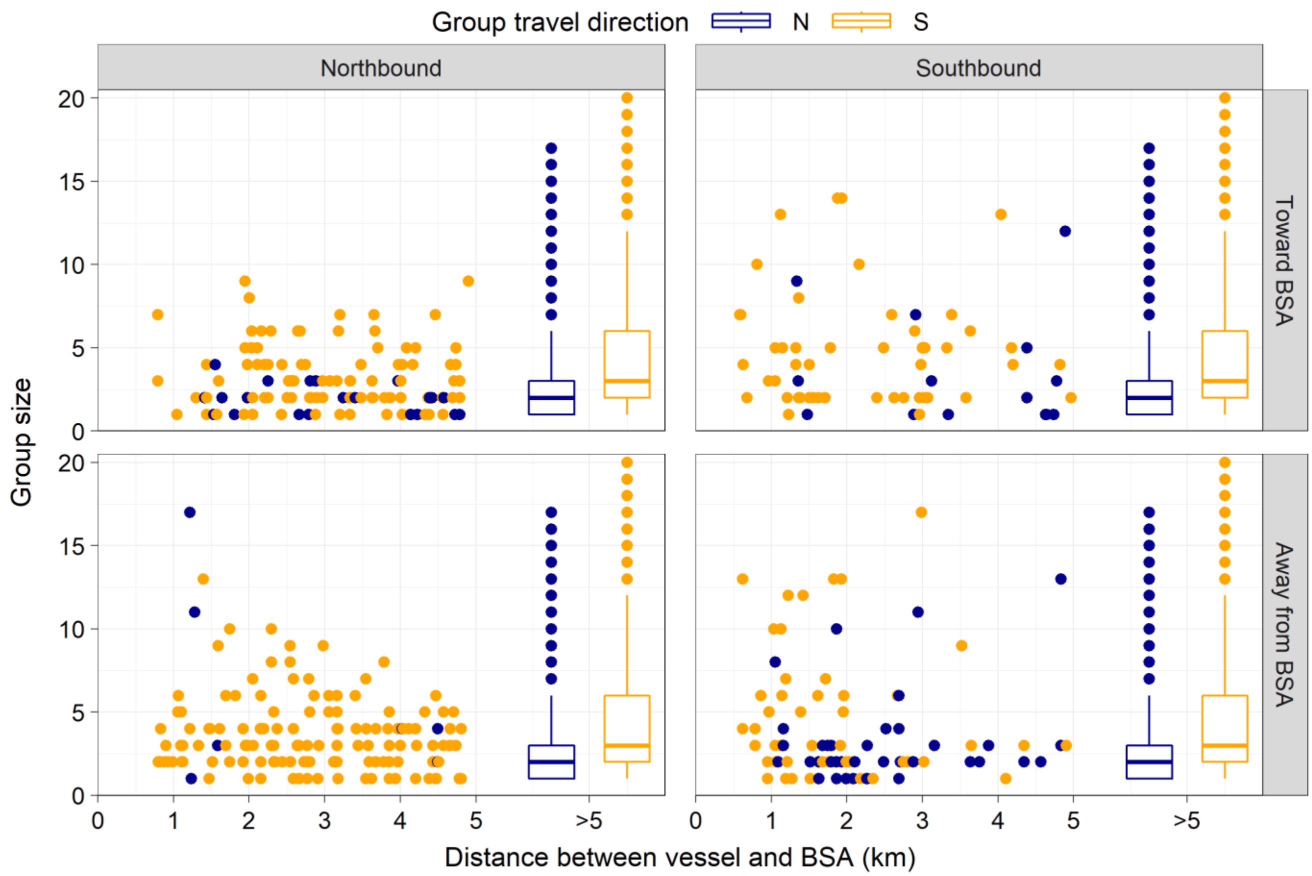


Figure 6-29: Comparison of group size between southbound and northbound narwhal groups as a function of distance from vessel, vessel direction, and vessel position relative to BSA (combined seven-year dataset).

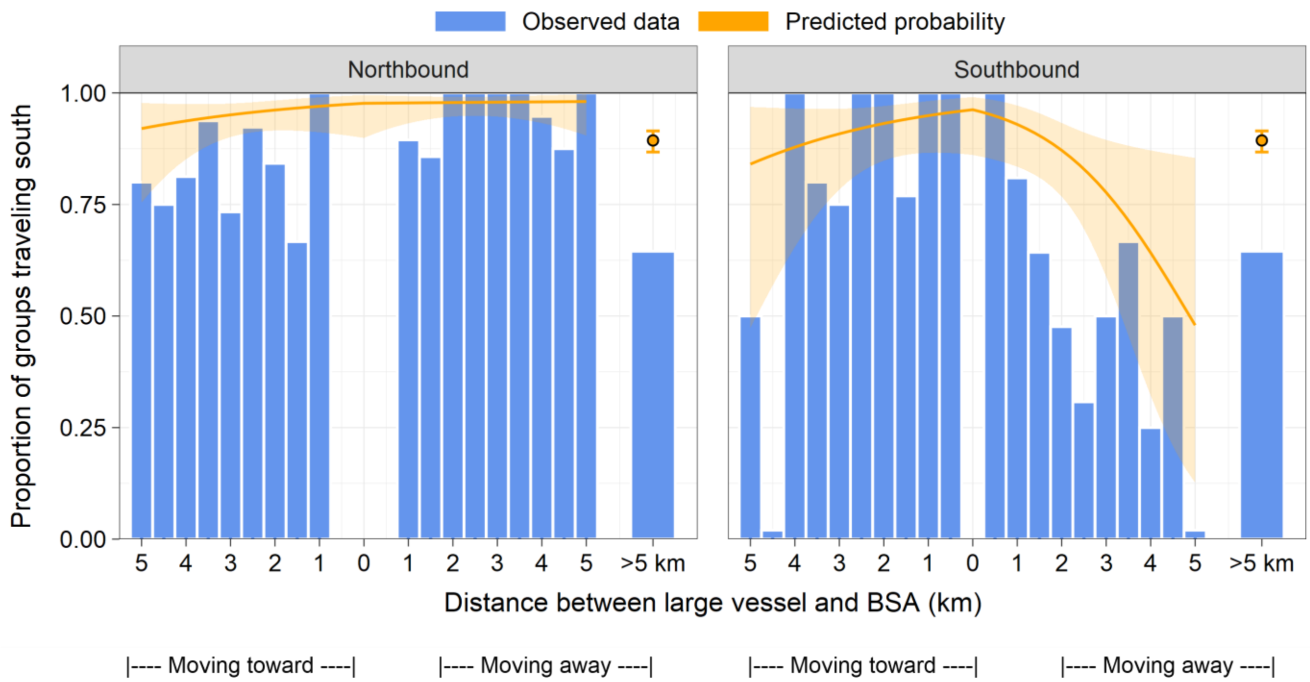


Figure 6-30: Proportion of narwhal groups travelling south as a function of distance (summarized to nearest 0.5 km value) from vessel, vessel travel direction (i.e., northbound vs. southbound) and vessel orientation relative to BSA (i.e., toward vs. away).

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

In the model of group direction, the interaction between vessel direction and distance from vessel was marginally significant (*P*=0.061), suggesting that the effect of shipping on group travel direction differed between north- and southbound vessels (APPENDIX C, Table C-11). During vessel exposure periods, modeling results suggested that narwhal tended to travel south when a northbound vessel was moving away from the BSA (probability of 0.976-0.980 depending on distance; Figure 6-30). When a southbound vessel was moving away from the BSA, narwhal were estimated to travel north. That is, once a vessel was moving away from the BSA, narwhal tended to move in the opposite direction (and did not follow in the vessel's wake), regardless of whether the vessel was north- or southbound. One exception to this finding was that narwhal were most likely to travel south when a southbound vessel was at 0 km from the BSA centroid (probability of 0.962). Estimated effect sizes for a vessel at 0 km from the BSA were large (i.e., +401% for a northbound vessel and +205% for a southbound vessel), due to the nonlinear nature of the logit transformation used in analysis of binomial data. On the probability scale (which extends from 0 to 1), the probability of a group to travel south increased from 0.893 when no vessels were present to 0.977 when a northbound vessel was at 0 km, and to 0.962 when a southbound vessel was at 0 km. Narwhal were significantly more likely to travel south when a northbound vessel was at 1-4 km and moving farther away from the BSA, when compared to when no vessels were present within 5 km from the BSA (Table 6-9. Other comparisons were not significant, due to the large uncertainty associated with the estimates (Figure 6-30). The model had low power to detect the observed effect sizes, and effect sizes of -87% or +700% were required to achieve sufficient power (APPENDIX A).

Table 6-9: Multiple comparisons of predictions of proportion of narwhal groups travelling south 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 – Least-squares Means with *P* values in Brackets			
	Northbound vessel, toward BSA	Northbound vessel, away from BSA	Southbound vessel, toward BSA	Southbound vessel, away from BSA
0	0.977 (0.265)	0.977 (0.265)	0.962 (0.569)	0.962 (0.569)
1	0.970 (0.140)	**0.978 (0.042)**	0.949 (0.600)	0.929 (0.904)
2	0.962 (0.066)	**0.978 (0.003)**	0.932 (0.837)	0.871 (0.981)
3	0.951 (0.168)	**0.979 (0.004)**	0.908 (0.998)	0.777 (0.300)
4	0.937 (0.781)	0.980 (0.052)	0.878 (1.000)	0.642 (0.158)
5	0.920 (0.993)	0.981 (0.240)	0.84 (0.989)	0.479 (0.142)

Other variables that were statistically significant predictors of group travel direction were group size (*P*<0.001), travel direction of previous group recorded on the same day (*P*<0.001), Beaufort level (*P*<0.001), tide (*P*=0.013), and hunting (P=0.006). The effects of glare and presence of small vessels within the SSA were not statistically significant (*P*=0.117 and P=0.058, respectively; APPENDIX C, Table D-15).

Statistically significant variables that were not related to shipping were further tested using pairwise comparisons. Groups where the previous group was also travelling south were significantly more likely to travel south, compared to groups where the previous group was travelling north (*P*<0.001). Groups were significantly less likely to be recorded travelling south at Beaufort level 1, compared to Beaufort levels 2 or 3 (*P*<0.001 for both), but no other significant pairwise comparisons were found. Multiple comparisons among tide levels indicated that groups were significantly less likely to travel south during high slack compared to either flood or ebb (*P*=0.030 and *P*=0.021, respectively), but no other significant differences were estimated (*P*>0.5 for all other comparisons). Narwhal groups were also significantly more likely to be travelling south when hunting took place in the last 70 min than when no hunting occurred (*P*=0.006). This was likely an artefact of the association between travel direction and distance from shore – south-travelling narwhal are more likely to travel close to shore (Section 6.5.7), and hunting is more likely to occur when narwhal are close to shore than when they occur offshore, resulting in an association of hunting events and south-travelling groups.

In summary, findings based on the combined multi-year dataset suggest that travel direction by narwhal groups is not affected by approaching vessels but that narwhal groups may avoid “following” in the wake of vessels moving away from the BSA. That is, narwhal tended to move in the opposite direction of vessels that move away from the BSA, regardless of whether the vessel was north- or southbound. The noted response was shown to be short in duration (i.e., within 4 km of a vessel or equivalent to a total disturbance period of 28 min per vessel transit based on a 9 knot vessel transit speed) with animals returning to their pre-response behaviour shortly following the initial exposure. During the 2021 Bruce Head Program (1 - 26 Aug), there were approximately two transits per day in the SSA (58 one-way transits in SSA over a 24-day period). The daily disturbance period associated with a change in group direction was therefore equivalent to approximately 56 min. As discussed in Section 3.0, a change in orientation response (e.g., a change in group direction) by narwhal is consistent with a low severity behavioural

response. Given the temporary nature of the effect, this would not be considered a 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

6.5.6 Travel Speed

In assessing the effect of vessel exposure on narwhal travel speed, it was predicted that slow travel speed may be indicative of narwhal exhibiting a “freeze response” while fast travel speed may indicate an avoidance or flee response. The majority of narwhal groups observed in the BSA during the seven-year Program travelled at a medium speed, with slow speed being the next most common travel speed (Figure 6-31). The mean annual proportion of narwhal groups travelling at a medium speed in the BSA ranged from 38% (in 2019) to 81% (in 2014), with a mean proportion of 44% observed in 2021. The mean annual proportion of narwhal groups travelling at a slow speed ranged from 17% (in 2014) to 36% (in 2021). Fast-travelling groups were relatively rare, with mean annual proportions of 2%, 18%, 13%, 9%, 19%, 16%, and 15% in 2014-2017 and 2019-2021, respectively. In 2021, travel speed was successfully recorded for all observed groups.

The travel speed of narwhal groups in the BSA was analysed in relation to the proximity and orientation of transiting vessels (Figure 6-32). In the combined multi-year dataset, the majority of group travel speed observations were recorded during vessel non-exposure periods (n = 5,170), of which 26% of the groups were travelling slowly, 57% were travelling at a medium speed, and 17% were travelling fast. Mean narwhal group size was smallest for slow groups (2.8 individuals), intermediate for medium speed groups (3.8 individuals), and largest for fast groups (4.7 individuals).

During vessel exposure periods, a total of 438 groups with a known travel speed were recorded. The proportion of groups travelling slowly varied with vessel travel direction and orientation relative to the BSA, ranging from 18% for northbound vessels heading away from the BSA to 29% for southbound vessels heading away from the BSA. The proportion of groups travelling at a fast speed ranged from 7% for northbound vessels heading toward the BSA to 35% for southbound vessels heading toward the BSA. Similar to vessel non-exposure periods, travel speed and group size were positively related, with mean group size increasing from 2.9 individuals for slow groups to 5.4 individuals for medium speed groups and 5.0 individuals for fast groups.

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

A comparison between the observed data and model predictions for group travel speed, as a function of distance from vessel and sampling year (both response variables associated with significant changes), is presented in Figure 6-33. Note that the orange line represents the predicted proportion of groups in non-parallel formation for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars summarize the entirety of the observed data. This leads to some visual discrepancies between the observed and predicted values.

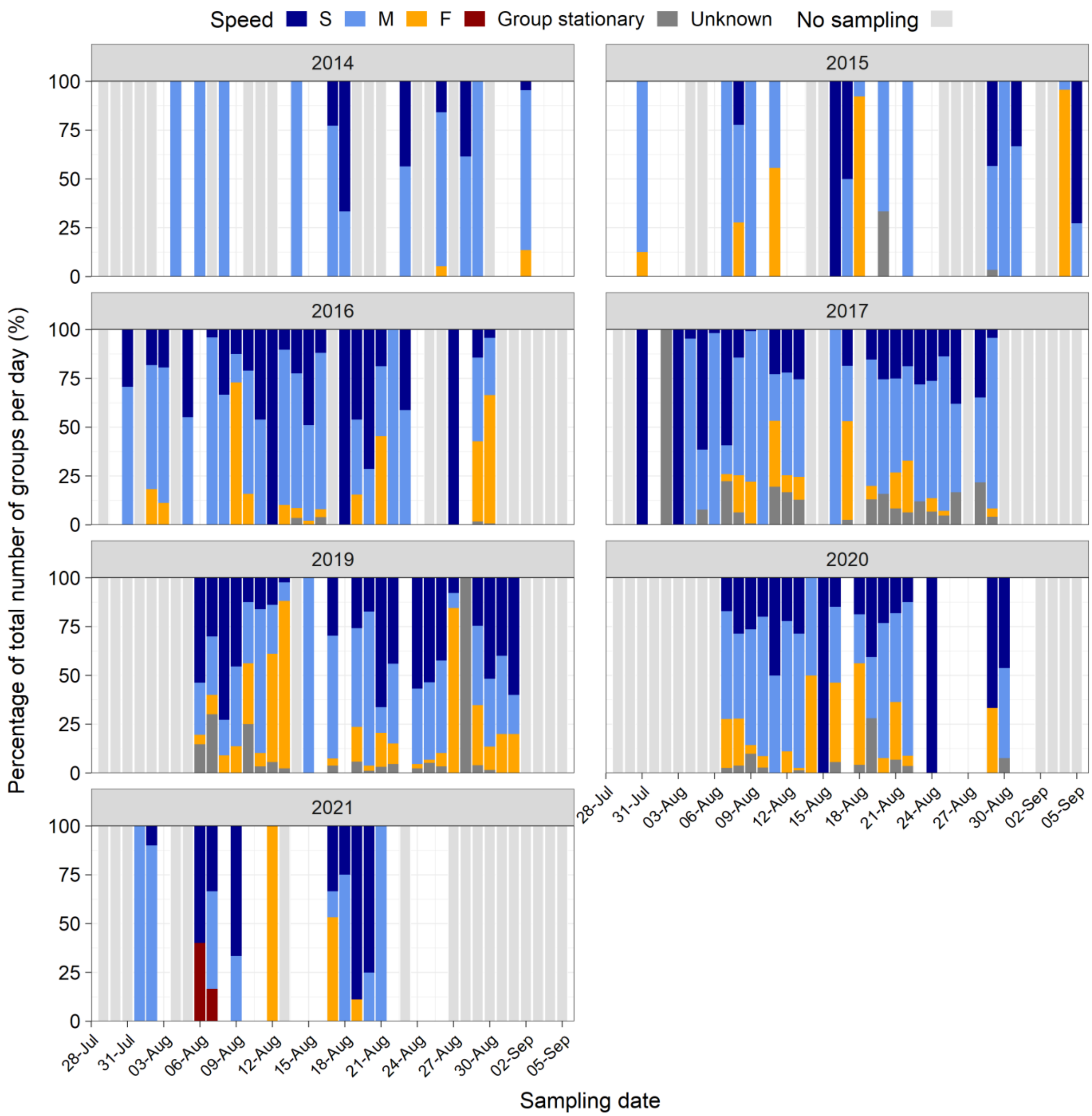


Figure 6-31: Relative daily proportion of narwhal group travel speed categories observed in the BSA (combined 7-year dataset).

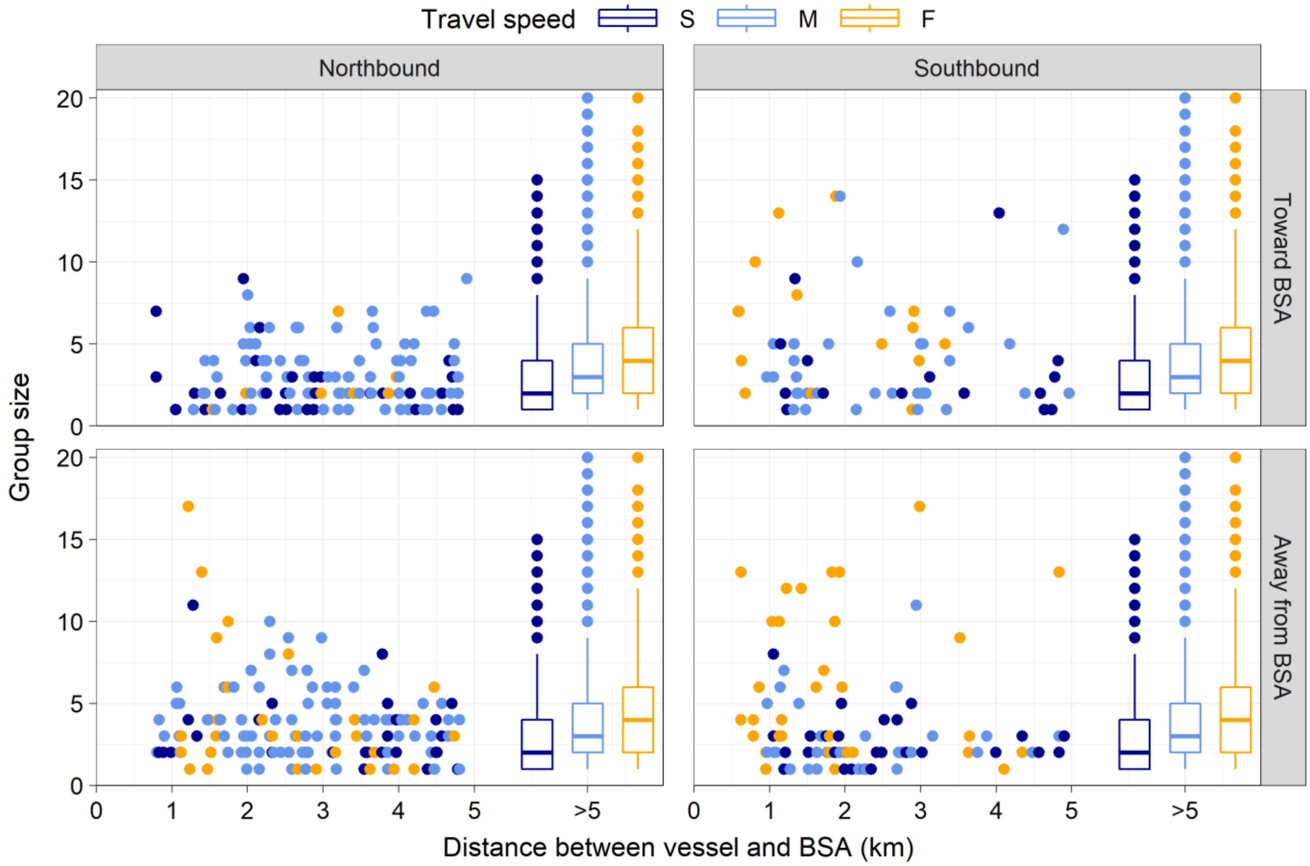


Figure 6-32: Comparison of group size between group travel speed categories observed in the BSA as a function of distance from vessel, vessel direction, and vessel orientation relative to the BSA (combined seven-year dataset).

The interaction between the effect of distance from vessel and the travel speed of the previous recorded group was significant (*P*=0.019; APPENDIX C, Table D-13), indicating that the effect of shipping on group speed differs for groups that were among others that were travelling slowly versus groups that were among others that were travelling at medium or fast speeds. Specifically, when the previously recorded group travelled at slow speed, the effect of vessel was small, with the probability of a group to travel slowly decreasing from 0.551 when a vessel was at 5 km to 0.430 when a vessel was at 1 km (Figure 6-33). In comparison, when the previously recorded group travelled at a medium or fast speed, the effect of vessel was larger and bowl-shaped, with the probability of a group to travel slowly increasing from 0.173 when a vessel was at 5 km to 0.325 when a vessel was at 1 km (Figure 6-33). Note that the closest vessel distance in the dataset of groups moving in slow or medium speed was 0.8 km, and hence predictions were restricted to vessel distances of 1 km or higher, to avoid extrapolation. Estimated effect sizes at 1, 2, 3, and 4 km from vessels for groups among others travelling at slow travel speeds was -50%, -38%, -26%, and -15%, respectively, and +107%, -13%, -29%, and +11%, respectively, for groups among others travelling at medium/fast speeds. These results suggest that the spatial extent of the biologically significant effect of vessel traffic on narwhal travel speed is less than 4 km from a vessel. The model had sufficient power to detect the observed effect size (APPENDIX A).

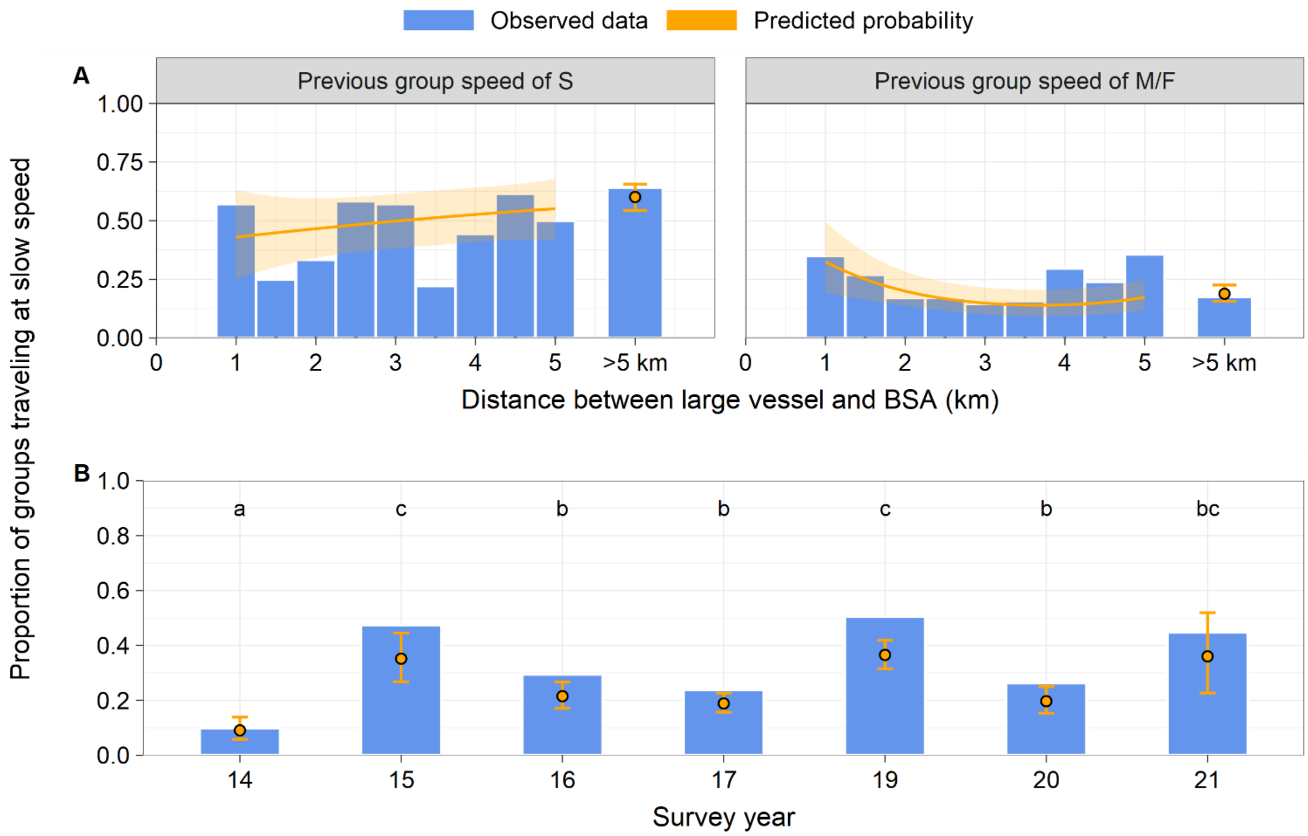


Figure 6-33: Proportion of narwhal groups travelling slowly as a function of distance (summarized to nearest 0.5 km value) from vessel and travel speed of the previously recorded group (Panel A; S = slow, M = medium, F = fast) and survey year (Panel B).

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

The effect of survey year on group travel speed was also shown to be significant (*P*<0.001). A significant effect of survey year may indicate a long-term change in travel speed within the BSA. Multiple comparisons between survey years indicated that groups were significantly more likely to move at a slow speed in 2015 compared to 2014 (Figure 6-33). The 2021 probability of moving at a slow speed was not significantly different from any previous survey year, except for 2014 (*P*<0.001), and the assessment of the overall 2014-2021 estimates did not suggest a long-term trend in group speed (Figure 6-33).

Other variables that were statistically significant predictors of group speed included group size (*P*<0.001) and Beaufort level (*P*=0.001; APPENDIX C, Table C-13). Statistically significant categorical variables that were not related to shipping were further tested using pairwise comparisons. The probability of observing a group travelling at slow speed (as opposed to medium speed) was significantly lower when the previously recorded group travelled at medium or fast speed (value of 0.217) compared to when the previously recorded group travelled at a slow speed (value of 0.645; *P*<0.001 for significance of comparison). The probability of observing travelling at slow speed was significantly lower at Beaufort levels of 3 and 4 or higher (values of 0.283 and 0.278, respectively) when compared to Beaufort level 1 (value of 0.371; *P*=0.02 for both). This suggests that detection of groups that travel slowly was more difficult in high sea states. The effect of glare, however, was not significant

(*P*=0.07); that is, sea state had a stronger effect than glare on an observers' ability to detect slowly-moving groups.

In the multiple comparison analysis of proportion of slowly travelling group between vessel exposure (i.e., 1-5 km) and non-exposure (i.e., >5 km) periods, none of the comparisons were significant (*P*>0.1 for all; Table 6-10). However, comparisons could not be made at 0 km due to limited data, where effects generally tend to be largest for other response variables.

In summary, findings based on the combined multi-year dataset suggest that if narwhal were among others travelling at a medium or fast speed, they were more likely to travel slowly when less than 4 km from a vessel compared to when no vessel was within 5 km of the BSA. For narwhal groups among others already travelling slowly, no significant change in travel speed relative to vessels was evident. The noted response was shown to be short in duration (i.e., within 4 km of a vessel or equivalent to a total disturbance period of 28 min per vessel transit) with animals returning to their pre-response behaviour shortly following the initial exposure. During the 2021 Bruce Head Program (1 - 26 Aug), there were approximately two transits per day in the SSA (58 one-way transits in SSA over a 24-day period). The daily disturbance period associated with a change in group travel speed was therefore equivalent to approximately 56 min. As discussed in Section 3.0, a change in energy expenditure (e.g., a change in travel speed) by narwhal is consistent with a moderate severity response. Given the temporary nature of the effect, this would not be considered a 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

Table 6-10: Proportion of narwhal groups travelling slowly (rather than at medium speed) - multiple comparison analysis between vessel exposure (1 to 5 km distances) and non-exposure (>5 km) periods. Statistically significant values shown in bold.

Distance from Vessel (km)	Multiple Comparisons to No-exposure – Least-squares Means with *P* values in Brackets	
	Previously recorded group travelling slowly	Previously recorded group travelling at medium or fast speed
0	Not estimated to avoid extrapolation	
1	0.430 (0.304)	0.325 (0.146)
2	0.466 (0.102)	0.199 (0.983)
3	0.498 (0.194)	0.148 (0.483)
4	0.527 (0.477)	0.141 (0.363)
5	0.551 (0.846)	0.173 (0.953)

6.5.7 Distance from Bruce Head Shoreline

Based on several reports indicating that narwhal move close to shore when attempting to escape predation by killer whales (Steltner et al.1984; Laidre et al. 2006; Marcoux et al. 2009; Breed et al. 2017), it was predicted that narwhal moving close to shore when exposed to vessel traffic may indicate an avoidance response to a perceived threat (i.e., vessel traffic). The majority of narwhal groups observed in the BSA during the seven-year study were recorded close to shore (i.e., <300 m distance classification; Figure 6-34). The mean annual proportion of groups close to shore ranged from 54% in 2021 to 89% in 2015. In comparison, the mean annual proportion of groups far from shore ranged from 9% in 2015 to 46% in 2021.

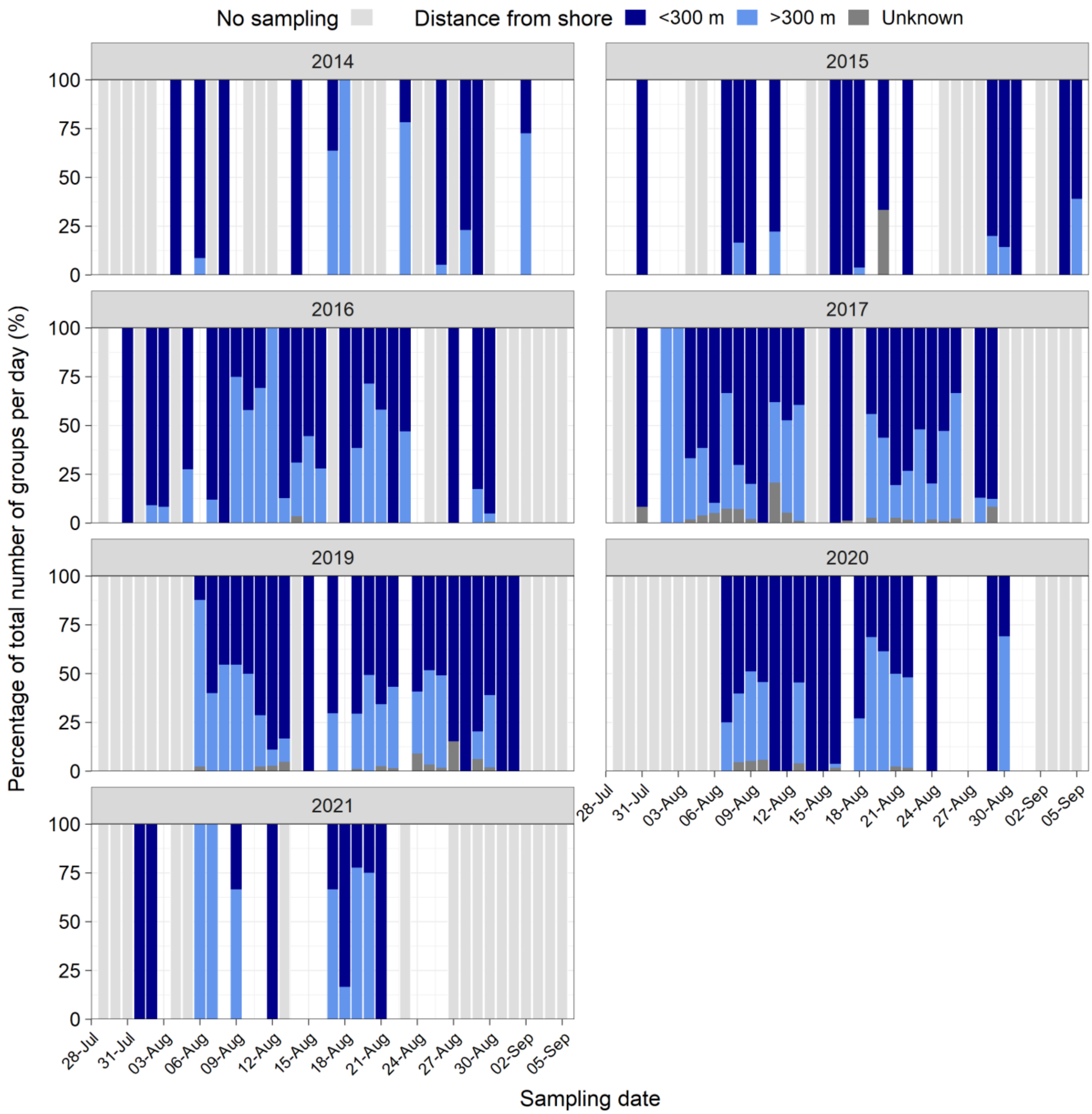


Figure 6-34: Relative daily proportion of narwhal groups observed close to shore (< 300 m) vs. offshore (≥ 300 m) in the BSA (combined seven-year dataset).

Distance from shore was analyzed for narwhal groups in the BSA in relation to the proximity and orientation of transiting vessels (Figure 6-35). In the combined multi-year dataset, the majority of ‘distance from shore’ observations were recorded during vessel non-exposure periods (n = 5,363), of which 35% were >300 m from shore (mean annual proportion ranged from 22% in 2015 to 46% in 2021). Mean narwhal group size was larger for groups occurring closer to shore than for groups ≥300 m from shore (i.e., 4.1 and 2.9 individuals, respectively; Figure 6-35).

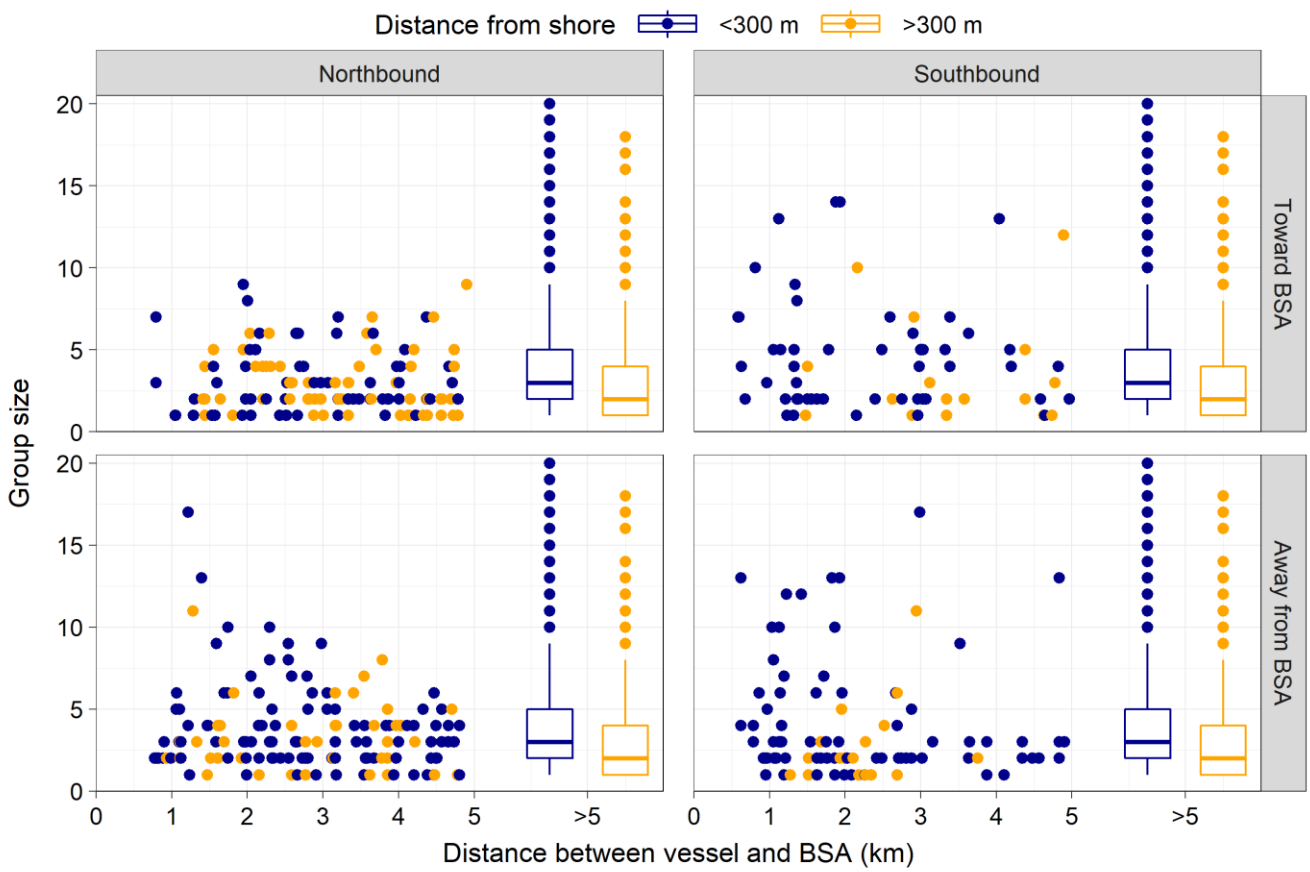


Figure 6-35: Comparison of group size between narwhal groups observed close to shore (< 300 m) vs. offshore (≥ 300 m) as a function of distance from vessel, vessel direction and vessel orientation relative to BS A (combined seven-year dataset).

During vessel exposure periods, 446 groups with a known distance from shore were recorded. The proportion of narwhal groups occurring far from shore (i.e., ≥300 m) was influenced by vessel travel direction and vessel orientation relative to the BSA. The proportion of groups occurring far from shore was lowest for southbound vessels (21% and 23% for vessels heading toward and away from the BSA, respectively), intermediate (30%) for northbound vessels heading away from the BSA and highest (50%) for northbound vessels heading toward the BSA.

Test statistics and coefficient estimates for the model are provided in APPENDIX C. Residual diagnostic plots are provided in APPENDIX D. The model did not have sufficient power to detect the observed effect sizes, and effect sizes of -100% or +330% were required for sufficient power (APPENDIX A).

A comparison between the observed data and model predictions for ‘distance from shore’, as a function of distance from vessel, is presented in Figure 6-36. Note that the orange line represents the predicted proportion of groups in non-parallel formation for a specific set of predictor values (Section 5.4.2.4), whereas the blue bars summarize the entirety of the observed data. This leads to some visual discrepancies between the observed and predicted values.

The effect of distance from vessel on narwhal group distance from shore was significant (*P*=0.029; APPENDIX C, Table D-15). When vessels were present within 5 km of the BSA centroid, modeling results suggested a dome-shaped relationship (Figure 6-36), with the predicted probability of observing groups away from shore peaking at a value of 0.294 when a vessel was 4 km away. When a vessel was in the immediate vicinity of the BSA (distance of 0 km from centroid), groups were least likely to be away from shore (probability of 0.049). Estimated effect size for a vessel at 0 km from the BSA was -81% relative to when no vessel was present within 5 km from the BSA, with effect size decreasing with vessel distance (e.g., -48% at 1 km, and +3% at 2 km), suggesting that there may be a moderate biologically significant effect (i.e., >25% change – as per Section 5.4.2), with a spatial extent of less than 2 km relative to the BSA centroid. The statistical power to estimate the observed effect at 0 km was low (0.5; Appendix B). 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 a -100% or a +330% effect size in the test of the overall effect of distance from vessel (Appendix B).

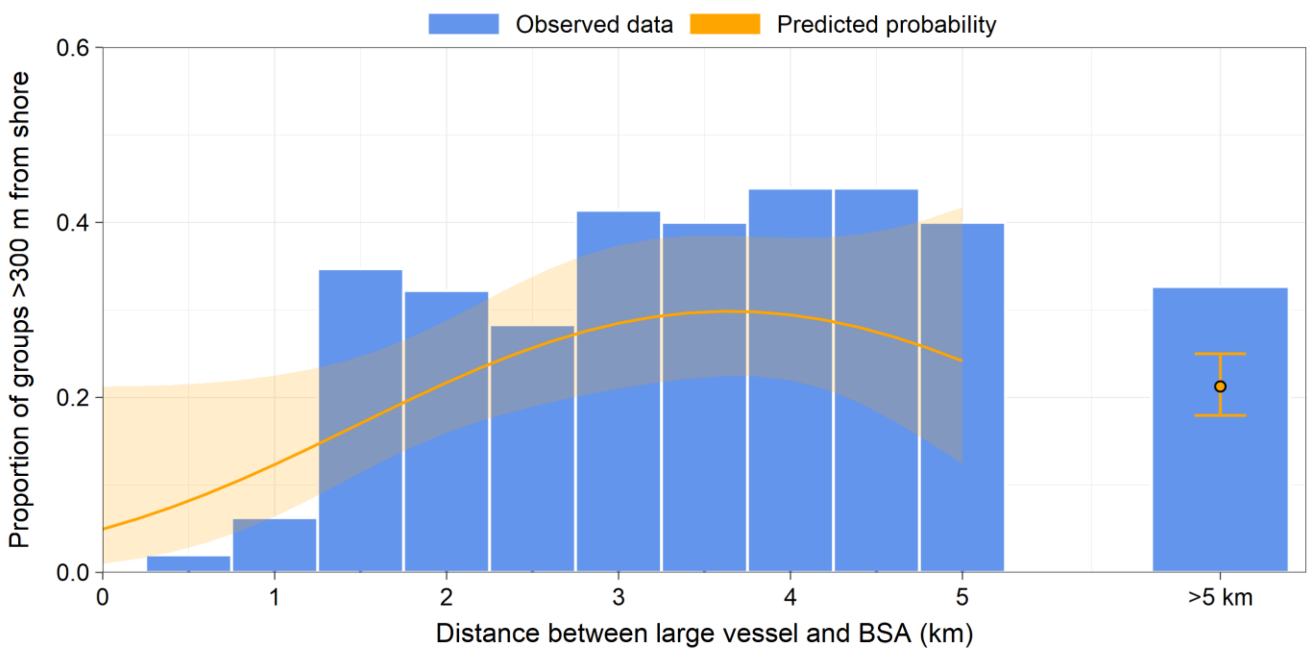


Figure 6-36: Proportion of narwhal groups observed >300 m from shore as a function of distance from vessel.

Notes: observed data depict total proportion of groups observed >300 m from shore at each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

Other variables that were statistically significant predictors of group distance from shore included group size (*P*<0.001), group travel direction (*P*<0.001), distance from shore of previous group recorded on the same day (*P*<0.001), Beaufort level (*P*<0.001), tide (*P*=0.001), and presence of small vessels within the SSA (*P*=0.042). The effects of year, glare, and hunting were not statistically significant (*P*>0.19 for all; APPENDIX C, Table D-15).

Statistically significant categorical variables that were not related to shipping were further tested using pairwise comparisons. North-travelling groups were significantly more likely to be far from shore than south-travelling groups (*P*<0.001). Groups where the previous group was also travelling far from shore were significantly more likely to be far from shore, compared to groups where the previous group was travelling close to shore (*P*<0.001). Groups were significantly less likely to be recorded far from shore at Beaufort level 3, compared to Beaufort levels 0, 1, or 2 (*P*<0.001 for all), indicating that detection of groups farther from shore was more difficult in higher sea states.

Multiple comparisons among tide levels indicated that groups were significantly more likely to be far from shore during flood period compared to either high slack or ebb (*P*=0.003, *P*=0.013, respectively), but no other significant differences were estimated (*P*>0.2 for all other comparisons). Narwhal groups were also significantly more likely to be far from shore when small vessels were present in the SSA than when no small vessels were present (*P*=0.042).

In the multiple comparison analysis of 'narwhal group distance from shore' between vessel exposure (i.e., 0–5 km) and non-exposure (i.e., >5 km) periods, none of the multiple comparisons were significant (Table 6-11), due to the high uncertainty associated with the estimated effect (Figure 6-36). The comparison was not significant at 1 km despite a -48% effect size, which reflected uncertainty in the effect of vessel distance on the response variable.

Table 6-11: Distance of narwhal group from shore - multiple comparison analysis between vessel exposure (0 to 5 km distances) and non-exposure (>5 km) periods. Statistically significant values shown in bold.

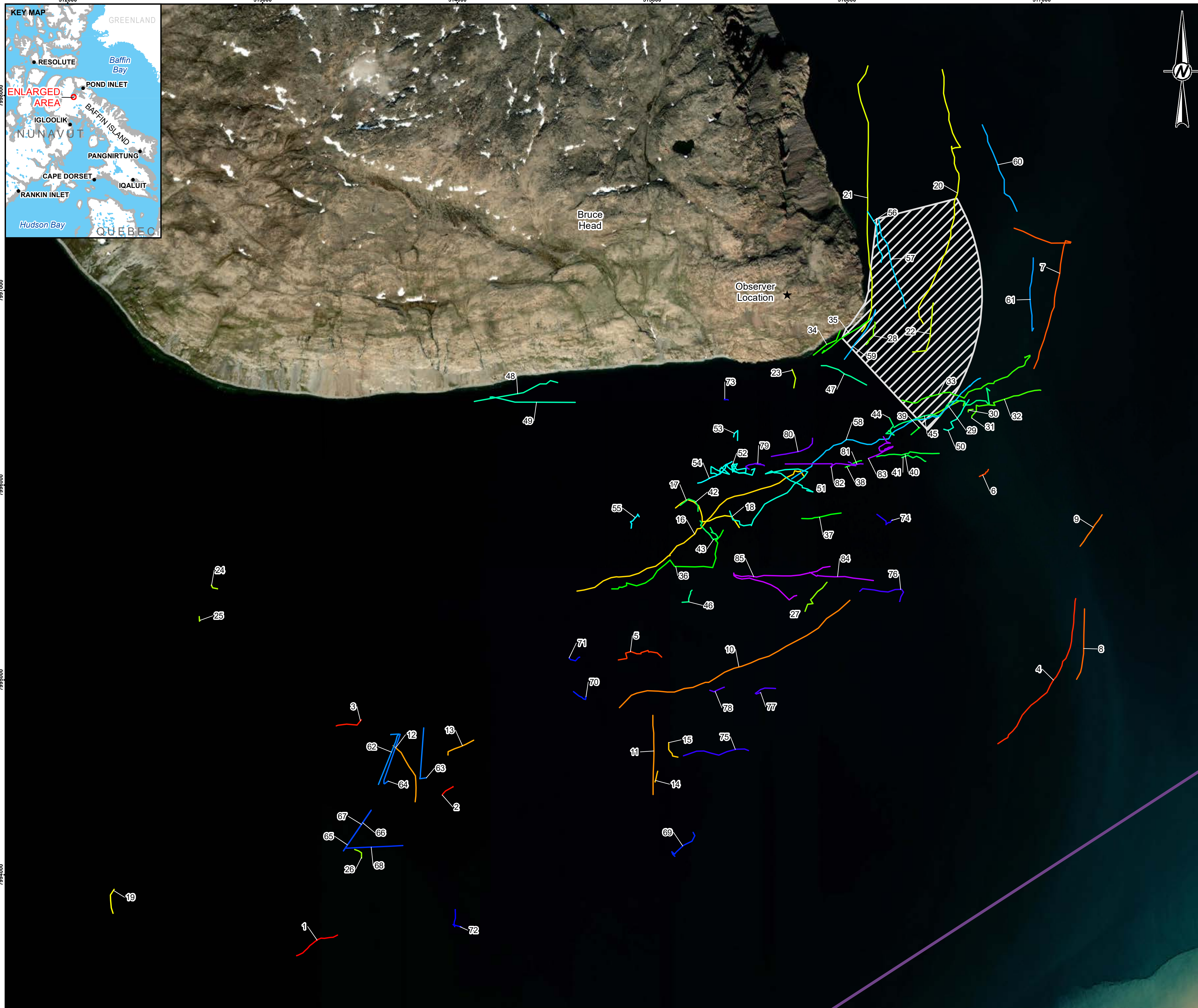
Distance from Vessel (km)	Multiple Comparisons to No-exposure	
	Least-squares Mean	*P* value
0	0.049	0.208
1	0.123	0.275
2	0.217	0.999
3	0.285	0.155
4	0.294	0.072
5	0.242	0.980

In summary, findings based on the combined multi-year dataset suggest that narwhal may swim closer to shore when in close proximity (≤2 km) to vessels. The noted response was shown to be short in duration (total disturbance period of 14 min per vessel transit based on a 9 knot vessel transit speed) with animals returning to their pre-response behaviour shortly following the initial exposure. During the 2021 Bruce Head Program (1 - 26 Aug), there were approximately two transits per day in the SSA (58 one-way transits in SSA over a 24-day period). The daily disturbance period associated with a change in narwhal distance from shore was therefore equivalent to approximately 28 min. As discussed in Section 3.0, a minor deviation from typical migratory pathway (e.g., a change in distance from shore) by narwhal is consistent

with a low severity response. Given the temporary nature of the effect, this would not be considered a 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

6.6 Focal Follow Surveys (UAV)

A total of 85 and 164 focal follow surveys of narwhal were undertaken in the RSA in 2020 and 2021, respectively, representing a total of 23.6 h of behavioural observations recorded over a total of 249 surveys (Figure 6-37, Figure 6-38). In 2020, ships 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 (Table 6-12). In 2021, ships 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 (Table 6-13). Note that each unique focal follow survey is denoted with its own identification (FFID) number. Survey tracklines of the 43 focal follow surveys involving a vessel transit are presented in APPENDIX E, with an example survey figure (Focal Follow ID #33, 2021) provided below (Figure 6-39). For illustrative purposes, photos associated with focal follow surveys 35, 40,137, and 142 (2021) are presented in Figure 6-40 to Figure 6-43.



LEGEND

- ● COMMUNITY
- ★ 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

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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 BIM, JULY 14, 2020. 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 SURVEYS CONDUCTED DURING THE 2020 FIELD SEASON AT BRUCE HEAD

CONSULTANT

GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000-04	0	6-37

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

25mm

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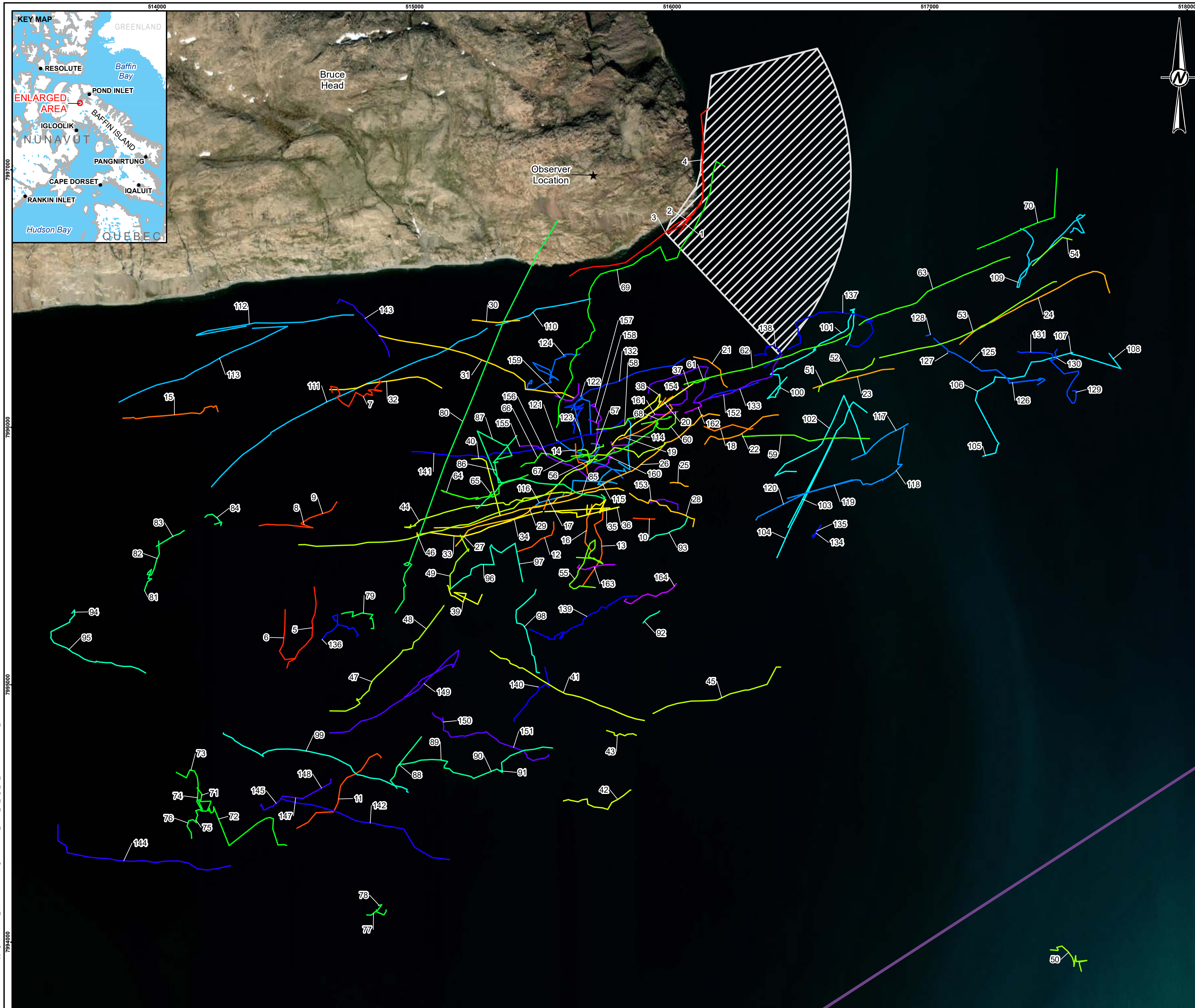

LEGEND

- • COMMUNITY
- ★ 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

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1:15,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT ©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 SURVEYS CONDUCTED DURING THE 2021 FIELD SEASON AT BRUCE HEAD

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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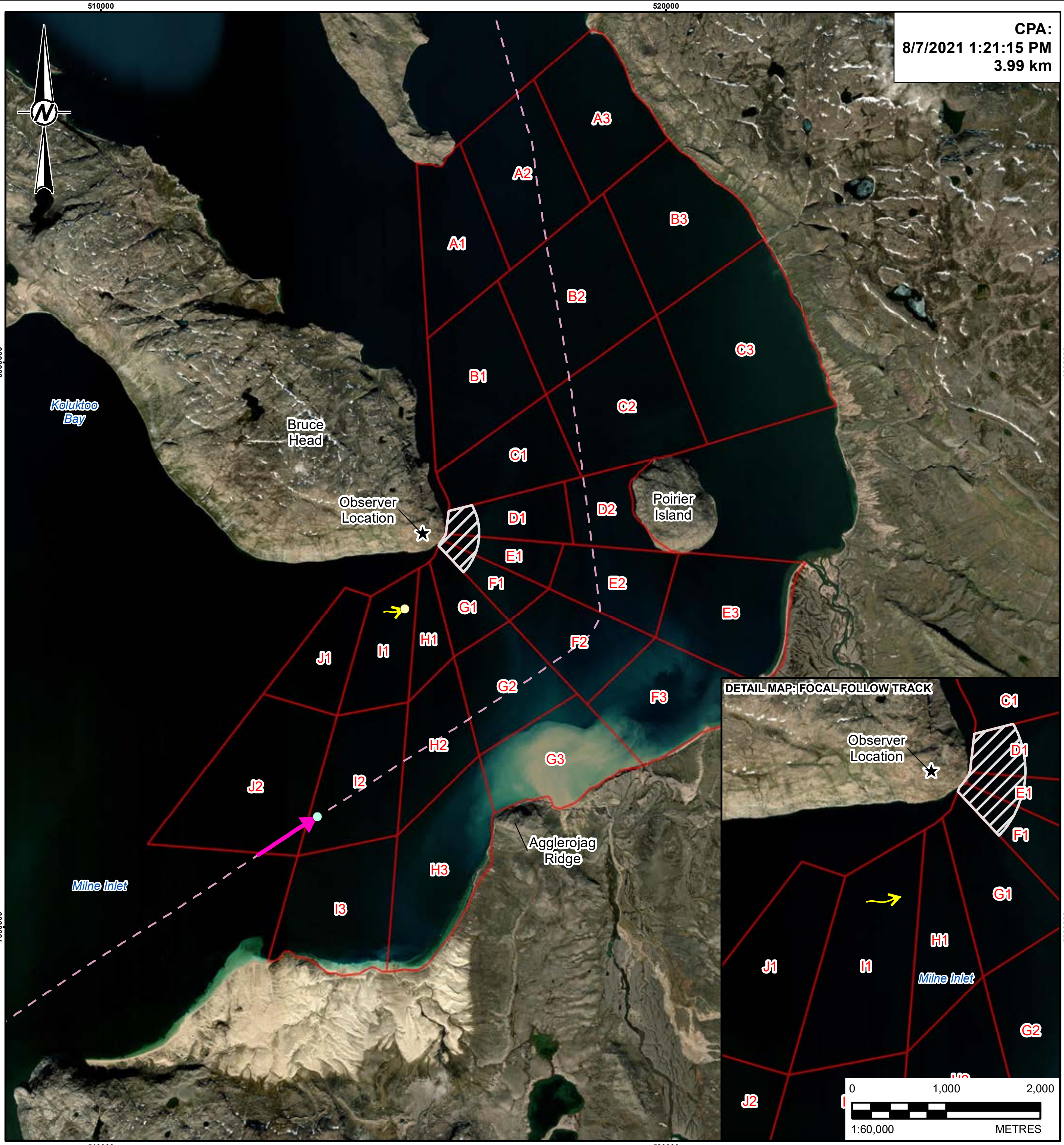

LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 33 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- 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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 33 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	6-39

Table 6-12: 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 down

FFID #	Date / Time at CPA (EDT)	Total Time with Group	Vessel CPA (km)	Group Composition	Observations (Including reason for survey end)
					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 6-13: 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.

Figure 6-40: Still frame taken during focal follow survey #35 showing seven adults (with tusks) at a distance of 4.2 km from a northbound vessel (MSV Botnica) on 7 August 2021 (13:16). Evidence of defecation visible below adult in bottom-right of image.

Figure 6-41: Still frame taken during focal follow survey #104 showing single adult (tusked) engaged in milling behaviour at a distance of 3.4 km from a northbound vessel (MSV Botnica) on 7 August 2021 (13:43).

Figure 6-42: Still frame taken from focal follow survey #83 showing mother and calf pair with yearling observed at a distance of 6.0 km from a southbound ore carrier (Golden Rose) on20 August 2021 (06:24). Calf can be seen rubbing against its mother.

Figure 6-43: Still frame taken from focal follow survey #142 showing four adults (no tusks) and a single calf located 1.5 km from a southbound ore carrier (Golden Rose) on 20 August 2021 (07:28). Adult at top of image can be seen rolling horizontally on its side.

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) to 22 (20 August 2021; Figure 6-44). The daily number of focal follow surveys conducted in the presence of vessels ranged from one (9 August 2020) to ten (7 and 19 August 2021). The total daily amount of time spent following groups (excluding UAV transit and search time) ranged from 50 seconds on 14 August 2020 to 167 min (2.8 h) on 20 August 2021 (Figure 6-45). The daily amount of time spent following groups when a vessel was present ranged from 6 min (22 August 2020) to 51 min (20 August 2021).

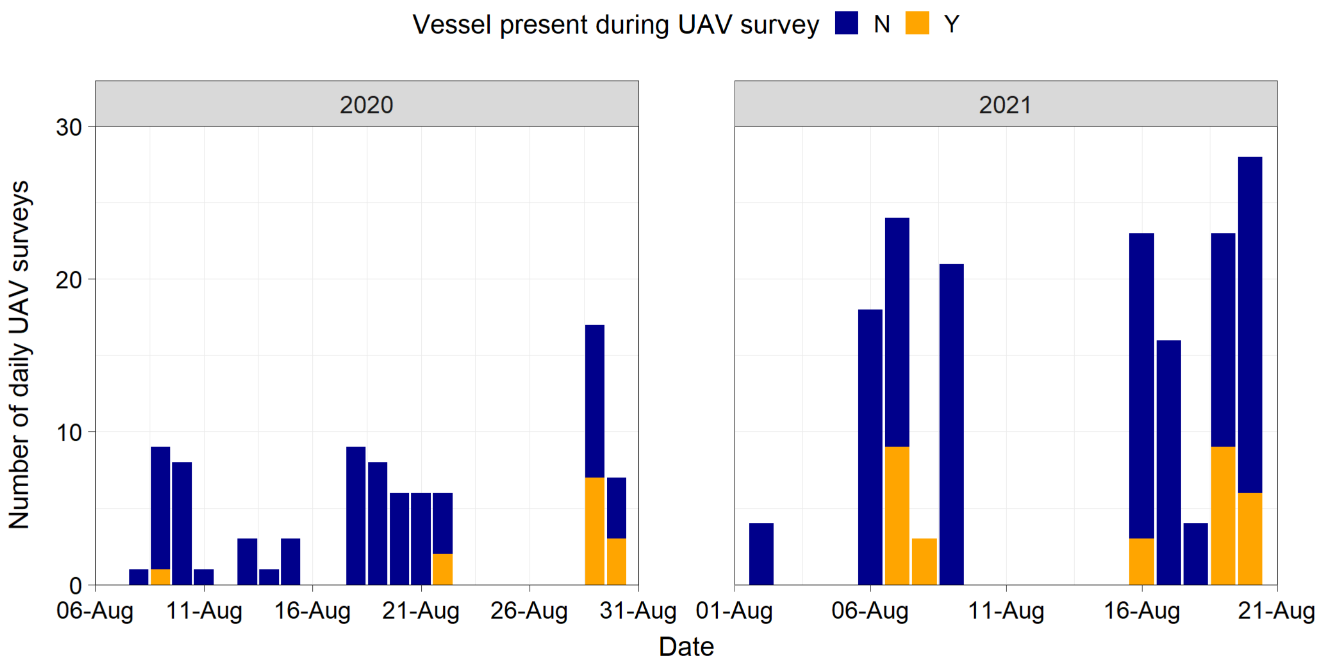

Figure 6-44: Time series of total number of daily UAV surveys conducted in 2020 and 2021.

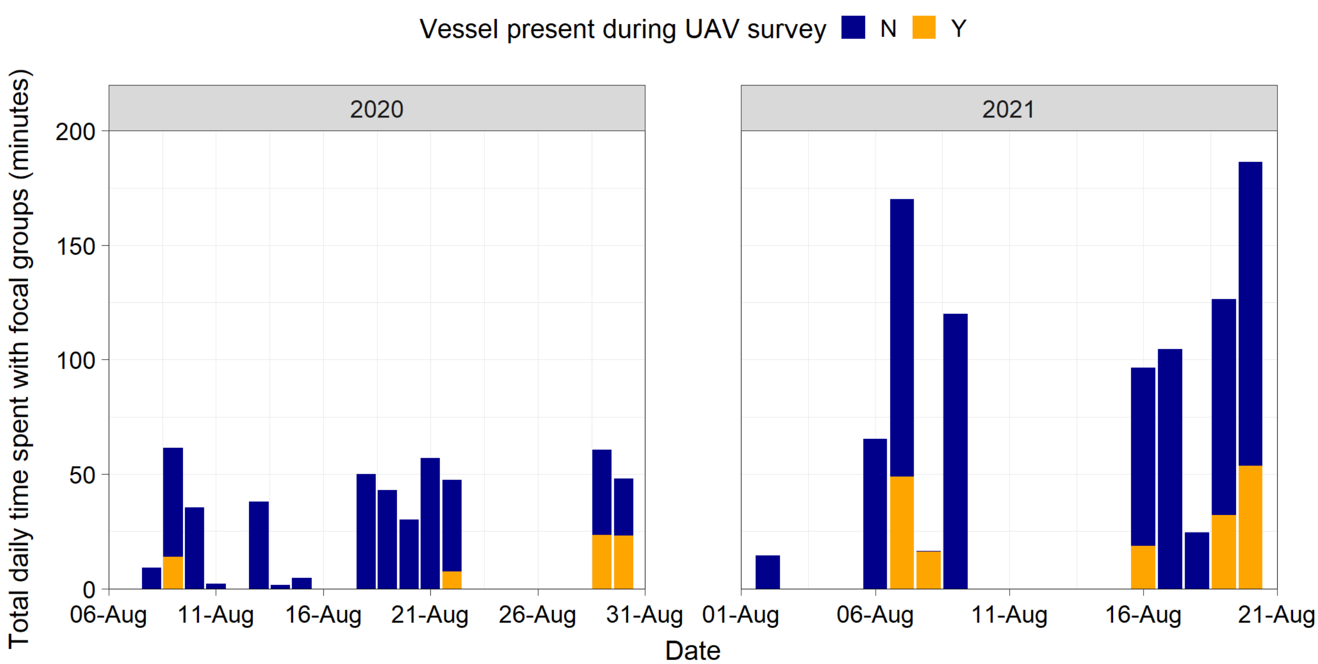

Figure 6-45: Time series of total daily time spent with focal groups in 2020 and 2021.

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 6-46), including a total of 135 unique focal follow surveys representing 535 min (8.9 h) of recorded behaviour. Mother-immature pairs were observed in 45 individual focal follow surveys for a total of 170 min (2.8 h), while mixed groups with immatures were observed in 27 focal follow surveys for a total of 103 min (1.7 h) of recorded data. Calves were observed on their own (i.e., either as a single calf or two calves together without other individuals) during 22 individual focal follow surveys, for a total of 158 min (2.6 h) of recorded data.

When vessels were present within 5 km of focal groups (i.e., vessel exposure periods), the majority of the data was collected when vessels were at a distance of 2-4 km, including a total of 39 unique focal follow surveys representing 204 min (3.4 h) of recorded behaviour, coinciding with 9 different vessel transits (Figure 6-46). In close proximity to vessels (0-1 km from the groups), only three unique focal follow surveys were collected representing 14 min of recorded behaviour, coinciding with two vessel transits. The discrepancy in the total number of focal follow surveys presented in text relative to that presented in Figure 6-46 is due to several of the UAV surveys having multiple focal follows within a given survey (where different focal groups were tracked at various distances from the vessel). 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 and results should be interpreted with caution. While focal follows of adult groups provided 153 min of recorded behaviour in the presence of vessels, focal follows of mother-immature pairs were limited to 21 min, mixed groups with immatures were limited to 39 min, mixed groups without immatures were limited to 14 min, and lone calves to were limited to 12 min.

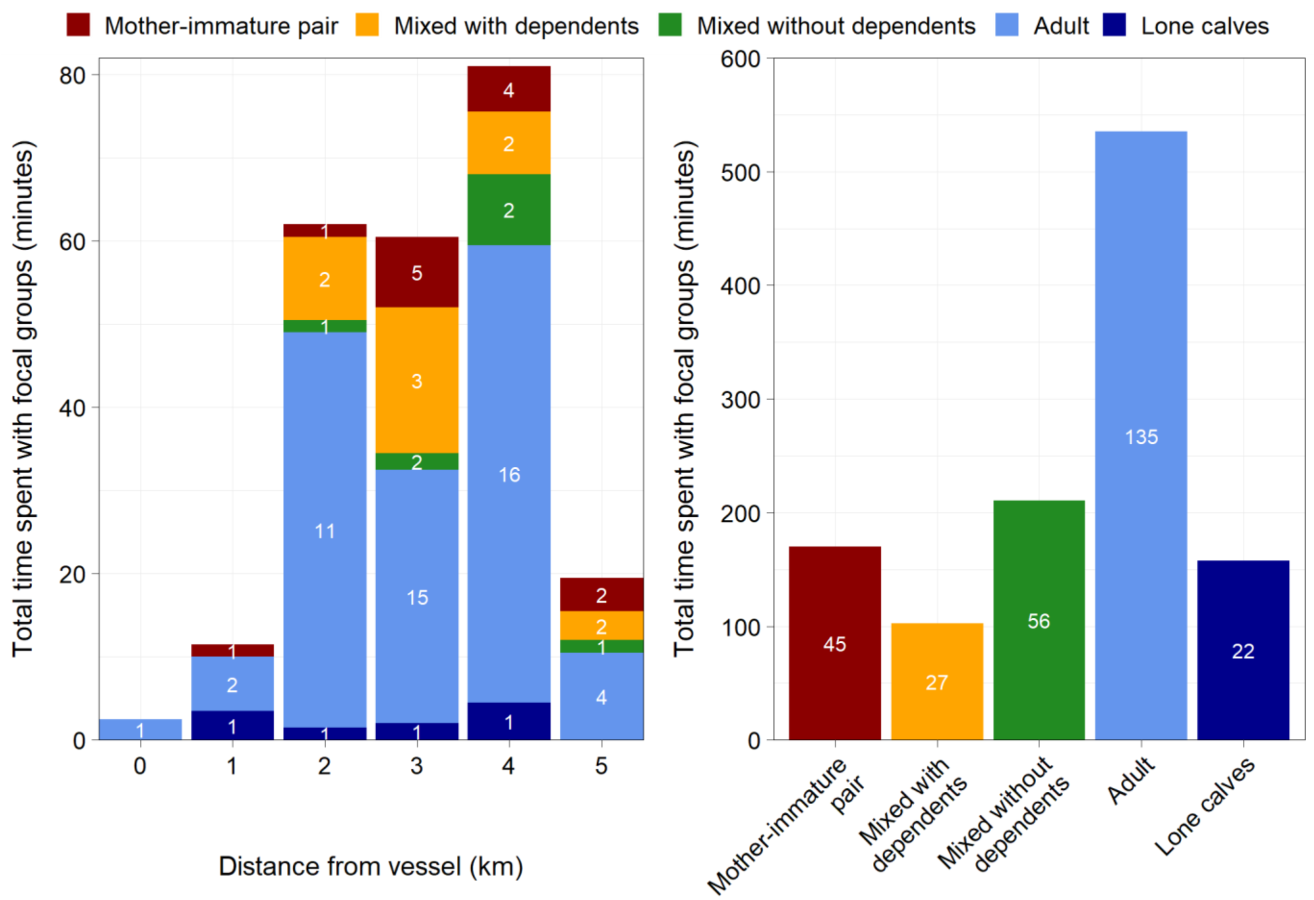

Figure 6-46: Total time spent with focal groups, presented relative to distance from vessel (vessels ≤ 5 km; left panel) and by group type when no vessels were present (vessels > 5 km; right panel). White text provides number of unique focal follows within each group type. Distances rounded to nearest km.

6.6.1 General Characteristics of Focal Groups

6.6.1.1 Group Size and Composition

The majority of the focal follow surveys conducted consisted of small group sizes (Figure 6-47). Focal groups comprised of two or fewer individuals accounted for 154 of the 249 focal follow surveys (62%). The same size groups accounted for 27 of the 43 surveys undertaken when vessels were present (63%) and for 131 of the 212 surveys when no vessels were present (within 5 km; 62%). Note that since 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 ten narwhal were only recorded during seven of the focal follow surveys; four in 2020 (maximum group sizes of 11 [two follows] and 13 [two follows]), and three in 2021 (maximum group sizes of 11, 12, and 18 individuals). In the absence of vessels, the median value of maximal group size was 2.0 narwhal, and the mean group size was 3.0 narwhal (SD of 2.8 narwhal). When vessels were present, the median value of maximal group size was 2.0 narwhal, and the mean group size was 2.5 narwhal (SD of 1.6 narwhal). Group sizes were generally similar between both sampling years, although more groups of larger sizes (≥7 narwhal) were recorded in 2021 compared to 2020 (Figure 6-47). These results should be interpreted with caution, however, due to non-random selection of focal groups (i.e., in 2021, 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.

In the analysis of group size, a mixed-effect model with a truncated Poisson distribution was used. The fixed effects included the effect of vessel presence within 5 km from the group, group type, and the interaction between the two variables. The group types were: mother-immature pairs, mixed groups with dependents, mixed groups without dependents, and adult groups (lone calves were removed from analysis). The random effect was an intercept of focal follow ID, which accounts for the variability between groups and the correlation of observations within group. No significant effect of vessel presence on group size was demonstrated (P=0.3 for both main effect of vessel presence and interaction between vessel presence and group type). That is, the effect of vessel did not differ between group types, and no significant effect of vessel presence was found. The statistical power to estimate the observed effect was calculated to be up to 0.75 (depending on group type; Appendix B). 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 a -38% or a +55% effect size of vessel presence (Appendix B).

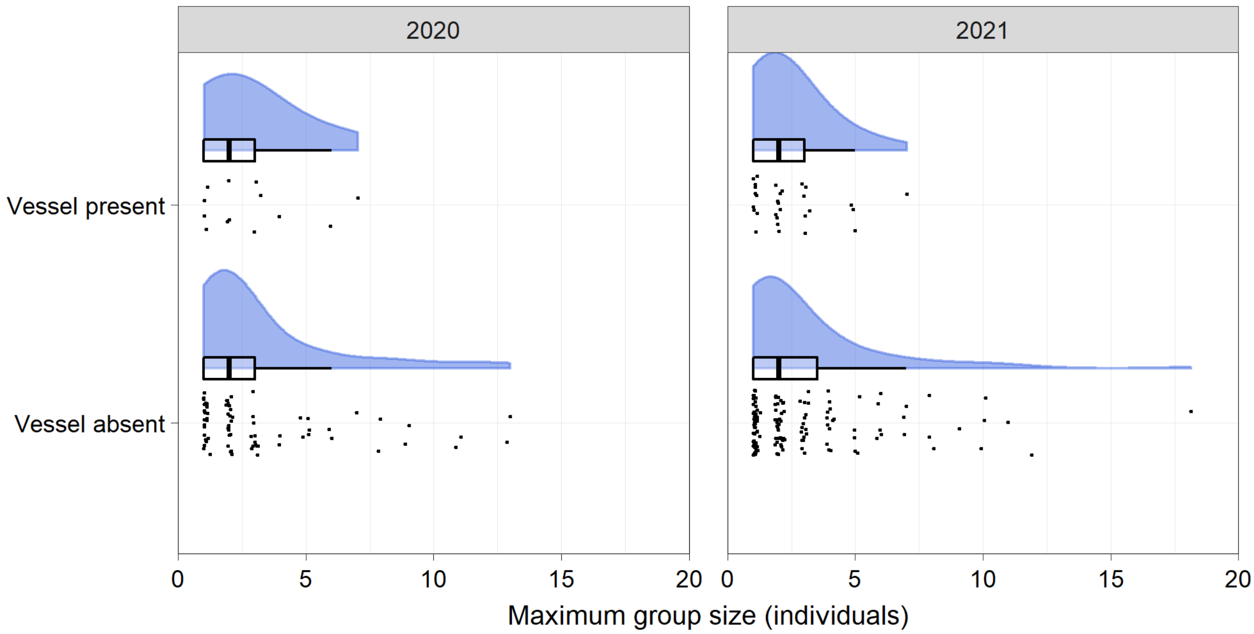

Figure 6-47: Narwhal maximum group size during focal follow surveys relative to vessel presence, 2020-2021. Points depict raw data (with added random jitter), boxplots show the 25th, 50th, and 75th quantiles (whiskers extend to 1.5 times the interquartile range), and the distribution of the data is provided as a probability density.

Of the focal groups, adult narwhal were observed most frequently (71% of all narwhal), followed by juveniles (16%), calves (7%) and yearlings (6%; Figure 6-48). During the 2021 season, 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, focal groups were comprised of 54% adults, 23% juveniles, 15% yearlings, and 8% calves. When no vessels were present, focal groups were comprised of 42% adults, 32% juveniles, 13% yearlings, and 6% calves. A total of 72 of the focal groups surveyed comprised one or more females with dependent young (36 in both 2020 and 2021), of which 13 coincided with vessel passages (six in 2020 and seven in 2021).

In the analysis of group composition relative to vessel presence, the model included a main fixed effect of vessel presence. Group composition was analyzed using a multivariate mixed model with an underlying Poisson distribution for each of the three response variables – count of adult, juvenile, and calf or yearling individuals within each group. The effect of vessel presence was not a significant predictor of group composition (P>0.2 for any of the three life stages). That is, no significant vessel effect on group composition was demonstrated.

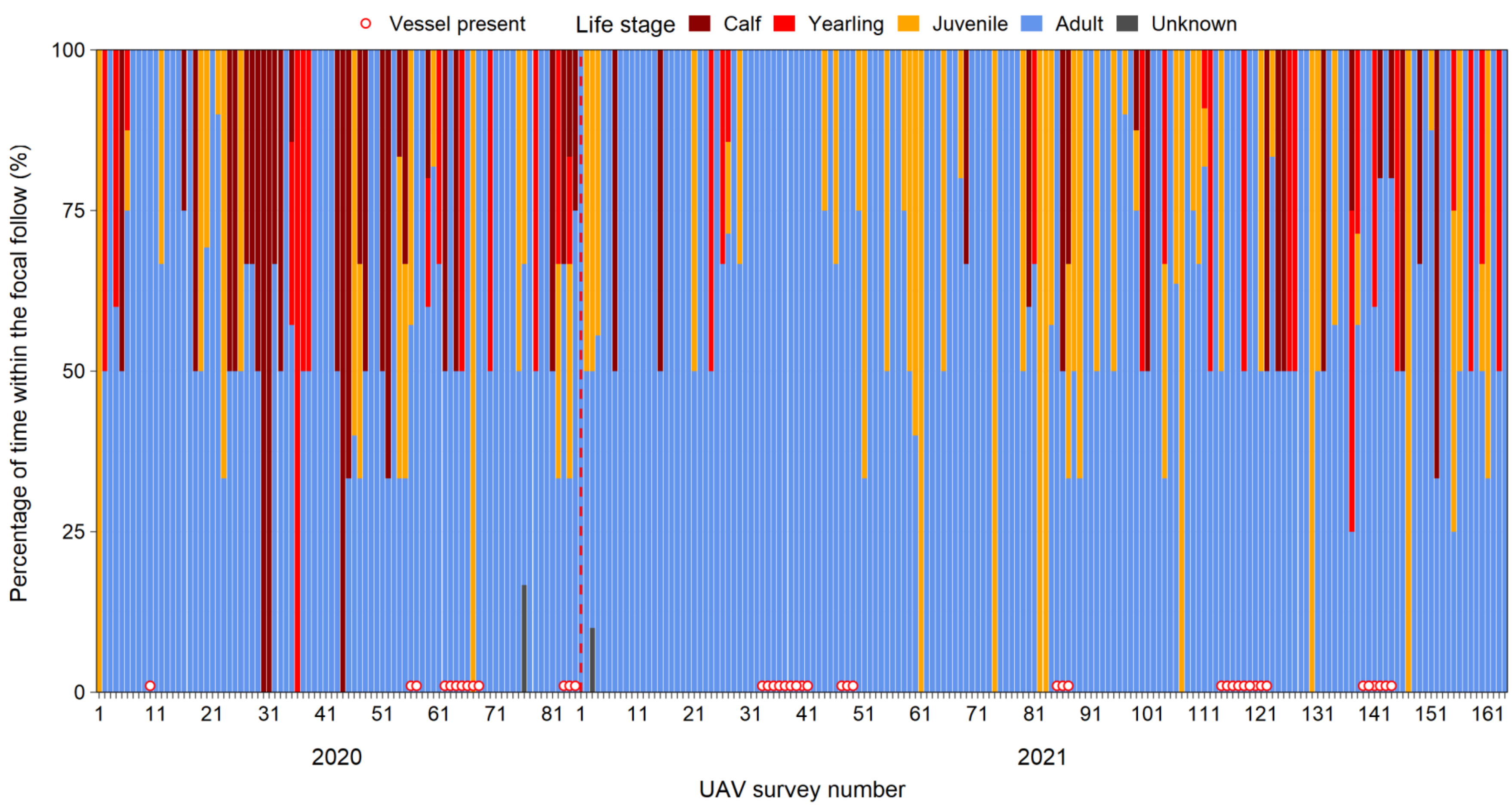

Figure 6-48: Group composition recorded during focal follow surveys, 2020-2021.

6.6.1.2 Group Formation and Spread

Of the followed groups, the most frequently observed group formation was parallel (42% of time), similar to the predominant formation recorded by shore-based observers in the BSA. This was followed by linear formation (23% of the time) and cluster formation (23% of the time; Figure 6-49). In the absence of vessels, the proportion of groups in parallel formation was lower (40% of the time) compared to when vessels were present (52%). In contrast, the proportion of groups in linear formation was higher in the absence of vessels (24%) relative to when vessels were present (15%). The proportion of groups in cluster formation was similar when a vessel was absent compared to when a vessel was present (23% and 26%, respectively).

Mother-immature pairs were generally observed in linear formation, whether in the absence (55% of the time) or presence of vessels (41-67% of the time, depending on distance (Figure 6-50). Note that this finding should be interpreted with caution 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 (55%) or presence of vessels (49-86% of the time, depending on distance). Mixed groups without immatures were most likely to be in parallel formation in the absence of vessels (32%) but were recorded mostly in linear formation when vessels were at 4-5 km from the groups and in cluster formation when vessels were at 2-3 km from the groups. Adult-only groups were often groups of a single animal when vessels were absent (58% of the time) or present (15%-82% of the time, depending on distance from vessel). When adult-only groups had at least two individuals, groups were most commonly recorded in parallel formation (40% of time when vessels were absent and 42%-100% of the time when vessels were present, depending on distance from vessel). Lone calves were usually in a group comprised of a single individual (82% of the time in absence of vessels and 100% of the time in presence of vessels).

In the analysis of group formation as a function of vessel presence, the model included a main fixed effect of vessel presence. Group type was not included as a predictor due to low sample size; instead, groups were analyzed as “groups with immatures” and “groups without immatures”. Group formation was analyzed as a multinomial variable, with three categories – parallel, cluster, and linear formations. The effect of vessel presence was not significant for either group formation ($P>0.25$ for all three formations in both groups with and without immatures). That is, no significant vessel effect on group formation was demonstrated. The statistical power to estimate the observed effect sizes was low (<0.25 for all; Appendix B). That is, the observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). Of the assessed effect sizes, ranging from -100% to +300%, none had sufficient power (≥0.8; Appendix B).

Of the followed groups, narwhal groups were shown to spend less time in a “tight” spread compared to a “loose” spread (42% and 58% of the time, respectively; Figure 6-51). In the absence of vessels, the proportion of time that narwhal groups spent tightly associated was higher (44% of the time) compared to when vessels were present (32% of the time). Mother-immature pairs were generally observed tightly associated, whether in the absence (82% of the time) or presence of vessels (41-100% of the time, depending on distance (Figure 6-52). In comparison, mixed groups with immatures were mostly observed loosely associated, whether in the absence (79%) or presence of vessels (86-100% of the time, depending on distance). Mixed groups without immatures were most likely to be loosely associated in the absence of vessels (48%), but their distal association varied in the presence of vessels, from 100% loose at 5 km (three cases) to 100% tight at 2 km (three cases). Adult-only groups were often groups comprised of a single animal; representing (58% of the time when vessels were absent and 15%-82% of the time when vessels were present (depending on distance from vessel). When adult-only groups were comprised of at least two individuals, groups were most commonly recorded in loose spread (73% of time when vessels were absent and 23-86% of the time when vessels were present, depending on distance from vessel). Lone calves were usually in a group of a single individual (82% of time when vessels were absent and 100% of time when vessels were present). In the absence of vessels, when groups of two calves were recorded, groups were in tight and loose spreads 10% and 8% of the time, respectively.

In the analysis of group spread relative to vessel presence, the model included a main fixed effect of vessel presence, a main fixed effect of group type, and an interaction between the two (group types were adult, mother-immature pairs, mixed with immatures, and mixed without immatures; lone calves were excluded from the analysis as groups of more than a single lone calf were not recorded when vessels were present). The interaction between vessel presence and group type was significant (P=0.027), indicating that the effect of vessel presence on group spread differed between group types. Comparisons between vessel presence and absence within each group type found that mother-immature groups were marginally more likely to be loosely associated when vessels were present (P=0.071); no effects were found for other group types (P>0.2 for all). The statistical power to estimate the observed effect was calculated to be up to 0.7 (depending on group type; Appendix B). 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 vessel presence when effect sizes were larger than +600% (Appendix B).

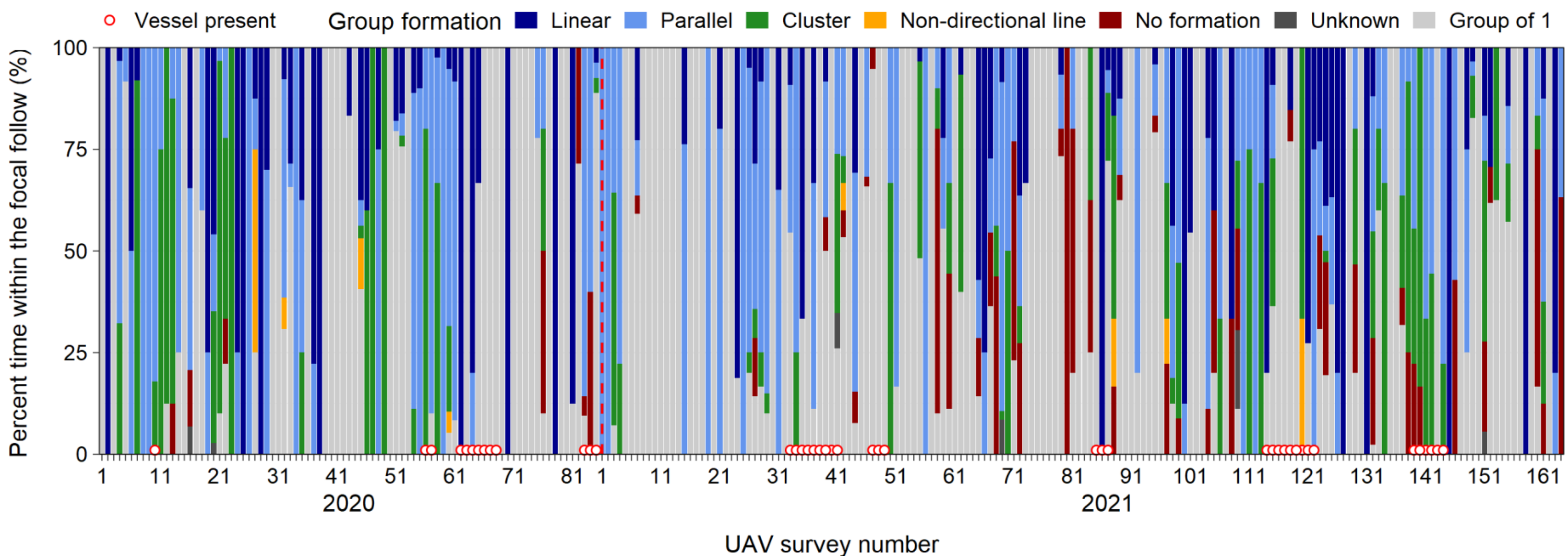

Figure 6-49: Group formation recorded during focal follow surveys, 2020-2021.

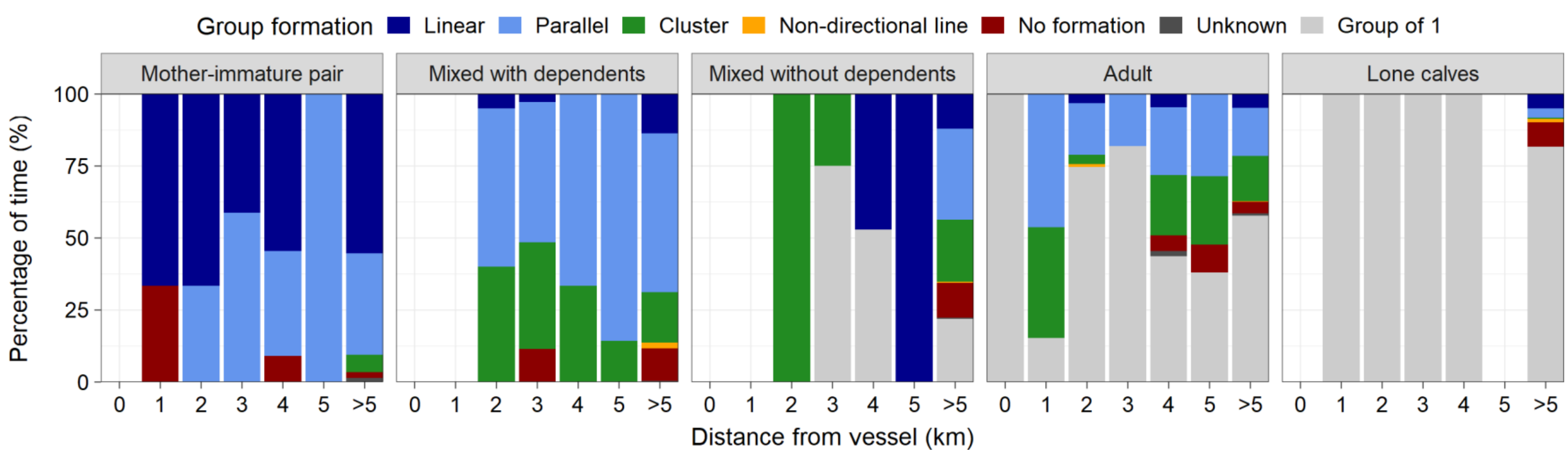

Figure 6-50: Percentage of time narwhal groups spent in each formation relative to distance from vessel, presented by group type.

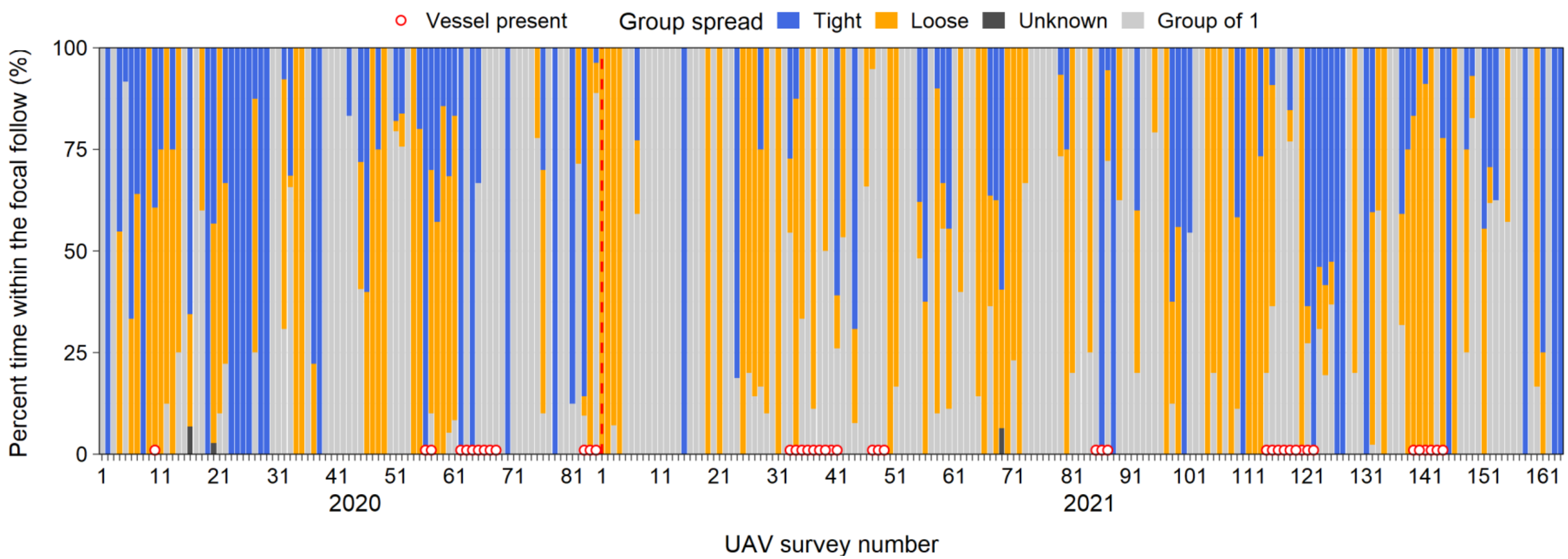

Figure 6-51: Group spread recorded during focal follow surveys, 2020-2021.

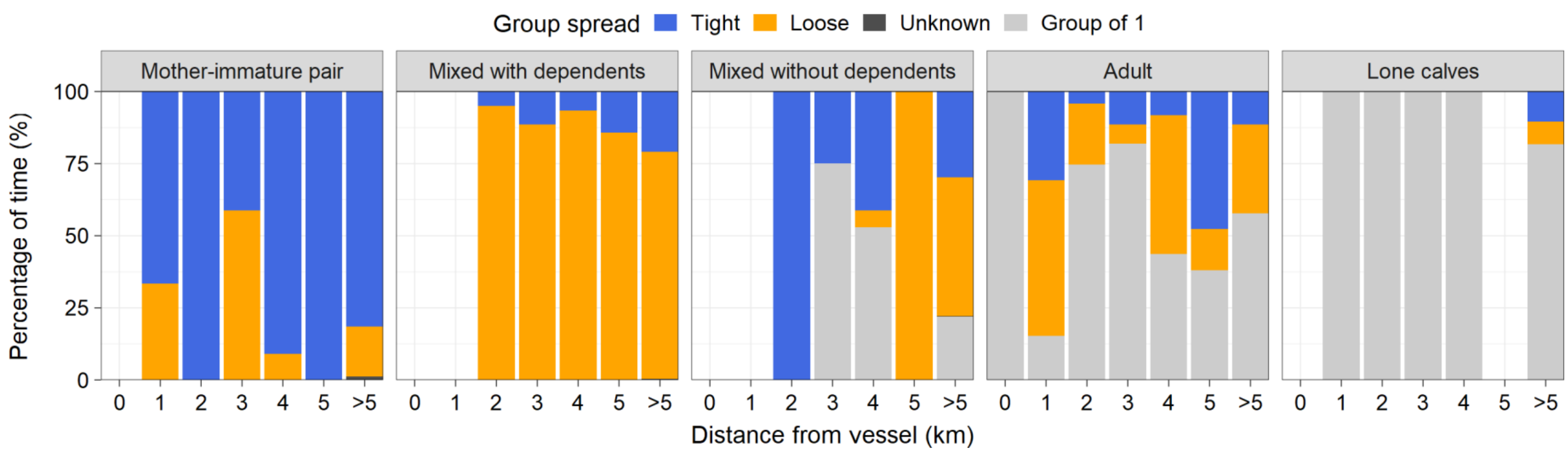

Figure 6-52: Percentage of time narwhal groups closely associated relative to distance from vessel, presented by group type.

6.6.1.3 Primary and Unique Behaviours

Primary behaviours assessed included travelling (i.e., directional movement), milling (i.e., non-directional movement), 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, narwhal spent the majority of time travelling (71% of the time), followed by resting / milling (22% of the time) and social behaviours (7% of the time; Figure 6-53). The proportion of time groups spent travelling was slightly higher when vessels were present compared to when no vessels were present (80% and 70%, respectively). The proportion of time that narwhal spent resting or milling was similar when a vessel was present compared to when no vessels were present (23% and 18%, respectively). The proportion of time spent resting or milling for mother-immature groups was 35% in the absence of vessels and 9-67% in the presence of vessels (depending on distance from vessel), and the proportion of time that mixed groups with immatures spent resting or milling was 22% in the absence of vessels and 14% in the presence of vessels (only recorded when vessels were at 3 km from group). The proportion of time that narwhal spent performing social behaviours was slightly lower when a vessel was present compared to when no vessels were present (4% and 13%, respectively, assessed for groups comprised of ≥ 2 individuals).

Travelling was the most common primary behaviour for all group types, regardless of vessel presence (Figure 6-54). Resting/milling behaviour was observed by most group types and at various vessel approach distances, including several incidences at 1-2 km from the vessel involving mother-immature pairs and lone calves. When vessels were absent, the proportion of time spent resting/milling was 35% for mother-immature pairs and lone calves, 22% for mixed groups with immatures, 20% for adults and 11% for mixed groups without immatures. When vessels were present, the proportion of time spent resting/milling by narwhal group types was 17% and 9% for mother-immature pairs and lone calves, 6% for mixed groups with immatures, 21% for adults, and 19% for mixed groups without immatures.

When vessels were absent, social behaviours (assessed for groups comprised of ≥ 2 individuals) were most often recorded for lone calves (72%), followed by mixed groups without immatures (21% of the time). Adult groups performed social behaviours in 10% of surveyed time when vessels were absent, while mother-immature pairs performed social behaviours in 3% of the time. In the presence of vessels, social behaviours were recorded at 3 km from the vessel (mixed group with immatures, two cases, 3% of the time) and at 4-5 km from the vessel (nine cases for adult groups, 7% of the time). It is not known whether this result is due to generally sparse focal follow data in close proximity to vessels or due to a decrease in social behaviours when in close proximity to vessels.

In the statistical analysis of primary behaviour as a function of vessel presence, a multinomial mixed-effects model was used. The model included a main fixed effect of vessel presence and a random effect of focal follow ID. Primary behaviour was analyzed as a multinomial variable, with three categories – travel, resting/milling, and social. The effect of vessel presence was not a significant predictor of primary behaviours ($P>0.4$ for all behaviours). That is, no significant vessel effect on primary behaviour was demonstrated.

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 in 119 of 249 focal follow surveys (including during 47 surveys in 2020 and 72 surveys in 2021; that is in 55% and 44% of all groups in 2020 and 2021, respectively; Figure 6-55). When assessed as a proportion of time, unique behaviours were recorded in 27% and 21% of the total survey time in 2020 and in 2021, respectively. Of these, unique behaviours were observed 23% of the time when vessels were absent and 19% of the time when vessels were present. Horizontal rolling was observed 12% of the time in the absence of vessels and 15% of the time when vessels were present (141 min and 37 min, respectively), while vertical rolling was recorded 1% of the time when vessels were absent and 0.4% of the time when vessels were present (total of 15 min and 1 min of recorded video, respectively). For groups comprised of two or more individuals, rubbing was recorded 8% of the total survey time in the absence of vessels and 4% of the time when vessels were present (58 min and 5 min, respectively). Sexual displays were recorded in six groups in 2021 (FFIDs 41, 44, 56, 60, 99, and 164), over a total of 8 min (2% of all recorded video of groups of two narwhal or larger), and typically consisted of males revealing their genitals and rubbing against conspecifics, often involving groups of two or more males. No sexual displays were observed in 2020. Sexual displays were observed 1% of the time in the absence of vessels and 0.8% of the time when vessels were present (7 min and 1 min, respectively). Jousting, or “directed movement by one tusked individual (typically sudden) toward another”, was also observed during two focal follow surveys in 2020 (FFID 4 and 7) and during a single survey in 2021 (FFID 109); vessels were absent in all three cases.

In the analysis of unique behaviour displays relative to vessel presence within 5 km, a mixed effects model with a binomial distribution was used. The model included a main fixed effect of vessel presence, a main fixed effect of group type, and an interaction between the two (group types were adult, mother-immature pairs, mixed with immatures, mixed without immatures, and lone calves). The random effect was an intercept of focal follow ID. The interaction between vessel presence and group type was significant (P=0.023), indicating that the effect of vessel presence on display of unique behaviours differed between group types. That is, comparisons between vessel presence and absence within each group type found that mixed groups with immatures were significantly less likely to display unique behaviours in presence of vessels (P=0.036). Both adult groups and lone calf groups were marginally less likely to display unique behaviours in presence of vessels (P=0.052 and P=0.066, respectively). No significant vessel effects were found for mother-immature groups and mixed groups without immatures (P=0.5 and P=0.2, respectively). The statistical power to estimate the observed effect was high (>0.9) for one of the five estimated effect sizes (mixed groups without dependents; Appendix B). That is, one of the observed effect sizes was larger than the effect size required to achieve sufficient statistical power (≥0.8). The model had sufficient power (≥0.8) to detect vessel presence when effect sizes were larger than +100% (Appendix B).

Nursing behaviour by immatures was observed in 24 of the 62 focal follow surveys conducted on groups with immatures when vessels were absent (39%), accounting for 9.6% of all focal follow surveys completed in 2020 and 2021 (n=249). In the 24 focal groups where nursing was observed and vessels were absent, the proportion of time nursing ranged from 5% to 63% (mean -= 25%; SD = 17%). In comparison, nursing behaviour by immatures was observed in 2 of the 13 focal follow surveys that included vessel presence (15%), accounting for <1% of all focal follow surveys undertaken (n=249). In these 2 focal groups, the proportion of time nursing was 42%.

In the absence of vessels, unique behaviours were recorded most often for mother-immature pairs (36% of the time), followed by mixed groups without and with immatures (30% and 29% of the time, respectively; Figure 6-56). Adult groups and lone calves displayed unique behaviours less often, 16% and 22% of the time, respectively.

When vessels were present, unique behaviours were recorded for all group types. Depending on distance from the vessel, unique behaviours were recorded 12-38% of the time for mother-immature pairs, 23-57% of the time for mixed groups with immatures, 12% of the time for mixed groups without immatures (4km from vessel), 7-46% of the time for adult groups, and 33-43% of the time for lone calves. Overall, the closest vessel approach distances in which unique behaviours have been recorded in the presence of a vessel was 3 km for mother-immature pairs (12% of the time), 2 km for mixed groups with immatures (30% of the time), and 1 km for adult groups (39% of the time) and lone calves (43% of the time).

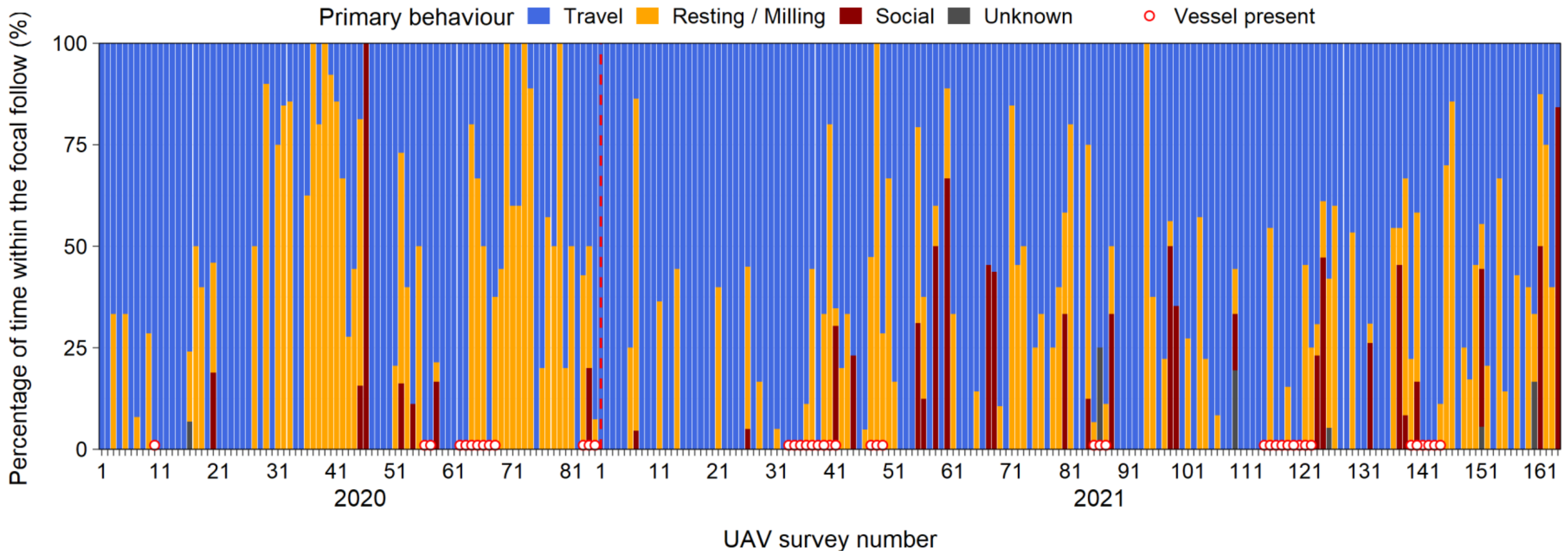

Figure 6-53: Primary behaviour recorded during focal follow surveys, 2020-2021.

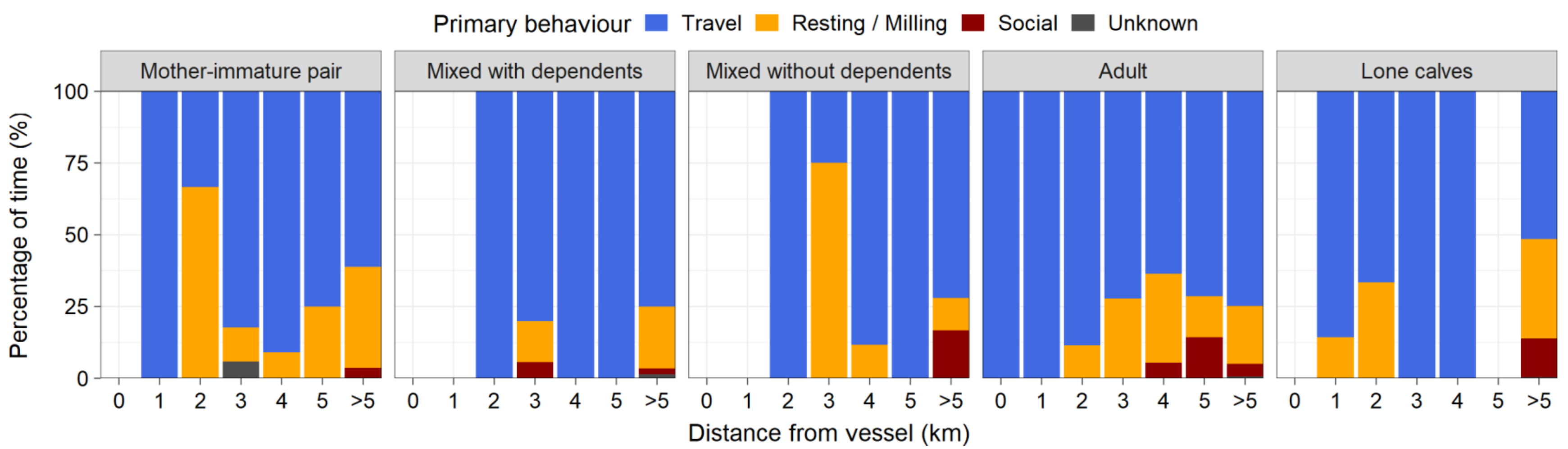

Figure 6-54: Percent time narwhal groups performed primary behaviours relative to distance from vessel, presented by group type.

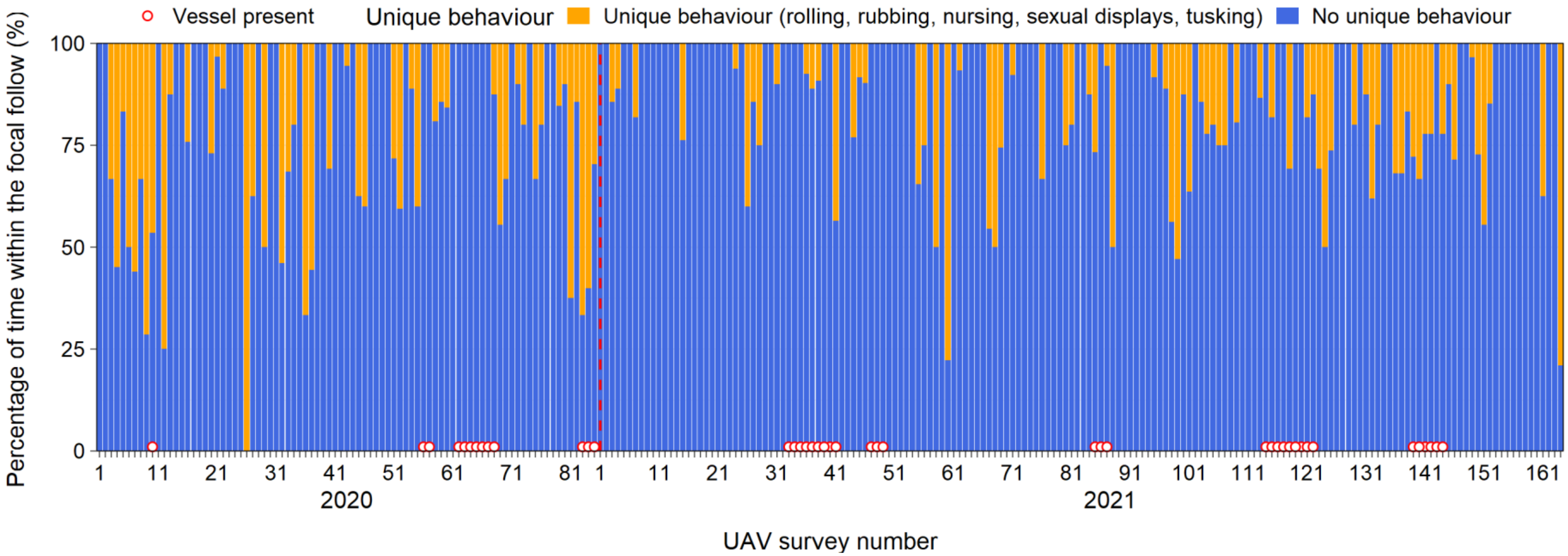

Figure 6-55: Unique behaviours recorded during focal follow surveys, 2020-2021.

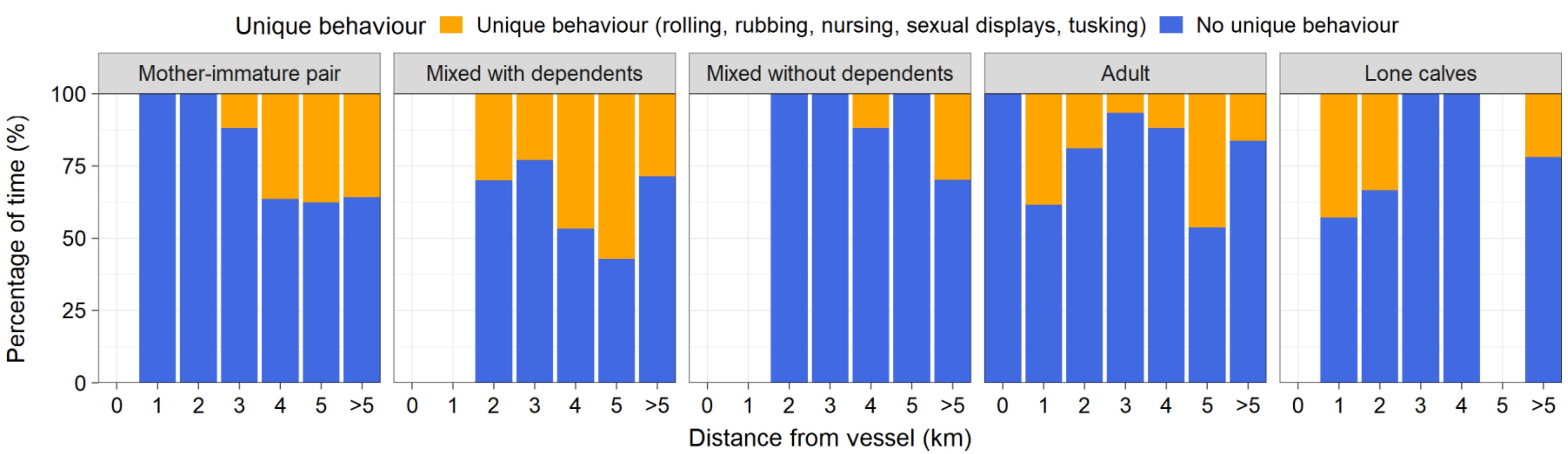

Figure 6-56: Percent time narwhal groups engaged in unique behaviours relative to distance from vessel, presented by group type.

6.6.2 Focal Groups with Immatures (i.e., Calves or Yearlings)

As presented in section 6.6.1.3, nursing behaviour was observed by an immature (i.e., calf or yearling) during 24 of the total 249 focal follow surveys conducted (Figure 6-57). Of these, nursing was observed for between 5% of the total focal follow survey duration (FFID 137 in 2021) and 63% of the total focal follow survey duration (FFID 81 in 2020), with a mean of 25% of the focal follow survey length (SD of 17%).

All focal follow surveys that included immatures in the presence of vessels (n=13) are shown in Figure 6-58, relative to distance from vessel, group type, and nursing behaviour. The 13 focal groups with immatures consisted of mother-immature pairs, mixed groups with immatures, and lone calf groups, of which 11 focal groups included a single immature and two focal groups included two immatures. Nursing was recorded in two of the 13 surveys when a vessel was present. In the first survey, the immature in FFID 83 (2020) engaged in nursing for a prolonged period of time (5 min of the total 10 min focal follow survey), commencing nursing when the vessel was outside of the 5 km exposure zone cut-off, and continuing to nurse as the distance to the vessel decreased to 4.5 km, at which point the UAV had to return due to battery limitations. In the second survey, the immature in FFID 122 (2021) was observed to nurse for a single 30 s period at a point in the survey when the vessel was outside of the 5 km exposure distance. When no vessels were present, nursing was recorded in 24 out of 62 focal follow surveys that included mother-immature pairs (39%), and nursing periods ranged from a minimum of a single 30 s period (four focal follow surveys) to a maximum of 5 min (one focal follow survey), with a mean of 4.3 min and SD of 2.4 min.

In the analysis of nursing activity relative to vessel presence, a mixed-effects model with a binomial distribution was used. The model only included a main fixed effect of vessel presence, given that insufficient information was available to further break the data by group type. The random effect was an intercept of focal follow ID. The main effect of vessel presence was not significant (P=0.09); that is, no significant effect of vessel presence was found on nursing activity in the 2020-2021 dataset. The statistical power to estimate the observed effect was low (<0.1; Appendix B). 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 vessel presence for any of the examined effect sizes, ranging from -100% to +600% (Appendix B).

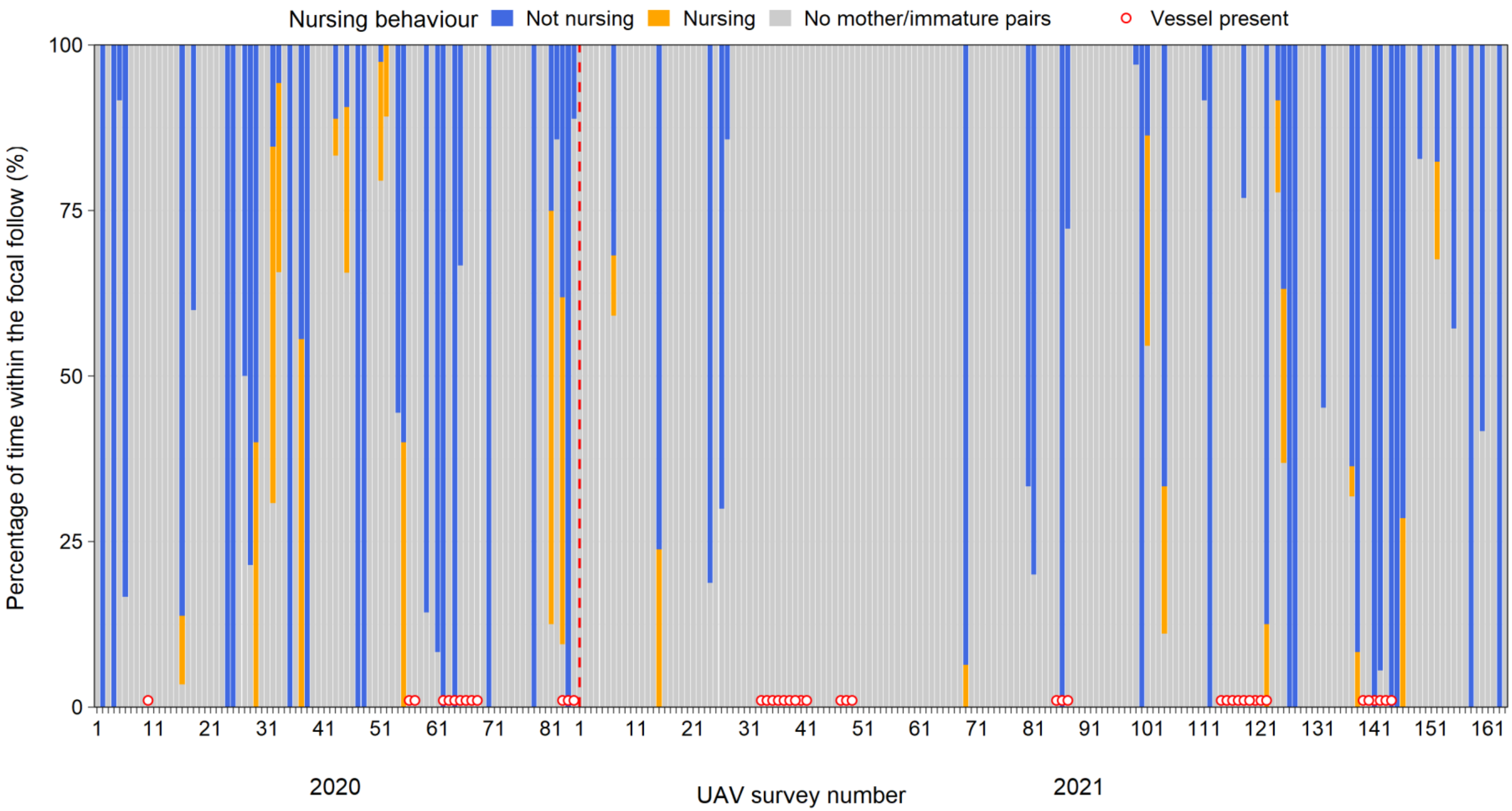

Figure 6-57: Nursing behaviour recorded during focal follow surveys, 2020-2021.

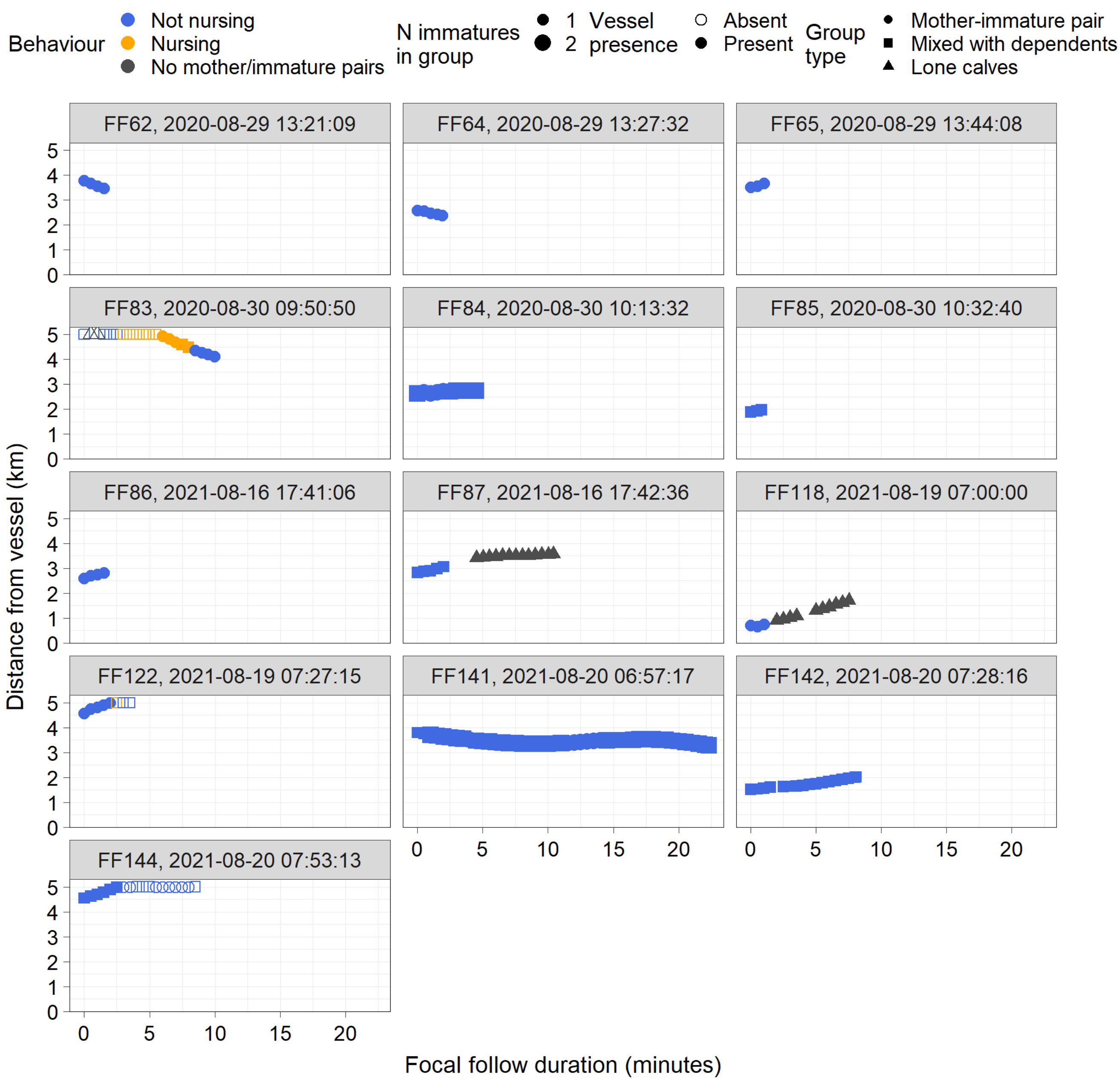

Figure 6-58: Presence of nursing behaviour (yellow) observed in focal follow surveys that included immatures during vessel exposure, 2020-2021.

Of the followed groups, immatures were most often recorded underneath their presumed mother compared to abreast (i.e., to the left or to the right), behind, or above in both the presence and absence of vessels (40% and 49% of the time, respectively). Position of immature often changed, with up to four relative positions recorded for a single individual within a single survey (Figure 6-59). Immatures positioned abreast their mother comprised the second most common relative positions (39% of the time in the absence of vessels and 27% of the time when a vessel was present). The proportion of time that immatures were recorded on top of their mother was 28% in the presence of vessels, but only 7% when no vessels were present. The relative and distal position of immatures in relation to their mothers for the 13 focal follow surveys conducted in the presence of vessels are shown in Figure 6-60 relative to distance from vessel. Note that the strong increase in proportion of immatures recorded on top of the mother during vessel exposure was likely due to the immature recorded in FF141, who was observed on top of the mother for the majority of the focal follow survey, affecting the overall distribution of relative positions during vessel exposure.

In the analysis of relative position of immatures relative to vessel presence, a multinomial mixed effects model was used. The model included a main fixed effect of vessel presence and a random effect of focal follow ID. Relative position of immatures was analyzed as a multinomial variable, with four categories – in front/behind, abreast, top, and under the adult. Vessel presence had a significant effect on the “top” relative position ($P<0.001$), with immatures observed adjacent to their mother’s dorsal ridge significantly more often in the presence of vessels than in the absence of vessels. Vessel presence did not have a significant effect on any of the other relative positions ($P>0.3$ for all). The statistical power to estimate the observed effects was low (up to 0.52.; Appendix B). 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 large negative effects (approximately -90% effects; Appendix B).

When an immature was positioned underneath of the presumed mother, it was tightly associated with the adult 99% of the time (Figure 6-60). This association was not affected by vessel presence (97% in presence of vessel and 99% when no vessels were present). In comparison, immature narwhal were tightly associated with the presumed mother 84% of time when positioned above the adult (90% in presence of vessel and 78% in absence of vessel), 65% of the time when they were positioned abreast (52% in presence of vessels and 67% in absence of vessels), 20% of the time when they were in front of the adult (0% in presence of vessels and 25% in absence of vessels), and only 13% of the time when they were behind the adult (20% in presence of vessels and 10% in absence of vessels).

In the analysis of immature association to an adult relative to vessel presence within 5 km, the model included a main fixed effect of vessel presence and a main fixed effect of group type; no interaction was included due to lack of convergence, likely because of insufficient data. The main effect of vessel presence was not significant ($P=0.11$). That is, no significant effect on spread of immature was found. The statistical power to estimate the observed effect was low (<0.2; Appendix B). 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 a +550% effect size in the test of the effect of vessel presence (Appendix B).

Additional monitoring is required to increase the sample size of focal follow surveys conducted in the presence of vessel traffic (given that the current sample size is limited to only 3.9 h of observational data).

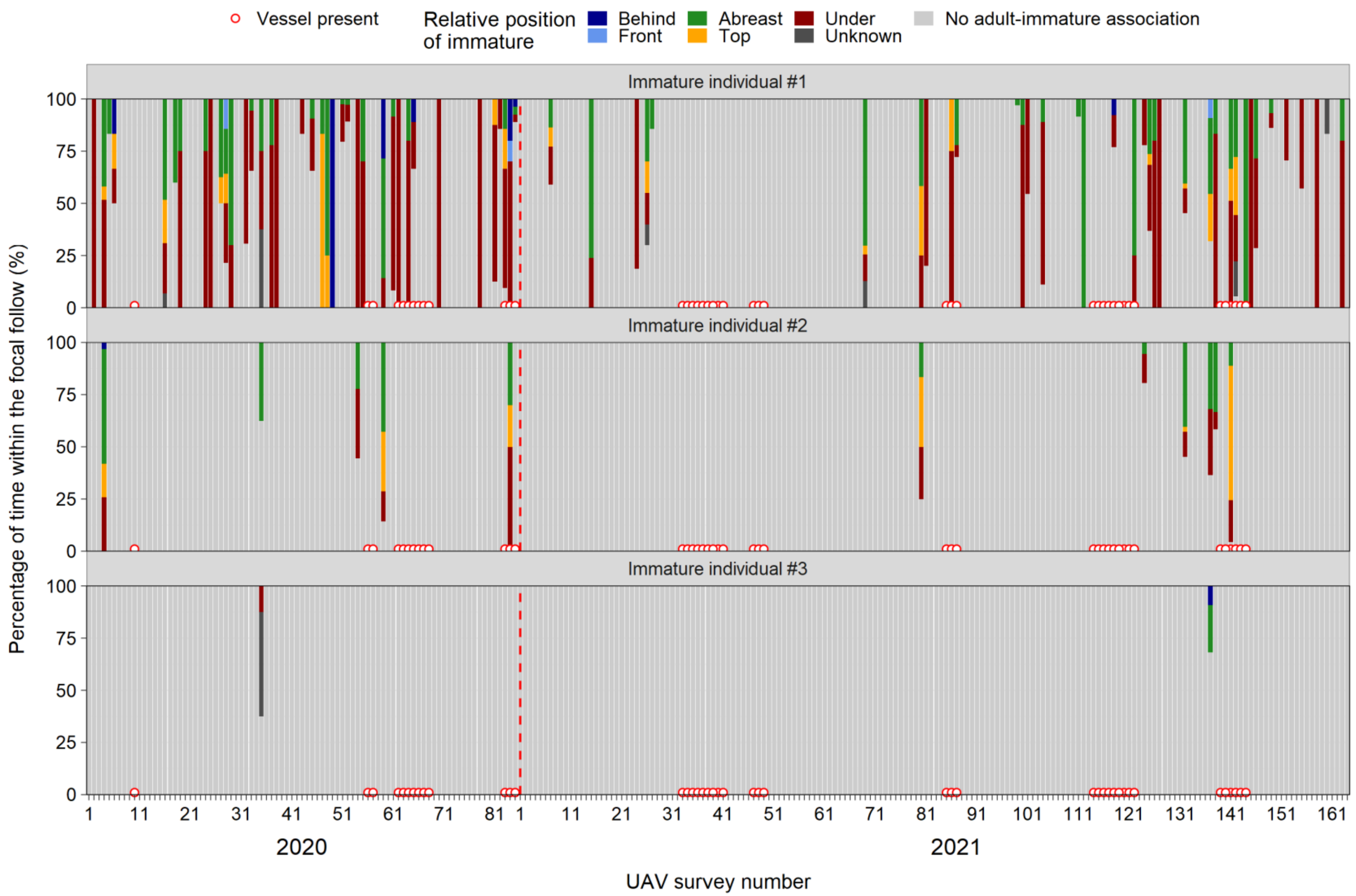

Figure 6-59: Relative position of immatures recorded during focal follow surveys. A separate plot is presented for each individual calf or yearling in a given group, 2020-2021.

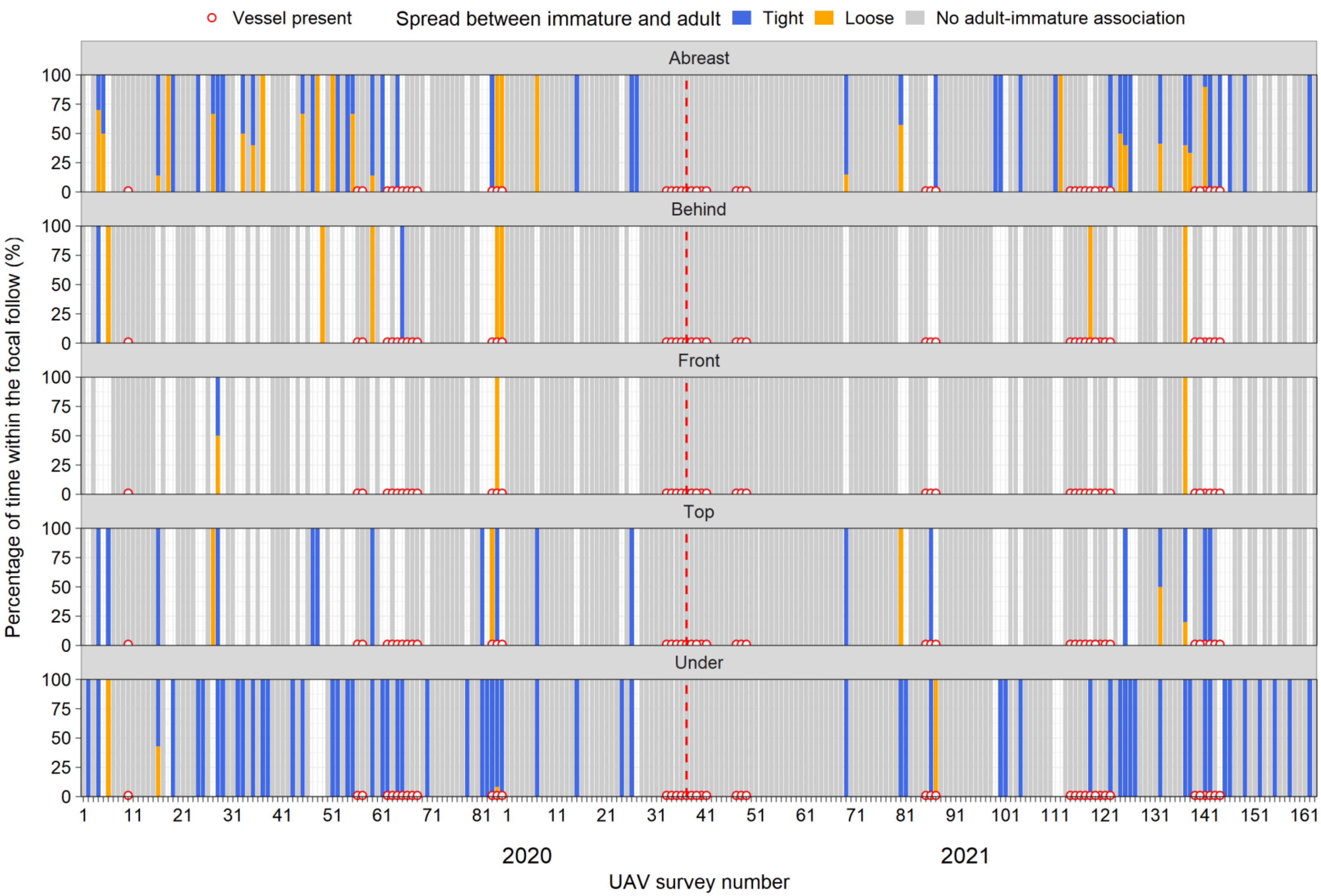

Figure 6-60: Position and spread of immatures relative to the presumed mother recorded during focal follow surveys, 2020-2021. A separate plot is presented for each known relative position.

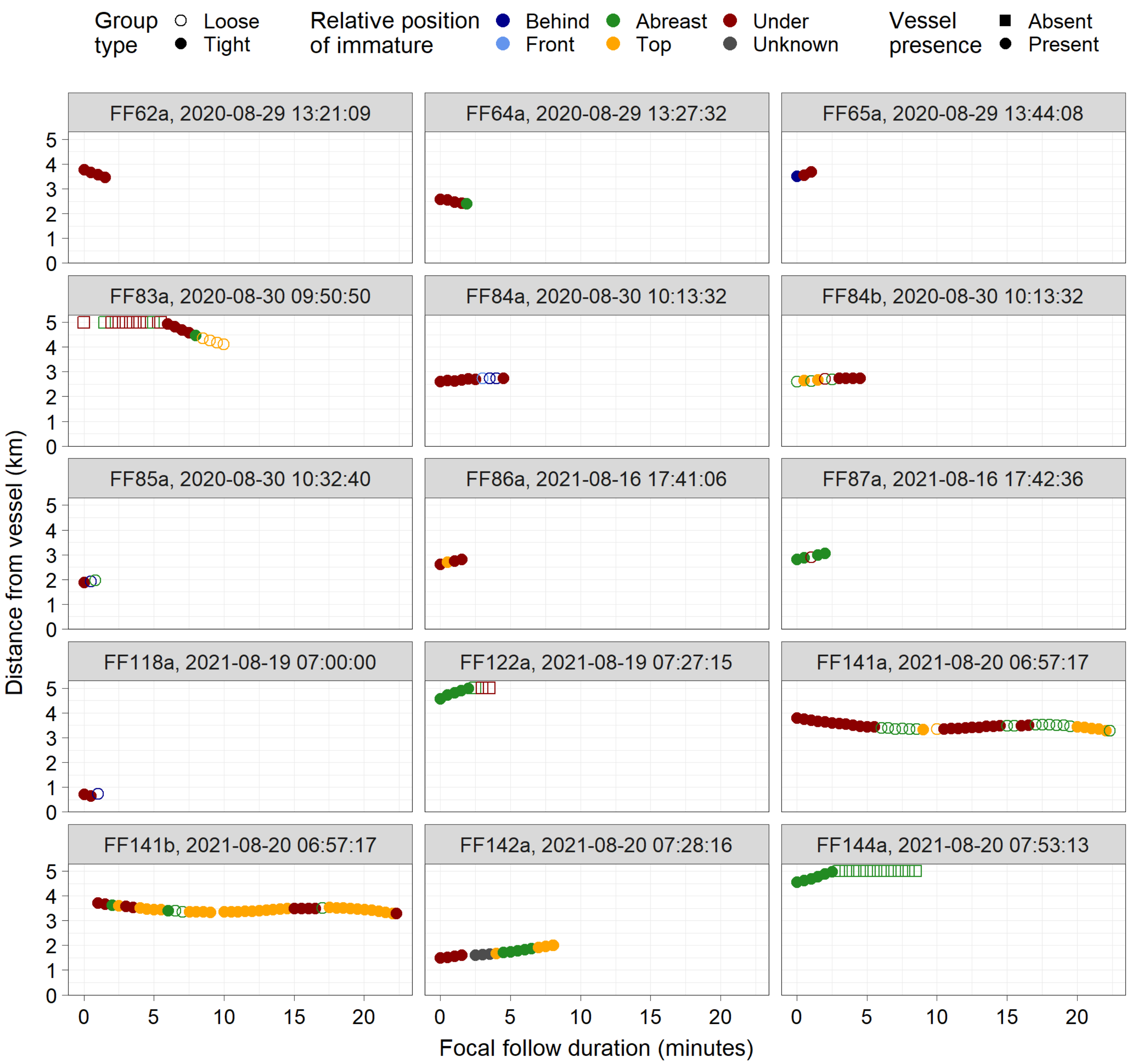

Figure 6-61: Relative and distal position of immatures in relation to their presumed mother, relative to distance from vessel, 2020-2021.

6.6.3 Anecdotal Observations (UAV)

A number of narwhal groups were re-sighted during focal follow surveys conducted via UAV. Notably, a pair of calves were re-sighted throughout the 2021 field season during at least four separate surveys (i.e., FFIDs 80, 124, 132, and 152; Figure 6-62). Both calves were observed nursing from their respective mothers during some portion of the surveys and tended to interact closely with one another for extended periods, often while their mothers dove out of sight. The mother of one of the calves had a clearly identifiable “S scar” on its back (also identifiable in FFID 137).

Figure 6-62: Two mother-calf pairs resighted several times throughout the 2021 field season identifiable by the "S scar" on the dorsal side of the leading adult and white patch visible on second adult’s fluke. Both pairs observed together on (a) 19 August 2021 at 15:48 (FFID #125) and b) 19 August 2021 at 16:38 (FFID #132). Single pair including “S scar” mother and calf resighted with unidentified yearling on (c) 20 August 2021 at 06:24 (FFID # 137.

During the 2021 field season, a single adult narwhal with two tusks was recorded (FFID #91; Figure 6-63), representing the second time that an individual with two tusks has been observed during the two years of focal follow surveys. A single individual with two tusks was recorded in 2022 mixed in with a group of five other narwhal with the group engaged in prolonged social (and possibly sexual) behaviour in the BSA. This event was also captured on video by the UAV team.

Figure 6-63: Adult narwhal possessing two tusks observed during UAV focal follow survey (FFID #91), 16 August 2021.

6.7 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; Golder 2020c) affirming the importance of Koluktoo Bay as a summering ground for narwhal during the open-water season.

The majority of narwhal recorded in the BSA over the seven years of data collection were engaged in travelling behaviour. Other behaviours observed in the BSA included nursing, rubbing, tusking, foraging, socializing and mating. In all years of the program, narwhal calves have been commonly observed, with evidence of nursing behaviour recorded in 2015 (two occasions), 2016 (four occasions), 2017 (two occasions) and 2019 (seven occasions). With the introduction of the UAV Program in 2020, nursing behaviour was observed during 12 focal follow surveys in 2020 and 12 focal follow surveys in 2021. 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 narwhals to ore carrier traffic is variable, ranging from ‘no obvious response’ in which animals remain in close proximity to ore carriers as they transit through the SSA, to temporary and localized displacement and related changes in behaviour.

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

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.

6.7.1 Other Cetacean Species

Several other cetacean species were observed in the SSA during the 2021 field season at Bruce Head (Table 6-14). On 10 August 2021 at approximately 06:30, a small pod of four killer whales (*Orcinus orca*) was observed travelling south through the BSA in relatively close proximity to shore. It was suspected that the killer whales may have successfully ambushed a pod of narwhal, however this was not possible to confirm. That is, the killer whales were observed heading directly toward a group of idle narwhal in substratum J2, at which point several narwhal fled toward Koluktooo Bay, followed shortly after by gulls and fulmars observed gathering in the area near the killer whales. The pod was again observed on 10 August 2021 at approximately 14:30 travelling outbound of the SSA. Leading up to the arrival by killer whales to the area, there were sporadic sightings of narwhal within the SSA. No narwhal were observed in the SSA following the sighting of killer whales. On this single day that killer whales were sighted in the SSA during the 2021 field season, the aerial survey team reported narwhal sightings deep into Koluktoo Bay and Assomption harbor.

A group of three bowhead whales (*Balaena mysticetes*) were recorded along the far shore of Milne Inlet on 2 August 2021 between 13:51 and 15:38 and a single bowhead whale was observed travelling through the BSA on 4 August 2021 at 21:45 and 12 August at 09:02. A single beluga whale (*Delphinapterus leucas*) was observed in the BSA on the afternoon of 8 August 2022.

Table 6-14: Other cetacean species observed in the SSA during the 2021 Bruce Head Program

Species	Date of Record	Number of Individuals
Killer whale (*Orcinus orca*)	10 August 2021	4
Beluga whale (*Delphinapterus leucas*)	8 August 2021	1
Bowhead whale (*Balaena mysticetes*)	2 August 2021	3
	4 August 2021	1
	12 August 2021	1

7.0 DISCUSSION

7.1 Relative Abundance and Distribution

Overall, the relative abundance of narwhal (total number of narwhal corrected for survey effort) in the Bruce Head study area was substantially lower in 2020 and 2021 than in previous survey years (2014-2019), including years prior to the start of Baffinland's iron ore shipping operations in the RSA (i.e., 2015). The observed decrease in local narwhal abundance at Bruce Head in 2021 is consistent with findings from the 2020 and 2021 aerial surveys which indicated that narwhal abundance in Eclipse Sound were statistically lower in 2020 and 2021 than in previous survey years (2013, 2016 and 2019) (Golder 2022). However, the combined narwhal abundance in Eclipse Sound and Admiralty Inlet was shown to be similar in 2020 to that observed in previous survey years (2013 and 2019); and was statistically higher in 2021 than in previous survey years (2013, 2019 and 2020) (Golder 2022). Collectively, these results suggest one or more of the following:

- A portion of the Eclipse Sound stock occupied the Admiralty Inlet summering ground during the 2020 and 2021 open-water seasons. Potential primary drivers of displacement considered in 2020 included i) acoustic disturbance effects from icebreaking, ii) acoustic disturbance effects from construction activities (e.g., Year 1 of impact pile driving) associated with the Pond Inlet Small Craft Harbour (SCH) Project, and/or iii) increased killer whale presence in the RSA (Golder 2021c). Note that open-water shipping was not identified as a likely contributing factor to the observed decline in 2020 for reasons identified in Baffinland (2021), and that rationale remains valid for 2021.
- Favorable environmental conditions (e.g., prey availability, ice coverage, lower predation pressure) during the spring and/or summer seasons in Admiralty Inlet may have attracted a larger influx of narwhal from the Eclipse Sound summer stock, and potentially from other proximal summer stock areas (i.e., Somerset Island, East Baffin Island) during the 2020/2021 open-water seasons.
- There is a natural exchange of narwhal between the two putative summer stock areas (i.e., Eclipse Sound and Admiralty Inlet) during the open-water season. This has been previously suggested by DFO based on historical aerial survey results (Doniol-Valcroze et al. 2015, 2020; DFO 2020b) and telemetry studies (DFO 2020b). Natural exchange of narwhal between these stock areas during the open-water season is also strongly supported by available Inuit Qaujimajatuqangit (IQ) (NWMB 2016a, 2016b; QWB 2022).
- As noted in Golder (2021c), the above factors may have independently or cumulatively contributed to the observed decrease in narwhal numbers in Eclipse Sound. Prior to the start of the 2021 shipping season, it was not possible to determine whether one of these factors alone was the source of the narwhal decline in Eclipse Sound, whether the combined influence of one or more of these factors was responsible, or whether the observed change was natural in occurrence.

If it was determined that the change in narwhal in the RSA was a result of Project activities, this would be consistent with a high severity response (Southall et al. 2021) as discussed in Section 3.0 and would be considered a significant alteration of natural behavioural patterns of narwhal in the RSA and/or disruption to their daily routine. This finding would be contrary to 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.

Baffinland's commitment to the community of Pond Inlet to not undertake icebreaking during the early shoulder season of 2021 provided an opportunity to determine whether Project activities were the cause of the observed changes in narwhal abundance in Eclipse Sound in 2020 (Baffinland 2021; Golder 2021c). The precautionary and temporary adaptive management measure applied in 2021 eliminated the possibility of acoustic disturbance to narwhal from icebreaking during the timing of narwhal migration into Eclipse Sound in 2021, and also served to avoid the potential for cumulative noise effects associated with the Pond Inlet SCH Project. As a result of this, underwater noise from icebreaking operations was not considered to be an influencing factor on narwhal abundance in Eclipse Sound during the 2021 season. It also provides additional confidence that observed changes in 2020 were likely not a result of Project activities (i.e., early shoulder season icebreaking).

With respect to underwater noise generated by the SCH construction in Pond Inlet, DFO confirmed that impact pile driving undertaken in 2021 was limited to seven days between 24 June and 01 July (DFO 2021), prior to breakup of the landfast ice and what DFO stated to be the possible arrival of narwhal into Eclipse Sound. DFO therefore concluded that underwater noise from pile driving could not be considered an influencing factor on narwhal abundance in Eclipse Sound or nearby waters during the 2021 season (DFO 2021). No further analysis on this can be completed given the lack of publicly available data. Any additional analysis would remain the responsibility of the Proponent for the SCH construction Project and associated regulatory authorities (i.e., DFO).

<u>Other Considerations:</u>

For the past three consecutive years (2019-2021), 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 indicates 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 is a 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). All of these surveys (i.e., 2004, 2010, 2013) occurred prior to the start of Baffinland iron ore shipping operations

Following is a summary of publicly 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 NEBI area. 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 (NIRB 2016)

- *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)*

In summary, despite the adaptive management measure of eliminating underwater noise from icebreaking in 2021, results from the 2021 monitoring programs again indicated lower narwhal numbers in Eclipse Sound during the 2021 shipping season. While underwater noise from open-water shipping cannot be ruled out as a potential cause of narwhal displacement from the RSA, monitoring results collected to date demonstrate that responses to Project-related shipping activities are temporary and localized, suggesting that there are likely other factors contributing to the observed change (Austin et al. 2022a, 2022b; Baffinland 2021; Golder 2020a, 2021b).

Given that the combined stock estimate for Admiralty Inlet and Eclipse Sound indicates that the regional narwhal population remains stable relative to pre-shipping conditions, and in consideration of the available IQ regarding the degree of exchange between narwhal groups on their summering grounds, the observed decrease in narwhal relative abundance in Eclipse Sound likely reflects natural exchange between the two putative stock areas, or alternatively, that animals shifted to Admiralty Inlet due to more favorable ecological conditions related to sea ice conditions, prey availability and/or predation pressure. 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. 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 in order to cope with climate change, and that summer narwhal habitats in this region are predicted to decline by between 31 and 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 changes in summer narwhal distribution in Eclipse Sound). To better understand what is occurring, additional engagement and monitoring with Inuit stakeholders and regulatory agencies are needed, inclusive of collaborative regional scale monitoring that looks at the population dynamics of the entire Baffin Bay narwhal stock.

7.2 Narwhal Density

Based on statistical analyses of the RAD data, both ‘distance from vessel’ and ‘vessel travel direction’ were shown to have a significant effect on narwhal density. While the model predicted significantly reduced narwhal densities in the SSA only when northbound vessels were in close proximity to a given substratum (within 2 km), effect sizes for both north- and southbound vessels suggest that there may be a moderate biologically significant effect up to a distance of 2 km from vessels transiting in both directions.

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, though to a lesser extent. This pattern could represent a refractory period during which narwhal reoccupy the SSA after their initial avoidance of the vessel. These findings are consistent with previous years’ findings and with behavioural results from the narwhal tagging study (Golder 2020a), indicating that narwhal density in the SSA is influenced by vessel traffic at close distances (i.e., within 2 km of a vessel).

Localized avoidance of the sound source (i.e., the vessel) by narwhal is indicative of a low severity behavioural response, as described in Section 3.0. As the observed response was of short duration (i.e., less than the duration of the vessel exposure), no significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine is anticipated. This is in line with impact predictions made in the FEIS for the ERP, in that the effects of ship noise on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

7.3 Group Composition and Behaviour in BSA

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

7.3.1 Group Size

Findings based on the combined multi-year dataset suggest that narwhal may associate in larger groups when in close proximity (≤1 km) to vessels, with mean group size increasing from 2.9 narwhal when 4 km from vessels to 4.0 narwhal when at a distance of 0 km from vessels. Similar to the social defence strategies that have been observed in other cetaceans in which animals form larger groups in the presence of vessels (Finley et al. 1990; Mattson et al. 2005), it is plausible that narwhal may also congregate into larger groups as a form of social defence. However, one would expect a larger change in narwhal group size than that observed in this study (<1 individual) to support this theory. The small increase in narwhal group size in close proximity to vessels is therefore likely an artefact of low sample size of narwhal observations at close range to vessels.

As discussed in Section 3.0, a change in group size by narwhal may suggest a change in group cohesion which would potentially indicate that a moderate severity response has been triggered. However, this response (i.e., an increase in group size) is not predicted to result in population level consequences given that it is evident for only a short duration (i.e., within 1 km of a vessel) and narwhal were shown to return to their pre-response behaviour shortly after the vessel exposure. This finding is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

7.3.2 Group Composition

7.3.2.1 Presence of Immatures

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

Findings based on the combined multi-year dataset suggest that narwhal groups are more likely to include immatures when in close proximity (<2 km) to vessels. This finding may be explained by the reduced mobility of calves and yearlings to dive or move away from vessels, thus increasing the probability of observing groups with calves or yearlings at the surface. The noted response was shown to be short in duration with animals returning to their pre-response behaviour shortly following the initial exposure.

As discussed in Section 3.0, a change in the presence of immatures in a group may suggest a change in group cohesion or a change in group composition by narwhal, both of which would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect, this would not be considered a 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

7.3.2.2 *Proportion of Immatures - EWI*

Findings from the multi-year dataset indicated that the proportion of immature narwhal (i.e., calves and yearlings) in the observed population in 2021 was lower than all previous sampling years. The observed change represented a 24% decrease in the proportion of immatures but was not significantly lower than the 2014/2015 baseline condition, indicating that the EWI threshold was not exceeded. However, the observed effect size and its 95% confidence interval (-55% to +7%) suggest a decrease in the 2021 annual proportion of immatures relative to the observed population, thereby warranting further investigation. Golder has recommended that Baffinland undertake an equivalent EWI analysis of the 2021 aerial survey data (using the dedicated 1000 ft. survey data which was collected for this purpose) to investigate this finding.

If shipping was shown to result in a prolonged separation of females and their dependent offspring, this would suggest that a critical life function (e.g., nursing) has been interrupted (i.e., high severity response). This finding would be contrary to 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. An evaluation of this component (i.e., potential separation of female from their dependant offspring) was assessed through focal follow surveys as part of the Unmanned Aerial Vehicle (UAV) Program, with results presented in Section 6.5 and a discussion provided in Section 7.4.

7.3.3 Group Spread

Findings based on the multi-year dataset suggest that narwhal congregate in more tightly associated groups when in close proximity (i.e., ≤ 2 km) to vessels. In the Eastern Canadian High Arctic, narwhal have been observed forming tight groups in response to approaches from icebreakers during the early shoulder season (Cosens and Dueck 1988, 1993; Finley et al. 1990) and to killer whales (Steltner et al. 1984; Laidre et al. 2006; Breed et al. 2017; Golder 2021a). These results are in agreement with other studies that suggest cetaceans form tighter groups in situations of perceived threat (Irvine et al. 1981; Au and Perryman 1982; Blane and Jaakson 1994; Bejder et al. 1999, 2006a; Nowacek et al. 2001) and may suggest that a similar response is elicited when narwhal are exposed to vessel traffic at close ranges.

As discussed in Section 3.0, a change in group cohesion (e.g., change in group spread) by narwhal is consistent with a moderate severity behavioural response. Given the temporary nature of the effect, this would not be considered a 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

7.3.4 Group Formation

Consistent with previous years findings, narwhal groups were most often observed in parallel formation under both vessel presence and vessel absence scenarios. Findings based on the combined multi-year dataset suggest that narwhal do not significantly alter their group formation in response to vessel traffic. These findings are inconsistent with other studies that have demonstrated that certain cetacean species respond to disturbance by changing their group formation (Irvine et al. 1981; Au and Perryman 1982). 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, though no such change was evident. The lack of response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

7.3.5 Group Direction

Consistent with observations from previous years, findings based on the combined multi-year dataset suggest that narwhal tend to move in the opposite direction of vessels when vessels are moving away from the BSA, regardless of whether the vessel was north- or southbound. These findings suggest that narwhal groups may experience some level of localized avoidance behaviour in the wake of vessels transiting through Milne Inlet (i.e., narwhal groups appear to avoid “following” vessels) but that travel direction by narwhal groups is relatively less affected during the approach of vessels, consistent with findings from the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a). One exception to narwhal groups not “following” in the wake of vessels was that narwhal still tended to travel south when within 1 km of a southbound vessel. This latter finding may be due to the limited sample size of narwhal groups present within 1 km of southbound vessels (i.e., only 49 groups from the combined dataset were observed within 1 km of southbound vessels, of which 40 groups were travelling south).

As discussed in Section 3.0, a change in orientation response (e.g., a change in group direction) by narwhal is consistent with a low severity behavioural response. Given the temporary nature of the effect (i.e., within 4 km of a vessel), this would not be considered a 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

7.3.6 Travel Speed

Findings based on the combined multi-year dataset suggest that if narwhal were among others travelling at a medium or fast speed, they were more likely to travel slowly when less than 4 km from a vessel compared to when no vessel was within 5 km of the BSA. For narwhal groups among others already travelling slowly, no significant change in travel speed relative to vessels was evident. While various studies have reported increased or erratic travel speeds of cetaceans in the presence of vessels (Nowacek et al. 2001; Bejder et al. 2006a; Miller et al. 2008; Matsuda et al. 2011), to our knowledge few studies have reported decreased travel speed in the presence of vessels (Finley et al. 1990). Therefore, while a change in travel speed by narwhal may suggest a change in energy expenditure which would potentially indicate that a moderate severity response has been triggered (as discussed in section 3.0), the fact that the response was to decrease travel speed rather than to increase it means that narwhal would actually expend less energy rather than more. Furthermore, this response (i.e., a change in travel speed) is not predicted to result in population level consequences given that the response lasted for a short duration (i.e., within less than 4 km of a vessel) and animals returned to their pre-response behaviour shortly after the exposure. This response is supportive of impact predictions made in the FEIS for the

ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

7.3.7 Distance from Bruce Head Shoreline

Findings based on the combined multi-year dataset suggest that narwhal may swim closer to shore when in close proximity (i.e., ≤2 km) to vessels. As available literature demonstrates that narwhal move close to shore when attempting to escape predation by killer whales (Steltner et al.1984; Laidre et al. 2006; Marcoux et al. 2009; Breed et al. 2017), it is plausible that narwhal moving closer to shore in the presence of vessels may indicate an avoidance response to a perceived threat (i.e., vessel traffic). These findings are consistent with those recently reported by Heide-Jørgenson et al. (2021) in which narwhal were also observed swimming closer to shore when in the presence of vessels.

As discussed in Section 3.0, a minor deviation from typical migratory pathway (e.g., a change in distance from shore) by narwhal is consistent with a low severity response. Given the temporary nature of the effect, this would not be considered a 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

7.4 Focal Follow Surveys (UAV)

A total of 85 and 164 focal follow surveys of narwhal were undertaken in the RSA during 2020 and 2021, respectively, representing a total of 23.6 h of behavioural observations recorded over a total of 249 surveys. Of this total, ships were present (within 5 km of the focal group) for 16 of the focal follow surveys in 2020 (representing 1.1 h) and for 38 of the focal follow surveys in 2021 (representing 2.8 h). Adult narwhal made up the majority of the animals observed during the focal follow surveys both in the presence and absence of vessels, consistent with group composition results from the shore-based observers in the BSA.

Overall, mean group size during the focal follow surveys (3.0 narwhal in the absence of vessels and 2.5 narwhal in the presence of vessels) was marginally smaller than that recorded in the BSA by shore-based observers during both vessel absence (3.3 narwhal) and vessel presence (3.7 narwhal) scenarios.

The proportion of immatures (i.e., calves or yearlings) in the absence of vessels (13% yearlings, and 6% calves) was similar to the proportion observed when vessels were present (15% yearlings, and 8% calves). This finding is contrary to the BSA results which observed a significant increase of immatures in close proximity to vessels, though it is important to note that the focal follow dataset is limited to two years with limited data available at close range to vessels (e.g., 2.5 min at 0 km,
11.5 min at 1.0 km, 62 min at 2 km, and 60.5 min at 3 km). As a result, caution should be taken when interpreting results.

Of the followed groups, the most frequently observed formation was parallel (42% of time), similar to the predominant formation observed via shore-based observers in the BSA. This was followed by linear formation (23% of the time) and cluster formation (23% of the time). When vessels were present, the proportion of focal groups in parallel formation was slightly higher (52% of the time) compared to when no vessels were present

(40%). In contrast, the proportion of groups in linear formation was slightly lower when a vessel was present (15%) relative to when no vessels were present (24%). The proportion of groups in cluster formation was similar when a vessel was present compared to when no vessel was present within 5 km from the group (26% and 23%, respectively). The lack of a significant effect of vessel presence on group formation in the focal follow is consistent with results of the shore-based monitoring dataset which also found no significant changes in group formation as a function of vessel exposure.

Of the followed groups, narwhal were shown to spend less time in tightly associated groups during vessel exposure period (32%) compared to non-exposure periods (44% of the time). This finding is inconsistent with results obtained from the shore-based monitoring dataset which found that narwhal formed tighter groups in the presence of vessels. Again, a limited sample size in the focal follow surveys at close range to vessels may contribute to the observed discrepancy for this response variable. Further monitoring of focal groups via UAV-based surveys in close proximity to vessels is therefore warranted to adequately assess formational changes by narwhal as a behavioural response to vessel traffic.

In regard to primary behaviour observed via UAV, narwhal groups spent the majority of time travelling (71% of the time), followed by milling (15% of the time), resting (6% of the time), and engaging in social behaviours (7% of the time). The proportion of time that narwhal spent resting or milling was similar when a vessel was present compared to when no vessels were present (19% and 12%, respectively). For groups including life stages that may be more vulnerable to disrupted opportunities to rest, the proportion of time spent resting or milling for mother-immature groups was 35% in the absence of vessels and 9-67% in the presence of vessels (depending on distance from vessel), and the proportion of time that mixed groups with immatures spent resting or milling was 22% in the absence of vessels and 14% in the presence of vessels (only recorded when vessels were at 3 km from group). While these findings are based on a very limited dataset, they are promising in that resting/milling behaviour was observed for most groups in relatively close proximity to vessels, including at 1-2 km from vessels for lone calves and for mother-immature pairs.

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 in 119 of the total focal follow surveys conducted, including during 23% of the time in the absence of vessels and 19% of the time when vessels were present. Unique behaviours were recorded for mother-immature pairs 36% of the time in the absence of vessels and 12-38% when a vessel was present (depending on distance from vessel). For mixed groups with immatures, unique behaviours were recorded 29% of the time in the absence of vessels and 23-57% of the time in the presence of vessels. For mixed groups without immatures, unique behaviours were recorded 30% of the time in the absence of vessels and 12% of the time in the presence of vessels (at 4km from vessel). Strictly adult groups displayed unique behaviours 16% of the time in the absence of vessels and 7-46% of the time in the presence of vessels, and lone calves displayed unique behaviours 22% of the time in the absence of vessels and 33-43% of the time when vessels were present.

One novel unique behaviour observed in 2021 was sexual display behaviour exhibited between narwhal. Little is known about sexual behaviour in narwhal although it is thought that narwhal tusks may be a sexually selected trait (Graham et al., 2020). Sexual displays and interactions were observed during six separate focal follow surveys conducted in 2021, though no such displays were observed in 2020. Of these, four were between adult male narwhal and two were between adult males and tusked juveniles. No sexual behaviour between males and females was observed. A single occurrence of sexual behaviour was observed in the presence of a vessel, which was observed in a group comprised of three adult males when the vessel was at a distance of approximately 4 km from the group.

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

In terms of positioning of immature narwhal to their presumed mother, immatures were most commonly observed below their mother (compared to abreast, behind or above) in both the presence and absence of vessels. The proportion of time that immatures maintained this position was similar when vessels were present compared to when no vessels were present (40% and 49%, respectively). The proportion of time that mothers and immatures were tightly associated with one another was similar in the presence of vessels (41-100% of the time, depending on distance) compared to periods when no vessels were present (82% of the time). Findings also suggest that when immatures are positioned underneath of their mother, they are almost always tightly associated (i.e., 99% of the time), compared to other relative positions (i.e., abreast, above, behind) in which they are relatively more loosely associated. Collectively, these findings may have implications for the broader shore-based monitoring program at Bruce Head, suggesting that calves and yearlings passing through the BSA may be disproportionally underrepresented given the reduced ability to sight a smaller animal underneath an accompanying adult.

Nursing behaviour involving calves or yearlings was recorded during 24 of the focal follow surveys conducted (during 12 surveys in 2020 and 12 surveys in 2021; accounting for 14% and 7% of all groups in 2020 and 2021, respectively). Only two focal follow surveys coinciding with vessel presence included observed nursing behaviour (FFID 83 in 2020 and FFID 122 in 2021), however nursing behaviour in the presence of vessel only occurred during FFID 83, whereas nursing observed during FFID 122 occurred after the vessel was beyond 5 km from the focal group. Although this represents a small sample size, this finding does suggest that mother and dependent young continue to carry out such critical life functions in the presence of vessel traffic. It is possible that nursing activities could be affected in closer proximity to vessels, however the current limited sample size does not allow nursing behaviour in close proximity to vessels to be adequately assessed. Additional monitoring is therefore required to increase the sample size of focal follow surveys conducted in the presence of vessel traffic.

Use of UAV surveys at Bruce Head in 2021 yielded further insights into narwhal group composition and behaviour, building on the data collected in 2020. Similar to 2020, evidence of nursing was observed, and calves were often seen on their own or with non-parental associations. The multiple sexual displays by male narwhal were a novel observation in 2021 not previously recorded in 2020. Conversely, there were no potentially "aggressive" behaviours observed in 2021 such as the two 'jousting' events recorded in 2020 (FFID 04 and FFID 07). Despite a lower abundance of narwhal being observed, the UAV team was able to almost double the number of focal follow surveys captured in 2021 by using two drones simultaneously, compared to having only a single drone in flight at a time in 2020. This approach increased the total number of hours spent following narwhal in the presence of vessels from 1.1 hours to 3.9 hours. However, the current number of hours spent following narwhal in the presence of vessels would need to be increased to allow for a meaningful quantitative analysis.

It is recommended that focal follow surveys be continued in future monitoring campaigns at Bruce Head to further increase the sample size and allow for a quantitative assessment of narwhal behavioural response relative to distance from vessel.

8.0 SUMMARY OF KEY FINDINGS

8.1 Relative Abundance and Distribution

- Interannual variation: The relative abundance of narwhal (total number of narwhal corrected for survey effort) in the Stratified Study Area (SSA) was substantially lower in 2020 and 2021 than in previous survey years (2014-2019), including years prior to the start of Baffinland's iron ore shipping operations in the RSA (i.e., 2014). The observed decrease in local narwhal abundance at Bruce Head in 2021 is consistent with findings from the 2020 and 2021 aerial surveys which indicated that narwhal abundance in Eclipse Sound was statistically lower in 2020 and 2021 than in previous survey years (2013, 2016 and 2019) (Golder 2022). However, the combined narwhal abundance in Eclipse Sound and Admiralty Inlet was shown to be similar in 2020 to that observed in previous survey years (2013 and 2019); and was statistically higher in 2021 than in previous survey years (2013, 2019 and 2020) (Golder 2022). These results suggest a displacement or shift of a portion of the Eclipse Sound stock to the Admiralty Inlet summering ground during the summer of 2021.

- Narwhal Density: Vessel exposure was shown to result in a significant decrease in narwhal density in the SSA compared to when no vessels were present, but only when narwhal were in close proximity to vessels (i.e., within 2 km from a vessel). This was equivalent to a maximum period of 14 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remain 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 (1-26 Aug), there were approximately two vessel transits per day in the SSA (58 one-way transits in SSA over a 24-day period). Therefore, the maximum period per day associated with vessel disturbance on narwhal density was 28 minutes. These findings are consistent with previous years' findings and with behavioural results from the narwhal tagging study (Golder 2020a), indicating that narwhal density in the SSA is influenced by vessel traffic, but this was limited to close distances (i.e., within 2 km of a vessel). 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., up to 14 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

8.2 Group Composition and Behaviour

- Group Size: Modelling results from the combined multi-year dataset suggest that narwhal may associate in marginally larger group sizes when in close proximity (<1 km) to vessels. 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 remain stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). The maximum period per day associated with vessel disturbance on narwhal group size was 14 minutes (based on an average of two vessel transits per day in the SSA). A change in group cohesion (e.g., change in group size) by narwhal is consistent with a moderate severity behavioural response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., up to 7 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

- Group Composition:
  - All narwhal life stage categories (adults, juveniles, yearlings, and calves) were recorded in the BSA throughout the seven-year sampling program.
  - The mean daily proportion of calves recorded in the BSA (relative to the total number of narwhal observed per day) was higher in 2021 (annual mean of mean daily calf proportions = 14.8%) than all previously estimated annual means, which ranged from 9.5% (2017) to 12.9% (2015). While this may suggest that calving rate (i.e., reproductive success) of the Eclipse Sound summering stock in 2021 was consistent with pre-shipping levels, the finding is likely attributed to the influence of two survey days when narwhal sightings in the BSA were limited to a single mother-calf pair, resulting in a 50% daily calf proportion on those days.
  - Presence of Immatures: Consistent with previous years' findings, results based on the combined multi-year dataset suggest that narwhal groups are more likely to include immatures when in close proximity (<2 km) to vessels. This finding is potentially due to groups without calves or yearlings being more capable of diving and moving away, thus inflating the probability of observing groups with calves or yearlings at the surface. The noted response was shown to be short in duration, equivalent to a maximum period of 14 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial exposure (i.e., a temporary effect). The maximum period per day associated with vessel disturbance on narwhal group composition was 28 minutes (based on an average of two vessel transits per day in the SSA). A change in group cohesion and/or a disruption of female and dependant offspring (exceeding baseline case) is consistent with a moderate severity behavioural response. However, given the temporary nature of the effect (i.e., up to 14 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.
  - Proportion of Immatures (Early Warning Indicator "EWI"): Findings from the multi-year dataset indicated that the proportion of immature narwhal (i.e., calves and yearlings) in the observed population in 2021 was lower than all previous sampling years. The observed change represented a 24% decrease in the proportion of immatures but was not significantly lower than the 2014/2015 baseline condition, indicating that the EWI threshold was not exceeded. While the lack of significance was likely associated with the low sample size and high variability observed in 2021 relative to the other sampling years, the effect size and its 95% CI (-55% to +7%) suggest a decrease in the 2021 annual proportion of immatures relative to the observed population, thereby warranting further investigation. Golder has recommended that Baffinland undertake an equivalent EWI analysis of the 2021 aerial survey data (using the dedicated 1000 ft. survey data which was collected for this purpose) to further investigate this finding.

- Group Spread: Modelling results from the combined multi-year dataset suggest that narwhal congregate in more tightly associated groups when in close proximity (i.e., ≤ 2 km) to vessels. The noted response was shown to be short in duration, equivalent to a maximum period of 14 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial exposure (i.e., a temporary effect). The maximum period per day associated with vessel disturbance on narwhal group spread was 28 minutes (based on an average of two vessel transits per day in the SSA). A change in group cohesion (e.g., change in group spread) by narwhal is consistent with a moderate severity behavioural response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., up to 14 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.
- Group Formation: Narwhal groups were most often observed in parallel formation under both vessel presence and vessel absence scenarios. Consistent with previous years' findings, results from the combined multi-year dataset suggest that narwhal do not significantly alter their group formation in response to vessel traffic. The lack of response is supportive of impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.
- Group Direction: Narwhal groups were predominantly observed travelling south through the BSA. Consistent with previous years' findings, results from the combined multi-year dataset suggest that narwhal group travel direction is not affected by approaching vessels but that narwhal groups may avoid "following" in the wake of vessels moving away from the Behavioural Study Area (BSA). That is, narwhal tended to move in the opposite direction of vessels that move away from the BSA, regardless of whether the vessel was north- or southbound. The noted response was demonstrated up to a maximum distance of 4-km from the vessel, equivalent to a period of 28 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). The maximum period per day associated with vessel disturbance on narwhal group direction was 56 minutes (based on an average of two vessel transits per day in the SSA). A change in orientation response (e.g., a change in group direction) by narwhal is consistent with a low severity behavioural response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., up to 28 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.
- Travel Speed: Results from the combined multi-year dataset suggest that if narwhal were among other narwhal groups travelling at a medium or fast speed, they were more likely to travel slowly when less than 4 km from a vessel compared to when no vessels were present. For narwhal occurring among other narwhal groups already travelling slowly, no significant change in group travel speed was evident. The noted response was shown to be short in duration (i.e., within 4 km of a vessel) equivalent to a maximum period of 28 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remain stationary during

exposure), with animals returning to their pre-response behaviour shortly following the initial exposure (i.e., a temporary effect). The maximum period per day associated with vessel disturbance on narwhal group travel speed was 56 minutes (based on an average of two vessel transits per day in the SSA). A change in energy expenditure (e.g., a change in travel speed) by narwhal is consistent with a moderate severity response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., up to 28 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

- Distance from Bruce Head Shoreline: Narwhal groups were observed more often within 300 m of the Bruce Head shoreline under both vessel presence and vessel absence scenarios. Results from the combined multi-year dataset suggest that narwhal may swim closer to shore when in close proximity (≤2 km) to vessels. The noted response was shown to be short in duration, equivalent to a maximum period of 14 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remain stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). The maximum period per day associated with vessel disturbance on narwhal distance from shore was 28 minutes (based on an average of two vessel transits per day in the SSA). A minor deviation from typical migratory pathway (e.g., a change in distance from shore) by narwhal is consistent with a low severity response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., up to 14 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 may ultimately affect population parameters. This response is in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

8.3 UAV Focal Follow Surveys

- The UAV focal follow surveys differed from the observer-based data collection in the BSA in that emphasis was placed on narwhal groups that comprised immatures (e.g., mother/calf pairs) to better assess potential behavioural responses of narwhal in more vulnerable life stages, including potential vessel effects on nursing behaviour and relative positioning of dependants during vessel interactions.

- A total of 249 unique focal follow surveys have been conducted to date (85 surveys in 2020 and 164 surveys in 2021), providing 23.6 hours of recorded behavioural data of narwhal near Bruce Head. Of the focal follow surveys conducted, 43 surveys coincided with a vessel transiting within 5 km of the focal group, providing a total of 3.9 hours of behavioural data in the presence of vessels (CPA between 0.4 km and 4.7 km). While the additional data collected via UAV focal follow surveys in 2021 is valuable in providing insight into narwhal behaviour, the sample size in close proximity to vessels remains insufficient to conduct a meaningful quantitative analysis of behavioural response variables relative to ‘distance from vessel’, with total time spent within 0 km, 1 km, 2 km, and 3 km of focal groups including only 2.5 min, 11.5 min, 62.0 min, and 60.5 min, respectively. Therefore, results presented below pertaining to the UAV focal follow surveys should be interpreted accordingly.

- Group Formation (UAV-based): The most frequently observed group formation during the focal follow surveys was parallel (42% of time), similar to the predominant formation recorded in the BSA by shore-based observers. This was followed by linear formation (23% of the time) and cluster formation (23% of the time). In the absence of vessels, the proportion of groups in parallel formation was slightly lower (40% of the time) compared to when vessels were present (52%). In contrast, the proportion of groups in linear formation was slightly higher in the absence of vessels (24%) relative to when vessels were present (15%). The proportion of groups in cluster formation was similar when a vessel was absent compared to when a vessel was present (23% and 26%, respectively). No significant effect of vessel presence on group formation was demonstrated.
- Group Spread (UAV-based): Narwhal were shown to spend less time in tightly associated groups when vessels were present (32%) compared to when vessels were absent (44% of the time). This finding is inconsistent with results obtained from the shore-based monitoring dataset which found that narwhal formed tighter groups in the presence of vessels. A limited sample size in the focal follow surveys at close range to vessels may contribute to the observed discrepancy. Vessel presence was shown to have a marginally significant effect on group spread in mother-immature narwhal groups ($P=0.071$); but not for other group types ($P>0.2$ for all).
- Primary Behaviour (UAV-based): Narwhal spent the majority of time travelling (71% of the time), followed by resting / milling (22% of the time), and social behaviours (7% of the time). The proportion of time that narwhal spent resting / milling was similar when a vessel was present (19%) compared to when no vessels were present (12%). For groups including life stages that may be more vulnerable to disrupted opportunities to rest (i.e. mother-immature groups), the proportion of time engaged in resting / milling behaviour was 9-67% when a vessel was present (depending on distance from vessel) compared to 35% when no vessels were present. The proportion of time that mixed groups with immatures engaged in resting / milling behaviour was 14% when a vessel was present (sightings limited to 3 km distance form vessel) and 22% when a vessel was absent. No significant effect of vessel presence on primary behaviour was demonstrated.
- Unique Behaviours (UAV-based): 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 in 119 of the total focal follow surveys conducted, including during 23% of the time in the absence of vessels and 19% of the time when vessels were present. Vessel presence was shown to have a marginally significant effect on unique behaviour in adult groups ($P=0.052$) and lone calves ($P=0.066$); but not for mother-immature groups ($P=0.5$) or mixed groups with immatures ($P=0.2$).
  - Nursing: Nursing of a calf or yearling from its mother was recorded during 24 of the focal follow surveys (12 surveys in 2020 and 12 surveys in 2021; accounting for 14% and 7% of all groups in 2020 and 2021, respectively). During the 24 events where nursing was observed, time spent nursing ranged between 5% and 63% of the focal follow period (mean value of 25% of the time, SD of 17% of the time). Two focal follow surveys coinciding with vessel presence included nursing behaviour. No significant effect of vessel presence on nursing activity was demonstrated.

- Focal Groups with Immatures: Mother-immature pairs were observed in 45 individual focal follow surveys for a total of 170 min (including 21 min in the presence of vessels), while mixed groups with immatures were observed in 27 focal follow surveys for a total of 103 min (including 39 min in the presence of vessels). Calves were observed on their own (i.e., either as a single calf or two calves together without other individuals) in 22 individual focal follow surveys, for a total of 158 min (including 12 min in the presence of vessels).
  - Relative and Distal Association of Immature with Mother: Immatures were most often recorded underneath their presumed mother compared to abreast, behind, or above in both the presence and absence of vessels (40% and 49% of the time, respectively). When an immature was positioned underneath of the presumed mother, it was tightly associated with the adult 99% of the time and the association was not affected by vessel presence (97% in presence of vessel and 99% when no vessels were present). That is, immatures did not appear to change their relative or distal association with their mother in response to vessel presence. No significant effect of vessel presence on the relative position or spread of immatures was demonstrated. In general, the results may have implications for the broader shore-based monitoring program at Bruce Head, suggesting that calves and yearlings passing through the BSA may be disproportionally underrepresented given the reduced ability to sight a smaller animal underneath an accompanying adult.

9.0 RECOMMENDATIONS

With respect to future monitoring initiatives for the Bruce Head Shore-based Monitoring Program, Golder recommends the following:

- Increase emphasis on the UAV survey component of the program, given the valuable insight this tool provides with respect to monitoring changes in group composition and fine scale behaviours in the presence of shipping (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 or signs of aggression. While the sample size of surveys conducted when ships were 'present' remains insufficient to achieve adequate detection power for statistical analysis based on the 2020- 2021 integrated dataset alone, increasing the sample size through future UAV surveys would have the potential to quantitatively evaluate changes in key narwhal behaviours in response to shipping. Furthermore, UAV survey methods allow for increased data collection at the closer vessel approach distances (i.e., 0-2 km range) compared to the BSA study design because focal follows can be undertaken directly on the shipping lane; whereas vessels rarely approach at close distances to the BSA given the location of the shipping lane (which was adjusted further eastward in 2020).
- Undertake additional analysis of the 2021 aerial survey data for specific evaluation of the EWI metric (using the dedicated 1,000 ft survey data which was collected for this purpose) to confirm that this is a reflection of the low samples size and not a pattern of decreasing proportion of immature narwhal in the RSA.
- Undertake dedicated UAV surveys for narwhal group composition as a secondary assessment of the Early Warning Indicator metric (i.e., proportion of immature narwhal relative to the adult population). This would provide for improved detection probability and increased accuracy in animal detection and enumeration, age class determination and gender confirmation compared to the current traditional monitoring method (observer-based data collection). Having a permanent record of the UAV video survey will eliminate observer bias in the data collection phase and allow for a better assessment of variability in the EWI data

10.0 CLOSURE

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

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APPENDIX A

Training Manual

REPORT

2021 Bruce Head Shore-based Monitoring Program

Training Manual

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Distribution List

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1.0 INTRODUCTION

Golder will undertake and manage the 2021 Bruce Head shore-based monitoring program (the Program) to investigate the behavioural response of marine mammals to vessel traffic serving Milne Port as part of Baffinland Iron Mines Corporation's Mary River Project (the Project). The Program is based at Bruce Head, a high rocky peninsula (215 m above sea level) on the western shore of Milne Inlet, Nunavut, overlooking the Project's Northern Shipping Route (Photograph 1 to Photograph 3) and providing an unobstructed view of Milne Inlet from the south end of Stephens Island in the north, to the embayment south of Agglerojaq Ridge in the south. The primary objective of the Program is to evaluate potential disturbance of narwhal from shipping activities along the Northern Shipping Route that may result in changes in animal distribution, abundance, and migratory movements throughout Milne Inlet.

The 2021 Program represents the ninth consecutive year of environmental effects monitoring undertaken at Bruce Head in support of the Project. Previously developed by LGL Limited (LGL) in 2013 and implemented until 2016, the Program was assumed by Golder Associates beginning in 2017. Due to safety concerns associated with the distance that the team was required to travel between the Bruce Head camp and the observation platform each day, as well as concerns raised about the integrity of the previous observation platform, the Program was temporarily moved to a vessel-based platform in 2018 while plans to relocate and renovate the camp and observation platform were being drafted. Following the relocation of camp adjacent to the observation platform in 2019, data collection from the shore-based observation platform resumed. A new observation platform consisting of a modified seacan securely anchored to the ground was utilized during the 2020 field season and will continue to be used going forward.

The 2021 study design is similar to that applied in previous survey years (2014-2020), with data collected on narwhal relative abundance and distribution (RAD) within a defined Stratified Study Area (SSA); on group composition and behaviour within a 1-km Behavioural Study Area (BSA); and on environmental conditions and anthropogenic activities (e.g., shipping and hunting activities) to distinguish between the potential effects of Project-related shipping activities and confounding factors which may also affect narwhal behaviour. As will be discussed in greater detail in Section 3.2, the 2021 study design includes integration of data collection via an Unmanned Aerial Vehicle (UAV) that will be correlated with concurrently collected visual data. New to the 2021 Program, UAV surveys will also collect narwhal morphometric data to inform interannual changes in narwhal health (i.e., body condition) over time.

The 2021 scientific Program will be overseen by Ainsley Allen (Program Technical Lead) and Phil Rouget (Senior Technical Lead), with Mitch Firman (Systems Technician) acting as Field Lead. Ben Widdowson (Site Supervisor) and Shea Pollard (Camp Manager) will lead logistical coordination between the camp and Mine site, ensuring the overall health and safety of the team while living in the remote field camp. The Program's Data Analyst, Sima Usvyatsov, will also work closely with the field team (virtually) throughout the duration of the field program.

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

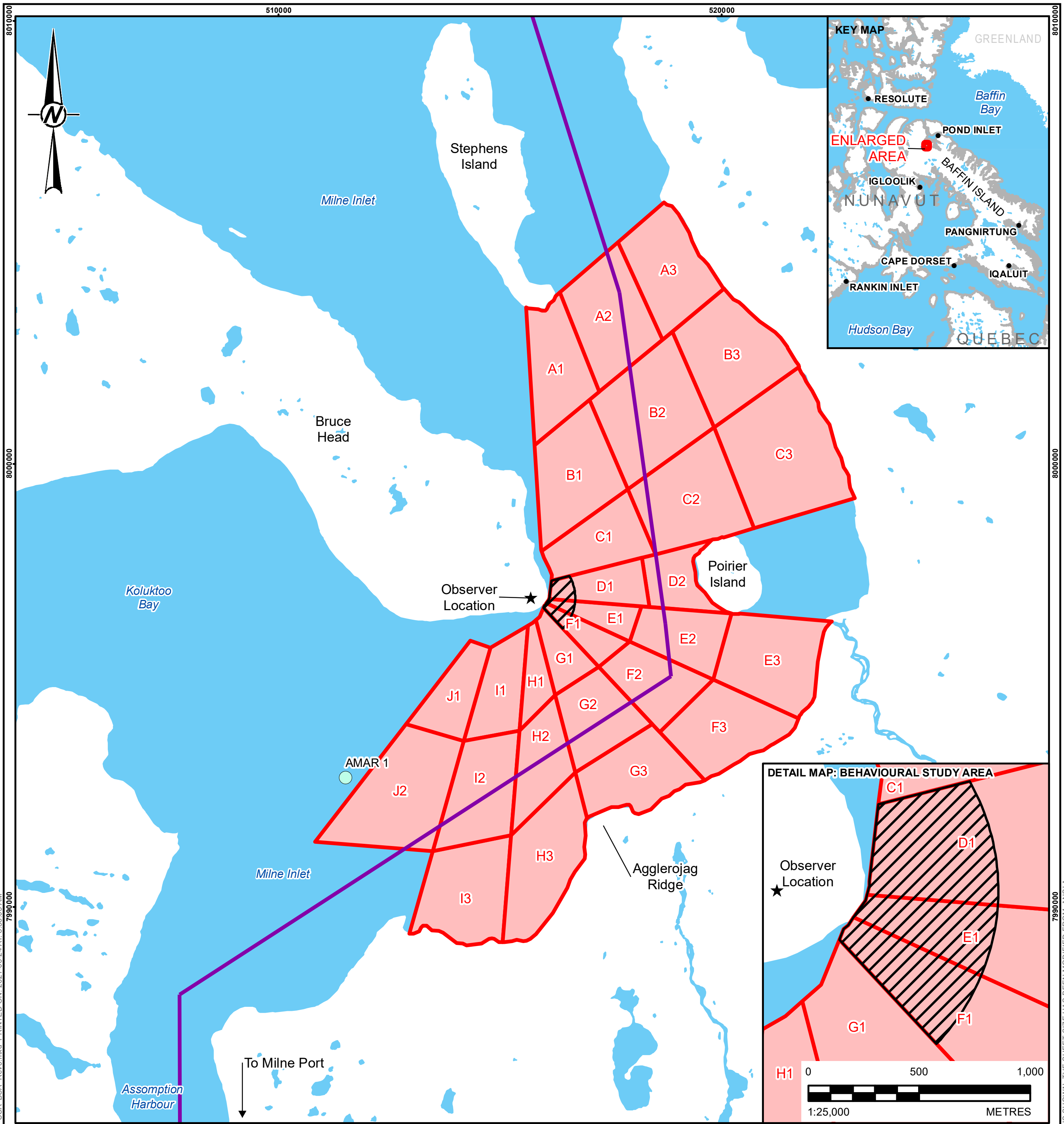
Photograph 2: Camp at Bruce Head, overlooking Milne Inlet.

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

1.1 Study Area

The Study Area is approximately 6 km wide on average and is comprised of the broader Stratified Study Area (SSA) and, nested within the SSA, the Behavioural Study Area (BSA) (Figure 1.1). The SSA is stratified into strata A (northernmost stratum) through J (southernmost stratum) and further separated into substrata 1 through 3 (1 being closest to the Bruce Head shore and 3 being the furthest away). There are a total of 28 substrata within the SSA as strata D, and J are comprised of only 2 substrata each. The boundaries of each substratum are visually estimated in the field using landmarks (APPENDIX B). The BSA covers portions of strata D, E, and F that are within 1 km of the Bruce Head shore where the observation platform is located.

Beginning in 2019, the SSA was expanded westward to include substrata J. The objective of including additional substrata was to systematically capture the “pulsing” of narwhal in and out of Koluktoo Bay that has been observed anecdotally in past monitoring programs (Golder 2018, Golder 2020, Golder 2021, Smith et al. 2015, Smith et al. 2016, Smith et al. 2017).



LEGEND

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

STRATIFIED STUDY AREA (SSA) SUBSTRATA

- PREVIOUS SUBSTRATA

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY CLIENT, JULY 14, 2020. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

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

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-06-24
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000-01	0	1

25mm

2.0 MONITORING SCHEDULE

The 2021 Bruce Head Shore-based Monitoring Program will consist of 16 hours of daily monitoring effort (weather permitting), undertaken by two teams comprised of 5 core individuals each (‘Early shift’ and ‘Late shift’), alternating at 4 hr observation intervals (Table 1). Individuals will work with their respective teams throughout the duration of their time at Bruce Head and will alternate working the ‘Early’ or ‘Late’ shift according to a 3-day rotation schedule (Table 2). Individuals will also take turns assisting with 2 hours of data entry each day, depending on the duration of daily monitoring shifts. Crew Leads will ensure that data collected by visual observers is properly entered into the database at the end of each monitoring shift, QA/QC’d, and then the Field Lead will forward the compiled dataset to the Program’s Data Analyst at the end of each survey day.

Two individuals from InDro Robotics will also conduct UAV surveys throughout each day and will work closely with Golder co-pilots, Mitch Firman and Phil Rouget (Sam Sweeney), to plan and execute daily flight operations. Golder co-pilots will work between the observation platform, data entry and analysis at the computer, and with Indro Robotics during flight operations. Golder co-pilots will also be responsible for providing Program Technical Lead, Ainsley Allen, with updated flight log at the end of each survey day.

Table 1: Daily monitoring schedule and time available for meals

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

Table 2: 2021 Monitoring Schedule[1]

Date (2021)	Early Shift	Late Shift
July 29, 30	N/A: Travel	
July 31	N/A: Orientation / Training (in-class, if possible)	
August 1, 2	N/A: Training (practical) / set-up camp	
August 3, 4, 5	**SS**, IS*, JR, EB, DA / GM, MF	**BW**, KH*, DB, JB / DW, PR
August 6, 7, 8	**BW**, KH*, DB, MA, JB / DW, PR	**SS**, IS*, JR, EB, DA / GM, MF
August 9, 10, 11	**SS**, IS*, JR, EB, DA / GM, MF	**BW**, KH*, DB, MA, JB / DW, PR
August 12, 13, 14	**BW**, KH*, DB, MA, JB / DW, PR	**SS**, IS*, JR, EB, DA / GM, MF
August 15, 16, 17	**AR,** IS*, JR, EB, DA, KW / GM, SS	**BW**, KH*, DB, MA, JB, NO / DW, MF
August 18, 19, 20	**BW**, KH*, DB, KK, NO / DW, MF	**AR,** IS*, JR, EB, KW / GM, SS
August 21, 22, 23	**AR,** IS*, JR, EB, KW / GM, SS	**BW**, KH*, DB, KK, NO / DW, MF
August 24, 25	**BW**, KH*, DB, KK, NO / DW, MF	**AR,** IS*, JR, EB, KW / GM, SS
August 26, 27	N/A: Camp de-mobilization / Travel	

[1] Andrew Rippington (AR), Ben Widdowson (BW), Dave Angus (DA), Dan Beaudry (DB), Dustin Wales (DW), Emily Bishop (EB), Geoff Mullins (GM), Ian Snider (IS), Jeremie Brunel (JB), Jeff Reynolds (JR), Kirby Hjermenrude (KH), Krista Kenyon (KK), Kristin Westman (KW), Melanie Austin (MA), Mitch Firman (MF), Niallan O'Brien (NO), Phil Rouget (PR), Sam Sweeney (SS)

(bold font denotes Crew Lead/ Quality Assurance personnel, * denotes Polar Bear Monitor, _ denotes UAV Co-pilot)

3.0 PROGRAM OVERVIEW

3.1 Visual Survey by MMOs

During each 4-hr monitoring shift, three complementary surveys will be undertaken by Marine Mammal Observers (MMOs); the first survey conducted by a team of two individuals (i.e., Team 1) and the second and third surveys conducted by a team of three individuals (i.e., Team 2):

1) Relative Abundance and Distribution (RAD) surveys will be conducted throughout the SSA.

2) Group Composition and Behaviour surveys will be conducted within the BSA.

3) Anthropogenic activity and environmental conditions will be documented throughout the SSA.

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

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

3.1.1 Team 1 - Relative Abundance and Distribution (RAD)

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

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

Data to be recorded for each substratum within the SSA:

- Number of narwhal.
- Narwhal direction of travel (i.e., N,S,E,W, or N/A if group travel is multi-directional such as milling).
- Presence of other marine mammals.
- Vessel presence and direction of travel.
- Beaufort scale, glare and a subjective assessment of sightability (see section 3.1.1.3).

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

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

3.1.1.1 Roles and Responsibilities – Team 1

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

Team Role	Responsibility	Equipment
Person 1 – Marine Mammal Observer (MMO)	■ Count all visible narwhal within each substratum and note direction of travel (N, S, E, W) whenever possible. ■ Note other marine mammal species observed in each substratum. All other cetaceans (whales) observed are to be documented as a separate sighting while any pinnipeds (seals) and walrus observed are to be documented anecdotally in the comments section. ■ Report beaufort scale, glare and sightability within each substratum. ■ Document vessel presence in relation to each substratum and hunting/shooting activity whenever possible. This will be documented in greater detail by Team 2. ■ Communicate all observations to the Recorder.	10x42 binoculars
Person 2 – Recorder	■ Record all information received from the MMO using the RAD data sheet. All times should be recorded in local time (EDT) using the 24-hr clock (e.g. 2 pm is recorded as 14:00).	Data sheet[4]

3.1.1.2 Survey Protocol - RAD

- Observations of the SSA will be made by a team of two individuals (Team 1) from two pre-determined observation locations (15 m apart) that provide an overview of strata A to F, and G to J, respectively (APPENDIX B).
- RAD counts are to be undertaken at the start of each observation period and every hour, on the hour, during the 10-hr observation period.
- RAD counts are to be undertaken continuously upon visual detection of large vessels prior to entering the SSA (exact distance to be defined in the field) and for the full duration that the vessel is present within the SSA. A final RAD count is to be made once the large vessel has left the SSA. If a large vessel enters the SSA mid-way through conducting an hourly RAD count, that count is to be completed and another count will commence immediately after.
- General Rules:
  - If majority of narwhal are travelling in one direction (i.e., north → south), begin counting the strata from the opposite direction (i.e., south → north) in order to avoid / minimize double counting.
  - During incoming vessels, begin counts in the stratum closest to the incoming vessel.
  - Other whales observed in each substratum are to be documented as an individual sighting while seals and walrus observed are to be documented in the comments section of the data sheet.
  - The observer is to spend a minimum of 3 minutes scanning each stratum (i.e., 1 minute per substratum).

[4] Data Sheets: Relative Abundance and Distribution

- Data will not be collected for a substratum that cannot be observed in its entirety due to weather. When a substratum is omitted due to weather, glare and sightability must still be documented.

3.1.1.3 Additional data to be collected

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

- Record all whale sightings as you would a narwhal sighting (as a separate line item in datasheet).
- For seal and walrus sightings within each substratum, include a descriptive comment in the data sheet including information on species, group size, and behaviour (as possible). Always prioritize whale sightings.
- Vessel presence, vessel class[5], and direction of travel (i.e., entering or exiting Milne Inlet and approaching or departing substratum) within individual substratum.
- Specific environmental conditions for individual substratum:
  - Beaufort scale (see APPENDIX C)
  - Glare: severe (S), light (L), none (N).
  - Sightability (a subjective assessment of the overall viewing conditions):
    - Excellent (E): conditions such that 100% certain that marine mammals at surface would be detected.
    - Good (G): conditions such that marine mammals at surface would *very likely* be detected.
    - Moderate (M): conditions such that marine mammals at surface may be detected.
    - Poor (P): water is mostly obscured by fog, ice, or high sea state; detections severely impaired and unlikely.
    - Impossible (I): water is completely obscured by fog, ice, or high sea state.

3.1.2 Team 2 - Group Composition and Behaviour

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

Data to be recorded for the BSA:

- Narwhal group composition.
- Narwhal group primary and secondary behaviour.
- Beaufort scale, glare, and an assessment of sightability (as per definitions in Section 3.1.2.3).

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

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

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

3.1.2.1 Roles and Responsibilities – Team 2

Table 4: Team 2 roles, responsibilities, and monitoring equipment employed

Role	Responsibility	Equipment
Person 1 – Marine Mammal Observer (MMO)	■ Document group composition as well as primary and secondary behaviour of all narwhal within the BSA. Specific behaviour (e.g., nursing) within each of the seven behavioural categories should be documented whenever possible. ■ Note any other marine mammal species (and behaviour) observed in the BSA ■ Report glare and sightability within the BSA every hour. ■ Communicate all observations to the Recorder (Person 2).	Big eye binoculars
Person 2 – Recorder (Visual Observations of Narwhal)	■ Record all information received on the data sheet from the MMO. ■ Complement the data collected by taking photographs of narwhal within the BSA and of vessels in the SSA whenever time permits. ■ All times should be recorded in local time (EDT) using the 24-hr clock (e.g., 2 pm is recorded as 14:00).	HD camera, 10 x 42 binoculars, Datasheets[7]
Person 3 – Recorder / Observer (Environmental & Anthropogenic Observations)	■ Communicate to the Golder co-pilot whenever a herding event begins through the BSA. ■ Observe environmental conditions and complete the associated data sheet every hour and whenever conditions change. ■ Document all small vessels (< 50 m length) whenever present in the SSA, noting the time and location upon first entry to the SSA, general activity within the SSA, and the time and location upon departure from the SSA. ■ Record all hunting activity (i.e., gun shots) throughout each 4-hr observation period, the associated time, and the target species whenever possible. ■ Once datasheets have been completed, assist Person 1 with marine mammal observing.	10 x 42 binoculars, Datasheets[8],

[7] Datasheets: Group Composition and Behaviour

[8] Datasheets: Vessel Passages and other Anthropogenic Activity; Environmental Conditions

3.1.2.2 Survey Protocol – Group Composition and Behaviour

- Observations of narwhal group composition and behaviour will be made by the **Team 2 MMO** who will communicate findings to the **Team 2 Recorder.**
- The third individual from Team 2, the **Recorder of Environmental and Anthropogenic Observations**, will be responsible for collecting vessel traffic and anthropogenic data for both the BSA and the broader SSA and will document environmental conditions for the entire SSA every hour and whenever conditions change.
- The three individuals that are part of Team 2 will be stationed at the observation platform.
- Surveys will consist of 50-minute observation periods, abbreviated by 10-minute rest periods.
- General Rules:
  - Primary[9] (1) and secondary[10] (2) behavioural data are to be recorded for every sighting whenever possible, based on seven behavioural categories[11] (Table 8).
  - Unique behaviours[12] are also to be recorded in the datasheet whenever observed.
  - If majority of narwhal are travelling through the BSA in one direction (i.e. north → south), begin counting and characterizing the animals from the opposite direction (i.e. south → north).
  - Herding events[13]: If multiple groups pass through the BSA too quickly such that group composition and behaviour cannot be recorded (based on best judgment of **Team 2 MMO**), counts should be conducted, and the sightings grouped into 5-minute bins. One herding event may have multiple 5-minute sightings that will be added together at a later time to determine the total group size of the herding event. In this scenario, the **Team 2 Recorder** is to announce the completion of each 5-minute interval, the count is to be recorded, and the **Team 2 MMO** then begins counting (and characterizing whenever possible) the next sighting, beginning the count again at 1.
  - If a group of animals remains in the BSA for a period exceeding 10 minutes, that group is to be 'resighted' every 10 minutes until the group leaves the BSA. In this scenario, the initial sighting number is to be repeated as a new line item in the datasheet, along with the associated time.

The following tables outline the group composition data (Table 5 and associated tables) and the behavioural data (Table 8) that is to be recorded for each sighting[14] within each 50-minute survey.

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

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

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

[12] Unique behaviours (see Table 8) = logging (LO), chase prey (CH), catch prey (CA), rubbing/petting (RU), rolling (RO), tusk (TU), tail slap (TS), nursing (NU), mounting (MO), sexual display (SX), bubble rings (BU), spyhopping (SP), breaching (BR), diving (DY).

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

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

Table 5: Group composition and behaviour data to be recorded

Data to be recorded	Description
Time of sighting	For every sighting, time of passage through the BSA must be recorded. See ‘General rule’ for herding events above.
Sighting #	For each group of animals observed in the BSA, a sighting number is to be used as a unique identifier. If a group of animals remains in the BSA for a period exceeding 10 minutes, that group is to be ‘resighted’ every 10 minutes until the group leaves the BSA. In this scenario, the initial sighting number is to be repeated as a new line item in the datasheet, along with the associated time.
Whale species	Although narwhal are the focal species of this program, all other whale species observed are to be recorded as a separate sighting (with the same level of detail as would be provided for narwhal). Seals and walrus are to be noted in the comments section only.
Group size	Number of narwhal within 1 body length of one another. Includes group size of 1.
Number of narwhal with tusks	■ Present ■ Absent ■ Unknown (i.e., head not visible).
Number of narwhal in age categories adult, juvenile, yearling, and calf.	See Table 6 (Life stages).
Spread	■ Tight: narwhal ≤ body width apart ■ Loose: narwhal >1 body width apart
Group Formation	See Table 7 (Formation).
Direction of travel	N, S, E, W
Speed of travel	■ Fast / Porpoising ■ Medium ■ Slow ■ Not travelling / Milling
Distance away from shore	■ Inner: <300 m ■ Outer:>300m
Primary & Secondary Behaviour	■ See Table 8 (Behavioural Data).
Associated photo range	■ For each sighting where photos are taken, the numeric photo range should be recorded.

Table 6: Life stages of narwhal

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

Table 7: Group formation categories

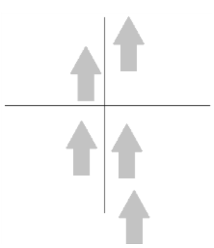
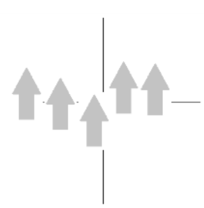
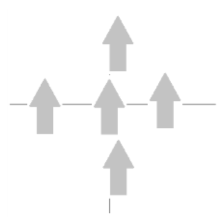
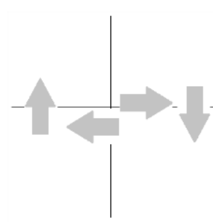
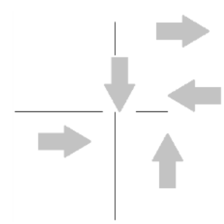
Linear	Parallel	Cluster/ circular	Non-directional line	No formation
Directional line	Directional line	Directional line	Non-directional line	Non-directional line
Stretched longitudinal	Stretched laterally	Stretched longitudinal + lateral	Linear formation	Non-linear
One animal after another in a straight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

Table 8: Behavioural data (primary and secondary) to be recorded

Behaviour	Description of behaviour	Unique behaviour examples
Travelling	Animal(s) exhibiting directed movement; moving steadily in a constant direction	-
Resting	Animal(s) not moving	Logging (LO)
Milling	Animal(s) exhibiting non-directional movement; moving about haphazardly within a limited area	-

Behaviour	Description of behaviour	Unique behaviour examples
Foraging	Animal(s) chasing or catching prey species	Chase prey (CH) Catch prey (CA)
Socializing	Animal(s) in physical contact with one another; includes tail slaps	Rubbing or petting (RU) Rolling (RO) Tusk displays or tusk contact (TU) Tail slap (TS)
Reproductive	Animal(s) exhibiting behavior known to be related to reproductive function	Nursing (NU) Mounting (MO) Sexual display (SX)
Other	Animal(s) exhibiting behavior not known to be context-related. A description of behavior is to be included in comments.	Bubble rings (BU) Spyhopping (SP) Breaching (BR) Diving (DY)

3.1.2.3 Additional data to be collected

In addition to Team 2 collecting group composition and behavioral data within the BSA, the following environmental conditions are to be observed for the entire SSA and documented by **Team 2** (Person 3) upon arrival to the observation site each day, every hour, and whenever conditions change:

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

The following environmental conditions are to be observed and recorded by **Team 2** (Person 3) for the BSA upon arrival to the observation site each day, every hour, and whenever conditions change:

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

All vessels present and hunting activity observed within the SSA (including the BSA) will be documented by **Team 2** (Person 3). The following will be recorded:

- Vessel class[15] for all vessel traffic present within the SSA, with special attention paid to small and medium vessels that are typically not outfitted with Automatic Identification Systems (AIS).
- The time, duration, and general location of all hunting activity observed (visually or aurally) during each 50-minute survey, noting the target species whenever possible.
- Fixed-wing aircraft and helicopters are to be noted in the 'comments' section of the data sheet if present, including aircraft travel direction.

3.2 UAV Survey by InDro Robotics Inc.

Unmanned Aerial Vehicle (UAV) surveys will be undertaken in conjunction with the 2021 Bruce Head Shore-based Monitoring Program to further investigate the behavioral response of narwhal to shipping activities. New to the 2021 Program, UAV units will be used to obtain morphometric measurements of narwhal present in the vicinity of Bruce Head. Whenever possible, focal follow surveys (Survey 1; section 3.2.1) should be flown so that morphometric measurements may be derived for the majority of individuals in each group followed. The UAV units will be used to conduct daily surveys of narwhal in coordination with shore-based visual observers, with the following objectives presented in order of priority:

1) Monitor narwhal group composition and behavior in relation to shipping activities under different behavioral contexts (i.e., resting/milling) than what is typically observed of animals strictly in the BSA (i.e. travelling) via focal follow surveys conducted throughout the SSA and toward Koluktoo Bay;
2) Obtain morphometric measurements to evaluate narwhal health (i.e., body condition);
3) Confirm sightings information (e.g., group composition, group size, behaviour) during narwhal herding events through the BSA; and
4) Evaluate observer detection performance (i.e., ability to effectively detect animals) throughout the SSA.

3.2.1 UAV Survey 1: Focal Follows, including Morphometric Measurements

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

- Survey location: Throughout the SSA and into Koluktoo Bay, as is possible (Figure 1.1).
- Focal follow surveys at the mouth of Koluktoo Bay will be conducted to assess behavioral changes (e.g., change in orientation) or narwhal in relation to shipping events under a different behavioral context (i.e., resting/milling) than what is typically observed of animals in the BSA (i.e., travelling).
- Flight schedule: Every hour, opportunistically, and continuously whenever a vessel is observed within the SSA.
- Flight details: The UAV will be flown to a predetermined "starting position" and will then scan the area until encountering the first group. It will then stay with the first group that it encounters until the group disappears or disperses widely. If the group disperses, the UAV will increase altitude in an attempt to remain with the

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

group for as long as possible. Once the group has disappeared, the survey is considered “terminated” until the next group is located, at which point a new survey is initiated.

- Data entry / Analytical approach: UAV footage will be reviewed at the end of each survey and the following response variables will be documented in 30 second increments: group composition, group spread, orientation, relative and distal position of immatures to the perceived mother, and unique behaviors (e.g., nursing).
- Considerations: It is critical the UAV stay with the first group that it encounters for as long as possible, without selecting groups of interest or switching between different groups throughout a given survey. The entire focal group should remain within the frame throughout the duration of the follow. The UAV is not to get any closer to the focal group than is necessary to obtain the necessary data. The UAV should be flown in such a way that morphometric data may be simultaneously obtained from the focal group, without compromising the focal follow survey itself.

3.2.2 UAV Survey 2: Confirmation of Group Composition

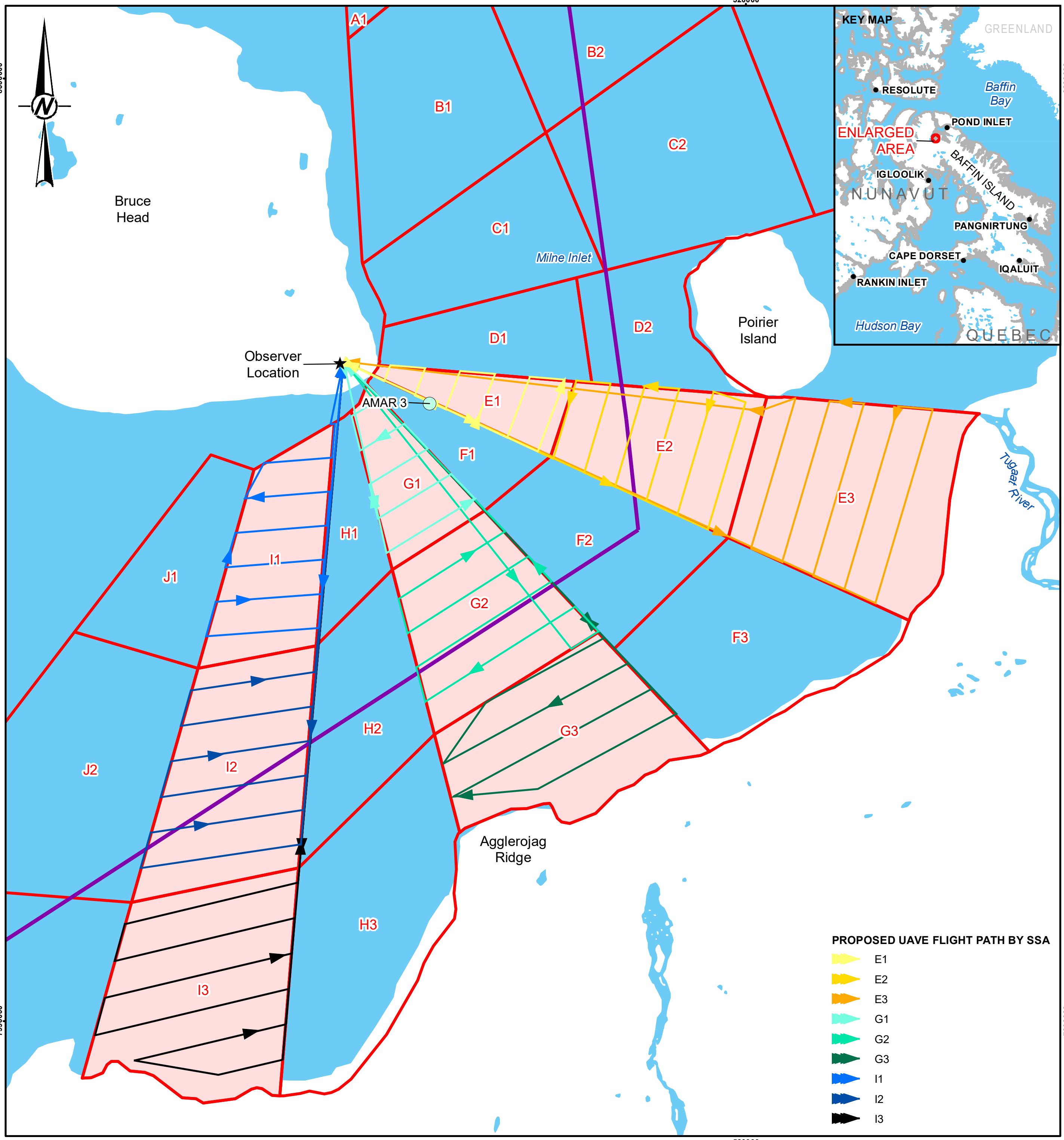
Below is a summary of pertinent information relating to UAV Survey 2.

- Survey location: BSA (Figure 1.1).
- The objective of this component of the survey is to confirm sightings information during narwhal herding events through the BSA, with special attention paid to proportion of immature animals present (i.e. calves, yearlings). Results of this survey will inform the proportion of immatures in the Eclipse Sound summering stock.
- Flight schedule: Daily, opportunistically as narwhal herding events occur.
- Flight details: The UAV will hover and hold over the BSA during herding events at an altitude that maximizes the number of narwhal observed in a single frame while still being able to decipher group composition and individual life stages. Should the herding event go on for a period of time that exceeds the flight capabilities of an individual UAV (e.g., due to battery limitations, etc), multiple UAVs will be “hot-swapped” to capture the full duration of the event.
- Data entry / analytical approach: UAV footage will be correlated to sightings data at the end of each day. It is predicted that composition of individual groups may not be feasible due to the large number of animals present during herding events. Therefore, the proportion of different life stages (i.e., adults, juveniles, yearlings, calves) observed via the UAV will be compared against proportion observed by MMOs during corresponding time periods. Should it be determined that numbers observed via the different survey methods are comparable (i.e., UAV confirms that data collected by MMOs is accurate), this survey will be terminated.
- Considerations: Narwhal herding events have typically been observed in the north→south direction, with animals moving through the BSA into Koluktoo Bay, though herding events have also been observed moving northward.

3.2.3 UAV Survey 3: Systematic Survey of SSA

Below is a summary of pertinent information relating to UAV Survey 3.

- Survey location: SSA (Figure 1.1 and Figure 3.2).
- The objective of this component of the survey is to evaluate observer detection performance (i.e. ability to effectively detect narwhal) throughout the SSA.
- Flight schedule: Daily, opportunistically as weather permits.
- Flight details: Systematic transects of strata E, G, and I will be conducted in coordination with MMOs collecting sightings data.
- Considerations: This survey will be contingent on weather conditions being suitable. For each stratum surveyed, it is predicted that two back-to-back flights will be required based on battery limitations (i.e., survey of substrata 1 and 2, battery swap, continued survey of substratum 3). It is critical that for each strata surveyed, individual substrata are surveyed in their entirety before the UAV moves on to survey the remainder of the strata.



LEGEND

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

0 1 2

1:60,000 KILOMETRES

REFERENCE(S)

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

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BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FLIGHT PATHS ASSOCIATED WITH THE SYSTEMATIC SURVEY OF STRATA E, G, AND I

CONSULTANT
GOLDER MEMBER OF WSP

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PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000-01	0	3.2

4.0 LITERATURE CITED

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https://golderassociates.sharepoint.com/sites/11206g/deliverables (do not use)/issued to client_for wp/1663724-310-r-rev0/1663724-310-r-rev0-bruce head 2021 training manual 24jun_21.docx

APPENDIX A

Glossary

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

Behaviour –

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

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

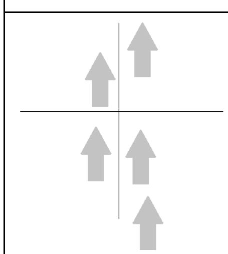
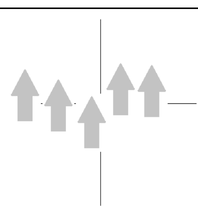
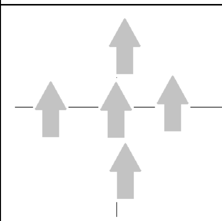
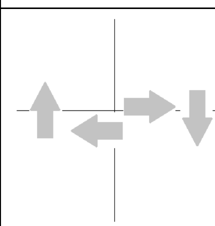
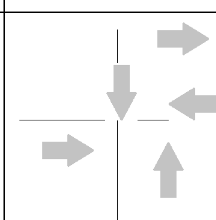
BSA – Behavioural Study Area covers portions of strata D, E and F that are within 1 km of the Bruce Head shore where the observation platform is located.

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

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

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

Table 2: Group formation categories

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

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

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

Table 3: Life stages of narwhal

	Adult	Juvenile	Yearling	Calf
Length	4.2 – 4.7 m	80-85% length of adult	2/3 length of accompanying female	1/3 to 1/2 length of accompanying female, usually in “baby” or “echelon” position close to mother. Newborn calves are ~1.6 m in length.
Colouration	Black and white spotting on their back, or mostly white (generally old whales)	Dark grey; no or only light spotting on their back	Light to uniformly dark grey	White or uniformly light (slate) grey
Photo				

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

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

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

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

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

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

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

> **Tight spread –** narwhal ≤ body width apart
>
> **Loose spread -** narwhal >1 body width apart

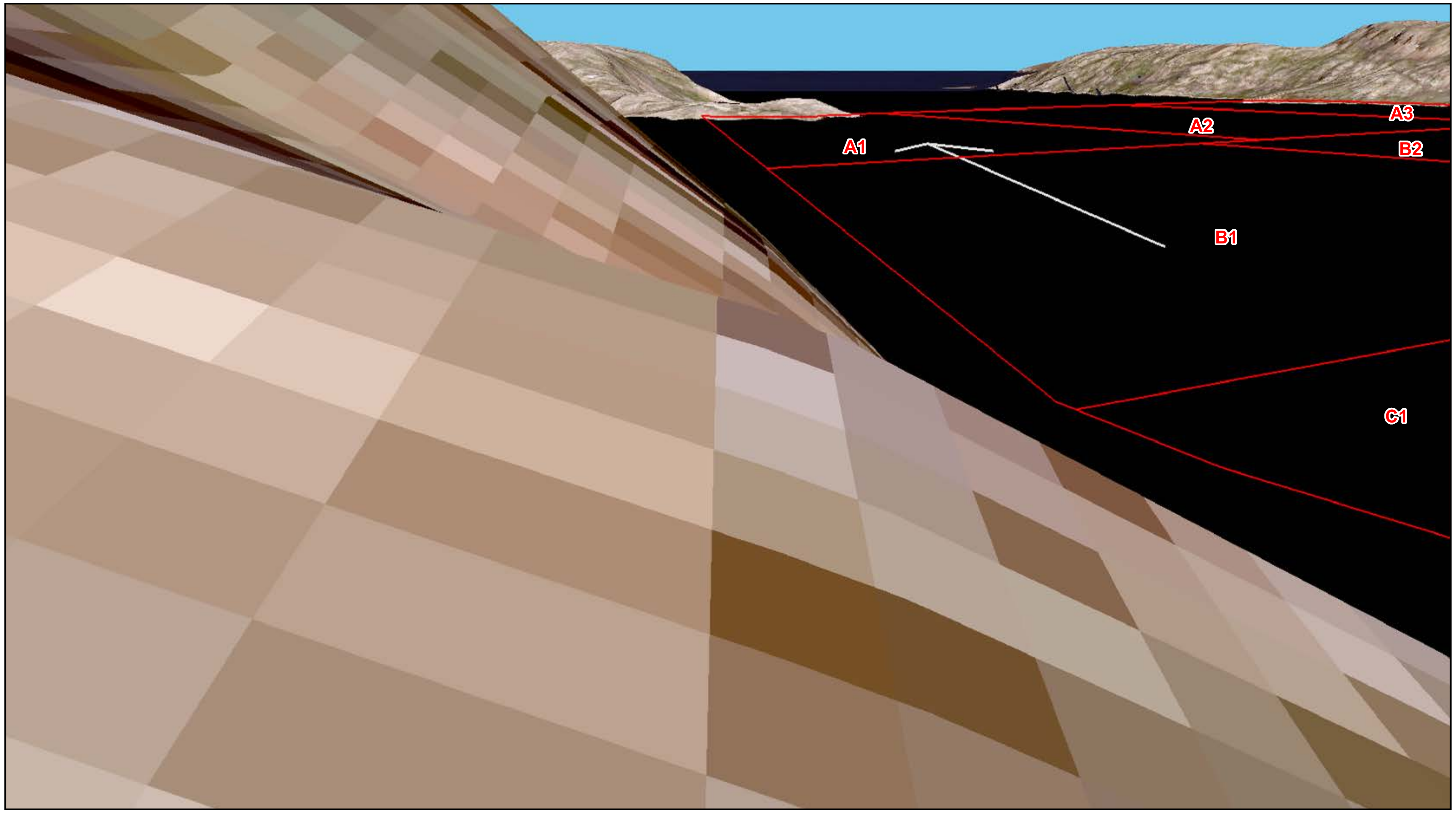
SSA – Stratified Study Area, the larger study area of the Program.

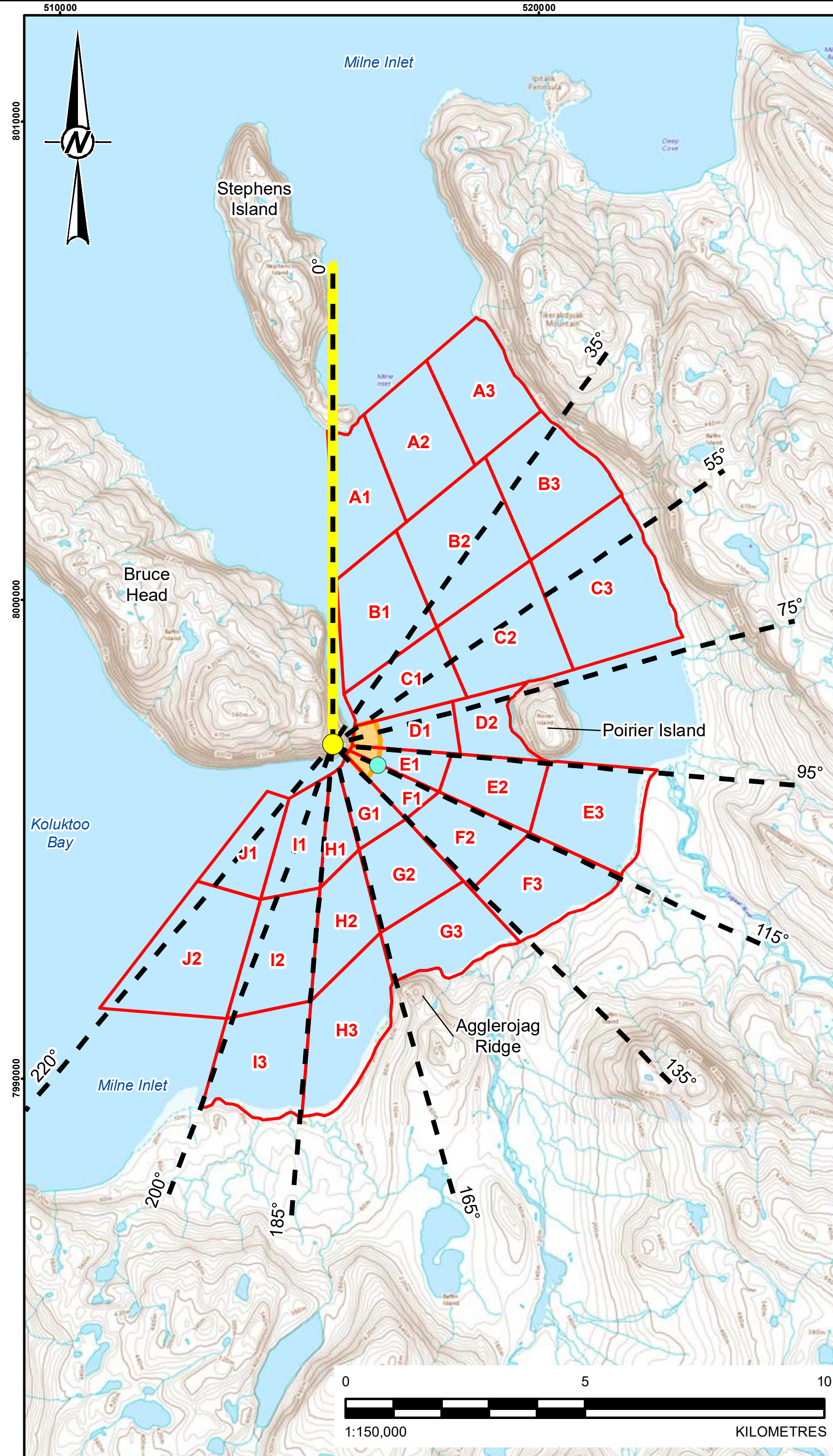
Stratum – Sections A through J of the SSA.

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

APPENDIX B

Perspective Images of Substrata





LEGEND

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

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

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BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2021

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-06-24
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2021 - OBSERVATION PERSPECTIVE AT 0°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000-01	0	B-1

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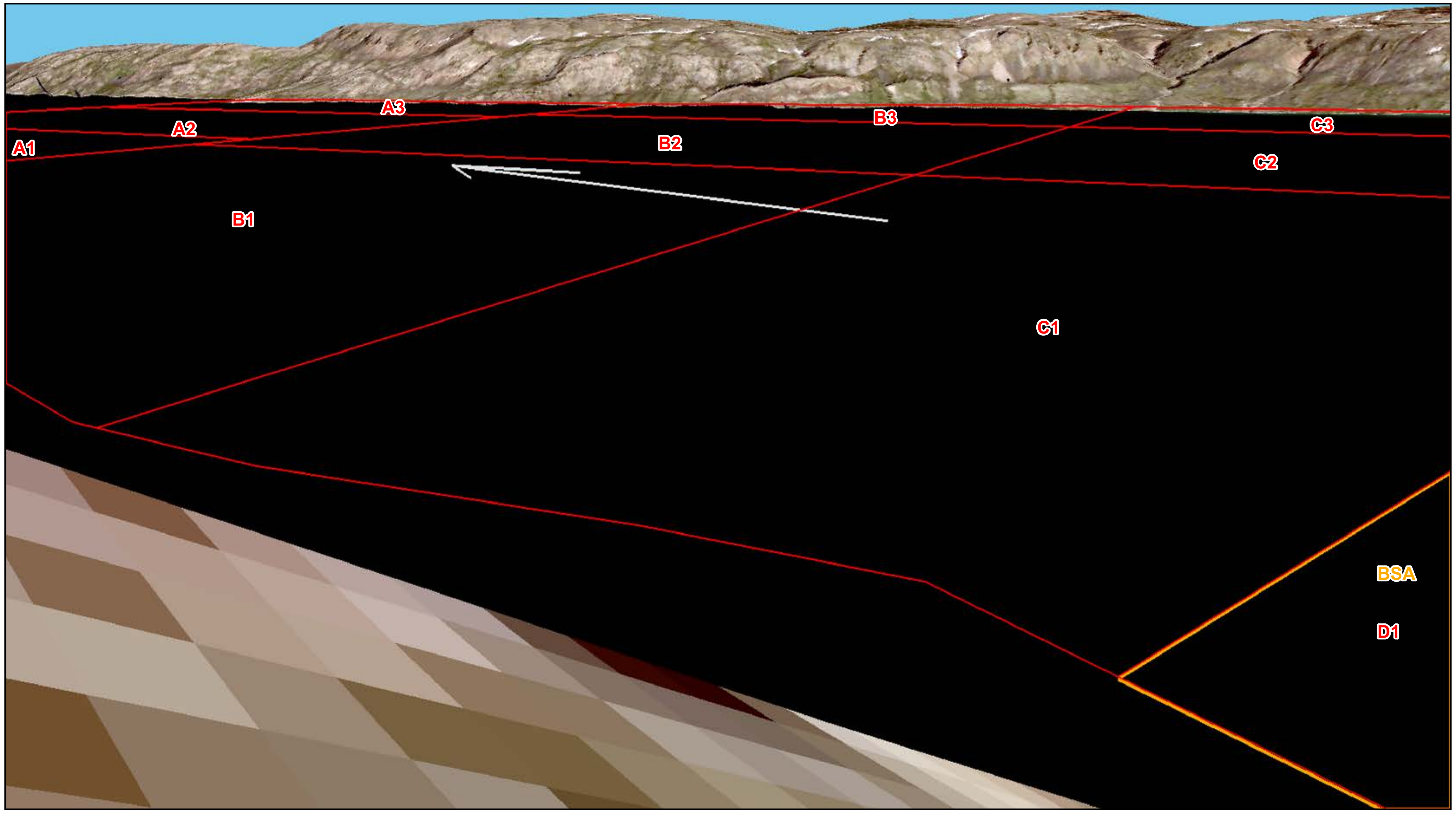
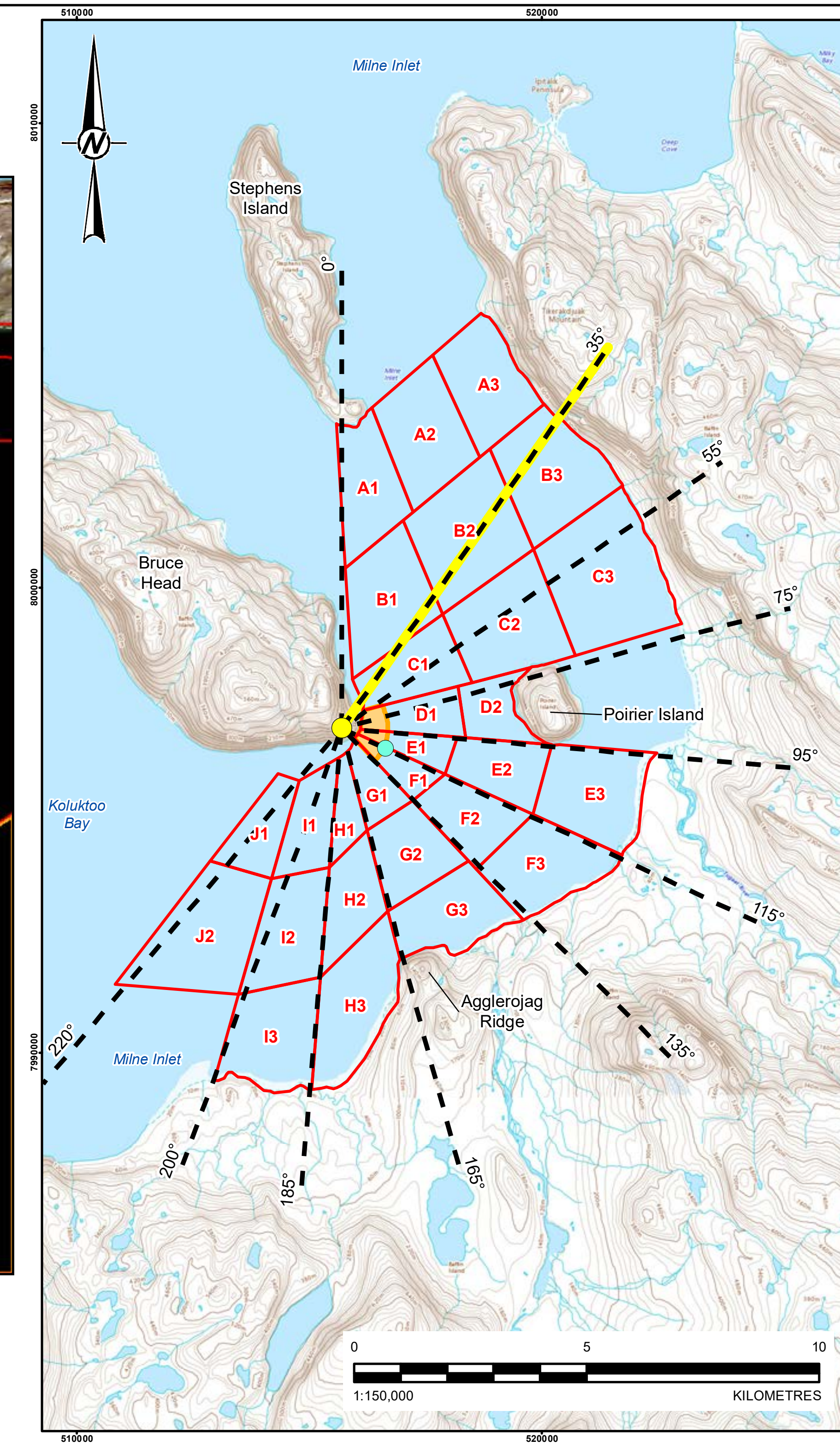
25mm





LEGEND

- AMAR LOCATION
- OBSERVER LOCATION
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- LINE OF SIGHT - CURRENT VIEW
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APPROVED	PR

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2021 - OBSERVATION PERSPECTIVE AT 35°

PROJECT NO.	CONTROL	REV.	FIGURE
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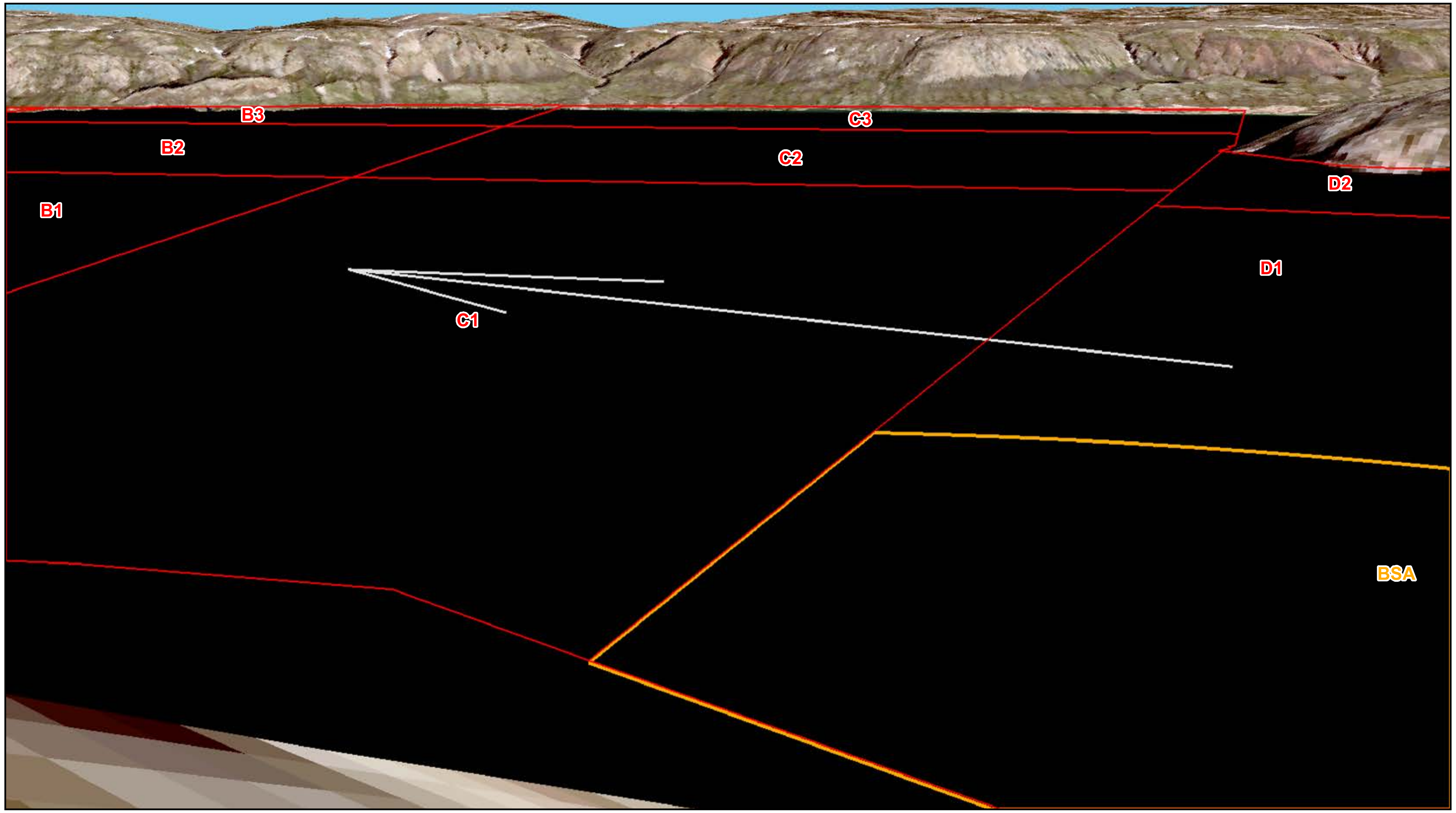

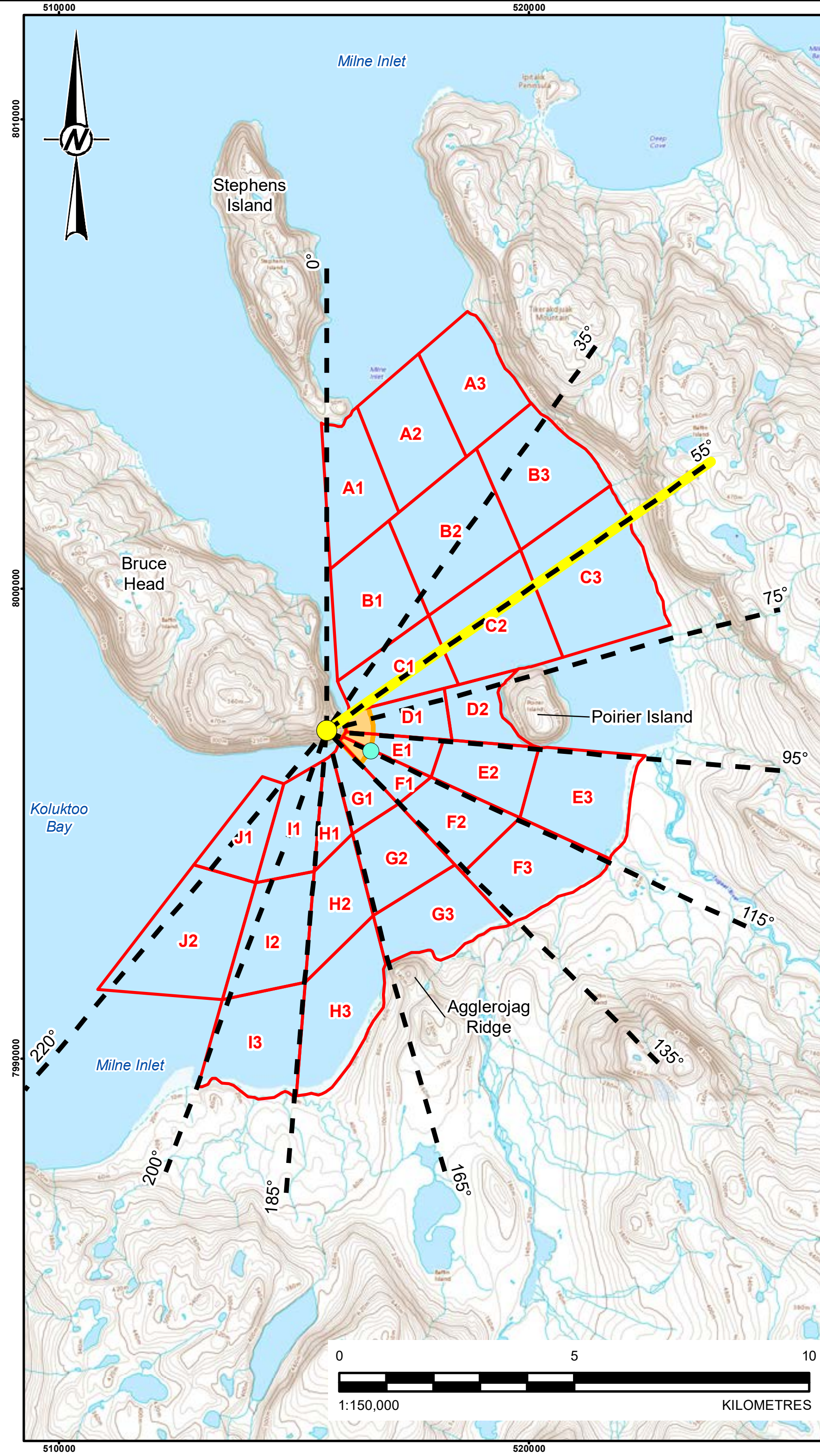

LEGEND

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

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MEMBER OF WSP

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TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2021 - OBSERVATION PERSPECTIVE AT 55°

PROJECT NO.	CONTROL	REV.	FIGURE
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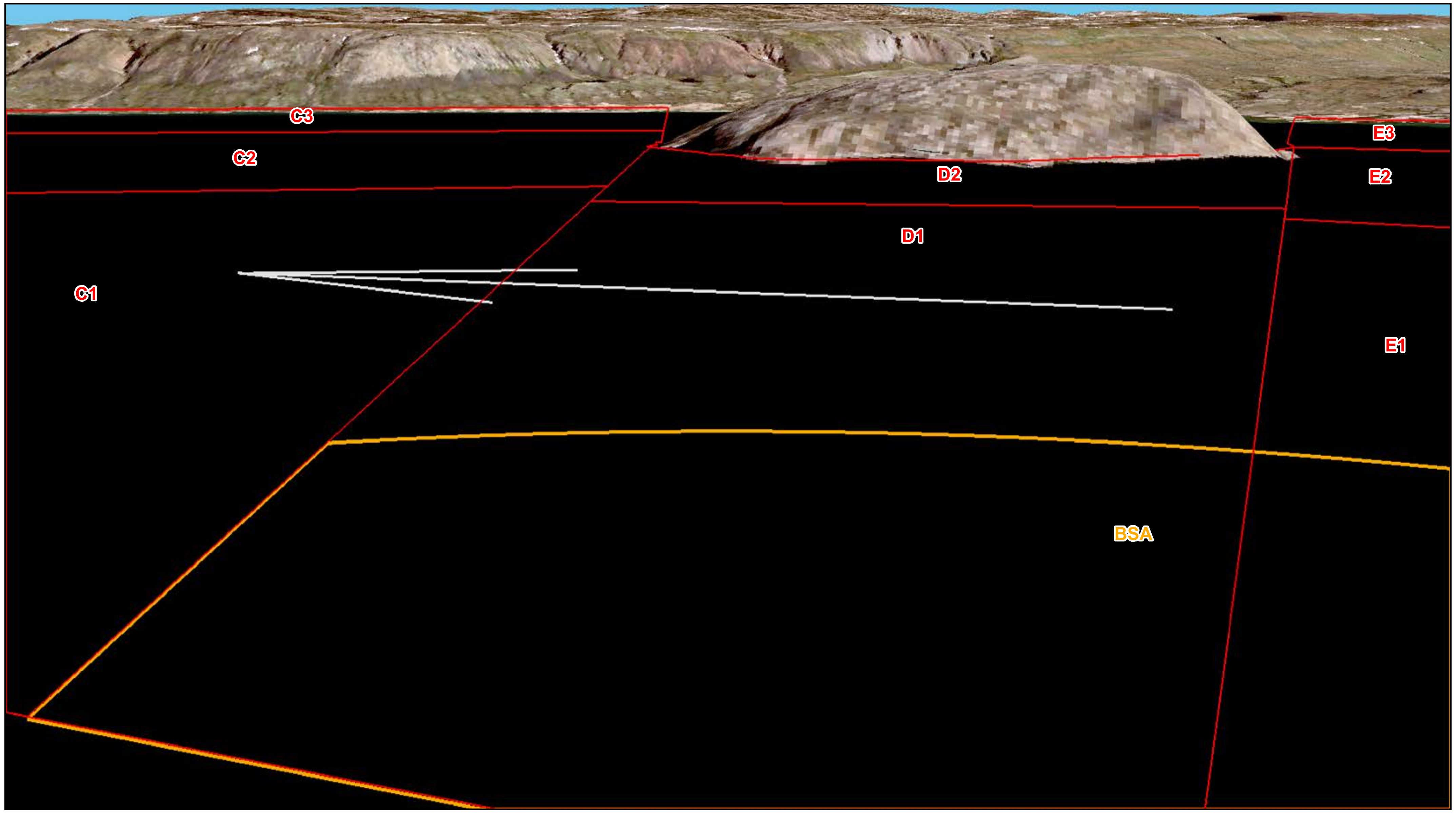

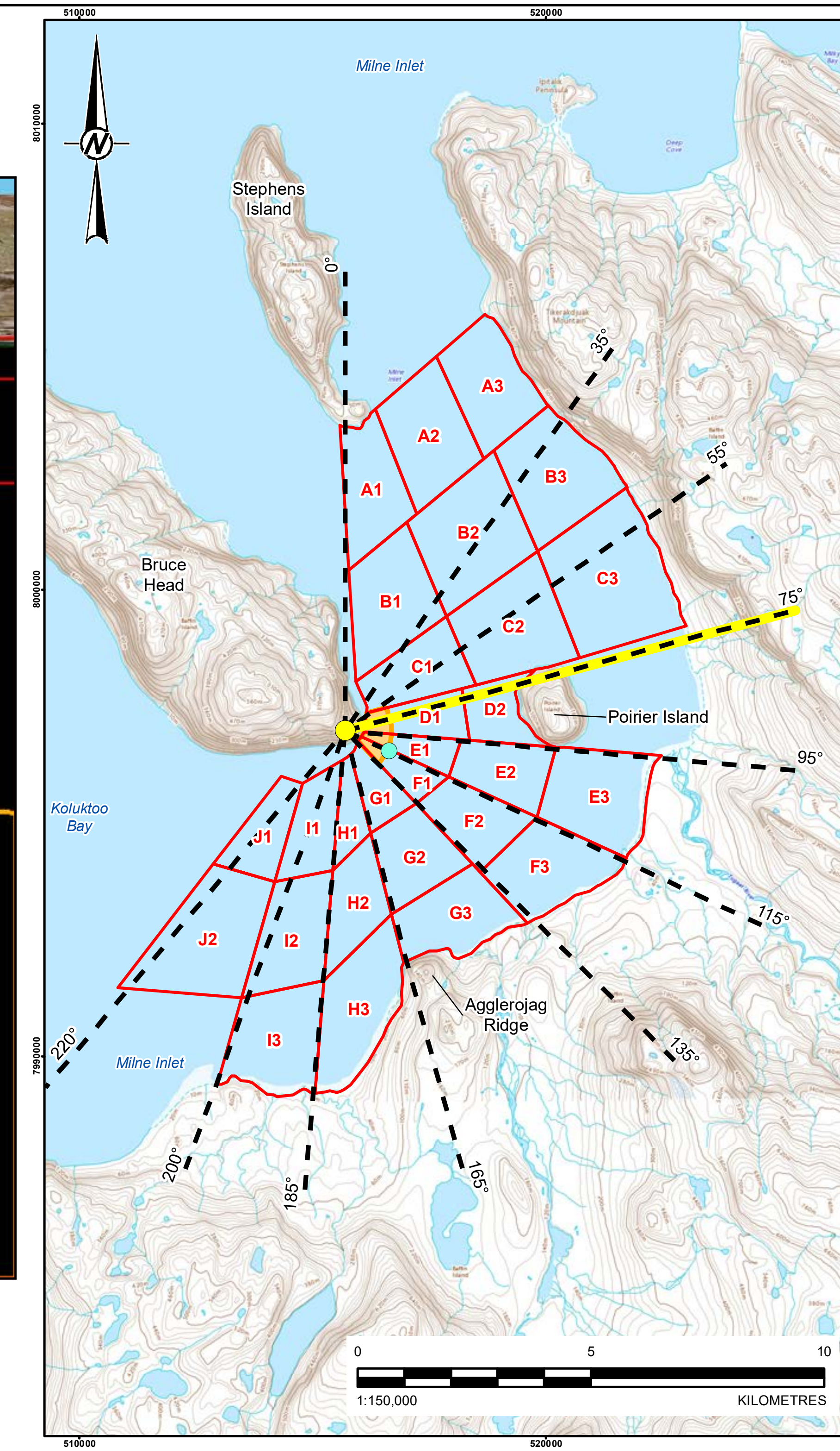

LEGEND

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

REFERENCE(S)

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REVIEWED	AA
APPROVED	PR

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2021 - OBSERVATION PERSPECTIVE AT 75°

PROJECT NO.	CONTROL	REV.	FIGURE
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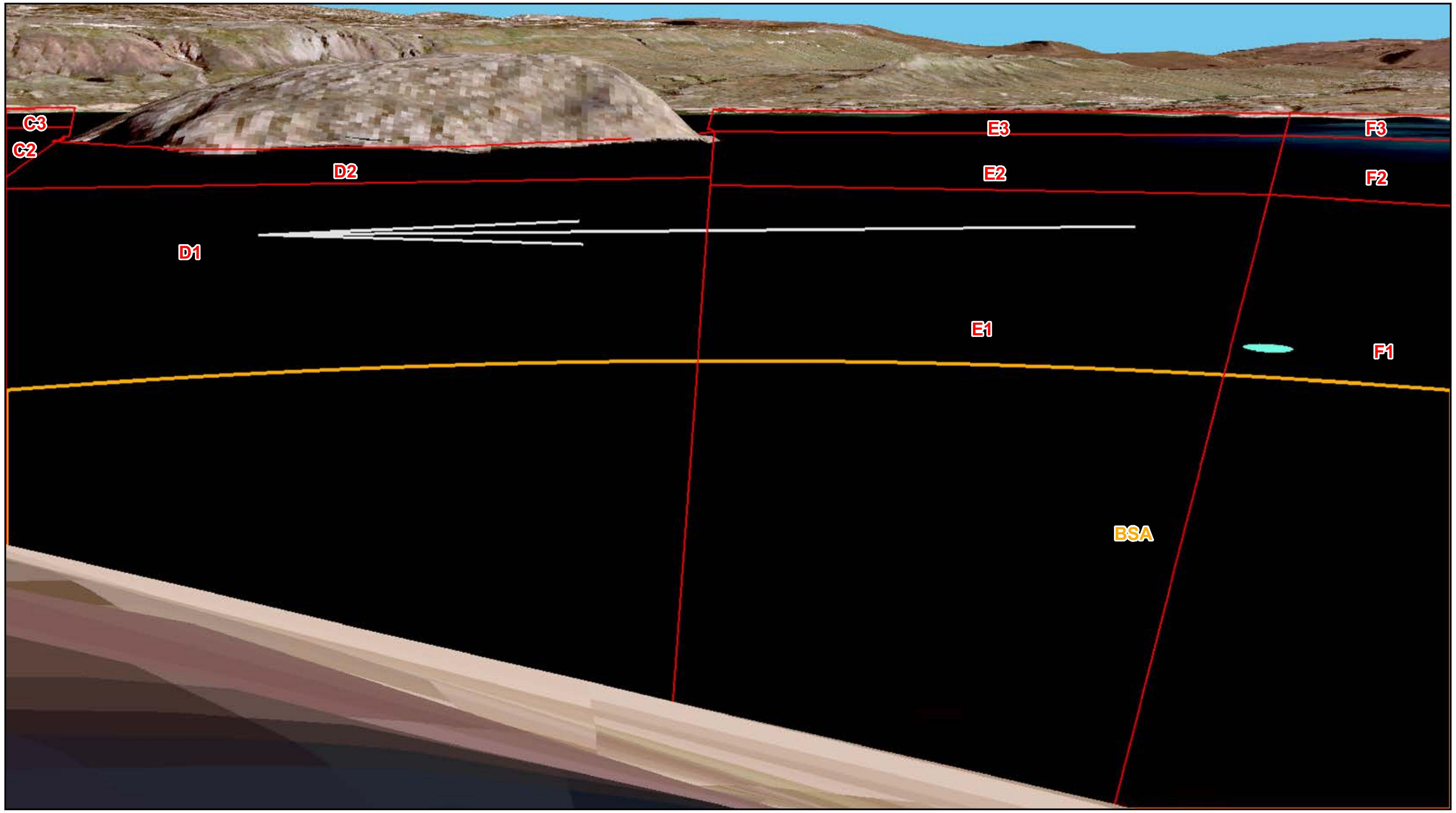

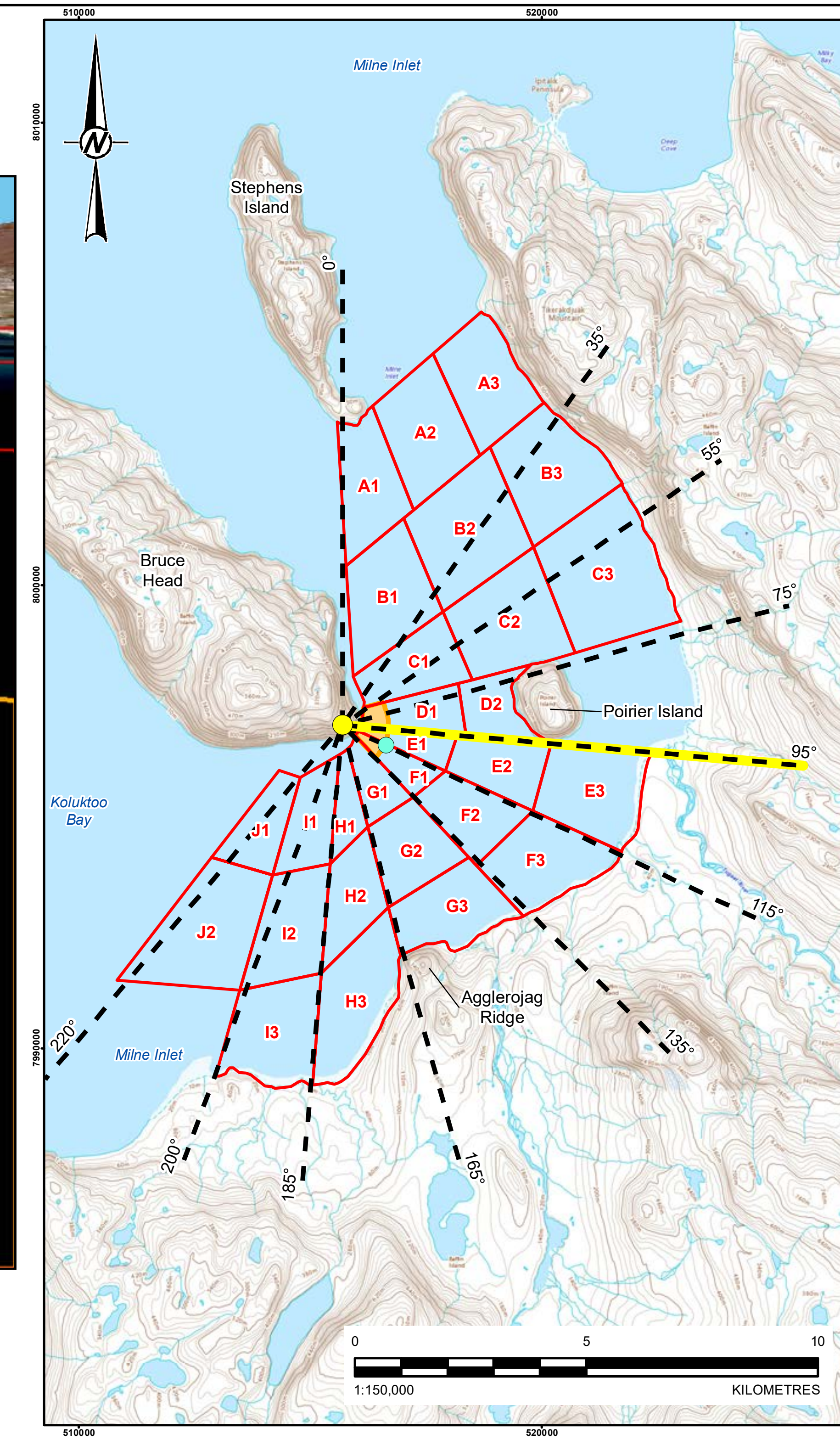

LEGEND

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

REFERENCE(S)
SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
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MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2021

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-06-24
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2021 - OBSERVATION PERSPECTIVE AT 95°

PROJECT NO.	CONTROL	REV.	FIGURE
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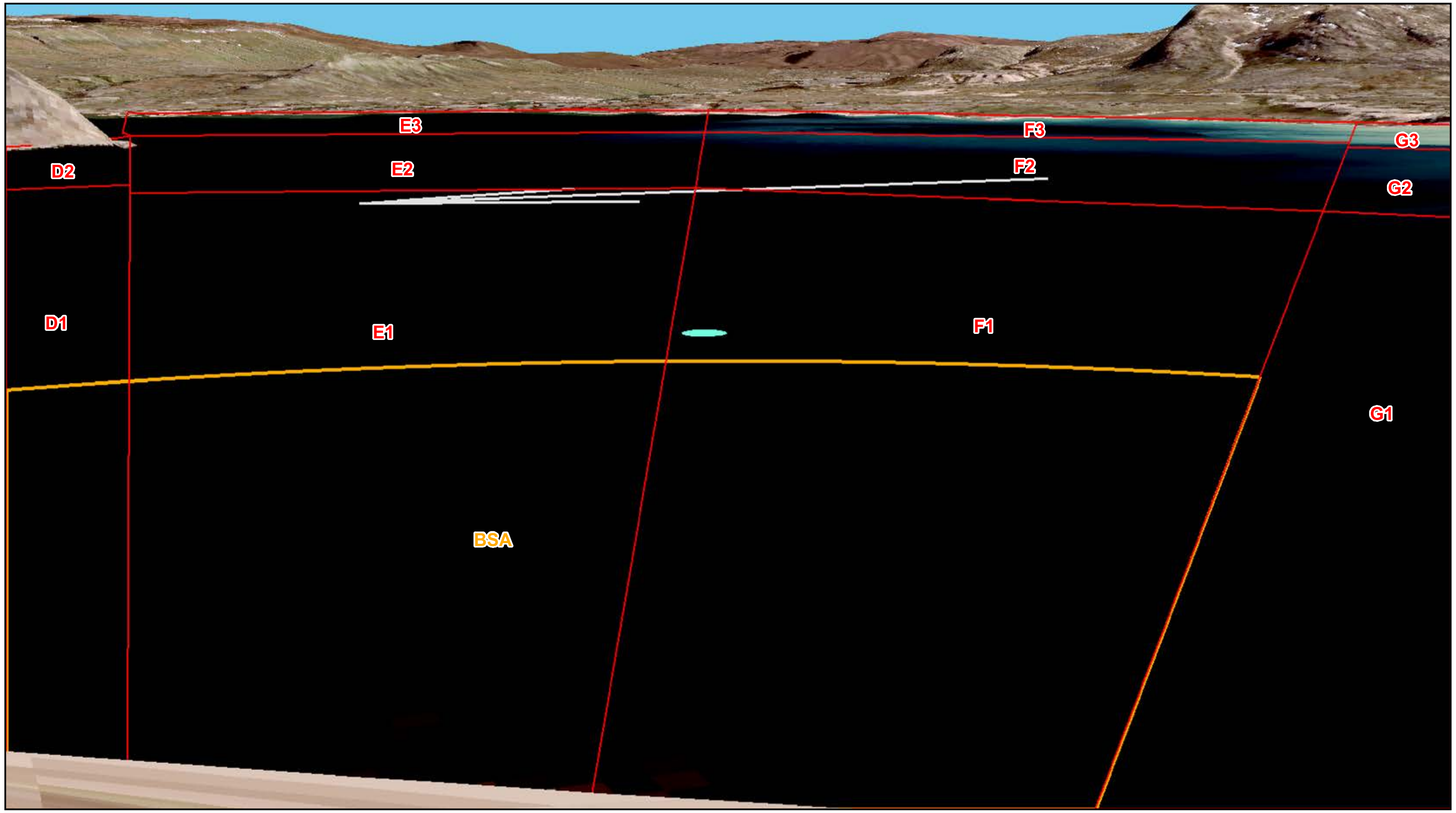

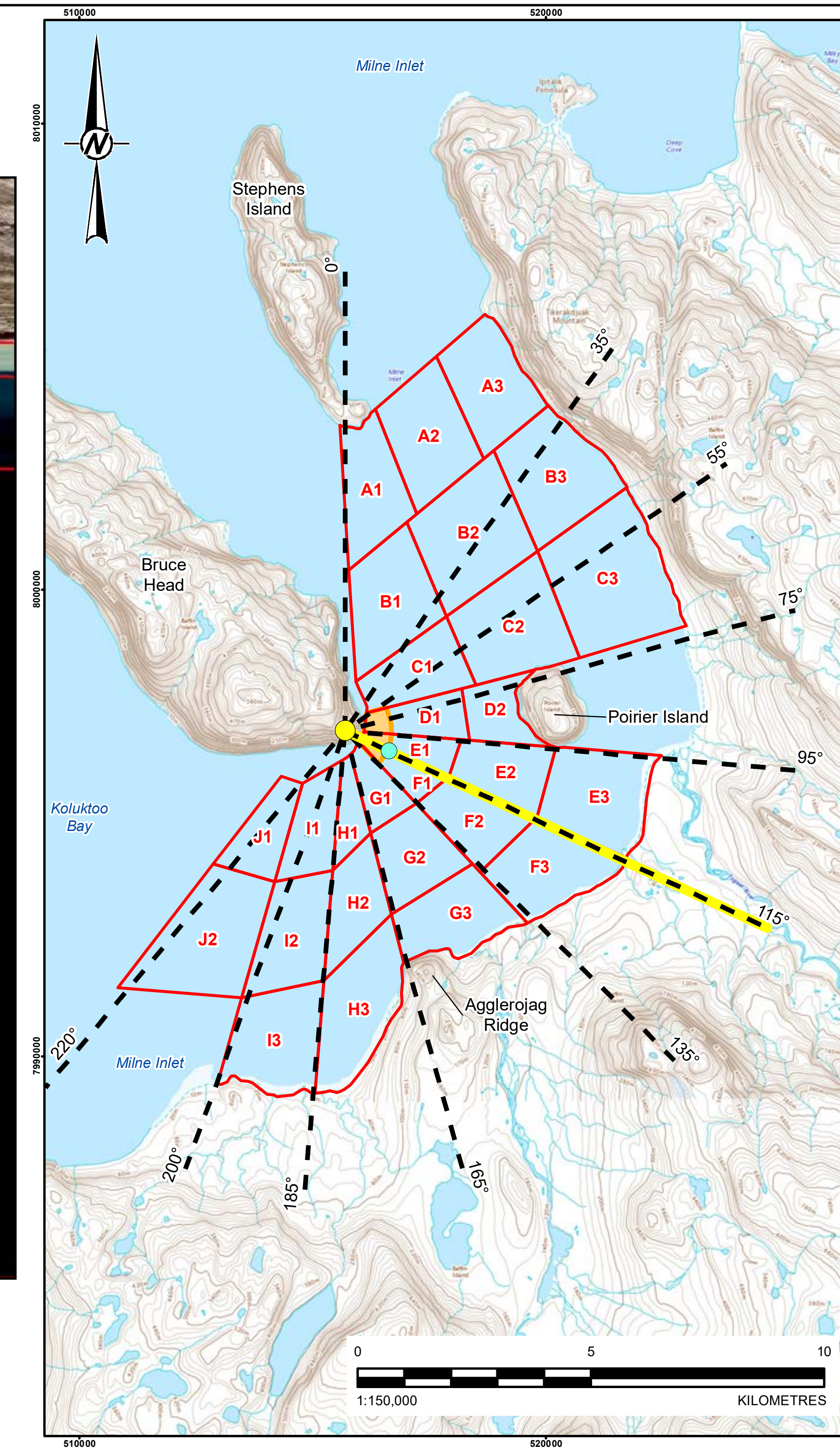

LEGEND

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

REFERENCE(S)
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PROJECTION: UTM ZONE 17 DATUM: NAD 83

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BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2021

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-06-24
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2021 - OBSERVATION PERSPECTIVE AT 115°

PROJECT NO.	CONTROL	REV.	FIGURE
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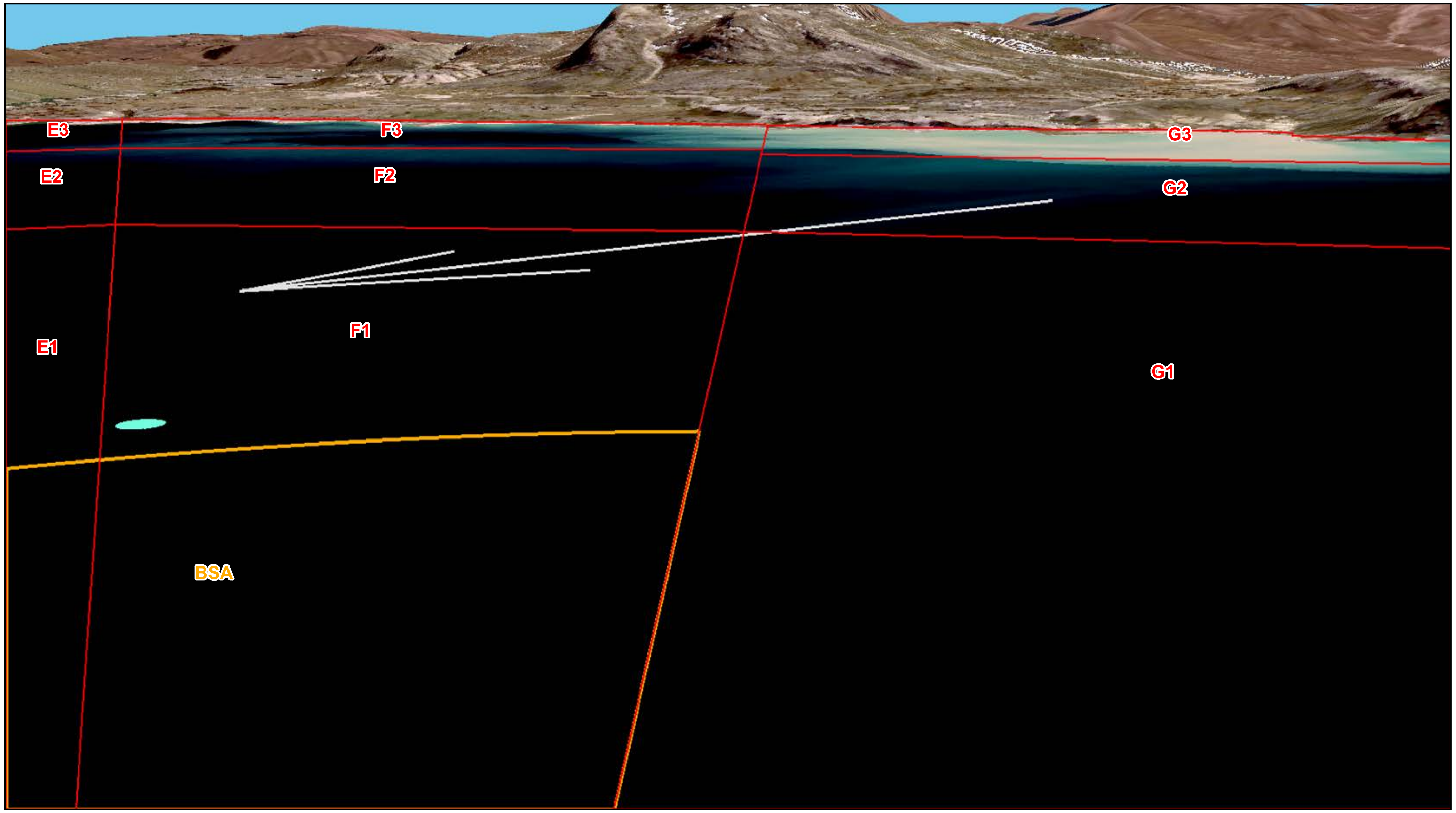

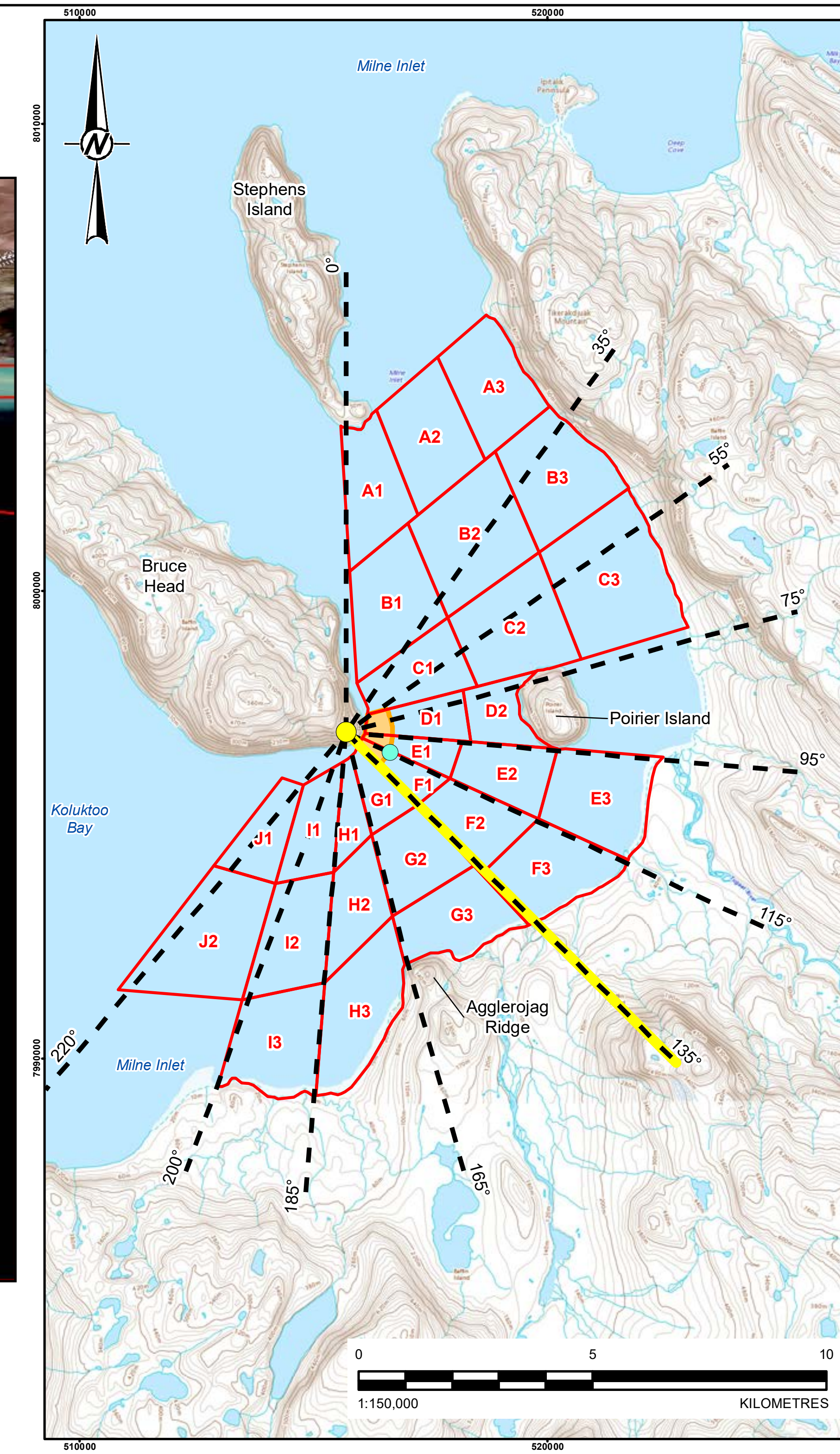

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- LINE OF SIGHT
- LINE OF SIGHT - CURRENT VIEW
- NORTH ARROW
- BEHAVIOURAL STUDY AREA (BSA)
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MEMBER OF WSP

YYYY-MM-DD	2021-06-24
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2021 - OBSERVATION PERSPECTIVE AT 135°

PROJECT NO.	CONTROL	REV.	FIGURE
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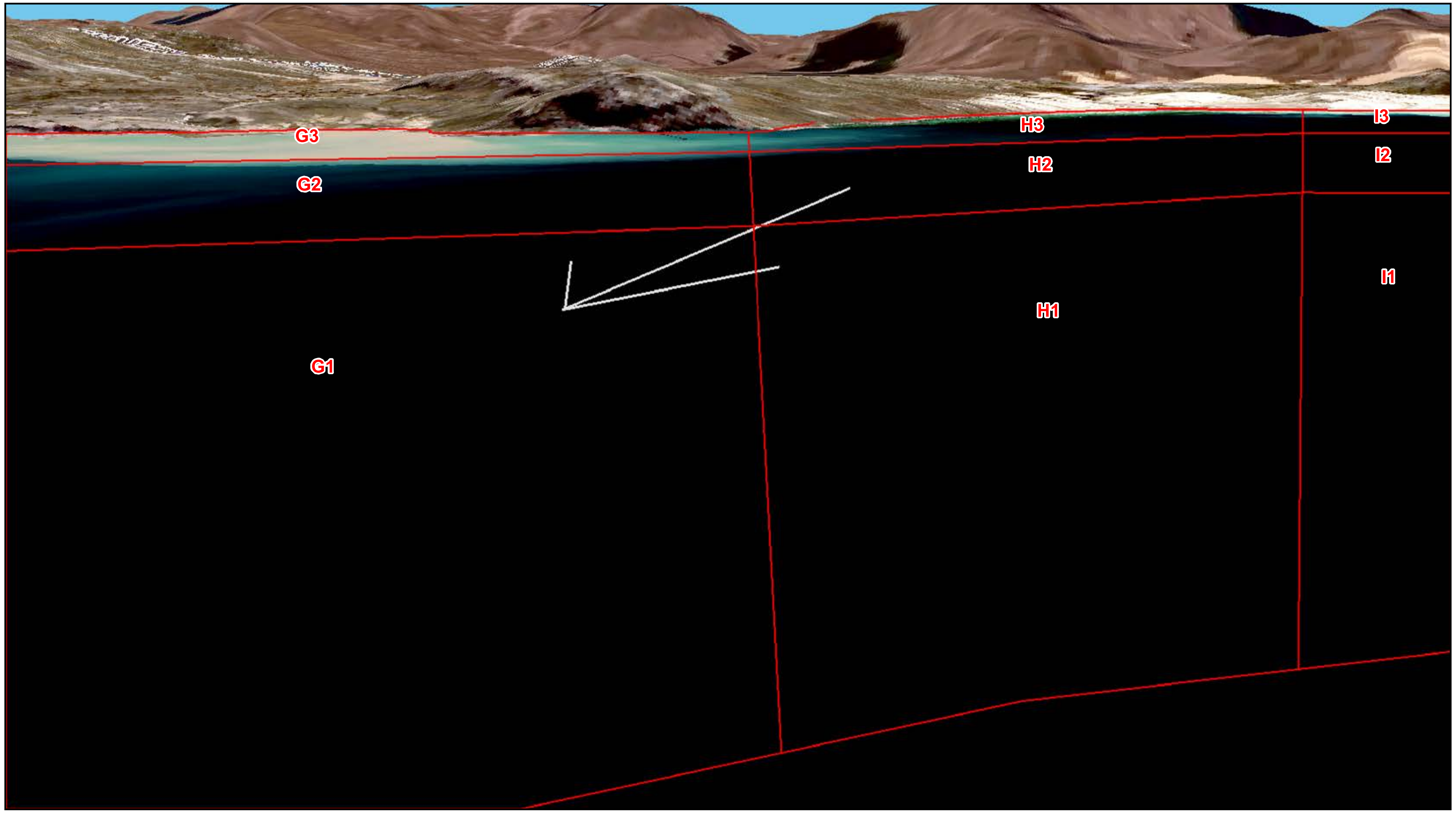
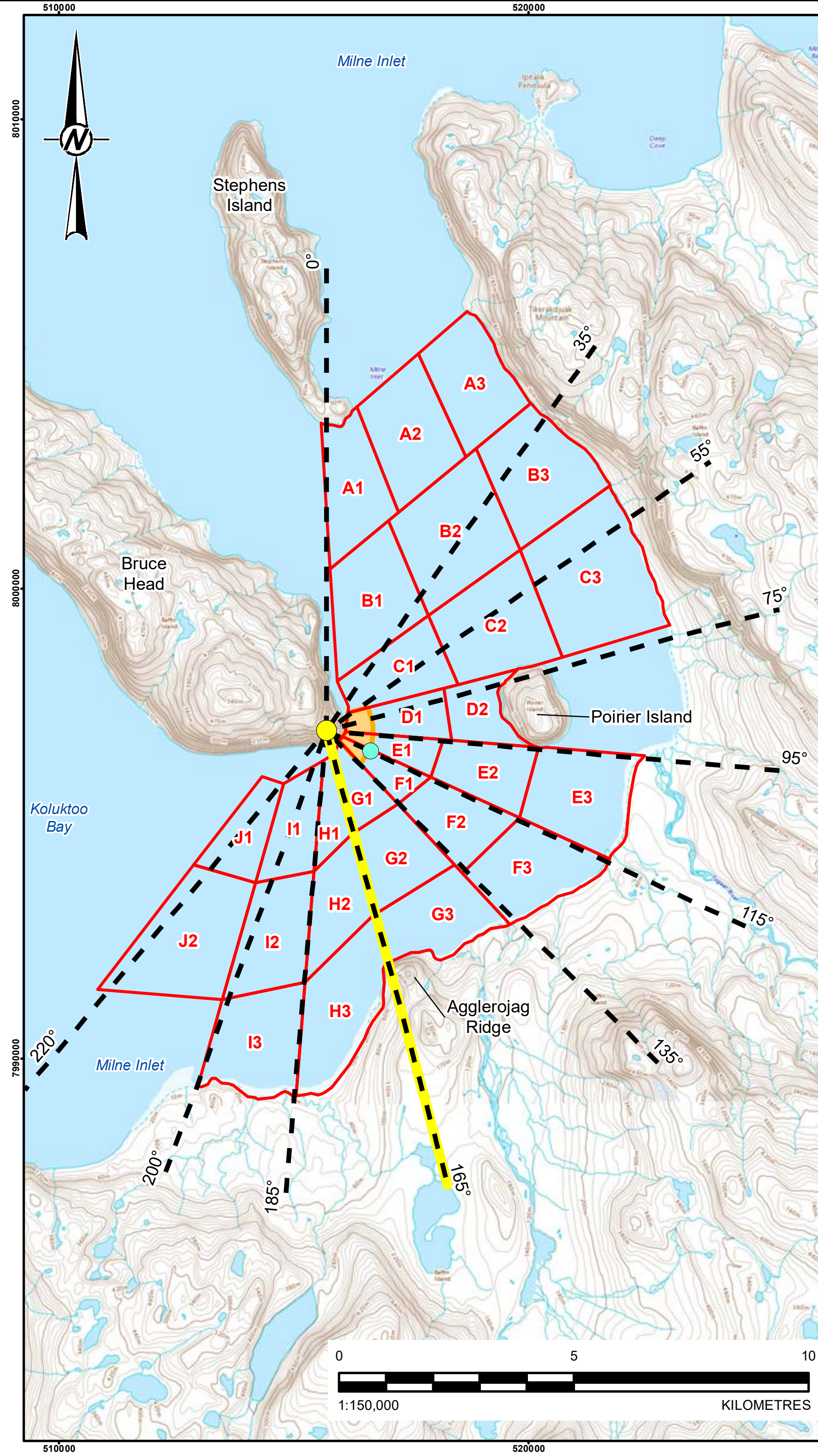




LEGEND

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

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

CLIENT
BAFFINLAND IRON MINES CORPORATION

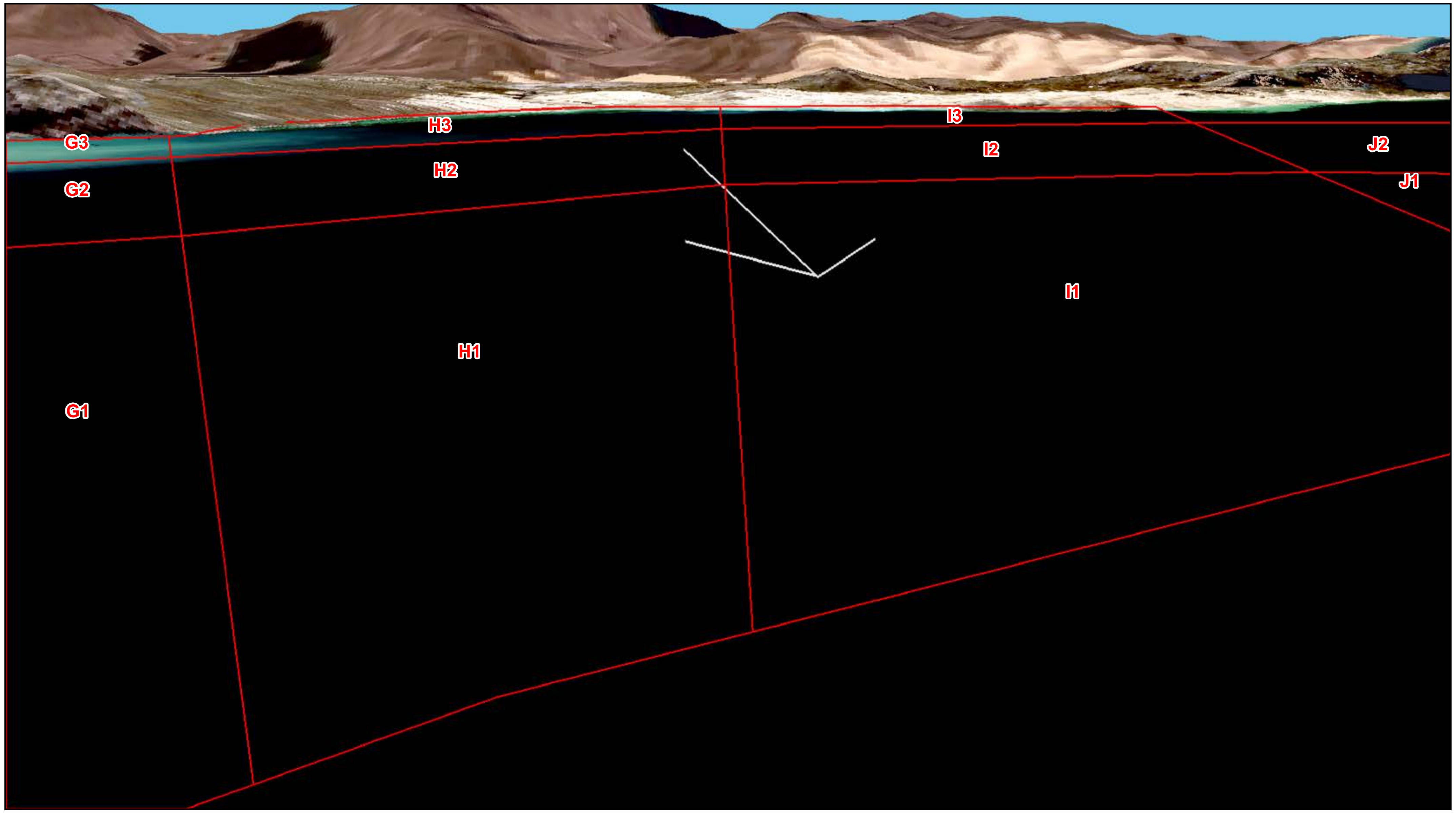
PROJECT
MARY RIVER PROJECT - BRUCE HEAD PROGRAM 2021

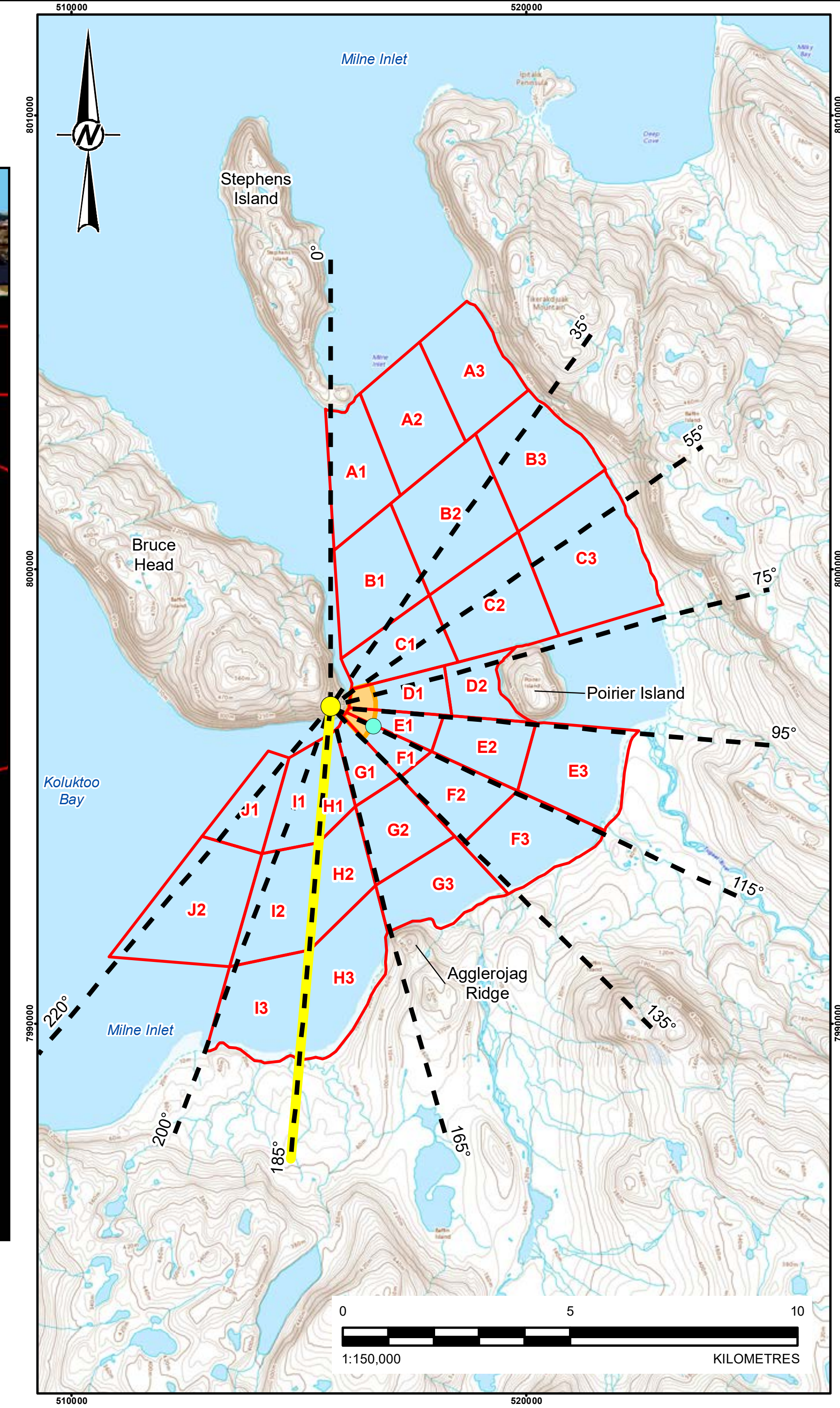
CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-06-24
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2021 - OBSERVATION PERSPECTIVE AT 165°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000-01	0	B-8





LEGEND

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

REFERENCE(S)

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

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GOLDER
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YYYY-MM-DD	2021-06-24
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2021 - OBSERVATION PERSPECTIVE AT 185°

PROJECT NO.	CONTROL	REV.	FIGURE
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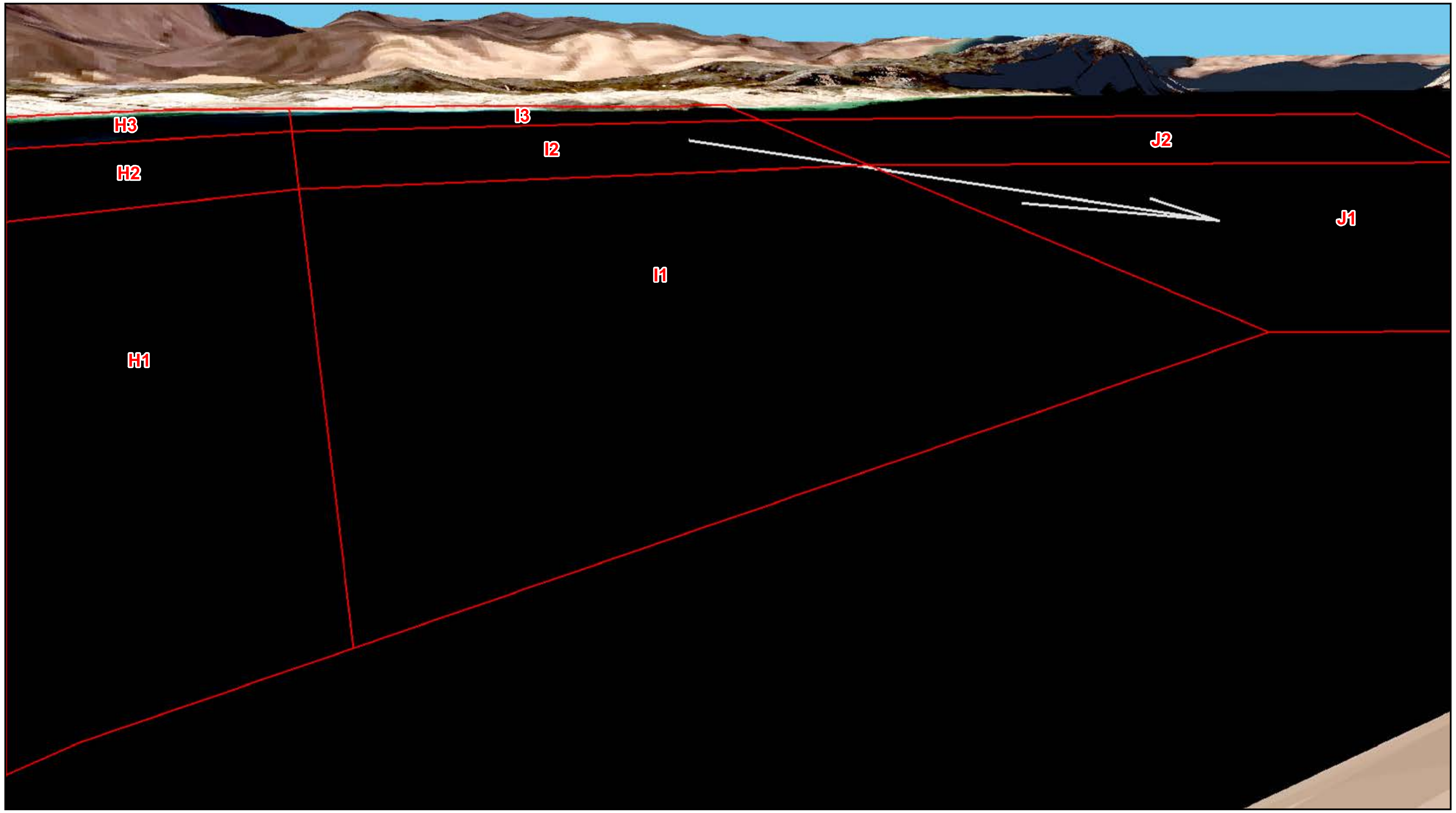

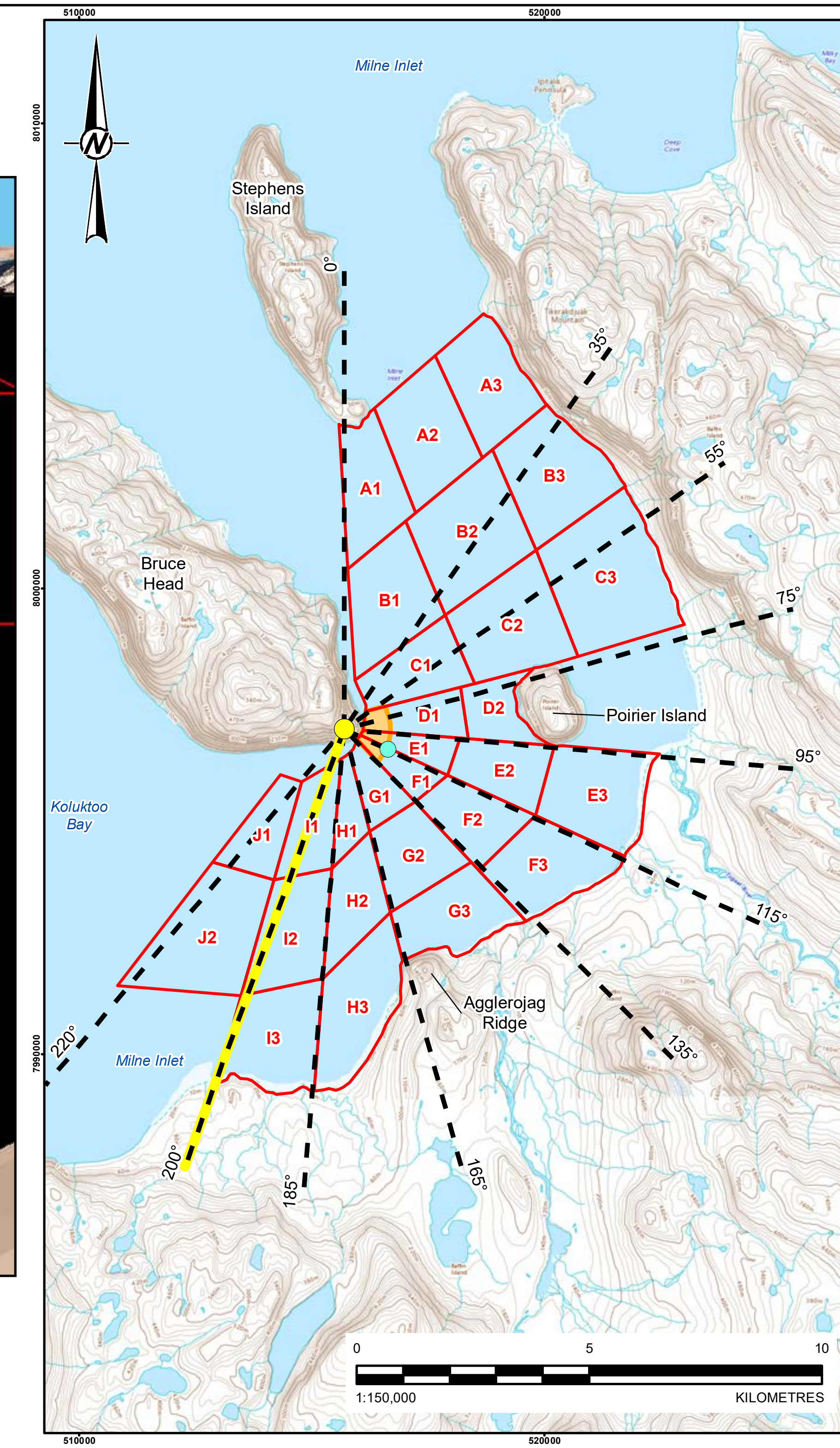

LEGEND

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

REFERENCE(S)

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PROJECTION: UTM ZONE 17 DATUM: NAD 83

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CONSULTANT

GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-06-24
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

TITLE

STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2021 - OBSERVATION PERSPECTIVE AT 200°

PROJECT NO.	CONTROL	REV.	FIGURE
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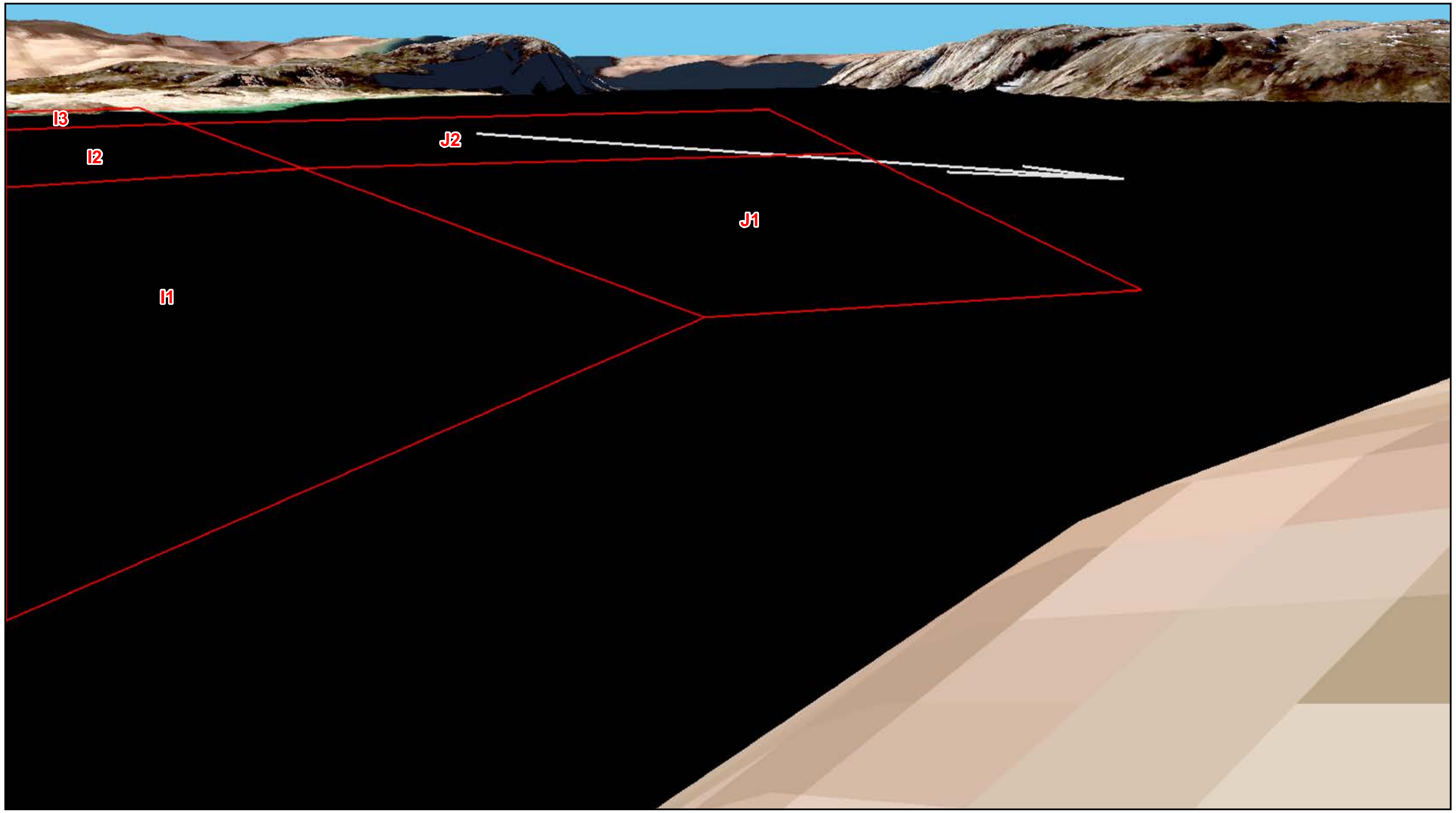

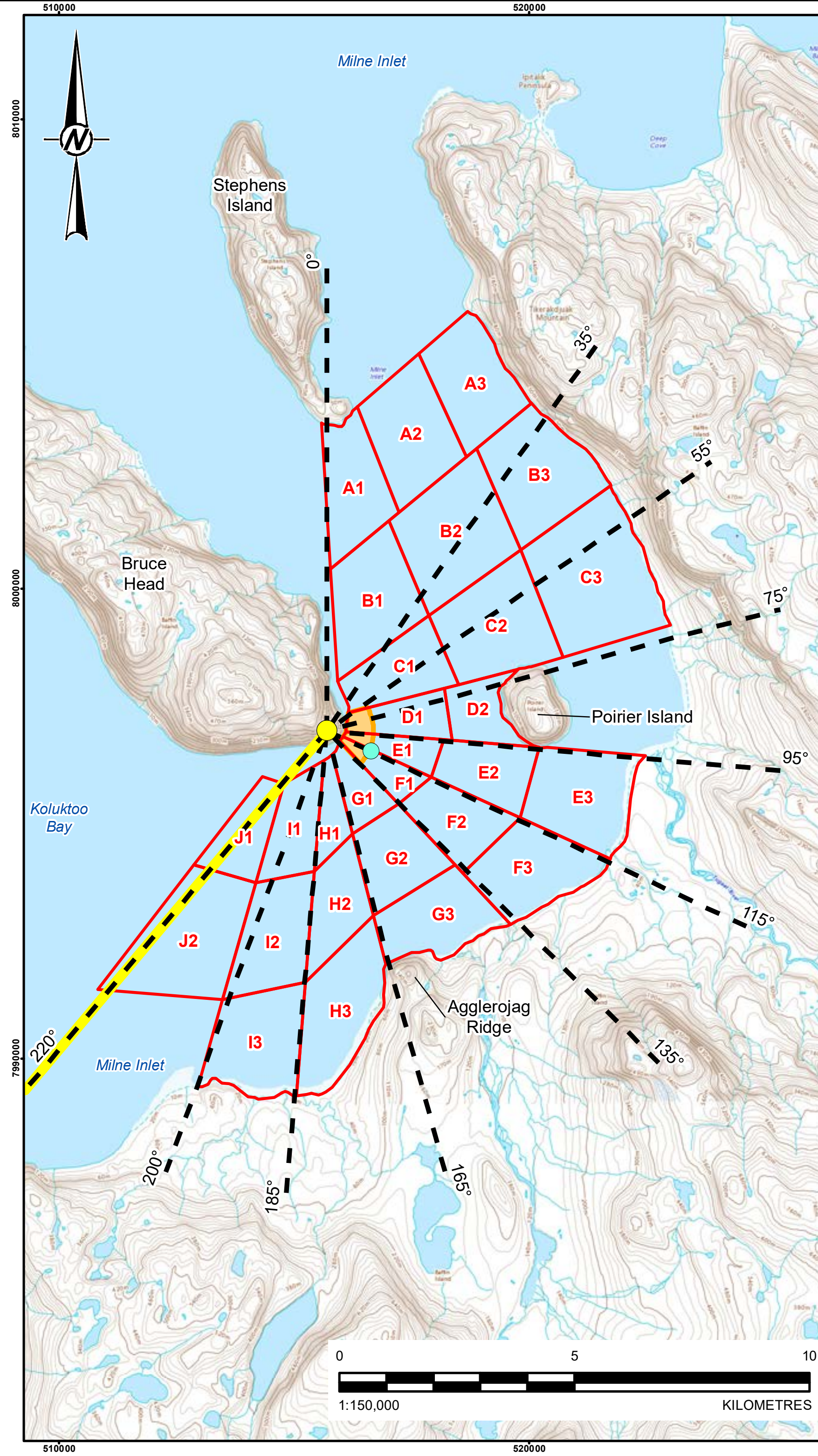

LEGEND

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

REFERENCE(S)
SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. TOPORAMA MAPS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
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GOLDER
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YYYY-MM-DD	2021-06-24
DESIGNED	AA
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

TITLE
STRATIFIED STUDY AREA FOR BRUCE HEAD MARINE MAMMAL MONITORING 2021 - OBSERVATION PERSPECTIVE AT 220°

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000-01	0	B-11

APPENDIX C

Beaufort Scale

The Beaufort scale

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

APPENDIX D

Marine Mammal Detection Cues

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

Blows

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

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

Splashes in the water

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

Footprints

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

Birds

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

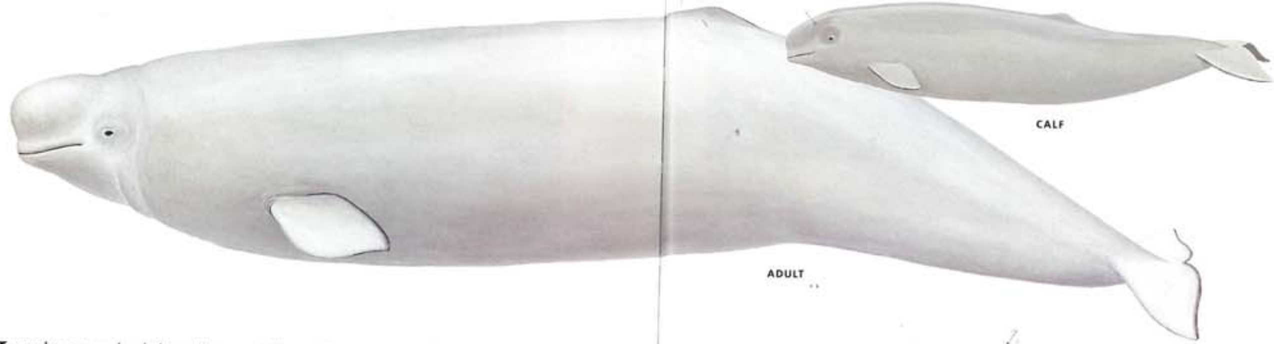
APPENDIX E

Marine Mammal Identification

Beluga

Delphinapterus leucas
(Pallas, 1776)

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

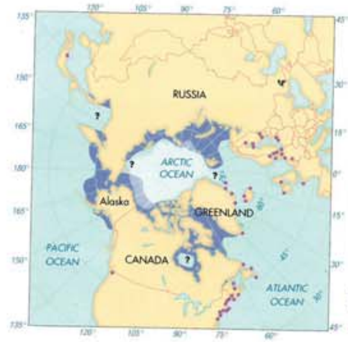


Known by some early whalers as "sea canaries" because of their loquacious natures, these whales are abundant and widespread in the Arctic and Subarctic. For many centuries, Belugas, also known as White Whales, have been a staple of arctic societies, providing food, fuel oil, and even soft durable leather.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

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

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

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



BELUGA
FAMILY MONODONTIDAE

MEASUREMENTS AT BIRTH

LENGTH	4'11"–5'3" (1.5–1.6 m)
WEIGHT	176–220 lb (80–100 kg)

MAXIMUM MEASUREMENTS

LENGTH	**MALE**	14–16' (4.2–4.9 m)
	FEMALE	13–14' (3.9–4.3 m)
WEIGHT	**MALE**	2,400–3,500 lb (1,100–1,600 kg)
	FEMALE	1,500–2,600 lb (700–1,200 kg)

LIFE SPAN
At least 25 years, possibly more than 50

- RANGE
- ? POSSIBLE RANGE
- EXTRALIMITAL RECORDS

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

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

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

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

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

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

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

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

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

Bowhead Whale

Balaena mysticetus
Linnaeus, 1758

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


JUVENILE


MATURE MALE

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

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

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

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

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

RANGE

BOWHEAD WHALE
FAMILY BALAENIDAE

MEASUREMENTS AT BIRTH

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

MAXIMUM MEASUREMENTS

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

LIFE SPAN

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

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

REPRODUCTION Females give birth every three to four years. The gestation period has never been confirmed, but the best data suggest it lasts 13 to 14 months, with most calves born during the spring migration north. Weaning probably occurs when calves are 9 to 12 months old. Most conceptions are thought to occur in late winter or early spring, although mating behavior has been observed at other times of the year. Due to the male's unusually large testes, the mating system of the Bowhead Whale is thought to be based in part on sperm competition, involving a female mating with multiple males. Good evidence exists that, like Humpbacks, Bowhead males produce songs that may serve to advertise for females. These vocalizations are heard primarily in spring.

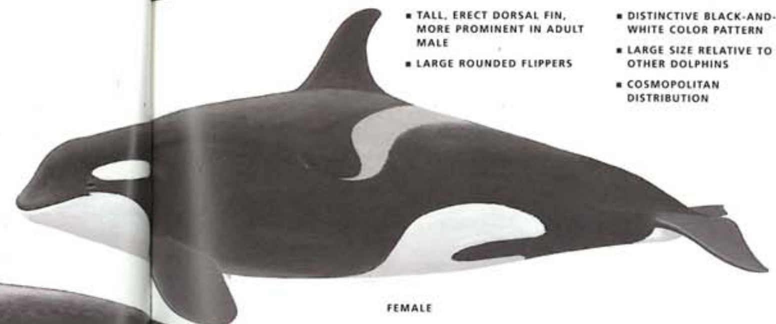
OPPOSITE TOP: *A Bowhead dives, showing its broad triangular tail.*
OPPOSITE BOTTOM: *Two Bowhead Whales surface next to ice floes. The prominent white chin patch is an identifying feature of these whales.*
LEFT: *A Bowhead raises its head above the surface in the open water of an ice lead.*

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

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

Killer Whale

Orcinus orca
(Linnaeus, 1758)



FEMALE

MALE

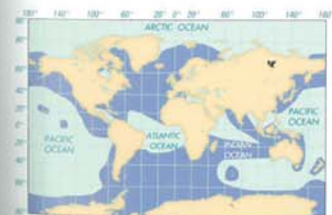
- TALL, ERECT DORSAL FIN, MORE PROMINENT IN ADULT MALE
- LARGE ROUNDED FLIPPERS
- DISTINCTIVE BLACK-AND-WHITE COLOR PATTERN
- LARGE SIZE RELATIVE TO OTHER DOLPHINS
- COSMOPOLITAN DISTRIBUTION

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

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

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

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



RANGE

KILLER WHALE
FAMILY DELPHINIDAE

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

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

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

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

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

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

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

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

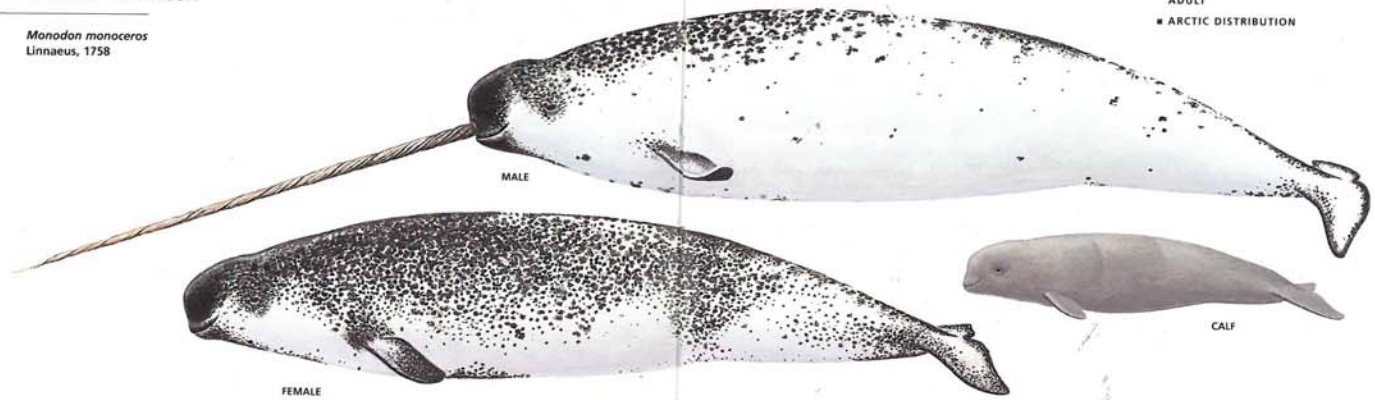
FOOD AND FORAGING Killer Whales eat a diet ranging from small schooling fish and squid to large baleen and sperm whales. Their prey items include sea turtles, otters, sirenians, sharks, rays, and even deer or moose, which they catch swimming across channels. Pods tend to specialize. For example, some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

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

Narwhal

Monodon monoceros
Linnaeus, 1758

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



MALE

FEMALE

CALF

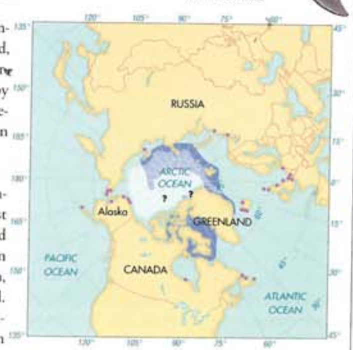
JUVENILE MALE

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

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

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

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



■ RANGE
● EXTRALIMITAL RECORDS
? POSSIBLE RANGE

NARWHAL
FAMILY MONODONTIDAE

MEASUREMENTS AT BIRTH

LENGTH	5'3" (1.6 m)
WEIGHT	176 lb (80 kg)

MAXIMUM MEASUREMENTS

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

LIFE SPAN
At least 25 years, possibly 50

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

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

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

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

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

FOOD AND FORAGING Narwhals are deep divers. They forage in the entire water column, taking pelagic fish (especially arctic cod), squid, and shrimp, as well as bottom-dwelling species such as Greenland halibut. Dives can last as long as 20 minutes and reach depths of more than 3,300 feet (1,000 m). Narwhals apparently suck prey into their mouth and swallow it whole. They do not use the tusk to spear fish.

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

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

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

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

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

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

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

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

Ringed Seal

Pusa hispida
(Schreber, 1775)

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

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

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

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

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

RINGED SEAL
FAMILY PHOCIDAE

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

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

LIFE SPAN
25–30 years

■ RANGE
? POSSIBLE RANGE
● VAGRANTS

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

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

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

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

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

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

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

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APPENDIX B

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 1,000 times for group behaviour and composition and focal follow analyses, 200 times for RAD models (due to the more intensive computing time), and 3,000 for the EWI analysis. 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.

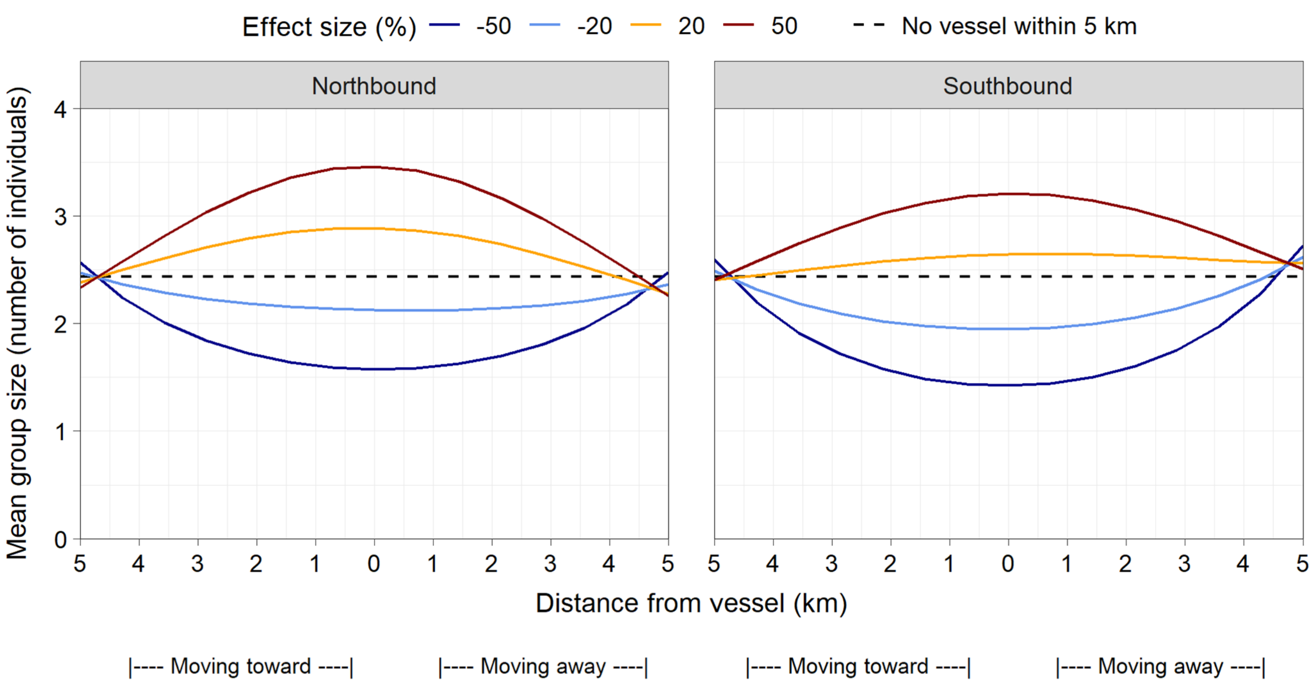


Figure 1: Application of effect sizes to a model with a numeric response variable (group size; effect applied to the full 5 km extent).

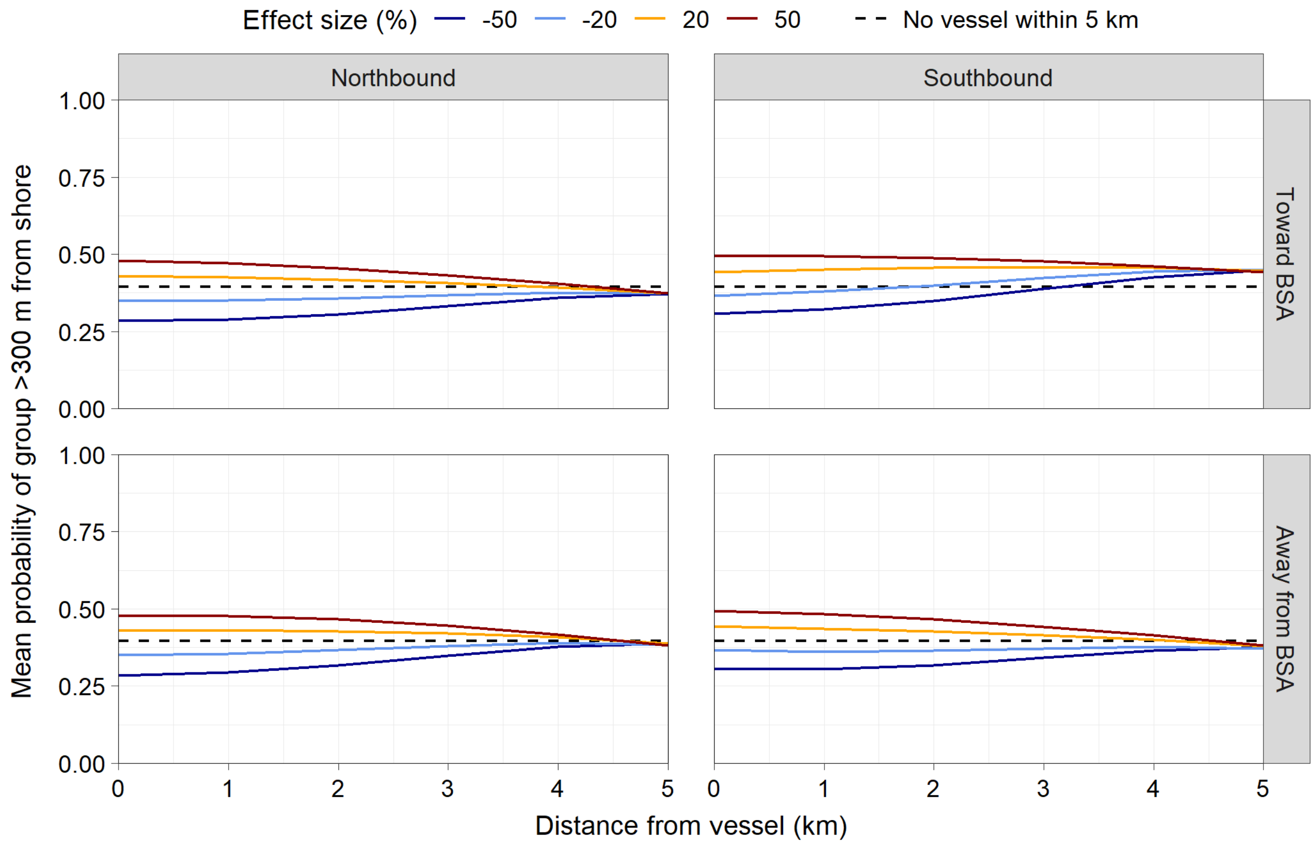


Figure 2: Application of effect sizes to a model with a binary response variable (group distance from shore)

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 -68% or +110% (Figure 3). In comparison, observed effect sizes at a distance of 0 km from vessels were -58% (for a northbound vessel) and -23% (for a southbound vessel). Statistical power to estimate the observed effects was approximately 0.6 for northbound vessels and <0.2 for southbound vessels. That is, the analysis had sufficient power to detect effect sizes of -68% or +110%, and the original analysis found a significant effect of vessel distance on relative abundance, despite effect sizes at 0 km being less than those required for power of 0.8.

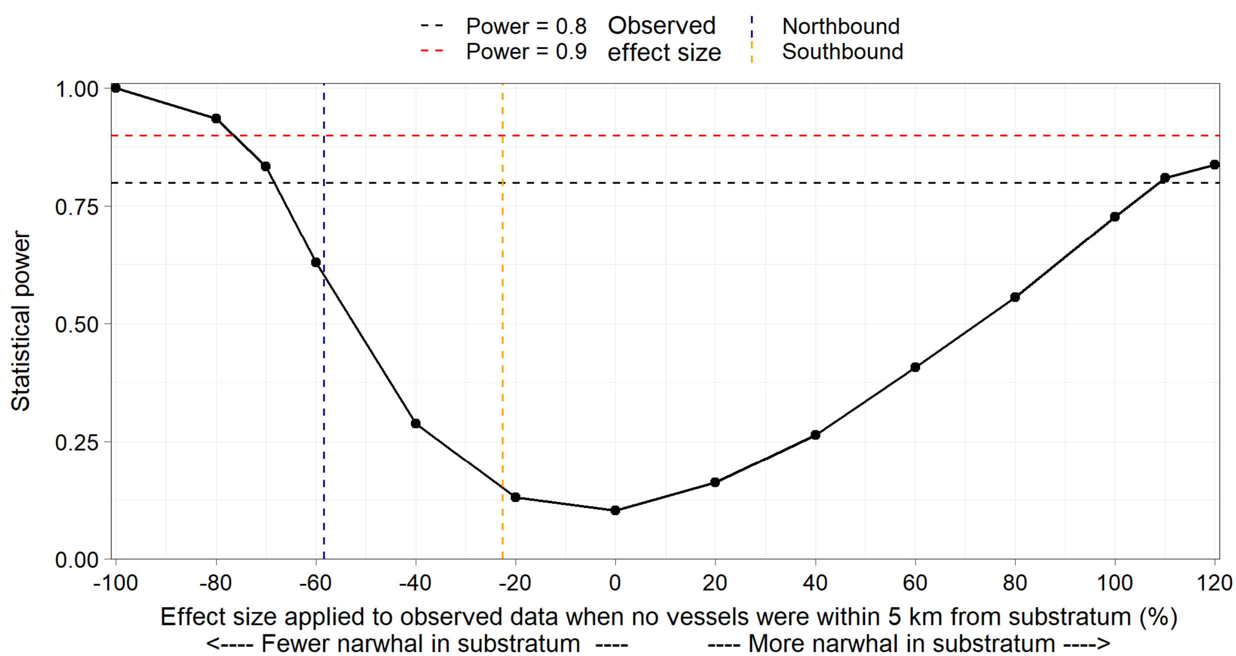


Figure 3: Statistical power of the overall model of RAD to detect a significant effect of distance from vessel, showing observed effect sizes for north- and southbound vessels.

Group Composition and Behaviour (BSA)

Group Size

There was sufficient power (≥0.8) to detect an effect of distance from vessel on group size at effect sizes of approximately -47% or +70% (Figure 4). In comparison, observed effect sizes at a distance of 0 km from vessels were +27% at a distance of 0 km from a vessel. Statistical power to estimate the observed effects was <0.3. That is, the observed effect size was smaller than the effect size required to achieve sufficient power. Due to the lower power, the original analysis did not find a significant effect of vessel distance on group size (Section 6.4.1 in main report).

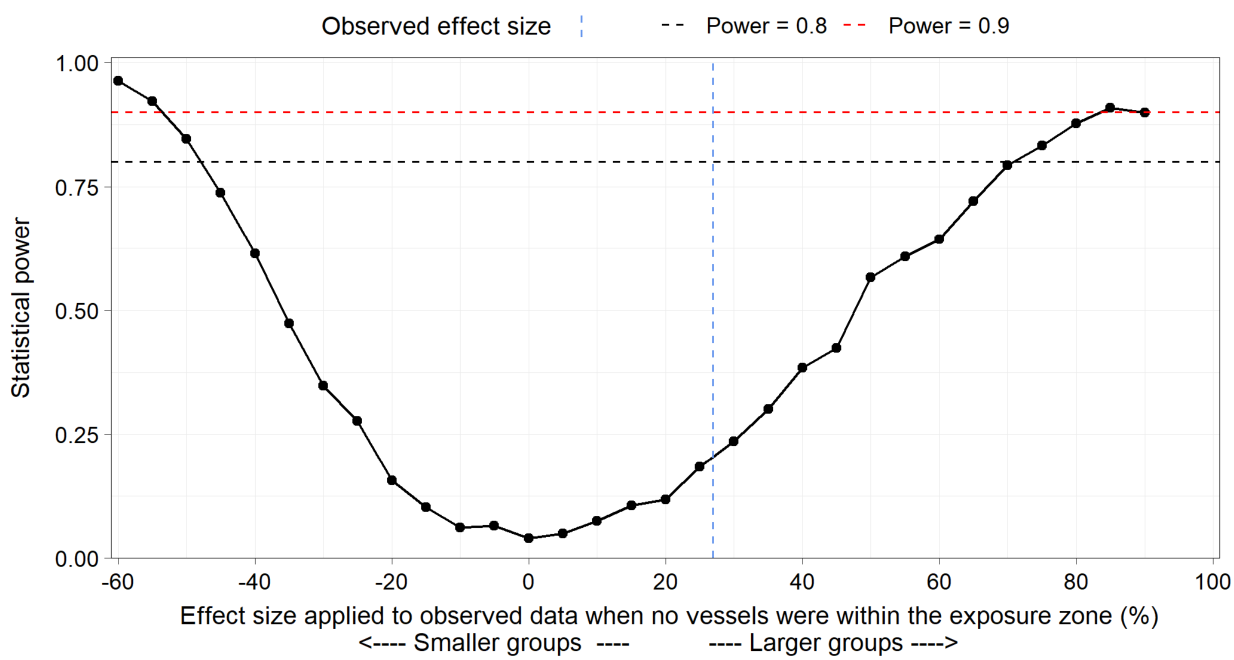


Figure 4: Statistical power of the overall model of group size to detect a significant effect of distance from vessel, showing the observed effect size when a vessel was at 0 km from the BSA centroid.

Group Composition - Presence of Immatures

There was sufficient power (≥0.8) to detect an effect of directional distance from vessel on presence of calves or yearlings within observed groups at effect sizes of approximately -85% or +390% (Figure 5). In comparison, observed effect sizes were +342% at a distance of 0 km from a vessel, and statistical power to estimate the observed effects was 74% at this distance. Despite the observed effect sizes being marginally below the effect size required to achieve sufficient statistical power (0.8), the original analysis found a significant effect of vessel distance (*P*=0.023; Section 6.4.2.1 in main report).

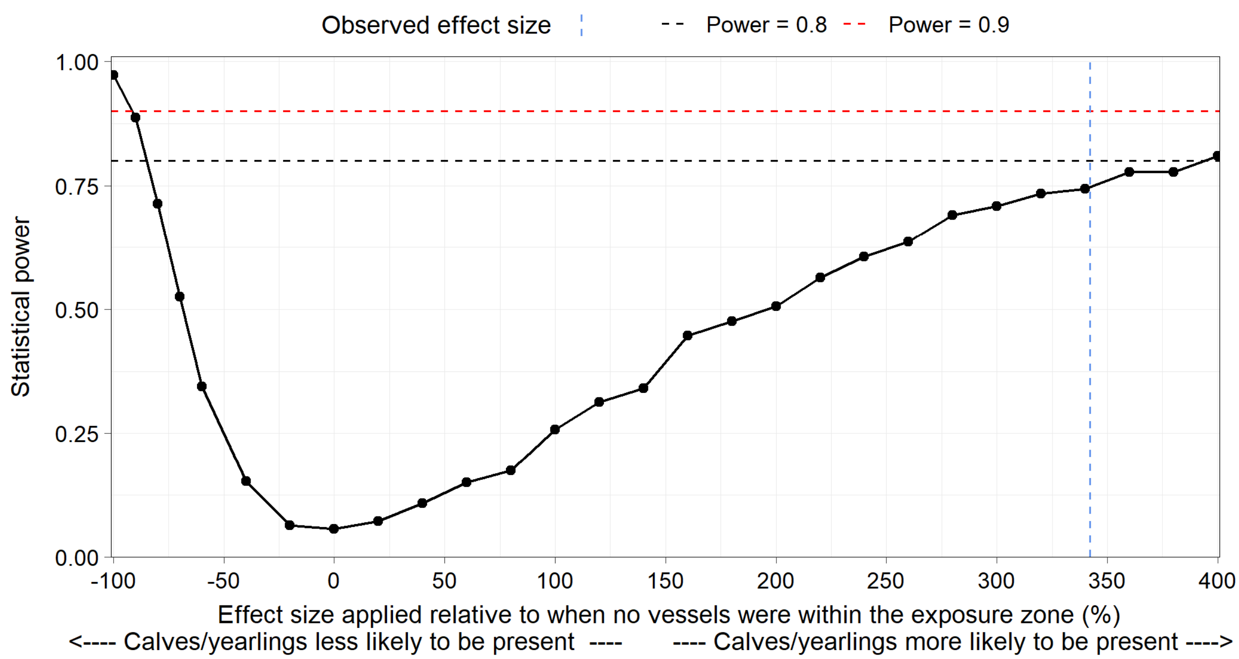


Figure 5: Statistical power of the overall model of presence of calves or yearlings to detect a significant effect of distance from vessel, showing the observed effect size when a vessel was at 0 km from the BSA centroid.

Group Spread

There was sufficient power (≥0.8) to detect an effect of distance from vessel on group spread at effect sizes of approximately -96% or +420% (Figure 6). In comparison, the observed effect size at a distance of 0 km from vessels was -92%. Statistical power to estimate the observed effects was approximately 0.72, and the original analysis found a significant effect of vessel distance (Section 6.4.3 in main report) despite of the statistical detection power being below 0.8.

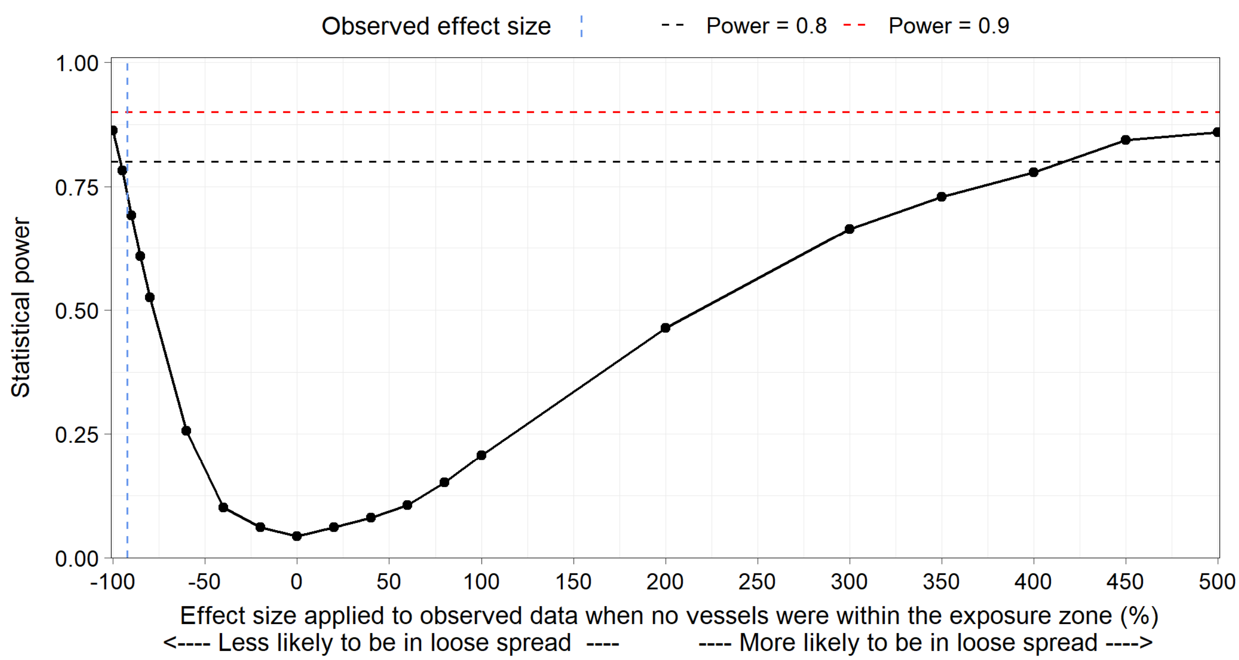


Figure 6: Statistical power of the overall model of group spread to detect a significant effect of distance from vessel, showing the observed effect size for a vessel at 0 km from the BSA centroid.

Group Formation

There was sufficient power (≥0.8) to detect an effect of distance from vessel on group formation at effect sizes of approximately -92% or +350% (Figure 7). In comparison, the observed effect sizes at a distance of 0 km from a vessel was -23%. Statistical power to estimate the observed effects was low (<0.2). The original analysis did not find a significant effect of distance from vessel but did find a significant effect of vessel presence over all (*P*=0.037; Section 6.4.4 in main report).

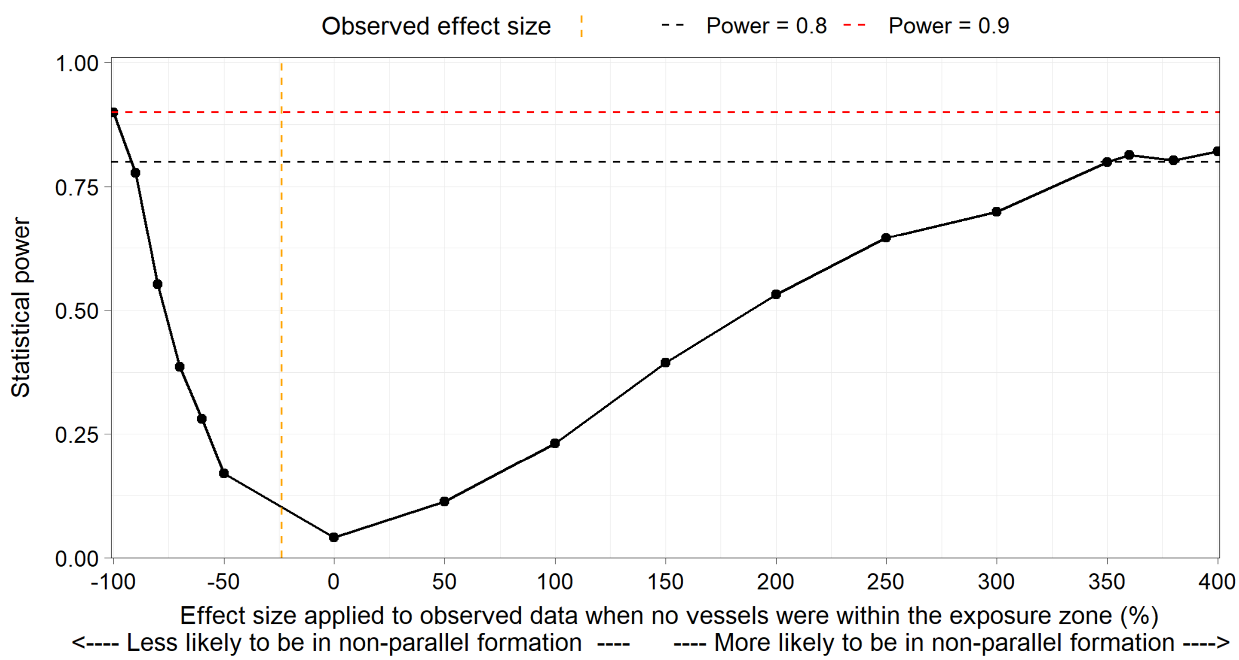


Figure 7: Statistical power of the overall model of group formation to detect a significant effect of distance from vessel, showing the observed effect size for a vessel at 0 km from the BSA centroid.

Group Direction

There was sufficient power (≥0.8) to detect an effect of distance from vessel on group direction at effect sizes of approximately -97%; to achieve sufficient power with a positive effect size, an effect size larger than 1000% would be required (Figure 8). Estimated effect sizes at a distance of 0 km from vessels were +401% (for a northbound vessel) and +205% (for a southbound vessel). Statistical power to estimate these effects was low (between 0.2 and 0.4). The estimated effect sizes were large due to the nonlinear nature of the logit transformation used in binomial data analysis. On the probability scale (which extends from 0 to 1), the probability of a group to travel south increased from 0.893 when no vessels were present to 0.977 when a northbound vessel was at 0 km, and to 0.962 when a southbound vessel was at 0 km. Due to the low detection power, the original analysis only found a marginally significant interaction between distance from vessel and whether the vessel was north- or southbound (*P*=0.061; Section 6.4.5 in main report).

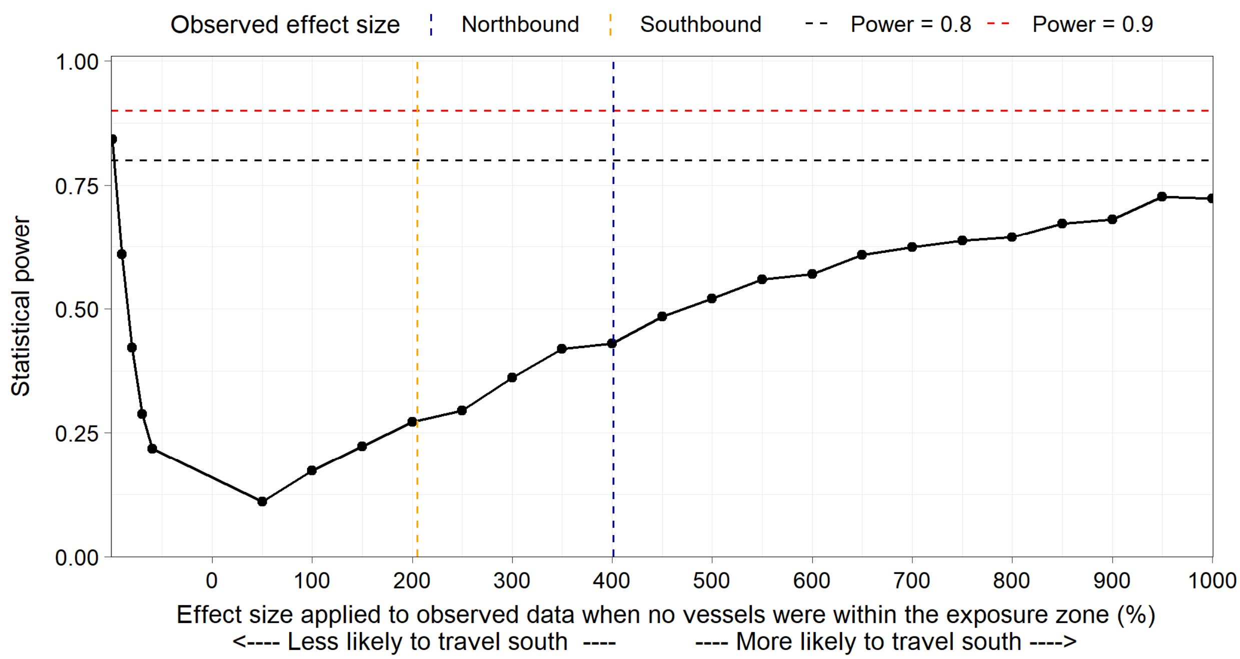


Figure 8: Statistical power of the overall model of group direction to detect a significant effect of distance from vessel, showing observed effect sizes for a vessel at 0 km from the BSA centroid for both vessel directions.

Travel Speed

There was sufficient power to detect an effect of distance from vessel on group travel speed at the examined effect sizes (Figure 9). The observed effect size at a distance of 0 km from vessels was +438% when groups were moving predominantly at a moderate / fast speed. Statistical power to estimate the observed effects was approximately 0.94 at a distance of 0 km from vessels. The original analysis found a significant interaction between the effect of vessel distance and the speed of movement of the previously recorded group (*P*=0.019; Section 6.4.6 in main report).

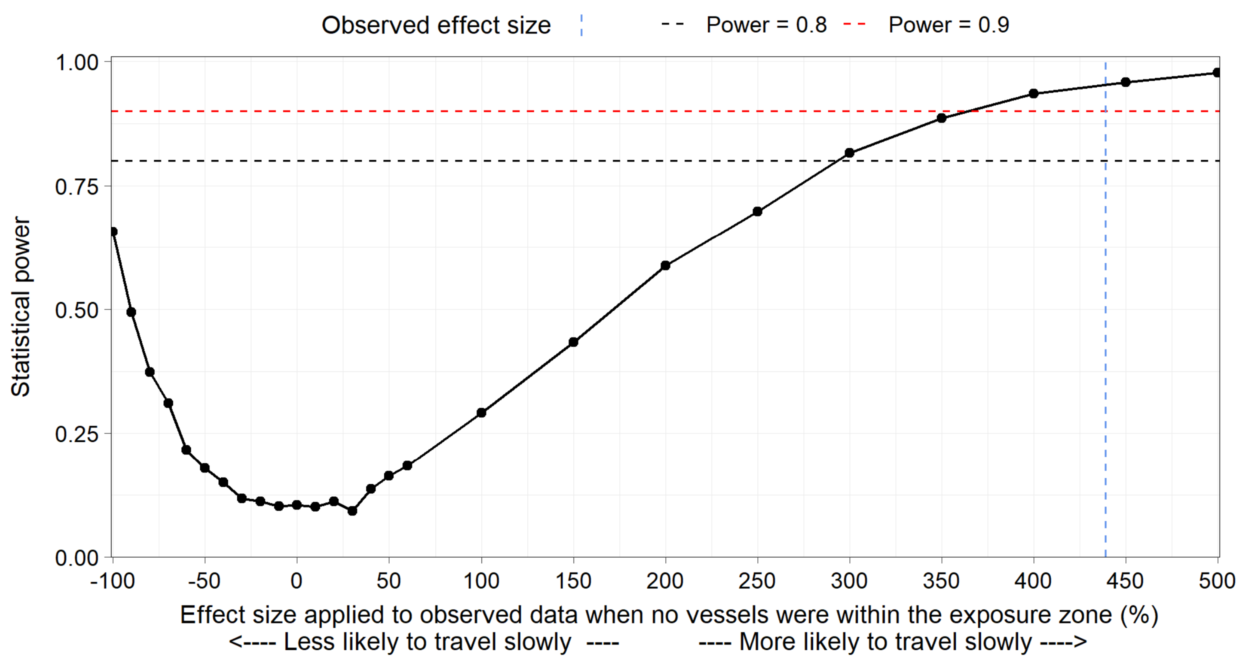


Figure 9: Statistical power of the overall model of group travel speed to detect a significant effect of distance from vessel, showing the observed effect size for a vessel at 0 km from the BSA centroid.

Distance from Shore

There was not sufficient power to detect an effect of distance from vessel on group distance from shore at the examined effect sizes, and effect sizes of approximately -100% and +330% would be required to obtain sufficient power (0.8) (Figure 10). The observed effect size at a distance of 0 km was -81%. Statistical power to estimate the observed effects at this distance was 0.50, however the original analysis still found a significant effect of vessel distance on group distance from shore (*P*=0.029; Section 6.4.7 in main report).

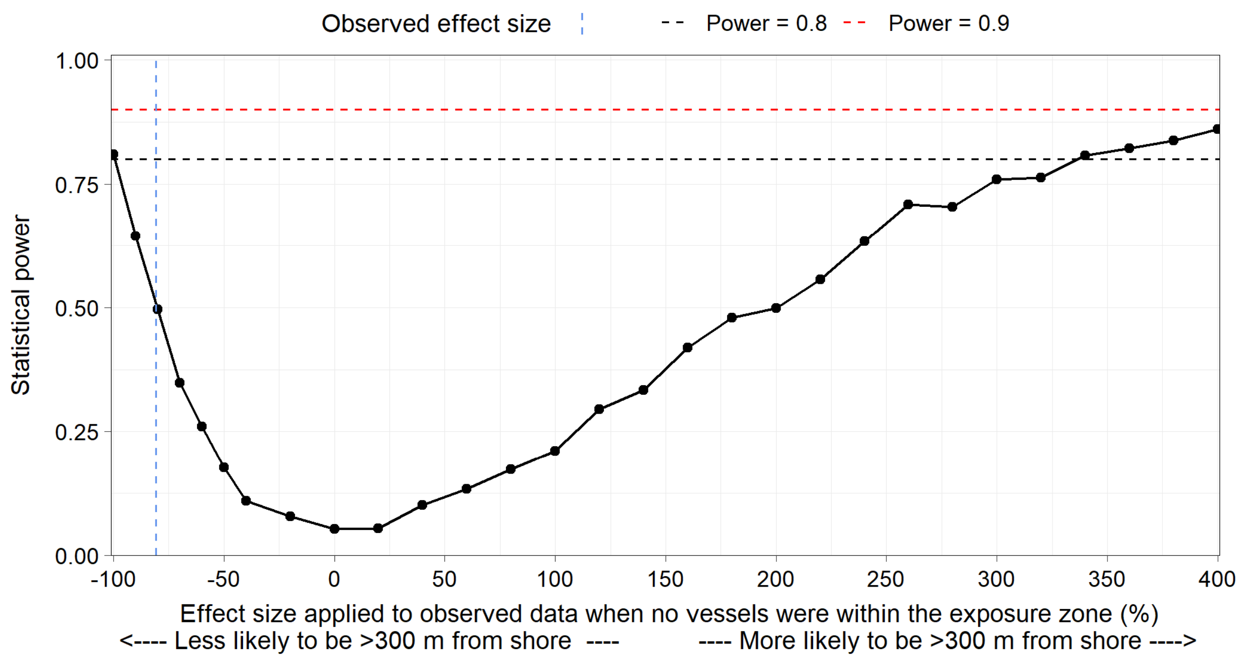


Figure 10: Statistical power of the overall model of group distance from shore to detect a significant effect of distance from vessel, showing observed the observed effect size for a vessel at 0 km from the BSA centroid.

Proportion of Immatures - Early Warning Indicator

There was sufficient power (≥0.8) to detect a significant difference between 2021 and the baseline 2014-2015 data at effect sizes of approximately -55% or +55% (Figure 3). In comparison, observed effect size for 2021 was -24%. Statistical power to estimate the observed effect was approximately 0.45. That is, the analysis had sufficient power to detect effect sizes of ±55%, and the original analysis did not find a significant difference between 2021 and the baseline 2014-2015 data due to the insufficient power.

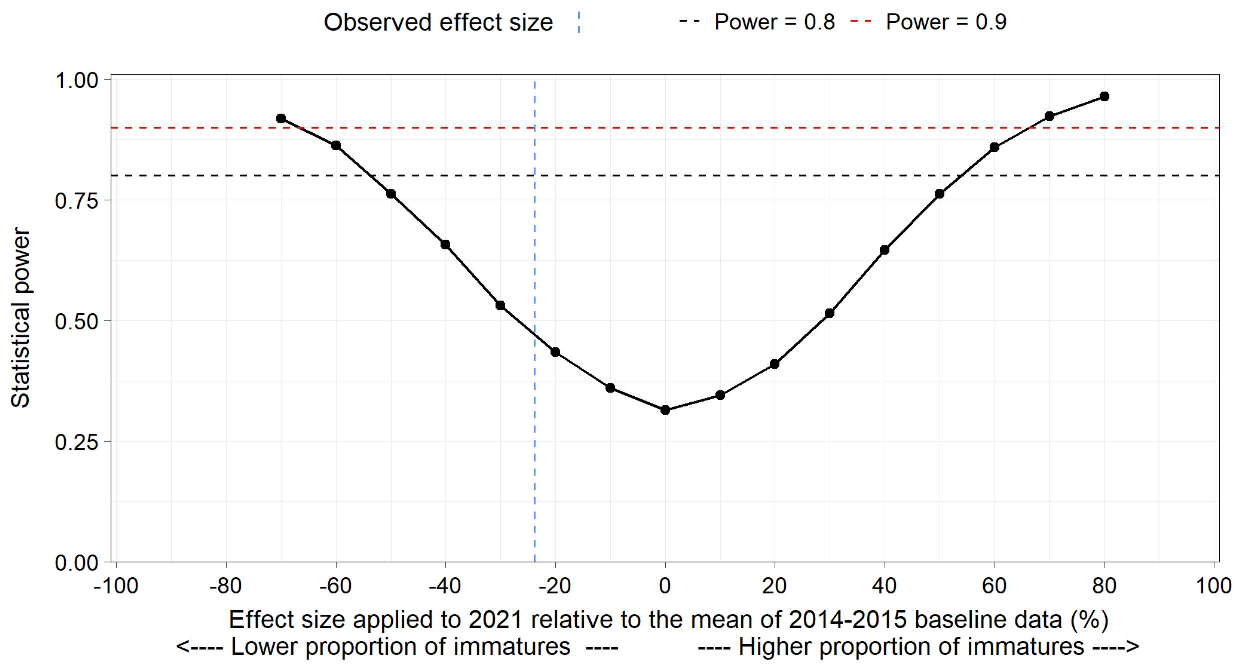


Figure 11: Statistical power of the planned comparison of 2021 to the 2014-2015 baseline data in the overall analysis of proportion of immatures as an Early Warning Indicator, showing observed effect size for 2021.

Focal Follow Surveys

Group Size

There was sufficient power (≥0.8) to detect a significant effect of vessel presence on group size at effect sizes of approximately -38% or +55% (Figure 12). In comparison, observed effect sizes for group sizes in focal follows were 46% for mother-immature pair, 34% for mixed group with dependents, -36% for mixed group without dependents, and -7% for adult groups. Statistical power to estimate the two largest observed effects was approximately 0.75 (for mixed group with dependents) and 0.66 (for mother-immature pair). Overall, the analysis did not have sufficient power to detect effect sizes less than 38%, and the original analysis did not find a significant effect of vessel presence (or an interaction between vessel presence and group type) on narwhal group size.

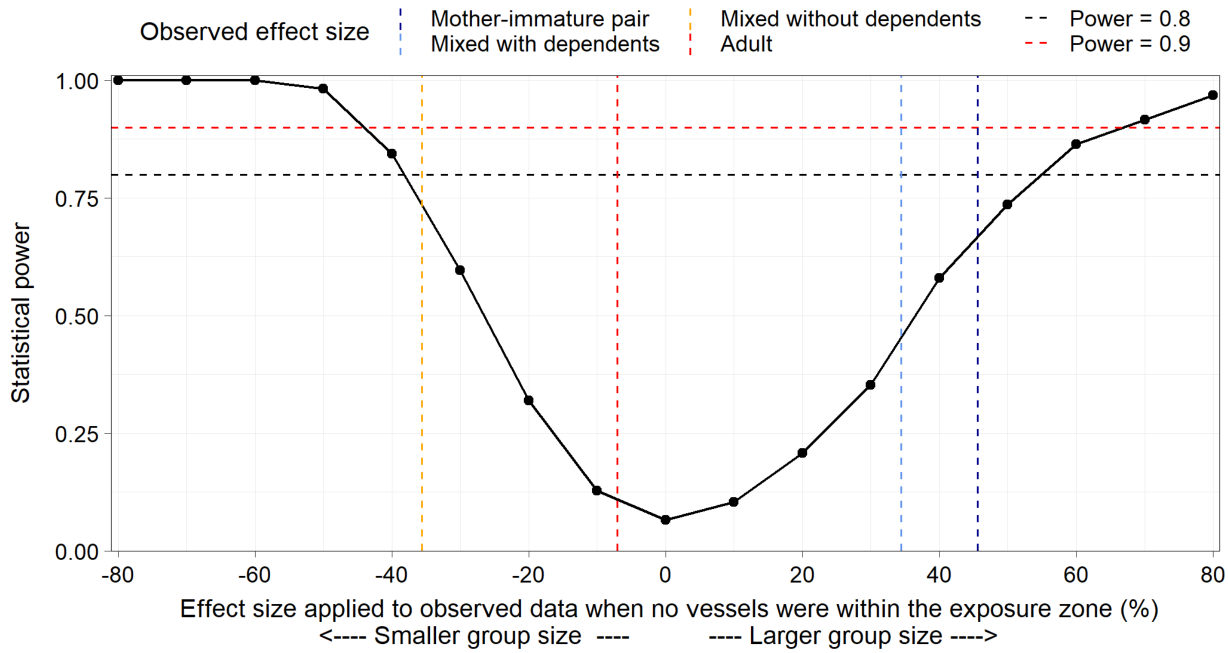


Figure 12: Statistical power of the overall model of group size to detect a significant effect of vessel exposure, showing the observed effect sizes when a vessel was present within 5 km from the followed group.

Group Composition

Group Formation

There was not sufficient power (≥0.8) to detect a significant effect of vessel presence on group formation for any of the examined effect sizes (-100% to +300%; Figure 14). The observed effect sizes for group formation in focal follows without immatures were -36% (for parallel formation), +34% (for cluster formation), and +75% (for linear formation). The observed effect sizes for group formation in focal follows with immatures were +222% (for parallel formation), +88% (for cluster formation), and -73% (for linear formation). Statistical power to estimate all the observed effect sizes was low (<0.25 for all). The analysis did not detect a significant effect of vessel presence on group formation (P>0.25 for all).

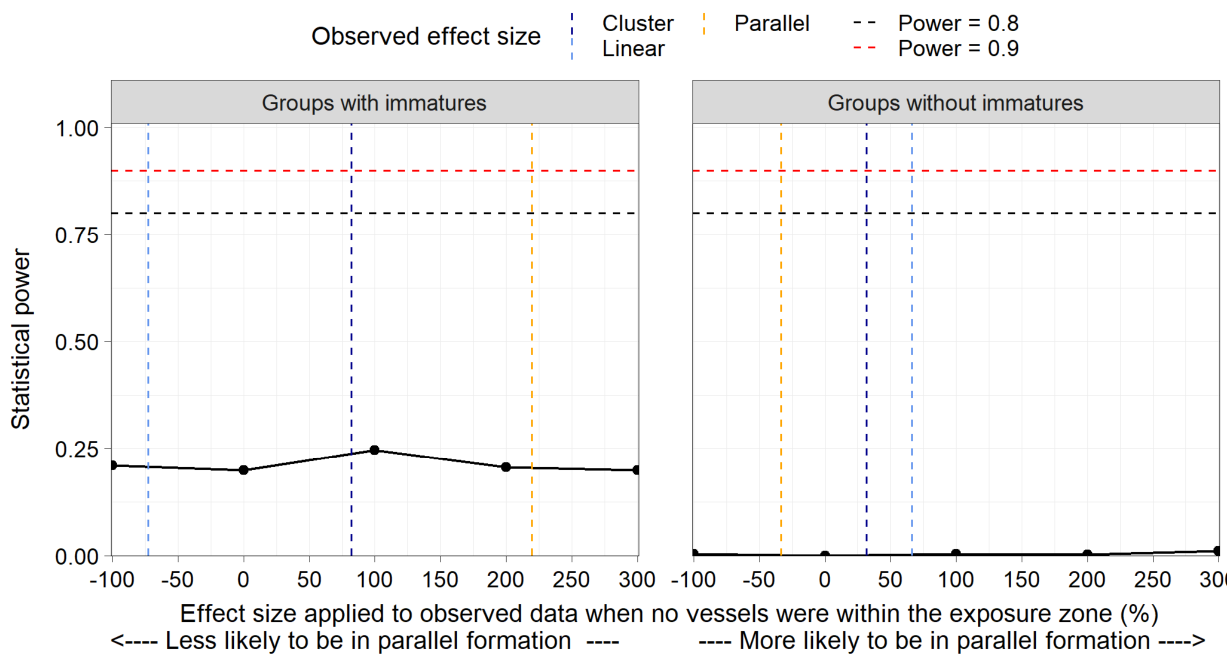


Figure 13: Statistical power of the overall model of group formation to detect a significant effect of vessel exposure, showing the observed effect sizes when a vessel was present within 5 km from the followed group.

Group Spread

In the power analysis of group spread, an effect size larger than +600% would be required for sufficient power (≥0.8) to detect a significant effect of vessel presence (Figure 14). In comparison, observed effect sizes for group spread in focal follows were +538% for mother-immature pair, -64% for mixed groups with dependents, -91% for mixed groups without dependents, and -49% for adult groups. Statistical power to estimate all the negative effect sizes was very low; power to detect the large positive effect size was approximately 0.7 (for mother-immature pair). Overall, power was insufficient to detect the observed effect sizes, however the analysis did find a significant interaction between group type and vessel presence (*P*=0.027), likely to the presence of both large negative and large positive effect sizes for the different group types.

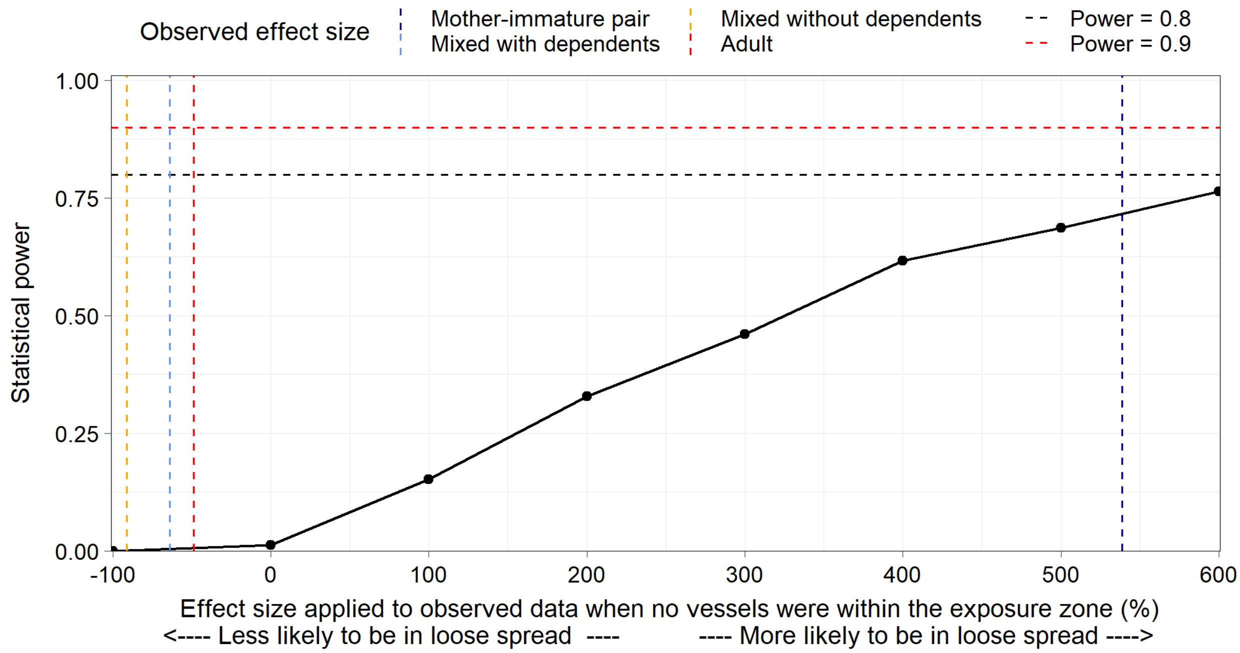


Figure 14: Statistical power of the overall model of group spread to detect a significant effect of vessel exposure, showing the observed effect sizes when a vessel was present within 5 km from the followed group.

Primary Behaviour

Unique behaviour

There was sufficient power (≥0.8) to detect a significant effect of vessel presence on unique behaviour at effect sizes of approximately +100%, but not at any of the negative effect sizes (Figure 15). In comparison, observed effect sizes for unique behaviour in focal follows were +50% for mother-immature pair, -73% for mixed groups with dependents, +521% for mixed groups without dependents, -55% for adult groups, and -87% for lone calves. Statistical power to estimate all the negative effect sizes was very low; power to detect positive effect sizes was approximately 0.5 (for mother-immature pair) and approximately 1.0 (for mixed groups without dependents). Overall, power was sufficient only to detect one of the observed effect sizes, however the analysis did find a significant interaction between group type and vessel presence (*P*=0.023), likely to the presence of both large negative and large positive effect sizes for the different group types.

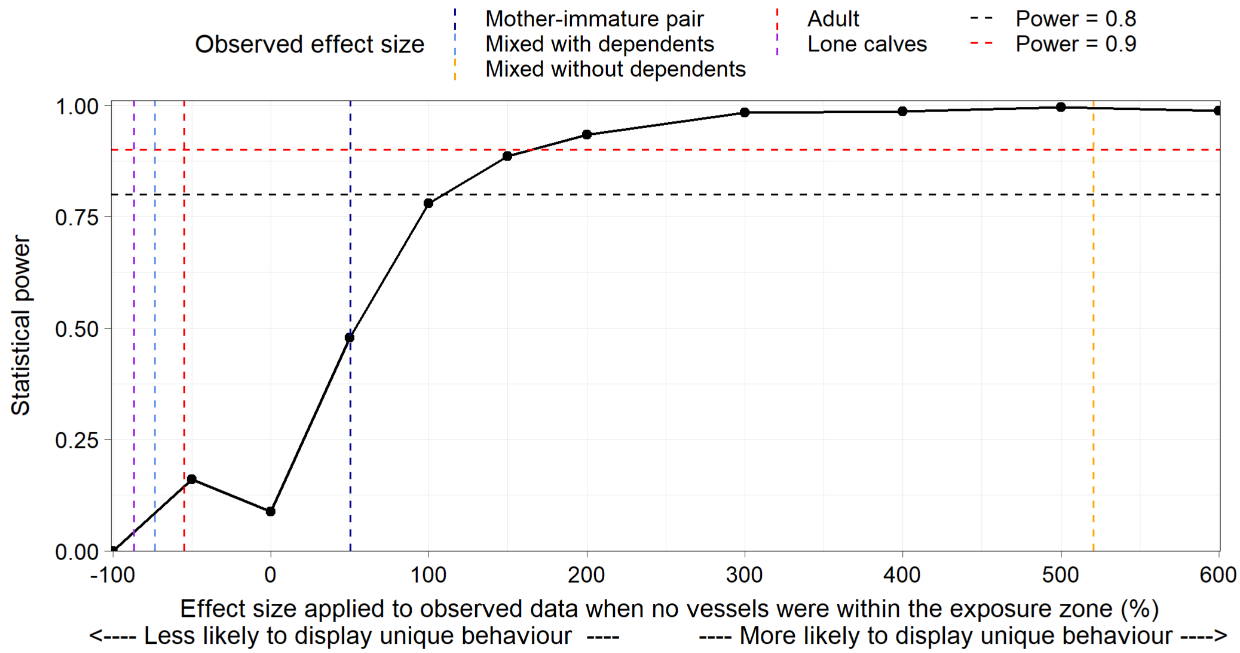


Figure 15: Statistical power of the overall model of unique behaviour to detect a significant effect of vessel exposure, showing the observed effect sizes when a vessel was present within 5 km from the followed group.

Nursing

There was not sufficient power (≥0.8) to detect a significant effect of vessel presence on nursing for any of the examined effect sizes (-100% to +600%; Figure 16). The observed effect size for nursing was -74% (combined mother-immature pairs and mixed groups with dependents). Statistical power to detect the observed effect size was <0.1. The analysis did not find a significant effect of vessel presence (*P*=0.092).

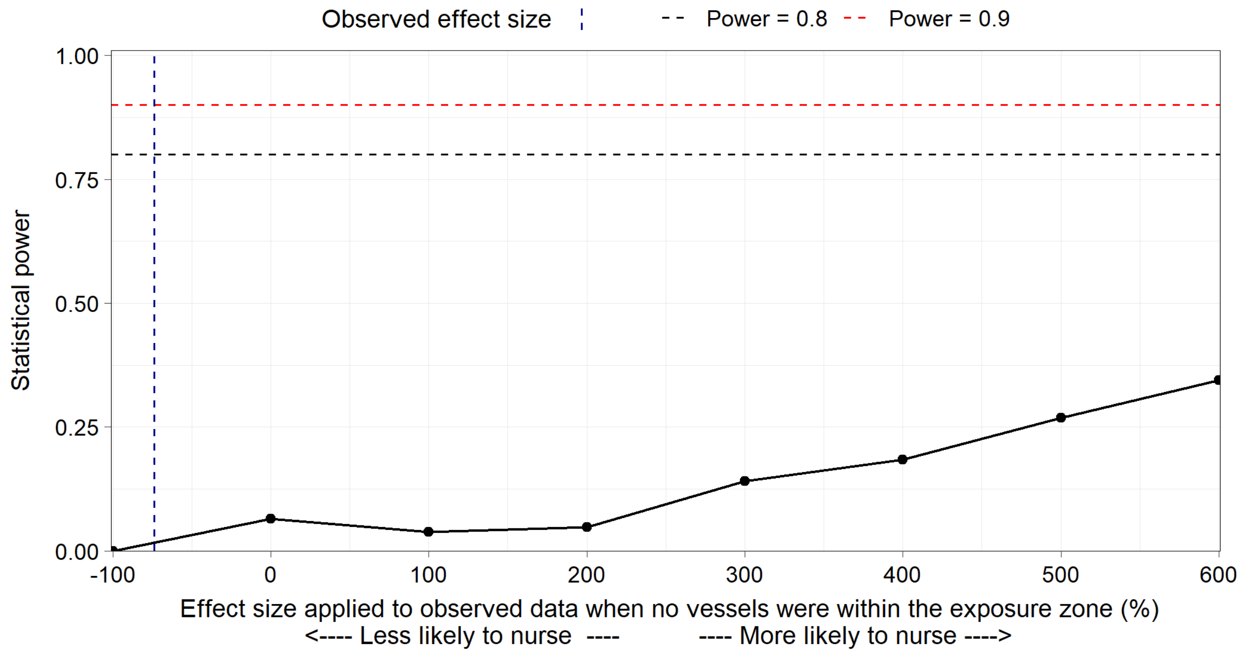


Figure 16: Statistical power of the overall model of nursing to detect a significant effect of vessel exposure, showing the observed effect sizes when a vessel was present within 5 km from the followed group.

Relative Position of Immature

In the power analysis of relative position of immatures, an effect size of approximately -90% would be required for sufficient power (≥0.8) to detect a significant effect of vessel presence (Figure 17). In comparison, observed effect sizes for relative position of immatures in focal follows were -56% for immatures under their mother, -7% for immatures abreast of the mother, +514% for immatures in front or behind the mother, and +1,117% for immatures on top of their mother. Statistical power to estimate the two largest absolute effect sizes was approximately 0.52 (for effect sizes of -56% and +1,117%). Overall, power was insufficient to detect the observed effect sizes. The analysis did find a significant effect for one position (on top of mother), but not for any of the other positions (P>0.3 for all).

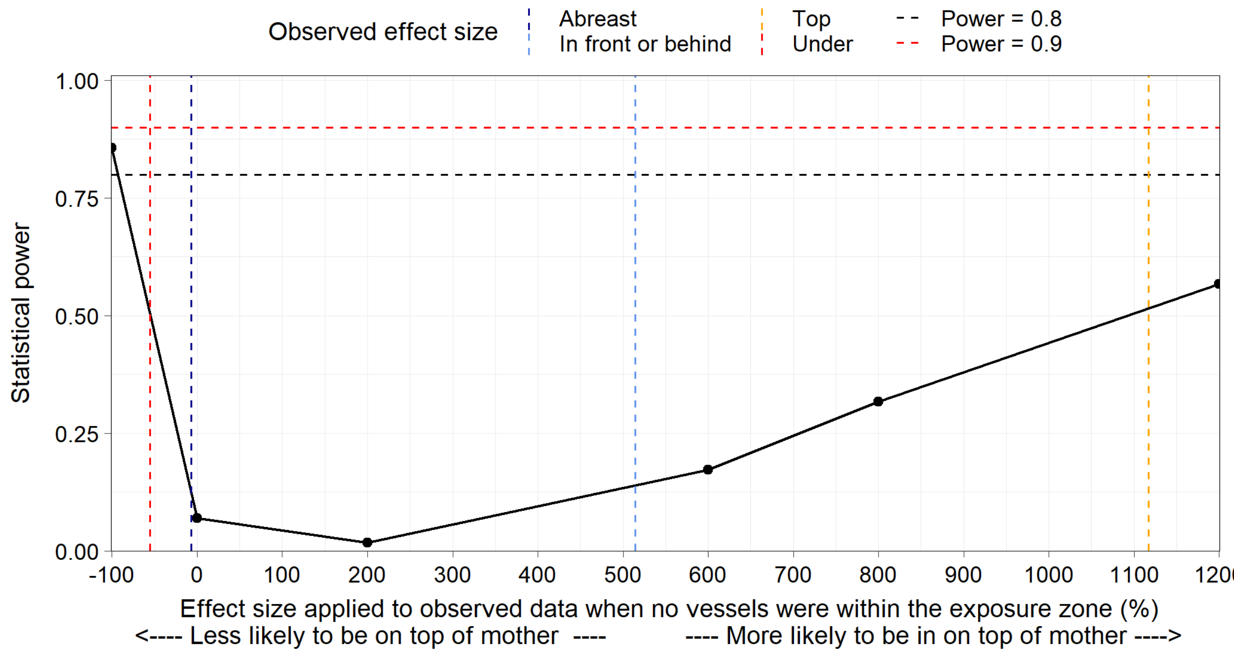


Figure 17: Statistical power of the overall model of relative position of immatures to detect a significant effect of vessel exposure, showing the observed effect sizes when a vessel was present within 5 km from the followed group.

Spread between Immature and Adult

There was sufficient power (≥0.8) to detect a significant effect of vessel presence on the spread between immature and adult at effect sizes of approximately +550%, but not at any of the negative effect sizes (Figure 18). In comparison, observed effect size for spread between immature and adult in focal follows was +157% (combined mother-immature pairs and mixed groups with dependents). 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 presence (P=0.11).

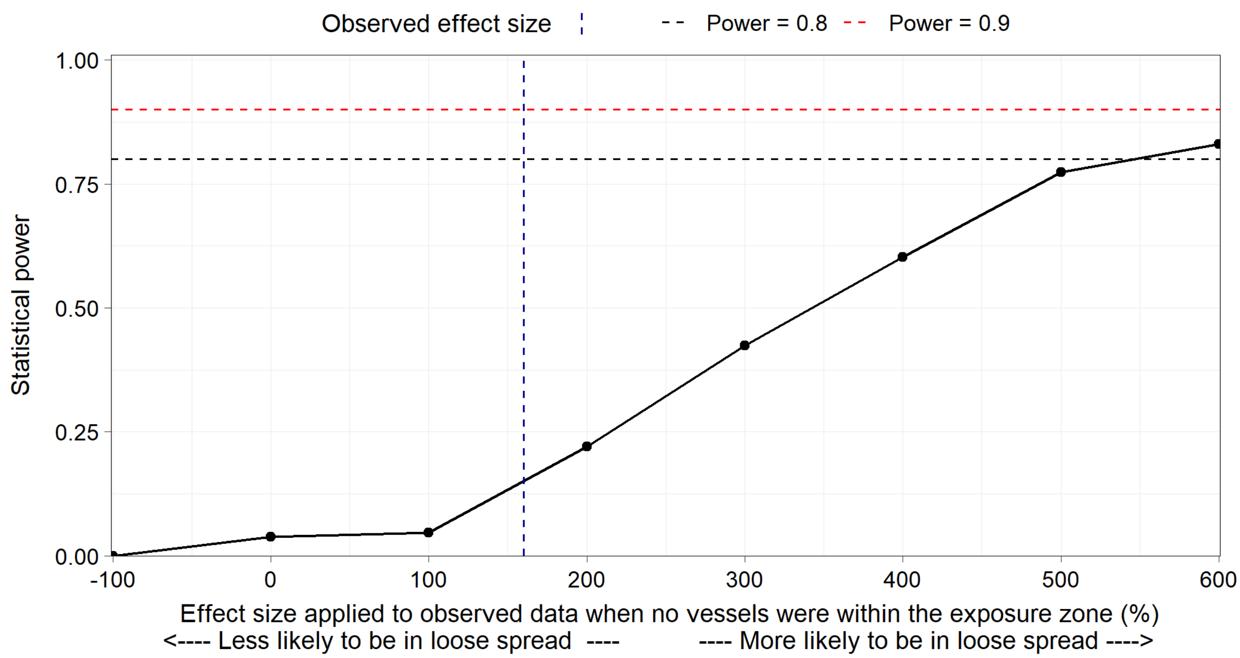


Figure 18: Statistical power of the overall model of distance between immature and adult to detect a significant effect of vessel exposure, showing the observed effect sizes when a vessel was present within 5 km from the followed group.

SUMMARY

Most of the assessed analyses required large effect sizes for sufficient (≥0.8) statistical power to detect an effect of distance from vessels (reductions of 90% or increases of approximately 300% 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
- Only sparse data was available at close approach distances to the BSA. For example, when Project vessels were within 1 and 2 km of the BSA centroid, only 28 and 153 groups were recorded as part of the group composition and behaviour dataset, respectively (throughout the seven-year study period). In 2020, only three groups were recorded when vessels were present within 2 km of the BSA centroid. In 2021, no groups were recorded while vessels were present within 2 km of the BSA centroid.
- Smaller dataset for group composition and behaviour data (5,954 cases, compared to 47,454 for RAD data), which reduces the statistical power of tests performed on group behaviour and composition data relative to the RAD data.

The focal follow analyses generally had lower power than either group composition and behavioural data (BSA dataset) 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 four of the seven group composition and behaviour analyses detected an overall effect of distance from vessel or a significant interaction between distance from vessel and another variable, with a marginal effect noted for another variable. Overall, the results of the power analysis presented here indicate that group composition analyses often had low power to detect small to intermediate 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	-68% or +110%	-23% and -58%	Y
Group composition and behaviour (BSA)	Group size	-47% or +70%	+27%	N
	Group composition – presence of calves or yearlings	-85% or +390%	+342%	Y
	Group spread	-96% or +420%	-92%	Y
	Group formation	-92 or +350%	-97% and +37%	N (but significant effect of vessel presence)
	Group direction	-97% or >+1000%	+401% and +205%	N (*P*=0.061, noted as marginal)
	Travel speed	+300%	-57% and +439%	Y
	Distance from Bruce Head shore	-100% and +330%	-81%	Y
EWI	Proportion of immatures	-55% and +55%	-24%	N
Focal follow surveys	Group size	-38% and +55%	Between -36% and +46%	N
	Group composition			
	Group formation	Not sufficient between effect sizes of -100% and +300%	Between -73% and +222%	N
	Group spread	>+600%	Between -91% and +538%	Y
	Primary behaviour			
	Unique behaviour	+100%	Between -87% and +521%	Y
	Nursing	>+600%	-74%	N

Component	Analysis	Effect size for power ≥ 0.8 (%)	Range of observed effect sizes[1] (%)	Effect detected in original analysis?
	Relative position of immature	-90%	Between -56% and +1,117%	Y
	Spread between immature and adult	+550%	+157%	N

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

APPENDIX C

Vessel Track Information

Medium (>50 m) and large (>100 m) vessel traffic in SSA during the 2021 BH Field Program

**Black Text = vessels observed. Grey text = Vessels not observed

Count	Date in SSA	Approximate time in SSA (EDT)	Vessel Name	Vessel Class	Travel Direction	Vessel speed in SSA (max)
1	August 1, 2021	(14:01 - 15:23)	Nordic Odyssey	Bulk (ore) carrier	north	under 8.8
2	August 1, 2021	(18:40 - 20:30)	Arkadia	Bulk (ore) carrier	south	under 8.7
3	August 2, 2021	(07:28 - 08:50)	Claude A. DesGagnes	General cargo	south	under 8.6
4	August 2, 2021	(16:40- 18:30)	Despina V	Bulk (ore) carrier	north	under 8.9
5	August 2, 2021	(19:37 - 20:58)	Sarah DesGagnes	Oil and Chemical Tanker	north	up to 9.0
6	August 2, 2021	(20:15 - 21:46)	Sagar Samrat	Bulk (ore) carrier	south	under 8.8
7	August 3, 2021	(13:11- 14:41)	Nordic Olympic	Bulk (ore) carrier	north	under 8.9
8	August 3, 2021	(22:39 - 00:06)	Golden Diamond	Bulk (ore) carrier	south	under 8.9
9	August 4, 2021	(08:51- 10:17)	Arkadia	Bulk (ore) carrier	north	under 8.9
10	August 5, 2021	(03:58 - 05:21)	Golden Freeze	Bulk (ore) carrier	south	under 8.9
11	August 5, 2021	(11:32 - 12:55)	Sagar Samrat	Bulk (ore) carrier	north	under 9.0
12	August 6, 2021	(08:45 - 10:10)	Golden Diamond	Bulk (ore) carrier	north	under 8.9
13	August 6, 2021	(10:36 - 12:13)	Golden Amber	Bulk (ore) carrier	south	under 8.9
14	August 6, 2021	(12:41 - 14:03)	Nordic Oasis	Bulk (ore) carrier	south	under 9.0
15	August 7, 2021	(11:36 - 13:04)	Golden Freeze	Bulk (ore) carrier	north	under 8.1
16	August 7, 2021	(13:03 - 14:25)	Botnica	Icebreaker	north	under 9.0
17	August 8, 2021	(00:18 - 01:55)	Golden Bull	Bulk (ore) carrier	south	under 8.6
18	August 8, 2021	(08:52 - 10:17)	Golden Amber	Bulk (ore) carrier	north	under 8.8
19	August 8, 2021	(08:57 - 11:05)	Botnica	Icebreaker	south	under 8.1
20	August 8, 2021	(12:17 - 13:46)	Golden Ruby	Bulk (ore) carrier	south	under 8.8
21	August 8, 2021	(16:06 - 17:25)	Sarah Desgagnes	Oil And Chemical Tanker	north	up to 9.2
22	August 9, 2021	(07:10 - 08:48)	Nordic Oasis	Bulk (ore) carrier	north	under 7.7
23	August 9, 2021	(09:42 - 11:00)	Admiral Schmidt	Bulk (ore) carrier	south	up to 9.2
24	August 9, 2021	(16:46 - 18:09)	Claude A. Desgagnes	General Cargo	north	under 9.0
25	August 10, 2021	(08:51 - 10:18)	Golden Bull	Bulk (ore) carrier	north	under 8.3
26	August 10, 2021	(12:59 - 14:24)	AM Buchanan	Bulk (ore) carrier	south	under 8.3
27	August 11, 2021	(11:12 - 12:42)	Golden Ruby	Bulk (ore) carrier	north	under 8.6
28	August 11, 2021	(13:48 - 15:12)	Pabal	Bulk (ore) carrier	south	up to 9.4
29	August 12, 2021	(21:22 - 22:40)	Admiral Schmidt	Bulk (ore) carrier	north	up to 9.4
30	August 12, 2021	(23:36 - 01:01)	M.V. Golden Brilliant	Bulk (ore) carrier	south	under 9.0

31	August 14, 2021	(00:18 - 01:40)	AM Buchanan	Bulk (ore) carrier	north	under 8.8
32	August 14, 2021	(03:12 - 04:37)	Vitus Bering	Bulk (ore) carrier	south	under 9.0
33	August 14, 2021	(18:56 - 20:17)	Pabal	Bulk (ore) carrier	north	under 8.8
34	August 14, 2021	(20:06- 23:42)	Golden Opal	Bulk (ore) carrier	south	under 7.8
35	August 15, 2021	(16:47 - 18:02)	M.V. Golden Brilliant	Bulk (ore) carrier	north	up to 9.3
36	August 15, 2021	(19:18- 20:45)	Nordic Qinngua	Bulk (ore) carrier	south	under 8.9
37	August 16, 2021	(17:05 - 18:30)	Botnica	Icebreaker	north	under 8.7
38	August 17, 2021	(01:41 - 03:01)	Vitus Bering	Bulk (ore) carrier	north	under 8.9
39	August 17, 2021	(04:48 - 06:12)	Gisela Oldendorff	Bulk (ore) carrier	south	under 8.7
40	August 17, 2021	(20:15- 21:49)	Golden Opal	Bulk (ore) carrier	north	under 8.0
41	August 17, 2021	(23:00 - 00:30)	Golden Opportunity	Bulk (ore) carrier	south	under 8.0
42	August 18, 2021	(11:03 - 12:23)	Botnica	Icebreaker	south	under 9.0
43	August 19, 2021	(02:04 - 03:22)	Nordic Qinngua	Bulk (ore) carrier	north	under 8.9
44	August 19, 2021	(06:01 - 07:55)	Golden Frost	Bulk (ore) carrier	south	under 6.6
45	August 20, 2021	(02:13 - 03:33)	Gisela Oldendorff	Bulk (ore) carrier	north	under 9.0
46	August 20, 2021	(06:21 - 08:02)	Golden Rose	Bulk (ore) carrier	south	under 7.6
47	August 21, 2021	(04:06 - 05:46)	Golden Opportunity	Bulk (ore) carrier	north	under 8.5
48	August 21, 2021	(06:24- 07:51)	Golden Ice	Bulk (ore) carrier	south	under 8.5
49	August 22, 2021	(04:19 - 05:42)	Golden Frost	Bulk (ore) carrier	north	under 8.9
50	August 22, 2021	(06:44 - 08:04)	Nordic Odin	Bulk (ore) carrier	south	under 8.9
51	August 23, 2021	(07:48 - 09:17)	Golden Rose	Bulk (ore) carrier	north	under 8.6
53	August 23, 2021	(10:06 - 11:29)	NS Yakutia	Bulk (ore) carrier	south	up to 9.1
54	August 24, 2021	(07:30 - 09:05)	Golden Ice	Bulk (ore) carrier	north	up to 9.0
55	August 24, 2021	(09:59 - 11:24)	Nordic Orion	Bulk (ore) carrier	south	up to 9.2
56	August 25, 2021	(09:35 - 11:22)	Nordic Odin	Bulk (ore) carrier	north	under 9.0
57	August 25, 2021	(11:18 - 13:59)	Gebe Oldendorff	Bulk (ore) carrier	south	under 7.6
58	August 26, 2021	(11:00 - 12:32)	NS Yakutia	Bulk (ore) carrier	north	under 9.0
59	August 26, 2021	(13:37 - 15:10)	AM Quebec	Bulk (ore) carrier	south	under 8.8
60	August 27, 2021	(10:50 - 12:22)	Nordic Orion	Bulk (ore) carrier	north	under 8.8
61	August 27, 2021	(17:21 - 18:52)	Conrad Oldendorff	Bulk (ore) carrier	south	under 8.7

APPENDIX D

Test Statistics and Coefficients

RAD analysis

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

Parameter	Chi squared	Df	*P* value
Negative binomial component of model			
Day	17.196	2	**<0.001**
Year	25.625	6	**<0.001**
Stratum	784.453	9	**<0.001**
Substratum	386.299	2	**<0.001**
Glare	80.275	2	**<0.001**
Beaufort scale	139.439	5	**<0.001**
Tide	77.253	3	**<0.001**
Directional distance	8.227	2	0.016
North- or southbound vessel	0.129	1	0.719
Vessel presence within 5 km from substratum	18.721	1	**<0.001**
Hunting event within 70 minutes prior to observation	23.618	1	**<0.001**
Presence of small vessels within the SSA	0.02	1	0.889
Interaction between vessel distance and whether vessel was north- or southbound	6.261	2	**0.044**
Zero-inflation component of model			
Stratum	45.038	9	**<0.001**
Substratum	30.855	2	**<0.001**
Year	99.692	5	**<0.001**
Beaufort scale	25.423	5	**<0.001**

Table D-2: Coefficient estimates for fixed effects in a mixed generalized linear model of narwhal counts

Parameter	Coefficient	SE	*z* value	*P* value
Negative binomial component of model				
Intercept (Year=2014, Glare="N", Beaufort = 0, Stratum = "A", Substratum = "1", no vessels within 5 km from substratum, Tide = low slack, no small vessels within the SSA, no hunting within preceding 70 minutes	-2.911	0.433	-6.721	<0.001
Day of year[1]	61.489	29.724	2.069	0.039
Day of year squared[1]	-110.547	29.600	-3.735	<0.001
Year (2015)	0.565	0.529	1.068	0.286
Year (2016)	0.869	0.538	1.617	0.106
Year (2017)	0.863	0.540	1.599	0.11
Year (2019)	0.722	0.545	1.327	0.185
Year (2020)	-0.463	0.559	-0.829	0.407

Parameter	Coefficient	SE	z value	*P* value
Year (2021)	-1.381	0.605	-2.283	0.022
Stratum (B)	-0.243	0.155	-1.567	0.117
Stratum (C)	0.360	0.160	2.246	0.025
Stratum (D)	1.794	0.161	11.140	<0.001
Stratum (E)	1.930	0.155	12.448	<0.001
Stratum (F)	2.344	0.154	15.235	<0.001
Stratum (G)	2.739	0.153	17.940	<0.001
Stratum (H)	2.989	0.155	19.345	<0.001
Stratum (I)	2.744	0.156	17.640	<0.001
Stratum (J)	2.926	0.181	16.192	<0.001
Substratum (2)	-0.171	0.052	-3.315	0.001
Substratum (3)	-1.268	0.076	-16.690	<0.001
Glare (L)	0.166	0.031	5.437	<0.001
Glare (S)	-0.451	0.073	-6.160	<0.001
Beaufort (1)	-0.004	0.073	-0.059	0.953
Beaufort (2)	-0.331	0.079	-4.197	<0.001
Beaufort (3)	-0.700	0.101	-6.946	<0.001
Beaufort (4)	-1.011	0.133	-7.578	<0.001
Beaufort (5)	-1.101	0.197	-5.584	<0.001
Tide (Flood)	-0.282	0.038	-7.353	<0.001
Tide (High slack)	-0.374	0.047	-7.898	<0.001
Tide (Ebb)	-0.206	0.039	-5.297	<0.001
Distance from vessel (before breakpoint)[1]	-0.729	0.203	-3.598	<0.001
Distance from vessel (after breakpoint)[1]	1.411	0.376	3.750	<0.001
Vessel southbound	0.664	0.315	2.105	0.035
Vessel presence within 5 km from substratum centroid	-0.838	0.194	-4.327	<0.001
Hunting occurred within preceding 70 minutes	0.194	0.040	4.860	<0.001
Small vessels present in the SSA	0.004	0.031	0.140	0.889
Interaction between distance from vessel (before breakpoint) and southbound vessel	0.763	0.305	2.499	0.012
Interaction between distance from vessel (after breakpoint) and southbound vessel	-1.377	0.576	-2.392	0.017
Zero-inflation component of model				
Intercept (Year=2014, Beaufort = 0, Stratum = “A”, Substratum = “1”)	-3.698	0.728	-5.078	<0.001
Stratum (B)	-0.082	0.359	-0.228	0.819
Stratum (C)	0.353	0.326	1.085	0.278
Stratum (D)	0.539	0.318	1.696	0.09
Stratum (E)	0.141	0.308	0.457	0.648

Parameter	Coefficient	SE	z value	*P* value
Stratum (F)	0.115	0.301	0.382	0.702
Stratum (G)	-0.102	0.298	-0.342	0.733
Stratum (H)	-0.249	0.298	-0.836	0.403
Stratum (I)	-0.367	0.298	-1.232	0.218
Stratum (J)	-0.404	0.312	-1.295	0.195
Substratum (2)	0.398	0.100	3.966	<0.001
Substratum (3)	0.698	0.126	5.554	<0.001
Year (2015)	2.334	0.647	3.610	<0.001
Year (2016)	2.275	0.640	3.552	<0.001
Year (2017)	-0.113	0.996	-0.114	0.909
Year (2019)	3.003	0.643	4.671	<0.001
Year (2020)	3.045	0.648	4.696	<0.001
Year (2021)	2.922	0.660	4.425	<0.001
Beaufort (1)	0.351	0.158	2.227	0.026
Beaufort (2)	0.300	0.165	1.816	0.069
Beaufort (3)	0.691	0.188	3.677	<0.001
Beaufort (4)	0.614	0.265	2.315	0.021
Beaufort (5)	1.194	0.301	3.972	<0.001

[1] = Variable was standardized prior to modeling.

Group Composition and Behaviour Analysis

Group Size

Table D-3: Test statistics of a generalized linear model of group size (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	53.157	6	**<0.001**
Group size of previously recorded group on the same day	301.969	2	**<0.001**
Glare	3.963	2	0.138
Beaufort scale	24.631	4	**<0.001**
Tide	15.179	3	**0.002**
Distance from vessel	3.589	2	0.166
Large vessel presence within 5 km from BSA	1.04	1	0.308
Hunting event within 70 minutes prior to observation	63.641	1	**<0.001**
Presence of small vessels within the SSA	0.003	1	0.957

Table D-4: Coefficient estimates for fixed effects in a generalized linear model of group size

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 5 km from BSA, Tide = low slack, no hunting within preceding 70 min, average number of narwhal in previous group)	1.138	0.089	12.853	<0.001
Year 2015	0.133	0.084	1.586	0.113
Year 2016	-0.269	0.072	-3.735	<0.001
Year 2017	-0.156	0.066	-2.355	0.019
Year 2019	-0.197	0.069	-2.868	0.004
Year 2020	-0.306	0.075	-4.072	<0.001
Year 2021	-0.248	0.139	-1.786	0.074
Number of narwhal in previous group[1]	0.274	0.017	15.735	<0.001
Number of narwhal in previous group [1]	-0.027	0.004	-6.362	<0.001
Glare Low	0.046	0.034	1.380	0.168
Glare Severe	0.092	0.054	1.692	0.091
Beaufort scale 1	0.035	0.055	0.628	0.53
Beaufort scale 2	0.076	0.057	1.340	0.18
Beaufort scale 3	0.215	0.063	3.420	0.001
Beaufort scale ≥4	0.168	0.071	2.377	0.017
Tide Flood	-0.083	0.042	-1.958	0.05
Tide High slack	-0.021	0.050	-0.412	0.681
Tide Ebb	0.040	0.042	0.971	0.332
Distance from vessel[1]	-0.086	0.047	-1.841	0.066
Distance from vessel squared[1]	0.035	0.047	0.742	0.458
Large vessel presence within 5 km from BSA	-0.070	0.069	-1.020	0.308
Hunting event within 70 min prior to observation	0.255	0.032	7.977	<0.001
Small vessels present within the SSA	-0.002	0.036	-0.054	0.957

[1] = Variable was standardized prior to modeling

Group Composition

Table D-5: Test statistics of generalized linear model of group composition (presence of calves or yearlings; type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	34.607	6	**<0.001**
Group size	41.433	2	**<0.001**
Glare	17.171	2	**<0.001**
Beaufort scale	9.609	4	**0.048**
Distance from a vessel	7.506	2	**0.023**
Vessel presence within 5 km from BSA	1.389	1	0.239
Hunting event within 70 minutes prior to observation	1.243	1	0.265
Presence of small vessels within the SSA	1.123	1	0.289

Table D-6: Coefficient estimates for effects in a generalized linear model of group composition (presence of calves or yearlings)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 5 km from BSA, no hunting within preceding 70 minutes, average group size, no small vessels present within the SSA)	0.079	0.210	0.376	0.707
Year 2015	0.384	0.220	1.750	0.08
Year 2016	0.622	0.194	3.214	0.001
Year 2017	0.187	0.178	1.047	0.295
Year 2019	0.376	0.184	2.045	0.041
Year 2020	0.096	0.194	0.497	0.619
Group size[1]	-0.584	0.342	-1.709	0.088
Group size squared[1]	4.014	2.245	1.788	0.074
Glare L	14.248	2.459	5.794	<0.001
Glare S	0.025	0.076	0.329	0.742
Beaufort scale 1	-0.536	0.136	-3.933	<0.001
Beaufort scale 2	-0.337	0.132	-2.546	0.011
Beaufort scale 3	-0.232	0.136	-1.698	0.09
Beaufort scale 4 or higher	-0.368	0.150	-2.459	0.014
Distance from vessel[1]	-0.158	0.168	-0.940	0.347
Distance from vessel squared[1]	-4.552	2.101	-2.167	0.03
Large vessel presence within 5 km from BSA	5.329	2.952	1.805	0.071
Hunting event within 70 min prior to observation	-0.191	0.163	-1.177	0.239
Presence of small vessels within the SSA	0.086	0.078	1.114	0.265

[1] = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Group Spread

Table D-7: Test statistics of generalized linear model of group spread (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	40.143	6	**<0.001**
Group size (categorical)	169.376	1	**<0.001**
Spread of previous group recorded on the same day	117.31	1	**<0.001**
Glare	0.307	2	0.858
Beaufort scale	7.781	4	0.100
Tide	2.65	3	0.449
Distance from vessel	8.143	3	**0.043**
Vessel presence within 5 km from BSA	1.34	1	0.247
Hunting event within 70 minutes prior to observation	19.19	1	**<0.001**
Presence of small vessels within the SSA	0.685	1	0.408

Table D-8: Coefficient estimates for fixed effects in a mixed generalized linear model of group spread

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 5 km from BSA, Tide = low slack, no hunting within preceding 70 minutes, group size of 2, previous group in tight spread, no small vessels within the SSA)	-2.300	0.270	-8.525	<0.001
Year 2015	0.787	0.248	3.171	0.002
Year 2016	0.475	0.226	2.098	0.036
Year 2017	0.655	0.208	3.143	0.002
Year 2019	0.709	0.214	3.312	0.001
Year 2020	1.145	0.227	5.048	<0.001
Year 2021	1.339	0.379	3.535	<0.001
NF>2	0.959	0.076	12.557	<0.001
Previous group in loose spread	0.736	0.068	10.816	<0.001
Glare L	0.006	0.088	0.073	0.942
Glare S	0.079	0.143	0.553	0.58
Beaufort scale 1	0.136	0.145	0.939	0.348
Beaufort scale 2	0.035	0.149	0.234	0.815
Beaufort scale 3	-0.170	0.168	-1.008	0.314
Beaufort scale 4 or higher	0.016	0.187	0.087	0.931
Tide Flood	0.048	0.110	0.438	0.662
Tide High slack	0.179	0.134	1.333	0.182
Tide Ebb	0.120	0.109	1.102	0.271
Distance from vessel[1]	1.925	2.310	0.833	0.405

Parameter	Coefficient	SE	z value	*P* value
Distance from vessel squared[1]	-4.948	3.295	-1.501	0.133
Distance from vessel cubed[1]	5.665	2.320	2.441	0.015
Large vessel presence within 5 km from BSA	0.203	0.175	1.162	0.245
Hunting event within 70 min prior to observation	-0.367	0.084	-4.353	<0.001
Small vessels present within the SSA	0.078	0.094	0.829	0.407

[1] = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Group Formation

Table D-9: Test statistics of generalized linear model of group formation (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	64.803	6	**<0.001**
Group size	582.274	1	**<0.001**
Glare	15.961	2	**<0.001**
Beaufort scale	6.431	4	0.169
Tide	10.145	3	**0.017**
Distance from vessel	0.292	2	0.864
Vessel presence within 5 km from BSA	4.333	1	**0.037**
Hunting event within 70 minutes prior to observation	0.505	1	0.477
Presence of small vessels within the SSA	1.222	1	0.269

Table D-10: Coefficient estimates for fixed effects in a generalized linear model of group formation

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 5 km from BSA, Tide = low slack, no hunting within preceding 70 minutes, average group size, no small vessels within the SSA)	-1.519	0.282	-5.394	<0.001
Year 2015	0.944	0.275	3.438	0.001
Year 2016	1.046	0.252	4.157	<0.001
Year 2017	1.163	0.236	4.927	<0.001
Year 2019	1.434	0.241	5.949	<0.001
Year 2020	1.637	0.251	6.520	<0.001
Year 2021	1.395	0.379	3.680	<0.001
Group size	0.861	0.041	21.218	<0.001
Glare L	-0.001	0.089	-0.012	0.99
Glare S	0.551	0.141	3.917	<0.001
Beaufort scale 1	-0.065	0.144	-0.452	0.651
Beaufort scale 2	0.023	0.148	0.158	0.874
Beaufort scale 3	-0.247	0.167	-1.484	0.138
Beaufort scale 4 or higher	0.042	0.184	0.230	0.818
Tide Flood	-0.203	0.110	-1.838	0.066
Tide High slack	-0.375	0.135	-2.780	0.005
Tide Ebb	-0.301	0.109	-2.751	0.006
Distance from vessel[2]	1.006	2.353	0.428	0.669
Distance from vessel squared[2]	1.033	3.309	0.312	0.755
Large vessel presence within 5 km from BSA	-0.378	0.184	-2.056	0.04
Hunting event within 70 min prior to observation	0.060	0.084	0.711	0.477
Small vessels present within the SSA	-0.108	0.098	-1.102	0.27

[1] = Variable was standardized prior to modeling. [2] = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Group Direction

Table D-11: Test statistics of generalized linear model of group direction (type II *P* values)

Parameter	Chi squared	Df	*P* value
Group size	35.704	1	**<0.001**
Glare	4.292	2	0.117
Beaufort scale	39.685	4	**<0.001**
Tide	10.758	3	**0.013**
Travel direction of the previous group recorded on the same day	2897.138	1	**<0.001**
Directional distance	2.709	2	0.258
North- or southbound vessel	13.083	1	**<0.001**
Vessel presence within 5 km from BSA	4.858	1	**0.028**
Hunting event within 70 minutes prior to observation	7.529	1	**0.006**
Presence of small vessels within the SSA	3.587	1	0.058
Directional distance: North- or southbound vessel	5.584	2	0.061

Table D-12: Coefficient estimates for effects in a generalized linear model of group direction

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Glare="N", Beaufort = 0, no vessels within 5 km from BSA, Tide = low slack, no hunting within preceding 70 minutes, no small vessels within the SSA, group traveling south, and previous group observed traveling north)	-1.635	0.270	-6.053	<0.001
Group size	0.333	0.057	5.818	<0.001
Glare L	0.050	0.121	0.410	0.682
Glare S	-0.417	0.215	-1.945	0.052
Beaufort scale 1	-0.553	0.223	-2.484	0.013
Beaufort scale 2	-0.040	0.230	-0.172	0.863
Beaufort scale 3	0.331	0.256	1.291	0.197
Beaufort scale 4 or higher	-0.070	0.268	-0.260	0.795
Tide Flood	0.215	0.159	1.354	0.176
Tide High slack	-0.206	0.190	-1.084	0.278
Tide Ebb	0.251	0.159	1.585	0.113
Previous group's travel direction (South)	4.217	0.097	43.447	<0.001
Directional distance before breakpoint (at 0 km)	0.764	0.739	1.033	0.302
Slope adjustment for directional distance after breakpoint (at 0 km)	-0.652	1.435	-0.455	0.649
Southbound vessel	-0.486	1.115	-0.436	0.663
Large vessel presence within 5 km from BSA	1.618	0.746	2.170	0.03
Hunting event within 70 min prior to observation	0.340	0.124	2.732	0.006
Small vessels present within the SSA	-0.251	0.133	-1.896	0.058
Directional distance before breakpoint (at 0 km) : Southbound vessel	0.169	1.085	0.156	0.876
Directional distance after breakpoint (at 0 km) : Southbound vessel	-2.243	2.109	-1.063	0.288

[1] = Variable was standardized prior to modeling. [2] = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Travel Speed

Table D-13: Test statistics of generalized linear model of travel speed (slow travel vs. medium travel speed; type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	132.135	6	**<0.001**
Group size	88.503	1	**<0.001**
Glare	5.235	2	0.073
Beaufort scale	19.848	4	**0.001**
Tide	4.103	3	0.251
Distance from vessel	4.175	2	0.124
Speed of previously recorded group	603.423	1	**<0.001**
Vessel presence within 5 km from BSA	2.825	1	0.093
Hunting event within 70 min prior to observation	0.842	1	0.359
Presence of small vessels within the SSA	0.205	1	0.651
Distance:Speed of previously recorded group	7.936	2	**0.019**

Table D-14: Coefficient estimates for fixed effects in a generalized linear model of travel speed (slow travel vs. medium travel speed)

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 5 km from BSA, Tide = low slack, no hunting within preceding 70 min, average group size, previous group traveling at slow speed)	-0.634	0.305	-2.076	0.038
Year 2015	1.695	0.296	5.728	<0.001
Year 2016	1.012	0.260	3.896	<0.001
Year 2017	0.848	0.246	3.440	0.001
Year 2019	1.755	0.248	7.072	<0.001
Year 2020	0.901	0.259	3.472	0.001
Year 2021	1.732	0.393	4.404	<0.001
Group size[1]	-0.396	0.045	-8.882	<0.001
Glare L	0.093	0.102	0.911	0.362
Glare S	0.345	0.153	2.255	0.024
Beaufort scale 1	-0.097	0.160	-0.606	0.545
Beaufort scale 2	-0.344	0.167	-2.056	0.040
Beaufort scale 3	-0.495	0.193	-2.566	0.010
Beaufort scale 4 or higher	-0.523	0.201	-2.595	0.009
Tide Flood	0.224	0.127	1.767	0.077
Tide High slack	0.080	0.152	0.529	0.597

Parameter	Coefficient	SE	*z* value	*P* value
Tide Ebb	0.090	0.124	0.728	0.467
Distance from vessel²	3.632	3.911	0.928	0.353
Distance from vessel squared²	-0.586	4.564	-0.128	0.898
Previously recorded group traveling at medium or fast speed	-1.833	0.076	-23.996	<0.001
Large vessel presence within 5 km from BSA	-0.355	0.215	-1.654	0.098
Hunting event within 70 min prior to observation	-0.087	0.095	-0.916	0.360
Presence of small vessels within the SSA	-0.047	0.103	-0.452	0.651
Distance²:Previous group speed medium or fast	-4.134	4.818	-0.858	0.391
Distance squared²: Previous group speed medium or fast	12.219	4.676	2.613	0.009

¹ = Variable was standardized prior to modeling. ² = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

Distance from Bruce Head Shore

Table D-15: Test statistics of generalized linear model of distance from Bruce Head shore (type II *P* values)

Parameter	Chi squared	Df	*P* value
Year	8.802	6	0.185
Group size	41.62	1	**<0.001**
Group travel direction	166.042	1	**<0.001**
Distance from shore of the previous group recorded on the same day	477.928	1	**<0.001**
Glare	0.103	2	0.950
Beaufort scale	33.162	4	**<0.001**
Tide	16.436	3	**0.001**
Distance from vessel	7.106	2	**0.029**
Vessel presence within 5 km from BSA	2.991	1	0.084
Hunting event within 70 minutes prior to observation	0.824	1	0.364
Presence of small vessels within the SSA	4.124	1	**0.042**

Table D-16: Coefficient estimates for effects in a generalized linear model of distance from Bruce Head shore

Parameter	Coefficient	SE	*z* value	*P* value
Intercept (Year=2014, Glare="N", Beaufort = 0, no vessels within 5 km from BSA, Tide = low slack, no hunting within preceding 70 minutes, no small vessels within the SSA, group traveling south, and previous group observed close to shore)	-0.815	0.260	-3.131	0.002
Year 2015	-0.183	0.264	-0.694	0.488
Year 2016	0.279	0.212	1.316	0.188
Year 2017	0.322	0.201	1.607	0.108
Year 2019	0.246	0.204	1.202	0.229
Year 2020	0.258	0.215	1.198	0.231
Year 2021	0.371	0.368	1.008	0.314
Group size[1]	-0.251	0.040	-6.224	<0.001
Group travel direction (N)	-0.959	0.075	-12.872	<0.001
Previous group's distance from shore (>300 m)	1.475	0.068	21.598	<0.001
Glare L	-0.003	0.089	-0.036	0.971
Glare S	-0.047	0.149	-0.319	0.75
Beaufort scale 1	-0.056	0.140	-0.403	0.687
Beaufort scale 2	-0.219	0.145	-1.511	0.131
Beaufort scale 3	-0.719	0.172	-4.190	<0.001
Beaufort scale 4 or higher	-0.295	0.180	-1.634	0.102
Tide Flood	0.128	0.112	1.141	0.254
Tide High slack	-0.255	0.138	-1.855	0.064
Tide Ebb	-0.130	0.110	-1.182	0.237
Absolute distance from vessel[2]	6.334	2.689	2.355	0.019
Absolute distance from vessel squared[2]	-6.034	3.913	-1.542	0.123
Hunting event within 70 min prior to observation	0.315	0.181	1.740	0.082
Small vessels present within the SSA	0.079	0.087	0.909	0.364

[1] = Variable was standardized prior to modeling. [2] = Variable was standardized prior to modeling; in addition, orthogonal polynomials were used, hence the coefficients cannot be interpreted simply as change in response variable with 1 SD change in predictor variable.

APPENDIX E

Model Diagnostics

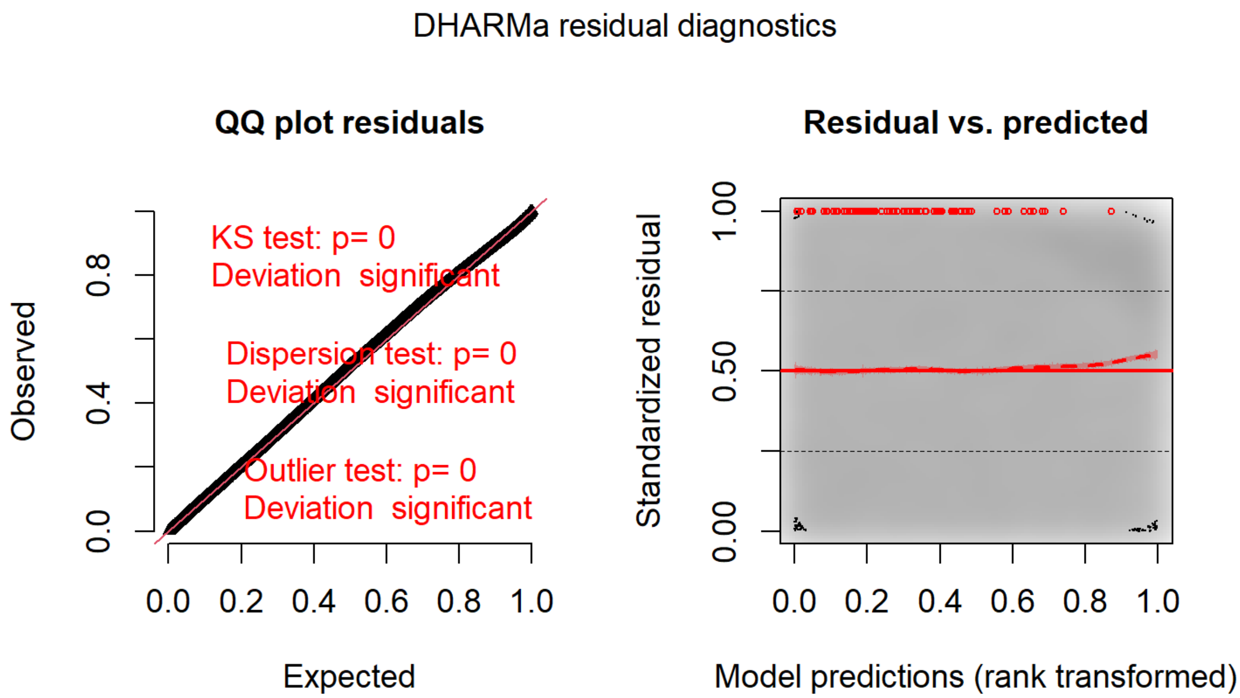


Figure E-1: Residual diagnostics for Density model – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

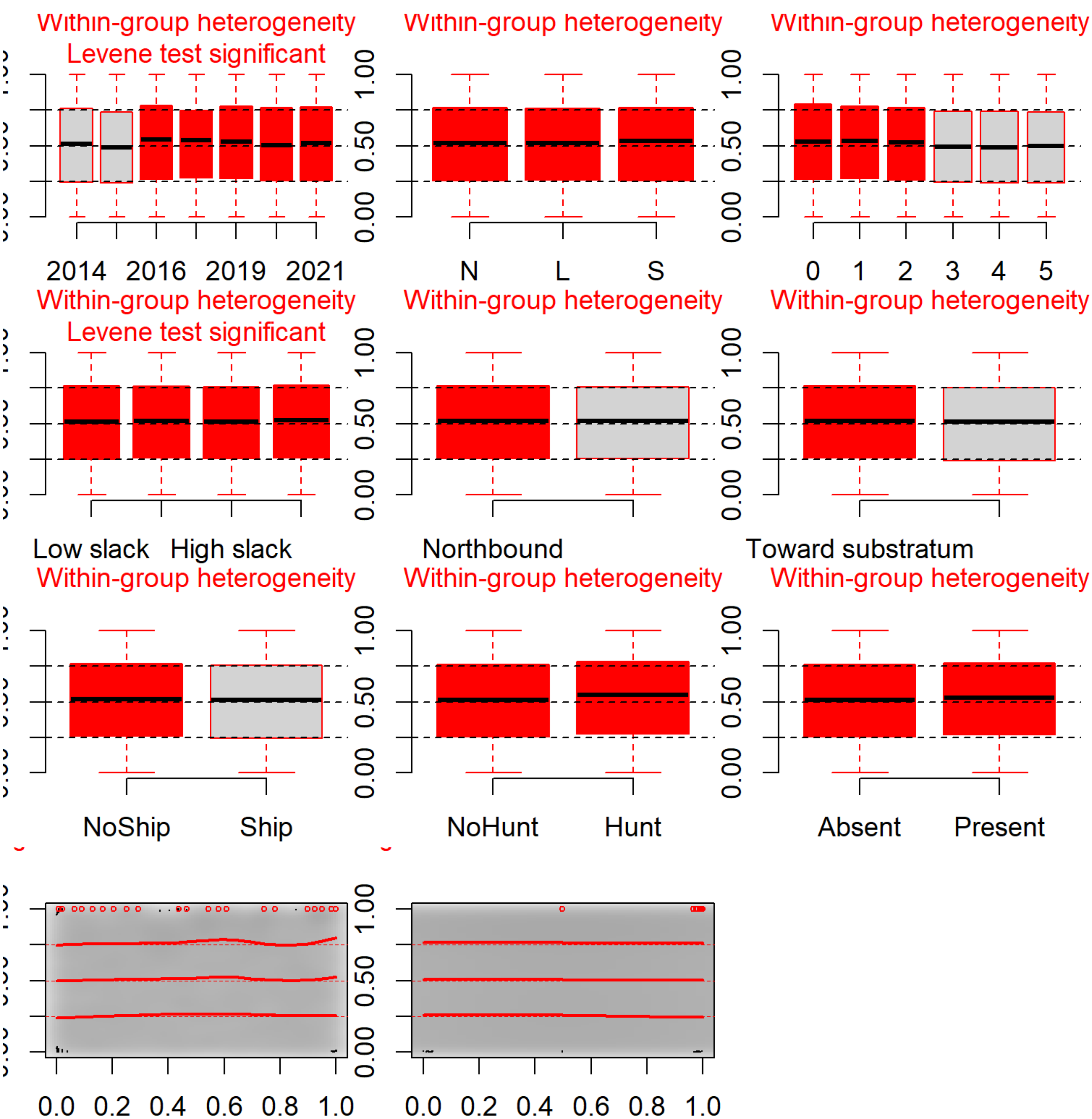


Figure E-2: Residual diagnostics for narwhal density model – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

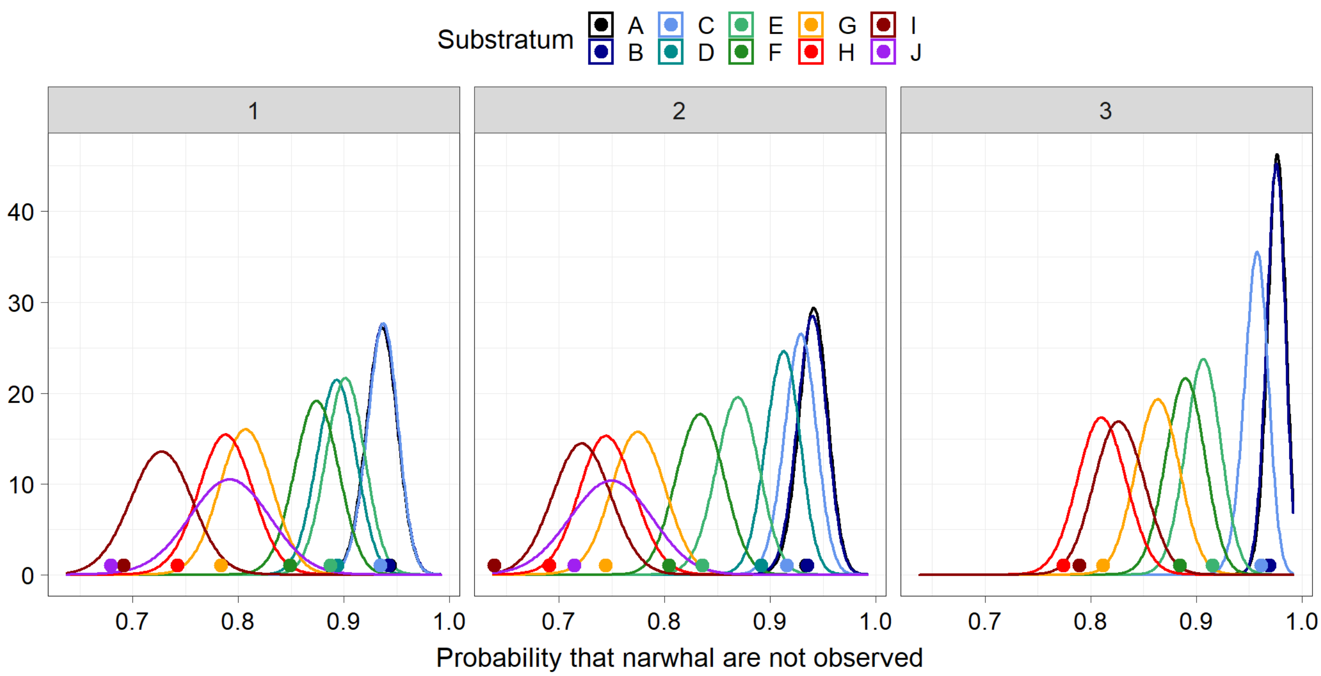


Figure E-3: Density model diagnostics – simulated zero counts. Each panel represents a different substratum (1, 2, or 3). Densities are values from 1000 data sets simulated from model selected for interpretation. Points represent the observed data.

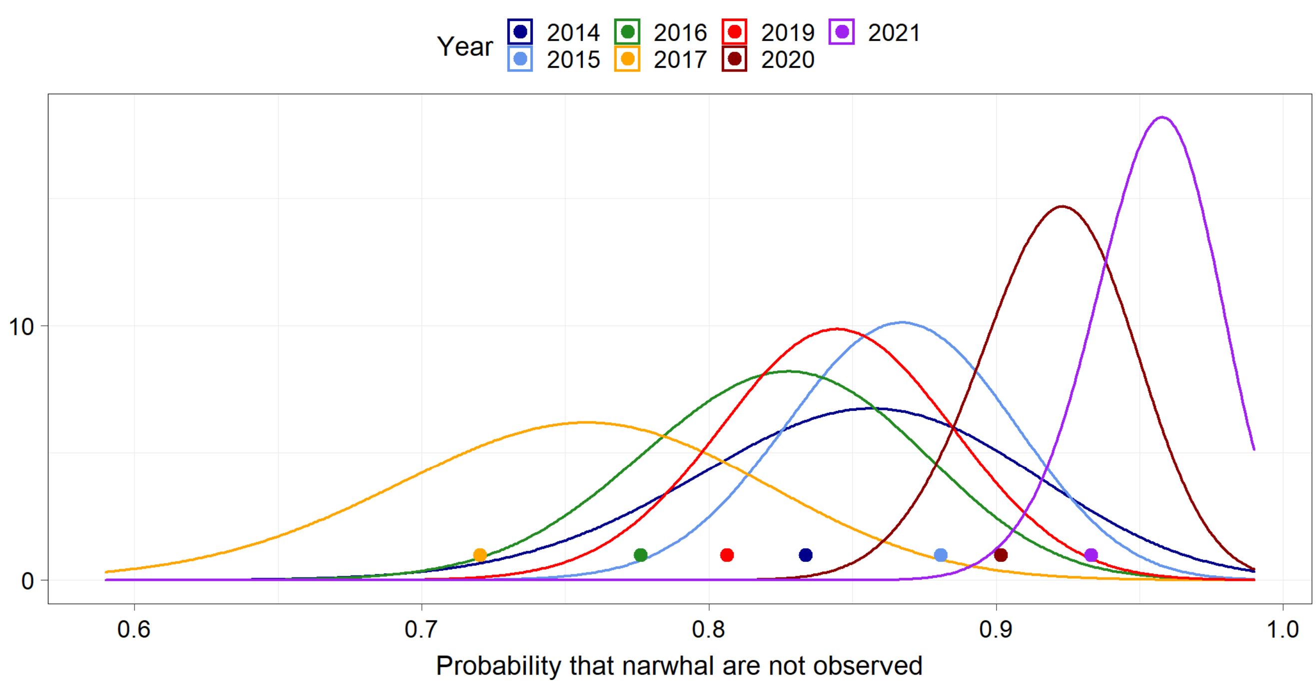


Figure E-4: Density model diagnostics – simulated zero counts. Each curve represents a different sampling year. Densities are values from 1000 data sets simulated from model selected for interpretation. Points represent the observed data.

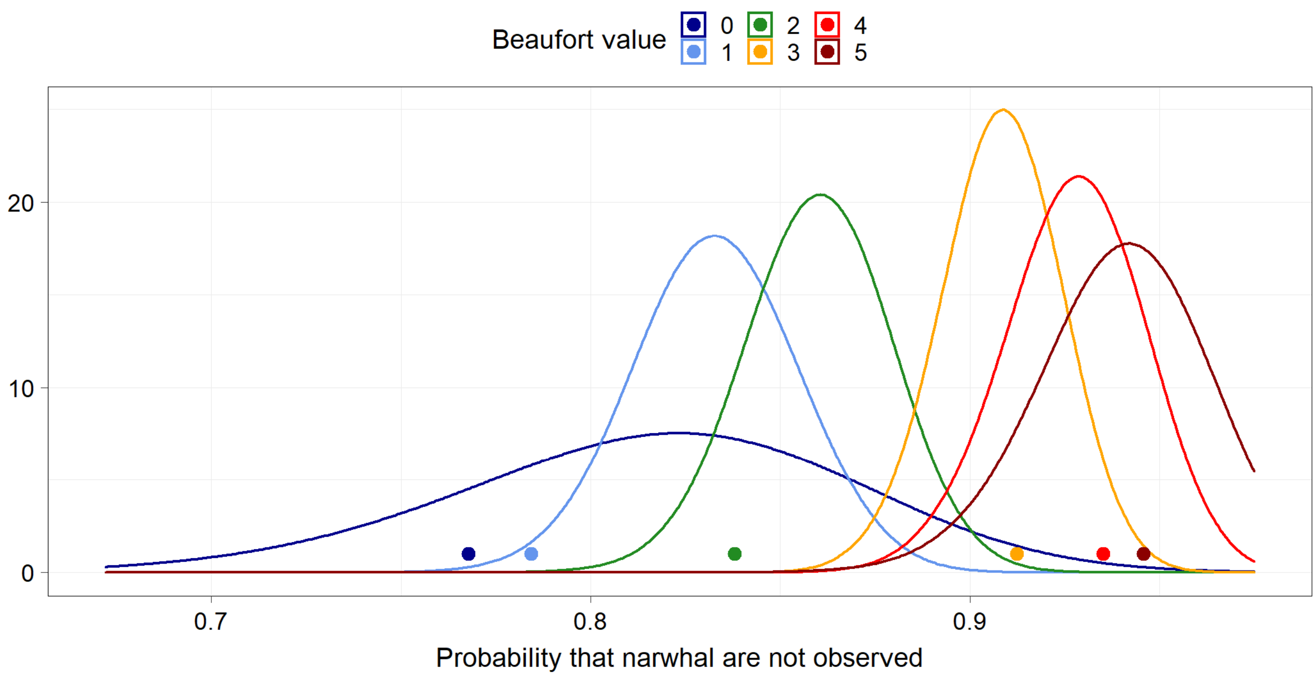


Figure E-5: Density model diagnostics – simulated zero counts. Each curve represents a different Beaufort scale value. Densities are values from 1000 data sets simulated from model selected for interpretation. Points represent the observed data.

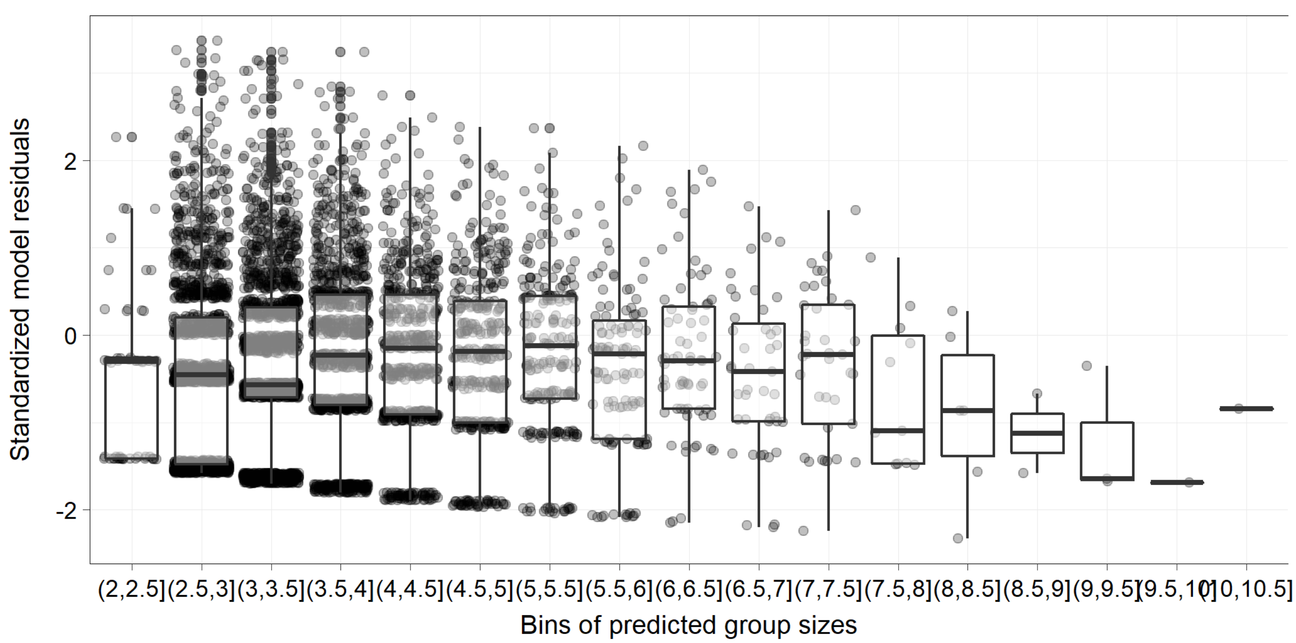


Figure E-6: Residual diagnostics for model of group size, showing distribution of standardized residuals for each bin of predicted group sizes.

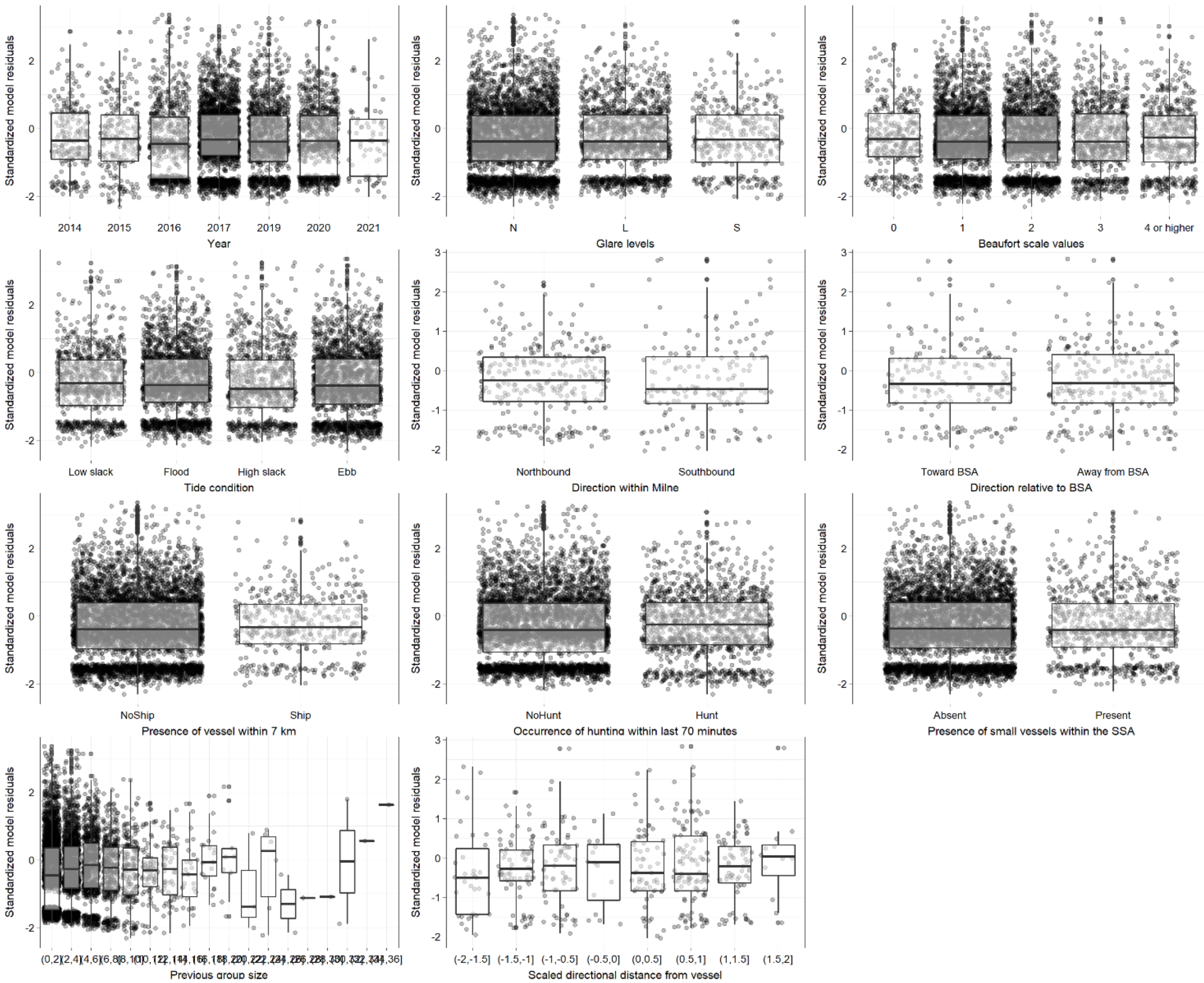


Figure E-7: Residual diagnostics for model of group size, showing distribution of standardized residuals versus all predictor variables; for continuous variables, values were binned.

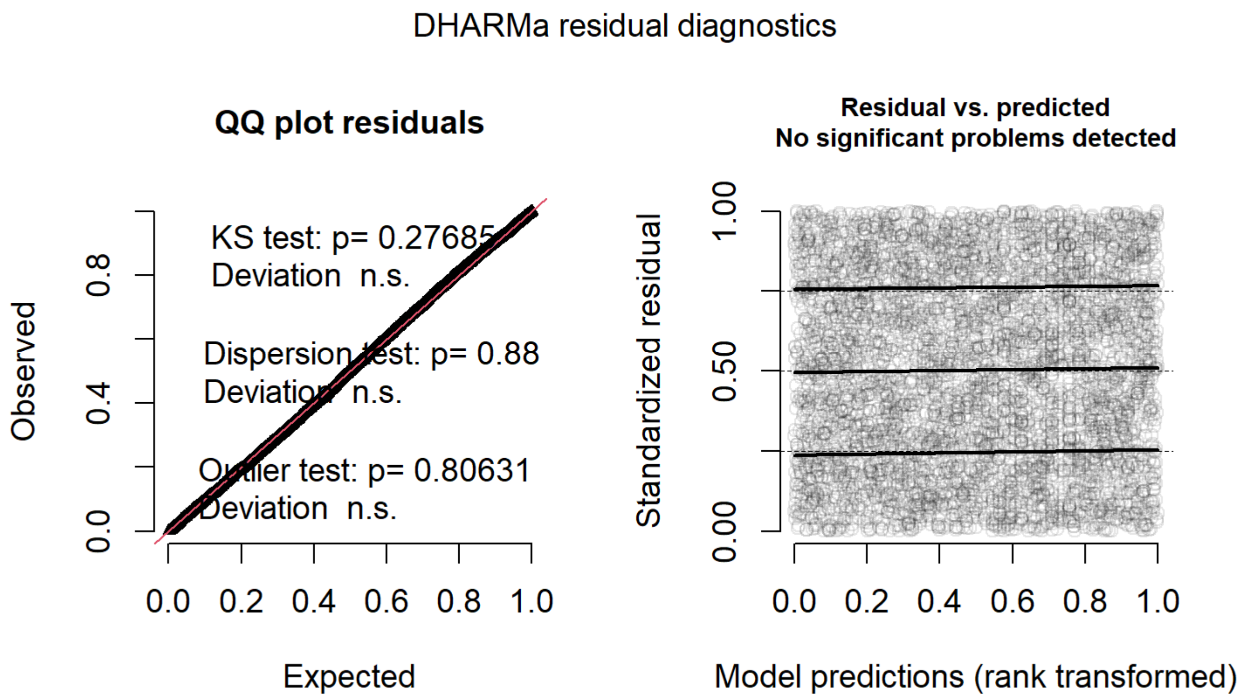


Figure E-8: Residual diagnostics for model of group composition – presence of calves and yearlings – QQ plot of scaled residuals, tests of scaled residuals, and a plot of scaled residuals versus transformed predicted values.

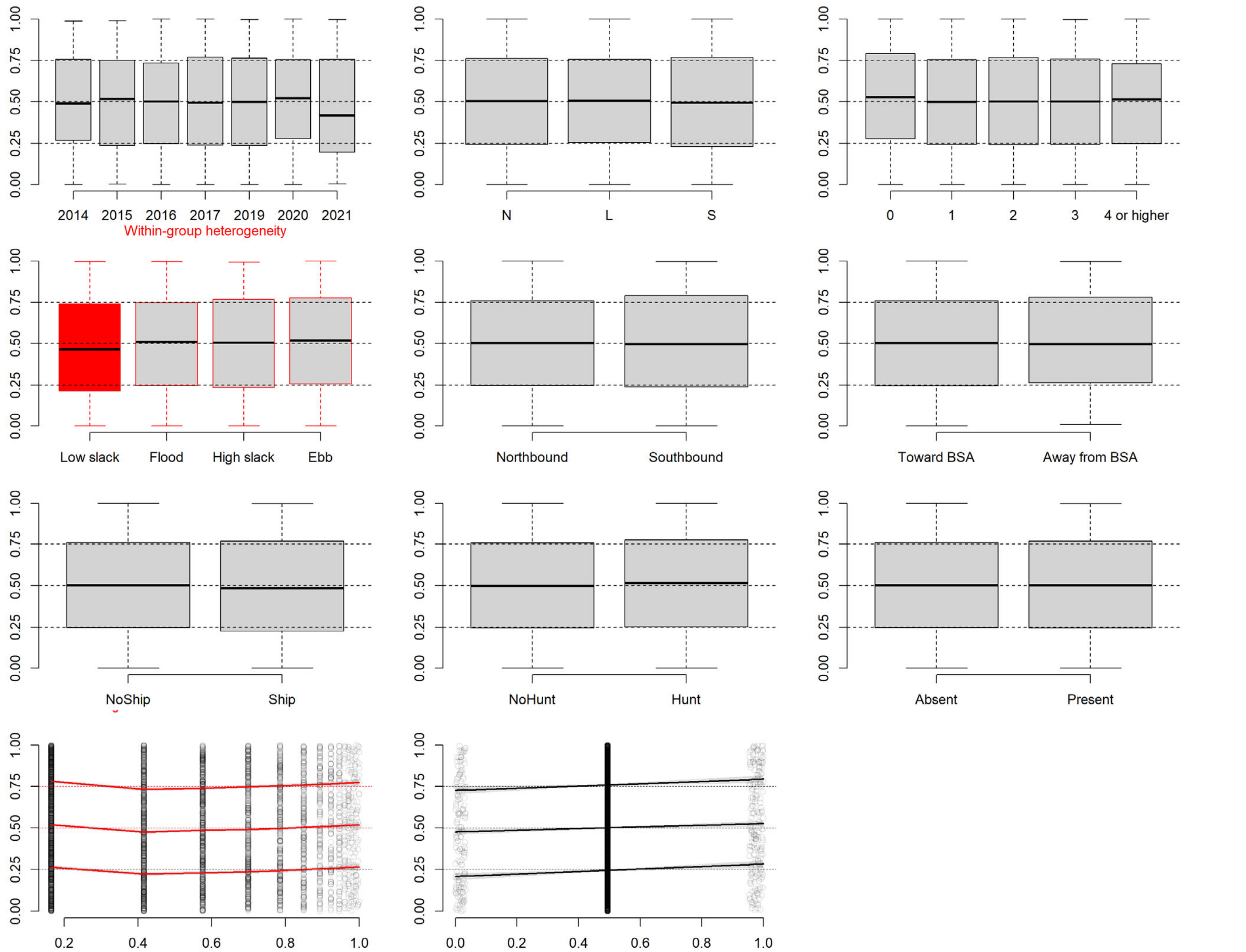


Figure E-9: Residual diagnostics for model of group composition – presence of calves and yearlings – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

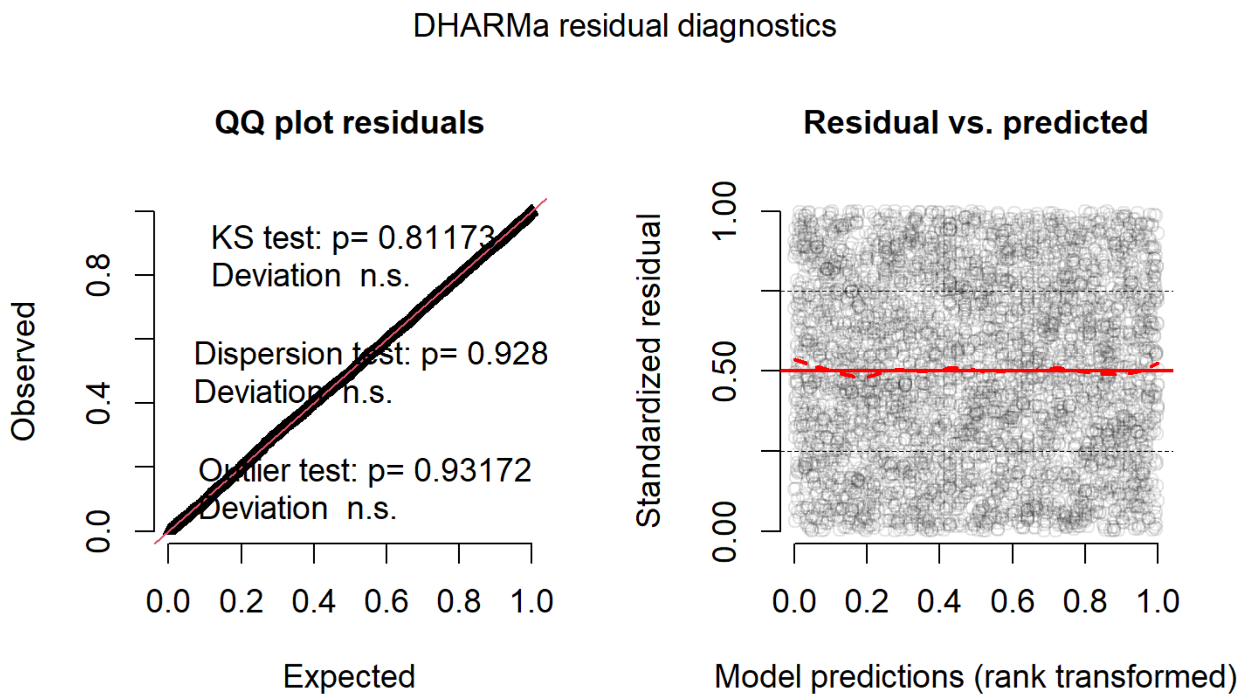


Figure E-10: Residual diagnostics for model of groups observed in a loose (rather than a tight) spread – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

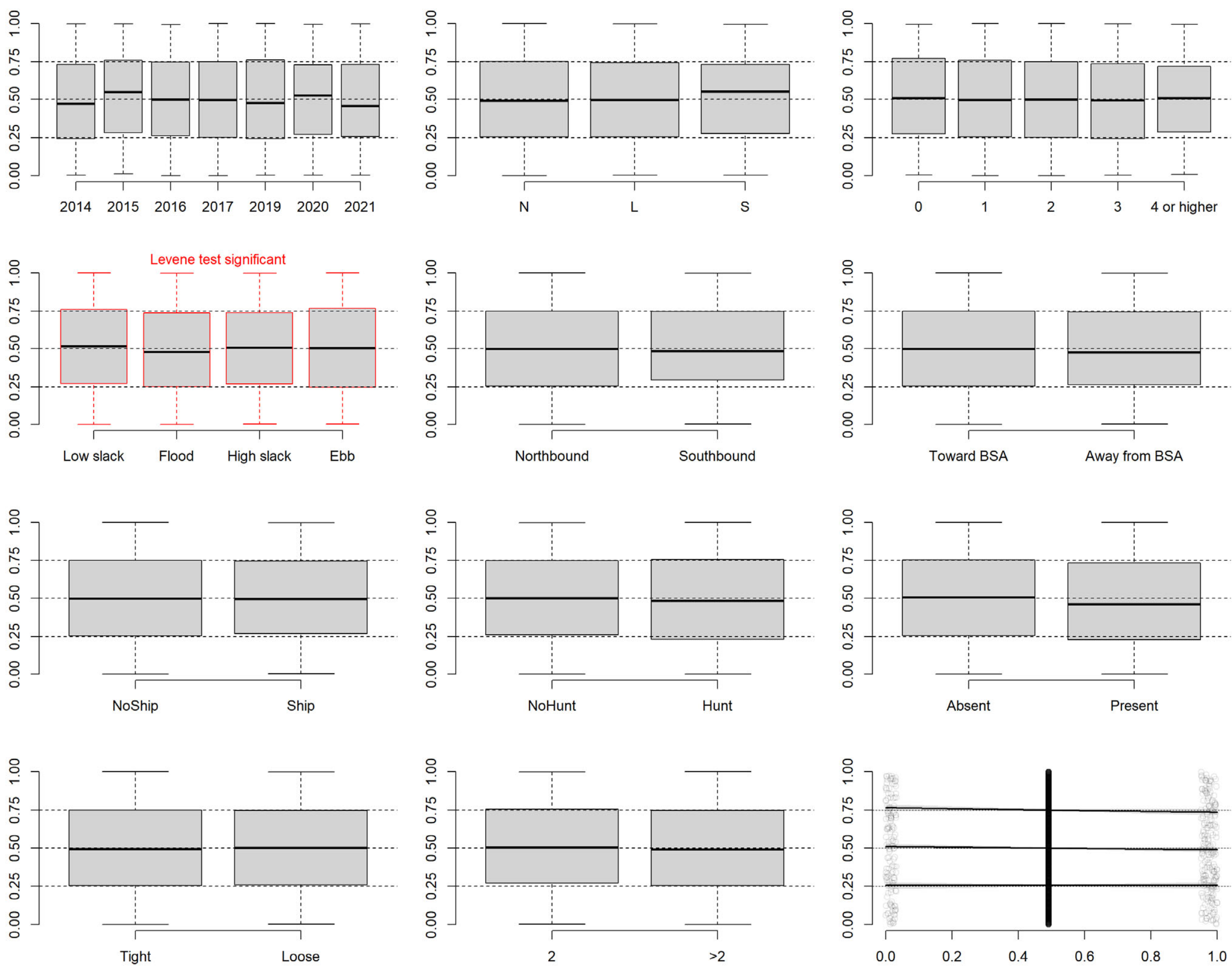


Figure E-11: Residual diagnostics for model of groups observed in a loose (rather than a tight) spread – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

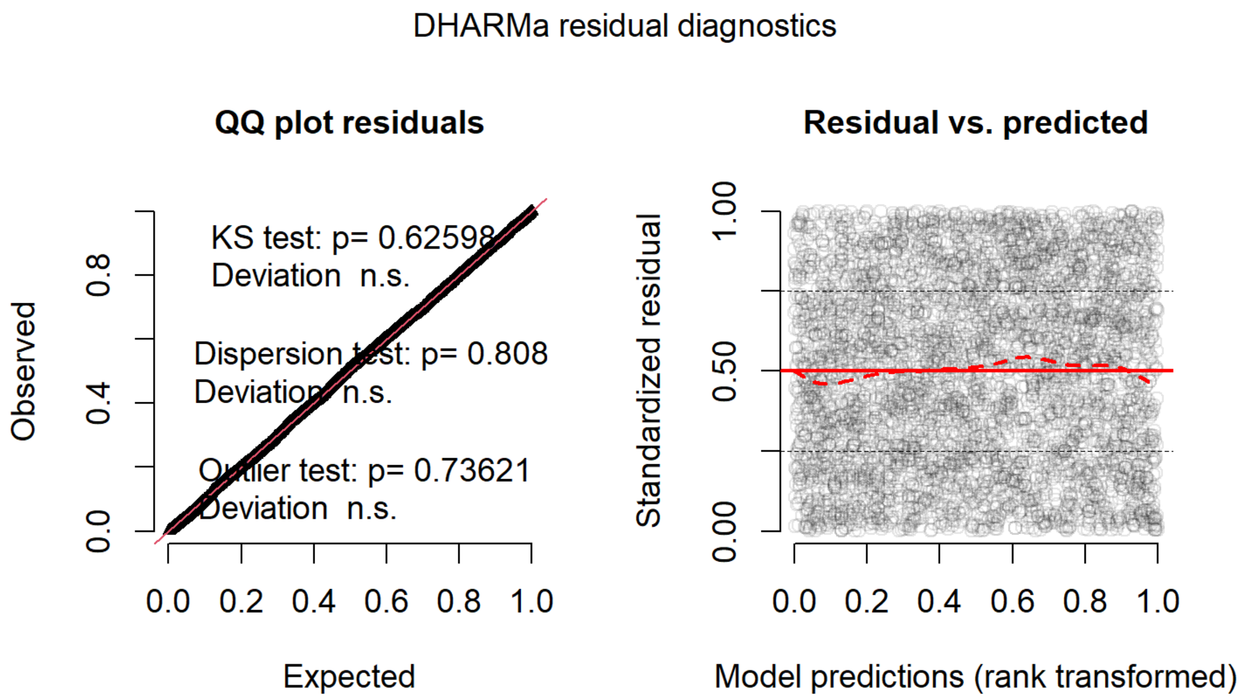


Figure E-12: Residual diagnostics for model of groups observed in non-parallel formation – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

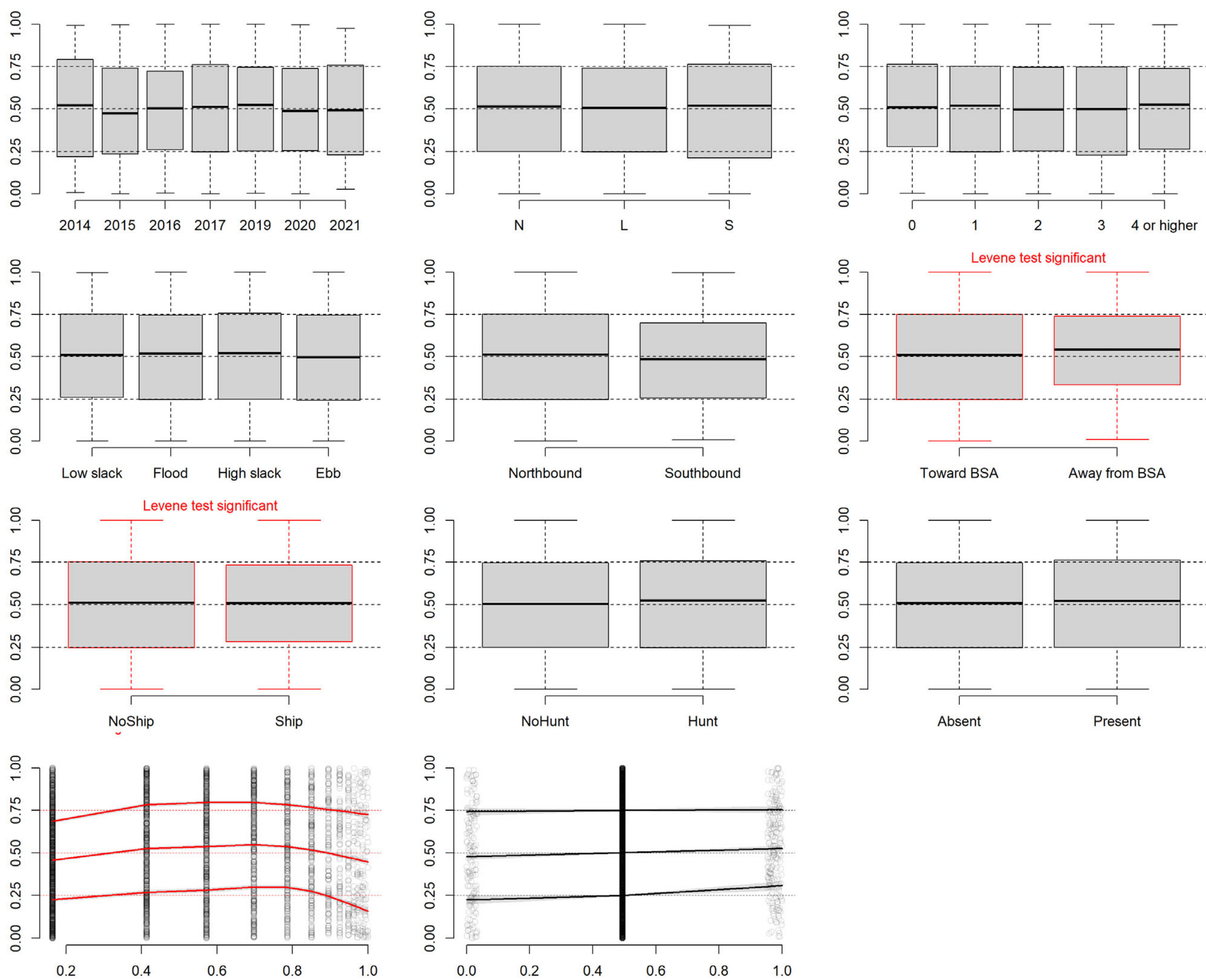


Figure E-13: Residual diagnostics for model of groups observed in non-parallel formation – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

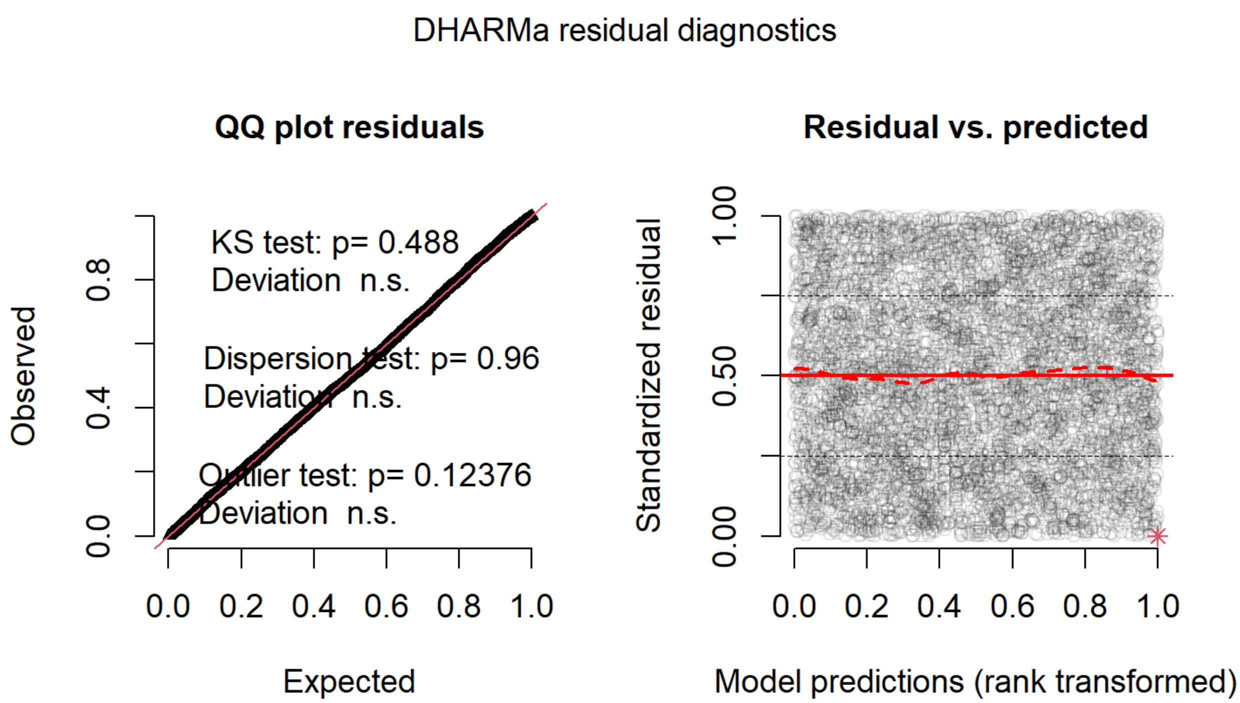


Figure E-14: Residual diagnostics for model of groups observed travelling south (rather than north) – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

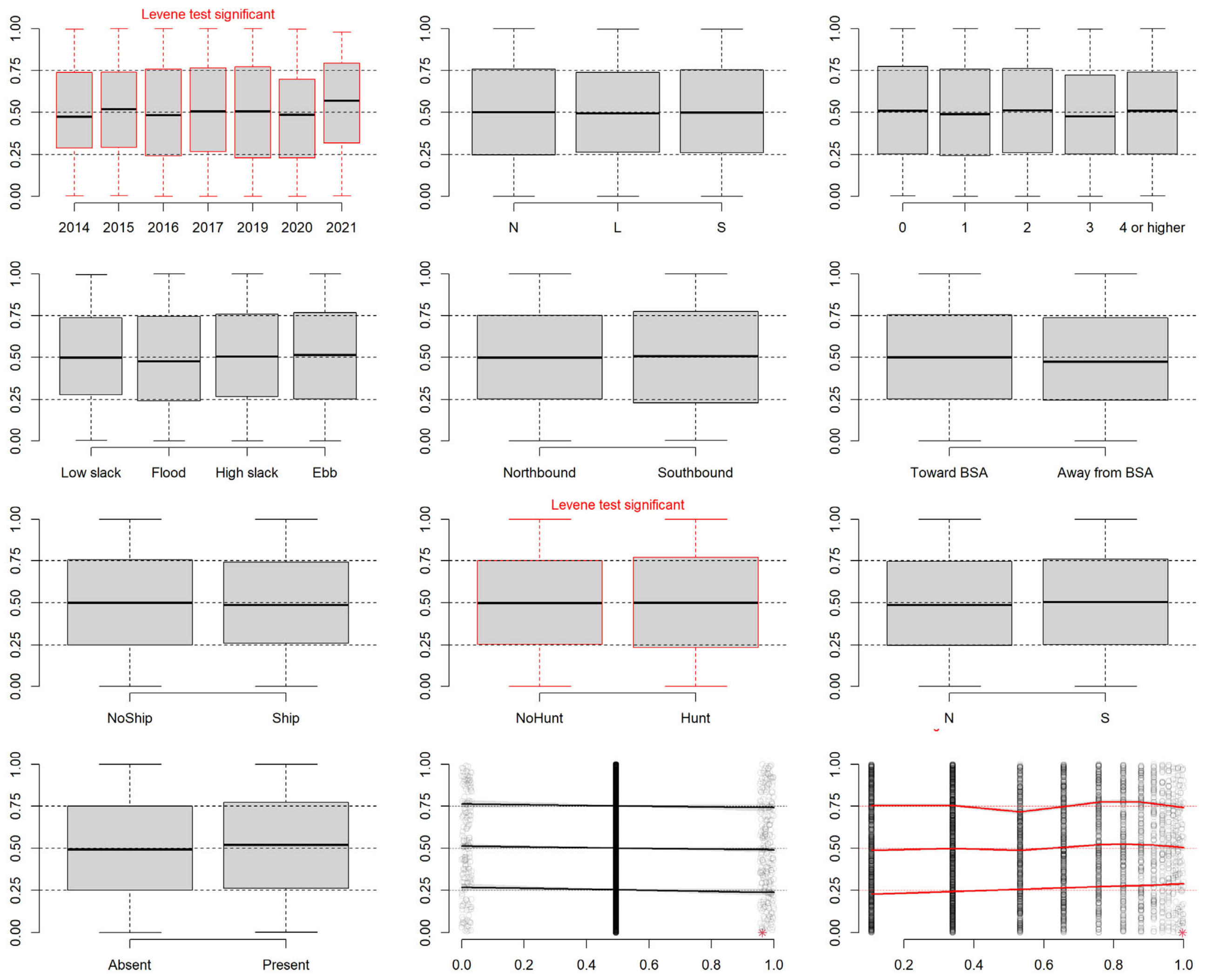


Figure E-15: **Residual diagnostics for model of groups observed travelling south (rather than north) – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.**

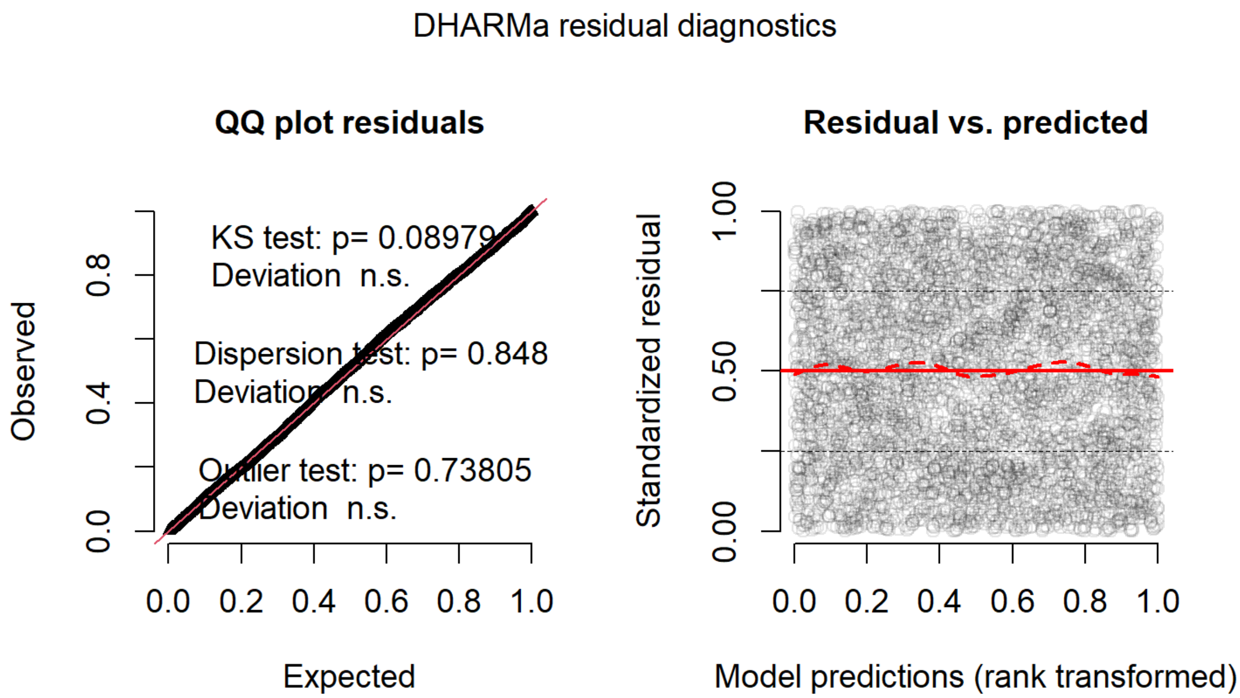


Figure E-16: Residual diagnostics for model of group travel speed (medium vs slow) – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

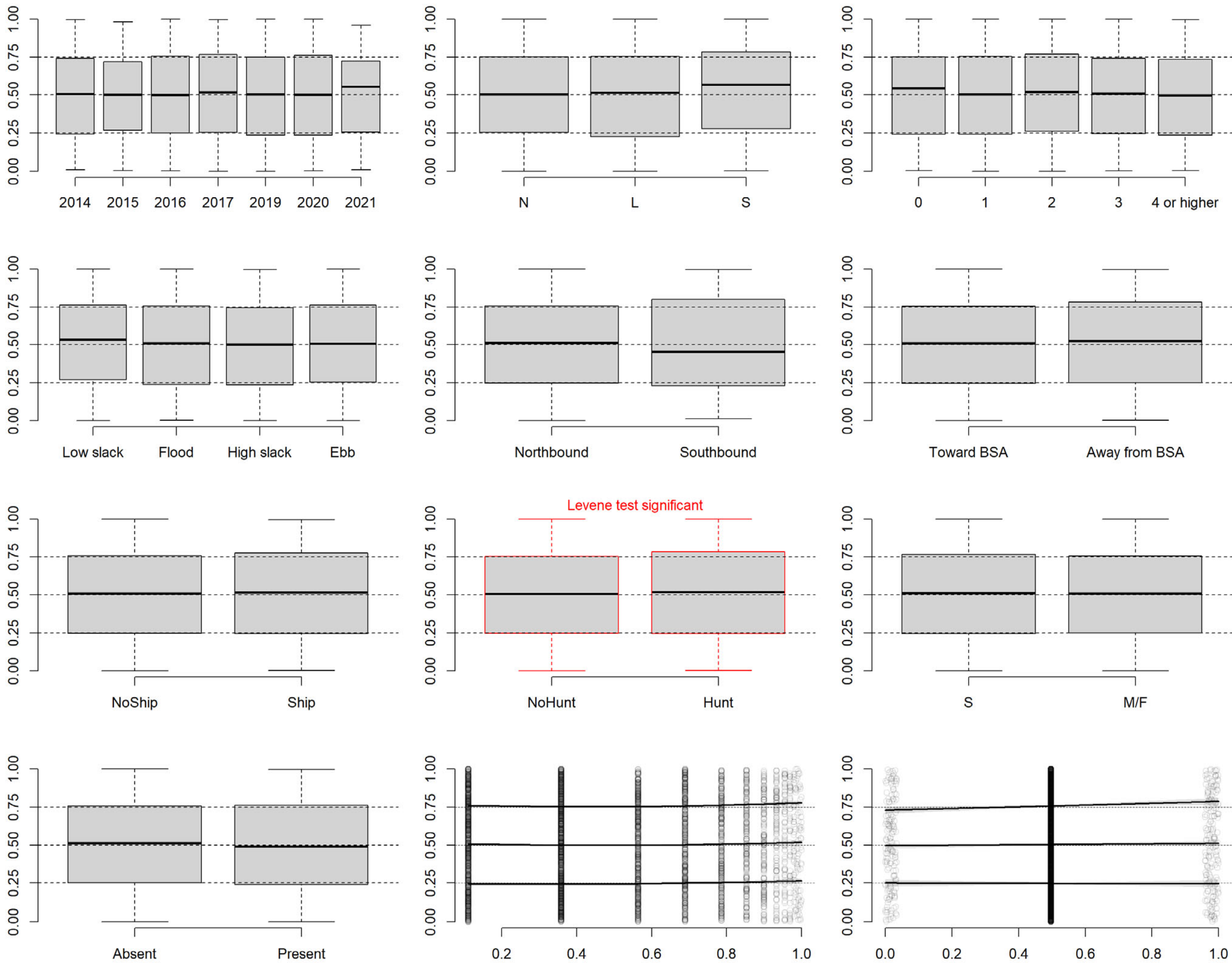


Figure E-17: Residual diagnostics for model of group travel speed (medium vs slow) – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

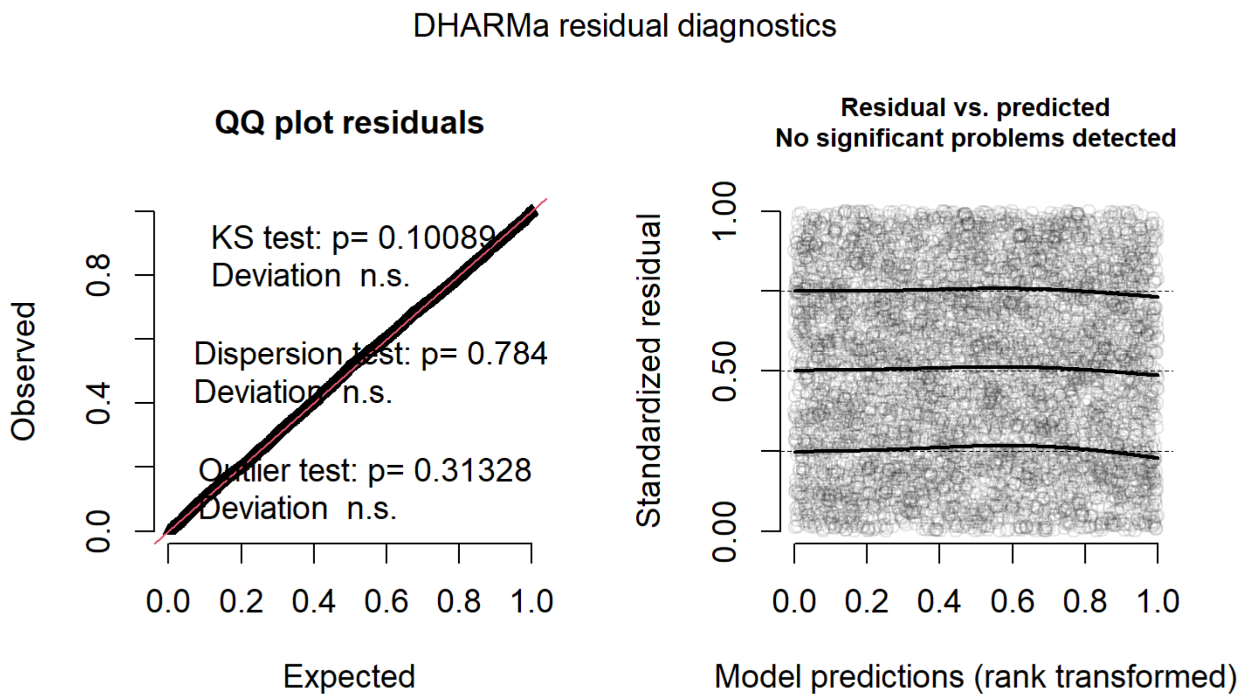


Figure E-18: Residual diagnostics for model of groups observed >300 m from shore – QQ plot of scaled residuals, tests of scaled residuals, and plot of scaled residuals versus transformed predicted values.

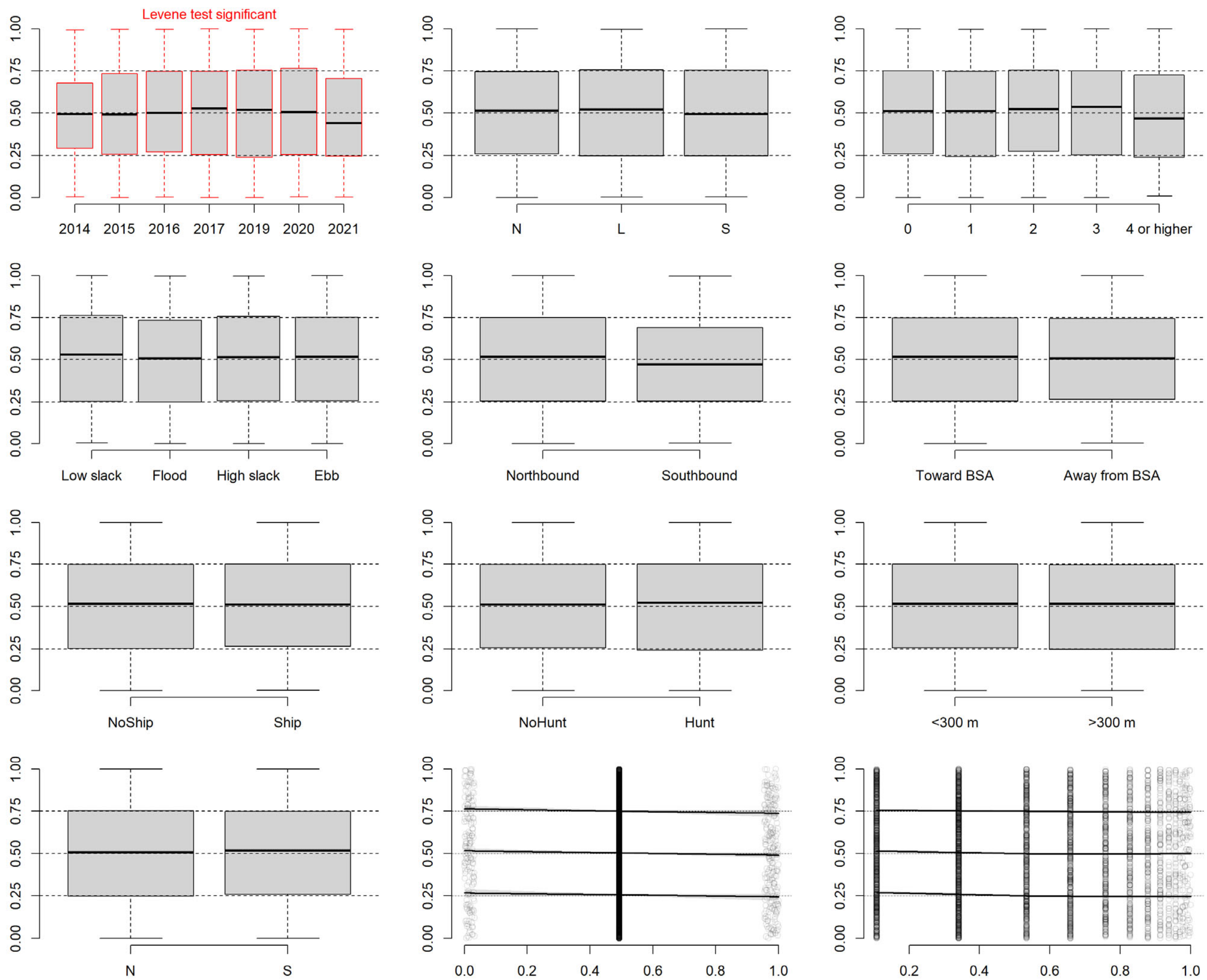
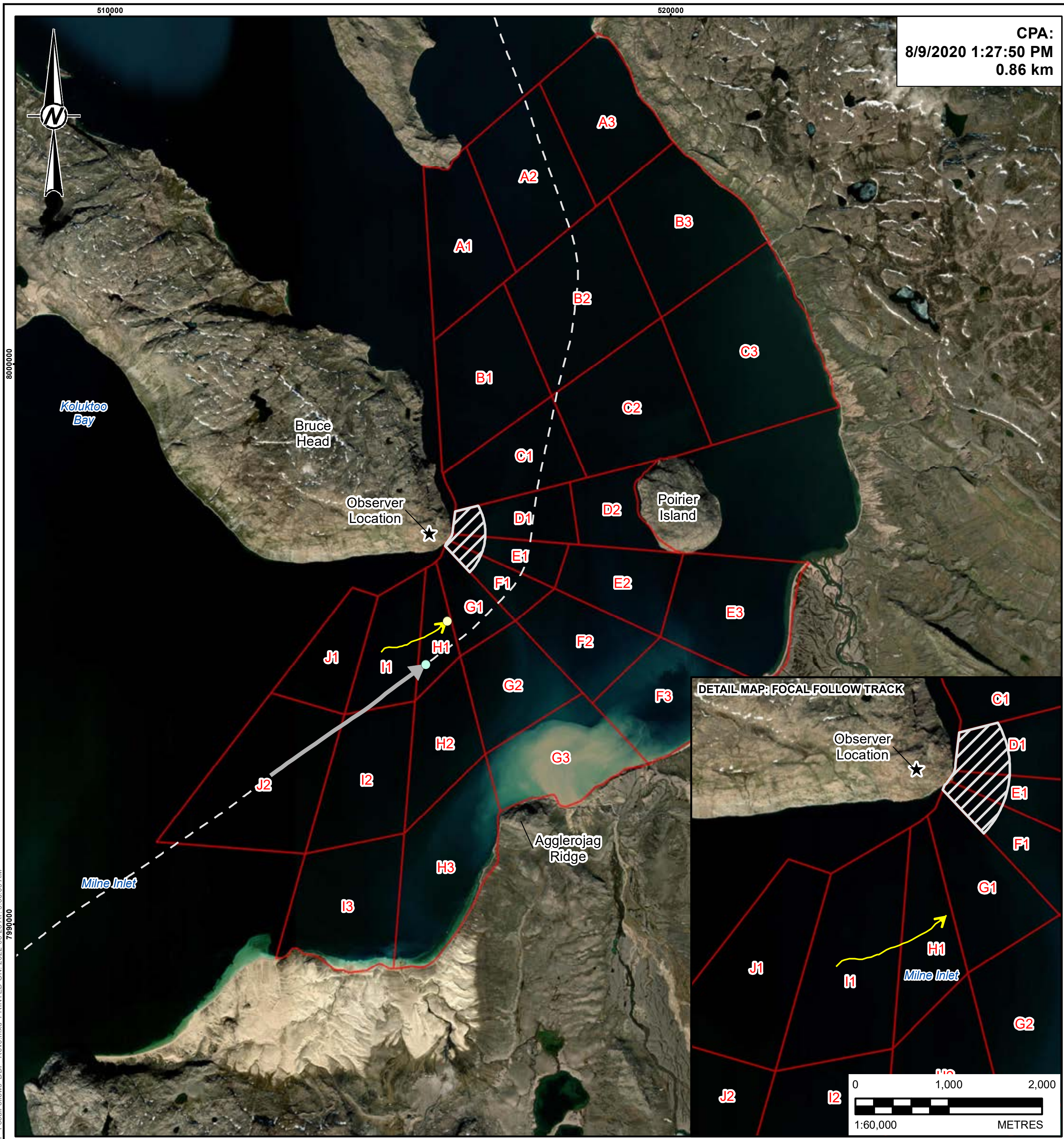


Figure E-19: Residual diagnostics for model of groups observed >300 m from shore – plots of scaled residuals versus all predictor variables; for continuous variables, quantile regression lines are shown.

APPENDIX F

Focal Follow Survey Tracks Relative to Vessel Tracks



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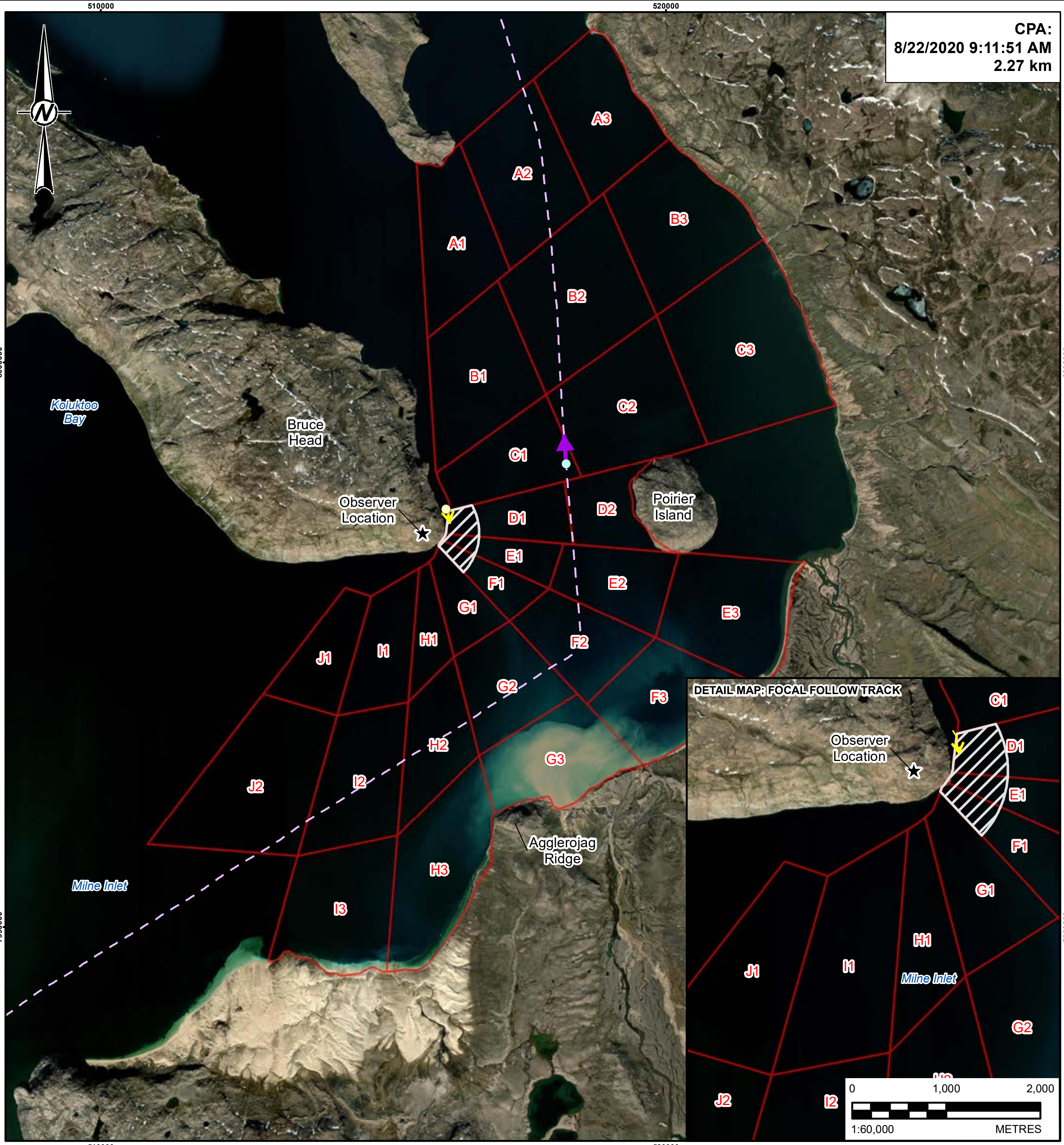

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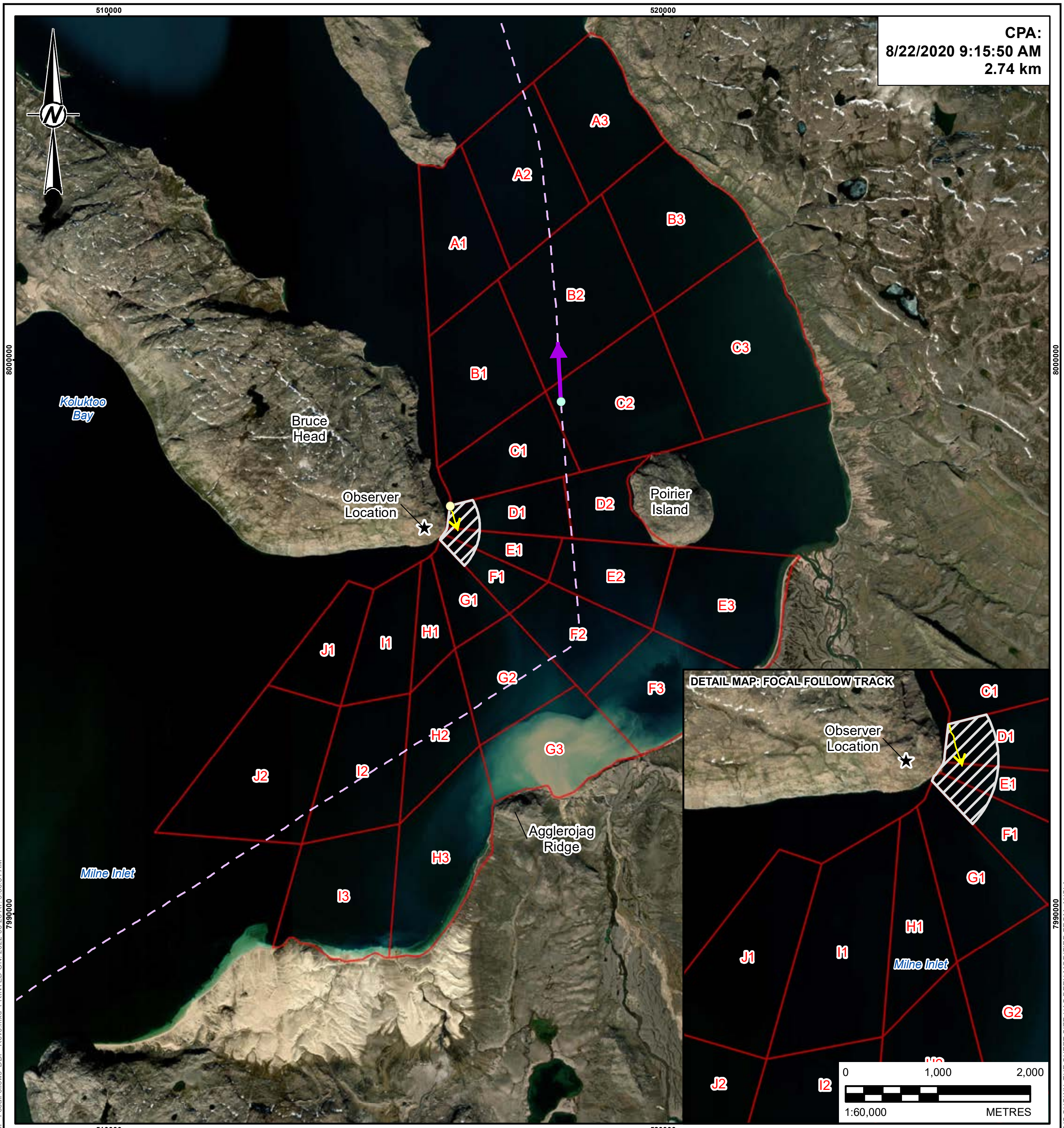

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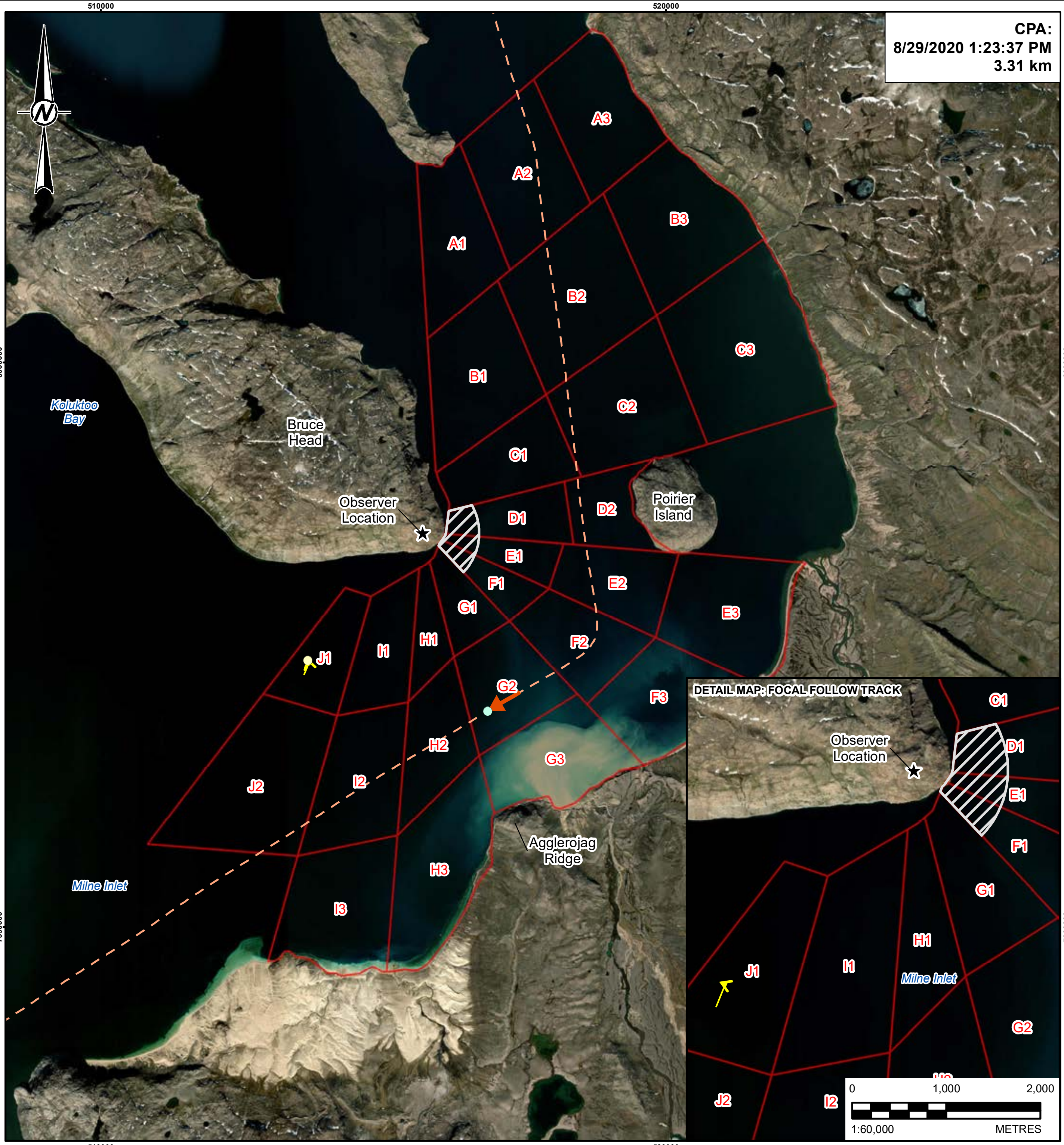

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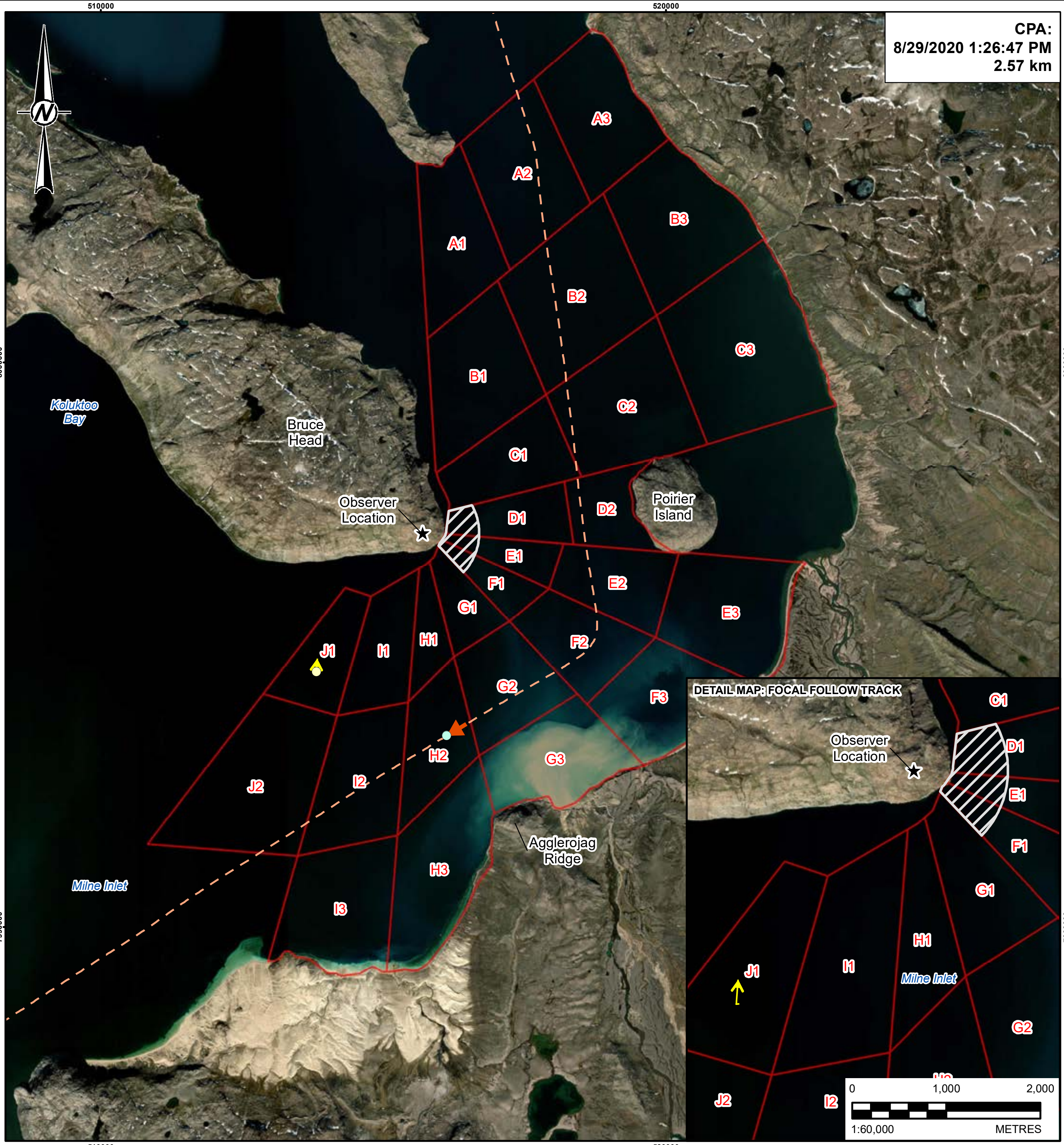

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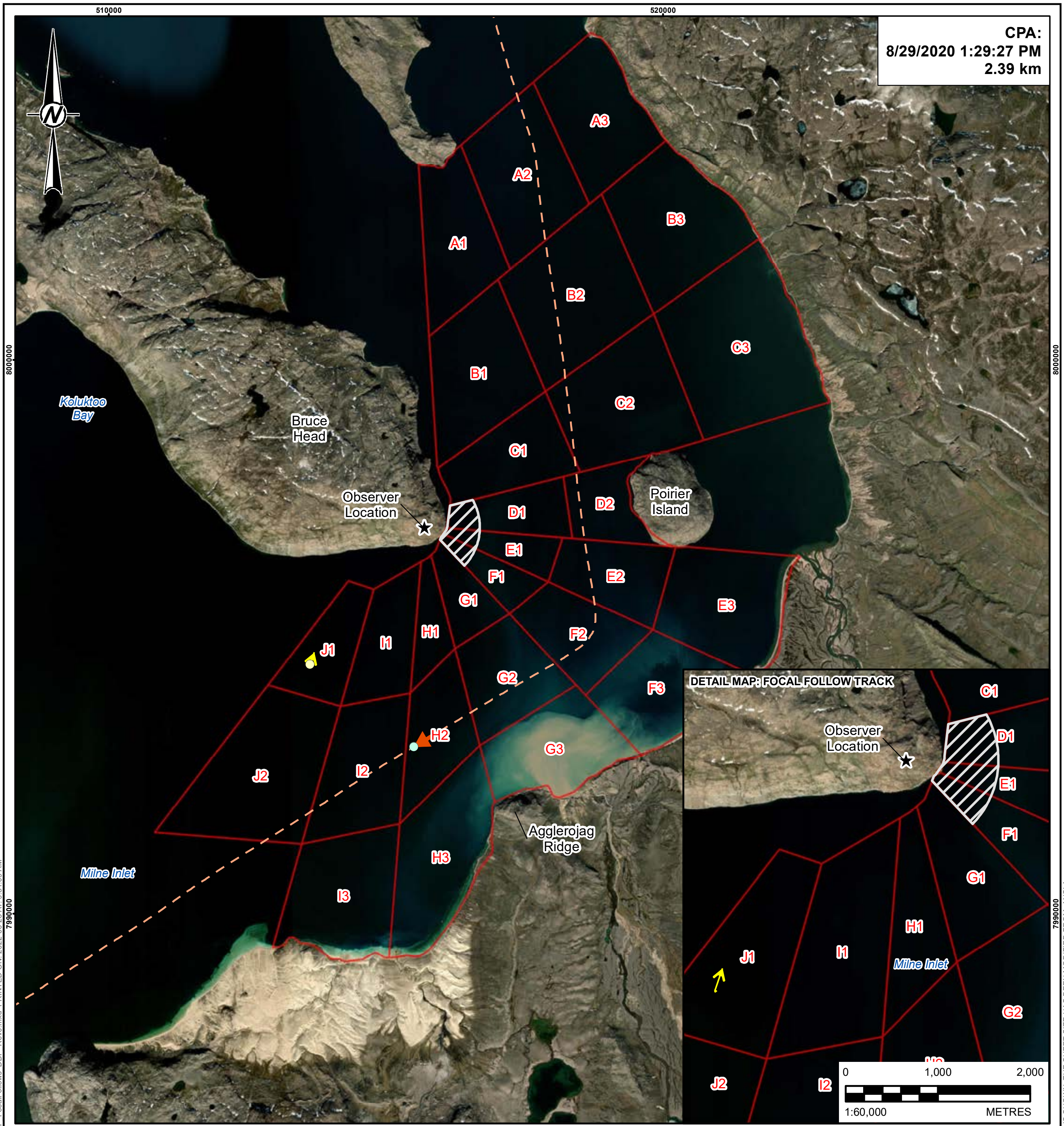

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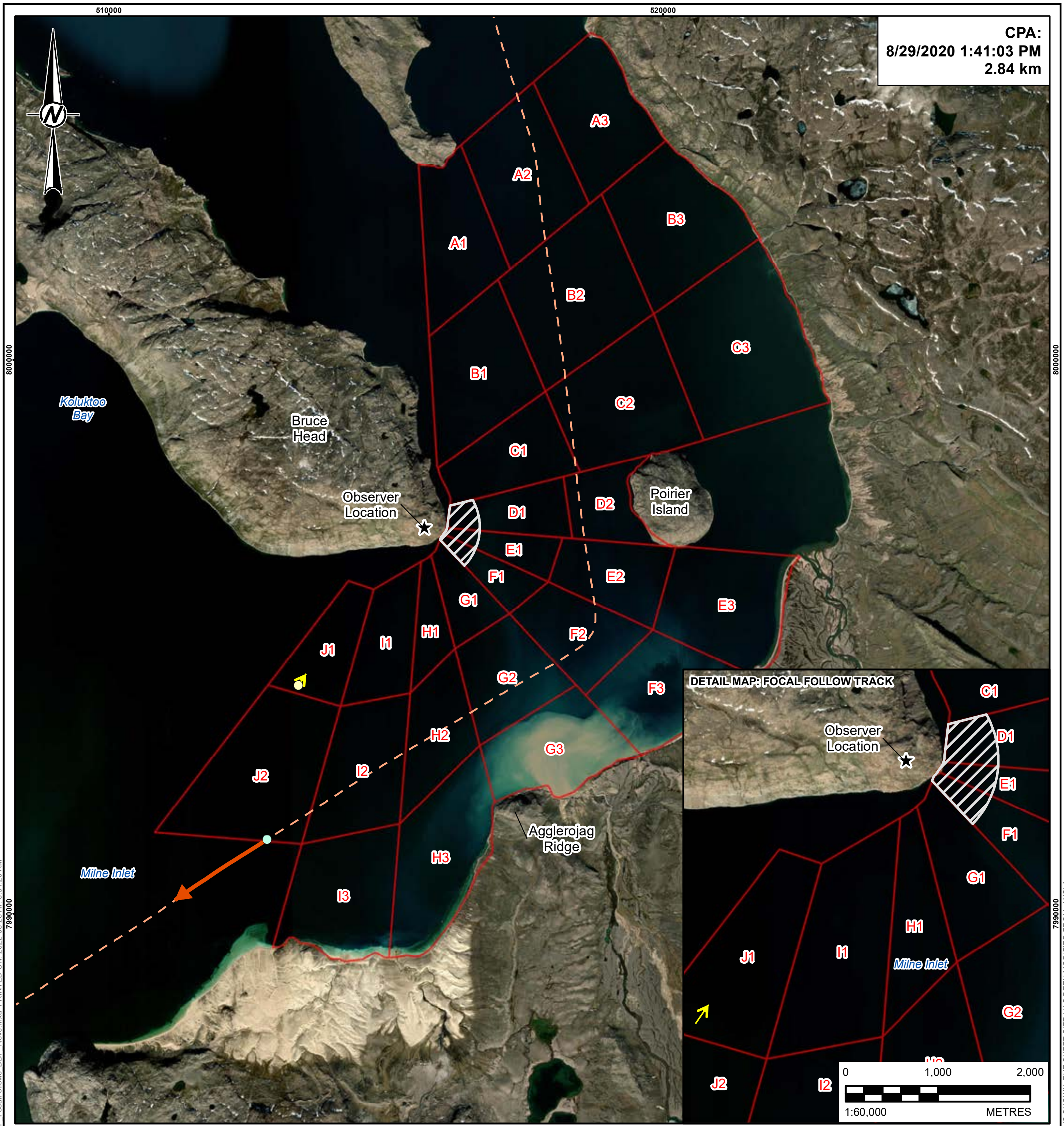

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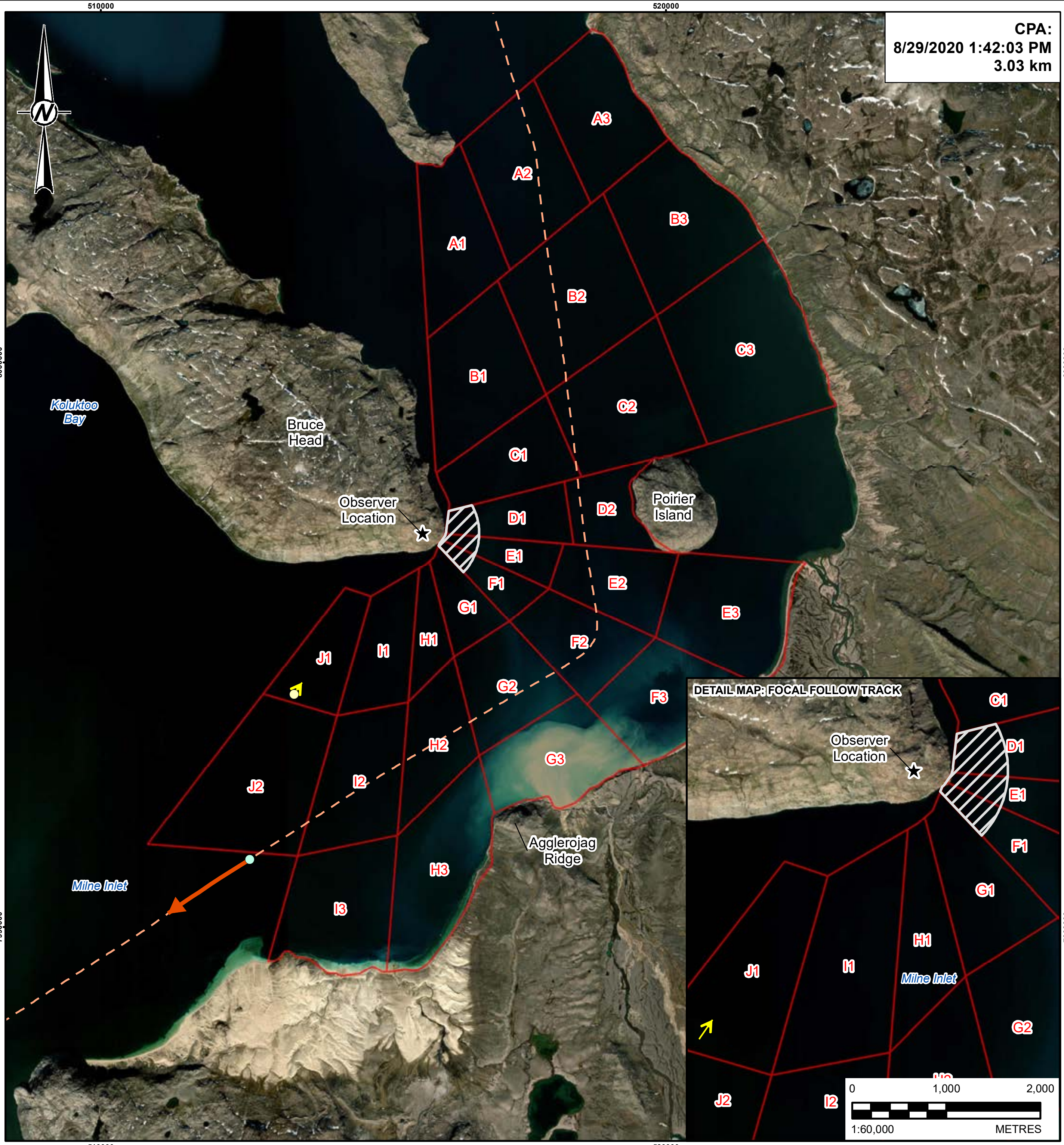

LEGEND

- • COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- ★ OBSERVER LOCATION
- FOCAL FOLLOW TRACK 66 (2020)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 66 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-8

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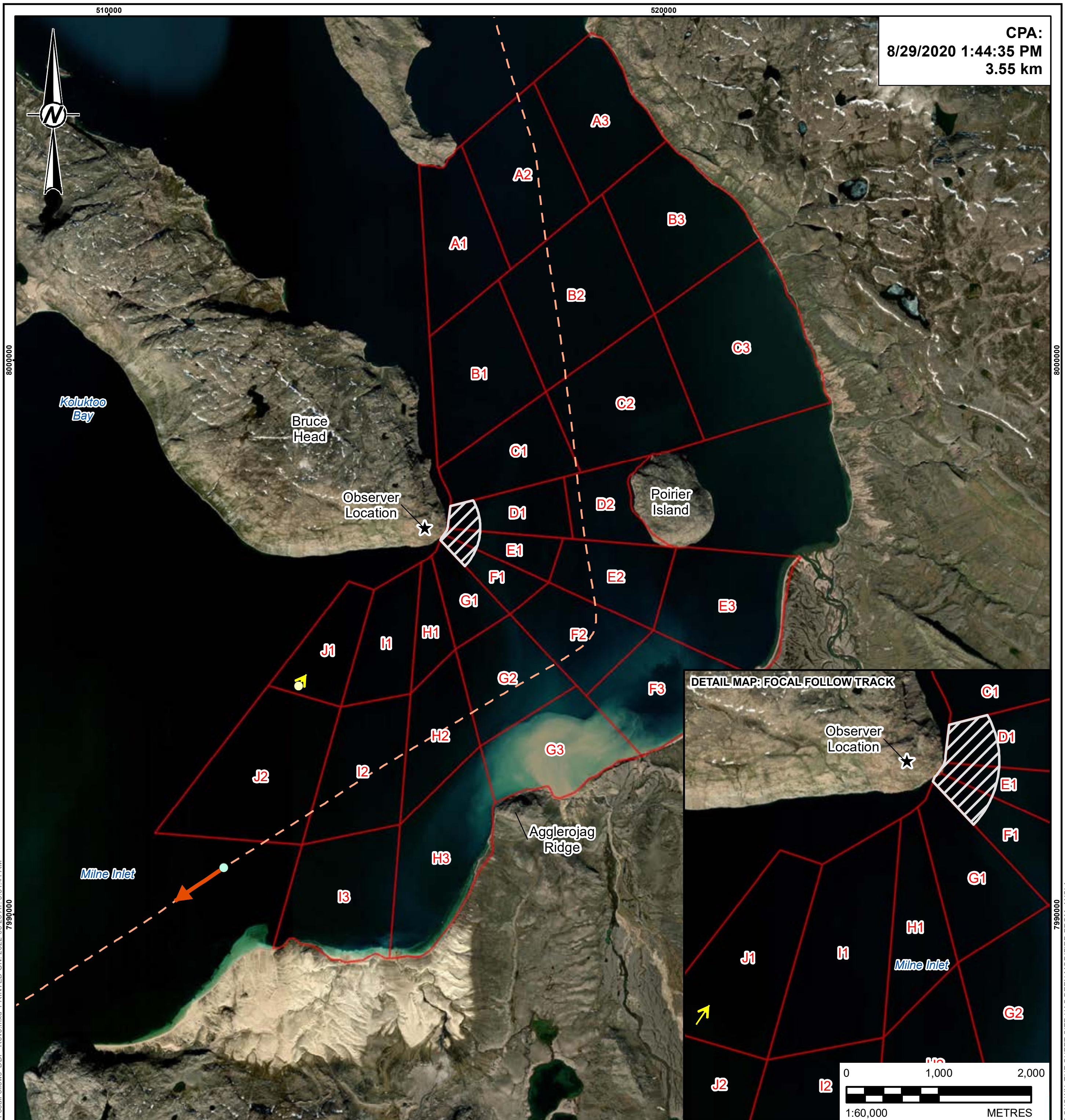

LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 67 (2020)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 67 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-9

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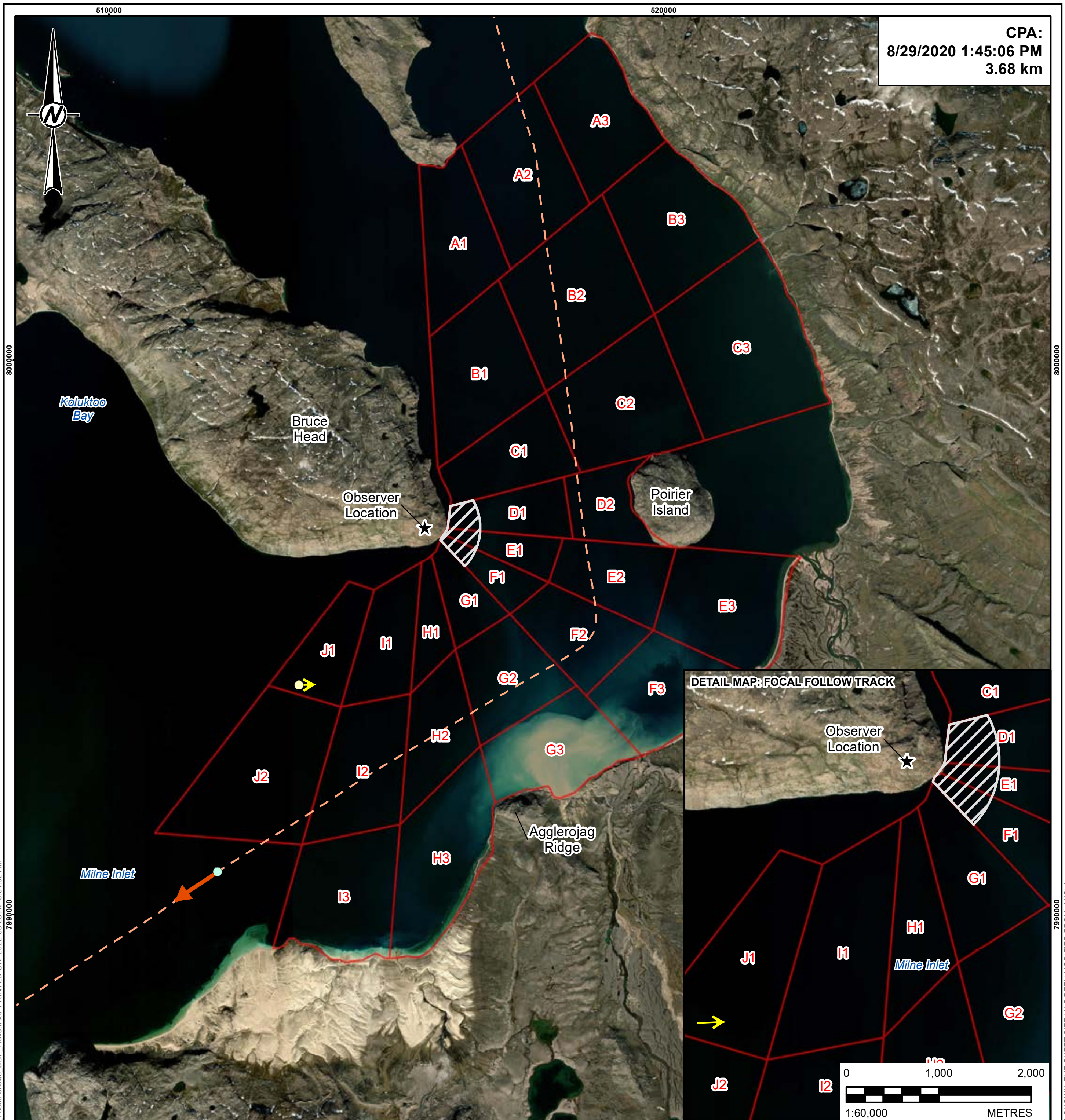


LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 68 (2020)
- ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- NON-ACTIVE VESSEL TRANSIT (NORDIC OLYMPIC)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

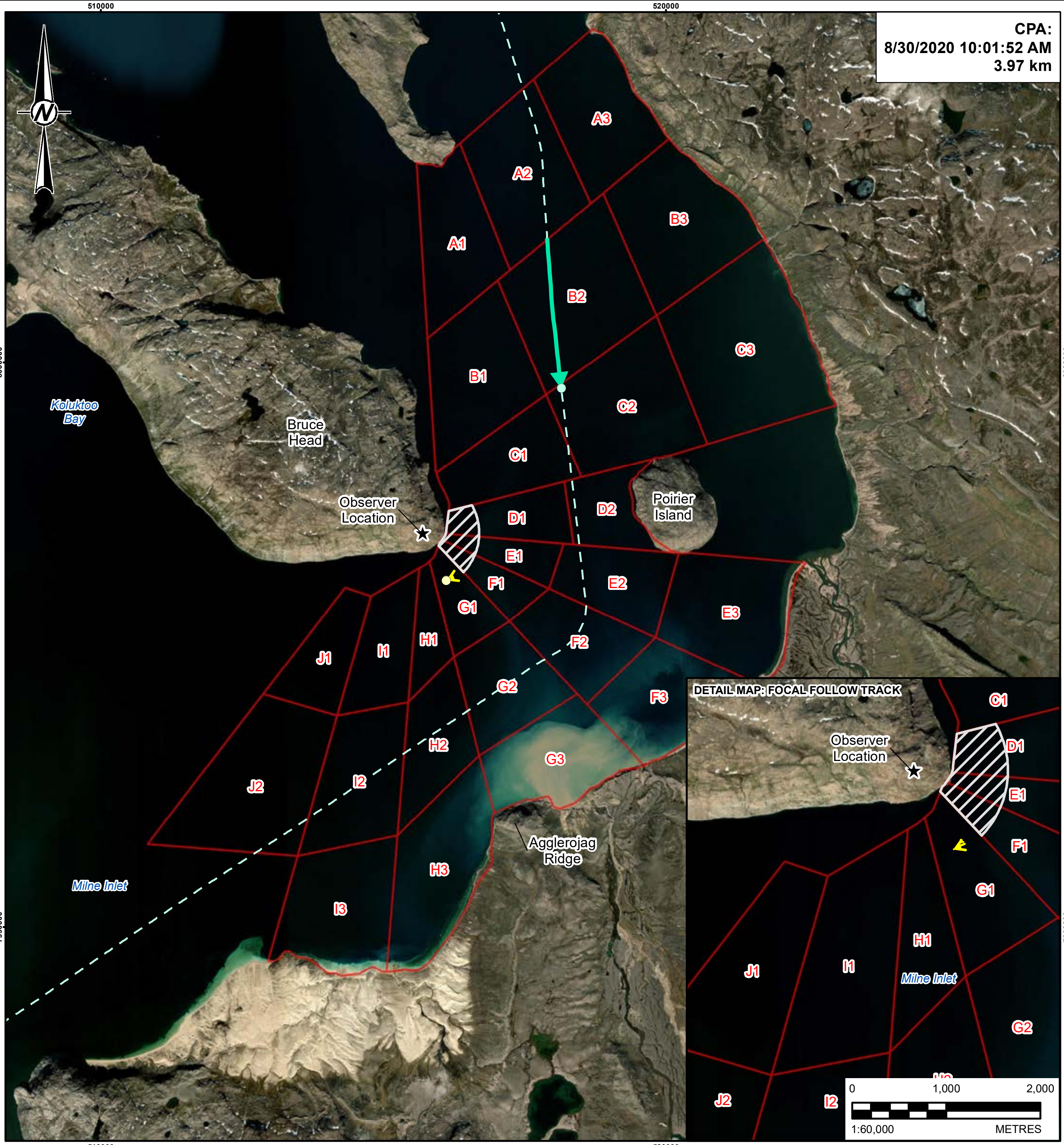
TITLE
FOCAL FOLLOW 68 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-10



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 83 (2020)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 83 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-11

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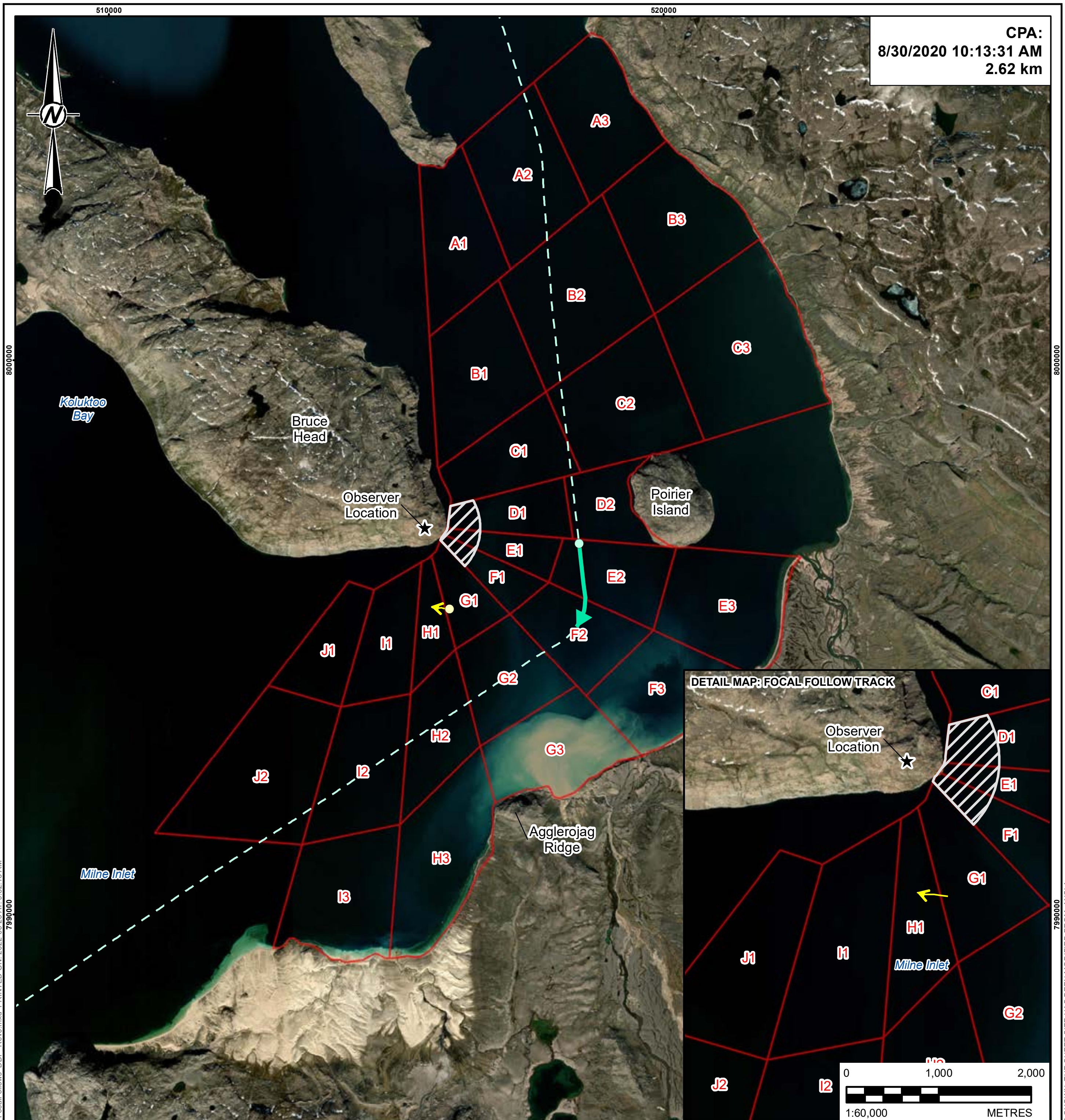

LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 84 (2020)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 84 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-12

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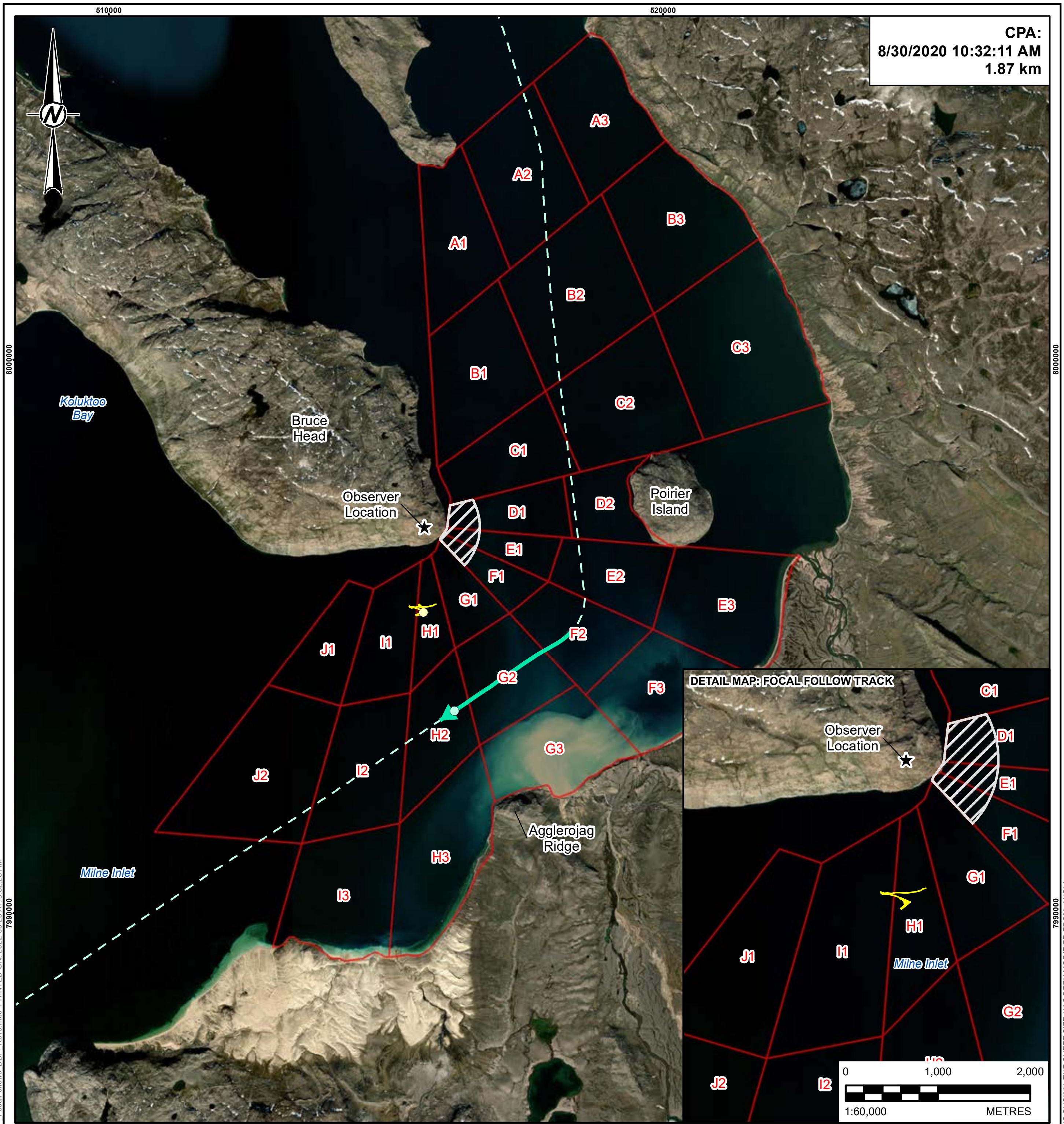


LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 85 (2020)
- ACTIVE VESSEL TRANSIT (BULK DESTINY)
- NON-ACTIVE VESSEL TRANSIT (BULK DESTINY)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

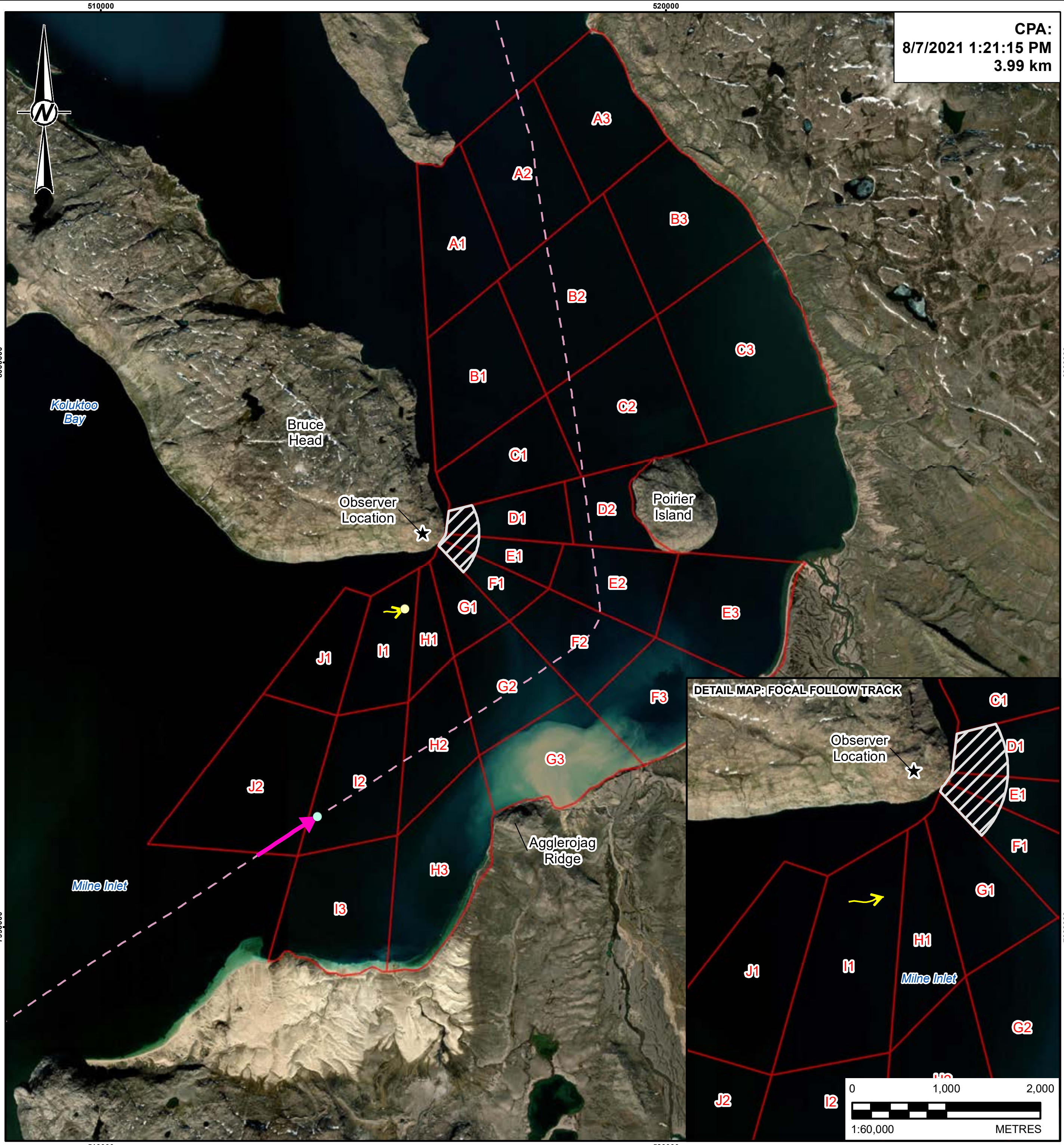
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 85 (2020) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-13



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 33 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

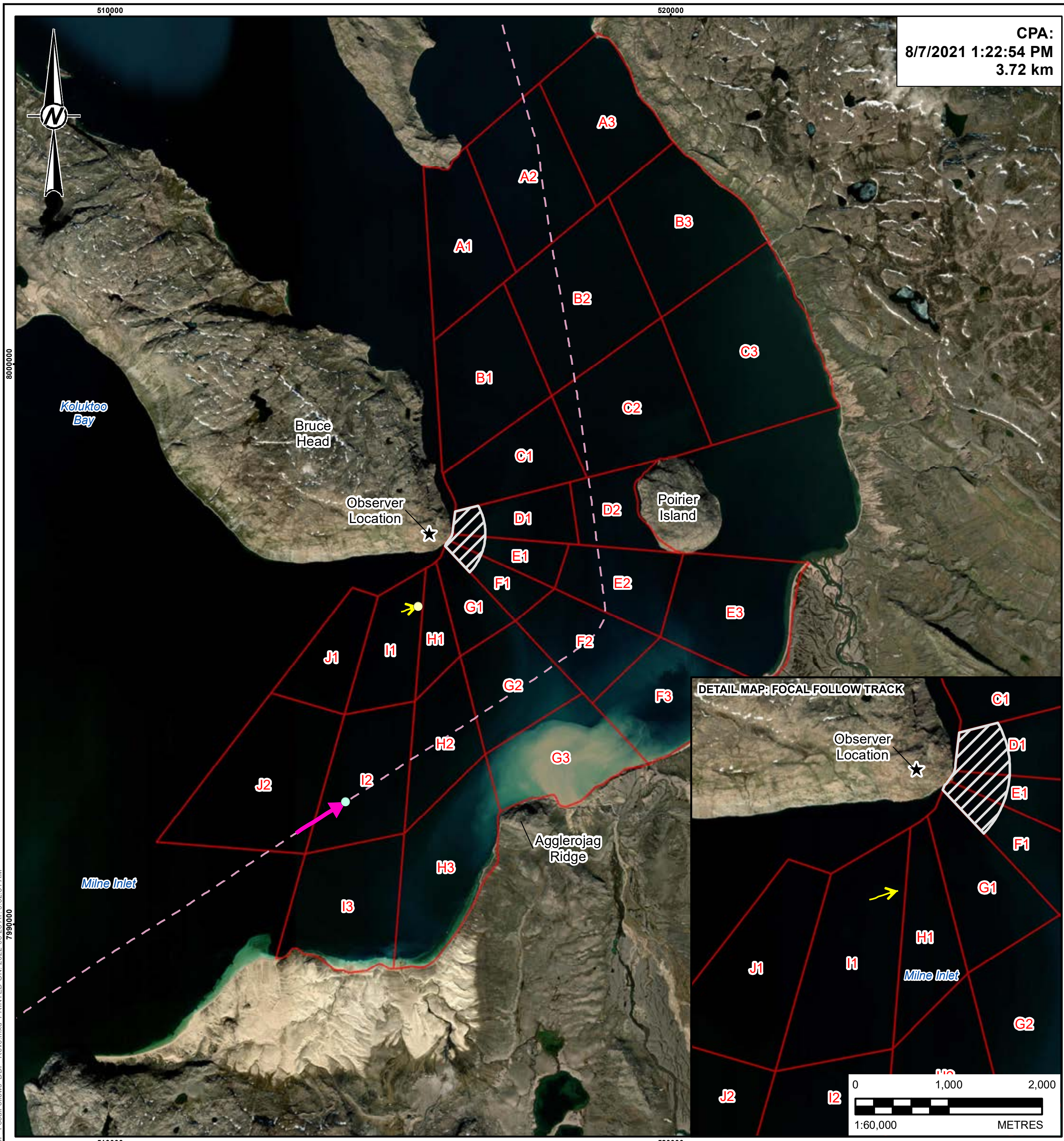
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 33 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-14



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 34 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

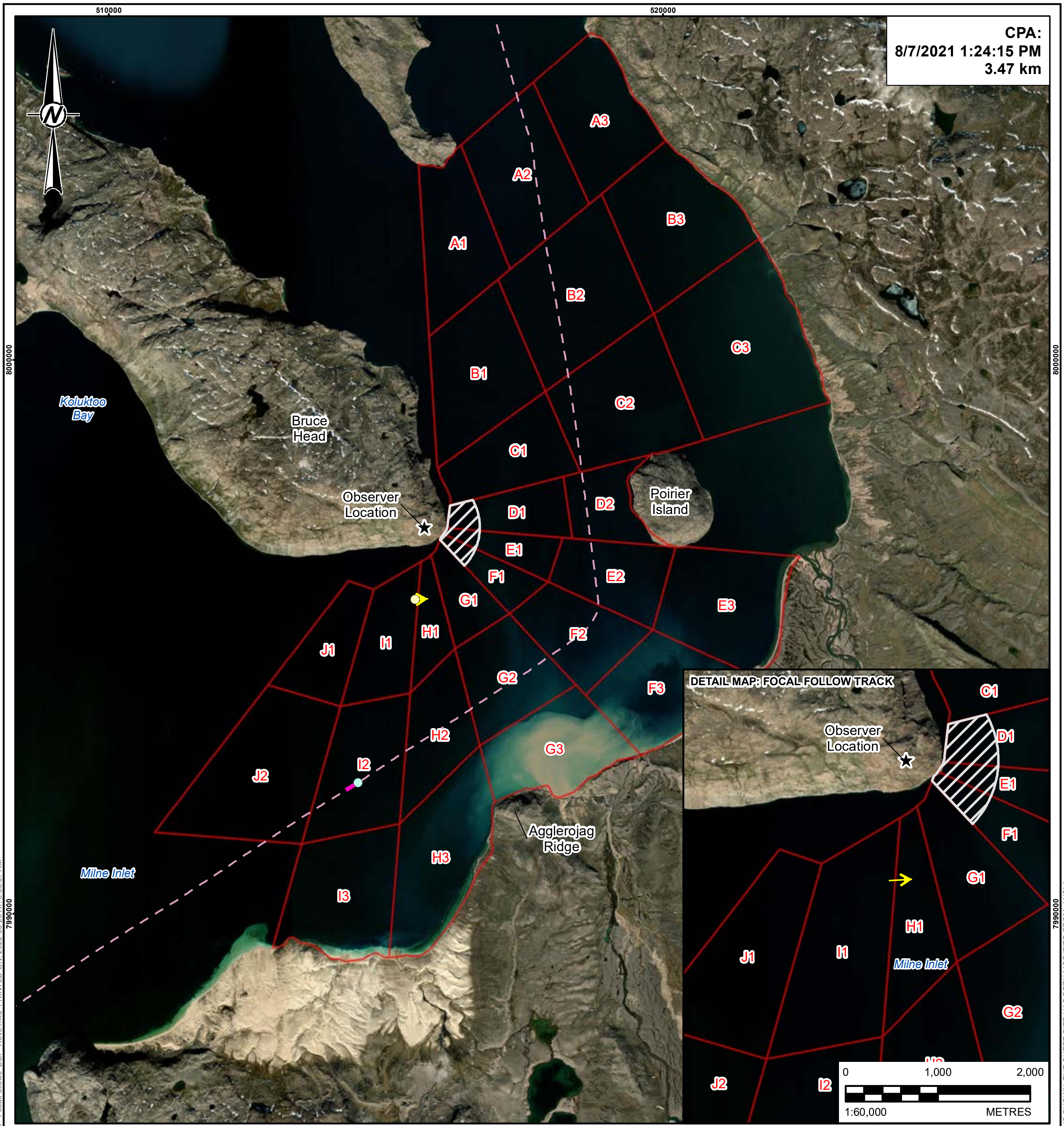
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 34 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-15



LEGEND

- • COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- ★ OBSERVER LOCATION
- FOCAL FOLLOW TRACK 35 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 35 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-16

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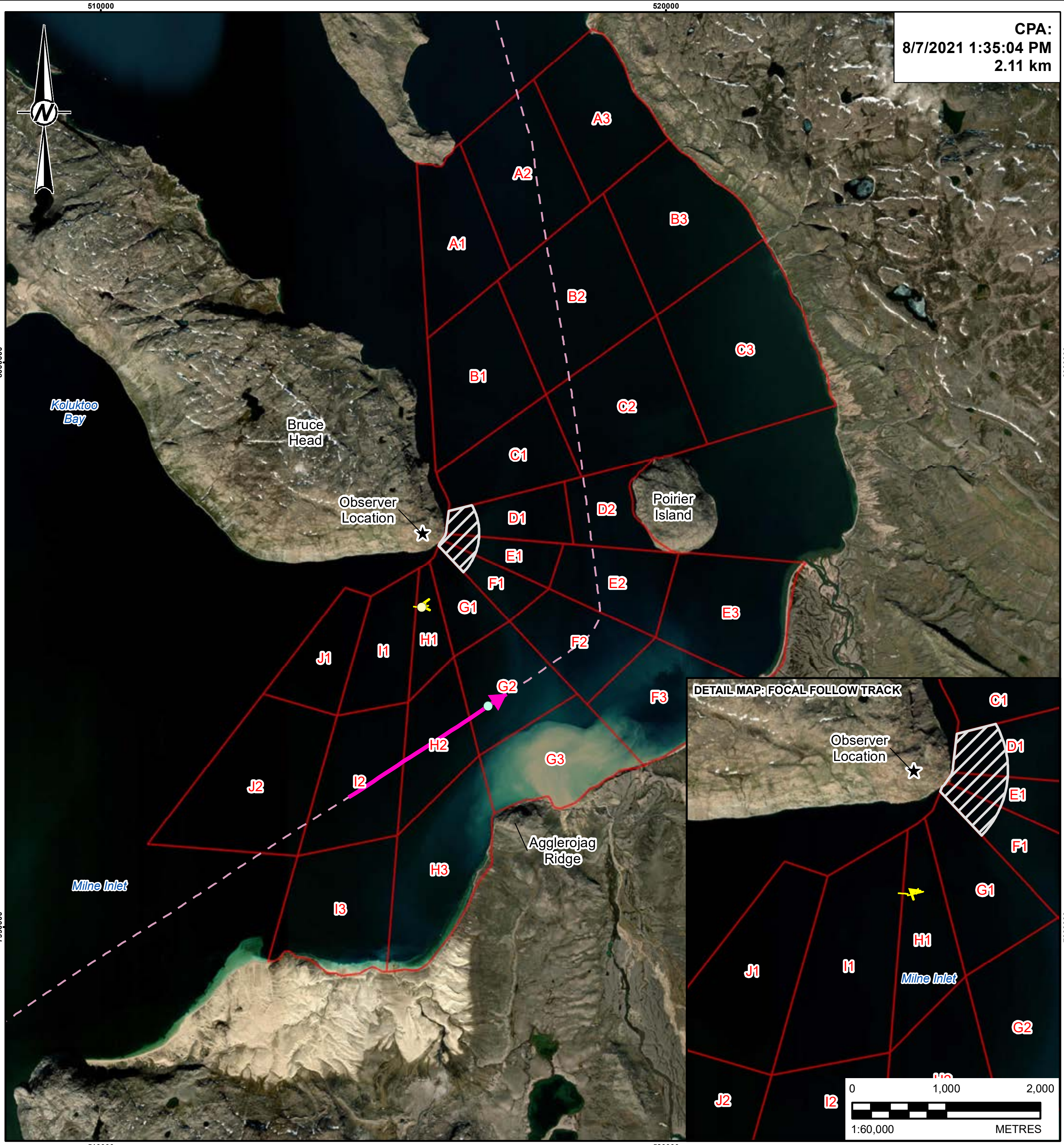


LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 36 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

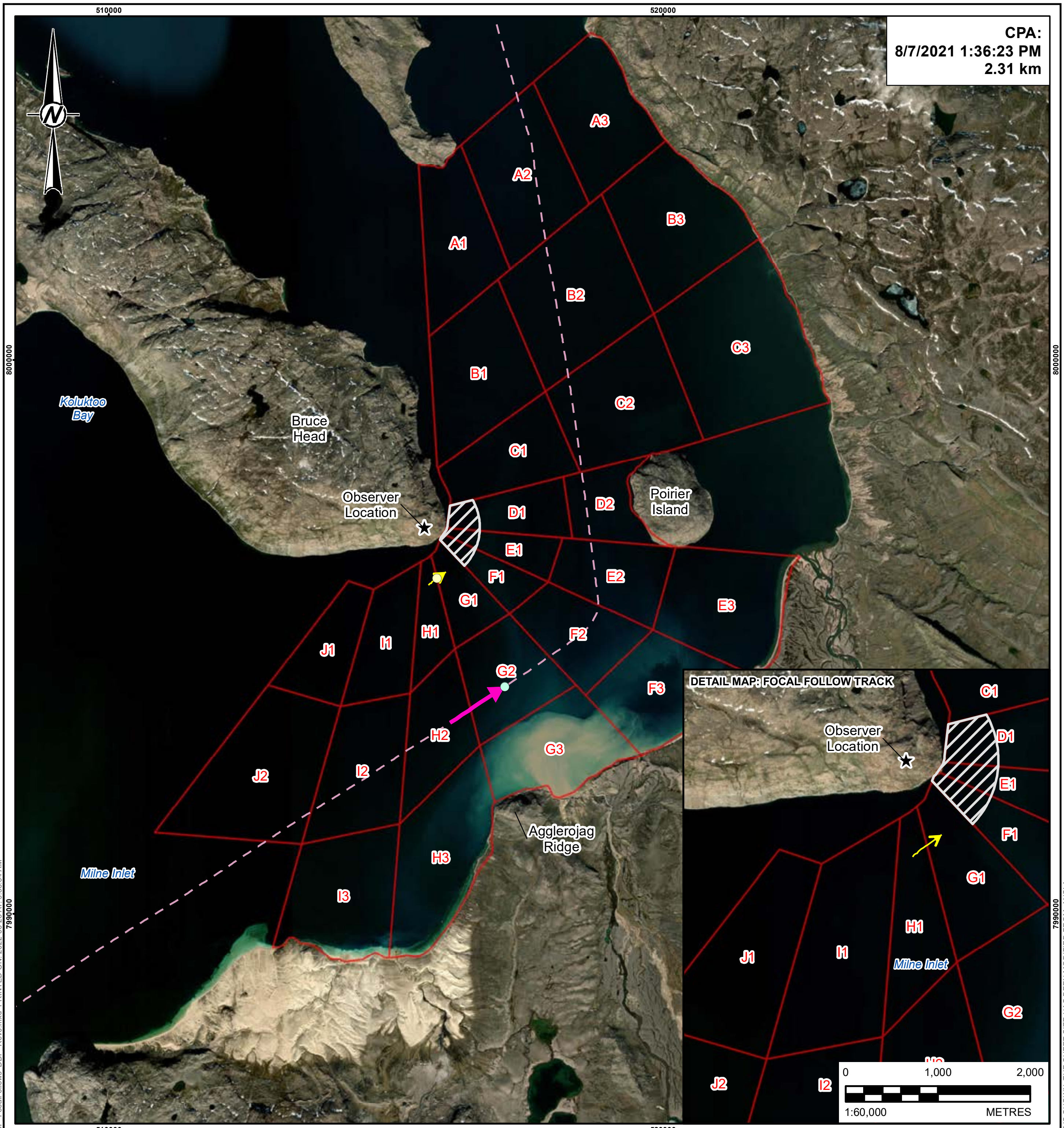
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 36 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-17



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 37 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

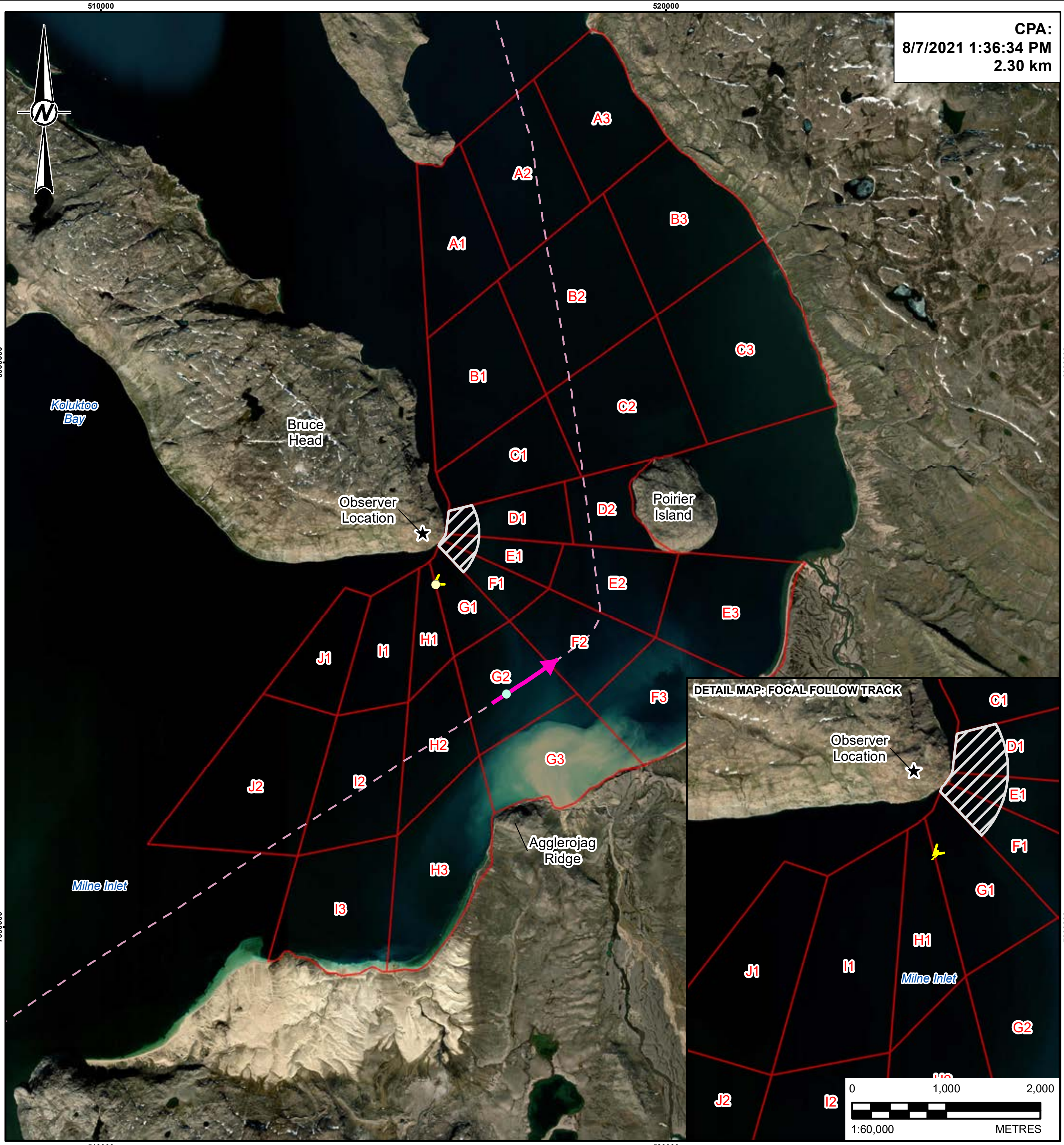
TITLE
FOCAL FOLLOW 37 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-18



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 38 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

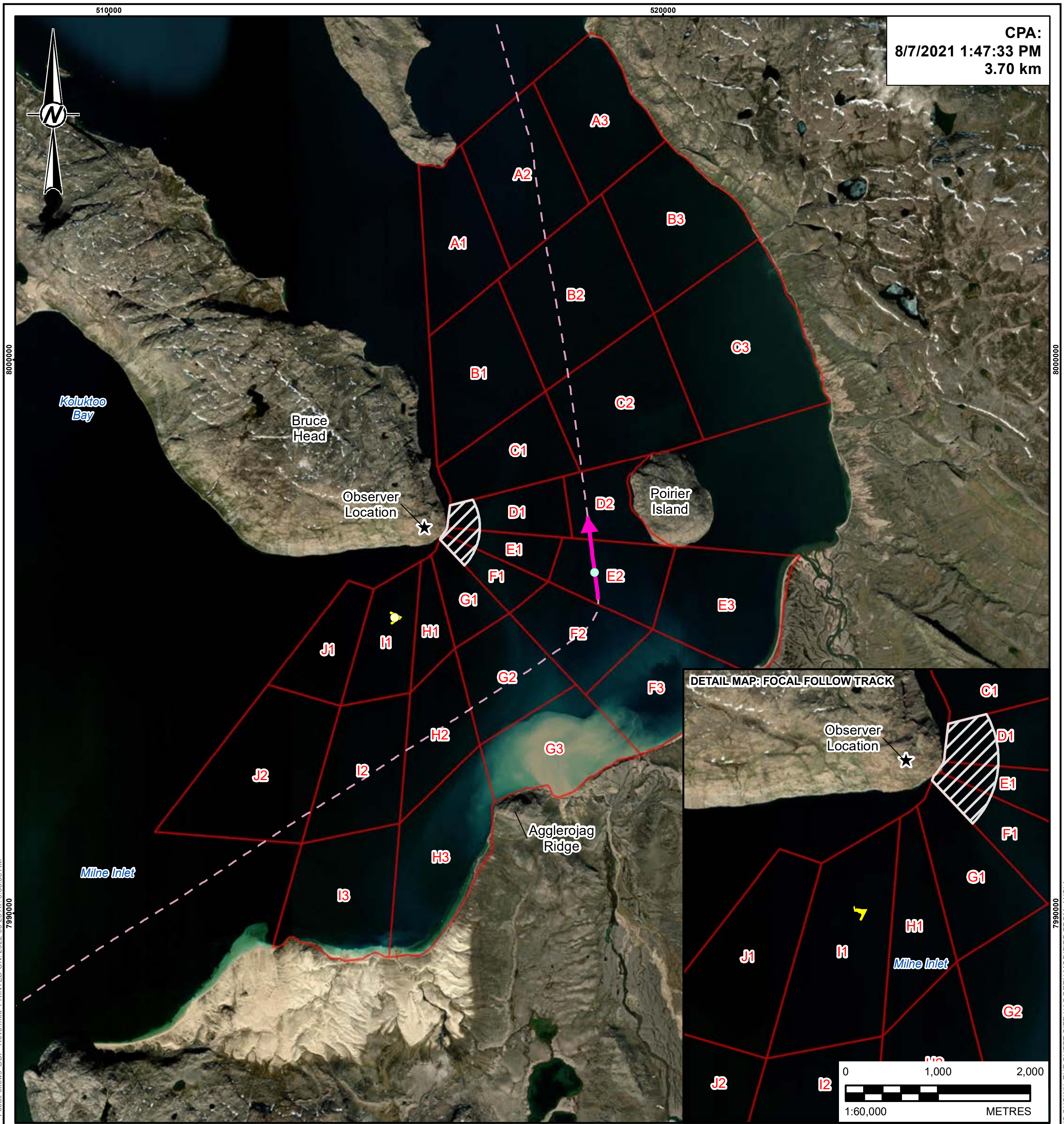
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 38 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-19



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 39 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 39 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-21

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

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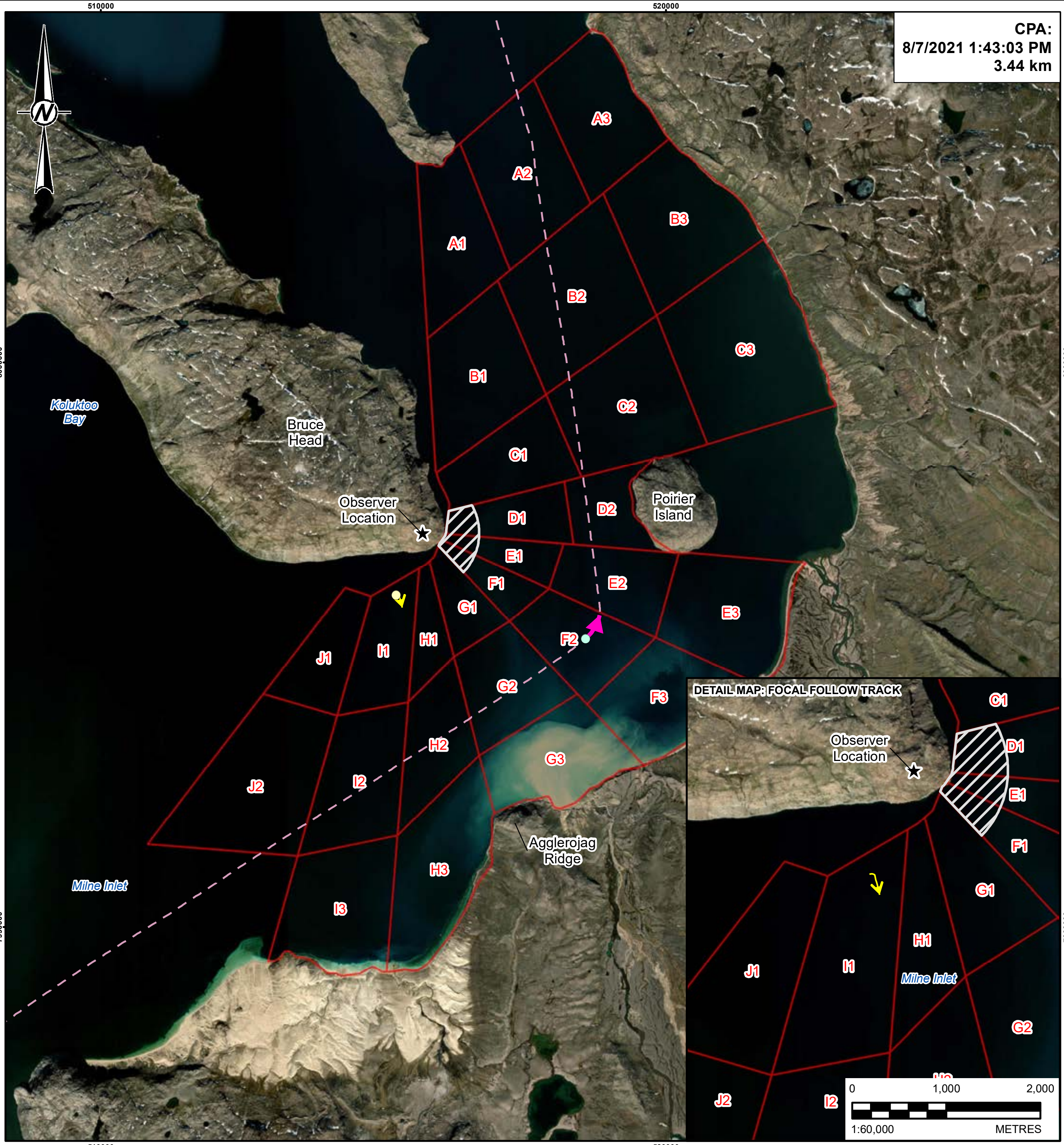


LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 40 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 40 (2021) AND ACTIVE VESSEL TRANSIT

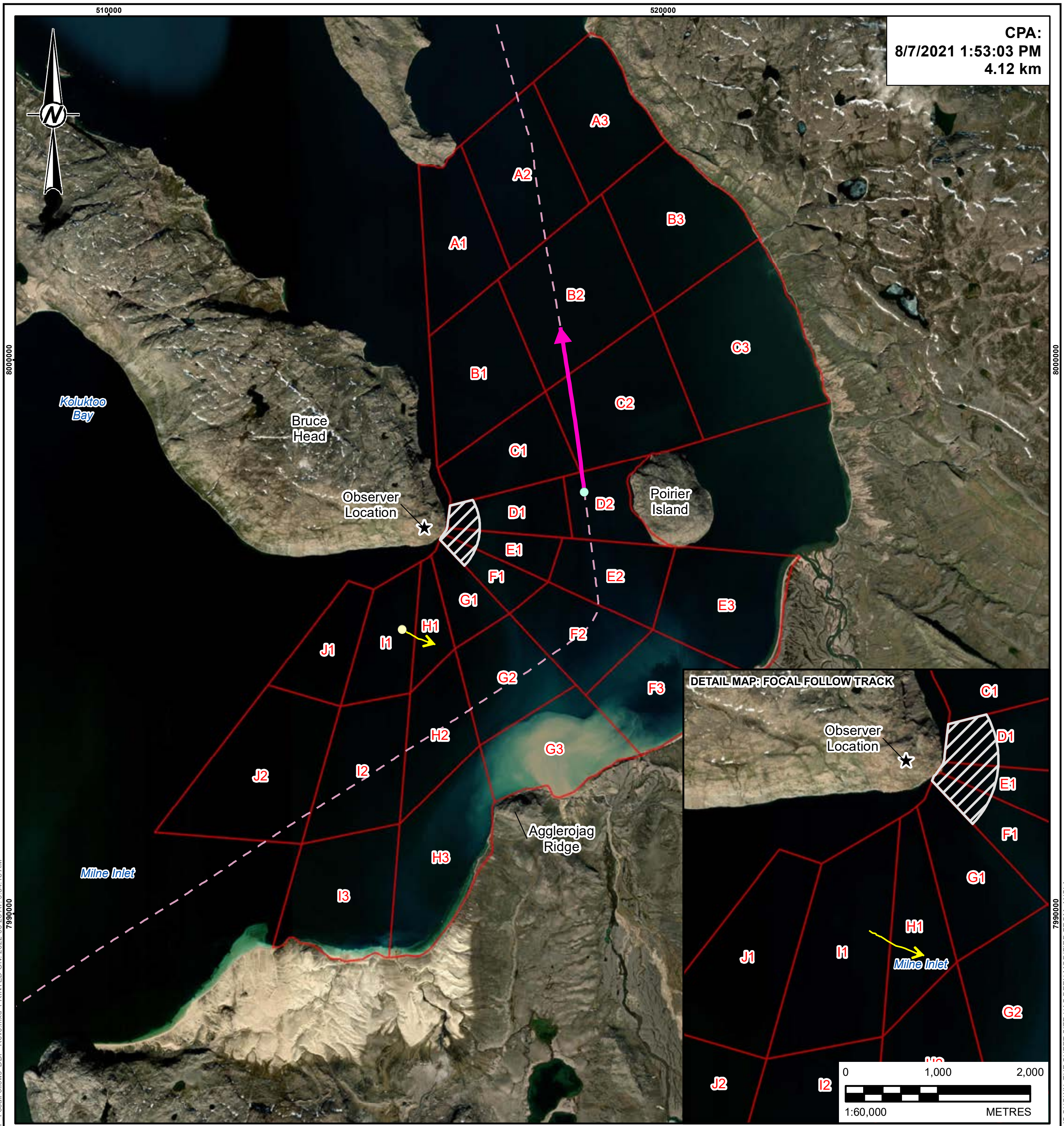
CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-20

PATH: I:\2016\1663724\Mapping\MXD\43000_2021BruceheadProgram\1663724_43000_04_AppF_FocalFollows_DDP_Rev0.mxd PRINTED ON: 2022-06-23 AT: 9:54:06 AM



LEGEND

- • COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- ★ OBSERVER LOCATION
- FOCAL FOLLOW TRACK 41 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 41 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

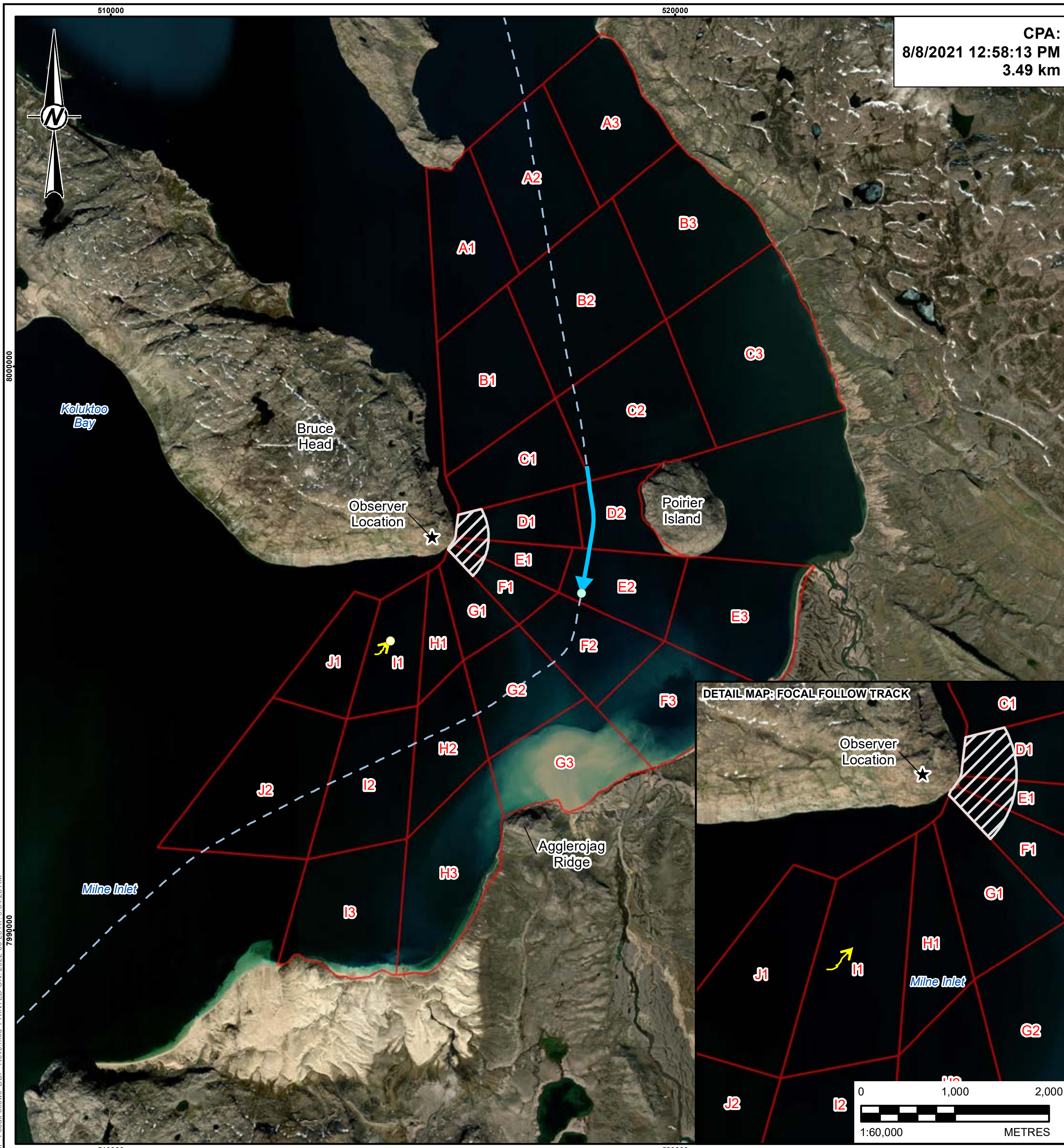
YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-22

PATH: I:\2016\1663724\Mapping\MXD\43000_2021BruceheadProgram\1663724_43000_04_AppF_FocalFollows_DDP_Rev0.mxd PRINTED ON: 2022-06-23 AT: 9:54:18 AM

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

25mm



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 47 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN RUBY)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN RUBY)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 47 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-23

PATH: I:\2016\1663724\Mapping\MXD\43000_2021BruceheadProgram\1663724_43000_04_AppF_FocalFollows_DDP_Rev0.mxd PRINTED ON: 2022-06-23 AT: 9:54:28 AM

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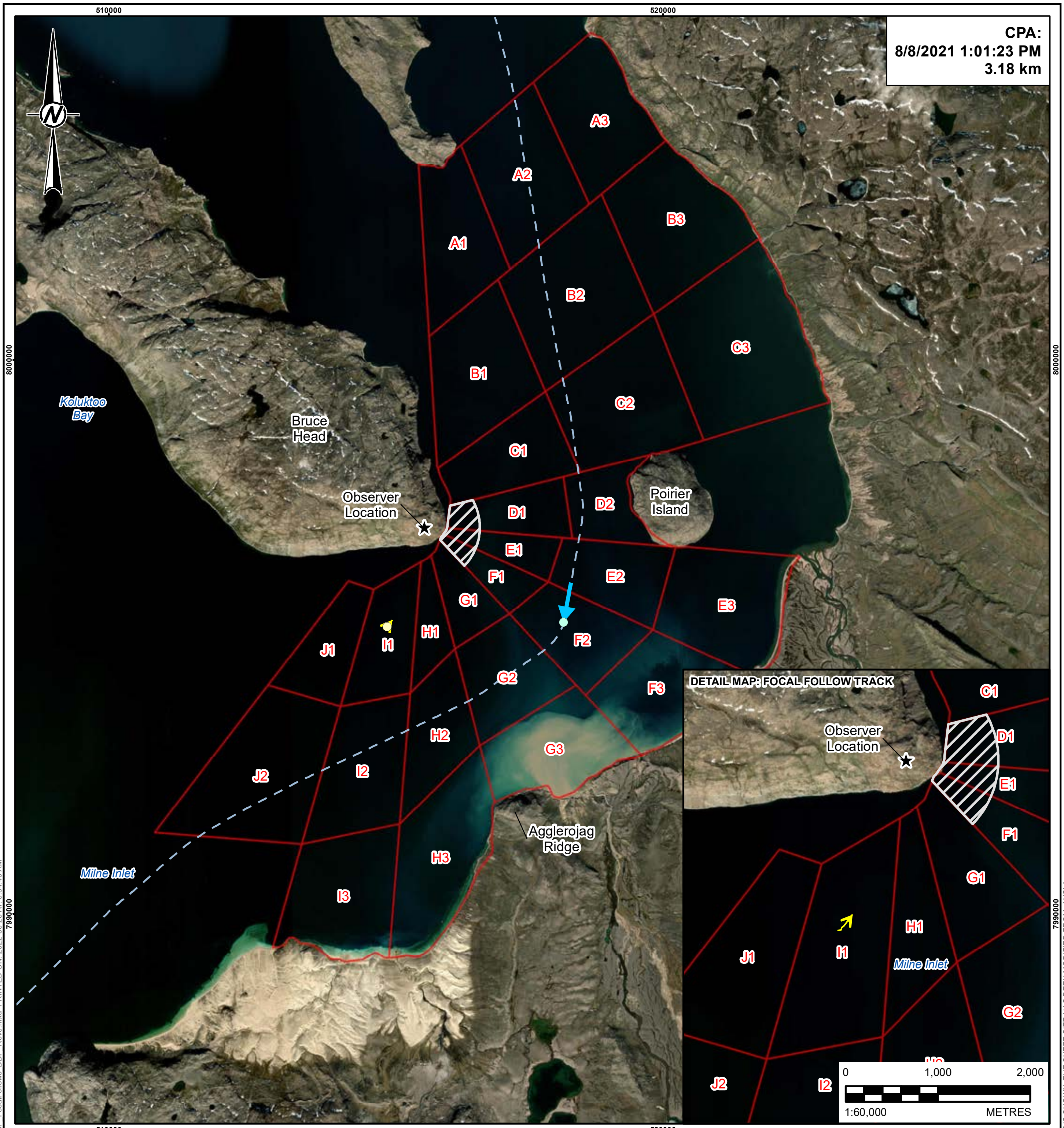
25mm 0



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 48 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN RUBY)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN RUBY)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 48 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-24

PATH: I:\2016\1663724\Mapping\MXD\43000_2021BruceheadProgram\1663724_43000_04_AppF_FocalFollows_DDP_Rev0.mxd PRINTED ON: 2022-06-23 AT: 9:54:40 AM

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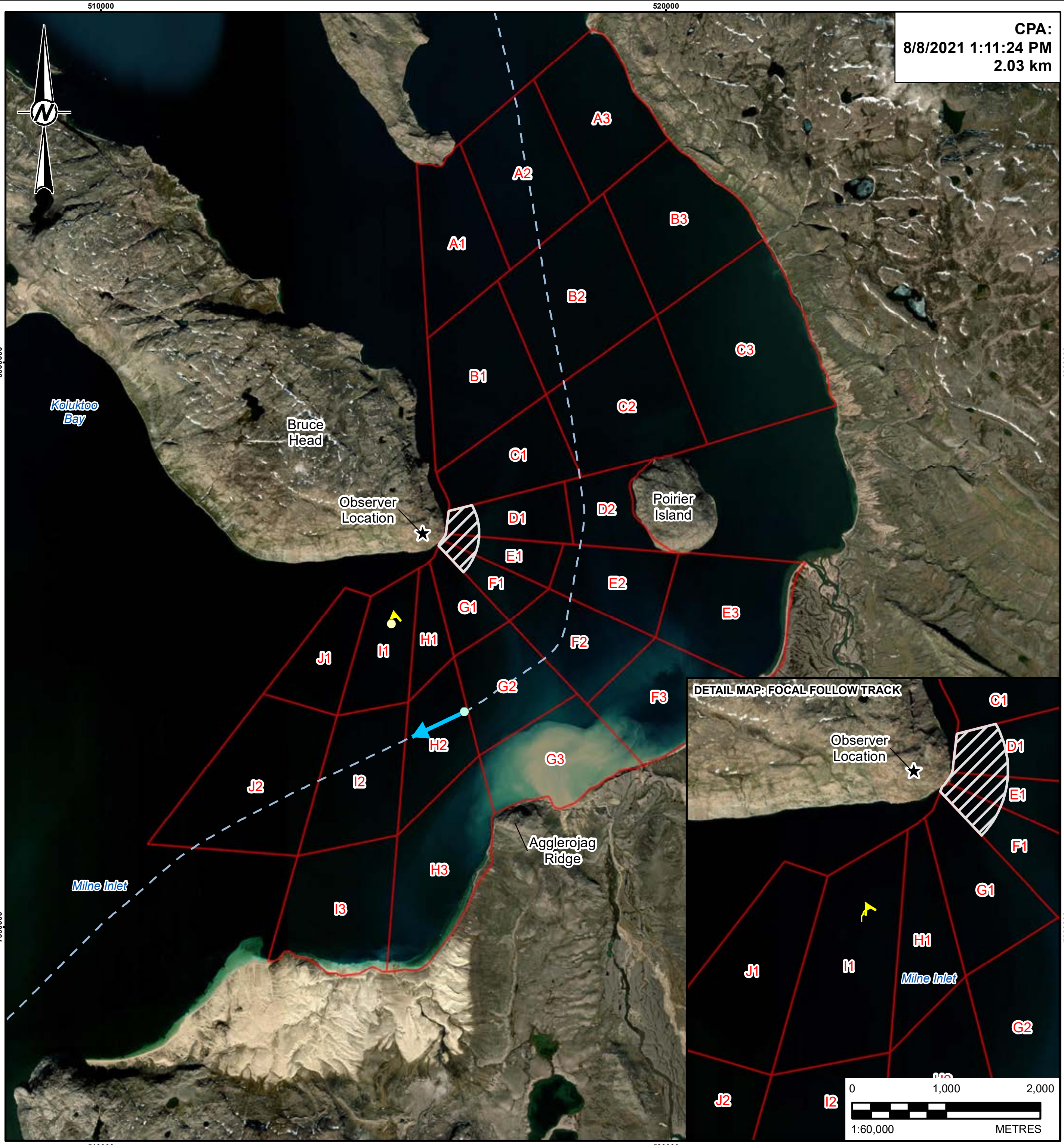
25mm
0



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 49 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN RUBY)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN RUBY)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 49 (2021) AND ACTIVE VESSEL TRANSIT

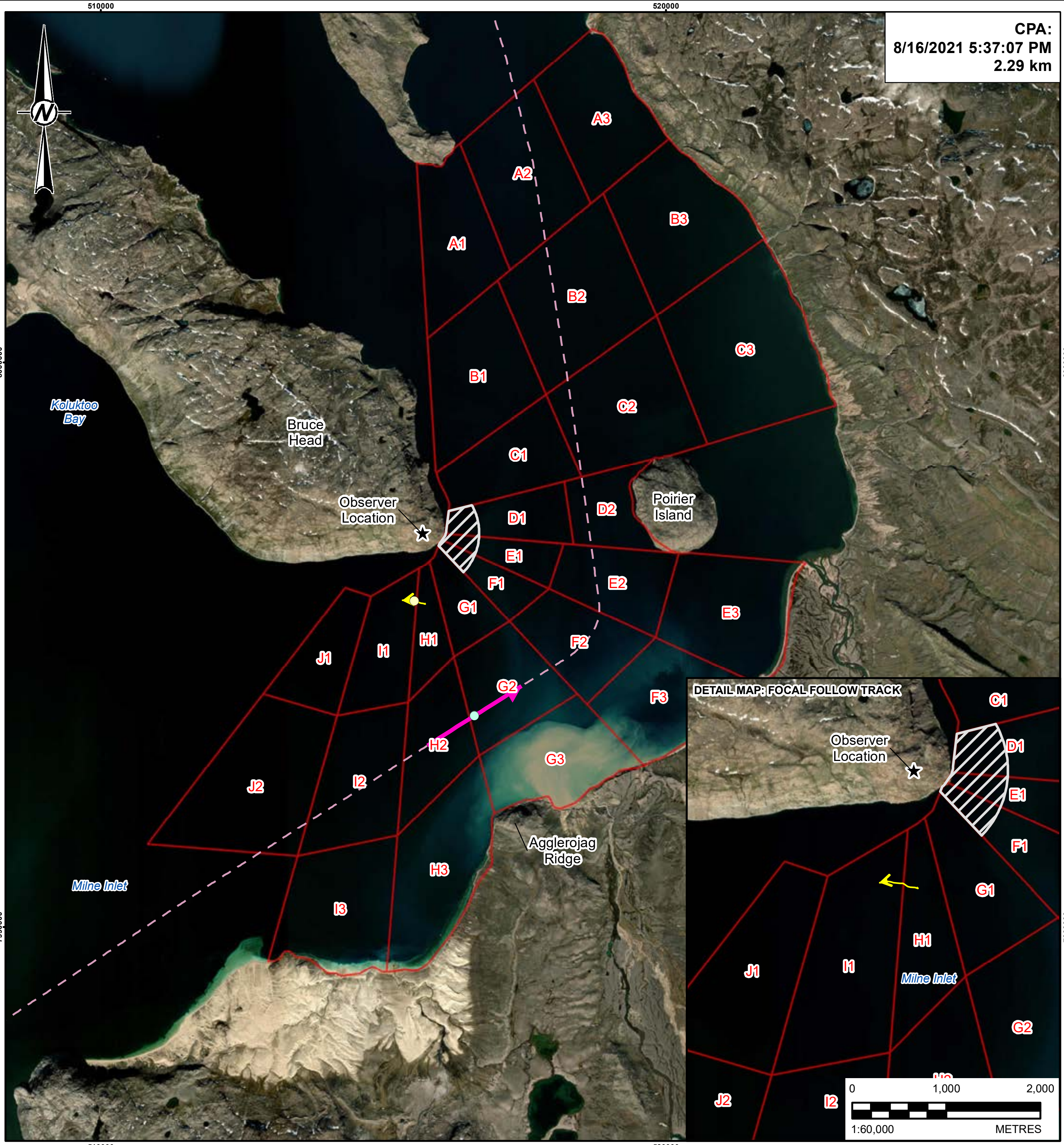
CONSULTANT

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-25

PATH: I:\2016\1663724\Mapping\MXD\43000_2021BruceheadProgram\1663724_43000_04_AppF_FocalFollows_DDP_Rev0.mxd PRINTED ON: 2022-06-23 AT: 9:54:50 AM

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



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 85 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 85 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-26

PATH: I:\2016\1663724\Mapping\MXD\43000_2021BruceheadProgram\1663724_43000_04_AppF_FocalFollows_DDP_Rev0.mxd PRINTED ON: 2022-06-23 AT: 9:55:01 AM

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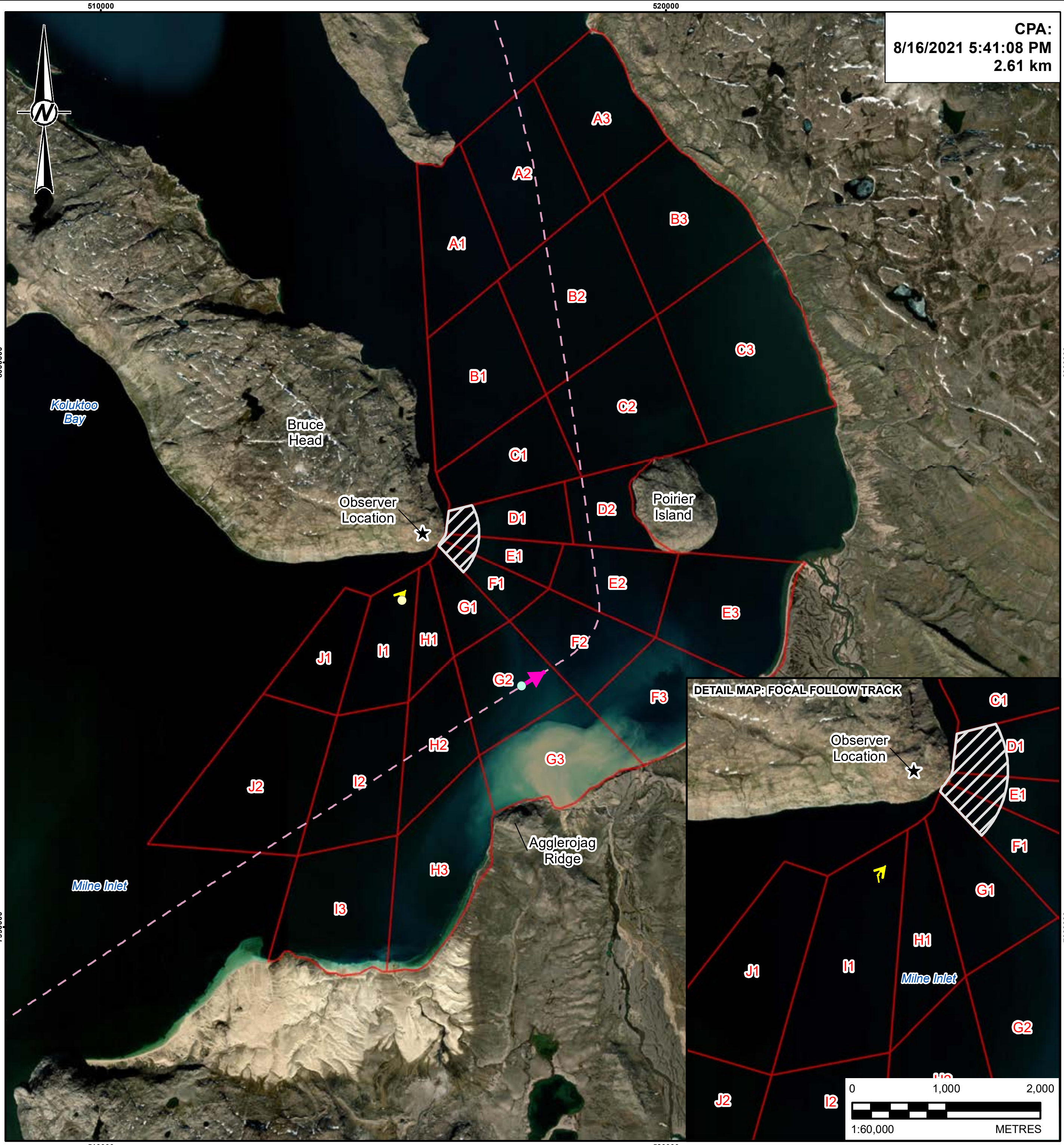
25mm 0



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 86 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

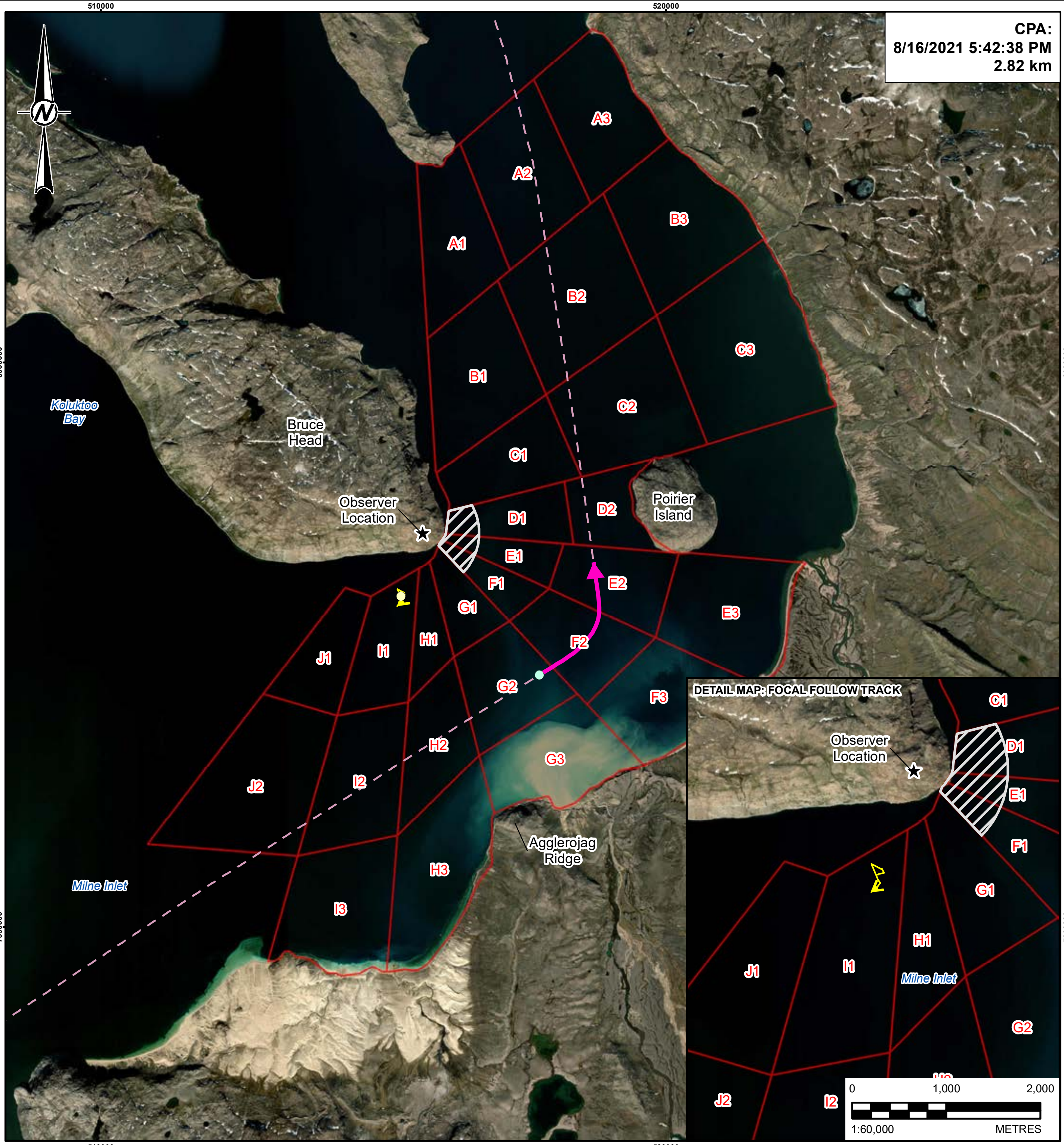
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 86 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-27



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 87 (2021)
- ACTIVE VESSEL TRANSIT (BOTNICA)
- NON-ACTIVE VESSEL TRANSIT (BOTNICA)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 87 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-28

PATH: I:\2016\1663724\Mapping\MXD\43000_2021BruceheadProgram\1663724_43000_04_AppF_FocalFollows_DDP_Rev0.mxd PRINTED ON: 2022-06-23 AT: 9:55:23 AM

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25mm
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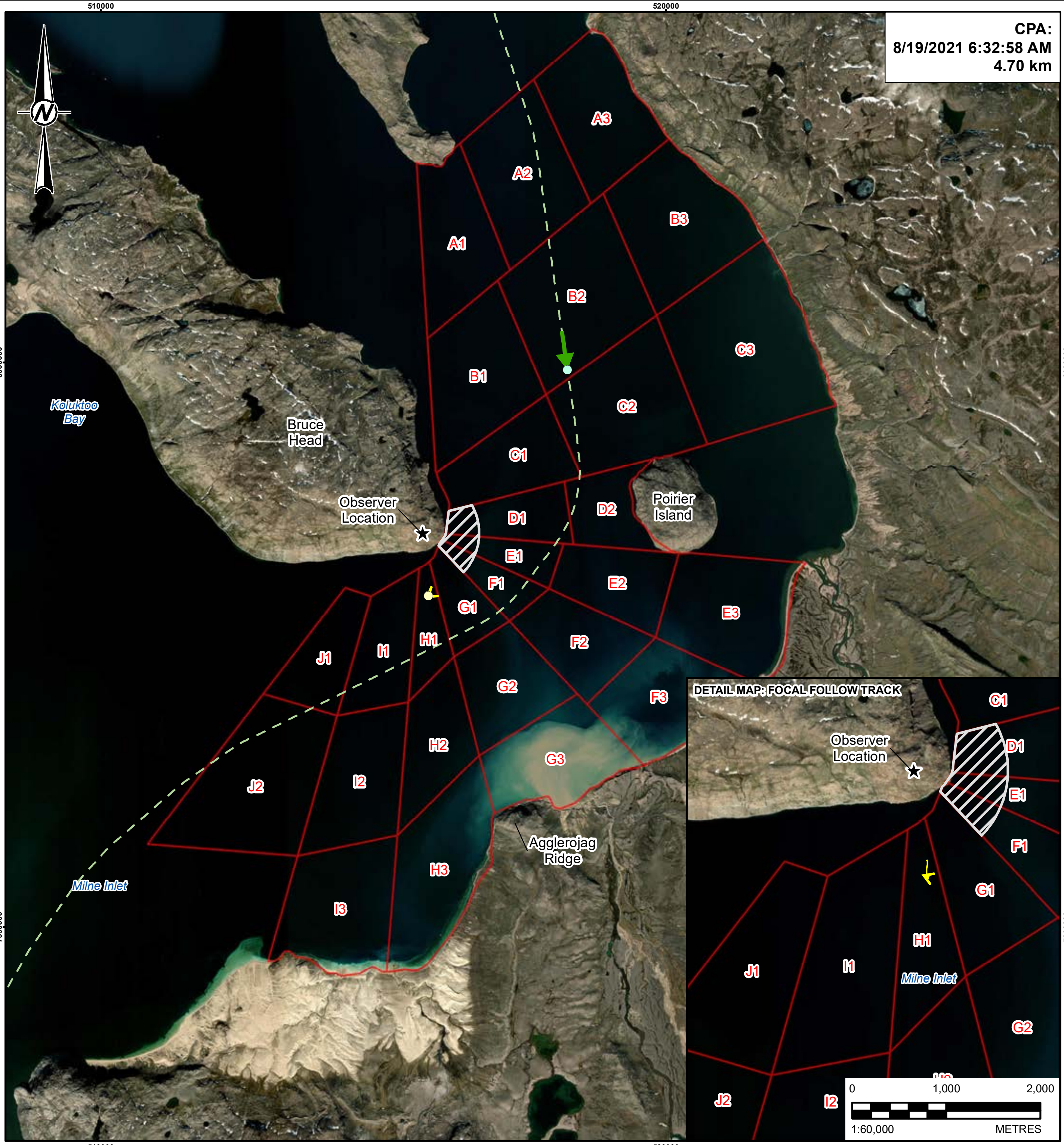


LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 114 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

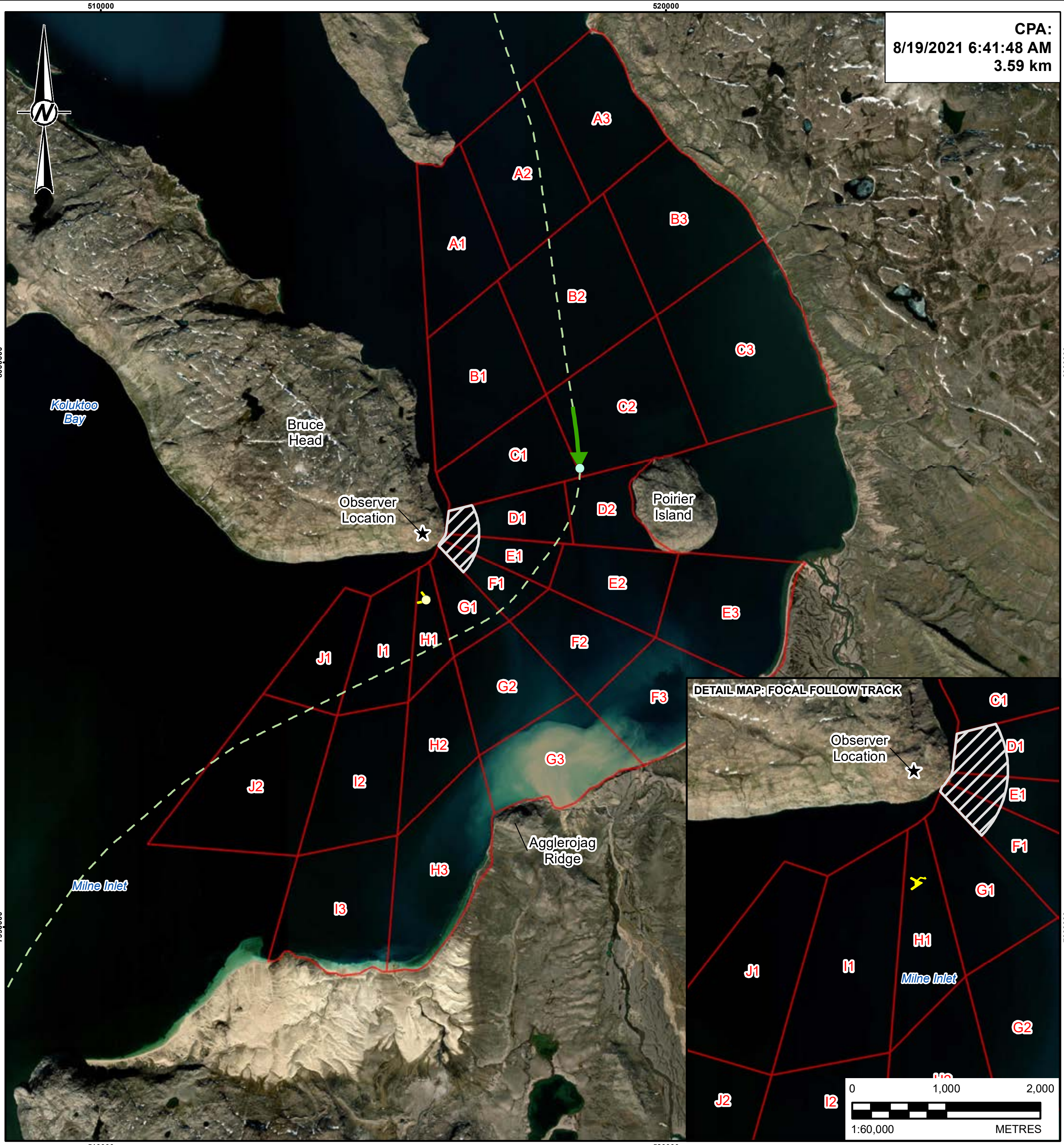
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 114 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-29



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 115 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

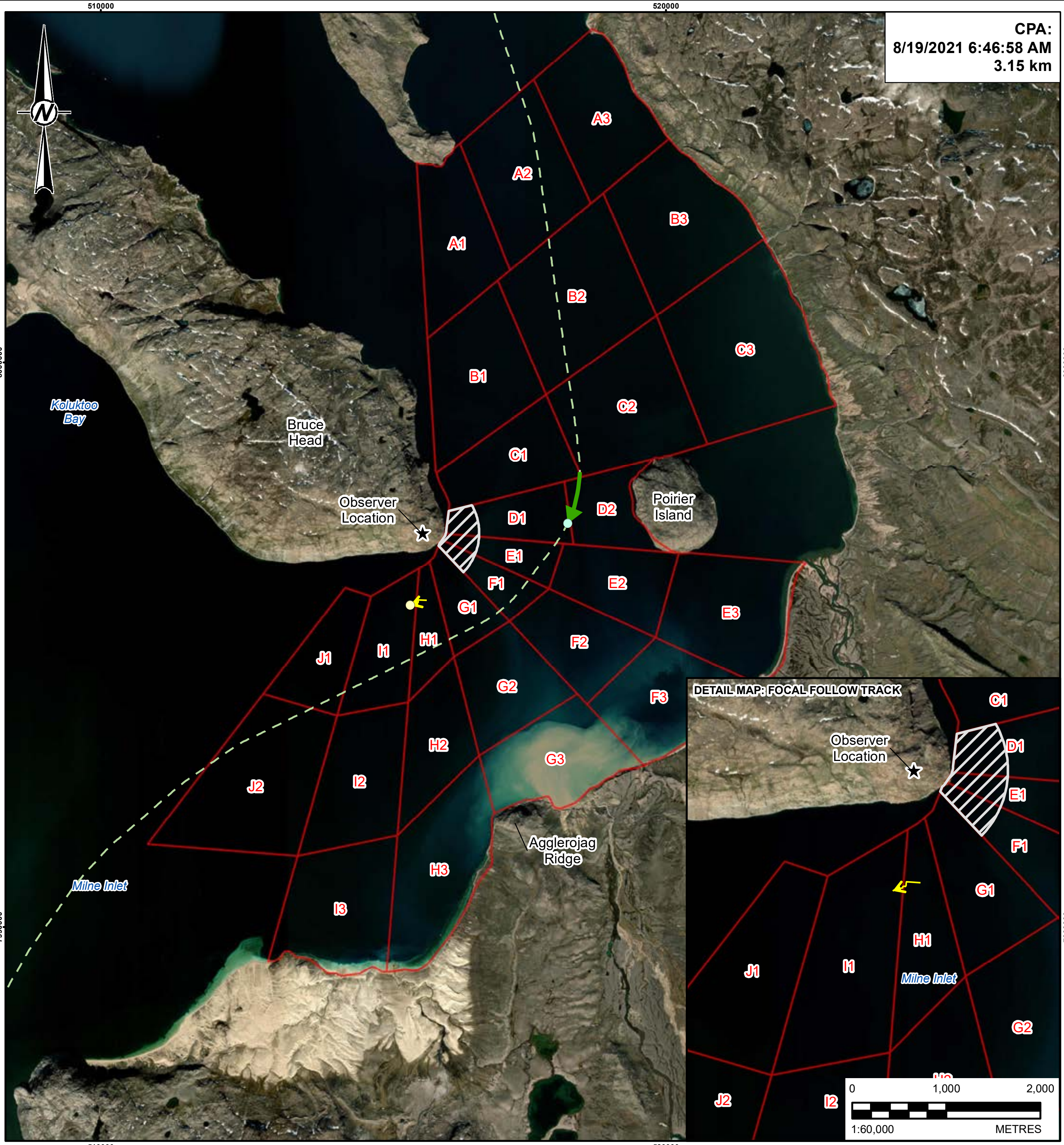
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 115 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-30



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 116 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

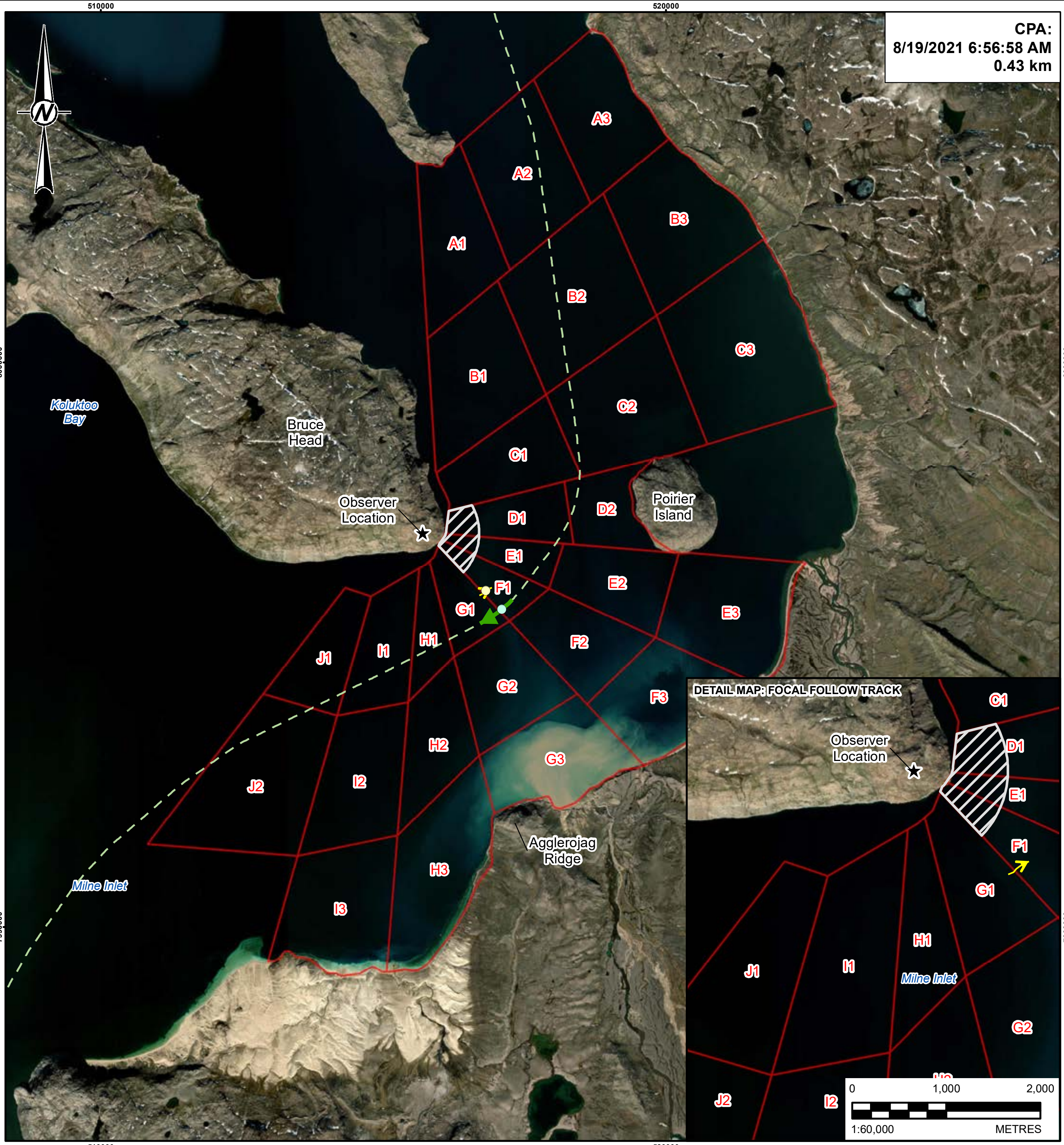
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 116 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-31



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 117 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

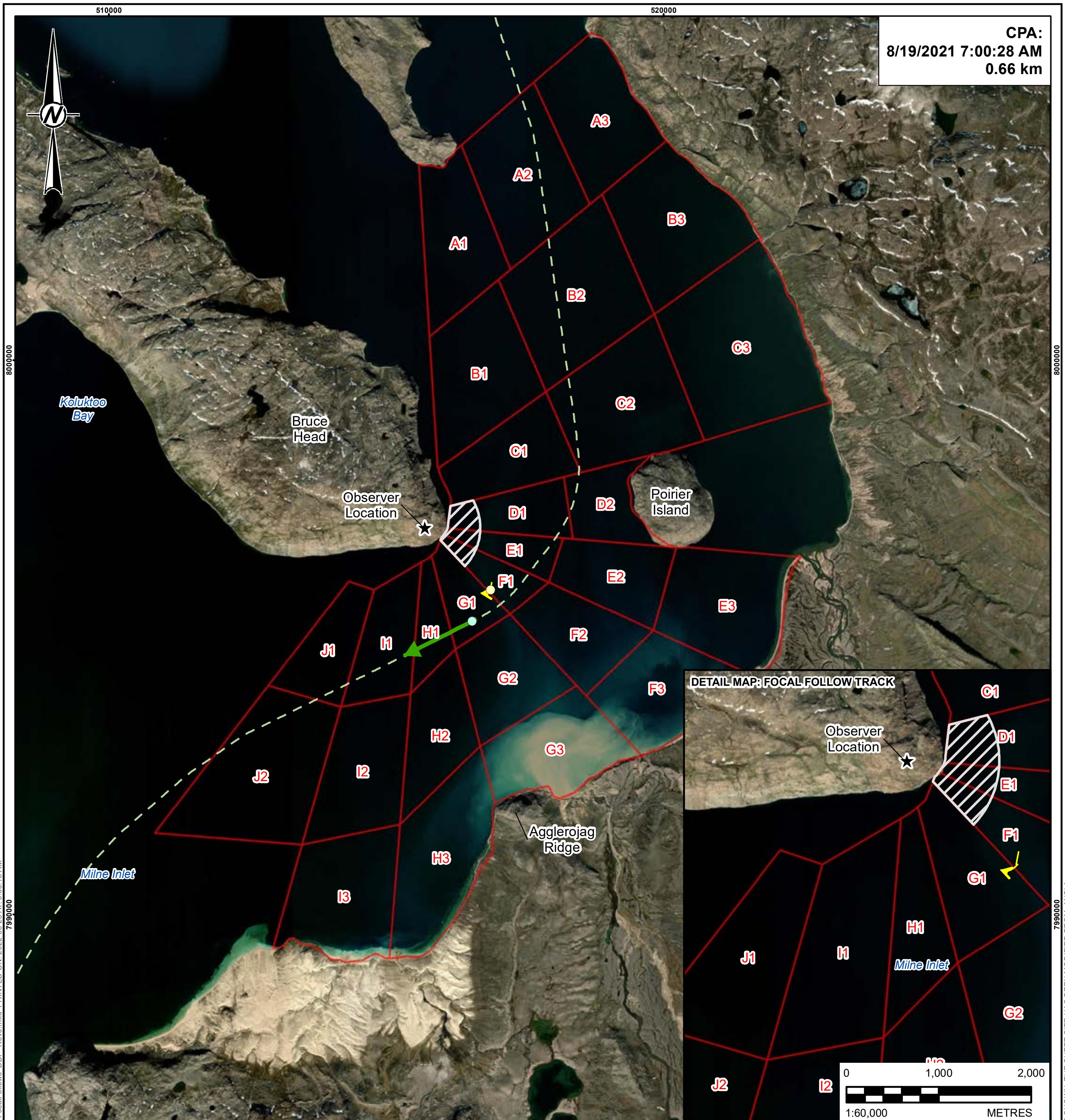
PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 117 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-32



LEGEND

- • COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- ★ OBSERVER LOCATION
- FOCAL FOLLOW TRACK 118 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 118 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

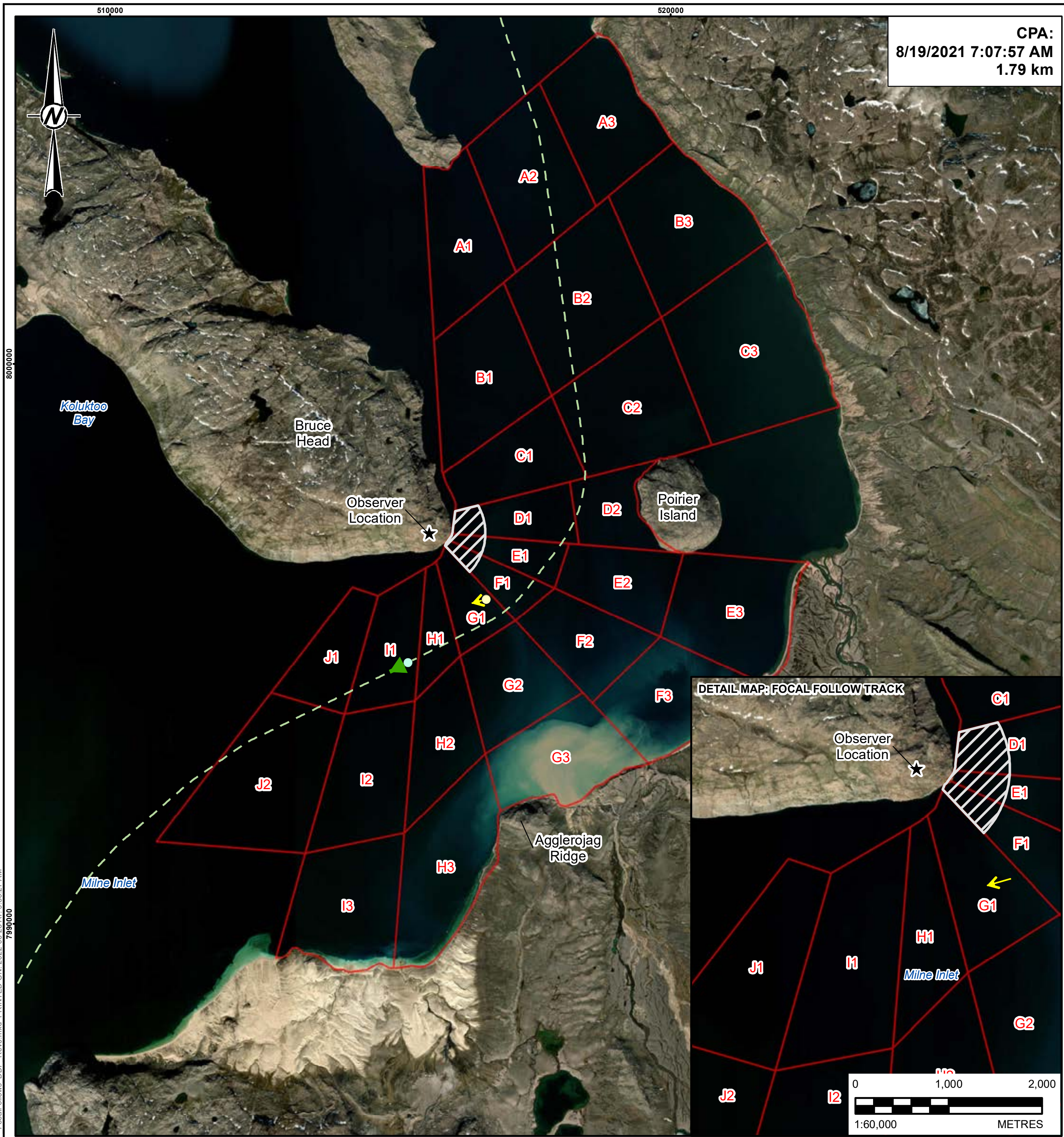
YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-33

PATH: I:\2016\1663724\Mapping\MXD\43000_2021BruceheadProgram\1663724_43000_04_AppF_FocalFollows_DDP_Rev0.mxd PRINTED ON: 2022-06-23 AT: 9:56:16 AM

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

25mm



LEGEND

- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
- FOCAL FOLLOW TRACK 119 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

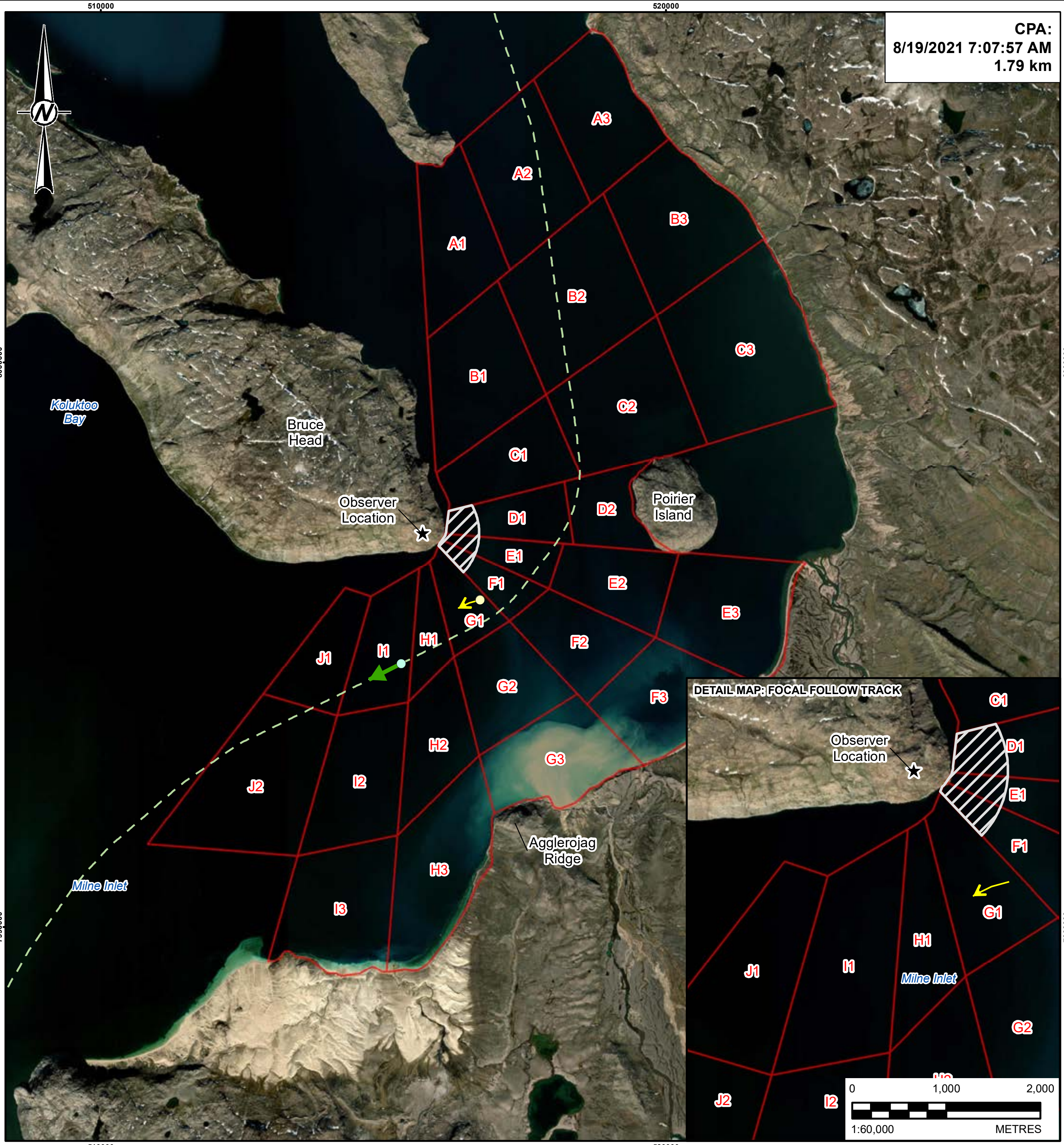
TITLE
FOCAL FOLLOW 119 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-34



LEGEND

- • COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- ★ OBSERVER LOCATION
- FOCAL FOLLOW TRACK 120 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
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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 BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 120 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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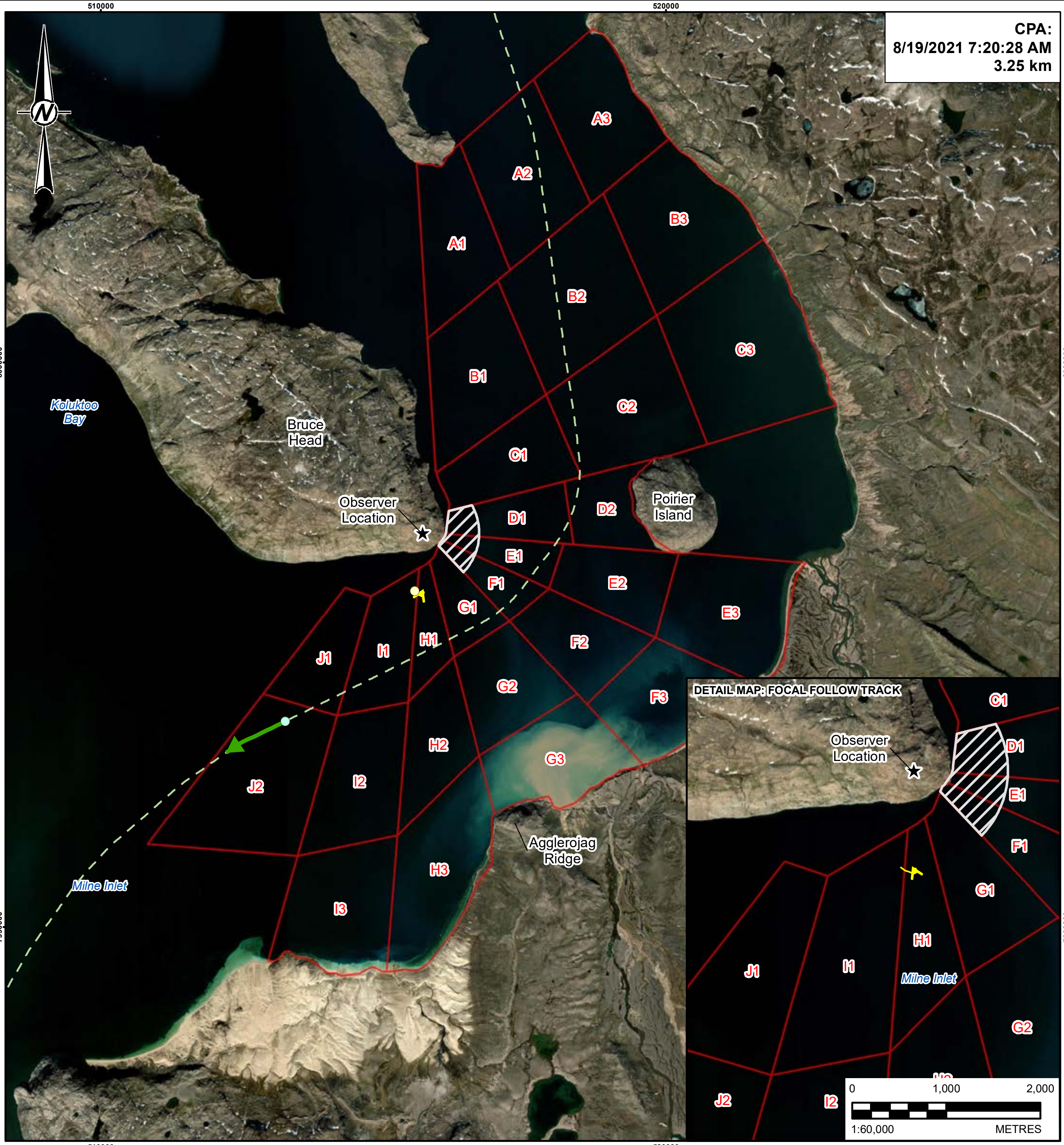

LEGEND

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- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
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- FOCAL FOLLOW TRACK 121 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 121 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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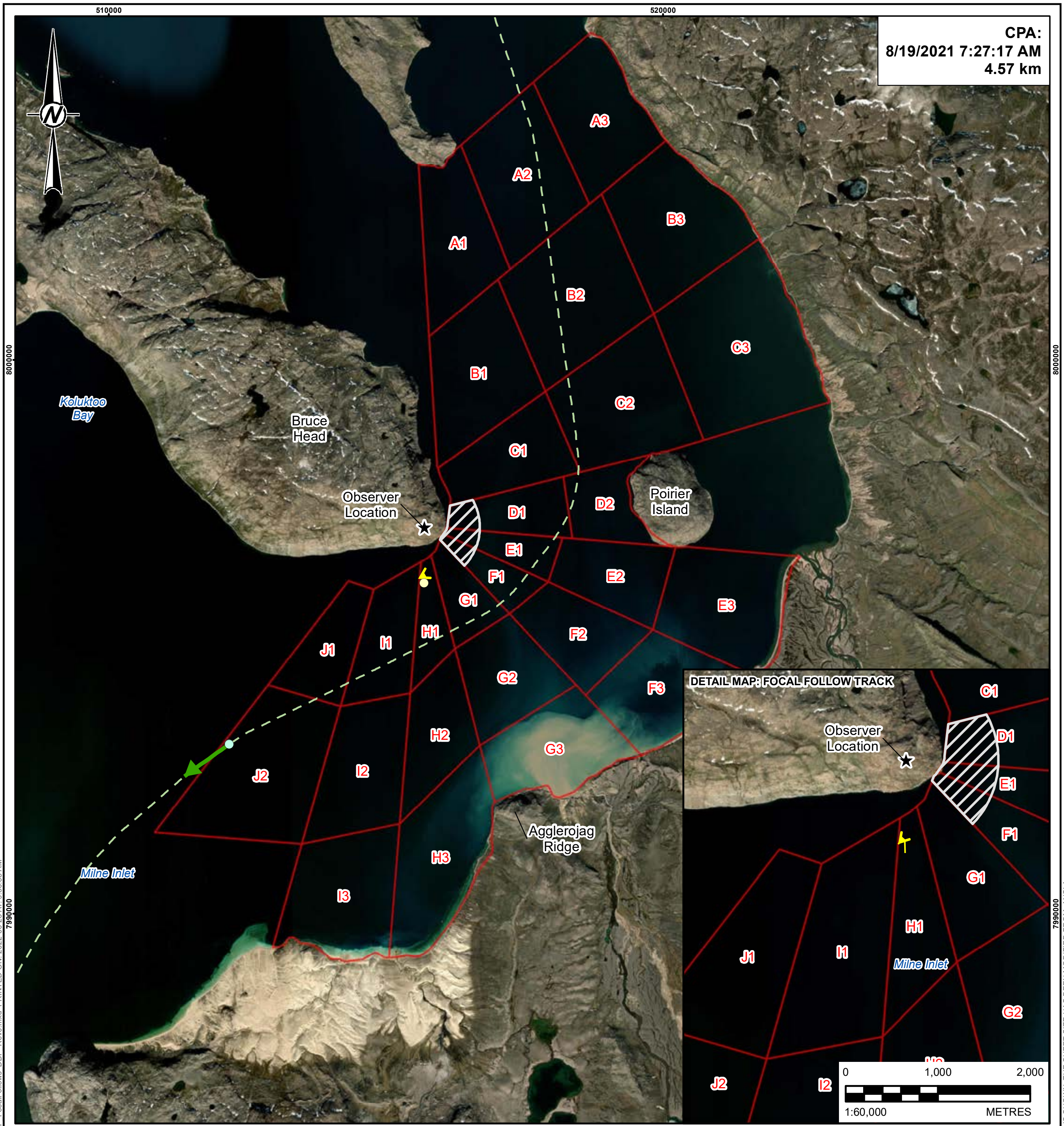

LEGEND

- COMMUNITY
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- CPA (FOCAL FOLLOW)
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- ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN FROST)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 122 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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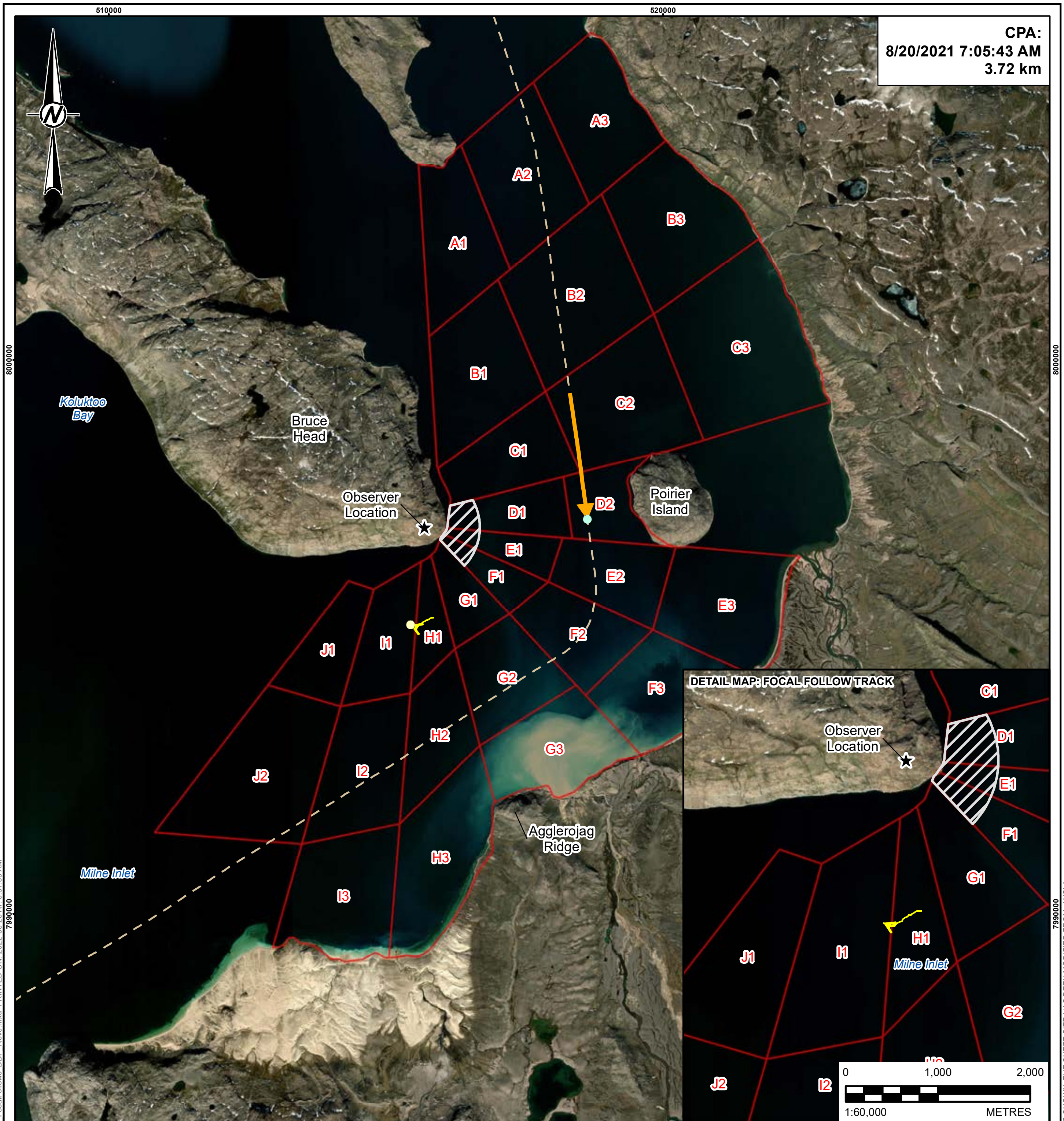

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- NON-ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 139 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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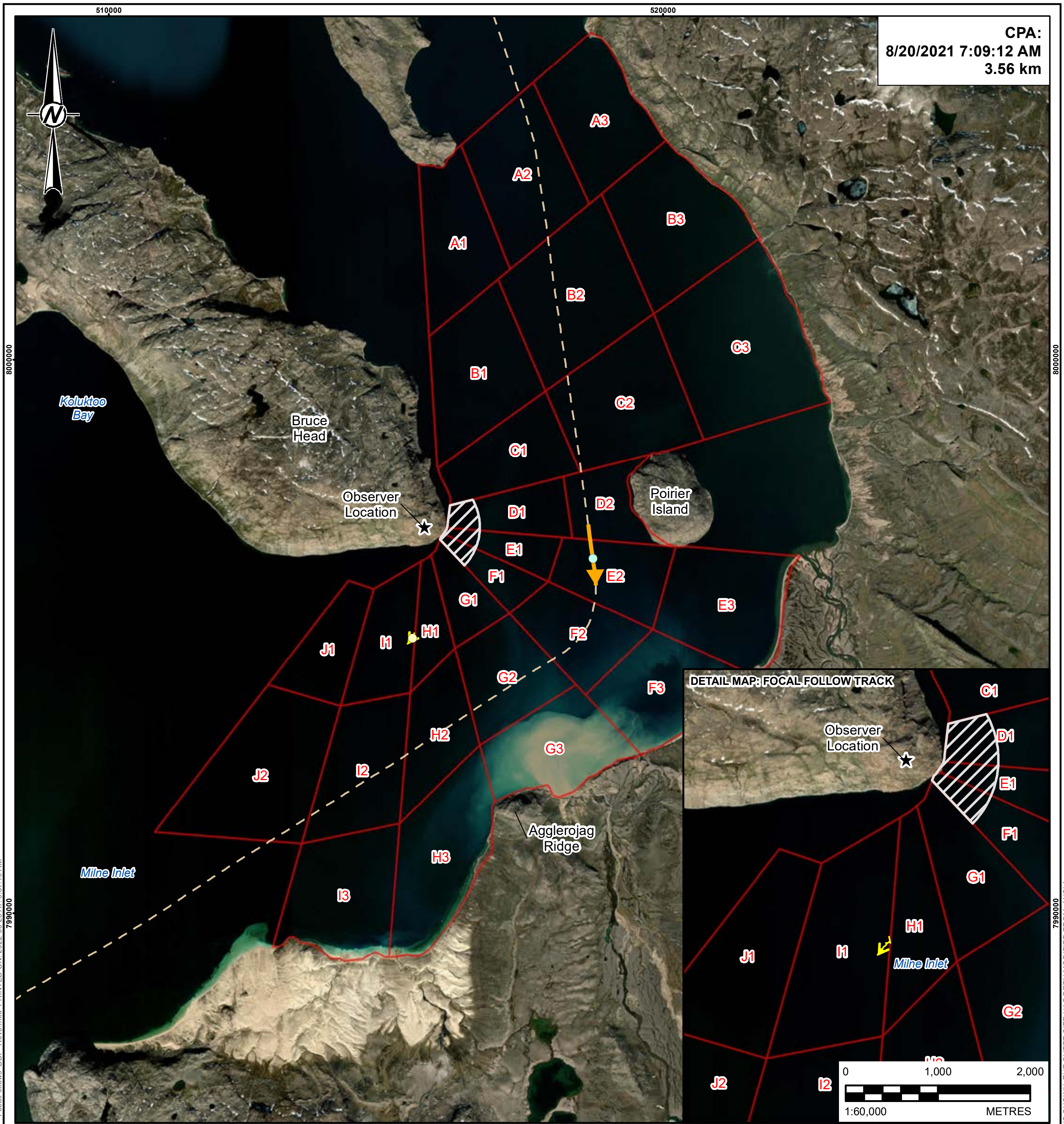

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- • COMMUNITY
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- ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

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

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 140 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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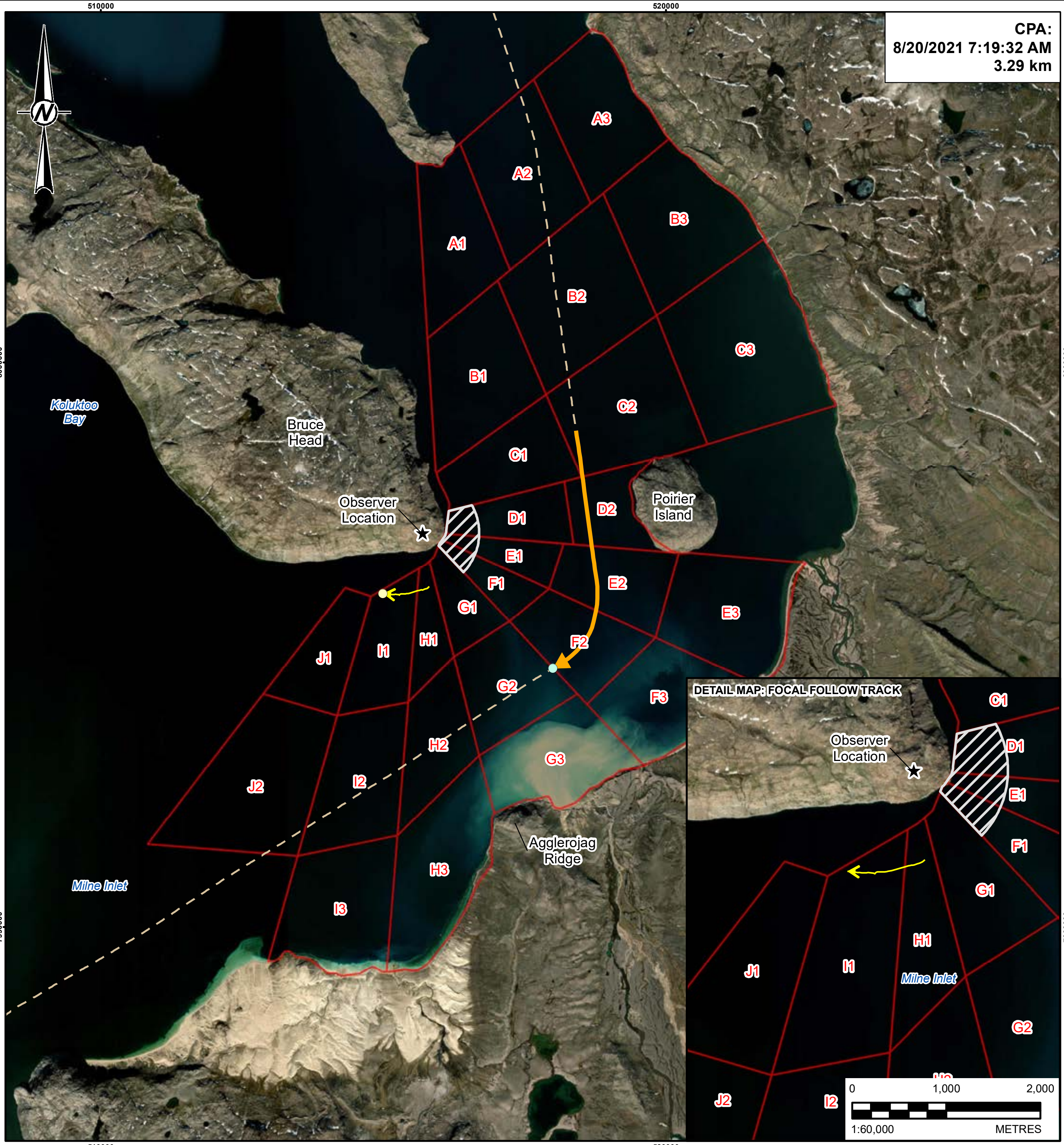

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LEGEND

- • COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- ★ OBSERVER LOCATION
- FOCAL FOLLOW TRACK 141 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 141 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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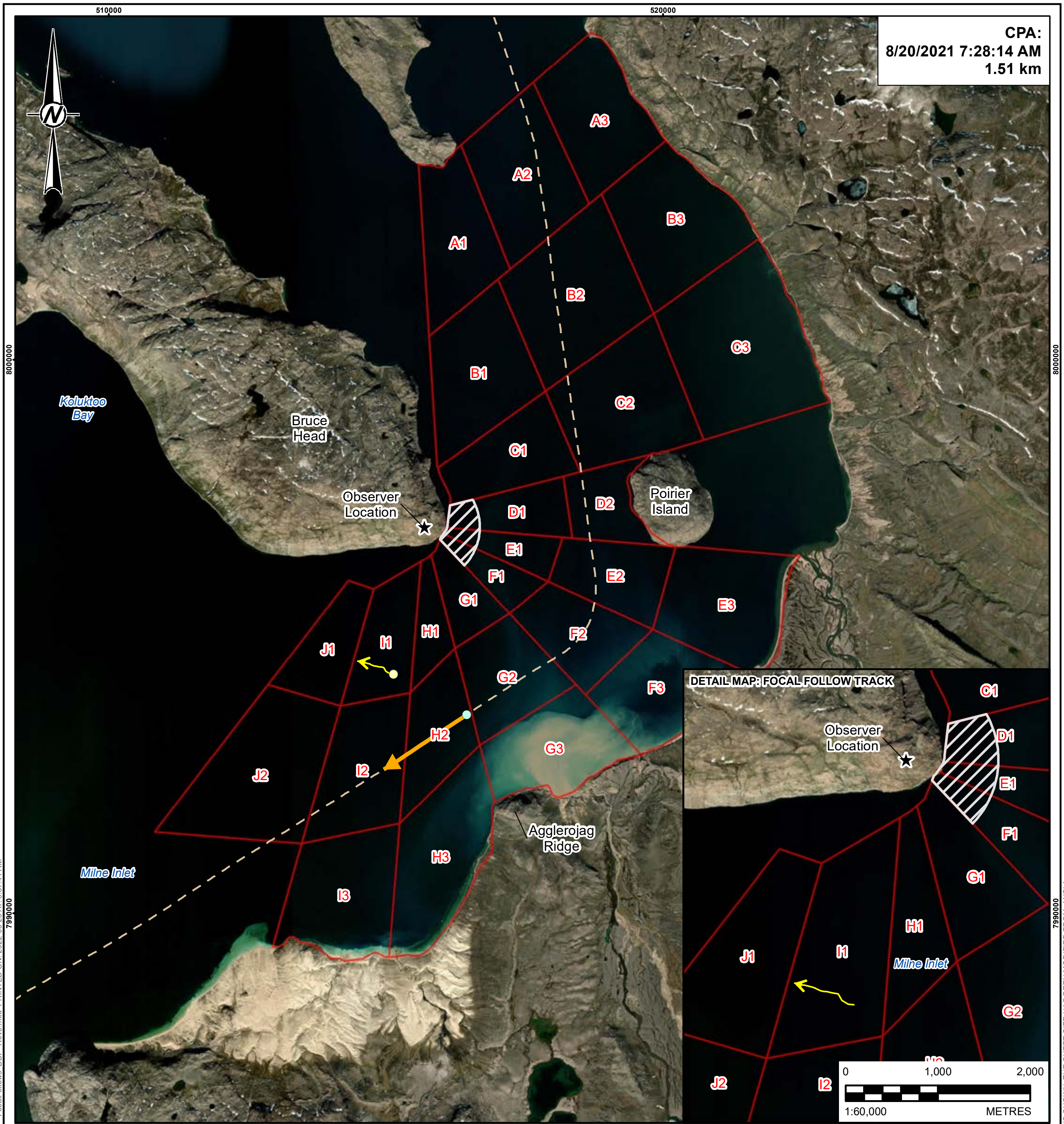

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- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
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- ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 142 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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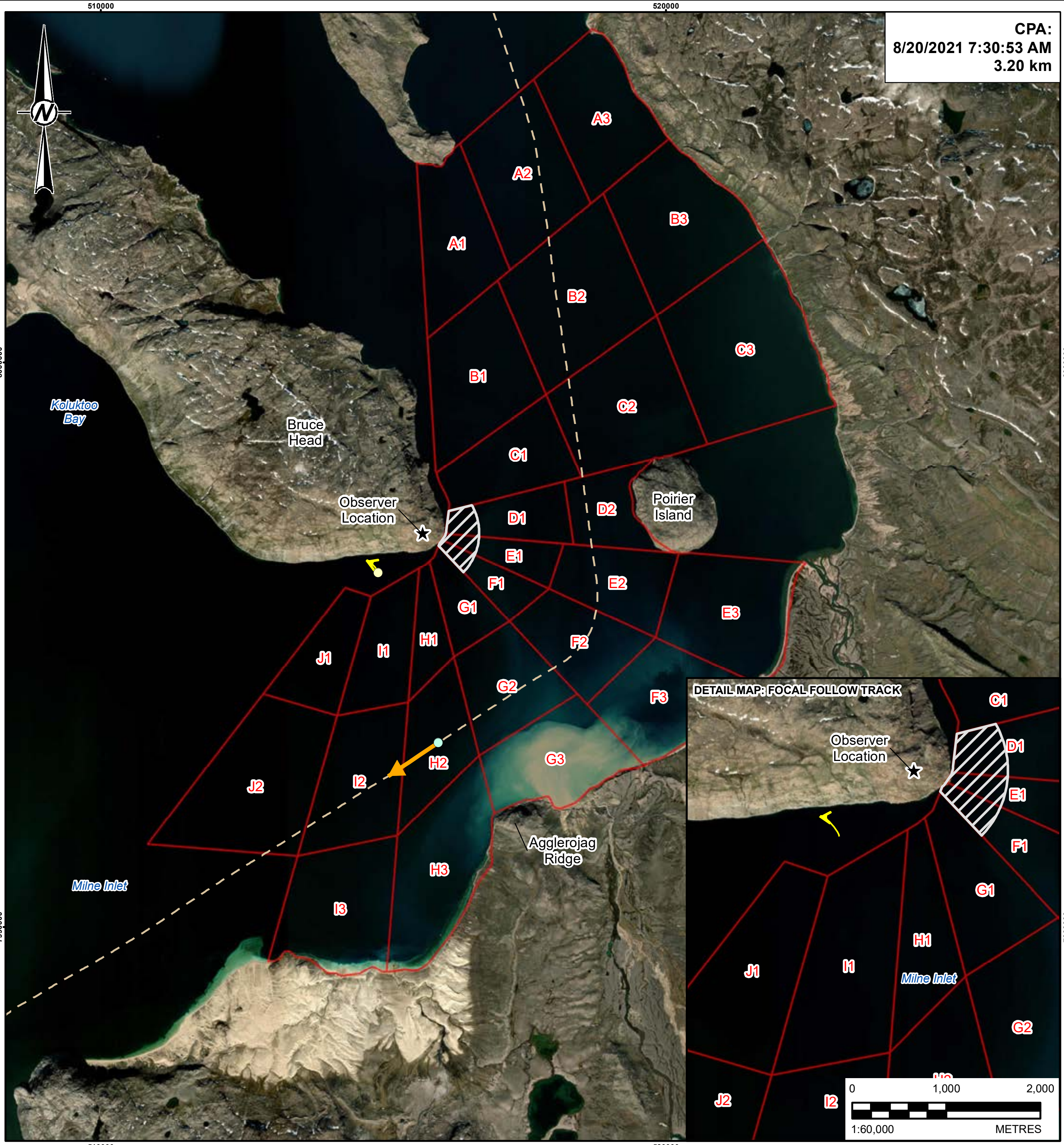

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- COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- OBSERVER LOCATION
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- NON-ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000
1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 143 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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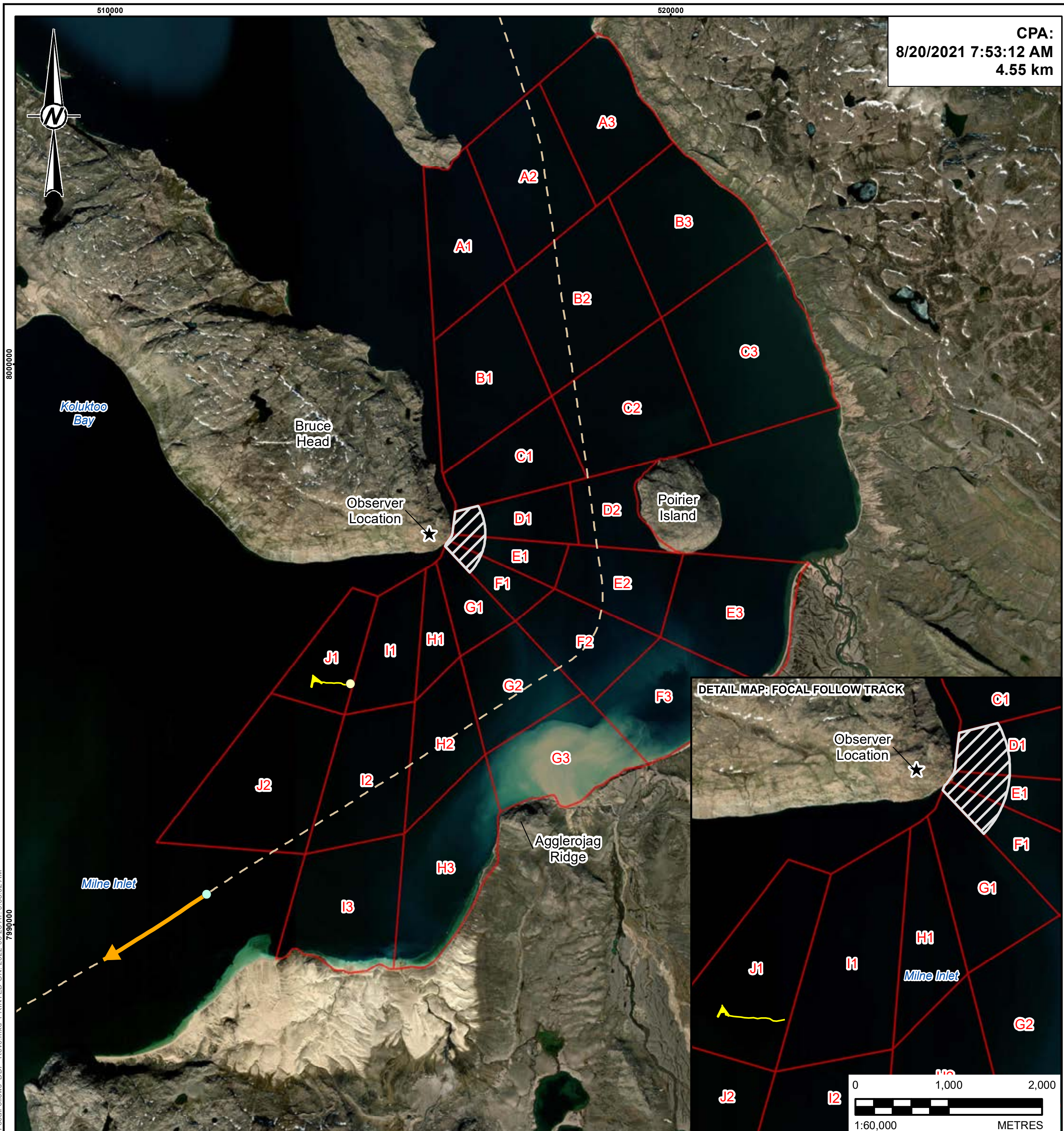

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LEGEND

- • COMMUNITY
- CPA (VESSEL)
- CPA (FOCAL FOLLOW)
- ★ OBSERVER LOCATION
- FOCAL FOLLOW TRACK 144 (2021)
- ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- NON-ACTIVE VESSEL TRANSIT (GOLDEN ROSE)
- CPA (FOCAL FOLLOW)
- BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA

0 2,500 5,000

1:100,000 METRES

REFERENCE(S)

SUBSTRATA AND OBSERVER LOCATION DIGITIZED FROM LGL SHORE-BASED MONITORING OF NARWHALS AND VESSELS AT BRUCE HEAD, MILNE INLET, 2016 REPORT. SHIPPING ROUTE DATA BY BIM, JULY 14, 2020. IMAGERY COPYRIGHT © 20170802 ESRI AND ITS LICENSORS. SOURCE: MAXAR VIVID. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT

TITLE
FOCAL FOLLOW 144 (2021) AND ACTIVE VESSEL TRANSIT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-06-23
DESIGNED	SU
PREPARED	AJA
REVIEWED	AA
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	43000	0	F-43

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25mm 0

APPENDIX G

Responses to MEWG Comments on Draft Report

Baffinland Mary River Project Report Working Group Comment Form

Reviewer Agency/Organization:	*Parks Canada Agency*
Reviewers:	*Allison Stoddart, Jordan Hoffman, Chantal Vis*
Document(s) Reviewed:	*2021 Bruce Head Shore Based Monitoring Program*
Date Review Completed	*2022-05-17*

Comment No.:	PCA-01
Section Reference:	2021 Bruce Head Report, Page viii, 'Future Recommendations', first bullet point
Comment:	

The UAV surveys have lacked enough data to conduct a meaningful analysis of behavioural responses relative to 'distance from vessel' for the Bruce Head monitoring program in 2020 and 2021.

1. How will this aspect of the monitoring program be adapted to ensure there is a sufficient sample size moving forward?
2. Will more drones/locations be added?

Baffinland Response:

Baffinland Iron Mines Corp. (BIMC) will continue to conduct UAV focal follow surveys throughout the 2022 field season at Bruce Head. Despite narwhal numbers being considerably lower in 2021 than in previous years, BIMC was successful in doubling the number of UAV-based focal follow surveys conducted in 2021 compared to 2020. This success can be attributed to the drone operations team being able to fly two drones simultaneously in 2021 (each conducting independent focal follow surveys), compared to only a single drone in 2020. In 2022, every effort will be made to have two drones in flight when narwhals are present in the study area in order to further increase sample size. However, the number of narwhal present in the study area is outside of BIMC's control. Having a regular presence of narwhals in the study area is ultimately what is required to reach a sample size that would allow for a meaningful quantitative analysis of behavioral responses relative to distance from vessel.

Comment No.:	PCA-02
Section Reference:	2021 Bruce Head Report, Page 165, Section 8.2 'Summary of Key Findings: Group Composition and Behaviour, Proportion of Immatures'
Comment:	

Results from the Bruce Head Monitoring Program report indicate a 24% decrease in the proportion of immatures from 2020 and the lowest observed proportion across all sampling years. The monitoring report indicated that the lack of a significant difference in the 2021 calf proportion relative to other years may have been due to the low sample size and high variability in 2021. Golder has indicated that additional analysis of aerial survey data will be presented in the near future to confirm whether the observed decline is significant.

1. Given that there is uncertainty in the results, will a precautionary approach be taken with adaptive management measures applied given that proportion of immatures is an Early Warning Indicator if results from the aerial survey have not been reviewed by the MEWG prior to the start of shipping or potential ice-breaking activities?
2. How will monitoring be adapted moving forward to ensure there is appropriate statistical power to determine the significance of change in the Early Warning Indicator of proportion of immatures?

Baffinland Response:

1. Yes, a precautionary approach has been taken by BIMC based on evidence from its existing narwhal monitoring programs and uncertainties related to external factor(s) that may have contributed to the observed decline in narwhal. These are summarized in section 5.2 of BIMC's 2022 Narwhal Adaptive Management Response Plan (NAMRP; BIMC 2022). For example, adaptive management measures implemented in 2022 include suspending icebreaking operations altogether during the 2022 early shoulder (spring season), having ore carriers travel in convoys to reduce the overall number of vessel passages and cumulative noise exposure to narwhal in 2022, and capping ore carrier transits in the RSA in 2022 at 80 vessels in a 6 million ton approval scenario, versus 86 vessels. These enhanced mitigation measures for implementation in 2022, in light of the precautionary principle, were also discussed in detail with Parks Canada and other MEWG members during four separate MEWG meetings in May and June 2022 (14 hours total, 03 May, 14 June, 22 June, 29 June). A 2022 shipping update with mitigation measures was also provided to MEWG members by BIMC during the 14 June meeting.

   The Early Warning Indicator (EWI) results from the 2021 aerial survey data have been included as an appendix to the 2021 Marine Mammal Aerial Survey Program (MMASP) Final Report.

2. EWI data will continue to be collected during future aerial survey programs (1,000 ft aerial imagery) to ensure that an additional source of EWI data is available for analysis should this be required. Statistical power will be largely dependent on sample size, which is a function of

survey effort in addition to narwhal abundance at the time of survey (the latter being outside of BIMC's control – also see response to PCA-01).

References:

BIMC. 2022. 2022 Narwhal Adaptive Management Response Plan (NAMRP). Document # BAF-PH1-830-P16-0024. Rev1. 19 July 2022.

Comment No.:	PCA-03
Section Reference:	Marine Mammal Aerial Survey, page 79, Section 3.6.1, 'Discussion: Narwhal Abundance and Distribution', first bullet point Bruce Head Monitoring Report, page 155, Section 7.1, 'Discussion: Relative Abundance and Distribution'
Comment:	

One of the conclusions made in the Marine Mammal Aerial Survey report is that underwater noise from open-water shipping was not considered to be a likely cause of narwhal displacement from the Regional Study Area based on the available monitoring results to date. Instead, other factors lacking area-specific data in Admiralty Inlet and Eclipse Sound such as prey availability or predation pressure (i.e., more favourable ecological conditions) are suggested to be causing the observed large-scale distribution shift to Admiralty Inlet. These conclusions are based on the past tagging data, open-water acoustic monitoring, and the Bruce Head study area. There are multiple lines of evidence, including Inuit Qaujimajatuqangit (IQ), which suggest shipping has an impact on narwhal. Monitoring studies to date have been spatially restricted (e.g., Bruce Head shore-based monitoring and UAV studies) or temporally restricted (e.g., aerial surveys, UAV studies, and marine mammal tagging) to fully consider that shipping is not a contributing factor to any potential long-term movements and displacement of narwhal. Further, in the Bruce Head monitoring report (page 155) Golder States that, "While **underwater noise from open-water shipping cannot be ruled out as a potential cause of narwhal displacement from the RSA**, monitoring results collected to date demonstrate that there are likely other factors contributing to the observed change."

1. How does Baffinland plan to follow up with studies to determine the influence of other ecological factors that are suggested in the 2021 monitoring reports or to further investigate the impacts of shipping on movement in less spatially restricted areas of Eclipse Sound (i.e., outside of inlets such as Tremblay Sound and Milne Inlet)?
2. Will a precautionary approach be taken which considers the impacts of shipping in the absence of evidence that other factor(s) are contributing to the observed decline in narwhal?

Baffinland Response:

1. This recommendation does not pertain to the 2021 Bruce Head Shore-based Monitoring Program. The intent of this exercise is for MEWG members to provide comments, points of clarification and/or recommendations related to the 2021 Bruce Head Program. We would ask Parks Canada to refer to the 2022 NAMRP (BIMC 2022), which can be found in Appendix D of the 2022 Marine Shipping and Vessel Management Report to the NIRB, for further details about future monitoring and adaptive management initiatives regarding narwhal in the regional study area (RSA) based on results available to date. Should Parks Canada wish to provide any formal recommendations to BIMC following their review of the NAMRP, they can be provided in writing to BIMC's Senior Director of Sustainable Development, Lou Kamermans (lou.kamermans@baffinland.com).
2. Yes, a precautionary approach will be taken which considers the impacts of shipping in the absence of evidence that other factor(s) are contributing to the observed decline in narwhal. These are summarized in BIMC's 2022 NAMRP (BIMC 2022). Section 5 of the 2022 NAMRP outlines current and future project effects monitoring programs, and Section 5.2 of the 2022 NAMRP outlines project mitigation and adaptive management measures that will be implemented throughout the 2022 shipping season.

References:

BIMC. 2022. 2022 Narwhal Adaptive Management Response Plan (NAMRP). Document # BAF-PH1-830-P16-0024. Rev1. 19 July 2022.

Comment No.:	PCA-08
Section Reference:	General Comment regarding Early Warning Indicators (EWI)

Comment:

Given the current issues obtaining a sufficient sample size to detect significant change in the calf proportion EWI and potential future issues if the local abundance of narwhal in Eclipse Sound remains low Parks Canada recommend the following:

- To implement additional EWIs proposed by the MEWG in 2019.
- To implement EWIs such as significant changes in narwhal or ringed seal local abundance that have data that is collected regularly and can be assessed before each operational season.
- Reengage the MEWG to develop additional mitigations and adaptive management practices to be triggered by reaching EWI thresholds.

Baffinland Response:

BIMC encourages PC to clarify what additional EWIs the organization would like to see implemented for the current Project, including available baseline data and proposed thresholds that would support using such indicators. These recommendations can be provided in writing to BIMC's Senior Director of Sustainable Development, Lou Kamermans, lou.kamermans@baffinland.com.

BIMC has incorporated multiple EWIs into its ongoing marine monitoring programs beyond this primary EWI (i.e., proportion of immatures relative to the adult population). This includes those indicators referenced above by Parks Canada (changes in narwhal and ringed seal abundance), but also multiple other behavioural response indicators, as summarized in the marine mammal Trigger, Action and Response Plan (TARP), which is integrated in BIMC's draft Marine Monitoring Plan (BIMC 2021). This information has and continues to be available to the NIRB and to members of the MEWG. Most recently, all indicators have been clearly defined in Section 5.2, p. 24, of BIMC's 2022 NAMRP (BIMC 2022a), which was filed with the NIRB (and submitted to MEWG members) as part of BIMC's 2022 Marine Shipping and Vessel Management Report (BIMC 2022b – see Appendix D). Throughout the life of the Project, MEWG members have been encouraged to assist in the continued development of EWI thresholds (for existing and new indicators) and adaptive management responses (i.e., follow-up studies, expanded monitoring, new and enhanced mitigation) that would be implemented in the event a Project-related activity was shown to exceed an established threshold (see Section 1.5 of Golder 2020).

BIMC's Adaptive Management Plan provides a tiered approach to adaptive management with respect to potential Project impacts on marine mammals. This approach is integrated in the draft MMP (BIMC 2021), in the form of the marine mammal TARP table that clearly outlines Baffinland's monitoring objectives, performance indicators, thresholds (low, moderate and high) and pre-defined responses in place to manage potential adverse Project effects of shipping on narwhal and other marine mammals in the RSA.

BIMC has applied the current draft MMP TARP to the 2022 marine monitoring programs on an interim basis while BIMC works with the MEWG to develop a final updated MMP to apply to 2023 onwards. MEWG members will continue to be engaged with regards to BIMC's adaptive management practices, including indicators and thresholds.

References:

BIMC. 2021. Draft Marine Monitoring Plan (MMP). Marine Mammal TARP and Action Toolkits. NIRB File # 334146.

BIMC. 2022a. 2022 Narwhal Adaptive Management Response Plan (NAMRP). Document # BAF-PH1-830-P16-0024. Rev1. 19 July 2022.

BIMC. 2022b. Marine Shipping and Vessel Management Report to the Nunavut Impact Review Board. 19 July 2022. 301 p.

Golder. 2020. Early Warning Indicators for Marine Mammals. Technical Memorandum No. 1663724-231-TM-Rev0-38000. 20 August 2020. 100 p.

Reviewer Agency/Organization:	*Oceans North*
Reviewers:	*Dr. Kristin Westdal, Dr. Josh Jones, & Amanda Joynt*
Document(s) Reviewed:	*Bruce Head Draft Report 2021*
Date Review Completed	*2022-05-27*

Comment No.:	*ON-01*
Section Reference:	*2021 Bruce Head Draft Report* *6.5.6 p.101*
Comment:	

Issue: The Bruce Head monitoring report notes that the "maximum period per day associated with vessel disturbance on narwhal group travel speed was 56 min." This is higher than estimates on other narwhal behavioural responses (density, group composition, group spread etc.).

Clarification: What is the maximum disturbance estimate over the shipping season? This would be a more useful measure of impact.

Recommendation: Cumulative effects of the impacts of disturbance related to narwhal travel speed are not taken into account. We would like to see true estimates via a table that provides an estimate of overall impact over the course of the shipping season.

Baffinland Response:

As noted by Oceans North, results from the 2021 Bruce Head Program indicates that 56 min is the 'maximum period per day associated with vessel disturbance on narwhal travel speed', based on an average of two vessel transits per day in the SSA. As outlined in Section 1.1, the total duration of the 2021 shipping season was 96 days. As such, the maximum period of disturbance over the entire shipping season is therefore calculated at 88 hours (96 days x 56 min/day). This conservatively assumes that the exposed narwhal would remain stationary on the shipping lane for a consecutive 96-day period. This value represents 4.2% of the exposed narwhal's normal life cycle over the course of the shipping season (88 h out of a possible 2,304 h). In contrast, the minimum period of disturbance over the entire shipping season would be 0 min (in cases where an individual narwhal never approached closer than 4 km of the shipping lane during the 96-day shipping season and therefore was never exposed to ship noise at levels known to elicit disturbance). Therefore, the maximum cumulative period for which narwhal travel speed would be influenced by Project shipping ranges between 0 and 4.25% of an individual narwhal's normal life cycle over the course of the shipping season. We do not feel that a table is necessary to summarize this level of information.

Comment No.:	ON-2
Section Reference:	*2021 Bruce Head Draft Report* 6.5.2.1 p.80-87
Comment:	

Issue:
The proportion of immature narwhals in the study area was lower than all previous years. The decrease in immatures with the confidence intervals presented is alarming. We understand from the MEWG call last month that when the 1,000 ft aerial survey was assessed to dig deeper into this observation that the calf ratio was indeed lower in Milne Inlet, and considerably lower than Admiralty Inlet.

Clarification and Recommendations:
1. What was the difference between the areas? Was it statistically significant? Golder noted on that call that this was to be expected as there were more whales in Admiralty. Why would the ratio change because there are more or less whales? Please provide the references used to suggest that this would be expected. A decline or alternatively a shift of females with calves to another location would suggest an issue.

2. On page 85, Golder notes that a decrease in the proportion in the RSA would be indicative of a high severity response "eg. Disruption of breeding behaviour sufficient to compromise reproductive success." What evidence does Baffinland have to suggest that a decline in calf abundance is not an issue? The data as it stands indicates an exceedance of the EWI if the CI is taken into account. How does Baffinland interpret this?

Baffinland Response:

1. The aerial survey EWI results are presented in the 2021 MMASP final report (Golder2022). The EWI aerial survey results indicated that the proportion of immature narwhal in the Admiralty Inlet stock decreased from 15.8% in 2020 to 14.2% in 2021. For the Eclipse Sound stock, the proportion of immature narwhal increased from 11.7% in 2020 to 12.8% in 2021. For comparative purposes, the proportion of immature narwhal in the Eclipse Sound stock was 15% in 2014 (pre-Project shipping) and 11% in 2015 (first year of iron ore shipping) (Moulton et al. 2019). When looking at the Milne Inlet strata independently, the aerial survey EWI results were in agreement with the Bruce Head EWI results in that they show a decrease in the proportion of immature narwhal in Milne Inlet South from 13.4% in 2020 to 7.5% in 2021. A reverse pattern was observed in Tremblay Sound, where the proportion of narwhal increased from 9.2% in 2020 to 15.6% in 2021. Shipping levels in the RSA were similar in 2020 (72 ore carriers) compared to 2021 (73 ore carriers). A statistical analysis was not conducted on the 2020/2021 EWI aerial survey results given that the ratio of immature narwhal in the RSA was shown to increase in 2021.

BIMC encourages Oceans North to revisit the August 4th MEWG meeting minutes. It was not stated that the calf ratio would change due to a change in narwhal abundance. Refer to p. 9 of the draft August 4th MEWG minutes, which were distributed on September 13th, 2022 to the MEWG via email. P. Rouget's statement with regards to the narwhal calf ratio in Admiralty Inlet is below:

"Again, we ran that additional analysis series in the aerial survey data because of such low sample sizes that we were dealing, with the same indicator for the Bruce Head program. We made the decision to analyze that secondary data set after the draft report went out for Bruce Head. Moving forward, we feel that the aerial survey data is probably a more reliable data set for that purpose or for that particular early warning indicator. Mainly because the sample sizes are larger, but also because we're able to look at that calf ratio not only in that one location in Milne to the south, but also the regional study area, as well as an adjacent reference areas such as Admiralty Inlet— where we also collect aerial survey data so we can have a comparison between shipping versus not shipping. That would help us dissect if any change would be related to shipping, as opposed to some other factor that would be of equal stress on the different stock areas (BIMC 2022c)."

2. If a significant decrease in the proportion of immature narwhal occurred and this was determined to be a Project-related impact, then this would be considered a 'high severity response', as noted in the 2021 Bruce Head Shore-based Monitoring Report. However, based on the subsequent EWI analysis of the aerial survey data (Golder 2022), there is no indication of a decline in the proportion of immatures (i.e., calves and yearlings) in the RSA (project-driven or otherwise).

References:

BIMC. 2022. 04 08 2022_Meeting Minutes DRAFT For MEWG.

Golder. 2022. 2021 Marine Mammal Aerial Survey Program - Final Report. WSP Golder Report No. 1663724-353-L-Rev0-49000. October 2022.

Comment No.:	ON-3
Section Reference:	*Bruce Head Draft Report* 1.3 p.5 1.4 p. 6-7
Comment:	

Issue:
Section 1.3 discusses early warning indicators that would be able to rapidly identify adverse effects on narwhal and that this currently only includes a change in the proportion of immature narwhal. The next section discuses adaptive management protocol but does not specify what the adaptive management response for a change in the proportion of immature narwhal is.

Clarification: If this EWI was not useful in identifying the declining narwhal population, will additional EWI's be added in advance of the 2022 shipping season and 2022 aerial survey?

Recommendation:
Please include [Baffinland. 2021b. Marine Mammal TARP and Action Toolkits. Marine Monitoring Plan (MMP).] with the Bruce Head Final Report, what actions will be triggered and what other EWI are being considered.

Baffinland Response:

We take this opportunity to remind Oceans North that the proportion of immature narwhal is not the only EWI in place for the Project. BIMC has incorporated multiple EWIs into its ongoing marine monitoring programs beyond the primary EWI (i.e., proportion of immatures). This includes numerous behavioural-based and population-based indicators along with pre-defined thresholds and responses (i.e., actions) for each of these indicators, as summarized in the marine mammal TARP which is integrated in BIMC's draft MMP (BIMC 2021a). These are also summarized in BIMC's 2022 NAMRP (BIMC 2022a), which was submitted to the NIRB (and MEWG members) as part of its 2022 Marine Shipping and Vessel Management Report (BIMC 2022b – see Appendix D). The marine mammal TARP and Action Toolkit was also provided as part of BIMC's responses to Post-Hearing Questions related to Phase 2 (BIMC 2021b). Given that the marine mammal TARP is readily available to MEWG members (including Oceans North) and the NIRB through these existing submissions, it has not been included in the present report.

We note to Oceans North that the primary indicator that is actively monitored in the MMASP is a 'change in abundance'. This indicator is clearly sensitive enough to detect a rapid change in abundance because this is precisely what it has done. The specific purpose of this indicator is to inform if narwhal numbers are changing (and by how much), but it does not provide information on why a change in numbers might be occurring. The latter is addressed through other indicators incorporated into BIMC's monitoring programs including, but not limited to, the primary EWI (change in proportion of immature narwhal). BIMC's other behavioural-based EWIs (e.g., change in travel speed, dive duration, surface time, bottom time, orientation) also provide timely information on whether an observed change in narwhal abundance or in the proportion of immature narwhal is Project-driven or not.

Of note, the results of the 2021 MMASP do not indicate a declining narwhal population for the combined Eclipse Sound and Admiralty Inlet stocks. They indicate a shift in narwhal distribution from Eclipse Sound to Admiralty Inlet. This shift has been progressively observed since the early 2000s. In 2003, aerial surveys undertaken by Fisheries and Oceans Canada (DFO) calculated narwhal abundance in Admiralty Inlet at 5,362 individuals (Richard et al. 2010). In 2010, aerial surveys conducted by DFO calculated narwhal abundance in Admiralty Inlet 18,049 (Asselin and Richard 2011). In 2013, aerial surveys conducted by DFO calculated narwhal abundance in Admiralty Inlet at 35,043 (Doniol-Valcroze et al. 2015). Thus, prior to any BIMC shipping activity in the RSA, narwhal abundance in Admiralty Inlet had increased from 5,362 to 35,043 individuals. The 2021 abundance estimate for Admiralty Inlet was 72,582 individuals (Golder 2022). This shows a trend of increasing narwhal abundance in the Admiralty Inlet area. The decreasing trend in Eclipse Sound from 2004 (20,225 individuals; Richard et al. 2010) to present (2,595 individuals; Golder 2022), which was first identified in 2013 (10,489 individuals; Doniol-Valcroze et al. 2015) prior to BIMC shipping activity in the RSA, may be linked to the increasing trend in Admiralty Inlet, both of which occurred prior to the start of BIMC shipping activities in the RSA.

References:

Asselin, N.C. and P.R. Richard, 2011. Results of narwhal (Monodon monoceros) aerial surveys in Admiralty Inlet, August 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/065. iv + 26 p.

BIMC. 2021a. Draft Marine Monitoring Plan (MMP). Marine Mammal TARP and Action Toolkits. NIRB File # 334146.

BIMC. 2021b. Post-Hearing Question Responses Phase 2 Proposal – Mary River Project. NIRB File # 08MN053. Mach 2021. 339 p.

BIMC. 2022a. 2022 Narwhal Adaptive Management Response Plan (NAMRP). Document # BAF-PH1-830-P16-0024. Rev1. 19 July 2022.

BIMC. 2022b. Marine Shipping and Vessel Management Report to the Nunavut Impact Review Board. 19 July 2022. 301 p.

Doniol-Valcroze, T, Gosselin, J.F., Pike, D., Lawson, J., Asselin, N., Hedges, K., and S. Ferguson. 2015. Abundance estimates of narwhal stocks in the Canadian High Arctic in 2013. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/060. v + 36 p.

Golder. 2022. 2021 Marine Mammal Aerial Survey Program - Final Report. WSP Golder Report No. 1663724-353-L-Rev0-49000. October 2022.

Richard, P., J.L. Laake, R.C. Hobbs, M.P. Heide-Jørgensen, N.C. Asselin and H. Cleator. 2010. Baffin Bay narwhal population distribution and numbers: Aerial surveys in the Canadian High Arctic, 2002-04. Arctic. 63: 85-99.

Comment No.:	ON-4
Section Reference:	*Bruce Head Draft Report* 6.5.3. p.87 6.5.4 p. 92 6.5.5 p. 96
Comment:	

Issue:
Daily cumulative effects are not addressed for behaviours such as spread, formation, direction of travel and distance from shore. The effects from one day are not the same as day after day after day for months.

Clarification:
What is Baffinland's analysis of cumulative effects on these changes in behaviours?

Recommendation:
This analysis is not useful without considering cumulative impacts (Project Certificate Condition No. 110). Baffinland needs to address this going forward. The assumption of no cumulative effects in the environmental assessments needs to be adjusted.

Baffinland Response:

The daily cumulative disturbance period has been provided in the 2021 Bruce Head Shore-based Monitoring Report for all response variables, including group spread, direction of travel and distance from shore (see Executive Summary, Section 6.5 and Section 8.2). This is represented by the 'maximum disturbance period per vessel transit (presented for each response variable)' multiplied by the 'number of ship transits occurring in the RSA each day'. This value can then be multiplied by the number of days in the shipping season (i.e., 96 days) to determine the seasonal cumulative disturbance period from Project vessel noise on each behavioural response variable (e.g., group spread, formation, etc), as detailed in our response to ON-01 (above). Note that there was no significant effect of shipping on 'group formation' and therefore no potential for a cumulative effect for this response variable.

Reviewer Agency/Organization:	*DFO*
Reviewers:	Marianne *Marcoux, Kimberly Howland, Joclyn Paulic, Daniel Coombs, Edyta Ratajczyk*
Document(s) Reviewed:	*Bruce Head Draft Report 2021*
Date Review Completed	

Comment No.:	*DFO-9*
Section Reference:	1.2 Program objectives 1.4.3 High Risk Threshold
Comment:	

Issue:

"Condition No. 111 The Proponent shall develop clear thresholds for determining if negative impacts as a result of vessel noise are occurring."

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

It is not clear what thresholds have been developed apart for the threshold for the proportion of juvenile. Please provide information on other thresholds developed.

Baffinland

Clarification:
What is the rationale for using the 2019 results as reference year for establishing a response threshold, rather than pre-project abundances.

Recommendation:
Change the reference threshold to data prior the start of the operation of the mine or provide a rational for using the 2019 threshold for the MEWG to consider.

Baffinland Response:

We note that this recommendation does not pertain to the 2021 Bruce Head Shore-based Monitoring Program (the comment is referring to the 2021 Marine Mammal Aerial Survey Program). The intent of this exercise is for MEWG members to provide comments, points of clarification and/or recommendations related to the 2021 Bruce Head Program. A brief response is provided below.

The 2019 aerial survey results are used as a reference year for this specific response threshold (i.e., change in abundance) as this is the earliest survey year available that offers a relatively low coefficient of variation (CV) in the Eclipse Sound abundance estimate (9,931 individuals; CV=0.05; 95% Confidence Interval: 9,009-10,946; Golder 2022). In other words, it is the earliest survey year available where there is some degree of accuracy (and by extension confidence) in the stated abundance estimate.

BIMC has multiple EWIs integrated into its ongoing marine monitoring programs beyond the primary EWI (i.e., proportion of immatures). This includes numerous behavioural-based and population-based indicators along with pre-defined thresholds and responses (i.e., actions) for each of these indicators, as summarized in the marine mammal TARP which is integrated in BIMC's draft MMP (BIMC 2021a). These are also summarized in BIMC's 2022 NAMRP (BIMC 2022a), which was submitted to the NIRB (and MEWG members) as part of its 2022 Marine Shipping and Vessel Management Report (BIMC 2022b – see Appendix D). The marine mammal TARP and Action Toolkit was also provided as part of BIMC's responses to Post-Hearing Questions related to Phase 2 (BIMC 2021b).

References:

BIMC. 2021a. Draft Marine Monitoring Plan (MMP). Marine Mammal TARP and Action Toolkits. NIRB File # 334146.

BIMC. 2021b. Post-Hearing Question Responses Phase 2 Proposal – Mary River Project. NIRB File # 08MN053. Mach 2021. 339 p.

BIMC. 2022a. 2022 Narwhal Adaptive Management Response Plan (NAMRP). Document # BAF-PH1-830-P16-0024. Rev1. 19 July 2022.

BIMC. 2022b. Marine Shipping and Vessel Management Report to the Nunavut Impact Review Board. 19 July 2022. 301 p.

Golder. 2022. 2021 Marine Mammal Aerial Survey Program - Final Report. WSP Golder Report No. 1663724-353-L-Rev0-49000. October 2022.

Comment No.:	*DFO-10*
Section Reference:	*1.3 Early Warning Indicators (EWIs)*
Comment:	

Recommendation:
DFO recommends that additional EWI are developed to monitor the different potential impacts of the project.

Baffinland Response:

See response to ON-03.

Engagement with the MEWG will continue, both in terms of identifying potentially useful EWIs (with corresponding baseline data available and thresholds) and other useful project indicators.

GOLDER
MEMBER OF WSP

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