**REPORT**

# Mary River Project

*2022 Bruce Head Shore-based Monitoring Report*

Submitted to:

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# Executive Summary

In August 2022, WSP Canada Inc. (WSP), on behalf of Baffinland Iron Mines Corporation (Baffinland), undertook the Bruce Head Shore-based Monitoring Program ('the Program'), a field-based study conducted annually since 2014 (with the exception of 2018) for the purpose of assessing narwhal responses to Baffinland shipping activities along an active shipping corridor off North Baffin Island, Nunavut. As part of the Program, systematic data on narwhal relative abundance and distribution (RAD), group composition and behaviour were collected from a cliff-based observation platform overlooking the Northern Shipping Route where Project vessels transit through an established narwhal summering ground in Milne Inlet. Ship movements in the study area were recorded using a combination of shore- and satellite-based Automatic Identification System (AIS) vessel tracking systems to provide high-resolution positional data on all medium- (50-100 m in length) and large-sized (>100 m in length) vessels transiting through Milne Inlet. Additional data were collected on environmental conditions and anthropogenic activities (e.g., recreational traffic and hunting activities) to distinguish between the potential effects of Project-related shipping activities and confounding factors that may also influence narwhal behaviour.

The Program specifically addresses Project Certificate (PC) conditions 99c, 101g, 109, and 111, related to evaluating potential disturbance of marine mammals from shipping activities that may result in changes in animal abundance, distribution, and behaviour within the Project's Regional Study Area (RSA). The 2022 Bruce Head Shore-based Program represents the eighth year of environmental effects monitoring (EEM) undertaken at Bruce Head in support of the Mary River Project.

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

## Relative Abundance and Distribution

- Interannual variation in relative abundance: The relative abundance of narwhal (total number of narwhal corrected for survey effort) in the Stratified Study Area (SSA) was higher in 2022 (84.9) than in 2020 and 2021 (47.5 and 29.4, respectively) and approaching the 2015 baseline level (first year of operations; 98.2). However, narwhal relative abundance in 2022 (84.9) was lower than the 2014 baseline level (131.4) and lower than levels observed in 2016 (178.0), 2017 (121.8) and 2019 (127.2). These findings indicate that narwhal numbers in the Regional Study Area (RSA) appeared to be increasing from the numbers observed in 2020/2021 but have not yet reached levels observed during the initial shipping years (2016, 2017) or those observed in 2019. Over the combined 2014 to 2022 monitoring period, the second highest relative abundance estimate at Bruce Head was observed in 2019, when shipping was highest and Project icebreaking occurred during the early shoulder season for the third consecutive year (2018 to 2020). In contrast, the lowest relative abundance estimates at Bruce Head were recorded in 2020 and 2021, when shipping levels were similar to 2016. Icebreaking operations took place during the 2020 early shoulder season but no icebreaking took place in the RSA during 2021. These results suggest that the annual volume of Project shipping in the RSA is not a reliable predictor of narwhal relative abundance at Bruce Head in the same year The 2022 results support the theory that some degree of natural exchange likely occurs between the two presumed narwhal summer stock areas and, while shipping cannot be ruled out as a contributing factor, that the regional distribution and movement of narwhal off North Baffin Island during the summer was likely influenced by other external factors (e.g., local ice conditions, water temperature, prey availability, predation pressure, etc.).

- Density: Vessel exposure was shown to result in a statistically significant temporary decrease in narwhal density in the SSA compared to when no vessels were present; this decrease was limited to when narwhal were in close proximity (≤2 km) to approaching northbound vessels, after which narwhal densities were shown to increase as northbound vessels transited away from the SSA (i.e., temporary effect). This was equivalent to a maximum period of 14 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). During the 2022 Program (31 July to 23 Aug), there were approximately two vessel transits per day in the SSA (56 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 min. These findings were consistent with previous years' findings and with behavioural results from the narwhal tagging study (Golder 2020a), indicating that narwhal density in the SSA was temporarily influenced by vessel traffic, with the decrease limited to close distances (i.e., within 2 km of a northbound vessel). Localized avoidance of the sound source (i.e., the vessel) by narwhal was consistent with a moderate severity behavioural response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., 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 were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the Final Environmental Impact Statement (FEIS) for the Early Revenue Phase (ERP), in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

## Group Composition – Behaviour Study Area (BSA)

- Group Composition: The number of narwhal groups in the BSA in 2022 was the second highest observed since the start of the eight-year study period, with 1,523 narwhal groups (comprising 5,864 individuals) recorded. All narwhal life stage categories (adults, juveniles, yearlings, and calves) were recorded in the BSA throughout the eight-year sampling program, with the majority of the sightings consisting of adult narwhal, followed by juveniles, calves, and yearlings.
- Proportion of Immatures (Early Warning Indicator; 'EWI'): Findings from the combined multi-year dataset indicated that the relative proportion of immature narwhal observed in the BSA in 2022 (0.105) was significantly lower than the 2014/2015 baseline condition (0.152 in 2014 and 0.167 in 2015). This was similar to the 2021 EWI results, in which the relative proportion of immature narwhal observed in the BSA in 2021 (0.102) was significantly lower than the 2014/2015 baseline condition. The 2021 and 2022 results indicate an exceedance of the Moderate Risk threshold for this specific indicator, as per the Trigger Action Response Plan (TARP) for marine mammals (Baffinland 2021c), and that the Risk Status / Threshold trigger has been observed in at least two consecutive monitoring years. The pre-defined response for exceedance of a moderate risk indicator includes the following: 1) investigate trend over time and consider any uncertainties (i.e., changes in operational processes, potential sources, confounding influences) in a formal Response Plan; and 2) initiate component-specific targeted studies as part of the response planning. Based on prior monitoring results for narwhal, Baffinland proactively refined and implemented the 2022 Narwhal Adaptive Management Response Plan (NAMRP; Baffinland 2022), which included a follow-up investigation involving an EWI analysis of 2020 to 2022 aerial survey data using dedicated 1,000-feet (305 m) aerial survey data (WSP 2023b). Findings from the aerial EWI indicated that the proportion of immature narwhal in Eclipse Sound in 2022 (0.124) was within the range of the 2014/2015 baseline condition (0.150 in 2014 and 0.110 in 2015), although a statistical analysis was not possible since the raw data from 2014/2015 aerial surveys

were not available. Both Bruce Head and aerial-based EWI datasets were associated with high variability and low sample sizes, resulting in high uncertainty in the EWI estimates. In summary, while the EWI data collected at Bruce Head suggested a localized change in narwhal group composition, the equivalent EWI analysis derived from the spatially broader aerial survey dataset provided no indication that the proportion of immature narwhal had declined in the broader RSA since the start of shipping operations (2014/2015) (WSP 2023b). Ongoing EWI monitoring through both the Bruce Head Shore-based Monitoring Program and Marine Mammal Aerial Survey Program is therefore recommended.

The following summarizes key findings pertaining to narwhal responses to ship traffic at Bruce Head based on three years (2020-2022) of drone-based focal follow imagery collected in Milne Inlet:

## Behaviour - UAV-based Focal Follow Surveys

- Primary behaviour: Findings based on the three-year UAV dataset provide possible, though conflicting, support that narwhal groups may change the proportion of time that they engage in critical activities (i.e., resting, milling, and social behaviours) when in the presence of vessels. Specifically, group types with immatures (i.e., mother-immature pairs and mixed groups with immatures) and adult groups were shown to decrease the proportion of time that they engage in critical activities when within 5 km and 4 km of vessels, respectively. Conversely, mixed groups without immatures were shown to increase the proportion of time that they engaged in critical activities when within 3 km of vessels. While these findings suggest that vessel traffic may have some effect on the ability of narwhal to carry out these critical life functions, the conflicting trends among group types suggest that the results should be interpreted with caution. Additional focal follow monitoring is recommended to increase overall sample size of the corresponding dataset.
- Unique behaviours: Unique behaviours were displayed less frequently by all narwhal group types in close proximity (<2 km) to transiting vessels, although comparisons relative to vessel absence scenarios were not significant despite large effect sizes at 0.5 km and 1.0 km from vessels. The lack of statistical significance was likely due to the low sample size and high data variability at close range (<2 km) to vessels. The results suggest that unique behaviours such as rubbing, rolling, nursing, and sexual displays may be temporarily disrupted in close proximity (<2 km) to vessel traffic, though this finding was based on a limited sample size at close range to vessels. Additional focal follow (UAV-based) monitoring is therefore recommended to increase overall sample size and the robustness of the corresponding analysis.
- Association of immatures with presumed mother: Immature narwhal were recorded in 148 of the 397 (37%) focal follow surveys conducted to date. Of these, immature narwhal occurred on their own in 35 of the surveys, with their presumed mother in 64 of the surveys, and in mixed groups in 49 of the surveys. Nursing behaviour was recorded during 30 of the surveys, of which five coincided with a vessel being present within 5 km of the focal group.
  - Presence of nursing behaviour: Immature narwhal engaged in nursing less often when in the presence of vessel traffic (vessel within 5 km of the focal group), although this effect was not statistically significant despite a large effect size (-69%). The lack of a statistically significant effect was likely due to low sample size and high data variability. As a result, these findings should be interpreted with caution. Additional focal follow monitoring is recommended to increase overall sample size and the robustness of the corresponding analysis.

- Relative and distal positioning of immatures: Immature narwhal were found to change their association with their mother when in close proximity to vessel traffic, for both mother-immature pairs and for mixed groups with immatures. That is, immature narwhal tended to favour the underside of their mother over other relative positions when within 1 km of vessels (though this finding was based on a small effect size) and they associated more tightly with their mother when within 5 km of vessels. The full spatial extent of the latter finding may be a modelling artefact and the effect may only extend to <3 km from a vessel. Additional focal follow surveys are required to increase sample size, thereby allowing for a more robust analysis.

- Group formation: Narwhal groups were shown to alter their group formation when in close proximity to vessels, with the majority of group types decreasing the proportion of time that they spend in parallel formation when within 1 to 3 km of vessels. Conversely, mother-immature pairs were the only group type to increase the proportion of time that they spend in parallel formation when within 2 km of vessels, however the effect size was small. These results were based on a limited sample size and should therefore be interpreted with caution. As discussed in Section 3.0, a change in group cohesion (e.g., change in group formation) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect (i.e., change in group formation within 3 km of a vessel), this finding was not anticipated to result in a biologically significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 21 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

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

- Group size: Of the different narwhal group types, only mixed groups with immatures were shown to temporarily associate in slightly larger groups when within 4 km of vessels. For the other group types, effect sizes were small and did not suggest a biologically significant effect. While mother-immature pairs had a large effect size, data in close proximity to vessels were limited, and additional focal follow surveys are recommended to increase sample size. As discussed in Section 3.0, a change in group cohesion (e.g., change in group size) by narwhal would be consistent with a moderate severity behavioural response.

Given the temporary nature of the effect evident for only mixed groups with immatures (i.e., increase in group size when within 4 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 28 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

- Group travel speed: Narwhal did not significantly alter their travel speed in response to vessel traffic. As discussed in Section 3.0, a change in energy expenditure (e.g., change in travel speed) by narwhal would be consistent with a moderate severity behavioural response, though no such change was evident. The lack of response was supportive of impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

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ᐋᒻᒫᓯ 2022-ᒥ, WSP ᑲᓇᑕᒃᑯᑦ ᑎᒥᖁᑖ, ᑭᒡᒐᖅᑐᖅᓱᑎᒃ ᐸᕙᓈᓐ ᓴᕕᑦᓴᖕᒥᒃ ᐅᓴᕋᖕᓂᐊᖅᑎᒃᑯᑦ (ᐹᕙᓈᓐᓂᕆᔩᒃᑯᑦ), ᐱᓕᕆᓚᐅᖅᐳᑦ ᐃᓗᕕᓕᖕᒥ ᓄᓇᒦᕐᓱᑎᒃ ᖃᐅᔨᓴᕐᓂᕐᒥᒃ ᐱᓕᕆᐊᕐᔪᒥ ('ᐱᓕᕆᐊᖅ'), ᓯᓚᒥ-ᑐᙵᕕᓕᖕᒥᒃ ᖃᐅᔨᓴᕐᓂᖅᑲᓚᐅᖅᑐᑦ ᐊᕐᕌᒍᑕᒫᑦ 2014-ᒥᓂᒃ (ᐱᖃᓯᐅᑎᖕᒋᕐᓱᒍ 2018) ᐱᔾᔪᑎᒋᓪᓗᓂᔾᔪᒃ ᖃᐅᔨᓴᖅᓯᓂᕐᒥᒃ ᕿᓚᓗᒐᕐᓂᒃ ᑭᐅᓂᕆᔭᖕᒋᓐᓂᒃ ᐹᕙᓈᓐᑯᑦ ᐊᐅᓪᓚᖅᑎᑦᑎᑲᑕᒃᑎᓪᓗᒋᑦ ᐱᓕᕆᐊᖑᕙᒃᑐᑎᒍᑦ ᐅᒥᐊᕐᔪᐊᒃᑰᖅᑎᑦᑎᑲᑕᒃᑎᓪᓗᒋᑦ ᕿᑭᖅᑖᓘᑉ ᐅᐊᖕᓇᖕᒑᓂ, ᓄᓇᕗᒻᒥ. ᐃᓚᒋᔭᐅᓪᓗᓂ ᐱᓕᕆᐊᒍᑦ, ᐋᖅᑭᐅᒪᔪᒃᑯᑦ ᑎᑎᕋᖅᑕᐅᕝᕚᖅᑐᑦ ᕿᓚᓗᒐᐃᑦ ᐊᒥᓲᓂᖕᒋᓐᓄᑦ ᐊᒻᒪᓗ ᓇᓅᓐᓂᖕᒋᓐᓄᑦ (RAD), ᑲᑎᙵᓪᓗᒋᑦ ᖃᓄᐃᓕᖕᖓᓂᖕᒋᑦ ᐊᒻᒪᓗ ᖃᓄᐃᓕᐅᕐᓂᖕᒋᑦ ᑲᑎᑕᐅᓚᐅᖅᑐᑦ ᐃᓈᕿᑉ ᖄᖕᖓᓂᑦ ᓇᐅᑦᑎᖅᓱᖅᑳᑦᑕᕐᓂᕐᒍᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐊᖅᑯᑎᒋᕚᒃᑖ ᐅᐊᖕᓇᒍᐊᖕᖓᔪᖅ ᐱᓕᕆᐊᒍᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖕᒋᕐᕋᓪᓗᑎᒃ ᐋᖅᑭᒃᑕᐅᓯᒪᔫᒃᑯᑦ ᕿᓚᓗᒐᕐᓄᑦ ᐃᓂᒋᔭᐅᕙᖕᓂᖕᒐᓄᑦ ᐊᐅᔭᒃᑯᑦ ᕿᙳᐊᓂ. ᐅᒥᐊᕐᔪᐊᑦ ᓇᒍᙵᖅᐸᓪᓕᐊᓂᖕᒋᑦ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ ᑎᑎᕋᖅᑕᐅᓚᐅᖅᑐᑦ ᒪᓕᒃᓱᑎᒃ ᑲᑎᓯᒪᔪᓂᒃ ᓯᒡᔭᒥ ᖃᖓᒋᑦᑕᖅᑎᑕᐅᓯᒪᔫᒃᑯᓪᓗ–ᑐᙵᕕᓕᖕᒥᒃ ᓇᓗᓇᐃᖅᓯᑲᐅᑎᒋᕙᒃᑐᒍᑦ ᐊᑐᖅᑕᐅᕙᒃᑐᒥᒃ ᐅᒥᐊᕐᔪᐊᓂᒃ ᐊᖅᑯᑎᐅᕙᒃᑐᑦ ᐊᑐᖅᑕᐅᕙᒃᑐᒥ ᐱᑎᑦᑎᔪᒪᓪᓗᑎᒃ ᖁᑦᑎᒃᑐᒦᑦᑐᒥᒃ ᐃᓂᒥᒃ ᑎᑎᕋᖅᓯᒪᔪᓂᒃ ᑕᒪᐃᓐᓄᑦ ᕿᑎᐊᓃᑦᑐᓄᑦ- (50-100–ᒦᑕᓄᑦ ᑕᑭᓂᖕᒐᓄᑦ) ᐊᖏᔫᓪᓗ (>100–ᒦᑕᓂᒃ ᑕᑭᓂᓕᖕᒥᒃ) ᐅᒥᐊᕐᔪᐊᑉ ᐃᖕᒋᕐᕋᓂᖕᒐᓂ ᕿᙳᐊᓂ. ᑎᑎᖅᑲᒃᑲᓐᓃᑦ ᑲᑎᑕᐅᓚᐅᖅᑐᑦ ᐊᕙᑎᒧᑦ ᖃᓄᐃᓕᖕᖓᓂᖕᒋᑦ ᐊᒻᒪᓗ ᐃᓄᖕᓂᙵᕐᑐᓂᒃ ᐱᓕᕆᐊᖑᔪᓂᑦ (ᓱᕐᓗ, ᐃᖕᒋᕐᕋᕝᕕᐅᑎᓪᓗᒋᑦ ᐊᒻᒪᓗ ᐊᖑᓇᓱᒃᐸᒃᑐᓐᓄᑦ) ᑐᑭᓯᓇᓱᒃᓱᑎᒃ ᐊᒃᑐᐃᔾᔪᑕᐅᑐᐃᓐᓇᕆᐊᓕᖕᓂᒃ ᐱᓕᕆᐊᒧᑦ–ᐊᒃᑐᐊᔪᓂᒃ ᐊᐅᓪᓚᖅᑎᑕᐅᔾᔪᑎᓄᑦ ᐱᓕᕆᐊᓄᑦ ᐊᒻᒪ ᐱᔾᔪᑕᐅᓲᓄᑦ ᐊᒃᑐᐃᔾᔪᑕᐅᑐᐃᓐᓇᕆᐊᖃᖅᑐᓄᑦ ᕿᓚᓗᒐᐅᑉ ᐱᐅᓯᖕᒋᑦᑎᒍᑦ.

ᐱᓕᕆᐊᖑᔪᖅ ᓇᓗᓇᐃᔭᐃᓯᒪᔪᖅ ᐱᓕᕆᐊᖑᔪᒧᑦ ᓇᓗᓇᐃᒃᑯᑦᑕᕐᓂᒃ ᐊᑐᖅᑕᐅᖁᔭᐅᓯᒪᔪᓂᒃ ᓇᐃᓴᐅᑎᓕᖕᓂᒃ 99c, 101g, 109, ᐊᒻᒪᓗ 111–ᒥᒃ, ᐊᒃᑐᐊᓂᓕᖕᓂᒃ ᖃᐅᔨᓴᖅᓯᓂᕐᒥᒃ ᐸᒡᕕᓴᒡᕕᐅᑐᐃᓐᓇᕆᐊᓕᖕᓂᒃ ᐃᒪᕐᒥᐅᑕᓂᒃ ᐆᒪᔪᓂᒃ ᐊᐅᓪᓚᖅᑎᑦᑎᓂᐊᕐᓗᓂ ᐱᓕᕆᐊᖑᕙᒃᑐᓂᒃ ᓴᖅᑭᑦᑎᑐᐃᓐᓇᕆᐊᖃᖅᑐᓂᒃ ᐊᓯᔾᔨᕐᓂᕆᔭᐅᔪᓂᒃ ᓂᕐᔪᑎᑦ ᖃᓄᖅ ᐅᓄᖅᑎᒋᓂᖕᒋᓐᓄᑦ, ᓇᓃᐸᖕᓂᖕᒋᓐᓄᑦ, ᐃᓕᖅᑯᓯᕆᕙᒃᑕᖕᒋᓐᓄᓪᓗ ᑖᕙᓂ ᐱᓕᕆᐊᕐᔪᒥ ᐊᕕᒃᓯᒪᓂᕐᒥ ᖃᐅᔨᓴᕐᕕᒋᔭᐅᔪᒥ ᐃᓂᒥ. 2022-ᒥ ᐃᓗᕕᓕᖕᒥ-ᑐᙵᕕᓕᒃ ᐱᓕᕆᐊᖅᔪᖅ ᑭᒡᒐᖅᑐᐃᒍᖅ 8-ᓂᒃ ᐊᕐᕌᒍᒋᓕᖅᑕᖕᒐᓂᒃ ᐊᕙᑎᑦᑎᓐᓂ ᐊᒃᑐᐃᔪᓂᒃ ᖃᐅᔨᓴᖅᓱᑎᒃ ᐱᓕᕆᐊᖑᓚᐅᖅᑐᖅ ᐃᓗᕕᓕᖕᒥ ᐃᑲᔪᖅᑐᐃᓪᓗᓂ ᓄᓖᔾᔪᖕᓂ ᐱᓕᕆᐊᖑᔪᒥᒃ.

ᐅᑯᐊ ᓇᐃᓈᖅᓯᒪᔪᑦ ᖃᐅᔨᔭᐅᓯᒪᔪᑦ ᐱᔾᔪᑎᓕᑦ ᕿᓚᓗᒐᐃᑦᑲᓄᖅ ᐱᖅᑯᓯᖃᖃᑦᑕᕐᓂᖕᒋᑦ ᐅᒥᐊᕐᔪᐊᑦᑲᖅᑎᓪᓗᒍᑦ ᐃᓗᕕᓕᖕᒥᑦ ᐊᕐᕌᒍᑦ 8 ᖃᐅᔨᓴᖅᑎᓪᓗᒋᑦ:

## ᖃᓄᖅ ᐅᓄᖅᑎᒋᓂᖕᒋᑦ ᓇᓃᐸᖕᓂᖕᒋᓪᓗ

- ᐊᕐᕌᒎᑉ ᐃᓗᐊᓂ ᐊᓯᔾᔨᖅᑕᕐᓂᕆᕙᒃᑕᖕᒋᑦ ᐅᓄᕐᓂᖕᒋᑕ: ᖃᓄᖅ ᐅᓄᖅᑎᒋᓂᖕᒋᑦ ᕿᓚᓗᒐᐃᑦ (ᑲᑎᖕᒍᒋᑦᕿᓚᓗᒐᐃᑦ ᐋᖅᑭᒋᐊᖅᑕᐅᓯᒪᔪᑦ ᖃᐅᔨᓴᖅᑕᐅᓇᓱᒃᑐᑦ ᐅᓄᖅᑎᒋᓂᖃᖅᑕᐅᖕᒋᑦ) ᐊᕕᒃᑐᖅᓯᒪᔪᑦ ᖃᐅᔨᓴᕝᕕᐅᔪᓂ (SSA) ᖁᑦᑎᖕᓂᖅᓴᐅᓚᐅᖅᑐᖅ 2022–ᒥ (84.9) 2020 ᐊᒻᒪᓗ 2021–ᒥ (47.5 ᐊᒻᒪᓗ 29.4, ᐊᑐᓂ) 2015–ᒥᓪᓗ ᑐᙵᕕᒋᔭᖕᒐᓄᑦ (ᓯᕗᓪᓕᕐᒥ ᐊᕐᕌᒍᒥ ᐊᐅᓚᓂᕆᔭᐅᔪᑦ; 98.2). ᑭᓯᐊᓂᓕ, ~~ᑑᒐᓖᑦ~~ ᕿᓚᓗᒐᐃᑦ ᐊᒥᓲᓂᖕᒋᑦ 2022–ᒥ (84.9) ᐅᓄᙱᓐᓂᖅᓴᐅᓚᐅᖅᑐᑦ 2014–ᒥ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᓯᒪᔪᒥᑦ (131.4) ᐊᒻᒪᓗ ᐅᓄᙱᓐᓂᖅᓴᐅᓪᓗᑎᒃ ᖃᐅᔨᔭᐅᓚᐅᖅᓯᒪᔪᓂᑦ 2016 (178.0), 2017 (121.8) ᐊᒻᒪᓗ 2019–ᒥ (127.2). ᑖᒃᑯᐊ ᖃᐅᔨᔭᐅᔪᑦ ᓇᓗᓇᐃᖅᓯᕗᑦ ᕿᓚᓗᒐᐃᑦ ᖃᔅᓯᐅᓂᖕᒋᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥ ᐅᓄᖅᓯᕚᓪᓕᖅᓯᒪᖅᑰᔨᓂᖕᒋᓐᓂᒃ ᖃᐅᔨᔭᐅᓚᐅᖅᑐᑦ 2020/2021–ᒥ ᑭᓯᐊᓂᓕ ᖃᐅᔨᔭᐅᓚᐅᙱᑦᑐᑦ ᓯᕗᓪᓕᖅᐹᒥ ᐅᒥᐊᕐᔪᐊᖃᓕᖅᑎᓪᓗᒋᑦ (2016, 2017). ᑲᑎᕐᒍᒋᑦ 2014–ᒥᑦ 2022–ᒧᑦ ᖃᐅᔨᓴᒐᒃᓴᓂᑦ, ᐊᐃᑉᐸᕆᓕᖅᑕᖓ ᐊᒥᓲᓖᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᔪᖅ ᐃᓗᕕᓕᖕᒥᑦ ᑕᑯᔭᐅᓚᐅᖅᑐᑦ 2019–ᒥ, ᐊᐅᓪᓚᖅᑎᑕᐅᓂᖕᒋᑦ ᖁᑦᑎᓖᖑᑎᓪᓗᒋᑦ ᐱᓕᕆᐊᓄᓪᓗ ᓯᑯᐃᕈᑎᓪᓗᑎᒃ ᐱᒋᐊᖕᓂᖕᒐᓂᑦ ᑐᐃᒃᑯᑦ ᐱᖕᒐᔪᖕᒐᓐᓂᑦ ᐊᕐᕌᒍᒥᑦ (2018–ᒥᑦ 2020–ᒧᑦ). ᐊᔾᔨᒋᖕᒋᕐᓱᓂᐅᒃ, ᐊᑦᑎᖏᑦ ᖃᔅᓯᐅᓇᓱᒋᔭᐅᔪᑦ ᐃᓗᕕᓕᖕᒥ ᑎᑎᕋᖅᑕᐅᓚᐅᖅᑐᑦ 2020–ᒥ 2021–ᒥᓗ, ᐊᐅᓪᓚᖅᑎᑕᐅᔪᑦ ᐅᓄᕐᓂᖕᒋᑦ 2016–ᒥ ᐊᔾᔨᕌᐸᓗᓚᐅᖅᑐᑦ. ᓯᑯᓂᒃ ᓯᖁᑦᑎᕆᔭᕆᐊᖃᓚᐅᖅᑐᑦ 2020ᒥ ᐱᒋᐋᓴᖅᑎᓪᓗᒍ ᐅᒥᐊᕐᔪᐊᒃᑯᑦ ᐅᓯᒃᖃᑦᑕᕐᓂᖅ ᑭᓯᐊᓂ ᓯᑯᓂᒃ ᐱᓕᕆᕝᕕᐅᔪᒥ 2021–ᒥ ᓯᑯᓂᒃ ᓯᖁᑦᑎᕆᓚᐅᖕᒋᑦᑐᑦ. ᑖᒃᑯᐊ ᖃᐅᔨᔭᐅᔪᑦ ᓇᓗᓇᐃᖅᓯᕗᑦ ᐊᕐᕌᒍᓕᒫᒧᑦ ᐊᖕᒋᓂᖓ ᐱᓕᕆᐊᒧᑦ ᐊᐅᓪᓚᖅᑎᑕᐅᔪᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥ ᓇᓚᐅᑦᑖᕆᑕᐅᓱᖑᙱᑦᑐᑦ ᐅᓄᕐᓂᖕᒋᓐᓂᒃ ᕿᓚᓗᒐᐃᑦ ᐃᓗᕕᓕᖕᒥ ᑕᐃᑲᓂ ᐊᕐᕌᒍᒥ. 2022–ᒥ ᖃᐅᔨᓴᕈᑎᕕᓃᑦ ᐃᑲᔪᖅᑐᐃᒍᑦ ᐃᓯᒪᕆᔭᐅᔪᒥᒃ ᐃᓚᖕᒋᑦ ᓄᓇᒦᙵᕐᑐᑦ

ᑕᐅᖅᓰᔾᔪᑕᐅᑐᐃᓐᓇᕆᐊᖃᕐᓂᖅᑎᓐᓂᒃ ᒪᕐᕈᒃ ᕿᑲᓗᒐᖃᕐᕕᐅᓇᓱᒋᔭᐅᔪᒃ ᐊᐅᔭᒃᑯᑦ ᐊᒻᒪᓗ, ᐊᐅᓪᓚᖅᑎᑕᐅᔪᓐᓇᙱᕐᓗᑎᒃ ᐱᔾᔪᑕᐅᓗᓂ, ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᓯᐊᒻᒪᒃᑎᖅᑕᐅᓂᖏᑦ ᓃᒃᑕᕐᓂᖏᓐᓄᑦᑐ ᑑᓚᓖᑦ ᕿᑭᖅᑖᓘᑉ ᐅᐊᖕᓇᖕᒪᓂ ᐊᐅᔭᒃᑯᑦ ᐊᒃᑐᖅᑕᐅᑐᐃᓐᓇᕆᐊᖃᓚᐅᖅᑐᑦ ᐊᓯᖏᓐᓄᑦ ᓯᓚᑖᓃᑦᑐᓄᑦ ᐱᔾᔪᑕᐅᓲᓄᑦ (ᓱᕐᓗ, ᓄᓇᓕᖕᓂ ᓯᑯᐃᑦ ᖃᓄᐃᓕᖕᒪᓂᖏᑦ, ᐃᒪᐅᑉ ᐆᓇᕐᓂᖕᒪ, ᕿᓚᓗᒐᓱᐊᖅᐸᒃᑐᓄᑦ ᓂᕐᔪᑎᓄᑦ ᐊᑐᐃᓐᓇᐅᓂᖏᑦ, ᐊᓯᖏᓪᓗ).

■ ᐅᓄᕐᓂᖏᑦ: ᐅᒥᐊᕐᔪᐊᒥᑦ ᓴᖅᑮᔭᕐᓂᖕᒪ ᑕᑯᓵᐅᑎᑕᐅᓚᐅᖅᑐᖅ ᑭᓪᓕᓯᓂᐊᖅᑕᐅᓯᒪᔪᓂᑦ ᖃᔅᓰᓐᓇᕈᖅᐸᓪᓚᐊᓂᖏᓐᓄᑦ ᑐᓚᓖᑦ ᐊᒥᓲᓂᖏᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᑦ ᖃᐅᔨᓴᕐᕕᖕᒥᑦ ᑕᑯᓪᓗᒍ ᐅᒥᐊᕐᔪᐊᖅᑕᕐᑲᖅᑎᓐᓇᒍ, ᑭᓯᐊᓂ ᑐᓚᓖᑦ ᖃᓂᒃᓴᓚᐅᖅᑐᑦ (≤2 km) ᑎᑭᕐᑲᑦᑕᖅᑐᑦ ᐅᐊᓐᓇᖅᐸᓯᖕᒍᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ, ᑭᖑᓂᖕᒐᒍᑦ ᑐᓚᓖᑦ ᐊᒥᓲᓂᖏᑦ ᑕᑯᒃᓴᐅᓚᐅᖅᑐᑦ ᐅᓄᖅᓯᒃᑲᓂᕐᓂᖏᓐᓄᑦ ᐅᑭᐅᑕᖅᑐᒥᑦ ᐅᒥᐊᑦ ᐃᖏᕋᓯᔪᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᑦ ᖃᐅᔨᓴᖅᑕᐅᕕᖕᓂᑦ (ᓲᕐᓗ, ᐊᑐᓚᐅᑲᖕᓂᐊᖅᑐᓂᑦ). ᑖᓐᓇ ᐊᔾᔨᖃᐸᓗᓚᐅᖅᑐᖅ ᐊᖏᓛᖑᔪᓐᓇᖅᑐᒧᑦ 14 ᒥᓂᕐᒥ ᐊᑕᐅᓯᕐᒧᑦ ᐅᒥᐊᕐᔪᐊᒧᑦ ᐃᖏᕋᓂᕐᒥ (ᑐᙵᕕᒋᓪᓗᒍ 9-ᑭᓛᒥᑕᓄᑦ ᐃᖏᕋᓂᕐᒧᑦ ᓱᒃᑲᓂᖕᒐ, ᐃᓱᒪᒋᓗᒍ ᑑᓚᓖᑦ ᐃᓂᖃᐃᓐᓇᕐᓗᑎᒃ ᓴᖅᑮᖅᑎᓪᓗᒋᑦ), ᓂᕐᔪᑎᑦ ᐅᑎᕐᓗᑎᒃ ᑭᐅᒋᐊᓚᐅᙱᑎᓪᓗᒋᑦ ᐃᓕᖅᑯᓯᖏᓐᓂ ᑭᖑᓂᐊᒍᑦ ᓯᕗᓪᓕᕐᒥ ᐅᒥᐊᑉ ᓴᖅᑮᔭᕐᓂᖕᒪ (ᓲᕐᓗ, ᐊᒃᑑᑎᓚᐅᑲᖕᓂᕐᑲᕐᓗᓂ). 2022–ᒥᑦ ᐱᓕᕆᐊᒃᓴᒥᑦ (31 ᔪᓚᐃᒥᑦ 23–ᒧᑦ ᐋᒡᒌᓯᑦ), ᒪᕐᕉᖕᓂᒃ ᐅᒥᐊᕐᔪᐊᒃᑯᑦ ᐅᓯᔪᖅᑲᖅᑲᑦᑕᓚᐅᖅᐳᖅ ᐅᓪᓗᖅ ᐊᑕᐅᓯᖅ ᐊᕕᒃᑐᖅᓯᒪᔪᑦ ᖃᐅᔨᓴᕐᕕ–ᒥᑦ (56–ᖏᖅᓱᖅᓗᑎᒃ ᐃᖏᕋᓪᓗᑎᒃ ᐊᕕᒃᑐᖅᓯᒪᔪᑦ ᖃᐅᔨᓴᕐᕕ–ᒥᑦ ᐅᓪᓗᓄᑦ 24–ᓄᑦ). ᑕᐃᒪᐃᒻᒪᑦ, ᐊᖏᓛᖑᔪᖅ ᐅᓪᓗᖅ ᐊᑕᐅᓯᖅ ᐊᒃᑐᐊᓂᓕᒃ ᐅᒥᐊᕐᔪᐊᒧᑦ ᐸᕝᕕᓵᖅᑕᐅᓂᕐᒧᑦ ᑑᓚᓖᑦ ᐅᓄᕐᓂᖏᓐᓄᑦ 28 ᒥᓂᓪᓄᒃ. ᑖᒃᑯᐊ ᖃᐅᔨᔭᐅᔪᑦ ᒪᓕᓚᐅᖅᐳᑦ ᐊᕐᕌᒍᓂ ᐊᓂᒍᖅᑐᓂᒃ ᖃᐅᔨᔭᐅᓚᐅᖅᑐᓂᒃ ᐊᒻᒪ ᐱᐅᓯᕆᔭᐅᔪᓂᒃ ᓴᖅᑭᑦᑐᓂᒃ ᑑᓚᓖᑦ ᓂᕕᖓᓛᓕᒃᑯᑦ ᖃᐅᔨᓴᖅᑕᐅᔪᓂᒃ (ᒎᑦ 2020a), ᓇᓗᓇᐃᖅᓯᓪᓗᑎᒃ ᑑᓚᓖᑦ ᐅᓄᕐᓂᖏᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᑦ ᖃᐅᔨᓴᕐᕕ–ᒥ ᐊᒃᑐᐃᔾᔪᑕᐅᓚᐅᑲᓚᐅᖅᐳᑦ ᐅᒥᐊᒃᑯᑦ ᐃᖏᕋᔪᓄᑦ, ᑭᓯᐊᓂ ᑭᒡᓕᖅᑲᖅᑎᑕᐅᓚᐅᖅᑐᖅ ᐅᖓᓯᒋᒐᓗᐊᖅᓗᒍ (ᓲᕐᓗ, 2 ᑭᓚᕖᑕᓂᒃ ᐅᖓᓯᖕᓂᓕᒃ ᐅᑭᐅᖅᑕᖅᑑᑉ ᑭᒡᓕᖕᒐᓂ). ᓄᓇᓕᖕᓂᙳᖅᑐᑦ ᓂᐱᖃᐅᑎᑦ (ᓲᕐᓗ ᐅᒥᐊᕐᔪᐊᖅ) ᑑᓚᓕᖕᓄᑦ ᒪᓕᓚᐅᖅᐳᖅ ᓈᒻᒪᒃᑐᒧᑦ ᐱᐅᓯᕐᒧᑦ (ᓂᒋᖅᐸᓯᖕᒥ et al. 2021). ᑭᓯᐊᓂᓕ, ᐊᑐᓚᐅᑲᑐᐃᓐᓇᖅᑎᓪᓗᒍ (ᓲᕐᓗ, 14 ᒥᓂᑦᒧᑦ ᑎᑭᓪᓗᒍ ᐊᑕᐅᓯᖅ ᐅᒥᐊᖅ ᐃᖏᕋᑎᓪᓗᒍ), ᑖᓐᓇ ᐃᓱᒪᒋᔭᐅᓇᔭᙱᑦᑐᖅ ᐆᒪᔪᓂᙳᖅᑐᓂᒃ ᐃᓕᖅᑯᓯᖃᕐᓂᖕᒪᓂᒃ ᓂᕆᐅᒋᔭᐅᓇᔭᙱᕐᓗᓂᓗ ᐊᓯᔾᔨᕐᔪᐊᕋᔭᕐᓂᖕᒪᓂᒃ ᐱᐅᓯᓇᕈᑕᖏᑦ ᑑᓚᓖᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᒃ–ᒥ ᐅᕝᕙᓘᓐᓃᑦ ᖃᐅᑕᒫᑦ ᐱᐅᓯᕈᑕᖏᓐᓄᑦ ᐅᓚᕕᓴᖅᑕᐅᓇᔭᙱᕐᓗᓂ. ᑕᐃᒪᐃᓐᓂᖕᒐᓄᑦ, ᐊᒃᑐᖅᑕᐅᓂᐊᕋᓱᒋᔭᐅᓚᐅᙱᑦᑐᑦ ᐃᓅᑉ ᑎᒥᖕᒐᓄᑦ ᐊᒻᒪ/ᐅᕝᕙᓘᓐᓃᑦ ᐱᕐᔪᐊᖑᑦᑐᑎᒃ ᐅᓄᕐᓂᖏᑦ ᑑᓚᓖᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᒃ, ᐊᒃᑐᐃᔾᔪᑕᐅᑐᐃᓐᓇᕆᐊᖃᕐᓗᑎᒃ ᐃᓄᒋᐊᖕᓂᖏᑦᑕ ᑭᒡᓕᖏᓐᓄᑦ. ᑖᓐᓇ ᑭᐅᔾᔪᑕᐅᔪᖅ ᒪᓕᓚᐅᖅᐳᖅ ᐊᒃᑐᐃᓂᐊᕋᓱᒋᔭᐅᔪᓂᒃ ᑭᖑᓪᓕᖅᐹᒥ ᐊᕙᑎᑎᓐᓂ ᐊᒃᑐᐃᔪᓂᒃ ᑎᑎᕋᖅᓯᒪᔪᓂᒃ ᖄᓇᐅᔭᓂᒃ ᐃᓱᖅᐸᓪᓕᐊᓕᕆᖅᑐᓂᒃ, ᐅᒥᐊᕐᔪᐊᒥ ᓂᐱᖅᑯᖅᑐᔪᓂᒃ ᐊᒃᑐᐃᔪᓂᒃ ᑑᓚᖕᓄᑦ ᓂᕆᐅᒋᔭᐅᓚᐅᖅᐳᑦ ᑭᒡᓕᖅᑲᖅᑎᑕᐅᓂᐊᕋᓱᒋᔭᐅᓪᓗᑎᒃ ᕿᓚᒻᒥᐅᔪᒃᑯᑦ, ᓄᓇᓕᖕᓂ ᓱᕐᑯᑎᒋᔭᐅᙱᕐᓗᑎᒃ ᐱᐅᓯᓇᔭᐅᔪᑦ.

## ᑲᑎᙵᔪᑦ ᖃᓄᐃᓕᖕᒪᓂᖏᑦ - ᐃᓕᖅᑯᓯᓇᔭᐅᓕᖅᐸᒃᑐᓄᑦ ᖃᐅᔨᓴᕐᕕᖕᓂ (BSA)

■ ᑲᑎᙵᓪᓗᑎᒃ ᖃᓄᐃᓕᖕᒪᓂᖏᑦ: ᐅᓄᕐᓂᖏᑦ ᑑᓚᓖᑦ ᕿᑲᓗᒐᐃᑦ ᐱᐅᓯᓇᔭᐅᔪᒥᒃ ᖃᐅᔨᓴᕐᓂᖅ-ᒥ 2022-ᒥ ᐊᐃᑉᐸᓇᔭᐅᓚᐅᖅᐳᖅ ᖁᑦᑎᓛᒥᒃ ᖃᐅᔨᔭᐅᓪᓗᓂ ᑕᐃᒪᙵᓪᓚᑦ 8-ᓄᑦ ᐊᕐᕌᒍᓄᑦ ᖃᐅᔨᓴᓯᒋᐊᓚᐅᖅᑎᓪᓗᒋᑦ, 1,523-ᖑᓪᓗᑎᒃ ᑑᓚᓖ (5,864-ᖑᓪᓗᑎᒃ ᐃᓄᐃᑦ) ᑎᑎᖅᑕᐅᔪᑦ. ᑑᓚᓖᑦ ᐆᒪᔪᓐᓇᕐᓂᓕᒫᖏᑦ (ᐃᓐᓇᑦ, ᐱᕈᓃᖅᓯᒪᙱᑦᑐᑦ, ᐊᕗᑎᓵᕐᓂᑯᑦ, ᒫᕋᓛᓪᓗ) ᑎᑎᖅᑕᐅᓚᐅᖅᐳᑦ ᐱᐅᓯᓇᔭᐅᔪᒥᒃ ᖃᐅᔨᓴᕐᓂᖅ–ᒥᑦ ᐊᕐᕌᒍᓄᑦ 8–ᓄᑦ ᖃᐅᔨᓴᒐᒃᓴᓂᑦ, ᐊᒥᓲᓂᕐᓴᐃᑦ ᑕᑯᔭᐅᓪᓗᑎᒃ ᐃᓐᓇᐃᑦ ᑑᓚᓖᑦ, ᑭᖑᓂᐊᒍᓪᓗ ᐱᕈᓃᖅᓯᒪᙱᑦᑐᑦ, ᒫᕋᓛᑦ, ᐊᕗᑎᓵᕐᓂᑯᓪᓗ.

■ ᐃᓚᖏᑦ ᐱᓗᐊᙳᐊᖅᑐᑦ (ᖃᐅᔨᓵᓕᓯᒪᔭᖅᑲᓇᐊᓕᑦ ᓇᓗᓇᐃᖅᓯᔾᔪᑎᑦ): ᖃᐅᔨᔭᐅᔪᑦ ᑲᑎᕝᓗᒋᑦ ᐊᕐᕌᒍᓴᖕᓄᑦ ᑎᑎᖅᑲᖅᓯᒪᔪᑦ ᓇᓗᓇᐃᖅᓯᕗᑦ ᐃᓚᖏᑦ ᑑᓚᓖᑦ ᑕᑯᔭᐅᓚᐅᖅᑐᑦ ᐱᐅᓯᓇᔭᐅᔪᒥᒃ ᖃᐅᔨᓴᕐᓂᕐᒥᒃ 2022-ᒥ (0.105) ᐅᔾᔨᕐᓇᖅᑐᒥᒃ ᐅᓄᖏᓐᓂᖅᓴᐅᓕᖅᑐᑦ 2014/2015-ᒥ ᑐᙵᕕᖕᒐᑕ ᖃᓄᐃᓕᖕᒪᓂᖕᒪᓂᒃ (0.152-ᒥ 2014-ᒥ ᐊᒻᒪᓗ 0.167-ᒥ 2015-ᒥ). ᑖᓐᓇ ᐊᔾᔨᐸᓗᒋᓚᐅᖅᐸᖕᒪ 2021-ᒥ ᖃᐅᔨᓵᓕᓯᒪᔭᖅᑲᓇᐊᓕᑦ ᓇᓗᓇᐃᖅᓯᔾᔪᑎᒧᑦ ᖃᓄᐃᓕᖕᒪᓕᕐᓂᓇᔭᐅᓚᐅᖅᑐᓄᑦ, ᐃᓚᖕᒪᓗ ᐃᓚᖕᒪ ᑑᓚᓖᑦ ᖃᐅᔨᔭᐅᓚᐅᖅᑐᑦ ᐱᐅᓯᓇᔭᐅᔪᒥᒃ ᖃᐅᔨᓴᕐᓂᖅ–ᒥ 2021–ᒥ (0.102) ᐅᔾᔨᕐᓇᖅᑐᒻᒪᓇᖕᒥ ᐊᑦᑎᖕᓂᖅᓴᒻᒪᓇᐅᓚᐅᖅᐳᖅ 2014/2015–ᒥ ᑭᒡᓕᒋᔭᖕᒪᑕ ᖃᓄᐃᓕᖕᒪᓂᖕᒪᓂᒃ. 2021, 2022–ᒥᓪᓗ ᖃᓄᐃᓕᖕᒪᓕᕐᓂᖏᑦ ᓇᓗᓇᐃᖅᓯᔾᔪᑦ ᖄᖏᐅᑎᓂᖏᓐᓂᒃ ᐊᑦᑕᕐᓇᑐᐃᓐᓇᕆᐊᓕᖕᒧᑦ ᑭᒡᓕᒋᑎᑕᐅᔪᒧᑦ ᑖᔅᓯᒧᖕᒪ ᓇᓗᓇᐃᖅᓯᔾᔪᑎᒧᑦ, ᒪᓕᒡᓗᒍ ᐱᒋᐊᖅᑎᑦᑎᓂᕐᒧᑦ ᐸᕐᓇᐅᑎ (TARP)

ᐃᒪᕐᒥᐅᑕᓄᑦ ᐆᒪᔪᓄᑦ ᓇᓗᓇᐃᖅᓯᒪᔪᑦ ᐃᒪᕐᒥᐅᑕᓂᒃ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐸᕐᓇᐅᑎᒥᒃ (ᑕᕆᐅᒥ ᖃᐅᔨᓴᖅᐸᓪᓕᐊᖏᓐᓇᕐᓂᕐᒧᑦ ᐸᕐᓇᐅᑏᑦ; ᐹᕚᓖᓐ 2022c), ᐊᑦᑕᕐᓇᖕᓂᖕᒐᓪᓗ ᖃᓄᐃᓕᖓᓂᖓ/ᐅᑎᕐᑎᑕᐅᔪᓐᓇᖕᓂᖓ ᖃᐅᔨᔭᐅᓯᒪᓕᖅᑐᖅ ᐊᕐᕌᒎᖕᓄ ᒫᕐᕉᖕᓄᑦ ᑭᖑᓕᕇᓄᑦ ᖃᐅᔨᓴᖕᓂᖕᓄᑦ. ᓇᓗᓇᐃᖅᑕᐅᕙᓕᖅᓯᒪᔪᑦ ᑭᐅᔾᔪᑕᐅᔪᑦ ᖃᖏᐅᑎᔪᓄᑦ ᐊᑦᑕᕐᓇᖅᑐᓄᑦ ᓇᓗᓇᐃᖅᓯᔾᔪᑎᓄᑦ ᐅᑯᓂᖓ ᐃᓚᖃᖅᐳᑦ: 1) ᖃᐅᔨᓴᕐᓗᒋᑦ ᖃᓄᐃᓕᕚᓪᓕᐊᓂᕆᔭᐅᔪᑦ ᖃᑯᙳᖅᐸᓪᓕᐊᑎᓪᓗᒍ ᐃᓱᒪᒋᓗᒋᓪᓗ ᖃᓄᑐᐃᓐᓇᖅ ᓇᓗᓈᕿᔪᑦ (ᓲᕐᓗ, ᐊᓯᔾᔨᖅᑐᑦ ᐊᐅᓚᑦᑎᔾᔪᑎᓄᑦ ᐱᕙᓪᓕᐊᓂᐅᔪᑦ, ᓇᑭᙵᕈᓐᓇᖅᑐᑦ, ᐊᒃᑐᐃᔾᔪᑕᐅᑐᐃᓐᓇᕆᐊᓖᑦ) ᑭᐅᔾᔪᑕᐅᔪᓄᑦ ᐸᕐᓇᐅᑎᒧᑦ; ᐊᒻᒪᓗ 2) ᐱᒋᐊᖅᑎᑦᑎᓗᑎᒃ ᐃᓗᓕᕆᓐᓂᒃ ᑐᕌᕆᔭᐅᔪᓂᒃ ᖃᐅᔨᓴᕐᓂᕆᔭᐅᔪᓂᒃ ᑕᒪᓐᓇ ᐃᓚᒋᔭᐅᑎᑕᐅᓗᓂ ᑭᐅᓯᓂᕐᒧᑦ ᐱᕚᓕᔭᕐᓂᕐᒥ. ᑐᙵᕕᒋᓪᓗᒍ ᖃᐅᔨᓴᖅᑕᐅᓵᓚᐅᖅᑐᑦ ᑑᓕᓖᑦ, ᓄᓘᔭᓕᕆᔮᒃᑯᑦ ᐋᖅᑭᐊᖅᓯᓚᐅᖅᐳᑦ ᐊᑐᓕᖅᑎᑦᑎᓪᓗᑎᒡᓗ 2022-ᒥ ᑑᓕᓖᑦ ᓲᕐᒋᐅᓴᓂᕐᕆᓐᓄᑦ ᐊᐅᓚᑦᑎᓂᕐᒧᑦ ᐸᕐᓇᐅᑎᒥᒃ (ᐋᖅᑭᒡᕕᖃᐃᓐᓇᖅᑐᒥᒃ ᐊᐅᓚᑦᑎᓂᕐᒧᑦ ᐸᕐᓇᐅᑏᑦ; ᐹᕚᓖᓐ 2022), ᐃᓚᖃᓚᐅᖅᑐᑦ ᖃᐅᔨᓴᒃᑲᓐᓂᖕᓂᖕᓂᑦ ᐃᓚᖃᖅᖢᑎᒃ ᖃᐅᔨᓵᓕᓯᒪᔭᖃᕆᐊᓕᑦ ᓇᓗᓇᐃᖅᓯᒪᔾᔪᑎᑦ ᖃᐅᔨᓴᖕᓂᖕᒥᑦ 2020−ᒥᑦ 2022−ᒧᑦ ᖃᖓᑕᓲᒃᑯᑦ ᓇᐃᓴᐃᔾᔪᑎᕕᓂᖕᓂᑦ ᐊᑐᖅᖢᑎᒃ 1,000−ᓂᑦ−ᐃᓯᒐᓂᑦ (305 m) ᖃᖓᑕᓲᒃᑯᑦ ᓇᐃᓴᐃᔾᔪᑎᕕᓂᖕᓂᑦ. ᖃᐅᔨᔭᐅᔪᑦ ᖃᖓᑕᓲᒃᑯᑦ ᖃᐅᔮᓴᓕᓯᒪᔭᕆᐊᓕᑦ ᓇᓗᓴᐃᖅᓯᓂᕐᒥ ᓇᓗᓇᐃᖅᓯᓚᐅᖅᐳᑦ ᐃᓚᖏᑦ 2014/2015−ᒥ ᑐᙵᕕᖓᑕ ᖃᓄᐃᓕᖓᓂᖓ (0.150−ᒥ ᑕᓯᐅᔭᕐᒥ 2022−ᒥ (0.124) 2014/2015−ᒥ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᓯᒪᙱᒃᑲᓗᐊᖅᖢᑎᒃ 2014/2015−ᒥ ᖃᖓᑕᓲᒃᑯᑦ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᓯᒪᙱᕐᖢᑎᒃ. ᑕᒪᕐᒥᒃ ᐃᓗᕕᓕᖕᒥᑦ ᐊᒻᒪᓗ ᖃᖓᑕᓲᒃᑯᑦ−ᑐᙵᕕᓖᑦ ᖃᐅᔮᓕᓯᒪᔭᖃᕆᐊᓕᑦ ᓇᓗᓇᐃᖅᓯᔾᔪᑎᒧᑦ ᑎᑎᕋᖅᓯᒪᔪᑦ ᐊᒃᑐᐊᓂᖃᓚᐅᖅᐳᑦ ᐊᔾᔨᒌᙱᕐᔪᐊᖅᑐᓄᑦ ᐊᒻᒪ ᐊᑦᑎᒃᑐᓄᑦ ᖃᐅᔨᓴᒃᓴᓄᑦ ᐊᖏᓂᖏᓐᓄᑦ, ᓇᓗᓇᖅᑐᒦᔾᔪᑕᐅᕐᔪᐊᖅᓱᓂ ᖃᐅᔮᓕᓯᒪᖃᕆᐊᓕᑦ ᓇᓗᓇᐃᖅᓯᓂᕐᒧᑦ ᒥᒃᓴᐅᑎᓯᒪᔪᓂᒃ. ᓇᐃᓈᕐᓗᒍ, ᖃᐅᔮᓕᓯᒪᔭᖃᕆᐊᓕᑦ ᓇᓗᓇᐃᖅᓯᔾᔪᑎᑯᑦ ᑎᑎᕋᖅᓯᒪᔪᑦ ᑲᑎᑕᐅᔪᑦ ᐃᓗᕕᓕᖕᒥᑦ ᓄᓇᓕᖕᓂᙳᖅᑐᓂᒃ ᐊᓯᔾᔨᕐᑯᔨᓚᐅᖅᐳᑦ ᑑᓕᓖᑦ ᖃᓄᐃᓕᖓᓂᕆᓐᓂᒃ, ᐊᔾᔨᐸᓗᖕᒋᑦ ᖃᐅᔮᓕᓯᒪᔭᖃᕆᐊᓕᑦ ᓇᓗᓇᐃᖅᓯᓂᒃᑯᑦ ᖃᐅᔨᓴᕈᑎᖕᒋᑦ ᐱᔭᐅᓚᐅᖅᑐᑦ ᖃᖓᑕᓲᒃᑯᑦ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᑐᑦ ᑎᑎᕋᖅᓯᒪᔪᑦ ᓇᓗᓇᐃᖅᓯᓚᐅᙱᕐᖢᑎᒃ ᐃᓚᖏᑦ ᑑᓕᓖᑦ ᐅᓄᕈᓐᓃᖅᐸᓪᓕᕐᓂᖕᒋᓐᓂᒃ ᐊᖏᓂᖅᓴᒥ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᒃ−ᒥ ᑕᐃᒪᙵᑦ ᐅᒥᐊᕐᔪᐊᒃᑯᑦ ᐊᐅᓪᓚᖅᑎᑦᑎᖃᑦᑕᓯᒋᐊᓚᐅᖅᑎᓪᓗᒋᑦ (2014/2015). ᑲᔪᓰᓐᓇᖅᑐᖅ ᖃᐅᔮᓕᓯᒪᔭᕆᐊᓕᑦ ᓇᓗᓇᐃᒃᑯᑕᕐᒧᑦ ᓇᐅᑦᑎᖅᓱᖅᓯᓂᖅ ᐅᑯᑎᒎᓇᖅ, ᑕᒪᐃᖕᓄᑦ ᐃᓗᕕᓕᖕᒧᑦ ᓯᓪᔭᒥ−ᑐᙵᕕᓕᖕᒥᒃ ᓇᐅᑦᑎᖅᓱᖅᓯᓂᕐᒧᑦ ᐱᓕᕆᐊᖑᕙᒃᑐᑎᒧᑦ ᐃᒪᕐᒥᐅᑕᓂᓪᓗ ᐆᒪᔪᓂᒃ ᑎᕐᒥᓲᒃᑯᑦ ᖃᐅᔨᓴᖅᓯᓂᕐᒧᑦ ᐱᓕᕆᐊᖑᕙᒃᑐᒥᒃ ᑕᒪᓐᓇ ᑕᐃᒪᐃᕐᑯᔭᐅᕝᕙᖅ.

ᐅᑯᐊ ᓇᐃᓈᖅᓯᒪᔪᑦ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᑎᓪᓗᒋᑦ ᖃᐅᔨᔭᐅᓚᐅᖅᑐᑦ ᑲᑎᕐᖢᒋᑦ ᐊᕐᕌᒍᓄᑦ ᐅᓄᖅᑐᓄᑦ (2020-2022) ᖃᖓᑕᓲᕿᓖᑦ ᐊᔾᔨᓕᐅᕈᑎᓖᑦ ᐊᐅᓚᑕᐅᔪᓐᓇᖅᑐᑦ ᑎᑎᕋᖅᓯᒪᔪᑦ ᖃᐅᔨᓴᖅᑕᐅᓂᑯᑦ:

## ᐃᓕᖅᑯᓯᕆᔭᐅᓕᖅᐸᒃᑐᑦ - ᖃᖓᑕᓲᕿᓖᑦ ᐊᔾᔨᓕᐅᕈᑎᓖᑦ ᐊᐅᓚᑕᐅᔪᓐᓇᖅᑐᒃᑯᖅ ᐊᑐᖅᖢᑎᒃ ᓂᕐᔪᑎᓂᒃ ᒪᓕᒃᖢᑎᒃ ᖃᐅᔨᓴᕈᑎᑦ

- ᐱᐅᓯᒋᓪᓗᐊᑕᖅᑕᖕᒋᑦ: ᖃᐅᔨᔭᐅᔪᑦ ᑐᙵᕕᖃᖅᖢᑎᒃ ᐊᕐᕌᒍᓄᑦ ᐱᖓᓱᓄᑦ ᖃᖓᑕᓲᕿᓛᑦ ᐊᔾᔨᓕᐅᕈᑎᓖᑦ ᐊᐅᓚᑕᐅᔪᓐᓇᖅᑐᒧᑦ ᑎᑎᕋᖅᓯᒪᔪᑦ ᖃᐅᔨᓴᖅᑕᐅᓂᑯᐃᑦ ᐱᑎᑦᑎᕗᖅᐳᑦ ᐊᔪᕐᓇᙱᑐᐃᓐᓇᕆᐊᓕᖕᓂᒃ, ᐊᑲᐅᙱᓕᐅᕈᑎᑕᖃᕐᓗᐊᖅᑎᓪᓗᒍ, ᐃᑲᔪᖅᑐᐃᓗᓂ ᑑᓕᖕᓄᑦ ᐱᓕᕆᖃᑎᕐᒃᐸᒃᑐᑦ ᐊᓯᔾᔨᖅᓯᑐᐃᓐᓇᕆᐊᖃᕐᓂᖕᒋᓐᓂᒃ ᖃᓄᖅ ᐊᑯᓂᐅᑎᒋᔪᖅ ᐃᓚᐅᕙᖕᒪᖕᒫᑕ ᐱᒻᒪᕆᐊᓗᖕᓄᑦ ᐱᓕᕆᐊᖑᔪᓄᑦ (ᓲᕐᓗ, ᑕᖃᐃᖅᓯᕐᓂᖅ, ᐊᓂᖅᑎᕆᓂᖅ, ᐆᒪᔩᖃᑎᒋᔭᒥᓄᑦ ᐃᓕᖅᑯᓯᕆᔭᐅᕙᒃᑐᑦ) ᐅᒥᐊᕐᔪᐊᖃᓕᖅᖓᑦ. ᐱᓗᐊᖅᑐᒥᒃ, ᑲᑎᙵᔪᑦ ᖃᓄᐃᑦᑑᓂᖏᑦ ᐆᒪᕆᒃᑑᓪᓗᑎᒃ (ᓲᕐᓗ, ᐋᓅᓇᐅᖃᑎᕆᒃ−ᐱᕈᖅᓴᖅᑐᑦ ᑲᑎᙵᓪᓗᑎᒃ ᑲᑎᙵᓪᓗᑎᒃ) ᐊᒻᒪᓗ ᐃᓐᓇᐃᑦ ᑲᑎᙵᔪᑦ ᑕᑯᑎᑕᐅᓚᐅᖅᐳᑦ ᒥᒃᓵᒋᐊᖅᓯᒪᓂᖏᓐᓂᒃ ᐱᕕᒃᓴᕆᑎᑕᐅᔪᓂᒃ ᐃᓚᐅᓕᖁᖓᑕ ᐱᕐᔪᐊᓂᒃ ᐱᓕᕆᐊᓂᒃ 5 ᑭᓛᒥᑕᓂᒃ ᐊᒻᒪᓗ 4 ᑭᓛᒥᑕᓂᒃ ᐅᒥᐊᓂᑦ, ᐊᑐᓂ. ᐊᓯᐊᒍᓪᓕ, ᐊᔾᔨᙱᑦᑑᑎᑦ ᑲᑎᙵᐅᖅᑐᑦ ᐃᓚᐅᙱᕐᖢᑎᒃ ᑕᑯᑎᑕᐅᓚᐅᖅᐳᑦ ᐊᖏᒡᓕᒋᐊᖅᑎᑦᑎᔪᒪᓪᓗᑎᒃ ᐃᓚᖓᓂᒃ ᐃᓚᐅᕙᖕᓂᖕᒋᓐᓂᒃ ᐱᒻᒪᕆᐊᓗᖕᓄᑦ ᐱᓕᕆᐊᖑᔪᓄᑦ 3 ᑭᓗᒦᑕᐃᑦ ᐃᓗᐊᓂ ᐅᒥᐊᑦ. ᑖᒃᑯᐊ ᖃᐅᔨᔭᐅᔪᑦ ᐃᒪᐃᑎᑦᑎᖅᑰᔨᒐᓗᐊᖅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔭᒃᑐᑦ ᐊᒃᑐᐃᑐᐃᓐᓇᕆᐊᖃᕐᓂᖕᒋᓐᓂᒃ ᑑᓕᓖᑦ ᐱᔪᓐᓇᕐᓂᕆᔭᖕᒋᓐᓂᒃ ᐱᓕᕆᔪᓐᓇᕐᑯᓪᓗᒋᑦ ᑖᒃᑯᓂᖓ ᐱᕐᔪᐊᖑᓪᓗᒋᑦ ᐃᓅᓯᖕᒋᓐᓂᒃ, ᐋᒻᒪᖕᒋᓪᓕᐅᕈᑕᐅᓲᑦ ᖃᓄᐃᓕᕚᓪᓕᐊᓂᕆᔭᐅᔪᑦ ᑲᑎᙵᓪᓗᑎᒃ ᐱᐅᓯᖕᒋᑦ ᖃᓄᐃᖕᓚᓪᓕᕐᓂᕆᔭᖕᒋᑦ ᑐᑭᓯᔭᐅᑦᑎᐊᕆᐊᖃᖅᐳᑦ ᐅᔾᔨᖅᓱᑦᑎᐊᕐᓗᑎᒃ. ᖃᐅᔨᓴᒃᑲᓂᕐᑯᔭᐅᕚᑦ ᐊᖏᒡᓕᒋᐊᕐᑯᓪᓗᒍᑦ ᐆᒃᑐᕋᖅᑕᐅᔫᒃ ᐊᖏᓂᖓ ᐊᔾᔨᖅᑲᖅᑐᖅ ᑎᑎᕋᖅᓯᒪᔪᑦ ᖃᐅᔨᓴᖅᑕᐅᓂᑯᓂᑦ.

- ᐊᔾᔨᐅᙱᑦᑐᑦ ᐱᐅᓯᑦ: ᐊᔾᔨᐅᙱᑦᑐᑦ ᐱᐅᓯᑦ ᓴᖅᑭᔮᖅᑎᑕᐅᓚᔾᔪᙱᓐᓂᖅᓴᐅᓚᐅᖅᑐᑦ ᐊᓪᓚᖑᐊᓕᒫᓄᑦ ᖃᓄᐃᑦᑑᓂᖕᒋᓐᓄᑦ ᖃᓂᒍᖅᑎ (<2 ᑭᓛᑕ) ᓅᑦᑕᖅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ, ᐊᔾᔨᙱᖕᒋᓐᓂᖕᒋᑦ ᐊᒃᑐᐊᓂᓖᑦ ᐅᒥᐊᕐᔪᐊᒥ ᐱᑕᖅᑲᙱᓐᓂᕐᓂ ᐅᔾᔨᕐᓇᓗᐊᓚᐅᙱᑦᑐᑦ ᐊᖏᒐᓗᐊᖅᑎᓪᓗᒋᑦ ᐊᖏᓂᖕᒋᑦ 0.5 ᑭᓛᑕᑦ ᐊᒻᒪᓗ 1.0 ᑭᓛᑕᑦ

ᐅᒥᐊᕐᕚᐊᓂᑦ. ᐱᑕᕐᑲᑦᑎᐊᙳᕆᓐᓂᖓ ᑮᓚᓯᓂᐊᕐᓂᕐᒧᑦ ᐅᔾᔨᕐᓇᕐᓂᕆᔭᐅᔪᓂᒃ ᑕᐃᒪᐃᔾᔪᑎᖃᖅᑐᒃᓴᐅᓚᐅᖅᐳᖅ ᐊᑦᑎᒃᑐᒥᒃ ᖃᐅᔨᓴᕐᒃᓴᒥᒃ ᐊᙵᓂᖓᓄᑦ ᖁᑦᑎᒃᑐᒦᑦᑐᓄᑦᑐ ᑎᑎᕋᖅᓯᒪᔪᓄᑦ ᐊᔾᔨᒌᙱᓐᓂᖏᓐᓄᑦ ᖃᓂᑕᖓᓂ (<2 ᑭᓗᒦᑕᓂᒃ) ᐅᒥᐊᕐᕚᐊᓄᑦ. ᖃᐅᔨᓴᕈᑎᕙᓃᑦ ᓇᓗᓇᐃᖅᐳᖅ ᐊᔾᔩᐅᙱᑦᑐᑦ ᐱᐅᓯᑦ ᓱᕐᓗ ᐊᒃᑐᐊᓂᕐᒧᑦ, ᐅᐃᔾᔪᕐᓂᖅ, ᐃᓗᐊᖅᓴᐃᔾᑦ, ᐊᒻᒪᓗ ᓄᓚᐊᕐᓂᓕᕆᓃᑦ ᐅᓚᕕᓴᖅᑕᐅᓚᐅᑲᒍᓐᓇᕐᓂᖏᓐᓂᒃ ᖃᓂᑦᑐᒃᑯᑦ (<2 ᑭᓚᒦᑕ) ᐅᒥᐊᕐᕚᐊᓄᑦ ᐃᖏᕐᕋᔪᓄᑦ, ᑭᓯᐊᓂ ᑖᓐᓇ ᖃᐅᔨᔭᐅᔪᖅ ᑐᙵᕕᖃᓚᐅᖅᑐᖅ ᑮᓚᖃᖅᑐᓂᒃ ᖃᐅᔨᓴᕋᒃᓴᓂᒃ ᐊᖏᓂᖏᓐᓂᒃ ᖃᓂᒌᔭᓃᑦᑐᓄᑦ ᐅᒥᐊᕐᕚᐊᓄᑦ. ᖃᐅᔨᓴᖅᑕᐅᒃᑲᓐᓂᕆᐊᓖᑦ (ᖃᖓᑕᓰᕋᒫᑦ ᐊᔾᔨᓕᐅᕈᑎᓖᑦ ᐊᐅᓚᑕᐅᔾᓇᖅᑐᑦ - ᑐᙳᕕᓖᑦ) ᖃᐅᔨᓴᖅᑕᐅᔪᑦ ᑕᐃᒪᐃᒻᒪᑦ ᐅᓄᖅᓯᒋᐊᕐᑯᔭᐅᕗᑦ ᐊᑕᖏᕐᓗᒍ ᖃᐅᔨᓴᕐᒃᓴᑦ ᐊᖏᓂᖏᑦ ᐊᒻᒪᓗ ᐆᒻᒪᕆᖕᓂᖓ ᐊᒃᑐᐊᓂᓚᒃ ᖃᐅᔨᓴᖅᑕᐅᔪᖅ.

- ᑲᑐᔾᔨᖃᑎᒌᑦ ᐋᓇᐅᓇᓯᕆᔭᐅᔪᓄᑦ: ᑑᒑᓖᑦ ᑎᑎᕋᖅᑕᐅᓚᐅᖅᑐᑦ 148-ᓂᑦ 397-ᖑᔪᓂᑦ (37%) ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᑎᓪᓗᒋᑦ ᐅᓪᓗᒥᒧᑦ ᑎᑭᕐᖢᒍ. ᑖᒃᑯᓇᙵᑦ, ᑑᒑᓖᑦ ᓇᖕᒥᓂᖅ 35–ᖏᓐᓃᓚᐅᖅᐳᑦ ᖃᐅᔨᓴᖅᑕᐅᔪᓂᑦ, ᐋᓇᕐᑲᕐᓂᐊᕋᓯᕆᓪᓗᑎᒃ 64–ᓂᑦ ᖃᐅᔨᓴᖅᑕᐅᔪᓂᑦ, ᐊᔾᔨᒌᙱᑦᑐᓂᒡᓗ ᑲᑎᙳᓪᓗᑎᒃ 49–ᓂᑦ ᖃᐅᔨᓴᖅᑐᓂᑦ. ᐃᓱᐊᖅᓴᐃᔾᑦ ᐱᐅᓯᖏᑦ ᑎᑎᕋᖅᑕᐅᓚᐅᖅᐳᑦ 30–ᐅᓪᓗᑎᒃ ᖃᐅᔨᓴᖅᑕᐅᔪᓂᒃ, ᑕᓪᓚᒪᐅᓪᓗᑎᒃ ᒪᓕᒃᓱᑎᒃ ᐅᒥᐊᕐᕚᕐᒥᒃ 5 ᑭᓚᒦᑕᓂᒃ ᐅᖓᓯᒃᑎᕆᔪᒥᒃ.
  - ᐱᑕᕐᑲᕐᓂᖓ ᐃᓱᐊᖅᓴᐃᔾᑦ ᐃᓚᖅᑯᓯᕐᑲᕐᓂᖏᑦ:ᑑᒑᓖᑦ ᐃᓚᐅᙳᕆᓐᓂᖅᓴᐅᕐᑲᑦᑕᖅᑐᖓ ᐱᑕᕐᑲᖅᑎᓪᓗᒍ ᐅᒥᐊᕐᕚᐊᓂ ᐃᖏᕐᕋᓂᐅᔪᓂ (5 ᑭᓚᒦᑕ ᐃᓗᐊᓂ), ᑭᓯᐊᓂ ᑖᓐᓇ ᐊᒃᑑᑎᔪᖅ ᑮᓚᓯᓂᐊᕈᑎᓄᑦ ᐱᒻᒪᕆᐅᓚᐅᙳᕆᑦᑐᖅ ᐊᖏᔪᒥᒃ ᐊᒃᑑᑎᒐᓗᐊᖅᑎᓪᓗᒍ (-69%). ᐱᑕᕐᑲᑦᑎᐊᙳᕆᓐᓂᖓ ᑮᓚᓯᓂᐊᖅᑕᐅᓯᒪᔪᓂᒃ ᐅᔾᔨᕐᓇᖅᑐᒻᒪᕆᖕᒥᒃ ᐊᒃᑐᖅᓯᓂᕆᔭᐅᔪᒥᒃ ᑕᐃᒪᐃᔾᔪᑎᕐᑲᑐᐃᓐᓇᕆᐊᕐᑲᓚᐅᖅᐳᖅ ᒥᑭᓛᒥᒃ ᖃᐅᔨᓴᕐᒃᓴᒥᒃ ᐊᙵᓂᖓᓄᑦ ᖁᑦᑎᒃᑐᒦᑦᑐᓄᑦᑐ ᑎᑎᕋᖅᓯᒪᔪᓄᑦ ᐊᔾᔨᒌᙱᓐᓂᖏᓐᓄᑦ. ᑕᐃᒪᐃᓐᓂᖓᓄᑦ, ᑖᒃᑯᐊ ᖃᐅᔨᔭᐅᔪᑦ ᑐᑭᓕᐅᖅᑕᐅᓪᓗᐊᖅᑐᑦ ᐅᔾᔨᖅᓯᑦᑎᐊᕐᓗᑎᒃ. ᖃᐅᔨᓴᒃᑲᓐᓂᕐᑯᔭᐅᕗᑦ ᐊᑕᖏᕐᓗᒍ ᖃᐅᔨᓴᕐᒃᓴᑦ ᐊᖏᓂᖏᑦ ᐅᓄᖅᓯᒋᐊᕐᑯᓪᓗᒋᑦ ᐊᒻᒪᓗ ᖃᐅᔨᓴᖅᑕᐅᔪᑦ ᖃᓄᐃᙳᕆᓂᖏᑦ.
  - ᐃᓚᖏᑦ ᐱᐅᙳᕆᓐᓂᖏᓪᓗ ᐃᓂᓚᐅᖅᑕᐅᓯᒪᔪᑦ: ᑑᒑᓖᑦ ᓇᓂᔭᐅᓚᐅᖅᑐᑦ ᐊᓯᔾᔨᖅᓯᓪᓗᑎᒃ ᑲᑎᙳᓂᕆᔭᒥᓂᒃ ᐋᓇᒥᓄᑦ ᖃᓂᓗᐊᖅᑎᓪᓗᒋᑦ ᐅᒥᐊᒃᑯᑦ ᐃᖏᕐᕋᔭᒃᑐᓄᑦ, ᑕᒪᐃᓐᓄᑦ ᐋᓇᐅᔪᓄᑦ–ᐱᐳᖅᓴᖅᑐᓄᑦ ᐊᒻᒪᓗ ᑲᑎᙳᐅᖅᑐᓄᑦ ᑲᑎᙳᐅᖅᑐᓄᑦ. ᐃᒪᓐᓇ, ᑑᒑᓖᑦ ᐋᓇᖏᑕ ᐃᒡᓗᖓᑕ ᐊᑖᓃᕐᓗᑎᒃ ᐊᓯᖏᓐᓂᒃ ᐃᓚᖏᑕ ᐃᓂᖏᓐᓂᒃ 1 ᑭᓚᒦᑕᓂᒃ ᐅᒥᐊᓂᒃ (ᑖᓐᓇ ᖃᐅᔨᔭᐅᔪᖅ ᑐᙳᕕᖃᕋᓗᐊᖅᑎᓪᓗᒍ ᒥᑭᑦᑐᒥᒃ ᐊᒃᑐᐃᔪᒥᒃ) ᐊᒃᑐᐊᓂᕐᑲᕐᓂᖅᓴᐅᓪᓗᑎᒡᓗ ᐋᓇᒥᓄᑦ 5 ᑭᓚᒦᑕᓂᒃ ᐅᒥᐊᓂᒃ. ᐊᑕᖏᖅᑯᓂ ᐊᖏᓂᖓ ᖃᐅᔨᔭᐅᔫᑉ ᐃᔾᔪᐊᖅᓯᓂᐅᑐᐃᓐᓇᕆᐊᓚᒃ ᐃᑦᑕᕐᓂᓴᓂᑦ ᐊᒃᑑᑎᓂᖓᓗ ᐅᖓᑖᓃᕈᓐᓇᖅᑯᓂ <3 ᑭᓚᒦᑕᓄᑦ ᐅᒥᐊᕐᕚᐊᒥᒃ. ᖃᐅᔨᓴᖅᑕᐅᒃᑲᓐᓂᕆᐊᓖᑦ ᖃᐅᔨᓴᕐᒃᓴᑦ ᐊᖏᓚᒃᑲᓐᓂᕐᑯᓪᓗᒋᑦ, ᑕᐃᒪᐃᒻᒪᑦ ᖃᐅᔨᓴᖅᑕᐅᑦᑎᐊᕈᓐᓇᖅᓯᓪᓗᑎᒃ.
- ᐱᓚᓇᖅᑎᒌᑦ ᐋᖅᑭᒃᓯᒪᓂᖏᑦ: ᑑᒑᓖᑦ ᑲᑎᙳᔪᑦ ᑕᑯᑎᑕᐅᓚᐅᖅᑐᑦ ᐊᓯᔾᔨᕐᓗᑎᑦ ᑲᑎᙳᕝᕕᒋᔭᖏᓐᓂ ᖃᓂᓗᐊᕐᙵᑕ ᐅᒥᐊᓄᑦ, ᐅᓄᕐᓂᖅᓴᑦ ᑲᑎᙳᔪᑦ ᐊᔾᔨᒌᖑᓐᓂᖅᑎᑦᑎᓪᓗᑎᒃ ᐃᓚᖓᓂ ᐊᔾᔨᒌᒃᓗᑎᒃ ᐋᖅᑭᒃᓯᒪᓂᖏᓐᓂ ᐃᓗᐊᓂ 1-ᒥ 3-ᒧᑦ ᑭᓚᒦᑕᓂᒃ ᐅᒥᐊᕐᕚᐊᓂᑦ. ᐊᓯᐊᒍᓪᓚ, ᐋᓇᐅᔪᑦ–ᐱᕈᖅᓴᖅᑐᑦ ᑲᑎᙳᔪᑐᐊᙶᓚᐅᖅᐳᑦ ᐅᓄᖅᓯᒋᐊᖅᓯᓪᓗᑎᒃ 2 ᑭᓚᒦᑕᓂᒃ ᐅᒥᐊᓂᒃ, ᑭᓯᐊᓂ ᐊᒃᑐᐃᓂᖓ ᒥᑭᑦᑐᑯᓘᓚᐅᖅᐳᖅ. ᑖᒃᑯᐊ ᖃᐅᔨᓴᕈᑎᕙᓃᑦ ᑐᙵᕕᖃᓚᐅᖅᐳᑦ ᖃᐅᔨᓴᕐᒃᓴᑦ ᐊᖏᓂᖏᑦ ᑮᓚᖅᑎᑕᐅᓪᓗᑎᒃ ᑕᐃᒪᐃᒻᒪᑦ ᑐᑭᓚᐅᖅᑕᐅᔭᕆᐊᖃᖅᐳᑦ ᐅᔾᔨᖅᓯᑦᑎᐊᕐᓗᑎᒃ. ᐅᖃᐅᓯᐅᓯᒪᔪᖅ ᐃᓚᒍᑖ 3.0, ᐊᓯᔾᔨᕐᓂᖅ ᑲᑎᙳᐅᖅᑐᓂᑦ ᑲᑎᖓᐅᖅᑐᓂᑦ (ᓲᕐᓗ ᐊᓯᔾᔨᕐᓂᖅ ᑲᑎᙳᐅᖅᑐᓂᑦ) ᕿᓚᓗᒐᕐᓄᑦ ᒪᓕᑦᓯᐊᕋᔭᖅᑐᖅ ᓈᒻᒪᑦᑐᒧᑦ ᐱᐅᓯᕐᒧᑦ ᑭᐅᔾᔪᑎᒧᑦ. ᑕᒻᒪᖅᓯᒪᔪᖅ! ᖃᐅᔨᒋᐊᕐᕕᐅᔪᓐᓇᖅᑐᖅ ᓇᓂᔭᐅᙳᕆᑦᑐᑦ.ᖃᓄᐃᓕᖓᓂᖓᓄᑦ ᐊᒃᑐᐃᓂᐅᑉ (ᓲᕐᓗ, ᐊᓯᔾᔨᕐᓂᖓ ᑲᑎᙳᔪᓂ 3 ᑭᓚᒦᑕᒥ ᐅᒥᐊᒥ), ᑖᓐᓇ ᖃᐅᔨᔭᐅᔪᖅ ᓂᕈᐅᕆᔭᐅᓚᐅᙳᕆᑦᑐᖅ ᐱᑎᑦᑎᓗᓂ ᐆᒪᔪᓂ ᐊᓯᔾᔨᕐᔪᐊᖅᑐᓂᒃ ᐃᓚᖅᑯᓯᓪᓚᑦᑖᖏᓐᓂ ᑐᒑᓕᖕᓄᑦ ᐊᕙᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᒃ–ᒥ ᐅᓚᕕᑕᐅᓗᓂᓘᓐᓃᑦ ᖃᐅᑕᒫᑦ ᐊᑐᖅᑦᑕᖅᑕᖏᓐᓂ. ᐅᖃᐅᓯᐅᓚᐅᖅᑐᖅ ᑭᐅᔾᔪᑕᐅᔪᖅ ᑕᑯᒃᓴᐅᑎᑕᐅᓚᐅᖅᐳᖅ ᓇᐃᑦᑐᑯᓘᓂᖓᓂᒃ, ᓇᓚᒃᓯᖅᑯᓂ ᐊᖏᓛᓇᔪᓐᓇᖅᑕᖓᓄᑦ 21–ᓄᑦ ᑎᑦᑕᑯᓗᖓᓄᑦ ᐊᑕᐅᓯᕐᒧᑦ ᐅᒥᐊᕐᕚᐊᒧᑦ ᓄᒃᑕᕐᓂᓇᔭᐅᔪᒧᑦ (ᑕᒪᓐᓇ ᑐᙵᕕᖃᖅᑎᑕᐅᓗᓂ 9 ᑭᓗᒦᑕᓂᒃ ᓄᒃᑕᕐᓂᕐᒧᑦ ᓱᒃᑲᓕᓂᕆᔭᐅᔪᒥᒃ, ᐃᓱᒪᒋᓪᓗᒍ ᑑᒑᓖᑦ ᐃᓂᖏᓐᓂᖏᓐᓇᕋᓱᒋᔭᐅᓗᑎᒃ ᓵᑦᑎᐊᕐᒥᐅᑕᖃᖅᑐᖃᕐᓂᖓᓂ), ᓂᕐᔪᑎᑦ ᐅᑎᕐᓗᑎᒃ ᑭᐅᓯᓂᕐᒧᑦ ᐃᓚᖅᑯᓯᓇᕝᕙᑕᒥᓄᑦ ᑭᖑᓂᑦᑎᐊᖓᒍᑦ ᓯᕗᓪᓚᕐᒥ ᐅᒥᐊᑉ ᓵᑦᑎᐊᕐᒥᐅᑕᖃᓚᐅᖅᑎᓪᓗᒍ (ᓲᕐᓗ ᐃᒪᓐᓇ, ᐊᒃᑐᖅᓯᓚᐅᑲᖕᓂᕆᔭᐅᔪᒥᒃ). ᑕᐃᒪᐃᓐᓂᖓᓄᑦ, ᐊᒃᑐᖅᑕᐅᓂᐊᕋᓱᒋᔭᐅᓚᐅᙳᕆᑦᑐᑦ ᐃᓅᑉ ᑎᒥᖓᓄᑦ ᐊᒻᒪ/ᐅᖕᒍᓘᓐᓃᑦ ᐱᕐᔪᐊᖑᓪᓗᑎᒃ ᐅᓄᕐᓂᖏᑦ ᑑᒑᓖᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥᒃ–ᒥ, ᐊᒃᑐᐃᔾᔪᑕᐅᑐᐃᓐᓇᕆᐊᖃᓪᓗᑎᒃ ᐃᓄᒋᐊᖕᓂᖏᑦᑕ ᑮᓚᖏᓐᓄᑦ. ᑖᓐᓇ ᑭᐅᔾᔪᑕᐅᔪᖅ ᒪᓚᓚᐅᖅᐳᖅ ᐊᒃᑐᐃᓂᐊᕋᓱᒋᔭᐅᔪᓄᑦ

ᑮᖑᓪᓕᖅᐹᒥᑦ ᐊᕙᑎᒧᑦ ᐊᒃᑐᐃᓂᐊᓂᐊᖅᑐᑦ ᐅᓂᒃᑳᒧᑦ ᐱᒋᐊᖅᐸᓪᓕᐊᑎᓪᓗᒋᑦ ᑰᓇᐅᔭᓕᐅᖅᓵᓕᓇᓱᐊᕐᓂᕐᒧᑦ, ᐅᒥᐊᕐᔪᐊᑉ ᓂᐱᖅᑯᖅᑐᓂᖓᓄᑦ ᐊᒃᑐᐃᔾᔪᑕᐅᔪᑦ ᑑᒡᓕᕐᓄᑦ ᓂᕆᐅᒋᔭᐅᓚᐅᖅᐳᑦ ᑭᒻᓕᖅᖃᑎᑕᐅᓂᐊᕋᓱᒋᔭᐅᓪᓗᑎᒃ ᕿᓚᒻᒥᐅᔫᒃᑯᑦ, ᓄᓇᓕᖕᓂ ᓱᕐᑯᑎᒋᔭᐅᙱᕐᒐᔪᑎᒃ ᐱᐅᓯᕆᔭᐅᔪᑦ.

- ᑲᑎᙵᔪᑦ ᓯᐊᒻᒪᒃᓯᒪᔪᑦ: ᑑᒡᓕᑦ ᑲᑎᙵᔪᑦ ᑕᑯᑎᑦᑎᓚᐅᖅᑐᑦ ᖃᓯᑎᑦᑎᓪᓗᑎᒃ ᑲᑐᔾᔨᖃᑎᒌᖕᒐᓂ ᖃᓂᓗᐊᖅᑎᓪᓗᒋᑦ (≤3 ᑭᓚᒥᑕᑦ) ᐅᒥᐊᕐᔪᐊᓄᑦ ᐃᖏᕐᕋᔪᓄᑦ ᐊᔾᔨᒌᖕᒋᑦᑐᓄᑦ ᑲᑎᙵᔪᓄᑦ, ᐆᒃᑐᕋᐅᑎᓄᑦ ᐱᔭᕇᕈᑎᑦ ᓇᓗᓇᐃᖅᓯᓪᓗᑎᒃ ᑖᓐᓇ ᐊᒃᑑᑎᔪᖅ ᑭᒡᓕᓯᓂᐊᕈᑎᓄᑦ ᐱᒻᒪᕆᐅᙱᕋᓱᓂ ᐊᖏᔪᒥᒃ ᐊᒃᑑᑎᒐᓗᐊᖅᑎᓪᓗᒍ ᐊᖏᓂᖓ. ᐅᖃᐅᓯᐅᓯᒪᔪᖅ ᐃᓚᒍᑖ 3.0, ᐊᓯᔾᔨᕐᓂᖅ ᑲᑎᙵᐅᖅᑐᓂᑦ (ᓲᕐᓗ ᐊᓯᔾᔨᕐᓂᖅ ᑲᑎᙵᐅᖅᑐᓂᑦ ᓯᐊᒻᒪᖏᓯᒪᔪᖅ) ᕿᓚᓗᒐᕐᓄᑦ ᐊᔾᔨᒌᒐᔭᖅᑐᖅ ᓈᒻᒪᑦᑐᒧᑦ ᐱᐅᓯᖃᕐᓂᕐᒧᑦ ᑭᐅᔾᔪᑎᓄᑦ. ᑕᒻᒪᖅᓯᒪᔪᖅ! ᖃᐅᔨᒋᐊᕐᕕᐅᔫᓇᖅᑐᖅ ᓇᓂᔭᐅᙱᑦᑐᑦ. ᐊᑐᓚᐅᑲᑐᐃᓐᓇᖅᑎᓪᓗᒍ ᐊᒃᑑᑎᔪᖅ ᖃᐅᔨᔭᐅᔪᖅ, ᑖᓐᓇ ᖃᐅᔨᔭᐅᔪᖅ ᓂᕈᐅᒋᔭᐅᓚᐅᙱᑦᑐᖅ ᐱᑎᑦᑎᓗᓂ ᐊᓯᔾᔨᕐᔪᐊᕐᓂᕐᒥᒃ ᐃᓕᖅᑯᓯᕆᓚᔪᒃᑕᕆᓐᓂ ᐊᓪᓚᕐᓗᕐᓄᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥᒃ–ᒥ ᐅᓚᕕᑕᐅᓗᓂᓘᓐᓃᑦ ᖃᐅᑕᒫᑦ ᐊᑐᖃᑦᑕᖅᑕᕆᓐᓄᑦ. ᐅᖃᐅᓯᐅᓚᐅᖅᑐᖅ ᑭᐅᔾᔪᑕᐅᔪᖅ ᑕᑯᒃᓴᐅᑎᑕᐅᓚᐅᖅᐳᖅ ᓇᐃᑦᑐᑯᓘᓂᕐᒪᓂᒃ, ᓇᓕᒧᒃᓯᖅᓱᓂ ᐊᕐᒋᓖᓇᔪᓐᓇᖅᑕᕐᒪᓄᑦ 21–ᓄᑦ ᑎᑦᑕᑯᓗᕐᓄᑦ ᐊᑕᐅᓯᕐᒧᑦ ᐅᒥᐊᕐᔪᐊᒧᑦ ᓄᒃᑖᕐᓂᕆᔭᐅᔪᒧᑦ (ᑕᒪᓐᓇ ᑐᙵᕕᖅᑲᖅᑎᑕᐅᓪᓗᓂ 9–ᑭᓗᒦᑕᒥᒃ ᓄᒃᑖᕐᓂᕐᒧᑦ ᓱᒃᑲᓕᓂᕐᒥᒃ, ᐃᓱᒪᒥᐅᑕᖅᑲᖅᓱᓂ ᑑᒡᓖᑦ ᐃᓂᒋᕙᒃᑕᕐᓚᓃᕐᒋᓐᓇᕋᔭᕐᓂᕐᓚᓂᒃ ᓵᑎᐊᕐᒥᐅᑕᖅᑲᖅᑐᖅᑲᕐᓂᕐᓚᓂ), ᓂᕐᔪᑎᑦ ᐅᑎᕐᓗᑎᒃ ᑭᐅᓯᓂᕐᒧᑦ ᐃᓕᖅᑯᓯᕆᕙᒃᑕᒥᓄᑦ ᑮᖑᓂᑦᑎᐊᕐᓚᒍᑦ ᓯᕗᓪᓕᕐᒥ ᐅᒥᐊᑉ ᓵᑎᐊᕐᒥᐅᑕᖅᑲᓚᐅᖅᑎᓪᓗᒍ (ᓲᕐᓗ ᐃᒪᓐᓇ, ᐊᒃᑐᖅᓯᓚᐅᑲᕐᓂᕆᔭᐅᔪᒥᒃ). ᑕᐃᒪᐃᓐᓂᕐᓚᓄᑦ, ᐊᒃᑐᖅᑕᐅᓂᐊᕋᓱᒋᔭᐅᓚᐅᙱᑦᑐᑦ ᐃᓅᑉ ᑎᒥᕐᓚᓄᑦ ᐊᒻᒪ/ᐅᕝᕙᓘᓐᓃᑦ ᐱᕐᔪᐊᖑᓪᓗᑎᒃ ᐅᓄᕐᓂᕐᒋᑦ ᑑᒡᓖᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥᒃ–ᒥ, ᐊᒃᑐᐃᔾᔪᑕᐅᑐᐃᓐᓇᕆᐊᖅᑲᖅᑐᑎᒃ ᐃᓄᒋᐊᕐᓂᕐᒋᑦᑕ ᑭᒡᓕᕐᒋᓐᓄᑦ. ᑖᓐᓇ ᑭᐅᔾᔪᑕᐅᔪᖅ ᒪᓕᓚᐅᖅᐳᖅ ᐊᒃᑐᐃᓂᐊᕋᓱᒋᔭᐅᔪᓄᑦ ᑮᖑᓪᓕᖅᐹᒥᑦ ᐊᕙᑎᒧᑦ ᐊᒃᑐᐃᓂᐊᓂᐊᖅᑐᑦ ᐅᓂᒃᑳᒧᑦ ᐱᒋᐊᖅᐸᓪᓕᐊᑎᓪᓗᒋᑦ ᑰᓇᐅᔭᓕᐅᖅᓵᓕᓇᓱᐊᕐᓂᕐᒧᑦ, ᐅᒥᐊᕐᔪᐊᑉ ᓂᐱᖅᑯᖅᑐᓂᖓᓄᑦ ᐊᒃᑐᐃᔾᔪᑕᐅᔪᑦ ᑑᒡᓕᕐᓄᑦ ᓂᕆᐅᒋᔭᐅᓚᐅᖅᐳᑦ ᑭᒡᓕᖅᑲᖅᑎᑕᐅᓂᐊᕋᓱᒋᔭᐅᓪᓗᑎᒃ ᕿᓚᒻᒥᐅᔫᒃᑯᑦ, ᓄᓇᓕᖕᓂ ᓱᕐᑯᑎᒋᔭᐅᙱᕐᒐᔪᑎᒃ ᐱᐅᓯᕆᔭᐅᔪᑦ.
- ᑲᑎᙵᔪᑦ ᐅᓄᕐᓂᖏᑦ: ᐊᔾᔨᒌᙱᑦᑐᑦ ᑑᒡᓖᑦ ᐊᔾᔨᒌᙱᑦᑐᑦ, ᑲᑎᙵᔪᑐᐊᑦ ᑲᑎᙵᓪᓗᑎᒃ ᑕᑯᑎᑕᐅᓚᐅᖅᐳᑦ ᐊᖏᓂᖅᓴᐅᕌᕐᔪᒃᑲᓗᑎᒃ 4 ᑭᓚᒦᑕᓂᒃ ᐅᒥᐊᓂᒃ. ᐊᓯᖏᓐᓄᑦ ᑲᑎᙵᐅᖅᑐᓄᑦ ᖃᓄᐃᑦᑑᓂᖏᓐᓄᑦ, ᐊᒃᑑᑎᔪᑦ ᐊᖏᓂᖏᑦ ᒥᑭᑦᑐᑯᓘᓚᐅᖅᑐᑦ ᐊᒻᒪᓗ ᐃᒪᐃᖁᔩᓚᐅᙱᕐᒐᓗᑎᒃ ᐊᖏᔪᒥᒃ ᐊᒃᑑᑎᔪᒥᑦ. ᐊᖏᔪᖅ ᐊᒃᑑᑎᔪᖅ ᐊᒃᑐᐊᓂᓕᒃ ᐊᐆᓇᐅᑉ–ᐱᕈᖅᓴᖃᑎᒌᓄᑦ ᐱᖃᑎᒌᓄᑦ ᖃᐅᔨᔭᐅᓚᐅᙱᑦᑐᖅ ᑲᑎᖅᓱᖅᓯᒪᔪᓄᑦ ᖃᓂᑦᑐᓄᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ, ᓇᓗᓇᐃᖅᓯᓪᓗᓂ ᖃᐅᔨᓴᒃᑲᓐᓂᕆᐊᖃᕐᓂᖏᓐᓂ ᐊᖏᒃᑲᒋᐊᕐᓗᒍ ᖃᐅᔨᓴᕐᕕᓴᖅ ᐊᖏᓂᖓ. ᐅᖃᐅᓯᐅᓯᒪᔪᖅ ᐃᓚᒍᑖ 3.0, ᐊᓯᔾᔨᕐᓂᖅ ᑲᑎᙵᐅᖅᑐᓂᑦ ᑲᑎᖓᐅᖅᑐᓂᑦ (ᓲᕐᓗ ᐊᓯᔾᔨᕐᓂᖅ ᑲᑎᙵᐅᖅᑐᓂᑦ ᐊᖏᓂᖏᓐᓂᑦ) ᐊᓪᓚᖕᖑᐊᓄᑦ ᒪᓕᑦᓯᐊᕋᔭᖅᑐᖅ ᓈᒻᒪᑦᑐᒥᑦ ᐱᐅᓯᖅᑳᕐᓂᕐᒧᑦ ᑭᐅᔾᔪᑎᓂᑦ. ᑕᒻᒪᖅᓯᒪᔪᖅ! ᖃᐅᔨᒋᐊᕐᕕᐅᔫᓇᖅᑐᖅ ᓇᓂᔭᐅᙱᑦᑐᑦ. ᐊᑐᓚᐅᑲᑐᐃᓐᓇᖅᑎᓪᓗᒍ ᐊᒃᑑᑎᔪᖅ ᓇᓗᓇᙱᑦᑐᖅ ᑲᑎᙵᙱᑦᑐᑐᐊᓄᑦ ᑲᑎᙵᔪᓄᑦ (ᓲᕐᓗ, ᐊᖏᒃᑲᒋᐊᕐᓗᓂ ᑲᑎᙵᔪᓂ ᐊᖏᓂᖓᓂ ᐃᓗᐊᓂ 4 ᑭᓚᒦᑕ ᐅᒥᐊᑉ), ᑖᓐᓇ ᖃᐅᔨᔭᐅᔪᖅ ᓂᕈᐅᒋᔭᐅᓚᐅᙱᑦᑐᖅ ᐱᑎᑦᑎᓗᓂ ᐊᓯᔾᔨᕐᔪᐊᕐᓂᕐᒥᒃ ᐃᓕᖅᑯᓯᕆᓚᔪᒃᑕᕆᓐᓂ ᕿᓚᓗᒐᕐᓄᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥ ᐅᓚᕕᑕᐅᓗᓂᓘᓐᓃᑦ ᖃᐅᑕᒫᑦ ᐊᑐᖃᑦᑕᖅᑕᕆᓐᓂ. ᐅᖃᐅᓯᐅᓚᐅᖅᑐᖅ ᑭᐅᔾᔪᑕᐅᔪᖅ ᑕᑯᒃᓴᐅᑎᑕᐅᓚᐅᖅᐳᖅ ᓇᐃᑦᑐᑯᓘᓂᕐᒪᓂᒃ, ᓇᓕᒧᒃᓯᖅᓱᓂ ᐊᕐᒋᓖᓇᔪᓐᓇᖅᑕᕐᒪᓄᑦ 28–ᓄᑦ ᑎᑦᑕᑯᓗᕐᓄᑦ ᐊᑕᐅᓯᕐᒧᑦ ᐅᒥᐊᕐᔪᐊᒧᑦ ᓄᒃᑖᕐᓂᕆᔭᐅᔪᒧᑦ (ᑕᒪᓐᓇ ᑐᙵᕕᖅᑲᖅᑎᑕᐅᓪᓗᓂ 9–ᑭᓗᒦᑕᒥᒃ ᓄᒃᑖᕐᓂᕐᒧᑦ ᓱᒃᑲᓕᓂᕐᒥᒃ, ᐃᓱᒪᒋᓪᓗᒍ ᑑᒡᓖᑦ ᐃᓂᖃᐃᓐᓇᕋᓱᒋᔭᐅᓗᑎᒃ ᓵᑎᐊᕐᒥᐅᑕᖅᑲᕐᓂᕐᒥᓂ), ᓂᕐᔪᑎᑦ ᐅᑎᕐᓗᑎᒃ ᑭᐅᓯᓂᕐᒧᑦ ᐃᓕᖅᑯᓯᕆᕙᒃᑕᒥᓄᑦ ᑮᖑᓂᑦᑎᐊᕐᓚᒍᑦ ᓯᕗᓪᓕᕐᒥ ᐅᒥᐊᑉ ᓵᑎᐊᕐᒥᐅᑕᖅᑲᓚᐅᖅᑎᓪᓗᒍ (ᓲᕐᓗ ᐃᒪᓐᓇ, ᐊᒃᑐᖅᓯᓚᐅᑲᕐᓂᕆᔭᐅᔪᒥᒃ). ᑕᐃᒪᐃᓐᓂᕐᓚᓄᑦ, ᐊᒃᑐᖅᑕᐅᓂᐊᕋᓱᒋᔭᐅᓚᐅᙱᑦᑐᑦ ᐃᓅᑉ ᑎᒥᕐᓚᓄᑦ ᐊᒻᒪᓗ/ᐅᕝᕙᓘᓐᓃᑦ ᐱᕐᔪᐊᖑᓪᓗᑎᒃ ᐅᓄᕐᓂᕐᒋᑦ ᑑᒡᓖᑦ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥ, ᐊᒃᑐᐃᔾᔪᑕᐅᑐᐃᓐᓇᕆᐊᖅᑲᖅᑐᑎᒃ ᐃᓄᒋᐊᕐᓂᕐᒋᑦᑕ ᑭᒡᓕᕐᒋᓐᓄᑦ. ᑖᓐᓇ ᑭᐅᔾᔪᑕᐅᔪᖅ ᒪᓕᓚᐅᖅᐳᖅ ᐊᒃᑐᐃᓂᐊᕋᓱᒋᔭᐅᔪᓄᑦ ᑮᖑᓪᓕᖅᐹᒥᑦ ᐊᕙᑎᒧᑦ ᐊᒃᑐᐃᓂᐊᓂᐊᖅᑐᑦ ᐅᓂᒃᑳᒧᑦ ᐱᒋᐊᖅᐸᓪᓕᐊᑎᓪᓗᒋᑦ ᑰᓇᐅᔭᓕᐅᖅᓵᓕᓇᓱᐊᕐᓂᕐᒧᑦ, ᐅᒥᐊᕐᔪᐊᑉ ᓂᐱᖅᑯᖅᑐᓂᖓᓄᑦ ᐊᒃᑐᐃᔾᔪᑕᐅᔪᑦ ᑑᒡᓕᕐᓄᑦ ᓂᕆᐅᒋᔭᐅᓚᐅᖅᐳᑦ ᑭᒡᓕᖅᑲᖅᑎᑕᐅᓂᐊᕋᓱᒋᔭᐅᓪᓗᑎᒃ ᕿᓚᒻᒥᐅᔫᒃᑯᑦ, ᓄᓇᓕᖕᓂ ᓱᕐᑯᑎᒋᔭᐅᙱᕐᒐᔪᑎᒃ ᐱᐅᓯᕆᔭᐅᔪᑦ.
- ᐱᓕᕆᖃᑎᒌᑦ ᓅᒃᑖᕐᓂᕐᒧᑦ ᐃᖏᕐᕋᓂᖓ: ᑑᒡᓖᑦ ᐊᓯᔾᔨᖅᓯᓪᓚᕆᓚᐅᙱᑦᑐᑦ ᓄᒃᑖᕐᓂᕆᖃᑦᑕᖅᑕᖅᑕᕆᓐᓂᒃ ᑕᐃᒪᐃᔾᔪᑎᖃᖅᑐᒍᑎᒃ ᐅᒥᐊᑦ ᓇᒨᙵᐅᕙᓪᓕᐊᕙᕐᓂᕐᒋᓐᓄᑦ. ᐅᖃᐅᓯᐅᓯᒪᔪᖅ ᐃᓚᖓ ᑕᒻᒪᖅᓯᒪᔪᖅ!

ᖃᐅᔨᒋᐊᕐᕕᐅᔪᓐᓇᖅᑐᖅ ᓇᓂᔭᐅᙱᑦᑐᑦ., ᐊᓯᔾᔨᕐᓂᖅ ᐆᒪᖅᑯᑎᓄᑦ ᐊᑭᓕᐅᑎᓂᑦ (ᓲᕐᓗ, ᓅᓐᓂᐊᖅᓱᑎᒃ ᐃᖏᕐᕋᓂᖓᓄᑦ) ᑑᒐᓕᖕᓄᑦ ᒪᓕᒐᔭᖅᑐᖅ ᓈᒻᒪᒃᑐᒥᑦ ᐱᐅᓯᖕᒧᑦ, ᐊᓯᔾᔨᖅᑐᖃᓚᐅᙱᒃᑲᓗᐊᖅᓱᓂ. ᐱᑕᖃᑦᑎᐊᙱᓐᓂᖓ ᑭᐅᓯᓂᕐᒧᑦ ᐃᑲᔪᖅᑐᐃᓚᐅᖅᐳᖅ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᖃᓅᓂᐊᕋᓱᒋᔭᐅᔪᓄᑦ ᑭᖑᓪᓕᖅᐹᒥᑦ ᐊᕙᑎᒧᑦ ᐊᒃᑐᐃᓂᐊᓂᐊᖅᑐᑦ ᐅᓂᒃᑳᒧᑦ ᐱᒋᐊᖅᐸᓪᓕᐊᑎᓪᓗᒋᑦ ᑮᓇᐅᔭᓕᐅᖅᑳᓕᓇᓱᐊᕐᓂᕐᒧᑦ, ᑕᐃᑲᓂ ᐅᒥᐊᕐᔪᐊᒥ ᓂᐱᖅᑯᖅᑐᔪᓄᑦ ᐊᒃᑐᖅᓯᓂᐅᕙᒃᑐᓂᒃ ᑑᒐᓕᖕᓄᑦ ᓂᕆᐅᒋᔭᐅᓚᐅᖅᐳᑦ ᐃᓯᓕᑦᑕᖅᑎᑕᐅᓂᐊᕋᓱᒋᔭᐅᓪᓗᑎᒃ ᐊᑐᖅᑕᐅᓚᐅᑲᙱᓐᓂᐊᖅᑐᓄᑦ, ᓄᓇᓕᖕᓂ ᐊᑐᖅᑕᐃᓕᒪᕙᖕᓂᕐᒧᑦ ᐃᓕᖅᑯᓯᕆᔭᐅᕙᒃᑐᓂᒃ.

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# Table of Contents

**TABLES**

**FIGURES**

**APPENDICES**

# Acronyms / Abbreviations

| | |
|---|---|
| AIS | Automatic Identification System |
| Baffinland | Baffinland Iron Mines Corporation |
| BB | Baffin Bay |
| BSA | Behavioural Study Area |
| CPA | Closest Point of Approach |
| CI | Confidence interval |
| CV | Coefficient of variation |
| DFO | Fisheries and Oceans Canada |
| DSLR | Digital single lens reflex |
| ERP | Early Revenue Phase |
| EWI | Early Warning Indicator |
| FEIS | Final Environmental Impact Statement |
| FFID | Focal follow Identification |
| GPS | Global Positioning System |
| h | Hour |
| Hz | Hertz |
| ICI | Inter click interval |
| IQ | Inuit Qaujimajatuqangit |
| JASCO | JASCO Applied Sciences |
| kHz | Kilohertz |
| km | Kilometers |
| LDA | Linear Discriminant Analysis |
| LOESS | Locally estimated scatterplot smoothing |
| m | Meters |
| m/s | Meters per second |
| MHTO | Mittimatalik Hunters and Trappers Organization |
| MMOs | Marine Mammal Observers |
| Mtpa | million tonnes per annum |
| PAM | passive acoustic monitoring |
| PC | Project Certificate |
| PCoD | Population Consequences of Disturbance |
| RAD | Relative abundance and distribution |
| RSA | Regional Study Area |
| SARA | Species at Risk Act |
| SD | Standard deviation |
| SEL | Sound exposure level |
| SFOC | Special Flight Operations Certificate |
| SPL | Sound pressure level |
| $SPL_{rms}$ | Sound pressure level (root mean square) |

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

# 1.0 INTRODUCTION

This report presents the integrated results of an eight-year shore-based monitoring study of narwhal (*Monodon monoceros*) conducted near Bruce Head on North Baffin Island, Nunavut. During the open-water seasons of 2014-2022 (with exception of 2018), systematic data on narwhal relative abundance and distribution (RAD), group composition and behaviour were collected from a cliff-based observation platform overlooking an established shipping corridor as part of the Bruce Head Shore-based Monitoring Program (the Program). The objective of the Program was to investigate potential narwhal responses to open-water shipping activities. Additional data were collected on environmental conditions (e.g., glare, Beaufort wind scale level) and anthropogenic activities (e.g., shipping and hunting activities) to distinguish between the potential effects of Project-related shipping activities and potential confounding factors that may also influence narwhal behaviour (e.g., hunting, killer whale predation, recreational boat traffic).

## 1.1 Project Background

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

To date, Baffinland has been operating in the Early Revenue Phase (ERP) of the Project and is authorized to transport 4.2 million tonnes per annum (Mtpa) of ore by truck to Milne Port for shipping through the Northern Shipping Route using chartered ore carrier vessels. A production increase to ship 6.0 Mtpa from Milne Port was approved for between 2018 and 2022 through various Project Certificate amendments (provide the PIP, PIPE nd PIP Renewal references) 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 ~918,000 tonnes of iron ore from Milne Port involving 13 return ore carrier voyages. In 2016, the total volume of ore shipped out of Milne Port reached 2.6 million tonnes involving 37 return ore carrier voyages. In 2017, the total volume of ore shipped out of Milne Port reached 4.1 million tonnes involving 58 return ore carrier voyages. Following approval to increase production to 6.0 Mtpa, a total of 5.1 Mtpa of ore was shipped via 71 return voyages in 2018, 5.9 Mtpa of ore was shipped via 81 return voyages in 2019, 5.5 Mtpa was shipped via 72 return voyages in 2020, and 5.6 Mtpa via 73 (one vessel was released unloaded) return voyages in 2021. In 2022, a total of 4.7 Mtpa of iron ore was shipped via 62 return voyages with the first inbound transit of the season occurring on 30 July and the last outbound transit of the season occurring on 13 October 2022.

## 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 behaviour in the Project's Regional Study Area (RSA; Figure 1-1).

**Figure 1-1: Mary River Project Location; Nunavut, Canada.**

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

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 intended 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 Behavioural Study Area (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' (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 if it is determined that the change may stem from Baffinland-related activities.

To date, the EWI has been calculated based on the total number of immatures (i.e., calves and yearlings) recorded in the BSA over the annual study period divided by the total number of narwhal recorded over that same period - referred to hereafter as the 'combined annual proportion of immatures'. The annual mean of the daily proportions of immatures[1] 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, Fisheries and Oceans Canada (DFO) recommended that an index of variability in the EWI measurement be included, as well as an indication related to the error around the measurement (Baffinland 2021b). Therefore, the assessment of variation in the EWI analysis, in relation to the baseline levels (i.e., proportion of immature narwhal in 2014–2015), was modified to include an index of variability. The revised EWI threshold (currently in place for the Project) is now defined as a "statistically significant difference between a year's least squares mean and the average of 2014–2015 least squares mean values". Further information on the analysis of EWI is provided in Section 4.3.1.3.

## 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 2009). Adaptive management provides flexibility to identify and implement new mitigation measures or to modify existing ones during the life of a project. Adaptive strategies are implemented when unanticipated adverse effects are observed, or if effects exceed identified thresholds.

In support of Baffinland's Phase 2 Proposal for the Project, Baffinland developed a draft Adaptive Management Plan (AMP) which provides a framework for how adaptive management is incorporated into Project operations (Baffinland 2020). As part of this process, a Marine Mammal Trigger Action Response Plan (TARP) was developed for the Project which identifies a number of performance indicators, effect thresholds and pre-defined actions (i.e., responses) that are used to evaluate and respond to potential Project effects on narwhal (and other marine mammal species in the Project area; Baffinland 2021c). The TARP shares the same objective as the EWI identified in Section 1.3, 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-

[1] 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.

term adaptive management strategies. The pre-defined actions identified in the TARP describe the responses that Baffinland would implement should the corresponding threshold levels be exceeded and assuming there is some degree of certainty that the measured change is Project-related. Three levels of action have been identified: low, moderate, and high. These responses range from increased monitoring and data analysis (e.g., trend analysis); identification of possible sources; to risk assessment and/or mitigation. 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 2021c).

### 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:

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

For the threshold to be met, response in movement behaviour would need to be observed as a trend in the data across individuals. In the event that these threshold criteria are exceeded, a commensurate 'Low Risk' response would be triggered (Baffinland 2021b).

### 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 the exposure event, as described in Section 3.0.

***AND***

- A statistically significant decrease in the proportion of immature narwhal relative to baseline conditions (2014/2015 values).

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

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

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

For the threshold to be met, behavioural responses would need to be observed as a trend in the data across individuals. In the event that these threshold criteria are exceeded, a commensurate ‘Moderate Risk’ response would be triggered (Baffinland 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 moderate severity behavioural responses (Severity Score 5 and 6) that persist for a prolonged period (i.e., for several hours) following the exposure event, as described in Section 3.0.

**AND/OR**

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

***AND***

- A statistically significant decrease in the proportion of immature narwhal relative to baseline conditions (2014/2015 values).

***AND/OR***

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

For the threshold to be met, behavioural responses would need to be observed as a trend in the data across individuals. In the event that these threshold criteria are exceeded, a pre-determined ‘High Risk’ response would be triggered, as defined in Baffinland (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 is located on a cliff at Bruce Head, approximately 215 m above sea level (N 72° 4’ 17.76”, W 80° 32’35.52”) and approximately 40 km from Milne Port. From the observation platform, Marine Mammal Observers (MMOs) are provided with a mostly unobstructed view of Milne Inlet from Stephens Island to the north to the entrance of Koluktoo Bay. Poirier Island is visible directly east of the survey platform.

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

### 1.5.1 Stratified Study Area

Data on narwhal relative abundance and distribution data (RAD) is collected within the boundaries of the SSA which covers a total area of 90.5 $km^2$. The SSA is stratified into strata A (northernmost stratum) through J (southernmost stratum; added in 2019) and further separated into substrata 1 through 3 (substrata 1 being closest to the Bruce Head shore/observation platform and substrata 3 being the furthest away). There are a total of 28 substrata within the SSA as 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

Narwhal group composition and behavioural data is collected within the boundaries of the BSA which covers portions of strata D, E, and F that extends 600 m from the shoreline below the Bruce Head observation platform. The shoreline adjacent to the BSA is an established Inuit hunting camp.

**Figure 1-2: Stratified Study Area (SSA) and Behavioural Study Area (BSA)**

# 2.0 SPECIES BACKGROUND

## 2.1 Population Status and Abundance

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

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

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

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

Results from aerial surveys conducted by WSP in 2022 indicated an abundance estimate of 46,408 narwhal for the combined Eclipse Sound and Admiralty Inlet stocks (Coefficient of Variation (CV) = 0.13, 95% confidence interval (CI) = 36,129–59,611; WSP 2023a), which fell within the 95% CI of DFO’s 2013 abundance estimate of the combined stock (45,532 narwhal, CV= 0.33, 95% CI = 22,440 – 92,384; Doniol-Valcroze et al. 2015). Previously, results from aerial surveys conducted by Golder (now known as WSP Canada Inc.) in 2021 indicated an abundance estimate of 75,177 narwhal for the combined Eclipse Sound and Admiralty Inlet stocks (CV = 0.08, 95% CI = 63,795 – 88,590; Golder 2022a). Results from aerial surveys conducted by Golder in 2020 indicated an abundance estimate of 36,044 narwhal for the combined Eclipse Sound and Admiralty Inlet stocks (CV = 0.12, 95% CI = 28,267– 45,961; Golder 2021a), which fell within the 95% CI of DFO’s 2013 abundance estimate of the combined stock (45,532 narwhal, CV=0.33, CI = 22,440–92,384; Doniol-Valcroze et al. 2015). For the Eclipse Sound stock alone, the 2022 abundance estimate was 4,592 narwhal (CV = 0.10, 95% CI of 3,754–5,617, WSP 2023a) which is statistically higher than the 2021 estimate of 2,595 (CV = 0.33, 95% CI of 1,369–4,919; Golder

2022a) (t-test = 2.10, p = 0.040). 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).

**Figure 2-1: Narwhal Summering and Wintering Areas – Baffin Bay Population.**

## 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, 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 during drone-based surveys conducted during the 2021 open-water season. Calving has been reported in Pond Inlet, Eclipse Sound, Navy Board Inlet, Milne Inlet, and Koluktoo Bay (Remnant and Thomas 1992; JPCS 2017); which is consistent with IQ information indicating that calving has been observed in all areas of North Baffin Island (Furgal and Laing 2012). The birth of a narwhal calf near Bruce Head was also observed in August 2016, which supports IQ and previous suggestions from other research that Milne Inlet is used for calving in addition to calf-rearing (Smith et al. 2017). On average, females are thought to produce a single calf approximately once every two to three years and have a generation time of approximately 30 years (Garde et al. 2015). However, many Inuit believe that narwhal give birth more frequently, perhaps annually (COSEWIC 2004). Gestation for narwhal is on the order of 14-15 months (COSEWIC 2004) with IQ suggesting 15 months based on fetuses observed (Furgal and Laing 2012). Newborn calves are primarily born between May and August each year and measure 140 to170 cm in length, approximately 1/3 to 1/2 the body length of an adult female (Charry et al. 2018). Typically, newborn calves travel less than one body length away from their mother and in larger group sizes while in Eclipse Sound (mean group size = 5) compared to smaller group sizes along the east coast of Baffin Island (mean group size = 2; Charry et al. 2018). Calves are generally weaned at 1–2 years of age (COSEWIC 2004).

## 2.4 Diet

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

Studies using dietary biomarkers have found some evidence for sexual segregation in the feeding ecology of narwhal in Pond Inlet (Kelly 2014) and Greenland (Louis et al. 2021). In Kelly (2014), tissue samples were collected from narwhal hunted in Pond Inlet between 2004 and 2006 and tested to compare dietary biomarkers ($\delta^{13}C$ and $\delta^{15}N$) between males, females, and immatures (females with body lengths <337 cm and males with body lengths <388 cm; Garde et al. 2007). Significant differences in the fatty acids and carbon isotope enrichment of females, males and immature whales were found, suggesting that each group was consuming different prey. Females and immature narwhal were suggested to be feeding pelagically and nearer to the sea-ice while males were proposed to be feeding benthically (Kelly 2014). In another study by Louis et al. (2021), bone powder from the skulls of 40 narwhal from West Greenland and 39 narwhal from East Greenland was collected during subsistence hunts from 1990 and 2007. The same biomarkers used by Kelly (2014) were tested and used to compare differences in diet, over several years (vs shorter term data from skin tissue), between males and females. The results of this study also suggested differences in the foraging ecology of males and females. Of note, males from East Greenland had significantly higher levels of $\delta^{15}N$ and larger ecological niches than females (Watt et al. 2013). It was suggested that the differences in foraging ecology were driven by sexual size dimorphism, maternal investment, and deep-diving lifestyles. However, no sex-specific differences in depth were found in West Greenland narwhal, which suggests that differences in foraging ecology are population specific (Louis et al. 2021).

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

## 2.5 Seasonal Migration and Distribution

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

Telemetry studies (DFO 2020b) and available IQ (NWMB 2016a; 2016b; QWB 2022) indicate that some degree of mixing occurs between narwhals in the Admiralty Inlet and Eclipse Sound summer stock areas. Satellite tagging data obtained from 1999 (Heide-Jorgensen et al. 2002), 2009 to 2011 (Watt 2012), 2017 to 2018 (Golder 2020a), and 2016 to 2018 (Marcoux and Watt 2020) provide additional evidence of narwhal use of both areas. Natural exchange between the two summering areas was proposed as a possible reason why the 2013 aerial survey results for Admiralty Inlet (~35,000 narwhal) and Eclipse Sound (~10,000 narwhal) differed substantially from previous survey results for the same stocks (18,000 for Admiralty Inlet in 2010 and 20,000 for Eclipse Sound in 2004) (Doniol-Valcroze et al. 2015). While tagging data provides evidence of overlap in narwhal use of Admiralty

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

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

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

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

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

## 2.6 Group Composition

Narwhal are highly gregarious and are closely associated with one another by nature (Marcoux et al. 2009). Although knowledge regarding the context and function (if any) of narwhal aggregations is incomplete (Marcoux et al. 2009), they have been observed throughout Milne Inlet and Koluktoo Bay in small groups[5] or clusters[6] averaging 3.5 individuals (range: 1 to 25), and in herds[7] of up to hundreds of clusters (Marcoux et al. 2009; Golder 2020b). According to Marcoux et al. (2009), herds observed from the Bruce Head Peninsula were composed of
one to 642 clusters, with a mean of 22.4 clusters/herd. Observations from the Bruce Head Peninsula also revealed that narwhal generally enter Milne Inlet and Koluktoo Bay in larger clusters than when they exit and show strong site fidelity to Koluktoo Bay specifically (Marcoux et al. 2009; Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b, 2022b).

## 2.7 Response to Predators

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

## 2.8 Movement behaviour

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

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

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

[7] Herd = an aggregation of clusters

bodies. Detailed analyses of narwhal surface and dive movements throughout the RSA are presented in the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a).

### 2.8.1 Surface Behaviour

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

### 2.8.2 Dive Behaviour

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

During the summer months, narwhal spend a large proportion of time near the surface, milling[8] and socially interacting with one another (Pilleri 1983; Heide-Jørgensen et al. 2001). Narwhal (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 similar results, with narwhal spending 38% of the time within 2 m of the surface based on aerial surveys. The proportion of time that narwhal spend within 5 m of the surface is slightly greater; Heide-Jørgensen et al. (2001) reported narwhal (n = 21) spend

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

approximately 45.6% of time within the top five metres of the water column, while Laidre et al. (2002) reported a range of 30-53% of time that narwhal (n = 4) spent within this upper depth. Additionally, Tervo et al (2021) reported narwhal (n=13) spent 54% of their time in the upper 20 m of the water column. Although mother-calf pairs have been predicted to spend a greater proportion of time at the surface given the limited diving ability of calves (Watt et al. 2015), no obvious pattern between surface time and body length, sex, and/or presence/absence of calves was observed in a study conducted by Heide-Jørgensen et al. (2001).

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

In regard to descent and ascent speeds, one study conducted by Laidre et al. (2002) determined that a typical dive profile for two narwhal tagged in Tremblay Sound consisted of a steep descent, followed by a short bottom interval, a gradual ascent, and a relatively slow approach to the surface. In one study that tracked dive behaviour of three narwhal tagged in Tremblay Sound (Martin et al. 1994), the maximum rates of ascent and descent for each dive ≥ 20 m depth were positively correlated to the depth and duration of the dive. This finding was supported by the 2017-2018 Integrated Narwhal Tagging Study (Golder 2020a) in which mean descent rates were strongly correlated with the locally available depth. A recent study reported dive profiles similar to those reported by Laidre et al. (2002) where tagged narwhal (n=13) had steeper descents than ascents. Dives were described as either V- or U-dives and narwhal were recorded spending more time on V-dives. V-dives were on average, longer lasting (8.7 min vs 6.9 min respectively), deeper (257 m vs123 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 (i.e., tail strokes) during ascent, and demonstrated spinning behaviour (rolling along their longitudinal axis) typically during descents and during the bottom phase of a dive, particularly during presumed foraging (Tervo et al. 2021).

It is important to note that narwhal dive behaviour is variable based on parameters such as sex, life stage, location, season, and activity state (Heide-Jørgensen et al. 2001). For example, differences in dive rates (number of dives per hour) and dive depth have been found to vary between size and sex of narwhal tagged, with female narwhal generally diving shallower and having lower dive rates than males (Heide-Jørgensen and Dietz 1995). Surprisingly, female narwhal have also been found to spend more time at depth compared to males (Watt et al. 2015; Golder 2020a), despite hypotheses that those with larger body size (i.e., males) would have enhanced ability to dive deeper and for longer 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 2.7, does influence narwhal spatial distribution at the surface (Watt et al. 2017).

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

## 2.9 Acoustic Behaviour

Like all cetaceans, narwhal depend on the transmission and reception of sound to carry out the majority of 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).

### 2.9.1 Vocalizations

Narwhal are a highly vocal species that produce a combination of pulsed calls, clicks, and whistles (Ford and Fisher 1978; Marcoux et al. 2011a). Pulsed calls are the predominant form of narwhal vocalization and 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).

### 2.9.2 Hearing

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

### 2.9.3 Narwhal and Vessel Noise

Behavioural responses of marine mammals exposed to vessel traffic and associated noise have been documented for several species, however limited information is available for cetaceans inhabiting Arctic waters and for narwhal specifically. Vessel disturbance may elicit several different behavioural responses in cetaceans, including a shift in travel speed or dive rate, freeze 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: $1μPa^2·s$). Sound pressure level ($SPL_{rms}$) refers to the average of the squared sound pressure over some duration, while sound exposure level (SEL) is a cumulative measure of sound energy that takes into account the duration of exposure (Southall et al. 2007; NMFS 2018; Southall et al. 2019). It is generally accepted that cetaceans exposed to received sound levels above 120 dB re: 1μPa ($SPL_{rms}$) will begin to demonstrate behavioural disturbance, though the specific behavioural responses exhibited are highly variable depending on the context of the exposure, the receiving environment, the familiarity of the animal with the sound, and the behaviour of the animal during the exposure event (Southall et al. 2007, 2021; Ellison et al. 2012; Williams et al. 2013; NMFS 2018; Southall et al. 2019).

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

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

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

# 3.0 SEVERITY SCORE RANKING

Current scientific practice involves categorizing marine mammal behavioural responses to anthropogenic stressors based on a scale of increasing severity, commonly referred to as a “severity scale”, which includes descriptors of response type, magnitude, and duration (Southall et al. 2007, 2021; Finneran et al. 2017). Initially proposed by Southall et al. (2007) and adapted by Finneran et al. (2017), the severity scale scoring system includes tiered behavioural responses (categorized as low, moderate, or high severity), and has recently evolved to include a framework for linking behavioural responses of free-ranging marine mammals to vital rates (Southall et al. 2021). The most current severity score ranking derived by Southall et al. (2021) assesses behavioural responses of free-ranging marine mammals and their potential impact on (1) survival, (2) reproduction, and (3) foraging. Segregating behavioural responses into these three distinct categorical ‘tracks’ follows the rationale that changes in each category may differentially affect individual fitness and/or vital rates, which may ultimately affect population parameters. The three categorical tracks evaluate behavioural 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 (i.e., temporary) and the animal immediately returns to their pre-response behaviour; and high severity responses include those with immediate consequences to growth and survival, and those affecting animals in vulnerable life stages (i.e., calf, yearling; Southall et al. 2007, Finneran et al. 2017). While it is acknowledged that certain behavioural responses such as a change in foraging/dive behaviour and/or a change in vocal behaviour are relevant to assessing changes in individual fitness, the methodology of the current Program is not designed to detect all such changes[11]. Therefore, any further discussion of severity scaling in the present report is specific to those responses that may be detectable through (or informed by) the shore-based observer and/or drone-based components of the Bruce Head Program.

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

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

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

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

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

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

Moderate severity responses would be considered biologically significant behavioural responses if they were sustained for a long duration. What constitutes a long-duration response is different for each situation and species, although it is likely dependent upon the magnitude of the response, the context of the exposure (e.g., behavioural state of the receptor at the time of the exposure, site conditions), and individual variability within the species group (e.g., familiarity with the stressor, age and health of the receptor). In general, a response would be considered 'long-duration' if it lasted up to several hours, or enough time to significantly disrupt an animal's daily routine. For the derivation of behavioural criteria in this study, a long duration was defined as a response that persisted several hours after vessel exposure or longer.

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

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

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

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

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

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

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

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

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

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

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

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

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

Narwhal behavioural response variables evaluated through the Bruce Head Monitoring Program include group size, group composition, group spread, group formation, group travel direction, travel speed, and distance from shore. Depending on the nature and duration of behavioural responses observed, the response variables assessed herein are considered in relation to the revised and adapted severity score ranking outlined above.

# 4.0 METHODS

## 4.1 Study Team and Training

The 2022 field program took place between 30 July and 23 August 2022 and consisted of 16 hours of daily monitoring effort (weather permitting), undertaken by two teams comprised of five individuals each, alternating at four-hour observation intervals. Study teams consisted of WSP biologists with previous arctic marine mammal survey experience, qualified Marine Mammal Observer (MMO) subcontractors, and local Inuit researchers from Pond Inlet and Arctic Bay. The drone operations team, comprised of two individuals from Aeria Drone Systems Ltd., worked closely with WSP biologists to plan and execute systematic focal follow surveys[14] using a drone-based video system.

Upon arrival to the Bruce Head camp on 29 July 2022, the field team participated in an on-site orientation led by the Camp Manager and Site Supervisor. Topics covered during the orientation included general camp etiquette expectations, proper use of camp facilities, and health and safety considerations such as firearm storage and use requirements while in camp, polar bear awareness, communication procedures, and identification of general hazards in and around camp. All relevant health and safety policies and regulations by WSP and Baffinland were reviewed and discussed.

The study team also participated in a comprehensive training session led by the Field Technical Lead, with topics covered including observational survey procedures, data collection techniques, proper use of equipment, data recording and data entry, and post-processing of the survey data. During the training session, all study team members were provided with a Training Manual (Golder 2022c). Topics covered during the training session included the following study components:

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

## 4.2 Data Collection

Understanding the context and function (if any) of narwhal aggregations and spatial use patterns is important in assessing behavioural response to a potential perceived threat (e.g., vessel traffic, predators). Narwhal are a highly gregarious species (Marcoux et al. 2009; Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b, 2022b) 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

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

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

During the 2022 Program, the drone operations team was responsible for collecting narwhal behavioural data and coordinated survey effort with the MMOs, though worked primarily independently (see section 5.2.6). Detailed descriptions of data collection and survey methods employed during the annual programs are provided in the respective annual reports (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b, 2022b).

### 4.2.1 Relative Abundance and Distribution (SSA)

Consistent with previous years' data collection methods, RAD surveys were conducted throughout the SSA in 2022. Observations were made using survey and scan observation (Mann 1999), where the observer surveyed each stratum for a minimum of three minutes to identify narwhal groups, group size (solitary narwhal were considered a group of one), and travel direction. Once all narwhal present within each substratum were counted and their direction of travel was recorded, the observer moved on to the next substratum. Where the majority of narwhal were travelling in one direction (e.g., north → south), the observer would begin counting strata from the opposite direction (e.g., south → north) to minimize the potential of double-counting groups. RAD surveys were conducted in the SSA throughout the daily monitoring period, every hour, on the hour. In addition, RAD surveys were conducted continuously as a vessel approached the SSA, throughout the time that a vessel transited through the SSA, and once again after the vessel had exited the SSA. During vessel transits through the SSA, counting commenced in the stratum closest to the incoming vessel.

### 4.2.2 Group Composition (BSA)

Group composition data were collected for all narwhal observed within the BSA. Survey and scan sampling protocols (Mann 1999) were used to record group-specific data (Table 4-1, Table 4-2) from . Observations were made using a combination of Big Eye binoculars (25 x 100), 10 x 42 and 7 x 50 binoculars, and the naked eye. When herding[15] events took place and RAD team members were not conducting a RAD count, they assisted in collecting group composition data in the BSA. The data collection protocols were similar across all years of sampling, with the exception that only group composition data were collected in the BSA in 2022 (behavioural data were assessed exclusively through UAV-based focal follow surveys; see section 4.2.3). A detailed description of group composition data collected is provided in the Training Manual (Golder 2022c).

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

**Table 4-1: Narwhal group composition data collected in the BSA**

| Recorded Data | Description |
|---|---|
| Time of sighting | Time of initial observation within the BSA |
| Sighting number | A sighting number was used as a unique identifier for each single whale or group of whales |
| Marine mammal species | All marine species observed were recorded as a separate sighting |
| Group size[1] | Number of narwhal within one body length of one another |
| Number of narwhal by tusk classification | ■ Number of narwhal with tusks<br>■ Number of narwhal without tusks<br>■ Number of narwhal with unknown tusks (i.e., head not visible) |
| Number of narwhal by age category | Adult, juvenile, yearling, calf, unknown life stage (Table 4-2) |

Notes:

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

**Table 4-2: Life stages of narwhal**

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

### 4.2.3 Behaviour (UAV-based Focal Follow Surveys)

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

The use of UAVs equipped with high-resolution video or digital single lens reflex (DSLR) cameras, combined with other sensors, is a valuable tool commonly used for assessing fine-scale behaviours of cetaceans (Broker et al. 2019). As such, aerial imagery of narwhal within the SSA and along the shipping corridor was collected throughout the Program. The drone operations team (Aeria Inc.) worked closely with WSP marine mammal biologists to carry out systematic focal follow surveys of narwhal using a selection of UAV units, primarily the EVO 2 by Autel Robotics. The EVO 2 is a compact UAV unit that includes a powerful camera on a three-axis stabilized gimbal, capable of recording video at 8k resolution up to 25 frames per second and capturing 48 megapixel stills. In 2020, focal follow surveys were conducted via a single drone in flight at a time whereas two drones were typically flown simultaneously during the 2021 and 2022 field seasons to increase sample size. All survey footage was recorded at 4k resolution or higher. To conduct this work, a Special Flight Operations Certificate (SFOC) was obtained from Transport Canada to perform Beyond Visual Line of Sight (BVLOS) operations (SFOC #930030).

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

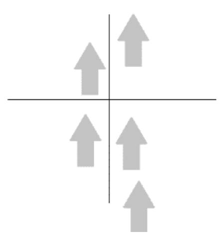
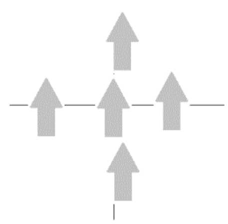
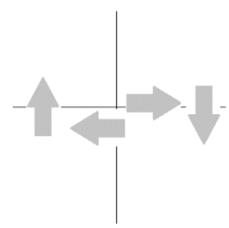
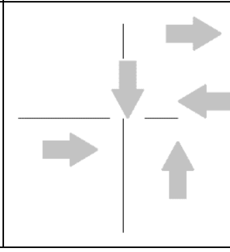
Effort was made to conduct consecutive focal follow surveys during active ship transits through the SSA, regardless of whether narwhal were visible to observers at the Bruce Head survey platform at the time. These surveys were considered “searches” and did not always result in focal groups being followed.

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

| Data recorded | Description |
|---|---|
| Primary behaviour | ■ Travelling (directed movement)<br>■ Milling (non-directional movement)<br>■ Resting (not moving or moving slightly in a low-activity state; logging)<br>■ Social (clear interaction between conspecifics) |
| Unique behaviours | ■ Nursing<br>■ Rubbing<br>■ Vertical roll<br>■ Horizontal roll<br>■ Sexual display<br>■ Jousting (directed movement toward another by tusked individual) |
| Association of immature with presumed mother | ■ Distal position (tight, loose)<br>■ Relative position (left, right, front, behind, top, under) |
| Group formation | ■ See Table 4-4 (Formation). |
| Group spread | ■ Tight: narwhal ≤ body width apart<br>Loose: narwhal >1 body width apart |

| Data recorded | Description |
|---|---|
| Group size | Number of narwhal within 1 body length of one another. Includes group size of 1. |
| Group travel speed | Assessed using UAV GPS metadata. |

**Table 4-4: Group formation categories**

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

## 4.2.4 Vessel Transits

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

The study teams also visually recorded vessel traffic in the SSA during each survey period. Vessels were classified by size (small <50 m, medium 50-100 m, and large >100 m in length), type of vessel, and general travel direction. In previous years of analysis (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b, 2022b), small vessels were modelled as either total count present during each RAD count or as present/absent. In the current analysis, only medium and large vessels were included, while small vessel presence was omitted from analysis due to concerns of small vessels being detected disproportionately between different substrata and between different levels of narwhal activity in the study area.

### 4.2.5 Non-vessel Anthropogenic Activity

The rocky shoreline below the Bruce Head observation platform serves intermittently as a hunting camp for local Inuit. Over the course of the eight-year program, active shooting events associated with hunting have been regularly observed by the study team both visually and acoustically from the observation platform. All hunting (i.e., shooting) events were recorded during each daily monitoring period, including the time of occurrence, duration of the event, number of shots fired, and target species. In addition, a pair of Wildlife Acoustic SM4 recorders were set up approximately 50 m from the hunting camp to record hunting events during times that the study team was not actively monitoring (**Photograph 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.**

### 4.2.6 Environmental Conditions

Environmental conditions were recorded at the start of the monitoring period, every hour, and whenever conditions changed. For the entire SSA, cloud cover (percent [%]), precipitation, and ice cover (%) were recorded. Beaufort wind scale 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 real-time updates of changing weather conditions, including wind speed and wind direction.

# 4.3 Data Analysis

## 4.3.1 Data Preparation for Analysis

### *4.3.1.1 Automatic Identification System (AIS) Data*

Satellite-based AIS data were merged with the AIS base station data. The full AIS dataset was clipped to only include ship track data collected in the Bruce Head study area (between Stephens Island and Milne Port). The full positioning dataset obtained in 2022 from the shore-based AIS station at Bruce Head had a mean of 0.2 min between positions (range of 0.02-248 min, median of 0.2 min, standard deviation [SD] of 0.85 min). The distances between positions ranged from 0.0 km to 0.77 km (mean of 0.04 km, median of 0.04 km, and SD of 0.02 km). Positioning data from the AIS satellite only (i.e., with removed Bruce Head antenna data) had a mean of 0.80 minutes between positions (range of 0.02-2.95 min, median of 0.63 min, SD of 0.70 min). The distances between positions ranged from 0 km to 0.95 km (mean of 0.20 km, median of 0.14 km, and SD of 0.18 km).

AIS data were subsequently filtered to only include data collected during active survey periods at the platform. In AIS positioning data filtered to the temporal extent of RAD/BSA sampling, <1% of the AIS data were contributed by satellite data. The combined shore-based and satellite-based AIS dataset had a mean of 0.18 minutes between positions (range of 0.02-248 min, median of 0.04 min, SD of 0.02 min). The distances between positions ranged from 0.0 km to 0.77 km (mean of 0.04 km, median of 0.04 km, and SD of 0.02 km). The resulting dataset was used to interpolate the AIS data to 1 min resolution, to create a high temporal resolution considered necessary to relate vessel positions to narwhal sightings and behaviour.

Each point in the compiled AIS dataset was used to calculate the distance and angle between the vessel's position and each centroid of the 28 SSA substrata (Figure 4-1). The resulting distances were used as continuous predictors of narwhal response to vessel traffic. To account for the orientation of the vessel relative to the substrata, vessels that were nearing the substrata (angles >270º and <90º) were classified as "Toward the substratum", whereas vessels that were moving away from the substrata (90º< angles <270º) were classified as "Away from the substratum". The interpretation of a vessel moving toward or moving away was therefore not that it departed the actual substratum, but that it was moving away from the substratum, acknowledging that an animal's response to a transiting vessel may vary depending on whether it is being approached by the vessel or is facing the stern of a departing vessel where the majority of radiated noise is generated. The AIS data preparation was repeated in an identical way for the behavioural and composition dataset, using the GPS position of the group at each time stamp in the UAV video analysis dataset as the reference point.

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 ≤4.64 km; Austin and Dofher 2021). Therefore, the study design was conservatively modified in 2020 to reduce the 10 km exposure zone to 7 km and further in 2021 to 5 km, to more accurately capture the predicted zone of disturbance for narwhal. This reduction in spatial extent was intended to reduce potential noise in the data at farther distances, which would allow to better quantify the effects at closer distances, where effects were likely to be stronger.

**Figure 4-1: Example of estimating angles and distances between Automatic Identification System (AIS) ship locations and substratum centroids.**

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

For each RAD count within a given substratum, AIS data were retrieved for each vessel present in the study area, including information on course, heading, and distance, and whether the vessel was moving toward or away from the substratum's centroid (recorded to the nearest time stamp). The data were then filtered using a temporal criterion: vessels with GPS positions recorded more than 15 min either before or after each substratum's count were removed from the analysis, leaving only relevant AIS data for inclusion in the model. In addition, a spatial criterion was added – vessels that were more than 5 km away from a centroid were not considered to affect relative abundance, distribution, or behaviour of narwhal. This spatial filter corresponded to the distance at which vessel noise levels were, on average, below 120 dB re: 1µPa (Austin and Dofher 2021). Data filtration was performed similarly for the behavioural and composition data. All data collected during conditions of impossible sightability were removed from the analyses.

#### 4.3.1.3 Group Composition Data (BSA)

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

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

| Year | Number of Narwhal Groups (Number of Individuals) | Number of Groups per Bin |
|---|---|---|
| 2014 | 250 (1,086) | 25 |
| 2015 | 268 (1,479) | 26–27 |
| 2016 | 761 (2,476) | 76–77 |
| 2017 | 2,416 (8,913) | 241–242 |
| 2018 | N/A | N/A |
| 2019 | 1,301 (4,986) | 130–131 |
| 2020 | 878 (2,847) | 87–88 |
| 2021 | 80 (263) | 8 |
| 2022 | 1,523 (5,864) | 152–153 |

#### 4.3.1.4 Behavioural Data (UAV-based Focal Follow Surveys)

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

#### 4.3.1.5 Anthropogenic Data

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

In previous analyses, the effects of hunting were assessed up to 12.5 h from the last shooting event (Smith et al 2017; Golder 2019) and up to 3 h post-shooting (Golder 2020b). As part of the analysis of the combined 2014-2019 dataset (Golder 2020b), the temporal extent of the effects of hunting on number of narwhal per substratum were assessed. The results indicated that the number of narwhal recorded up to 50 min following a shooting event were significantly different from 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 min 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 min, and narwhal recorded more than 70 min following a shooting event were considered as "no hunting" observations.

#### 4.3.1.6 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.

#### 4.3.1.7 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 (2,215 cases representing 3.7% of total individual substratum surveys). These cases accounted for a combination of high sea state, glare, fog, or ice cover, and therefore had to be removed from the modelling dataset.
- Data collected on days when killer whales were known to be present within southern Milne Inlet (1,780 cases, representing 2.9% 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 because narwhal behaviour and distribution are strongly affected by the presence of killer whales.
- Cases with narwhal density of ≥200 narwhal/km² (two cases, <0.01% of total individual substratum surveys) to resolve model convergence issues.

Note that some of these cases overlapped. For example, in 110 substratum surveys, sightability was "impossible" and Beaufort level was 6 or higher.

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

## 4.3.2 Statistical Models

### *4.3.2.1 Analytical Approach*

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

- Where possible, a simple, positive, non-directional distance was used, without variables accounting for the vessel's direction within Milne Inlet, or relative position of vessel (i.e., vessel moving toward or away from centroid). This was done to increase sample size and hence increase the models' power to detect a shipping effect. 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 a 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 allowed 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 centroids (i.e., exposure zone <5 km), as detailed in Section 4.3.1.1.
- 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.
- Effect size calculation – It was assumed that effects would be strongest at the closest distance between narwhal and vessels; that is, at a distance of 0 km. However, while RAD data were available for such close distances (with nearest distance between narwhal and vessels of 0.03 km), for the UAV-based dataset, the closest distance between narwhal and vessels was 0.4 km. Therefore, effect sizes for the RAD analysis were estimated for 0 km distance between narwhal and vessels, while for the UAV-based dataset, effect sizes were calculated at 0.5 km from vessels, to decrease extrapolation from models where no data were available.
- Effect size magnitude – In the current analysis, effect sizes are described as small (≥0.10), medium (≥0.25), or large (≥0.50), similar to effect size criteria used in other behavioural response studies related to vessel exposure (Cohen 1988; Richter 2006; Zapetis et al. 2017). In taking a conservative approach for detection of behavioural changes to vessels, narwhal responses with a medium effect size were considered for further investigation as this level of response was considered potentially biologically relevant. However, caution is warranted with respect to interpretation of results given the low sample size available for the nearfield (<5 km) vessel-narwhal interaction distances.

#### 4.3.2.2 Narwhal Density Modeling

Narwhal RAD data collected in the SSA were analysed as the total density of narwhal observed in each substratum during each RAD survey completed across eight 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 included the following:

- Glare (within SSA strata or BSA, as applicable) — categorical variable with the following categories: None (N), Low (L), Moderate (M), and Severe (S). A detailed description of glare categories are available in Golder (2022c).
- Beaufort level (within SSA strata, as applicable) — for the RAD, it was used as categorical variable, with categories ranging from 0 to 5. A detailed description of Beaufort Scale categories are available in Golder (2022c).
- Tide – categorical variable with the following categories: "low slack", "flood", "high slack", and "ebb", as detailed in Section 4.3.1.3.
- Distance from vessel — continuous variable (in km) calculated between vessel location and each of the SSA substratum centroids. Where directional distance was used, the values were negative when the vessel was heading toward the centroid and positive when the vessel was heading away from centroid.
- Vessel direction within Milne Inlet — categorical variable with two categories: ‘northbound’ and ‘southbound’, used for RAD analysis.
- Interaction between vessel distance and vessel direction.
- Vessel presence within the exposure zone (≤ 5 km) from the substratum centroid — categorical variable with two categories: ‘no vessel present within the exposure zone’, and ‘at least one vessel present within the exposure zone’, where exposure zone was 5 km (see Section 4.3.2.1).
- Whether hunting occurred within a pre-defined window prior to a sighting — categorical variable with two categories: ‘hunting occurred’ and ‘no hunting occurred’. For the RAD analysis, 70 min was selected as the pre-sighting cut-off limit for a hunting activity, as detailed in Section 4.3.1.5.
- Year — categorical variable with eight categories: 2014, 2015, 2016, 2017, 2019, 2020, 2021, and 2022.
- Day of year — continuous variable, where January 1 of each year is assigned a value of 1, only used for RAD analysis.
- Stratum – categorical variable (A to J), only used for RAD analysis.
- 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.
- Presence or absence of small vessels within the SSA when each observation was made.

Where possible based on previous findings, the effects of vessel direction within Milne Inlet and the interaction between vessel distance and direction were simplified to an effect of absolute distance from a vessel, to increase statistical power and to simplify interpretation of modeling results.

The effects of 'day of year' 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.

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 eight-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 what distance the estimated response values became significantly different from values predicted when no vessels were present within 5 km. All comparisons were made using the package emmeans (Lenth 2020) in R v. 4.2.2 (R 2022).

All analyses were performed using the package glmmTMB (Brooks et al. 2017) in the statistical package R v. 4.2.2 (R 2022). Model fit was assessed via diagnostic and residual plots using the DHARMa package (Hartig 2019).

#### 4.3.2.3 Proportion of Immatures (Calves and Yearlings)

A set of planned contrasts was constructed for the EWI dataset, so that each sampling year was compared to the average of 2014–2015 mean least squares. Since the question of interest was whether each sampling year was different from the baseline 2014–2015 years (as opposed to whether an overall difference between years existed), an overall 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 was deemed to have been exceeded if a statistically significant difference was observed between each year's least squares mean and the average of the 2014–2015 least squares mean values.

#### 4.3.2.4 Behaviour (UAV-based Focal Follow Surveys)

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

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

Focal groups were divided into five categories based on composition: 1) mother-immature pairs (groups comprised strictly of presumed mothers with calves or yearlings), 2) mixed groups with immatures (groups comprised of 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 immatures), 4) strictly adult groups, and 5) lone immatures.

Statistical analyses of data collected via drone footage were performed for all assessed variables – primary behaviour, unique behaviour, association of immatures with presumed mother, nursing behaviour, group formation, group spread, group size, and group travel speed. The analyses were performed using mixed models fitted in the package glmmTMB (Brooks et al. 2017) in R v. 4.2.2 (R 2022). Model fit was assessed via diagnostic and residual plots using the DHARMa package (Hartig 2019). Most models included a random effect of the focal follow survey for most models, except for the models of the relative position and distal position of immatures, given that multiple immatures were often present within each sampling time. These two models included a random effect that uniquely identified both the immature and the focal follow.

If a significant effect of 'distance from vessel' was identified, multiple comparisons (with Dunnett-adjusted *P* values) were performed to estimate at what distance the estimated response values became significantly different from values predicted when no vessels were present within 5 km. All comparisons were made using the package emmeans (Lenth 2020) in R v. 4.2.2 (R 2022).

The following sections describe the models used for analyzing the narwhal behavioural data. For each behavioural response variable, if effects were found to be statistically significant, and for all shipping effects regardless of their statistical significance, 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 behaviour and the various explanatory variables. Since each model contained multiple predictor variables, the visualization of predictions relative to specific variables of interest required setting the other predictor variables to a constant value.

##### 4.3.2.4.1 Primary Behaviour

In the analysis of primary behaviour, narwhal behaviours were binned in two categories – 'travel or resting,' 'milling or social activity', with the latter category assumed to comprise non-stressed behavioural state activities. A mixed-effect model with a binomial distribution was used to analyse the data. Fixed effects included vessel presence within 5 km from the group, distance from vessel, group type, and an interaction between distance from vessel and group type. The group types assessed included mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups, while lone immatures were removed from the analysis due to insufficient sample size. The random effect was an intercept of focal follow ID, which accounts for the variability between groups and the correlation of observations within group.

##### 4.3.2.4.2 Unique Behaviour

In the analysis of unique behaviour, behaviours were binned in two categories – 'unique behaviour' which included rolling, rubbing, nursing, sexual displays and tusking; and 'no unique behaviour.' A mixed-effect model with a binomial distribution was used to analyse the data. Fixed effects included vessel presence within 5 km from the group, distance from vessel, group type, and group size. An interaction between distance from vessel and group type could not be included at this time due to the low sample size involved. The group types assessed included mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups, while lone immatures were removed from the analysis due to insufficient sample size. Group size was included in the model to account for increased likelihood of unique behaviours being observed when more narwhal are present in the group. The random effect was an intercept of focal follow ID, which accounts for the variability between groups and the correlation of observations within group.

#### 4.3.2.4.3 Association of Immatures with Presumed Mother

##### *4.3.2.4.3.1 Presence of Nursing Behaviour*

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

##### *4.3.2.4.3.2 Relative and Distal Positioning of Immatures*

Both the relative and distal position analyses used only data from mother-immature pairs and mixed groups with immatures, since mixed groups without immatures, adult groups, and lone immatures did not provide data on relative or distal position between immatures and their mothers. The random effects were an intercept of focal follow ID, and the ID of the immature within the focal follow, nested within the focal follow ID; these two effects accounted for the correlation of observations within group, and the correlation of observations of each individual immature narwhal within groups that had multiple immatures.

In the analysis of distal position, a mixed-effect model with a binomial distribution was used. Fixed effects included vessel presence within 5 km from the group, distance from vessel, relative position of immature, and group type. An interaction between distance from vessel and group type or relative position could not be included at this time due to low sample size. Of the five relative position categories considered in the study design (i.e., on top, under, abreast, behind, in front), two categories (i.e., behind and in front) had low sample sizes; therefore, data were re-grouped into one of the following three categories: ‘on top’, ‘under’ and ‘lateral’, the latter which included ‘abreast’, ‘in front’, and ‘behind’ relative positions.

In the analysis of relative position, of the five relative positions recorded (on top, under, abreast, behind, in front), one (on top) was removed from the data analyses due to low sample size. In addition, to increase sample size, the remaining relative positions were grouped into the following two categories: ‘under’ and ’lateral’, the latter which included ‘abreast’, ‘in front’ and ‘behind’ relative positions. To analyze the dataset, a mixed-effect model with a binomial distribution was used. Fixed effects included vessel presence within 5 km from the group, distance from vessel, and group type. An interaction between distance from vessel and group type could not be included at this time due to low sample size.

#### 4.3.2.4.4 Group Formation

In the analysis of group formation, formations were binned in two categories – ‘parallel’ and ‘linear, cluster, non-directional line, or no formation.’ A mixed-effect model with a binomial distribution was used to analyse the data. Fixed effects included vessel presence within 5 km from the group, distance from vessel, group size, group type, and the interaction between group type and distance from vessel. The group types assessed included mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups, while lone immatures were removed from the analysis due to insufficient sample size. Group size was included in the model to account for decreased likelihood of a strictly parallel formation in larger groups. The random effect was an intercept of focal follow ID, which accounted for the variability between groups and the correlation of observations within group.

#### 4.3.2.4.5 Group Spread

In the analysis of group spread, a mixed-effect model with a binomial distribution was used. Fixed effects included vessel presence within 5 km from the group, distance from vessel, and group type. An interaction between distance from vessel and group type could not be included due to convergence issues during modelling. The group types were: mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups (lone immatures were removed from the analysis due to low sample size). The random effect was an intercept of focal follow ID, which accounts for the variability between groups and the correlation of observations within group.

#### 4.3.2.4.6 Group Size

In the analysis of group size, a mixed-effect model with a truncated Poisson distribution was used. The analysis of group size was performed on the following group types: mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups (lone immatures were removed from analysis). The goal of the analysis was to assess whether groups disperse (resulting in a decreased group size) or merge with other groups (resulting in an increased group size) in response to vessel traffic. For all group types, there was a minimum group size which could not be any smaller – a group size of one for adult groups and mixed groups without immatures, and group size of two for mother-immature pairs and mixed groups with immatures. These minimum-sized groups could only increase in group size, whereas groups sized larger than the minimum could either increase or decrease in size. Hence, the modeling needed to account for the difference in initial group size. Due to the differences in minimum group size between groups with and without immatures, a separate model was constructed for each group type. Fixed effects in each model included vessel presence within 5 km from the group, distance from vessel, and whether the group size was at minimum value in the previous time stamp in the survey. The random effect was an intercept of focal follow ID, which accounted for the variability between groups and the correlation of observations within groups.

#### 4.3.2.4.7 Group Travel Speed

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

- Cases where the drone was not directly above the narwhal group (since the drone's GPS position was used to represent the narwhal group's position, these cases would bias group position, and hence the travel speed estimates).
- Cases where the drone was at high altitude during focal follow surveys.
- The first position from each focal follow survey as the drone was typically still at high altitude and not necessarily positioned directly overhead of the focal group.
- Cases where estimated travel speed was higher than 2.5 m/s. This cut-off value was based on Heide-Jorgensen et al. (2002 and 2013a) and was consistent with the cut-off used in the Narwhal Tagging Study (Golder 2020a), as travel speeds greater than 2.5 m/s were unlikely and therefore presumed to be artefacts of the data. In the current dataset, this resulted in the removal of nine data points, with speeds up to 4.0 m/s (0.7% out of full dataset).

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

In the analysis of group travel speed, a mixed-effect model with a normal distribution was used. Fixed effects included vessel presence within 5 km from the focal group, distance from vessel, group type, and the interaction between group type and distance from vessel. The group types were: mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups (lone immatures were removed from analysis due to limited data in presence of vessels). The random effect was an intercept of focal follow ID, which accounted for the variability between groups and the correlation of observations, with a temporal autocorrelation within each group.

#### *4.3.2.5 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.

# 5.0 RESULTS

## 5.1 Observational Effort and Environmental Conditions

Each annual monitoring campaign at Bruce Head (2014–2017 and 2019-2022) was timed to extend over an approximate four-week period, coinciding with the open-water season (Table 5-1; Figure 5-1). In general, the study area was ice-free during each annual program, with occasional presence of drifting ice floes in the SSA. Survey effort varied between years (Table 5-1), largely due to changing weather conditions and the number of monitoring shifts used each year. For example, survey effort was lower in 2017 than in previous years due to only having a single ten-hour monitoring shift per day, while previous years consisted of two daily rotating eight-hour shifts. In 2019, two daily shifts were resumed, with each team monitoring for eight hours (16 hours total). The 2019 monitoring schedule was replicated in 2020-2022.

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

| Statistic | Survey year | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2019 | 2020 | 2021 | 2022 | |
| Shipping season extent | 08 Aug – 03 Sep | 03 Aug – 04 Sep | 28 Jul – 03 Sep | 02 Aug – 17 Oct | 18 Jul – 30 Oct | 05 Jul – 15 Oct | 27 Jul – 30 Oct | 30 Jul – 13 Oct | - |
| 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 | 3 Jul – 23 Aug | - |
| No. of active survey days | 23 | 29 | 27 | 26 | 26 | 26 | 24 (BSA), 22 (RAD) | 24 (RAD) | 181 |
| No. of survey days lost to weather | 14 | 9 | 11 | 2 | 3 | 0 | 4 | 0 | 43 |
| No. of observer hours (total) | 79.6 | 148.7 | 159.3 | 97.3 | 151.5 | 193.0 | 163.0 | 184.4 | 1,176.9 |
| Average daily survey effort (h) | 7.8 | 10.8 | 11.9 | 6.1 | 11.1 | 13.6 | 13.2 | 14.2 | 11.1 |
| No. of attempted RAD surveys | 179 | 314 | 321 | 160(1) | 288 | 353 | 290 | 341 | 2,246 |
| No. of complete RAD surveys | 166 | 313 | 311 | 109 | 169 | 206 | 188 | 278 | 1,740 |
| Number of RAD surveys with 0 narwhal counts(2) | 75 | 164 | 127 | 35 | 71 | 236 | 197 | 152 | 1,057 |
| No. of narwhal (total) | 10,463 | 14,599 | 28,309 | 11,862 | 19,210 | 9,047 | 4,762 | 15,548 | 113,800 |
| No. of narwhal excluding 'impossible' sightability | 10,463 | 14,599 | 28,309 | 11,831 | 19,200 | 9,047 | 4,762 | 15,548 | 113,759 |
| No. of narwhal excluding 'impossible' sightability, standardized by effort (total narwhal / total h) | 131.4 | 98.2 | 178.0 | 121.8 | 127.2 | 47.5 | 29.4 | 84.9 | 97.1(4) |
| No. of vessel transits during RAD effort | 7 | 11(3) | 21(3) | 22 | 32(3) | 42 | 31 | 40 | 206 |
| No. of RAD surveys with >1 vessel transiting | 1 | 0 | 1 | 2 | 2 | 3 | 1 | 4 | 14 |

(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 5-2 due to transits occurring outside of a RAD count or the vessel being farther than 5 km from relevant substrata during the RAD count.
(4) Total number of observed narwhal, divided by total effort

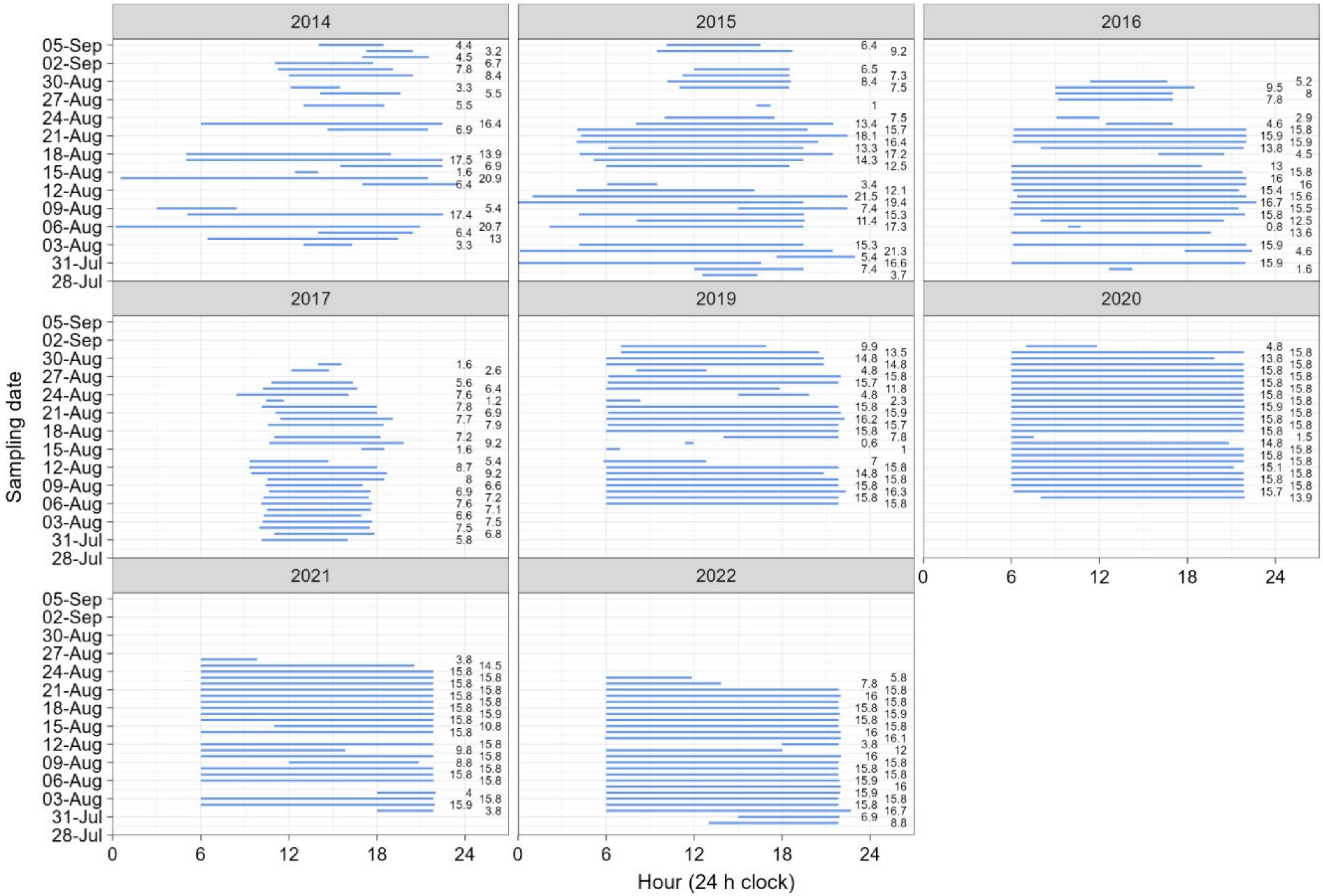



**Figure 5-1: Observer effort (h) by survey day, presented by year; lines extend from first to last observations made within each day.**

Across the eight-year dataset, sightability was shown to decrease with increasing wind levels, and with increasing stratum distance relative to the observation platform (e.g., substratum 3 was generally associated with reduced sightability compared to substratum 1; Figure 5-2). All sightings made during ‘impossible’ sighting conditions or during wind conditions of Beaufort level 6 or higher were removed from the multi-year analysis, equivalent to 2,247 rows of RAD data (2.5% of the total 2014–2017 and 2019-2022 dataset).

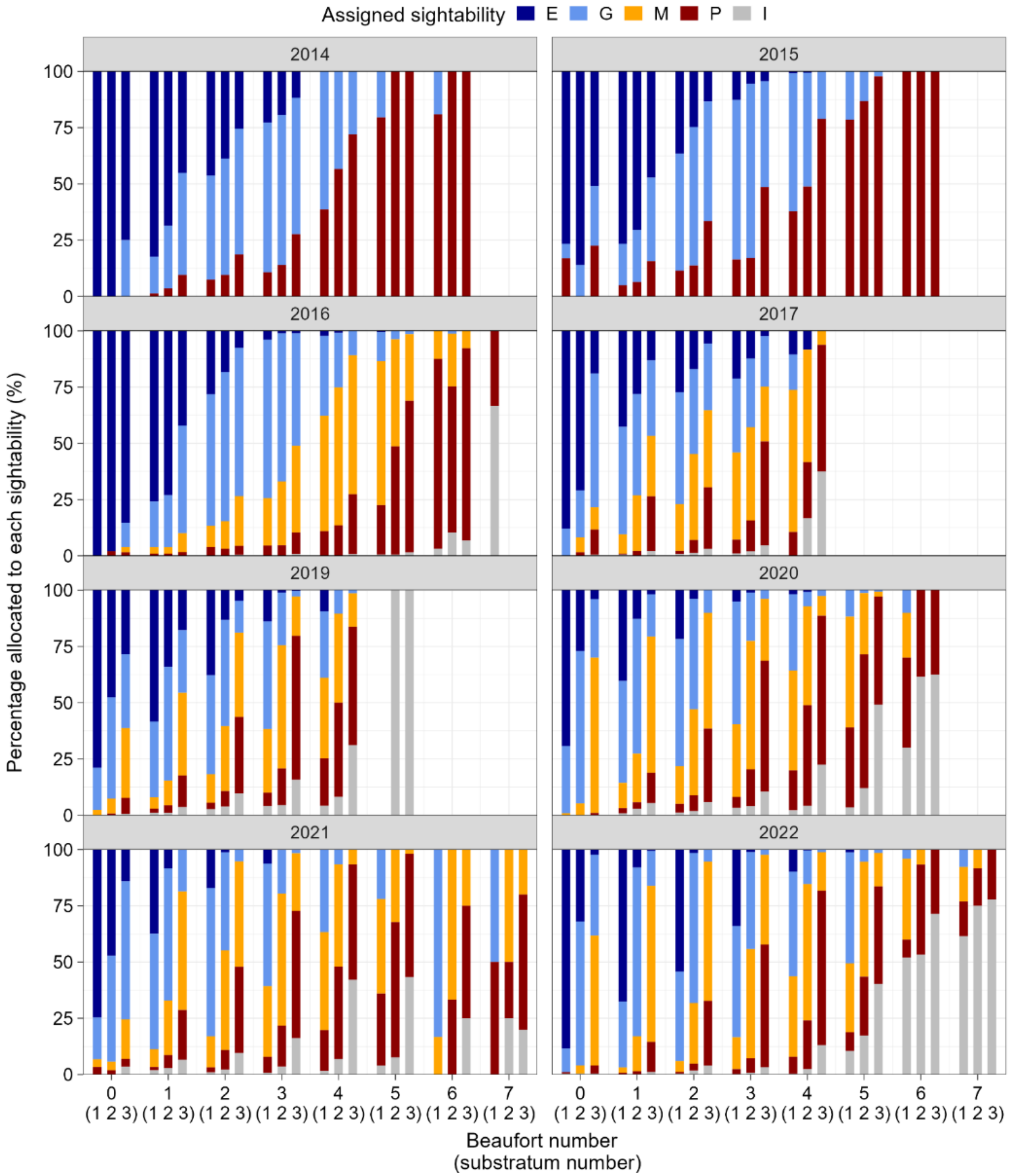



**Figure 5-2: Sightability conditions during RAD surveys in the SSA based on Beaufort wind scale, glare, and substratum location (plotted by year): (E) Excellent, (G) Good, (M) Moderate, (P) Poor, (I) Impossible.**

## 5.2 Vessel Transits and Other Anthropogenic Activity

### 5.2.1 Baffinland Vessels and Other Large/Medium-Sized Vessels

The total number of annual one-way vessel transits that passed through the SSA during the Bruce Head study period and throughout the full shipping season is summarized in Table 5-2 and Figure 5-3. In 2022, sightings data were recorded during 37 of 56 (66%) of all vessel transits that occurred during the study period. Large vessel traffic in the SSA consisted primarily of Project-related bulk ore carriers (23 unique vessels, 46 one-way transits; Table 5-2; APPENDIX B), accounting for 59%, 77%, 73%, 83%, 80%, 86%, and 82% of total one-way transits in 2015, 2016, 2017, 2019, 2020, 2021, and 2022 respectively (no ore carriers were present in 2014). Other large Project-related vessels included general cargo vessels and fuel tankers. One passenger vessel was recorded in the SSA in 2022. Recorded tracklines of all vessel transits through the SSA during the full extent of all shipping seasons combined are presented in Figure 5-4. Recorded tracklines of vessel transits occurring during the 2022 survey period specifically are presented in Figure 5-5.

Vessel speeds were plotted by vessel type for each year (Figure 5-6). As part of Baffinland's vessel management practices, a maximum vessel speed limit of nine knots along the Northern Shipping Route is enforced. No ore carriers exceeded the 9 knot speed limit in the SSA during 2022.

**Table 5-2: 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 | 186 (186) | 56 (56) | 42 (75%) |
| 2021 | 175 (175) | 58 (58) | 36 (62%) |
| **2022** | **150 (148)** | **56 (54)** | **37 (63%)** |
| **Total** | **996 (971)** | **386 (361)** | **222 (57%)** |

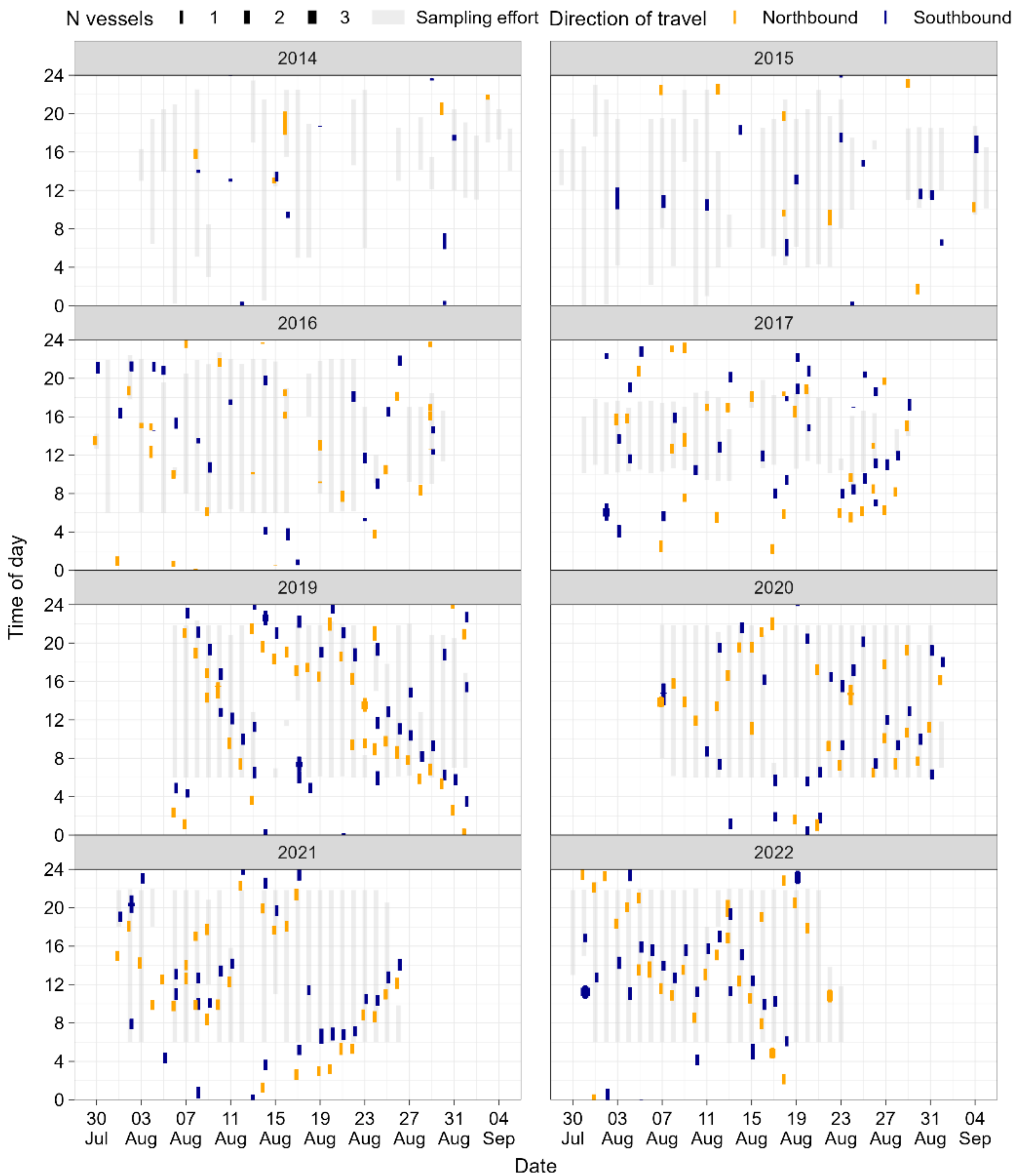



**Figure 5-3: Daily summary of vessel transits in SSA with associated survey effort. Grey boxes indicate daily monitoring periods and correspond to observer survey effort shown in Figure 5-1; grey boxes extend from first to last observations made within each day.**

**Figure 5-4: Tracklines of vessel transits in SSA during all shipping seasons (2014–2017, 2019-2022).**

**Figure 5.4A PLACE HOLDER**

**Figure 5.4B PLACE HOLDER**

**Figure 5-5: Tracklines of vessel transits in SSA during the 2022 Bruce Head study period (30 July to 23 August 2022).**

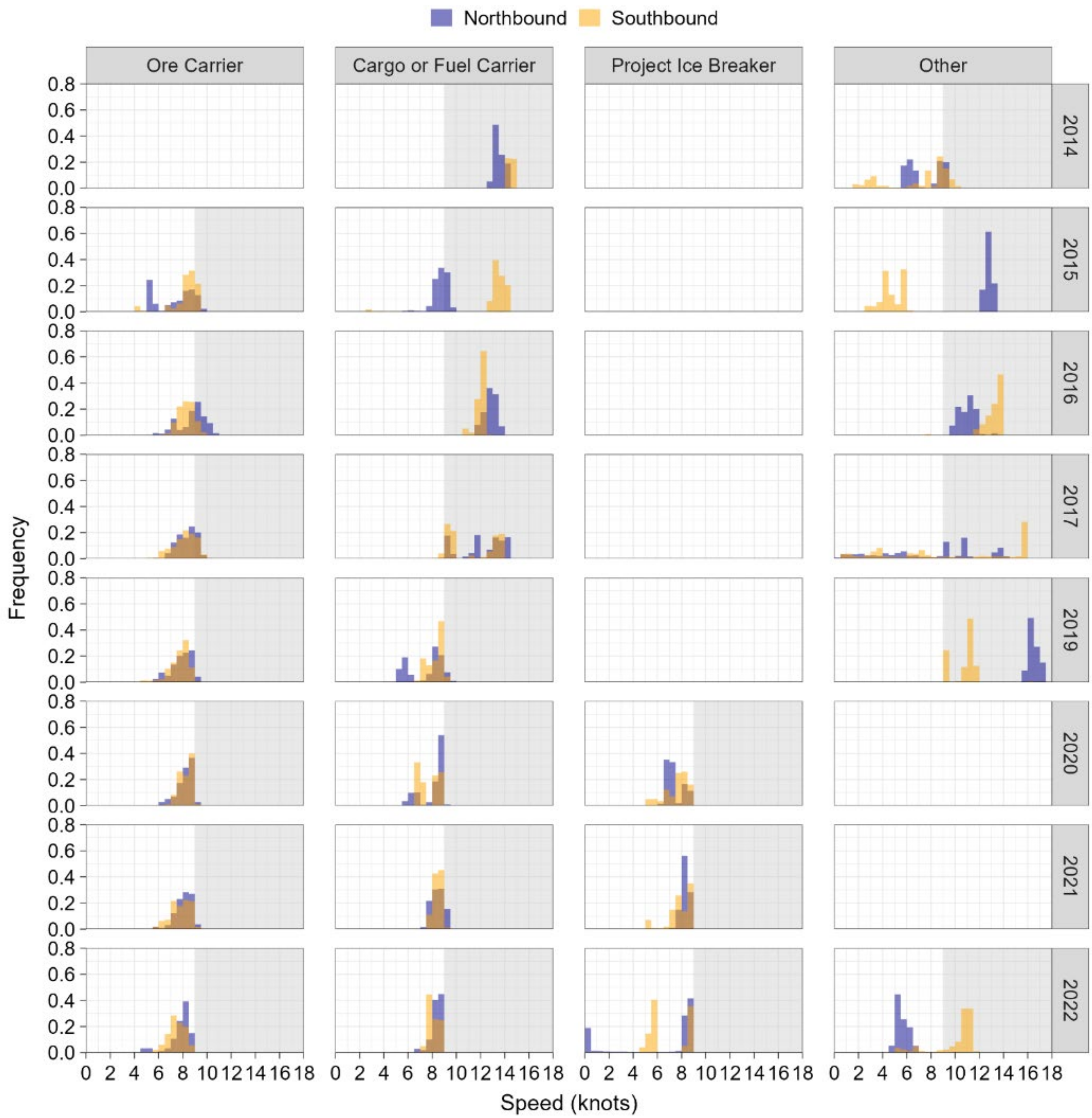



**Figure 5-6: Travel speed (knots) of all vessels in the SSA presented by survey year. Shaded area represents speeds >9 knots.**

### 5.2.2 Other Anthropogenic Activities

The shoreline directly below the observation platform at Bruce Head is an established narwhal hunting site commonly used by local community members. Inuit were often observed camping with tents at the site for multiple days at a time, though others only stopped for several minutes to several hours. During the 2022 field program specifically, the hunting camp was visited or occupied by local hunters for only 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 5-7). 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.

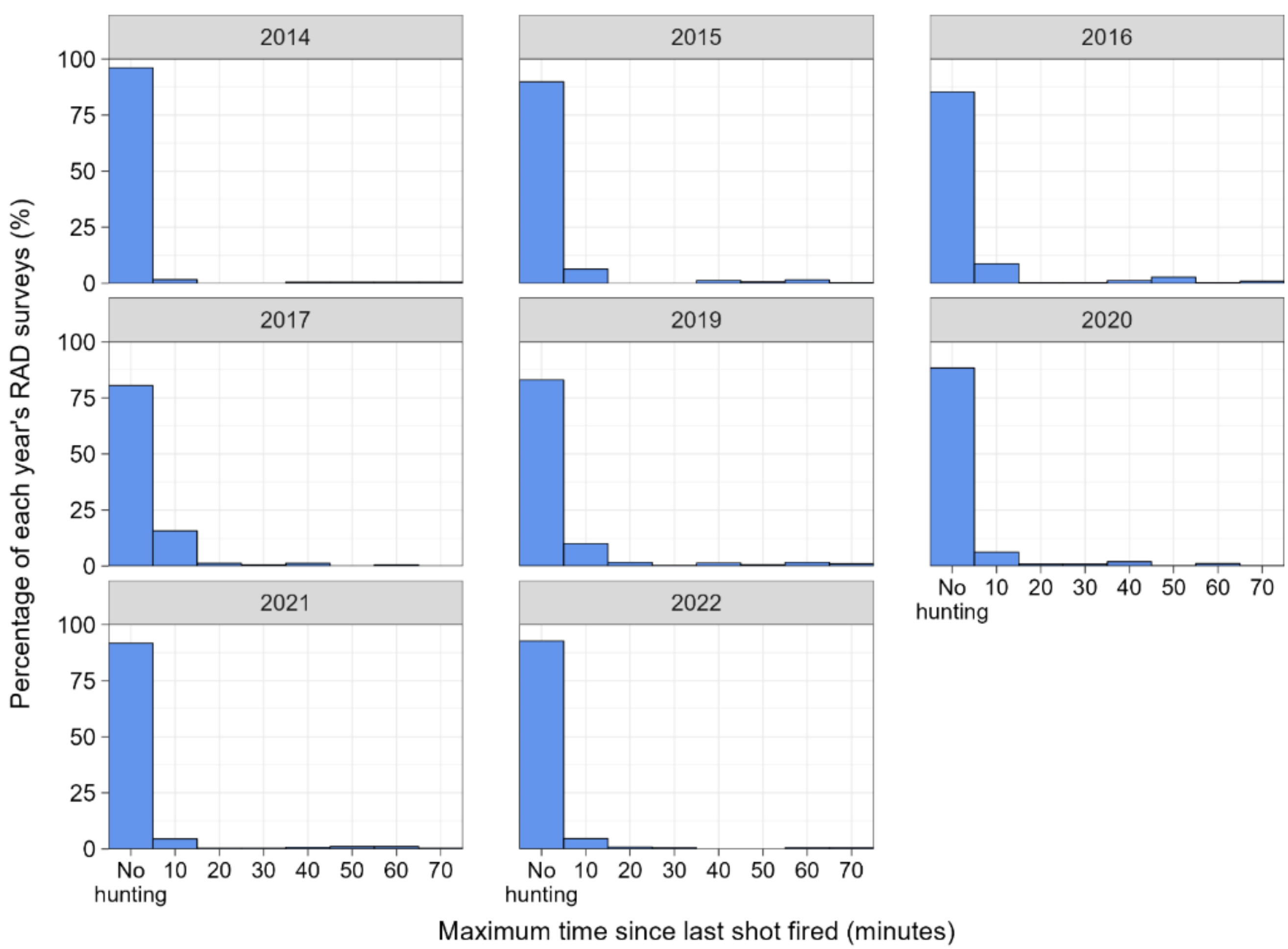



**Figure 5-7: Relative proportion of hunting activity at Bruce Head presented by sampling year showing 'maximum time since shooting occurred' breakdown.**

## 5.3 Relative Abundance and Distribution (RAD)

A total of 342 RAD surveys were completed over the course of 25 days between 30 July and 23 August 2022. A summary of the 2022 RAD data, compared to that collected from 2014 to 2021, is presented in Table 5-1. Similar to previous years, narwhal were the most common cetacean species recorded at Bruce Head in 2022. Less common cetacean sightings recorded in the SSA during 2022 included bowhead whale (n=5) and beluga (n=141). The relative abundance of narwhal in the SSA in 2022 (corrected for effort; total narwhal / total h) was 84.9 narwhal/h. In comparison, the lowest relative abundance of narwhal recorded during the eight-year monitoring period was in 2021 (29.4 narwhal/h), while the highest was in 2016 (178.0 narwhal/h) (Golder 2022b). Over the eight years of data collection, the number of RAD surveys performed per year ranged from 160 in 2017 to 353 in 2020 (Table 5-1). Where surveys were incomplete (e.g., at least one of the substrata had an impossible sightability or some of the substrata were not surveyed due to inclement weather), only the affected substrata were removed from analysis. That is, all substrata that were successfully surveyed, excluding those associated with impossible sightability, were included in the analysis. The average daily effort for RAD surveys ranged from 6.1 h in 2017 to 14.2 h in 2022. 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 113,800 narwhal were recorded in the SSA over eight years of data collection (Table 5-1). 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 29.4 narwhal/h in 2021 to 178.0 narwhal/h in 2016 (Figure 5-8). 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 5-8). In 2015, daily standardized numbers of narwhal were generally low (20 out of 29 survey days with values <70 narwhal/h). However, there were multiple days in 2015 (six days in August and one day in September) with relatively high standardized numbers of narwhal (>150 narwhal/h). In 2016, daily standardized numbers of narwhal observed were similar to 2014, with multiple days having high numbers of narwhal observed (>150 narwhal/h), with an initial peak in mid-August (205-406 narwhal/h) and a second peak in late August (150-820 narwhal/h). In both 2017 and 2019, no counts >400 narwhal/h were recorded. In 2020, three peaks in narwhal numbers were recorded: 9 August (142 narwhal/h), 22 August (183 narwhal/h), and 29 August (153 narwhal/h). In 2021, two peaks in narwhal numbers were recorded: 9 August (116 narwhal/h) and 19 August (212 narwhal/h). Daily numbers of narwhal in 2021 were the lowest observed since monitoring began in 2014. In 2022, narwhal counts were higher compared to 2020 and 2021, with two peaks in standardized counts – 331.3 narwhal/h on 14 August and 212 narwhal/h on 21 August (Figure 5-8).

Over the eight-year program, numerous RAD surveys were conducted where no narwhal were observed (see Table 5-1). The proportion of zero-count RAD surveys was 41% in 2014, 52% in 2015, 41% in 2016, 22% in 2017, 25% in 2019, 67% in 2020, 68% in 2021, and 45% in 2022. 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 5-8).

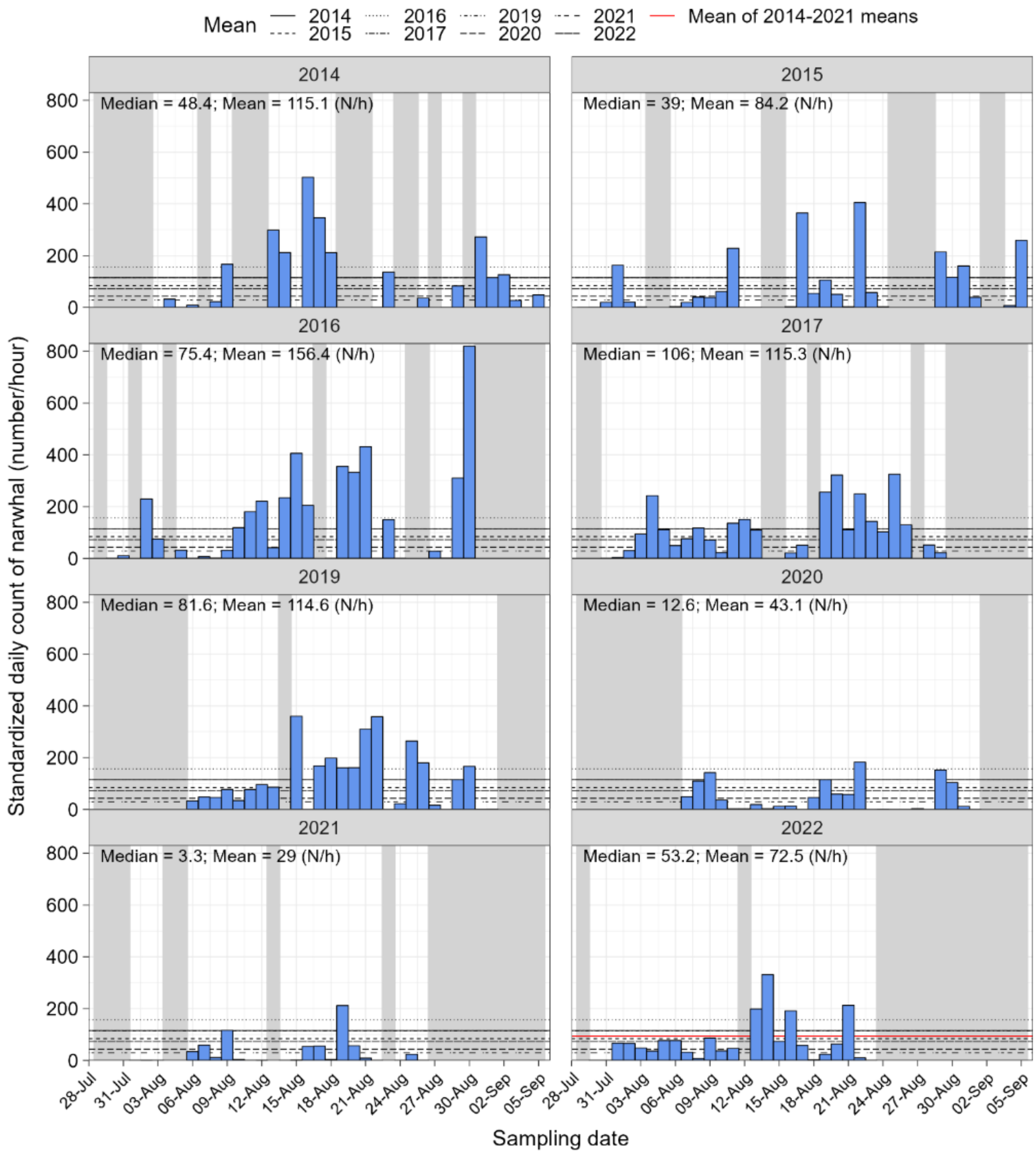



**Figure 5-8: Standardized daily numbers of narwhal recorded in the SSA from 2014–2022. Shaded area represents days where no data was collected.**

In general, higher numbers of narwhal were recorded in the southern strata (Smith et al. 2015, 2016, 2017; Golder 2018, 2019, 2020b, 2021b, 2022b). In each survey year, strata G, H, and I possessed the highest proportion of narwhal (Figure 5-9), accounting for 62 to 72% of total narwhal recorded in 2014–2017, and 47 to 57% of total narwhal recorded in 2019-2022, respectively (influenced by the introduction of new stratum J in 2019). Stratum J accounted for 21 to 28% of the total narwhal recorded in 2019-2022. Number of narwhal recorded also varied with substratum distance from the observation platform (Figure 5-9). Each year, substratum '2' (i.e., the mid-channel substrata) had the highest proportion of total narwhal recorded, accounting for 48 to 56% of total annual narwhal observations. In addition to stratum and substratum, sightability also affected the number of narwhal recorded (Figure 5-9). Number of narwhal recorded per RAD survey was considerably higher during periods when sightability was considered 'excellent' and 'good'.

The proportion of narwhal observed in the presence of at least one vessel (i.e., vessel present within 5 km of the substratum centroids) was 0.4% in 2014, 1.4% in 2015, 3.2% in 2016, 11.6% in 2017, 9.1% in 2019, 6.2% in 2020, 8.9% in 2021, and 10.6% in 2022. Of the narwhal recorded during periods when a single vessel was within 5 km, the majority were recorded when vessels were northbound (100%, 81%, 65%, 65%, 55%, and 53% in 2014, 2016, 2017 and 2020-2022, respectively), with the exception of 2015 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 = 52,383 surveys of individual substrata, with 104,928 individuals counted), with a mean of 2.0 narwhal per substratum and a mean density of 0.8 narwhal/km² (Figure 5-10).

During periods of single vessel exposure (single vessel ≤5 km), a total of 4,217 surveys of individual substrata were conducted, with a total of 6,646 individuals recorded (mean count of 1.6 narwhal per substratum and mean density of 0.7 narwhal/km²). In 2022, the mean number of narwhal per substratum during periods of single vessel exposure was 1.8 individuals, with a mean density of 0.8 narwhal/km².

During periods of multiple vessel exposure (two or more vessels ≤5 km), a total of 62 surveys of individual substrata were conducted, with a total of 44 narwhal recorded (mean count of 0.7 narwhal per substratum and mean density of 0.2 narwhal/km²). In 2022, 21 narwhal were observed during the 17 surveys of individual substrata (during two RAD survey) that coincided with exposure to multiple vessels.

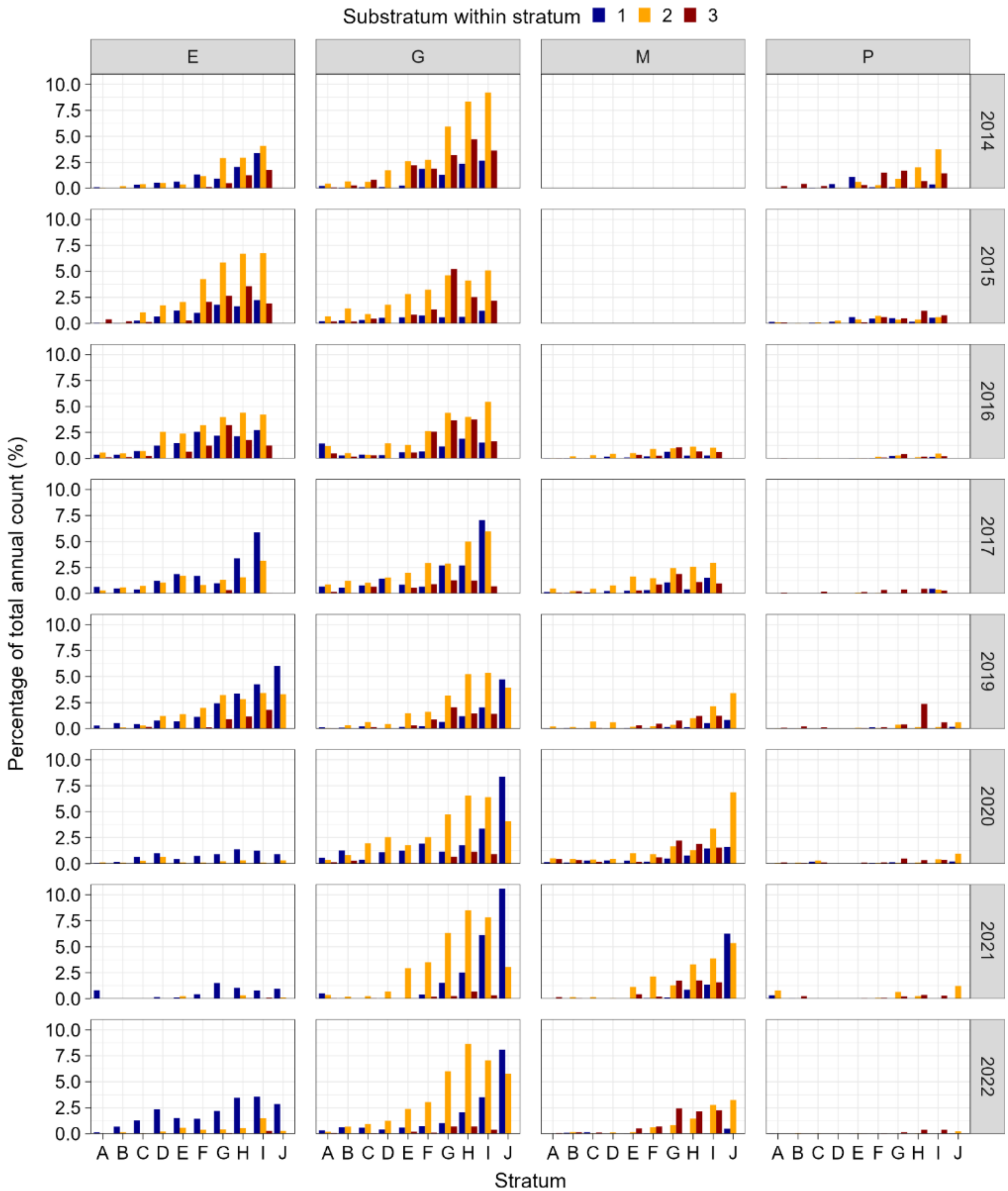



**Figure 5-9: Relative proportion of narwhal counts in each substratum as a function of sampling year and sightability (relative to total narwhal counts). Sightability categories: E = excellent, G = good, M = moderate, P = poor.**

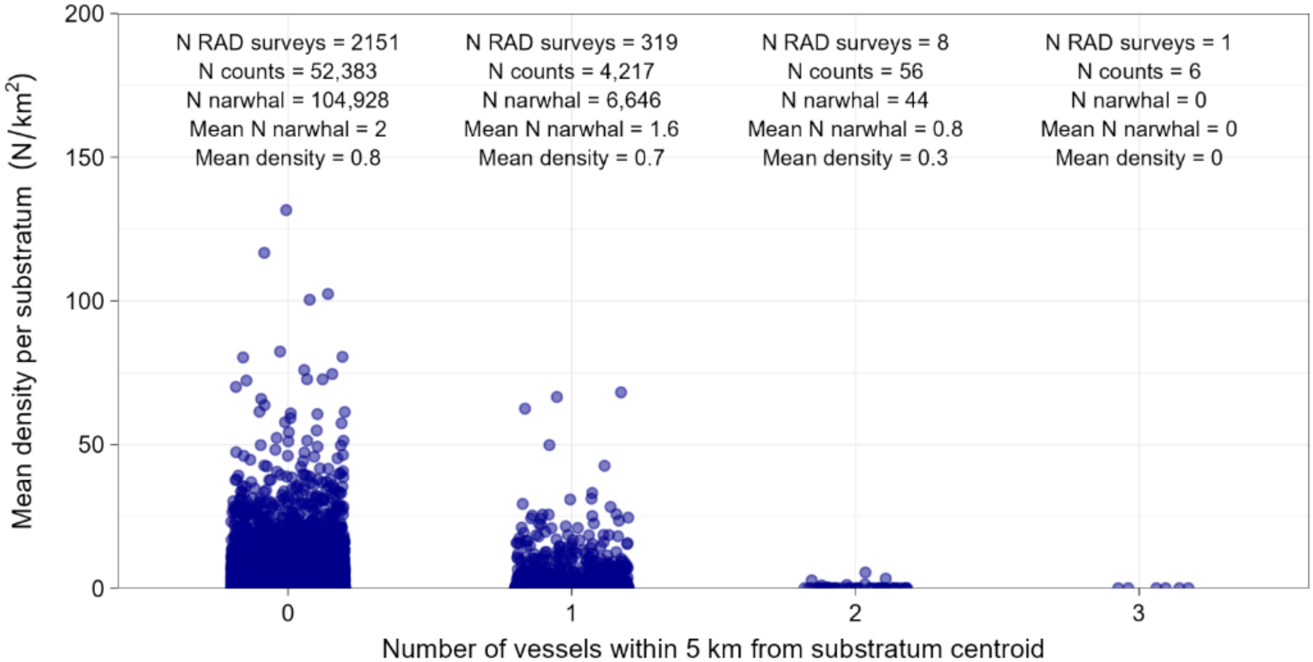



**Figure 5-10: Summary of surveys conducted in the SSA relative to vessel exposure level (no exposure, single vessel, and multiple vessels within 5 km); data exclude impossible sightability, cases with Beaufort levels of 6 or higher, and days with killer whales.**

In summary, the relative abundance of narwhal (total number of narwhal corrected for survey effort) in the SSA was higher in 2022 (84.9) than in 2020 and 2021 (47.5 and 29.4, respectively) and approaching the 2015 baseline level (98.2). However, narwhal relative abundance in 2022 was lower than the 2014 baseline level (131.4) and lower than levels observed in 2016 (178.0), 2017 (121.8) and 2019 (127.2). These findings indicate that narwhal numbers in the RSA appeared to be increasing from the low numbers observed in 2020/2021 but have not yet reached levels observed during the initial shipping years (2016, 2017) or those observed in 2019. Over the combined 2014-2022 sampling period, the second highest relative abundance estimate at Bruce Head was observed in 2019, when shipping was highest and when Project icebreaking occurred during the early shoulder season for the third consecutive year (2018-2020), while the lowest relative abundance estimates at Bruce Head were recorded in 2020-2021, when shipping levels were similar to 2016. Icebreaking operations took place during the 2020 early shoulder season but not in 2021. These results suggest that the annual volume of Project shipping in the RSA is not a reliable predictor of narwhal relative abundance at Bruce Head in the same year. The 2022 results support the theory that some degree of natural exchange likely occurs between the two putative narwhal summer stock areas and, while shipping cannot be ruled out as a contributing factor, that the regional distribution and movement of narwhal off North Baffin Island during the summer is likely influenced by other external factors (e.g., local ice conditions, water temperature, prey availability, predation pressure, etc.).

## 5.4 Density

Of the total 56,662 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), 4,217 surveys (7.4%) were associated with a single vessel exposure event and 62 surveys (0.1%) were associated with a multiple vessel exposure event.

Based on the distribution of the observed counts (i.e., not accounting for any other pertinent variables), an increase in narwhal density was commonly observed at vessel distances of 2-4 km (relative to the substratum), regardless of whether the vessel was moving toward or away from the substratum (Figure 5-11). In the presence of southbound vessels, this effect was less pronounced. Overall, the data suggest that narwhal density in the SSA may have been influenced by ‘vessel travel direction’ (northbound vs. southbound). In the combined 2014-2022 dataset, narwhal density was less influenced by ‘vessel orientation relative to substratum’ (moving towards vs. moving away) than in previous reporting years.

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 a given substratum, and sampling year (i.e., response variables associated with statistically significant changes), is presented in Figure 5-12. Note that the orange line represents the predicted mean group size for a specific set of predictor values (Section 4.3.2.2) whereas the blue bars summarize the entirety of the observed data. This leads to some visual discrepancies between the observed and predicted values.

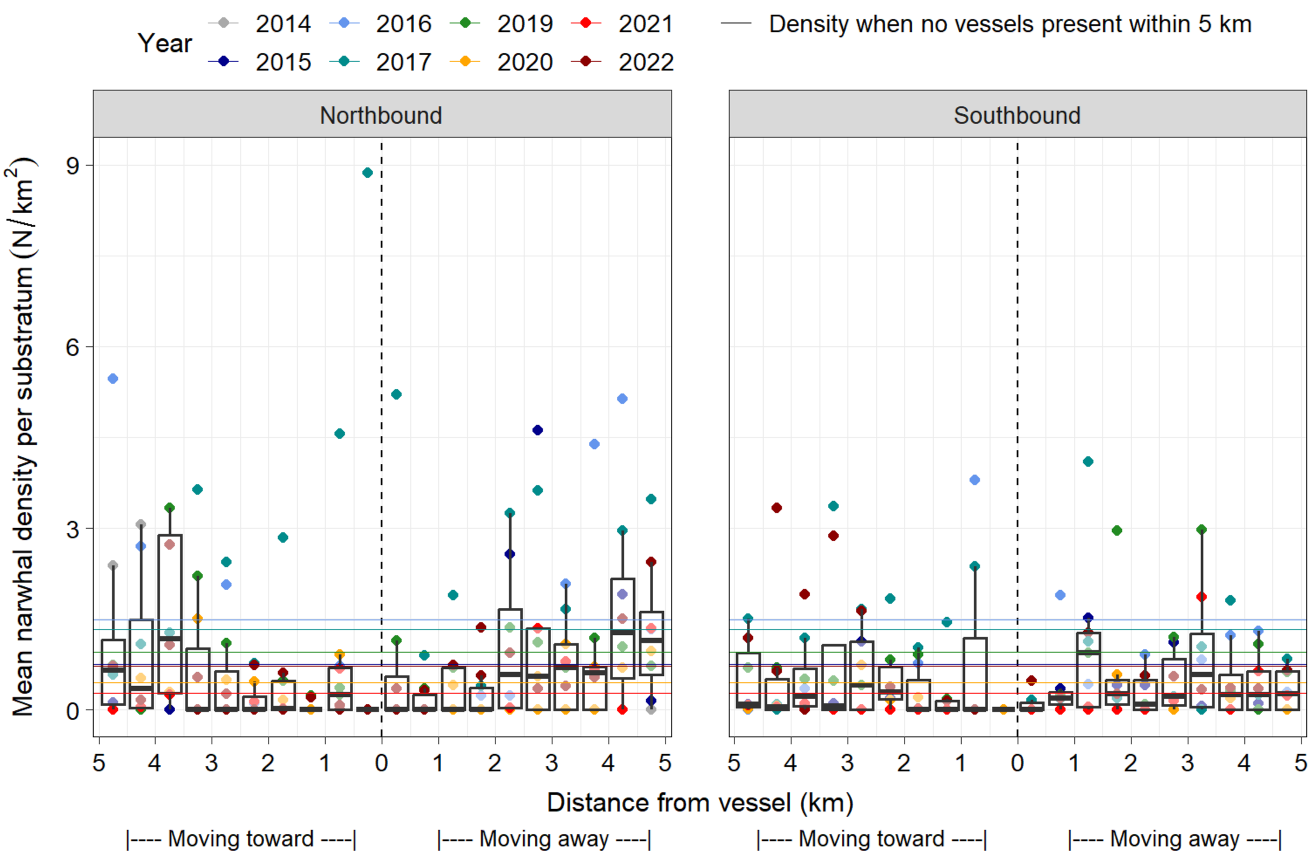



**Figure 5-11: Mean narwhal density per substratum as a function of distance from vessel (rounded up to 0.5 km), vessel travel direction, vessel orientation relative to substratum, and sampling year. Horizontal lines depict mean density of narwhal per substratum during vessel non-exposure periods.**

In the model of narwhal density, the effect of distance from vessel was significant (*P*=0.013; Appendix D, Table D-1), while the effect of vessel direction was not significant (*P=0.7*) and the interaction between vessel direction and distance from vessel was not significant (*P*=0.089). When exposed to northbound vessels, narwhal density 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 5-12). When exposed to southbound vessels, narwhal density remained generally stable as the vessel moved both toward the substratum and away from the substratum (slope significance >0.6 for both). Mean narwhal density was significantly lower in the presence of a northbound vessel (for both approaching and departing vessels) at distances ≤2 km from a substratum when compared to mean narwhal density during vessel non-exposure periods (≥5 km; Table 5-3). In comparison, in the presence of southbound vessels (both approaching or departing), narwhal density was not significantly different from that observed during vessel non-exposure periods. Effect sizes at 0 km were -51% and -23% for a northbound and a southbound vessel, respectively. Effect sizes at 1 km were -42 to -40% for a northbound vessel and -21 to -20% for a southbound vessel. The effect sizes of northbound vessels decreased below ±20% within 3 km (effect sizes at 3 km were -11% for a vessel moving toward the substratum and -20% for a vessel moving away). For a southbound vessel, the effect size at 3 km was -18% for a vessel moving toward the substratum and -15% for a vessel moving away from the substratum. These findings suggest that there may have been a moderate biologically significant effect (i.e., >25% change in density – as per Section 4.3.2.1) up to a distance of 2 km from a northbound vessel, but not a southbound vessel. However, the statistical power to estimate the observed effect at 0 km was shown to be low (APPENDIX A). 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 -60% or +87% 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 D, Table D-1). The effect of presence of small vessels in the SSA was not significant ($P=0.7$). 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. While narwhal density was significantly lower in 2021 when compared to 2015 ($P=0.021$), 2016 ($P=0.002$), 2017 ($P=0.002$), and 2019 ($P=0.004$), 2022 values were significantly higher from 2021 ($P=0.043$), and not significantly different from all other sampling years (Figure 5-12; $P>0.8$ for all comparisons).

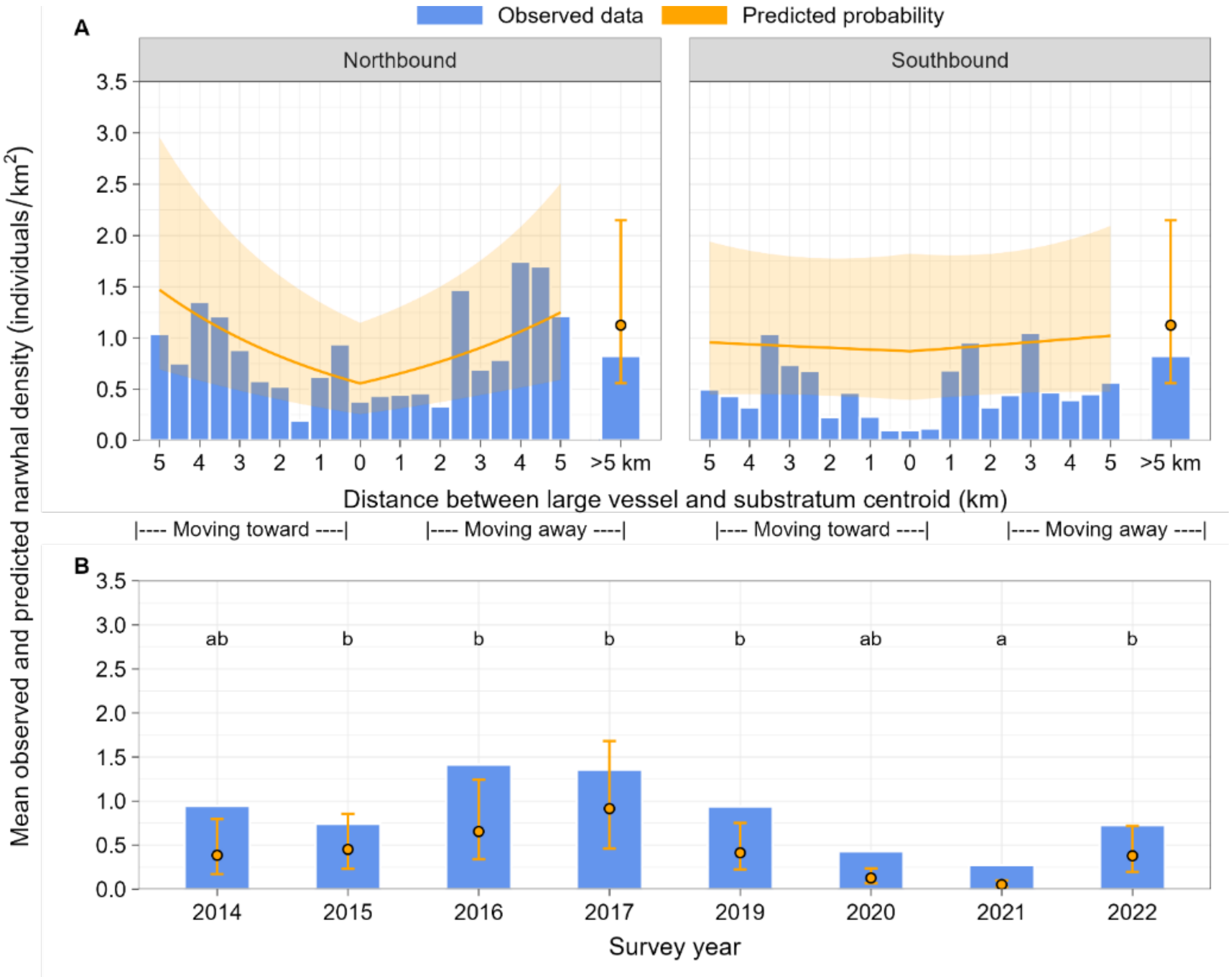



**Figure 5-12: Mean narwhal density (individual/km²) as a function of distance from vessel, vessel travel direction, vessel orientation relative to substratum (combined 8-year dataset; Panel A) and survey year (Panel B).**

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

**Table 5-3: 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 | **0.6 (0.001)** | **0.6 (0.001)** | 0.9 (0.722) | 0.9 (0.722) |
| 1 | **0.7 (0.001)** | **0.7 (<0.001)** | 0.9 (0.515) | 0.9 (0.559) |
| 2 | **0.8 (0.013)** | **0.8 (<0.001)** | 0.9 (0.265) | 0.9 (0.375) |
| 3 | 1.0 (0.687) | 0.9 (0.057) | 0.9 (0.216) | 1.0 (0.473) |
| 4 | 1.2 (0.970) | 1.1 (0.986) | 0.9 (0.540) | 1.0 (0.861) |
| 5 | 1.5 (0.381) | 1.2 (0.959) | 1.0 (0.864) | 1.0 (0.986) |

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*<0.001). Narwhal density was significantly higher when a hunting event occurred within the preceding 70 min (*P*<0.001). This was likely an artefact of the association between narwhal density and hunting, since hunting was more likely to take place when narwhal were present in larger numbers. Narwhal density was estimated to be significantly higher during low slack conditions than during flood, high slack, or ebb conditions (*P*<0.001 for all); also, density was significantly lower during high slack conditions compared to ebb conditions (*P*<0.001); no difference was found between high slack and flood conditions (*P*=0.9). 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*=0.9), and all comparisons between Beaufort values of 3, 4, and 5 (*P*>0.06 for all).

**In summary, vessel exposure was shown to result in a statistically significant temporary decrease in narwhal density in the SSA compared to when no vessels were present, this decrease was limited to when narwhal were in close proximity (≤2 km) to approaching northbound vessels, after which narwhal densities increased as the vessel moved away. 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).**

## 5.5 Group Composition (BSA)

The total number of sampling days in which data on narwhal group composition and behaviour were collected in the BSA ranged from 11 days in 2014 to 27 days in 2016. In 2022, data were collected in the BSA on 25 days (Table 5-4).

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 5-13). The proportion of narwhal groups recorded during 'poor' sightability conditions was relatively high in 2015 (21%), likely an artefact of the 'moderate' sightability category not being used during the first two years of the program, therefore inflating the number of sightings assigned to 'poor' by default. A total of 29 groups were recorded under 'impossible' sightability conditions (8, 19, and 2 groups in 2017, 2020, and 2022, respectively) and were excluded from further analyses.

The number of narwhal groups in the BSA in 2022 was the second highest observed since the start of the eight-year study period, with 1,523 narwhal groups (comprising 5,864 individuals) recorded. Both values were higher than all previous years except for 2017, with the number of recorded groups being 19 times higher than the 2021 value, and the number of individuals being 22 times higher than the 2021 value (Table 5-4).

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

| Survey Year | # Sampling Days | # 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 |
| 2022 | 25 | 1,523 | 5,864 |

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 = 6,893 cases; 92.2%). A total of 580 sightings occurred during single vessel exposure periods (7.8%) and four sightings occurred when two vessels were present within 5 km on 13 August 2022. 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 2022, 92% 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).

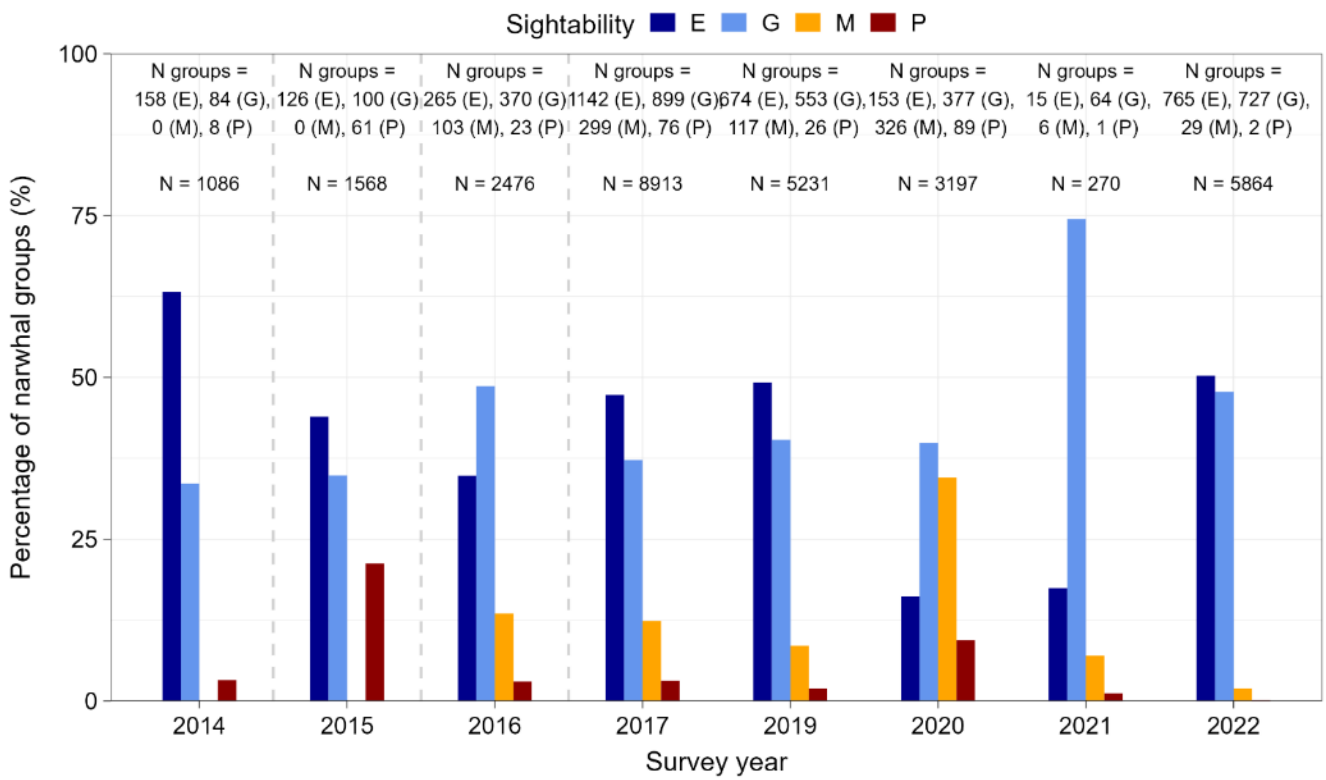



**Figure 5-13: Relative proportion of narwhal groups in the BSA as a function of sightability category and sampling year.**

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

A qualitative assessment of group composition by life stage in 2022 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 5-14). 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 in 2022, with the exception of only two days (30 July and 7 August) when no calves were recorded in the BSA. Yearlings were observed on 15 of the 22 days in which narwhal were observed in the BSA in 2022.

In 2022, the daily proportion of calves present in the BSA (relative to total narwhal counts) ranged between 0% (on 30 July and 7 August) and 33% (22 August 2022; sightings in the BSA on that day were limited to 2 groups, with a total of six narwhal and two calves). The daily proportion of yearlings (relative to total narwhal counts) ranged from 0.7% (2 August) to 9.5% (3 August). The life stage of 62 narwhal (1.1% of all narwhal recorded in the BSA in 2022) was unknown, due to either visibility restrictions or logistical challenges of accurately documenting all individuals during periods of high activity.

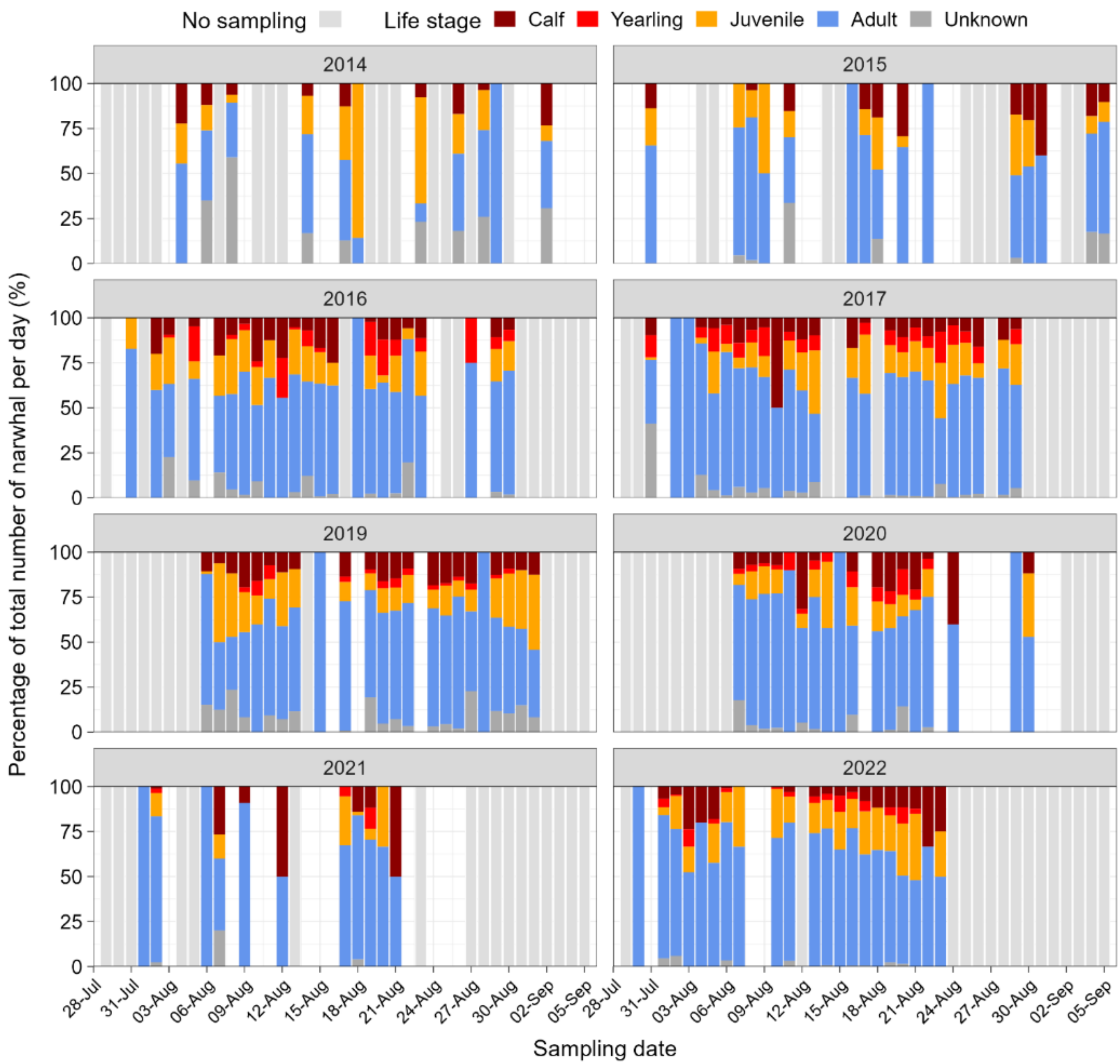



**Figure 5-14: Relative daily proportion of narwhal life stages observed in the BSA presented by survey year.**

The most common group composition recorded during the eight-year study period was exclusively adult narwhal groups (Figure 5-15), accounting for 38% of all observed narwhal groups with known composition. Mixed groups with and without immatures both accounted for 25% of all observed groups, respectively, while mother-immature pairs accounted for 13% of all observed groups. Of the groups observed in 2022 with known composition, exclusively adult groups accounted for 40% of all groups, mixed groups with and without immatures accounted for 19% and 30% of groups, respectively, and mother-immature pairs accounted for 8% of groups.

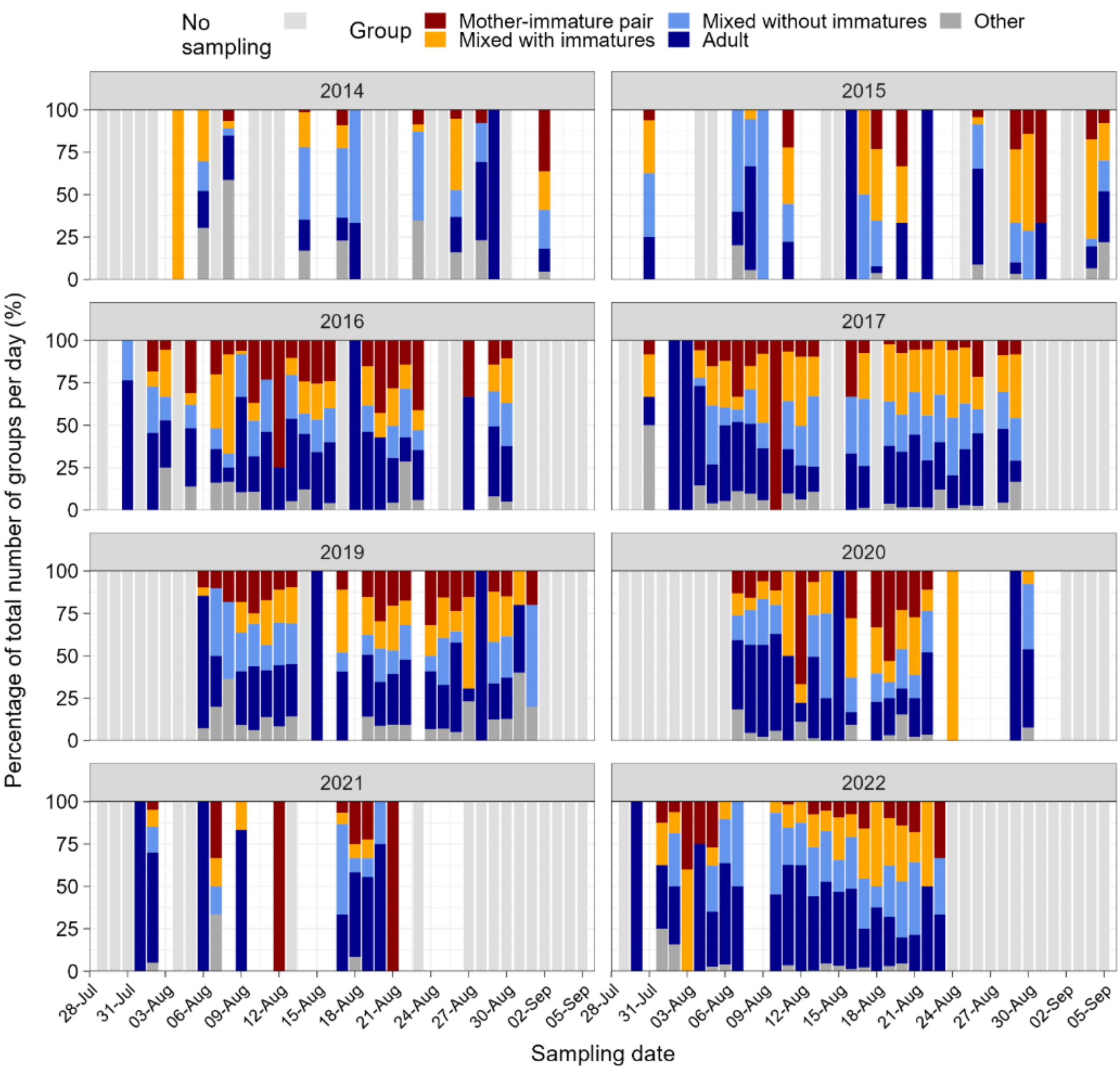



**Figure 5-15: Relative daily proportion of narwhal group composition categories observed in the BSA presented by survey year.**

### 5.5.1 Proportion of Immatures (Early Warning Indicator)

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

During 2022, a total of 1,523 narwhal groups (comprising 5,864 individuals) were observed in the BSA, including 357 calves and 251 yearlings. The combined annual proportion of immatures observed in the BSA in 2022 was 0.105. This was lower than most previous sampling years (with the exception of 2021), representing a 31% decrease from the 2014 combined annual proportion of 0.152 (Table 5-5). When accounting for interannual variability, the 2022 estimate was lower than all previous years, representing a 32% decrease from the 2014–2015 baseline that was statistically significant from the baseline condition (*P*=0.041; Figure 5-16 and Table 5-6). The model had sufficient statistical power (≥0.8) to detect effect sizes of -45% or +45% in the comparison of 2022 data relative to baseline (2014-2015 data; APPENDIX A). The observed effect size and its 95% confidence interval (-63% to -1.3%) suggest a decrease in the 2022 annual proportion of immatures relative to the observed population, thereby warranting further investigation.

**Table 5-5: Combined annual proportion and mean annual proportion of immatures (i.e., calves and yearlings) relative to the observed adult population at Bruce Head (combined eight-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 |
| **2022** | **1,523 (5,864)** | **0.105** | **0.126** | **0.098** |

The decrease in proportion of immatures observed in the BSA in 2022 exceeded the EWI threshold and one of the two ‘Moderate Risk’ triggers identified in the Marine Mammal TARP; (i.e., a statistically significant decrease in the proportion of immature narwhal relative to 2014/2015 baseline conditions; Baffinland 2021c). These results suggest a decreasing trend in the annual proportion of immatures relative to the observed population and therefore warranted further investigation via analysis of 2022 aerial survey data. Findings from the analysis of 2022 aerial survey data are discussed in Section 6.3.

**In summary, the relative proportion of immature narwhal observed in the BSA in 2022 (0.105) was significantly lower than pre-shipping values in 2014 and 2015 (0.152 and 0.167, respectively), representing a 32% decrease from the baseline condition. The effect size and its 95% CI (-63% to -1%) suggest a decrease in the 2022 annual proportion of immature narwhal relative to the observed population, and therefore warranted further investigation through EWI analysis of the 2022 aerial survey data.**

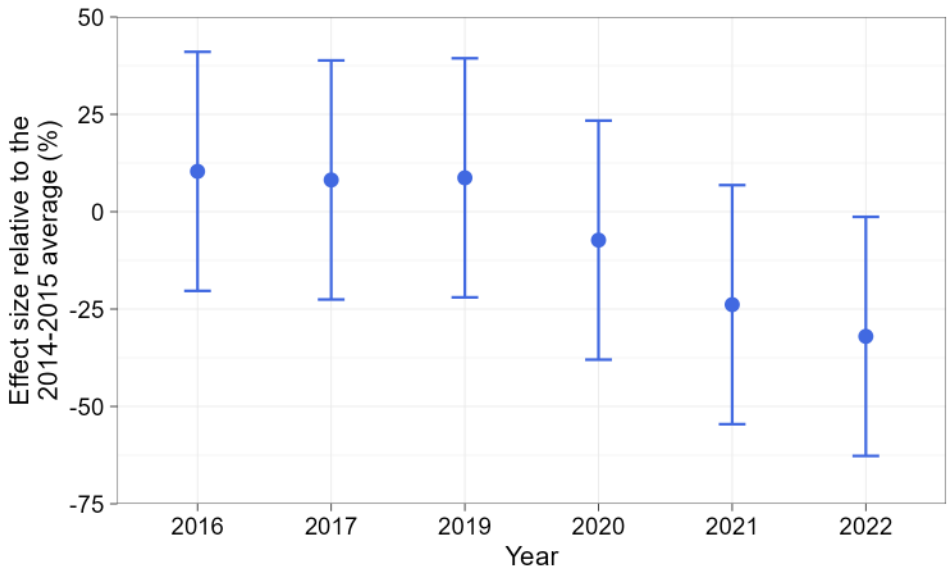



**Figure 5-16: Relative change in the proportion of immature narwhal compared to the 2014–2015 baseline condition, based on analysis of annual group composition data, grouped into 10 bins per year. Error bars are 95% confidence intervals.**

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

| Year | *P*-value | Effect Size (%) | |
|---|---|---|---|
| | | Mean | 95% Confidence Interval |
| 2016 | 0.503 | 10.4 | -20.3 to +41.0 |
| 2017 | 0.598 | 8.1 | -22.5 to +38.8 |
| 2018 | N/A | N/A | N/A |
| 2019 | 0.574 | 8.7 | -22.0 to +39.4 |
| 2020 | 0.637 | -7.3 | -38.0 to +23.4 |
| 2021 | 0.126 | -23.9 | -54.6 to + 6.8 |
| 2022 | 0.041 | -32.0 | -62.7 to -1.3 |

## 5.6 Behaviour (UAV-based Focal Follow Surveys)

A total of 85, 164, and 148 focal follow surveys of narwhal were undertaken in the RSA in 2020, 2021, and 2022 respectively, representing a total of 37.8 h of behavioural observations recorded over a total of 397 surveys (Figure 5-17, Figure 5-18, Figure 5-19). In 2020, vessels were present (within 5 km of the focal group) for 13 of the 85 surveys (15%), representing 1.1 h of recorded behaviour during ‘vessel exposure’ periods, with the closest point of approach (CPA) ranging from 0.9 to 4.0 km. In 2021, vessels were present for 30 of the 164 surveys (18%), representing 2.8 h of recorded behaviour during ‘vessel exposure’ periods, with the CPA ranging from 0.4 to 4.7 km. In 2022, vessels were present for 44 of the 148 surveys (30%), representing 4.2 h of recorded behaviour during ‘vessel exposure’ periods, with the CPA ranging from 0.8 km to 4.9 km. To assess narwhal behavioural responses to vessel traffic, UAV-based focal follow surveys conducted between 2020 and 2022 were analyzed as an integrated dataset, with findings of the analyses presented in the following sections.

Note that each unique focal follow survey was denoted with its own identification number (Focal Follow Identification or FFID). Survey tracklines of the 87 total focal follow surveys involving a vessel transit are presented in APPENDIX E, with an example survey provided below (Focal Follow ID #30, 2022; Figure 5-20). A description of each of the focal follow surveys conducted within 5 km of vessels is provided in APPENDIX F. For illustrative purposes, photos associated with focal follow surveys # 30, 73, 98, and 109 (2022) are presented in Figure 5-21 to Figure 5-24.

**Figure 5-17: Location of focal follow surveys conducted near Bruce Head in 2020.**

**Figure 5-18: Location of focal follow surveys conducted near Bruce Head in 2021.**

**Figure 5-19: Location of focal follow surveys conducted near Bruce Head in 2022.**

**Figure 5-20: Example of focal follow survey (FFID #30, 2022) in relation to the active southbound transit by the Golden Ice.**

**Figure 5-21: Still frame taken during focal follow survey #30 showing 5 individuals at a distance of 4 km from a South bound vessel (Golden Ice) on 4 August 2022.**

**Figure 5-22: Still frame taken during focal follow survey #73 showing an individual chasing prey at a distance of 5.8 km from a Southbound vessel (Nordic Orion) on 7 August 2022.**

**Figure 5-23: Still frame taken during focal follow survey #98 showing 5 individuals (2 adults, 1 juvenile and 2 yearlings) at a distance of 2 km from a Southbound vessel (Golden Suek) on 11 August 2022.**

**Figure 5-24: Still frame taken during focal follow survey #109 showing narwhal group comprised of four individuals at a distance of 1km from a Northbound vessel (Nordic NuluuJaak) on 13 August 2022.**

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, and 4 and 17 August 2022) to 22 (20 August 2021; Figure 5-25). The total daily amount of time spent following groups (excluding UAV transit and search time) ranged from 50 sec on 14 August 2020 to 167 min (2.8 h) on 20 August 2021 (Figure 5-26). The daily number of focal follow surveys conducted in the presence of vessels ranged from one (9 August 2020) to nine (7 and 19 August 2021). The daily amount of time spent following groups when a vessel was present ranged from 2.5 min (17 August 2022) to 54.0 min (20 August 2021).

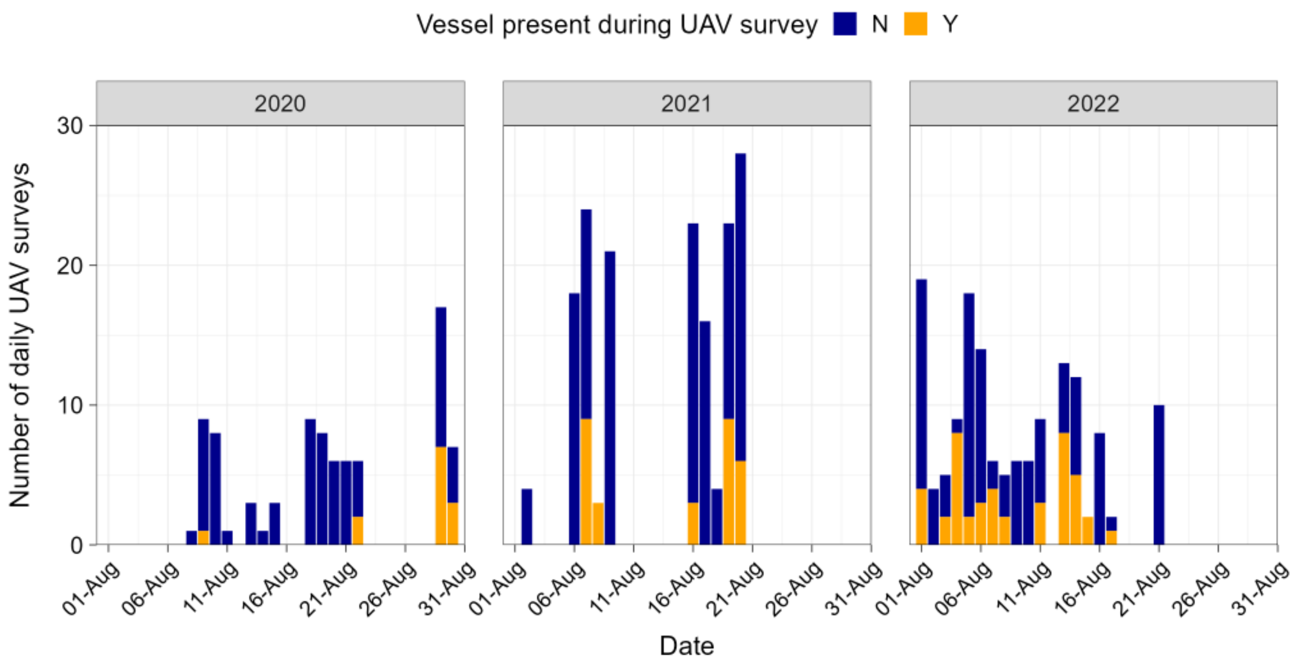



**Figure 5-25: Time series of total number of daily UAV surveys conducted in 2020, 2021, and 2022.**

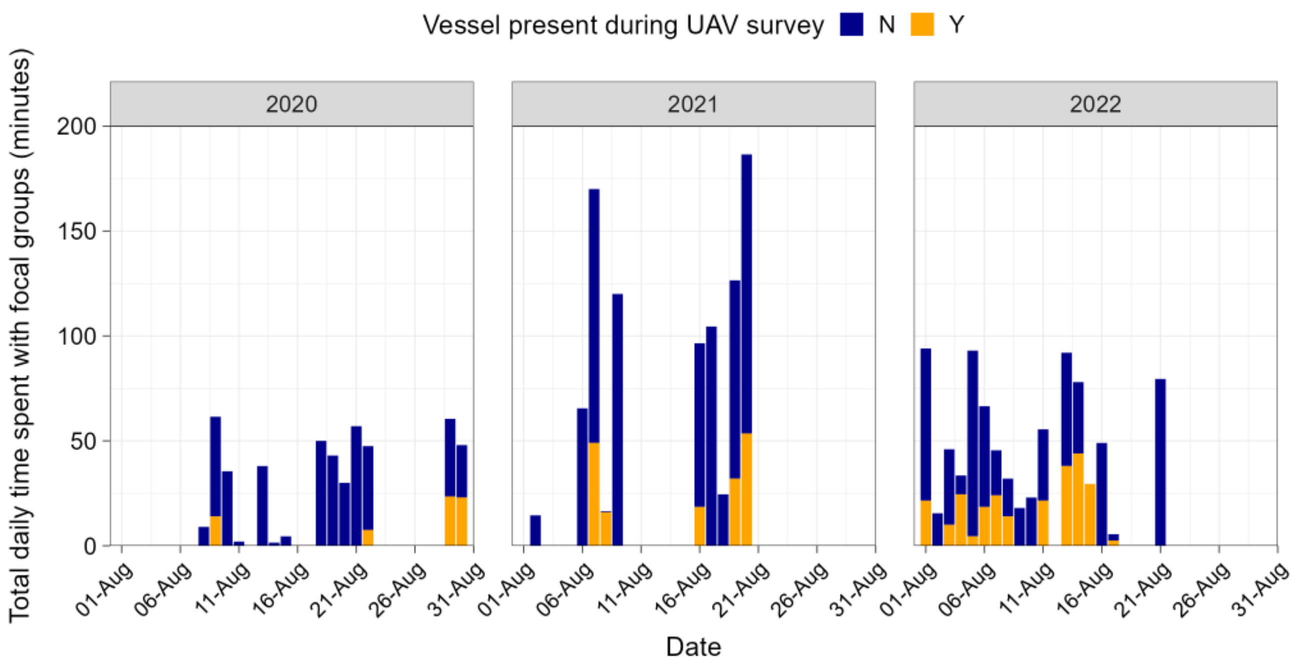



**Figure 5-26: Time series of total daily time spent with focal groups in 2020, 2021, and 2022.**

### 5.6.1 General Characteristics of Focal Groups

Of the focal groups surveyed via UAV, adult narwhal were observed most frequently (69% of all narwhal), followed by juveniles (18%), calves (7%) and yearlings (6%; Figure 5-27). During the 2021 and 2022 seasons, a greater emphasis was placed on following groups with immatures to inform behavioural responses of animals in vulnerable life stages to vessel traffic. When vessels were present (i.e., within 5 km of focal group), focal groups were comprised of 45% adults, 23% juveniles, 13% yearlings, and 3% calves (16% were categorized as 'unknown'). When no vessels were present, focal groups were comprised of 49% adults, 26% juveniles, 10% yearlings, and 10% calves (5% were categorized as 'unknown)'. A total of 121 of the focal groups surveyed were comprised of one or more females with dependent young (36 in both 2020 and 2021, and 49 in 2022), of which 32 coincided with vessel passages (six in 2020, seven in 2021, and 19 in 2022).

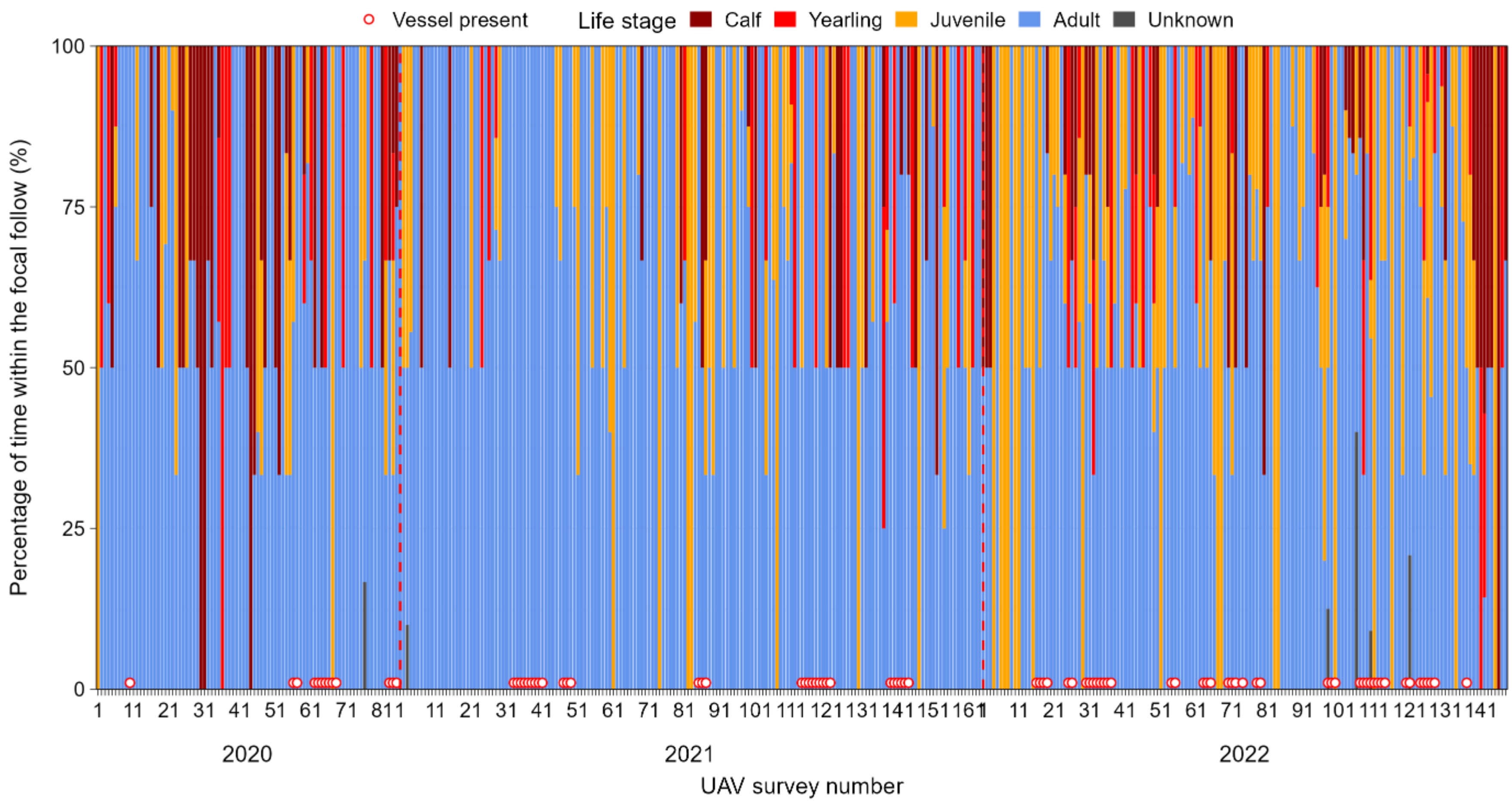



**Figure 5-27: Group composition recorded during focal follow surveys, 2020-2022.**

When no vessels were present within 5 km of the observed groups (i.e., vessel non-exposure periods), the majority of data collected was on adult groups (Figure 5-28), including a total of 180 unique focal follow surveys representing 691 min (11.5 h) of recorded behaviour. Mother-immature pairs were observed in 64 individual focal follow surveys for a total of 240 min (4 h), while mixed groups with immatures were observed in 49 focal follow surveys for a total of 222 min (3.7 h) of recorded data. Mixed groups without immatures were observed in 104 focal follow surveys for a total of 395 min (6.6 h) of recorded data. Finally, immature individuals were observed on their own (i.e., either as a single calf/yearling or as multiple calves/yearlings) during 35 individual focal follow surveys, for a total of 227 min (3.8 h) of recorded data.

When vessels were present within 5 km of focal groups (i.e., vessel exposure periods), the majority of the data were collected when vessels were at a distance of 2-3 km, including a total of 42 unique focal follow surveys representing 182 min (3 h) of recorded behaviour, coinciding with 21 different vessel transits (Figure 5-28). In close proximity to vessels (0-1 km from the groups), only six unique focal follow surveys were collected representing 14 min of recorded behaviour, coinciding with five vessel transits. The discrepancy in the total number of focal follow surveys reported in text relative to that presented in Figure 5-28 is due to several of the focal follow surveys changing group type within a given survey (where group type changed as narwhal of different life stages joined or left the followed group). Similar to data collected during vessel non-exposure periods, adult groups accounted for the majority of collected data across all distances from vessels. Some groups had very limited data in the presence of vessels and results should be interpreted with caution. While focal follow surveys of adult groups provided 224 min of recorded behaviour in the presence of vessels, focal follow surveys of mother-immature pairs were limited to 44 min, mixed groups with immatures were limited to 121 min, mixed groups without immatures were limited to 78 min, and lone immatures to were limited to 16 min.

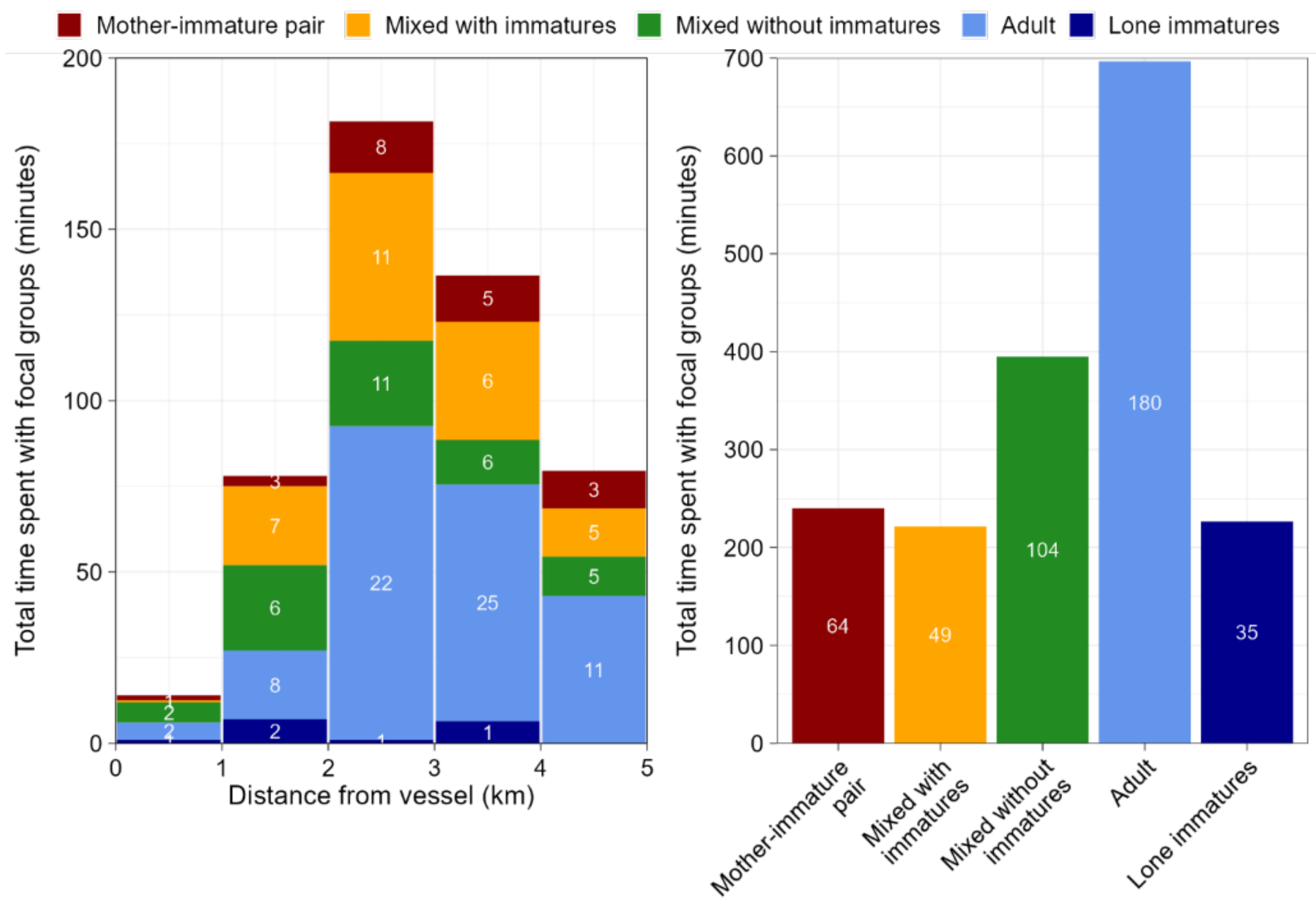



**Figure 5-28: Total time spent with focal groups, presented relative to distance from vessel (vessels ≤5 km; left panel) and by group type when no vessels were present (vessels >5 km; right panel). White text provides number of unique focal follows within each group type. Distances rounded up to nearest km.**

### 5.6.2 Primary Behaviour

Primary behaviours assessed included travelling (i.e., directional movement), milling (i.e., non-directional movement at the surface), resting (i.e., not moving/logging or moving slightly) and social behaviour (i.e., clear interaction between individuals with physical contact). Of the followed groups with an identified primary behaviour, narwhal spent the majority of time travelling (68% of the time), followed by resting or milling (23% of the time), and engaging in social behaviours (8% of the time; Figure 5-29). The proportion of time that narwhal spent travelling was slightly higher when vessels were present (77%) compared to when no vessels were present (66%), while the proportion of time that narwhal spent performing social behaviours was similar between vessel presence (13%) and vessel absence (11%) scenarios (assessed for groups comprised of ≥2 individuals). The proportion of time that narwhal spent resting or milling was slightly lower when a vessel was present (14%) compared to when no vessels were present (21%).

Groups with immatures (i.e., those considered more vulnerable to disrupted opportunities for rest) included mother-immature groups, mixed groups with immatures, and lone immatures. For mother-immature groups, the proportion of time spent resting or milling was higher in the absence of vessels (37%) compared to in the presence of vessels (14-23%, depending on distance from vessel; Figure 5-30). For lone immatures, the proportion of time spent resting or milling was also higher in the absence of vessels (43%) compared to in the presence of vessels (14% at 1-2 km from vessel, the only distance bin where lone immatures were observed in the presence of a vessel). For mixed groups with immatures, the proportion of time spent resting or milling in the absence of vessels (24%) was similar to that in the presence of vessels (7 to 32%, depending on distance from the vessel). These findings suggest that there may be some effect of vessel presence on resting and or milling activity, although these behaviours did not cease to occur in close proximity to vessels, including at 1-2 km from vessels for lone immatures and for mother-immature pairs. It should be noted that the above results are based on a limited sample size with high data variability and should therefore be interpreted with caution.

For groups that did not include life stages considered vulnerable to disrupted opportunities for rest, the proportion of time spent resting or milling for mixed groups without immatures was 19% in the absence of vessels and 4 - 33% in the presence of vessels (depending on distance from vessel), and the proportion of time that strictly adult groups spent resting or milling was 20% in the absence of vessels and 10 - 25% in the presence of vessels (depending on distance from vessel).

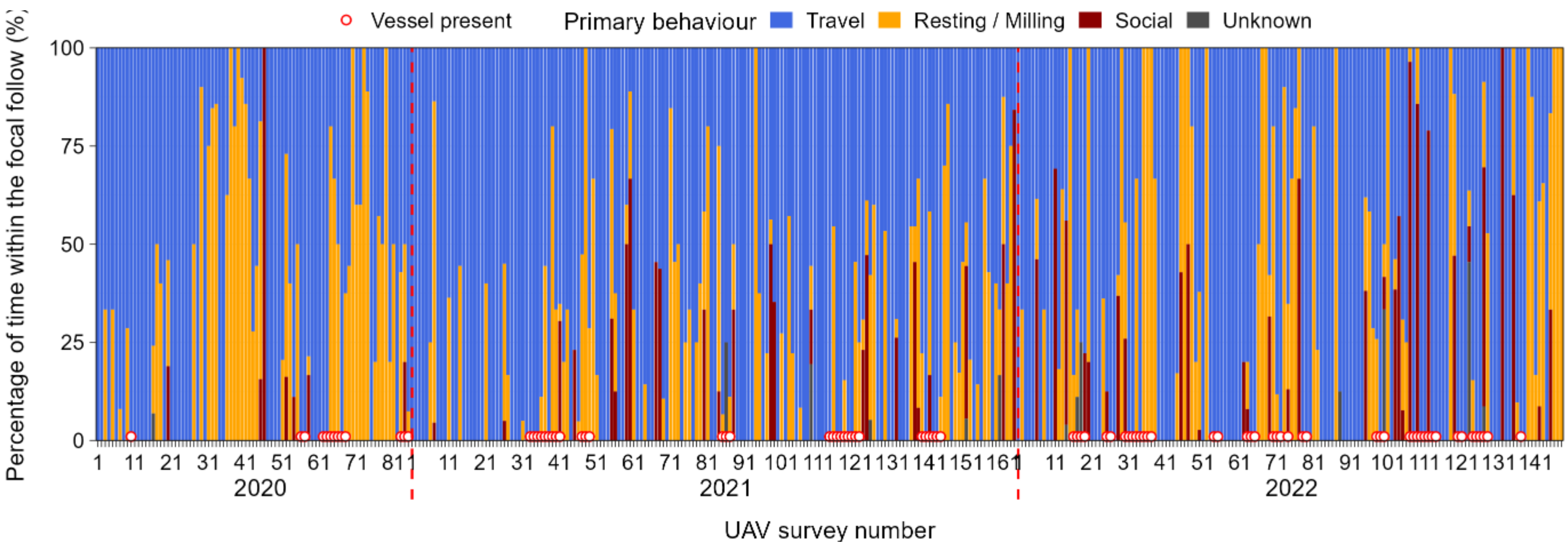



**Figure 5-29: Primary behaviour recorded during focal follow surveys, 2020-2022.**

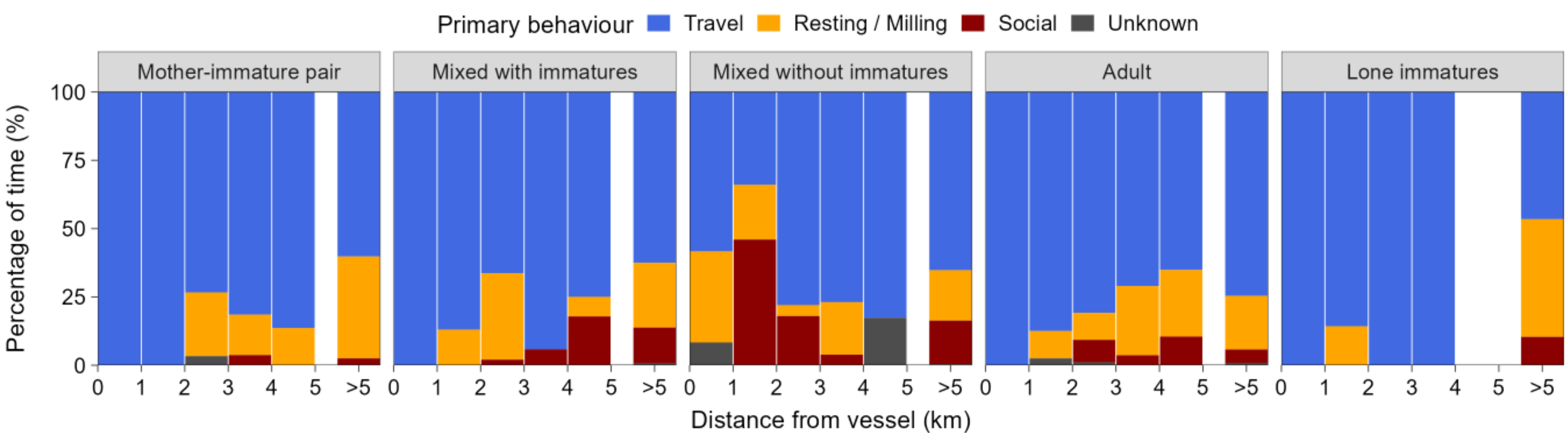



**Figure 5-30: Percent time narwhal groups performed primary behaviours relative to distance from vessel, presented by group type.**

In the analysis of primary behaviour, narwhal behaviours were binned into two categories – ‘travel’ and ‘resting, milling, or social activity’, with the latter category assumed to represent critical life activities for narwhal. Thus, an increase in resting, milling, or social behaviours meant a reduction in travel, while a decrease in resting, milling, or social activity behaviours meant an increase in travel behaviour. The interaction between group type and distance from vessel was significant (*P*=0.01), reflecting the difference in observed trends between the group types (Figure 5-31). Specifically, adult groups tended to decrease engagement in resting, milling, or social activities in close proximity to vessels, while mixed groups without immatures increased engagement in resting, milling, or social activities in close proximity to vessels. Neither group type with immatures (i.e., mother-immature pairs and mixed groups with immatures) was predicted to change its proportional engagement in primary behaviours relative to distance from vessels. Of the multiple comparisons between vessel absence and vessel presence at various distances, none of the multiple comparisons for mixed groups without immatures were significant (*P*>0.1 for all; Figure 5-11), with high uncertainty associated with the model predictions for this group type (Figure 5-31), while adult groups at distance of 0.5 km from vessel were significantly less likely to engage in resting, milling, or social activity (hereafter referred to as ‘critical activities’) relative to when no vessels were present (*P*=0.043). However, this finding was based on a very small sample size, with only a single survey occurring within 0.5 km of a vessel (FFID 117 in 2021), during which a lone adult was observed over a 3 min period, travelling adjacent to a passing vessel, but did not appear to increase speed or move away from the vessel.

Due to the nonlinear nature of the logistic function, while the difference in probability of a group engaging in critical activities changed little between when groups were in close proximity to vessels and when no vessels were present for mother-immature pairs, mixed groups with immatures, and adult groups (difference values of -0.012, -0.060, and -0.066, respectively), the odds of a group to engage in critical activities when in close proximity to vessels were 12%, 43%, and 90% lower than when no vessels were present, respectively. For mixed groups without immatures, the odds of a group to engage in critical activities were 1,071% higher than when no vessels were present compared to when groups were in close proximity to vessels, with a 0.540 increase in probability values.

At proximity to vessels, estimated effect sizes for mother-immature pairs ranged from -12% at 0.5 km to -43% at 5 km, always remaining negative and >10% in absolute value. Similarly, for mixed groups with immatures, estimated effect sizes ranged from -43% at 0.5 km to -17% at 5.0 km, always remaining negative and >10% in absolute value. Conversely, effect sizes for mixed groups without immatures decreased from +1,071% at 0.5 km to +103% at 2.0 km, and to -37% at 3.0 km, suggesting that a large biologically significant effect may exist (i.e., >50% change, as detailed in Section 4.3.2.1), with a spatial extent of less than 3 km from a vessel. For adult groups, effect sizes increased from -90% at 0.5 km to -25% at 3.0 km, and to +68% at 4.0 km, also suggesting that a large biologically significant effect may exist, with a spatial extent of less than 4 km from a vessel. For both mother-immature pairs and mixed groups with immatures, there was no strong trend in relation to vessel presence, however effect sizes remained negative and small/medium in size. This finding may be simplified as a decrease in odds of narwhal engaging in critical activities for mother-immature groups and for mixed groups with immatures when in the presence of vessels, compared to when no vessels were present within 5 km from the focal group. While adult groups also displayed an overall reduction in the odds of engaging in critical activities when vessels were within 4 km from the group, mixed groups with immatures tended to have increased odds of engaging in such behaviours when vessels were within 3 km from the group. These findings indicate possible, though conflicting, support for the alternate hypothesis that vessel presence has an effect (i.e., potential decrease) on critical narwhal activities at close proximity to vessels.

The statistical power to estimate the maximum observed effect size (for mixed groups without immatures) was approximately 0.75 (Appendix A). That is, the maximum observed effect size was still smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model only had sufficient power (≥0.8) to detect an effect size >1,500% (Appendix A). This effect size corresponds to the increase in probability of a group resting, milling, or socializing from 0.107 to 0.656 for mother-immature pairs, from 0.152 to 0.742 for mixed groups with immatures, from 0.180 to 0.778 for mixed groups without immatures, and from 0.074 to 0.561 for adult groups.

**In summary, findings based on the combined multi-year UAV dataset provide possible, though conflicting, support that narwhal groups may change the proportion of time that they engage in critical activities when in the presence of vessels. Specifically, group types with immatures (i.e., mother-immature pairs and mixed groups with immatures) and adult groups were shown to temporarily decrease the proportion of time that they engaged in critical activities when within 5 km and 4 km of vessels, respectively. Conversely, mixed groups without immatures were shown to temporarily increase the proportion of time that they engaged in critical activities when within 3 km of vessels. While these findings suggest that vessel traffic may have some effect on the ability of narwhal to carry out these critical life functions, the conflicting trends among group types suggest that results should be interpreted with caution. Additional focal follow monitoring is recommended to increase the overall sample size of the corresponding dataset.**

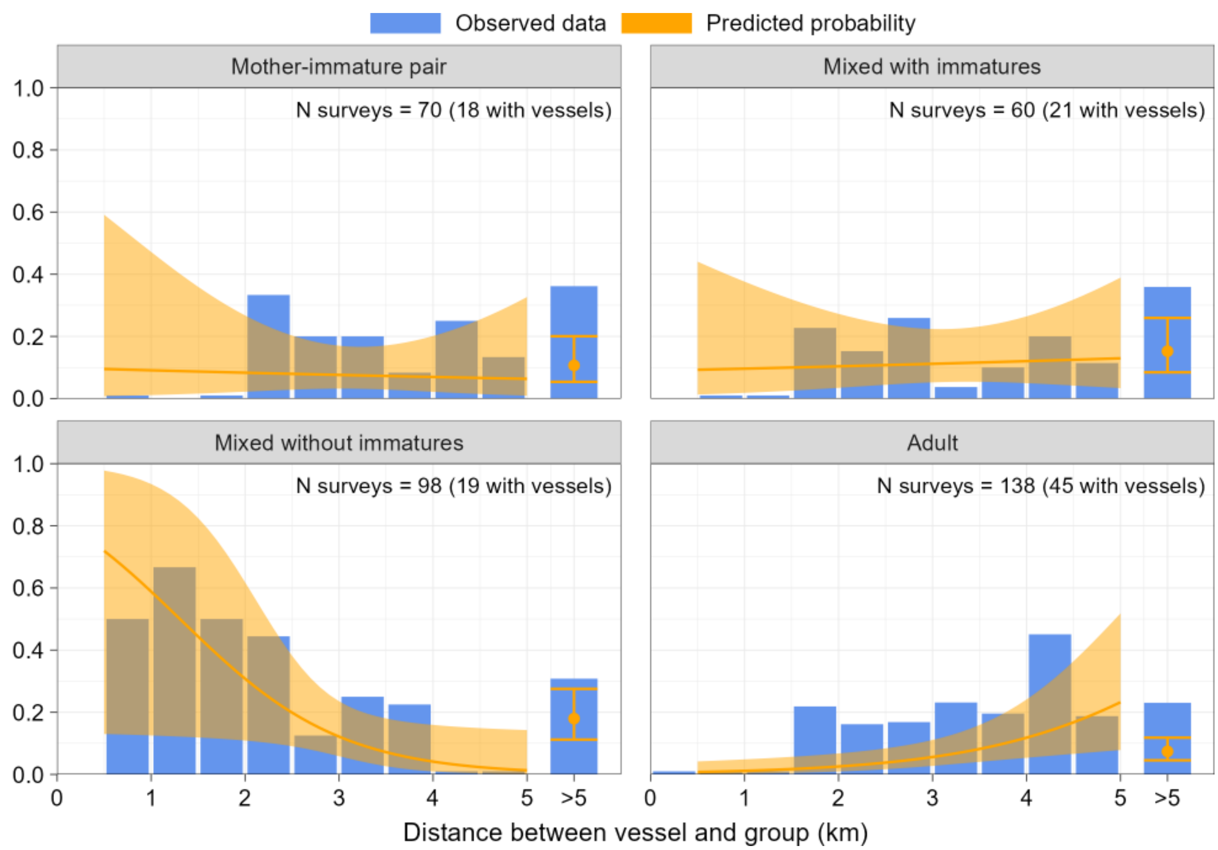



**Figure 5-31: Proportion of time narwhal groups were observed to engage in milling, resting, or social activity (rather than traveling) as a function of distance (rounded up to nearest 0.5 km value) from vessel, presented by group type.**

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

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

| Distance from Vessel (km) | Multiple Comparisons to No-exposure – Least-squares Means with *P* values in Brackets | | | |
|---|---|---|---|---|
| | Mother-immature pair | Mixed with immatures | Mixed without immatures | Adult |
| 0.5 | 0.095 (1.00) | 0.093 (0.956) | 0.719 (0.343) | **0.008 (0.043)** |
| 1 | 0.091 (0.999) | 0.096 (0.944) | 0.589 (0.400) | 0.012 (0.053) |
| 2 | 0.083 (0.979) | 0.104 (0.889) | 0.308 (0.727) | 0.026 (0.142) |
| 3 | 0.076 (0.759) | 0.112 (0.782) | 0.122 (0.637) | 0.056 (0.868) |
| 4 | 0.069 (0.833) | 0.120 (0.921) | 0.041 (0.109) | 0.118 (0.629) |
| 5 | 0.063 (0.940) | 0.130 (0.993) | 0.013 (0.115) | 0.232 (0.145) |

### 5.6.3 Unique Behaviours

Unique behaviours that would not be expected under stressful conditions, such as nursing, social rubbing, sexual displays, and rolling (either vertically in the water column or horizontally) were recorded for a total of 555 min in 161 of the total 397 focal follow surveys conducted (Figure 5-32). Narwhal spent a similar amount of time engaging in unique behaviours during vessel exposure (28% of the time) and non-exposure periods (29% of the time). Unique behaviours were recorded for mother-immature pairs 32% of the time in the absence of vessels and 0 to 43% when a vessel was present (depending on distance from vessel; Figure 5-33). For mixed groups with immatures, unique behaviours were recorded 40% of the time in the absence of vessels and 0 to 68% of the time in the presence of vessels (depending on distance from vessel). For mixed groups without immatures, unique behaviours were recorded 41% of the time in the absence of vessels and 9 to 59% of the time in the presence of vessels (depending on distance from vessel). Strictly adult groups displayed unique behaviours 20% of the time in the absence of vessels and 10 to 28% of the time in the presence of vessels, and lone immatures displayed unique behaviours 21% of the time in the absence of vessels and 0 to 29% of the time when vessels were present.

Sexual displays and associated interactions were observed during three separate focal follow surveys conducted in 2022 and during six surveys conducted in 2021, while no such displays were observed in 2020. Of those observed in 2021, four displays were between adult male narwhal and two were between adult males and tusked juveniles. In 2022, all observed sexual displays occurred between an adult (tusked) and a juvenile, with the juvenile in FFID 62 and FFID119 possessing no tusk and the juvenile in FFID124 possessing a tusk. FFID124 represented the single occurrence of sexual behaviour in the presence of a vessel in 2022, which occurred in a group comprised of two adult males, one adult female, and a tusked juvenile, at a distance of approximately 3 km from the vessel. In 2021, another occurrence of sexual behaviour was observed in the presence of a vessel, which was observed in a group comprised of three adult males when the vessel was at a distance of approximately 4 km from the group.

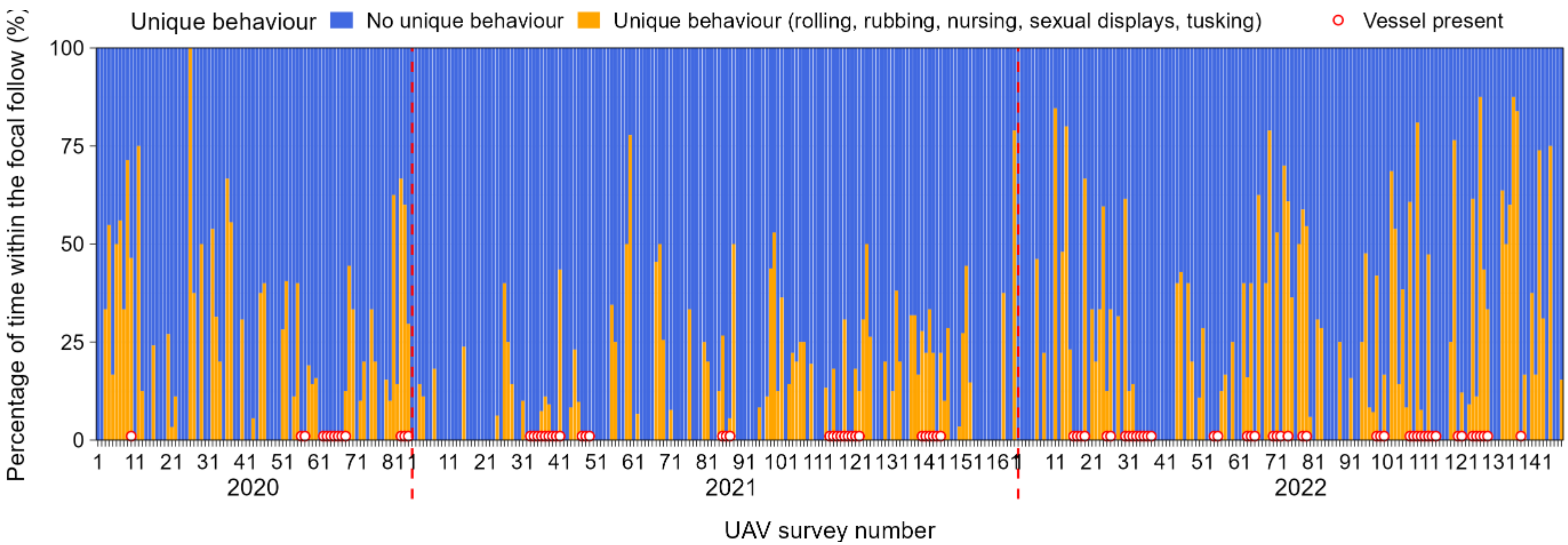



**Figure 5-32: Unique behaviour recorded during focal follow surveys, 2020-2022.**

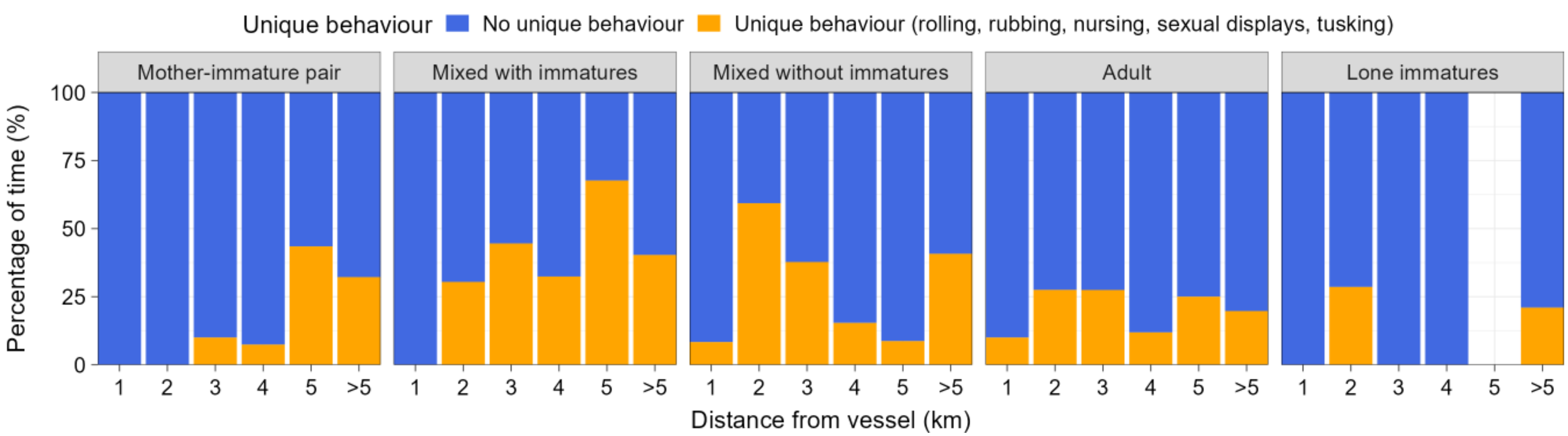



**Figure 5-33: Percent time narwhal groups performed unique behaviours relative to distance from vessel, presented by group type.**

In the analysis of unique behaviour, behaviours were binned in two categories – 'unique behaviour' (including rolling, rubbing, nursing, sexual displays and tusking) and 'no unique behaviour'. The overall effect of vessel distance on the probability of focal groups displaying unique behaviours was significant ($P$=0.017). The probability of individuals engaging in unique behaviours was estimated to be similar when focal groups were at a distance of 2 to 4 km from vessels and when no vessels were present within 5 km. However, at closer distances (≤1 km), the probability of individuals engaging in unique behaviours declined. The odds of engaging in a unique behaviour decreased up to 77% at a distance of 0.5 km relative to when no vessels were present within 5 km from groups (Figure 5-34). Of the multiple comparisons between vessel absence and vessel presence at various distance, only comparisons at 5 km were significant (Table 5-8), due to the higher estimated probability of engaging in unique behaviour at a distance of 5 km from a vessel, which was likely a modeling artefact. For the comparisons at other distances, the uncertainty associated with modelling estimates (Figure 5-34) resulted in lack of statistical significance. Sample size at close proximity to vessels was limited, with only six surveys conducted at distance <1 km and a single survey at a distance <0.5 km.

The effects of group type and group size were also significant ($P$<0.001 for both), with multiple comparisons between group types indicating that adult groups were significantly less likely to engage in unique behaviours than mother-immature pairs, mixed groups with immatures, or mixed groups without immatures ($P$=0.019, $P$=0.014, and $P$=0.001, respectively). No differences were found between mixed groups with or without immatures or mother-immature pairs ($P$>0.9 for all). The probability of engaging in unique behaviours was low for small group sizes, estimated to peak at group sizes of 9 to 12 narwhal, and declined for larger groups (Figure 5-35). However, data on large groups came from a limited set of focal follow surveys, with only 19 surveys having group sizes of more than ten narwhal, and only seven surveys having groups sizes of more than 15 narwhal.

At proximity to vessels, estimated effect sizes for a vessel at 0.5 km, 1.0 km, and 2.0 km distance from the group were -77%, -57% and +4%, respectively for all group types. These effect sizes suggest that a moderate biologically significant effect (i.e., >25% change in group spread – as per Section 4.3.2.1) may exist, with a spatial extent of less than 2 km from a vessel. This finding was in agreement with the hypothesis that narwhal may engage less often in unique behaviours in response to perceived threats such as vessel traffic.

The statistical power to estimate the observed effect size (-77%) was low (<0.5; Appendix A). That is, the observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model only had sufficient power (≥0.8) to detect an effect size >975% (Appendix A). This effect size corresponded to the increase in probability of a group engaging in unique behaviour from 0.170 to 0.688 for mother-immature pairs, from 0.173 to 0.691 for mixed groups with immatures, from 0.169 to 0.686 for mixed groups without immatures, and from 0.082 to 0.490 for adult groups.

**In summary, unique behaviours were displayed less frequently by all narwhal group types in close proximity (<2 km) to transiting vessels, although the multiple comparisons of groups at close proximity to the vessel compared to vessel absence scenarios were not statistically significant despite large effect sizes at 0.5 km and 1.0 km from vessels. The lack of statistical significance may have been associated with the low sample size and high data variability at close range (<2 km) to vessels. The results suggest that unique behaviours such as rubbing, rolling, nursing, and sexual displays may be temporarily disrupted in close proximity (<2 km) to vessel traffic, though this finding is based on a very small sample size at close range to vessels. Additional focal follow monitoring is therefore recommended to increase the overall sample size and the robustness of the corresponding analysis.**

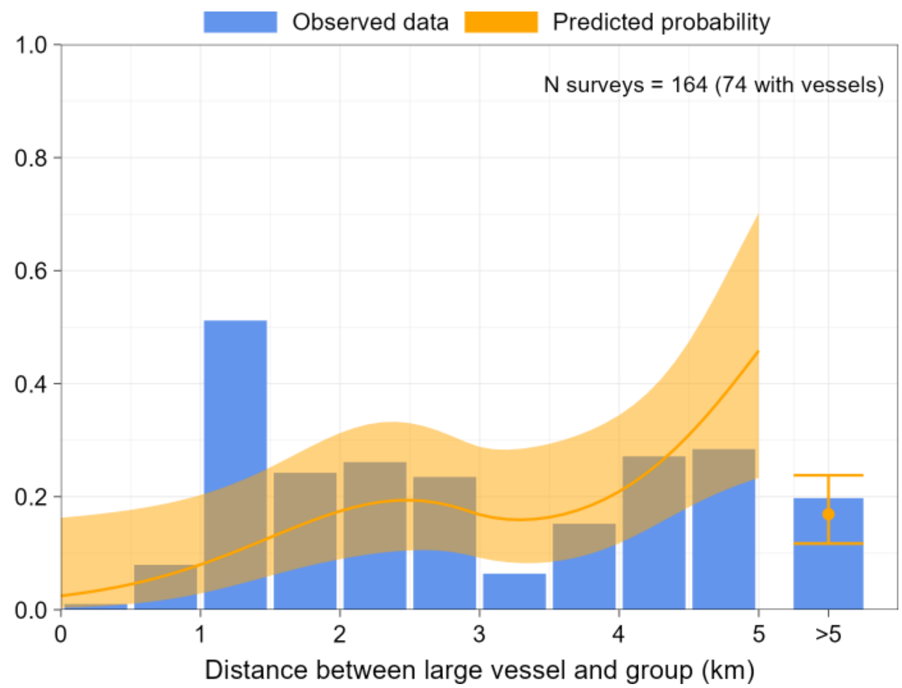



**Figure 5-34: Proportion of time narwhal groups were observed to engage in unique behaviours as a function of distance (rounded up to nearest 0.5 km value) from vessel.**

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

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

| Distance from Vessel (km) | Multiple Comparisons to No-exposure – Least-squares Means with *P* values in Brackets | | | |
|---|---|---|---|---|
| | Mother-immature pair | Mixed with immatures | Mixed without immatures | Adult |
| 0.5 | 0.045 (0.249) | 0.046 (0.249) | 0.045 (0.249) | 0.020 (0.249) |
| 1.0 | 0.081 (0.427) | 0.082 (0.427) | 0.080 (0.427) | 0.037 (0.427) |
| 2.0 | 0.176 (1.00) | 0.178 (1.00) | 0.174 (1.00) | 0.085 (1.00) |
| 3.0 | 0.170 (1.00) | 0.172 (1.00) | 0.168 (1.00) | 0.082 (1.00) |
| 4.0 | 0.211 (0.884) | 0.213 (0.884) | 0.209 (0.884) | 0.104 (0.884) |
| 5.0 | **0.461 (0.021)** | **0.465 (0.021)** | **0.458 (0.021)** | **0.271 (0.021)** |

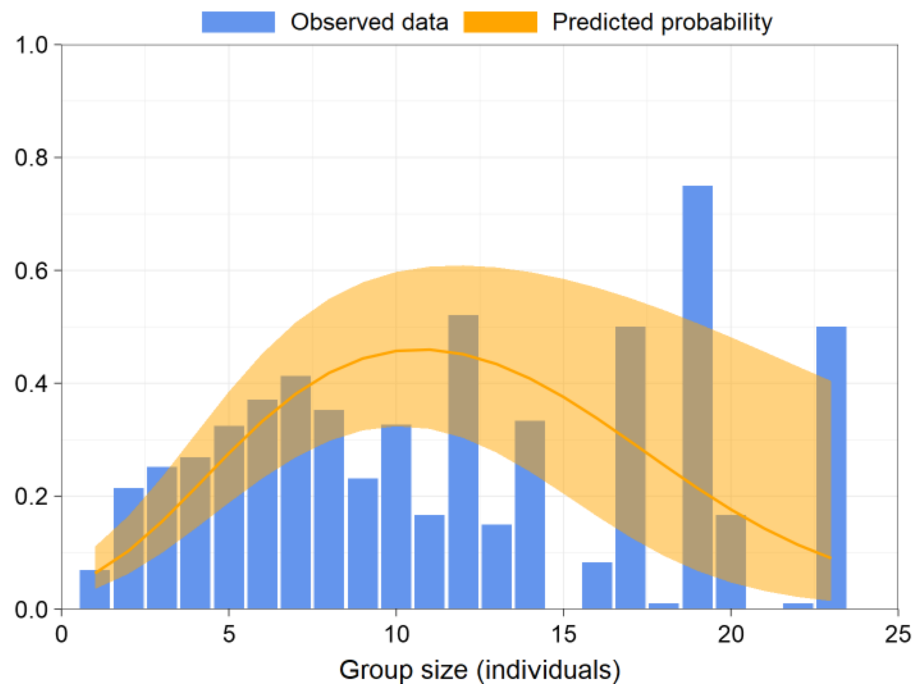



**Figure 5-35: Proportion of time narwhal groups were observed to engage in unique behaviours as a function of narwhal group size.**

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

### 5.6.4 Association of Immatures with Presumed Mother

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

#### *5.6.4.1 Presence of Nursing Behaviour*

Nursing behaviour involving immatures (i.e., calves or yearlings) was recorded during 30 of the total 397 focal follow surveys conducted (during 12 surveys in 2020, 12 surveys in 2021, and during six surveys in 2022; accounting for 14%, 7%, and 4% of all groups in 2020, 2021, and 2022 respectively; Figure 5-36). For all focal groups containing immatures (36 groups in 2020 and in 2021, and 54 groups in 2022), nursing was observed at some point within 33% of surveys conducted in 2020 and 2021, and in 11% of surveys conducted in 2022. Of these, nursing duration ranged between 5% of the total survey duration (FFID 137 in 2021) and 63% of the total survey duration (FFID 81 in 2020), with a mean of 23% of the survey length (SD of 17%).

All focal follow surveys that included nursing immatures (12 surveys in 2020, 12 surveys in 2021, and six surveys in 2022) are shown in Figure 5-37. The 30 focal groups with immatures consisted of mother-immature pairs, mixed groups with immatures, and lone immature groups. Of these groups, single immatures were recorded at some point in all 30 surveys, while two immatures were recorded in four surveys, and three immatures were recorded in a single survey in 2021 (FFID 137). Nursing events ranged between a single 30 sec period (one survey in 2020, three surveys in 2021, and two surveys in 2022) to ≥5 min nursing events (FFIDs 33 and 83 in 2020). On average, nursing events observed during a given survey lasted 2.2 min (SD of 1.3 min).

Of the 30 focal follow surveys consisting of nursing immatures, five of the surveys coincided with vessel presence, though for one of these surveys the actual nursing event took place when the vessel was beyond 5 km of the focal group. In this particular survey (FFID 122; 2021), the immature was observed to nurse for a single 30 sec period at a point in the survey when the vessel was outside of the 5 km exposure distance. During FFID 83 (2020), nursing lasted for 5.5 min, commencing when the vessel was outside of the 5 km exposure zone cut-off, and continuing as the distance to the vessel decreased to 4.5 km, at which point the UAV had to return due to battery limitations. For all surveys containing nursing and coinciding with vessel presence, narwhal were never closer than 2 km from the vessel (Figure 5-38). Of the remaining three surveys recorded in 2022, the immatures nursed for only a single 30-sec period when vessels were at a distance of 3.1 km (FFID 19) and 4.8 km (FFID 26) from the focal group, and for 1.5 min when the vessel was beyond 5 km of the focal group (FFID 30), followed by a single 30 sec interval two minutes later, when the same vessel was at 4.9 km distance from the group. Although this represented a small sample size of nursing events in the presence of vessels, this finding did suggest that mother and dependent young continued to carry out critical life functions in the presence of vessel traffic. When no vessels were present, nursing was recorded in 28 out of 97 focal follow surveys that included mother-immature pairs (29%), and nursing periods ranged from a minimum of a single 30 sec period (four focal follow surveys) to a maximum of 5 min (one focal follow survey), with a mean of 4.4 min and SD of 2.3 min.

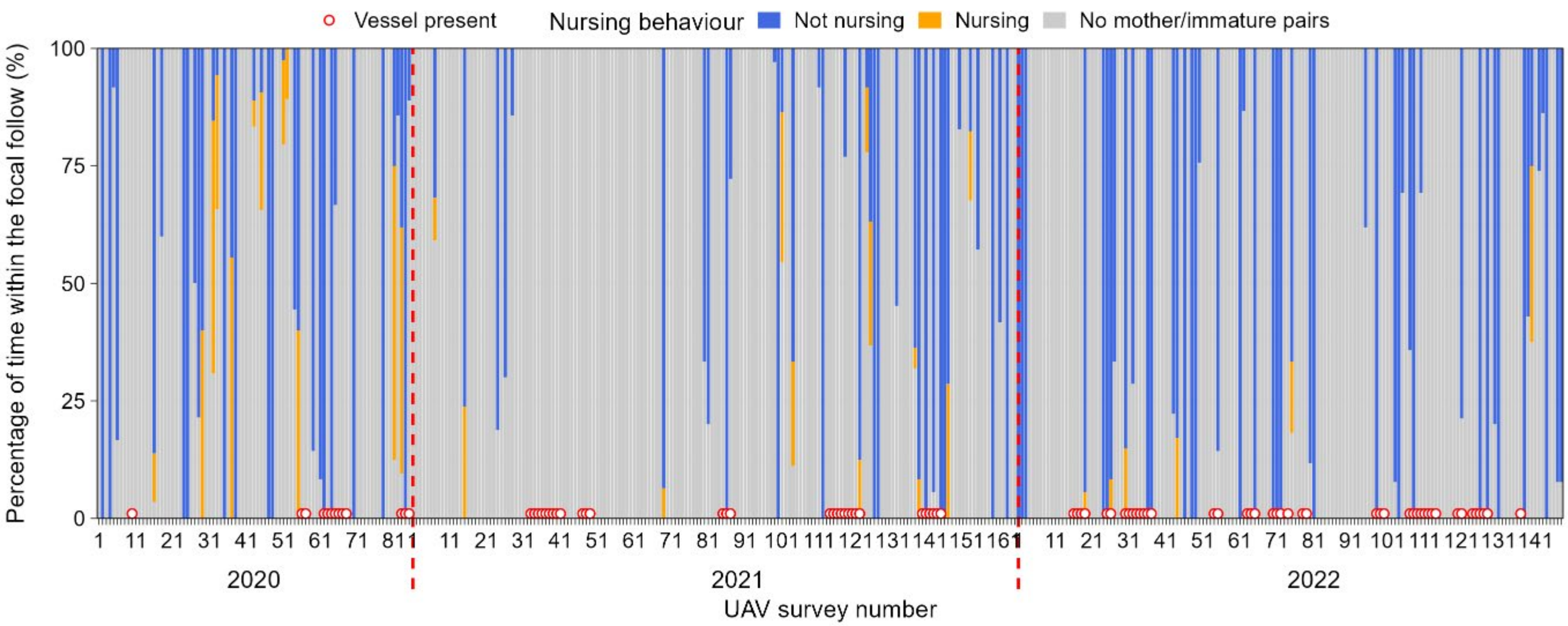



**Figure 5-36: Nursing behaviour recorded during focal follow surveys, 2020-2022.**

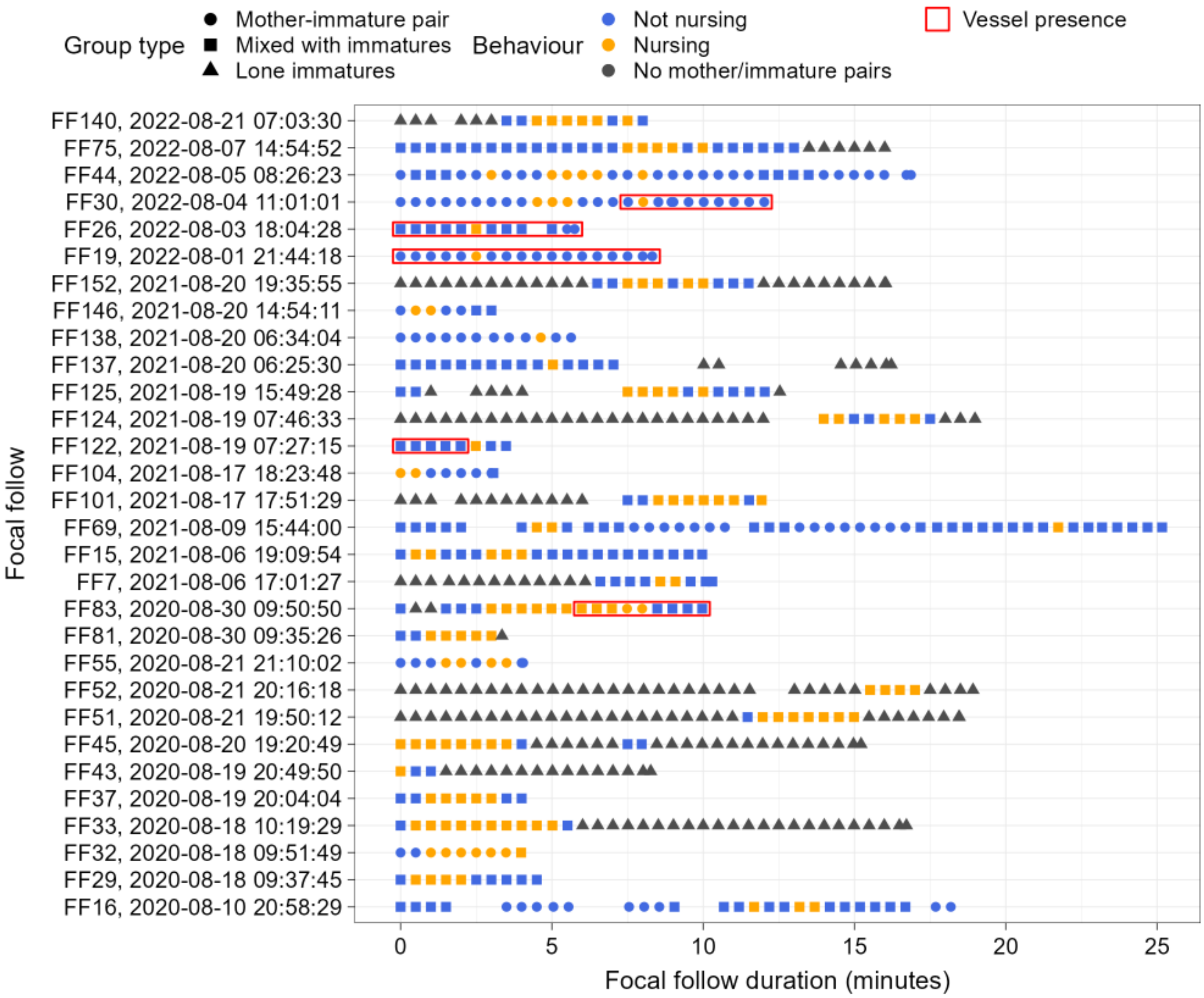



**Figure 5-37: Nursing behaviour (yellow) observed in focal follow surveys that included nursing immatures, 2020-2022. Vessel presence (vessel ≤5 km) denoted by red box.**

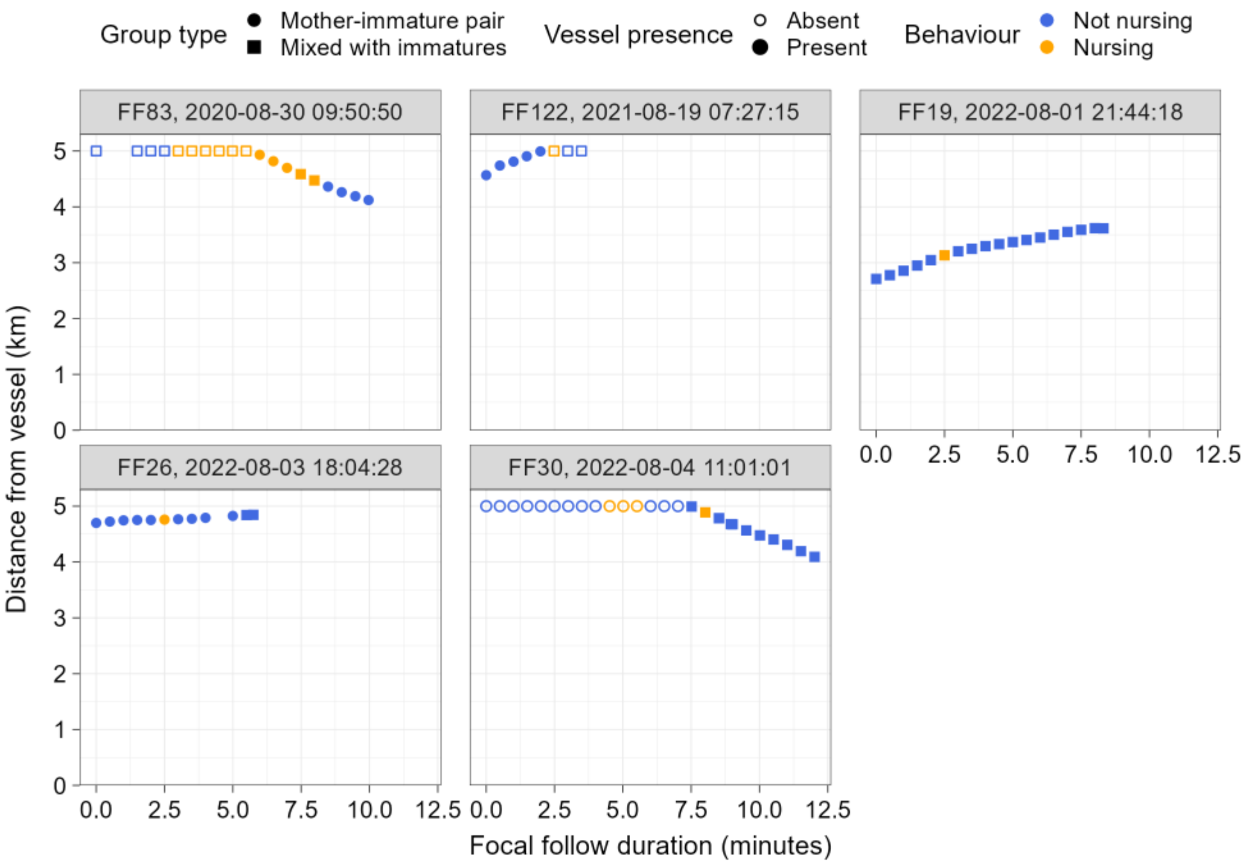



**Figure 5-38: Nursing behaviour (yellow) observed in focal follow surveys that included nursing activity when vessels were present (2020-2022).**

A mixed-effects model with a binomial distribution was used to test for the effect of vessel presence on nursing. The model included fixed effect of group size, group type, and vessel presence, but not vessel distance, given the limited data available for narwhal-vessel interactions at the near-field distances. Modelling results indicated that the effect of vessel presence on nursing was not significant (*P*=0.062; effect size of -69%; Figure 5-39). The lack of a significant effect despite the large effect size was likely due to the overall low sample size and high data variability. The model was based on limited and unbalanced data; specifically, only four of the 28 surveys involving active nursing occurred in the presence of vessels (<5 km). As a result, the above findings should be interpreted with caution.

The main effect of group type on nursing was not significant (*P*=0.3). The effect of group size was found to be significant (*P*=0.024), with nursing being significantly less likely to be observed in larger groups (Figure 5-40). However, data on large groups came from a limited set of focal follows – only seven surveys had group sizes larger than ten individuals, and only four surveys had group sizes larger than 15 individuals.

The statistical power to estimate the observed effect was low (<0.1; Appendix A). The model only had sufficient power (≥0.8) to detect an effect size of +1,000% (Appendix A). This effect size corresponds to the increase in probability of nursing behaviour from 0.003 to 0.029 for mother-immature pairs and from 0.005 to 0.057 for mixed groups with immatures.

**In summary, immature narwhal engaged in nursing less often when in the presence of vessel traffic (vessel within 5 km of the focal group), although this effect was not significant despite a large effect size of -69%. The lack of statistical significance was likely due to low sample size and high data variability. As a result, the above findings should be interpreted with caution. Additional focal follow monitoring is recommended to increase the overall sample size and the robustness of the corresponding analysis.**

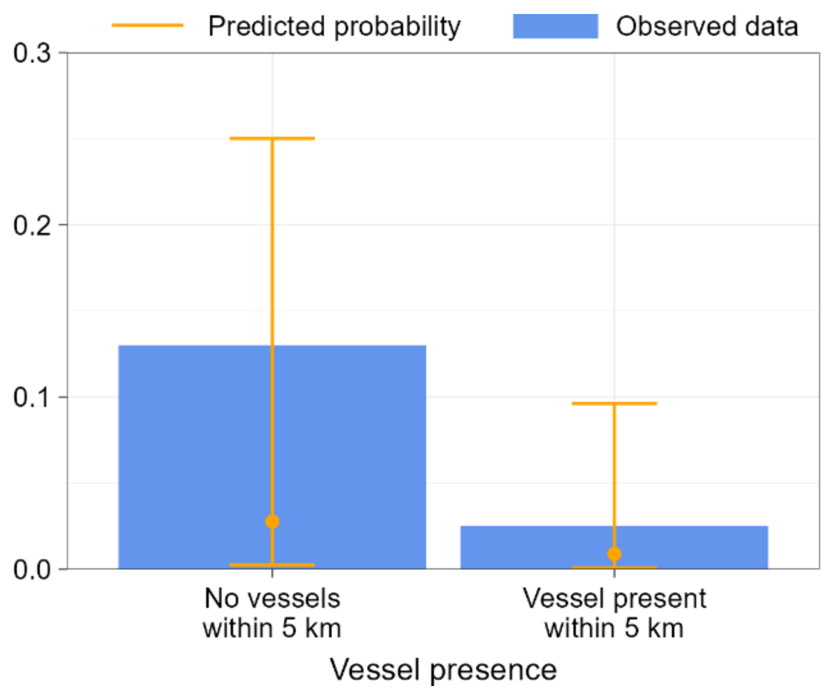



**Figure 5-39: Proportion of time immatures were observed nursing as a function of vessel presence.**

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

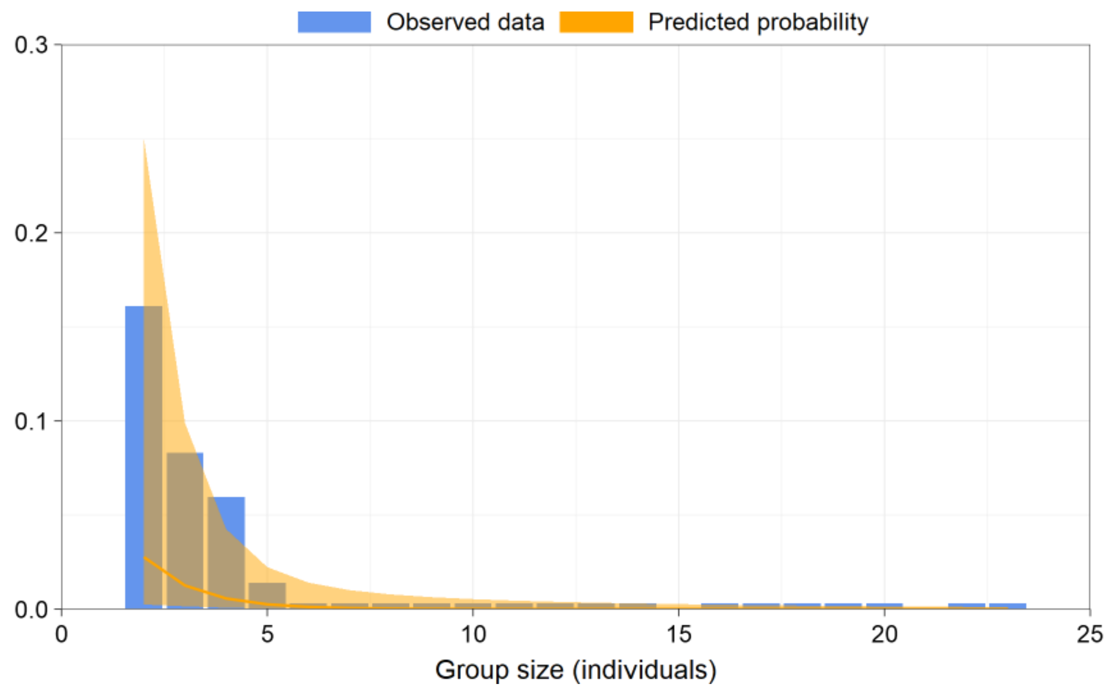



**Figure 5-40: Proportion of time immatures were observed nursing as a function of group size.**

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

#### 5.6.4.2 Relative and Distal Positioning of Immatures

With respect to positioning of immature narwhal relative to their presumed mother, immatures were most commonly observed under their mother (41%) compared to abreast (38%), on top (13%), in front (6%), or behind (2%). Relative position of immatures often changed, with up to four positions recorded for a single individual within a single focal follow survey (Figure 5-41). Immature narwhal were most commonly observed under their mother compared to other positions in both the presence and absence of vessels (38% and 42% of the time, respectively). Immatures positioned abreast of their mother comprised the second most common relative positions (32% of the time when a vessel was present and 41% of the time in the absence of vessels). The proportion of time that immatures were recorded on top of their mother was 12% in the presence of vessels and 18% when no vessels were present. The proportion of time that immatures were recorded in front or behind the mother was low, with 6% in the presence of vessels and 3% when no vessels were present.

In groups comprised solely of mother-immature pairs, immatures were generally observed under their mother more often than in mixed groups with immatures, for both vessel presence and vessel absence scenarios (Figure 5-42). In mother-immature pairs, the proportion of time that immatures spent under the mother decreased with distance from vessels, from 67% at 0-1 km to 41% at 4 to 5 km (however sample sizes were <10 at both distances). In the absence of vessels, immatures remained under the mother for 50% of the time in groups comprised solely of mother-immature pairs. In mixed groups with immatures, immatures spent 0%-28% of the time under the mother in the presence of vessels (depending on distance) and 34% of the time under the mother when no vessels were present.

When an immature was positioned underneath of its mother, it was tightly associated with the adult 99% of the time (Figure 5-43). A tight association was recorded for 92% of immatures observed on top of their mother, 69% of immatures abreast of the mother, 22% of immatures in front of the mother, and in 21% of immatures behind the mother. The proportion of time that mothers and immatures were tightly associated with one another ranged from 67% to 94% for mother-immature pairs in the presence of vessels (depending on distance) and 81% when no vessels were present (Figure 5-44). The proportion of time that mothers and immatures were tightly associated with one another ranged from 59% to 100% for mixed groups with immatures in the presence of vessels (depending on distance) and 81% when no vessels were present.

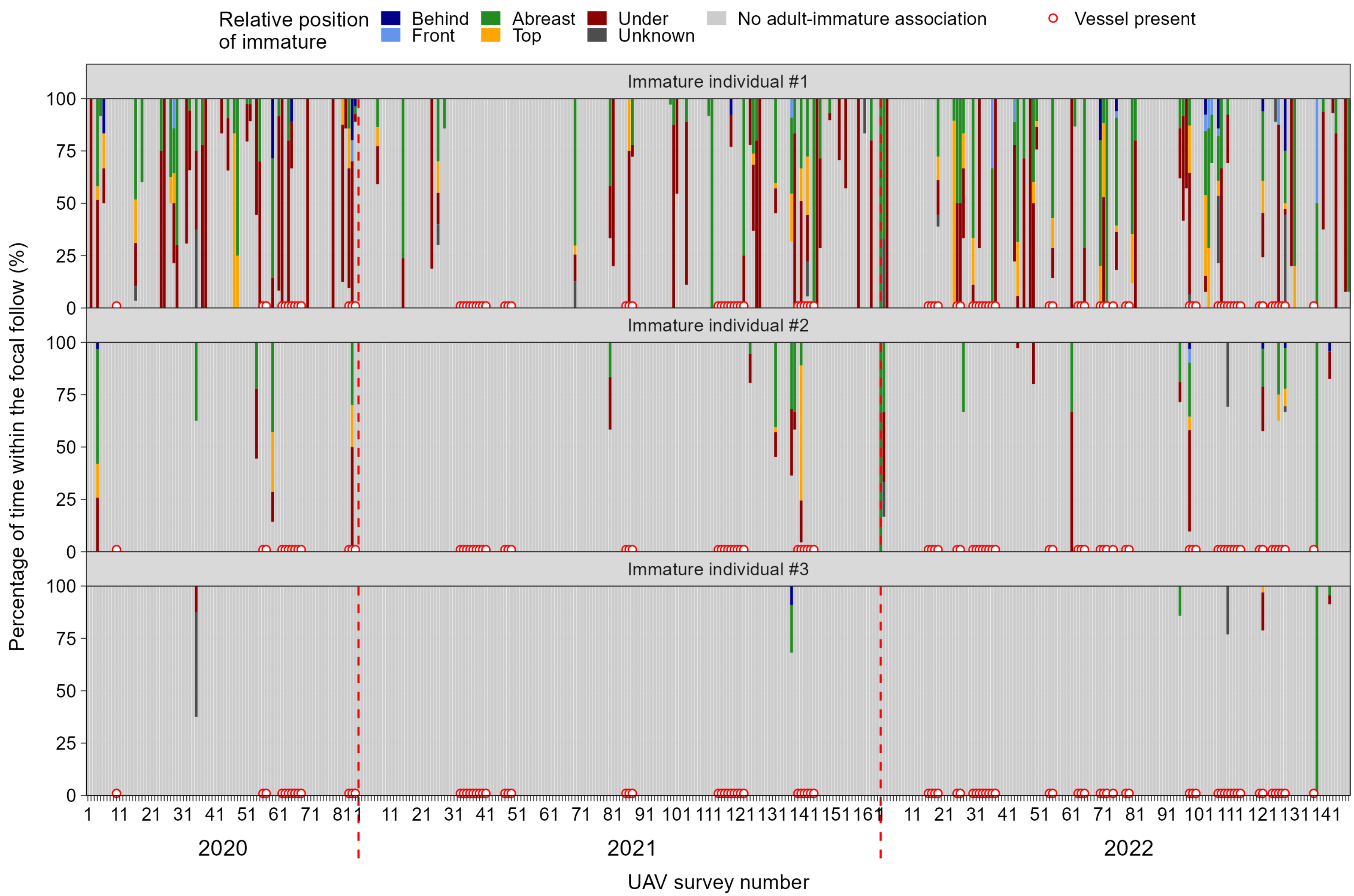



**Figure 5-41: Relative position of immatures recorded during focal follow surveys. A separate plot is presented for each individual immature in a given group, 2020-2022.**

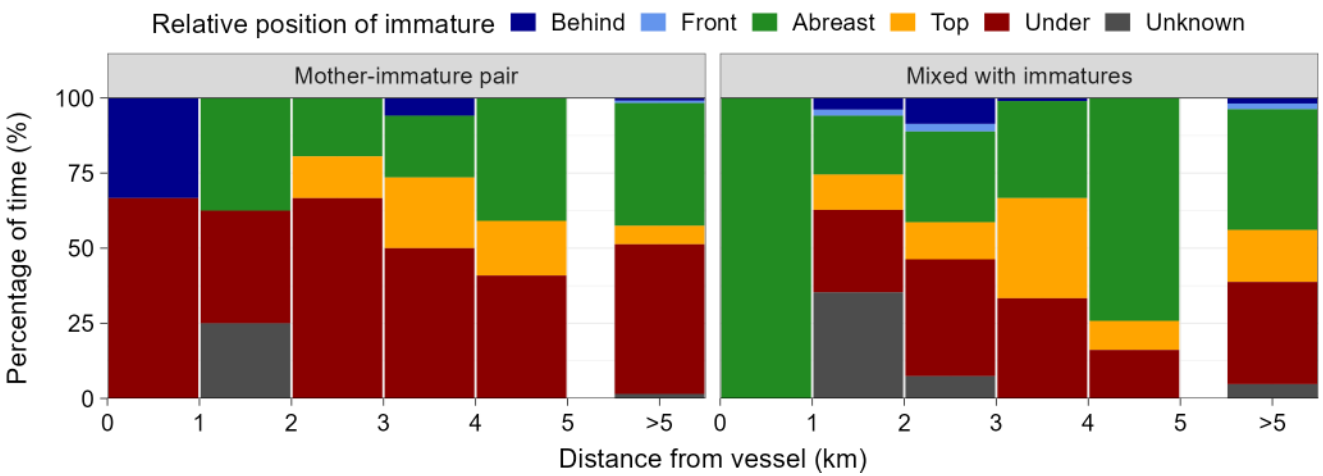



**Figure 5-42: Percentage of time immature narwhal associated in relative positions of presumed mother, relative to distance from vessel, presented by group type.**

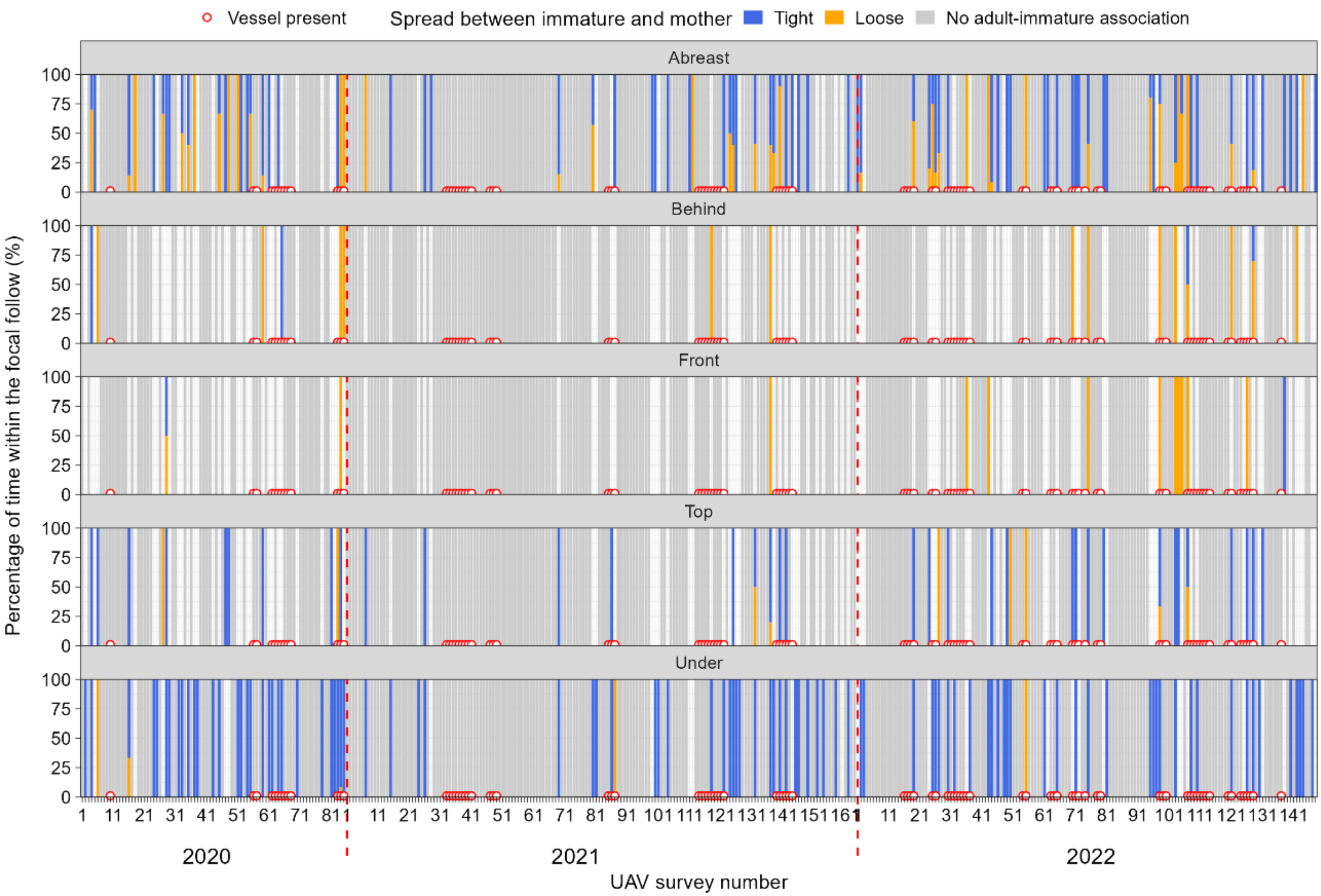



**Figure 5-43: Position and spread of immatures relative to the presumed mother recorded during focal follow surveys, 2020-2022. A separate plot is presented for each known relative position.**

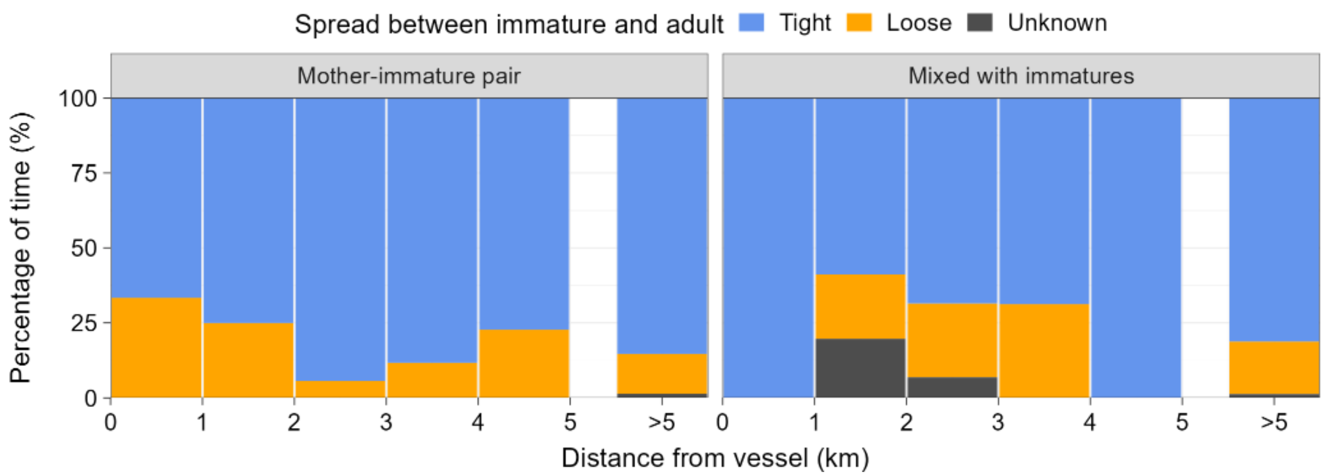



**Figure 5-44: Percentage of time immature narwhal spent in each distal position, relative to distance from vessel, presented by group type.**

In the analysis of distal position, the 'relative position of immature' was used as a predictor. Of the five relative positions recorded (on top, under, abreast, behind, in front), two (behind and in front) had low sample sizes (Figure 5-43). To increase sample size, several relative positions were grouped into the following three categories: 'lateral (which included abreast, in front, and behind), "on top", and "under".

The effect of distance from vessel on the relative position of immatures was not significant ($P$=0.2). The probability of an immature to be tightly associated with its mother was estimated to be lowest when vessels were at 3 km from the group. As vessels came in closer proximity, immatures were increasingly likely to be tightly associated (Figure 5-45). Due to the nonlinear nature of the logistic function, while the difference in probability of a tight association changed little between when a vessel was in close proximity and when no vessels were present (range of difference between 0.002 and 0.147 on the probability scale), the odds of a tight association at presence of a vessel at 0.5 km from a group were 307% higher than when no vessels were present. In comparison, while the difference in probability of a tight association decreased by 0.370, 0.079, and 0.009 for immatures in lateral position, on top, and under their mother, respectively for a vessel at 3 km relative to when no vessels were present, the effect size (calculated on the odds scale) was -81%. Note that data at close proximity (<1 km from vessels) were limited to only two focal follow surveys. The effect of group type (mother-immature pairs and mixed groups with immatures) was found to not be significant ($P$=0.5); that is, the distal position of immatures did not differ between mother-immature pairs and mixed groups with immatures. The effect of relative position was found to be significant ($P$<0.001), with immatures significantly more likely to be in a tight association with their presumed mother when found under the mother, compared to either on top of the mother or in a lateral position ($P$<0.001 for both). Similarly, immatures were significantly more likely to be in a tight association with their presumed mother when found on top of the mother, compared to a lateral position ($P$<0.001).

Estimated effect sizes for a vessel at 0.5 km, 1.0 km, 2.0 km, 3.0 km, 4.0 km, and 5.0 km distance from the group were +307%, +64%, -65%, -81%, -58%, and +109%, respectively for all group types and all relative positions. While all of these effect sizes were considered large (>50%), the effect sizes crossed the 0% (i.e., no effect) value twice – once at approximately 2.5 km, and again at approximately 4.5 km (Figure 5-45). That is, the estimated trends and effect sizes suggest that a biologically relevant effect (i.e., >50% change in distal position – as detailed in Section 4.3.2.1) may exist, with a spatial extent of less than 5 km from a vessel. It was expected that a vessel effect would result in an increase in the probability of immatures being tightly associated with their presumed mother; instead, the estimated effect was a decrease in the probability (for vessel distances of 3 km to 5 km), with an increase in the probability of tight association only at closer distances to the vessel (within 3 km). Therefore, it is possible that the trend observed between 3 km and 5 km is an artefact of the 5 km spatial extent of vessel effect modelling, and the actual effect has a smaller spatial extent (for example, within 3 km). However, a conservative approach would be to retain the full spatial extent for this effect; that is, a large biologically relevant effect (i.e., >50% change in distal position – as per Section 4.3.2.1) may exist on the distal positioning of immatures with their mother, with a spatial extent of less than 5 km from a vessel.

The statistical power to estimate the observed effect was low (0.25; Appendix A). That is, the observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model only had sufficient power (≥0.8) to detect an effect size >1,400% (Appendix A). This effect size corresponded to the increase in probability of a tight association between immature and its presumed mother from 0.792 to 0.983 for immatures found in a lateral position relative to the adult, from 0.979 to 0.999 for immatures found on top of the adult, and from 0.998 to 1.00 for immatures found under the adult.

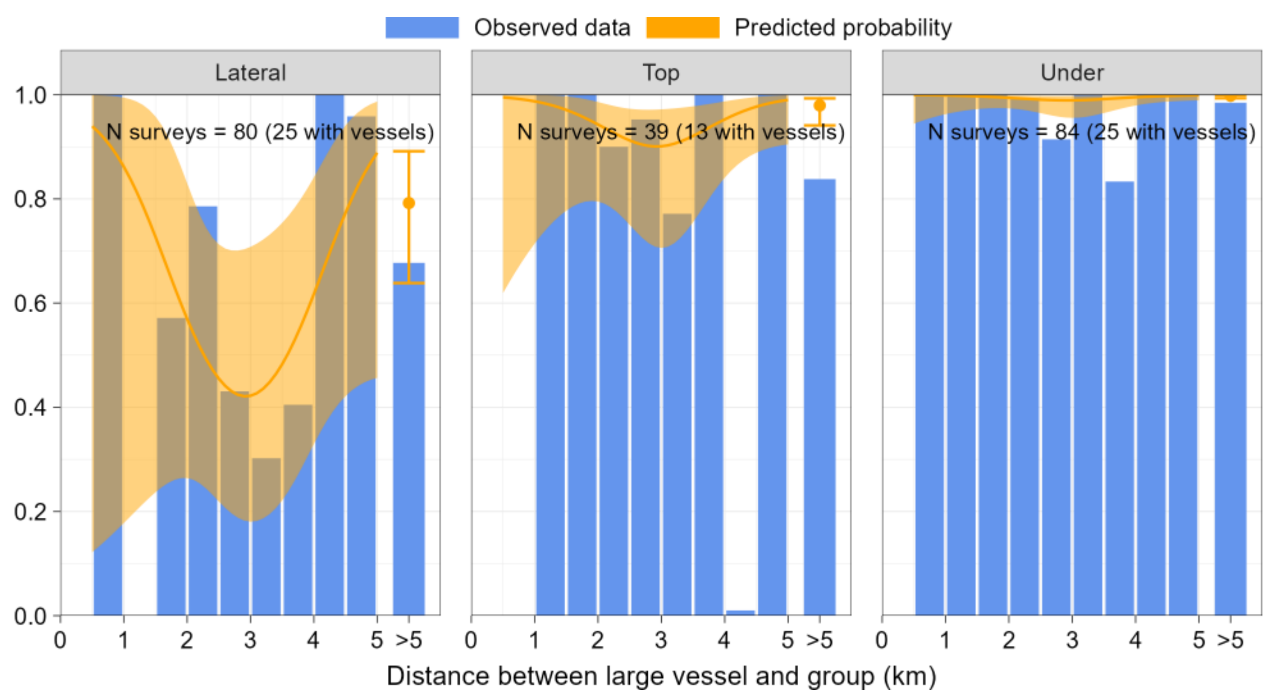



**Figure 5-45: Proportion of time immatures were observed tightly associated with their presumed mother as a function of distance (rounded up to nearest 0.5 km value) from vessel, presented by relative position of immature (lateral, on top, or underneath the mother).**

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

In the analysis of relative position, of the five relative positions recorded (on top, under, abreast, behind, in front), one (on top) was removed from the data, due to low sample size (Figure 5-43). In addition, to increase sample size, the remaining relative positions were grouped into two categories – “lateral”, which included abreast relative positions as well as behind and in front of the presumed mother, and “under”.

The effect of distance from vessel was not significant (*P*=0.4), likely due to the high uncertainty around the modelled estimates (Figure 5-46). The estimated effect size of vessel was small, with a 12% increase in odds of an immature under the mother when a vessel was at 0.5 km relative to when a vessel was not present. The effect of group type (mother-immature pairs and mixed groups with immatures) was found to be significant, with immatures being significantly more likely to be found under their presumed mother in mother-immature pairs than in mixed groups with immatures (*P*=0.012). At proximity to vessels, estimated effect sizes for a vessel at 0.5 km and 1.0 km from the group were -11% and -1%, respectively. These effect sizes suggest a potential small effect (i.e., >10% change in relative position of immatures – as detailed in Section 4.3.2.1) may exist for both mother-immature pairs and groups with immatures, with a spatial extent of less than 1 km from a vessel.

The statistical power to estimate the observed effect of vessel distance from narwhal groups was low (<0.5; APPENDIX A). That is, the observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model only had sufficient power (≥0.8) to detect an effect size of +1,400% (Appendix A). This effect size corresponds to the increase in probability of observing an immature under its presumed mother from 0.676 to 0.969 for mother-immature pairs and from 0.504 to 0.939 for mixed groups with immatures.

**In summary, the results suggest that immature narwhal may temporarily change their relative and distal association with their mother when in close proximity to vessel traffic, for both mother-immature pairs and for mixed groups with immatures. That is, immature narwhal tended to favour the underside of their mother over other relative positions when within 1 km of vessels (though this finding is based on a small effect size) and immature narwhal tended to associate more tightly with their mother when within 5 km of vessels. The full spatial extent of the latter finding may be a modelling artefact and the effect may only extend up to 3 km from a vessel. Additional focal follow surveys are recommended to increase sample size, thereby allowing for a more robust analysis.**

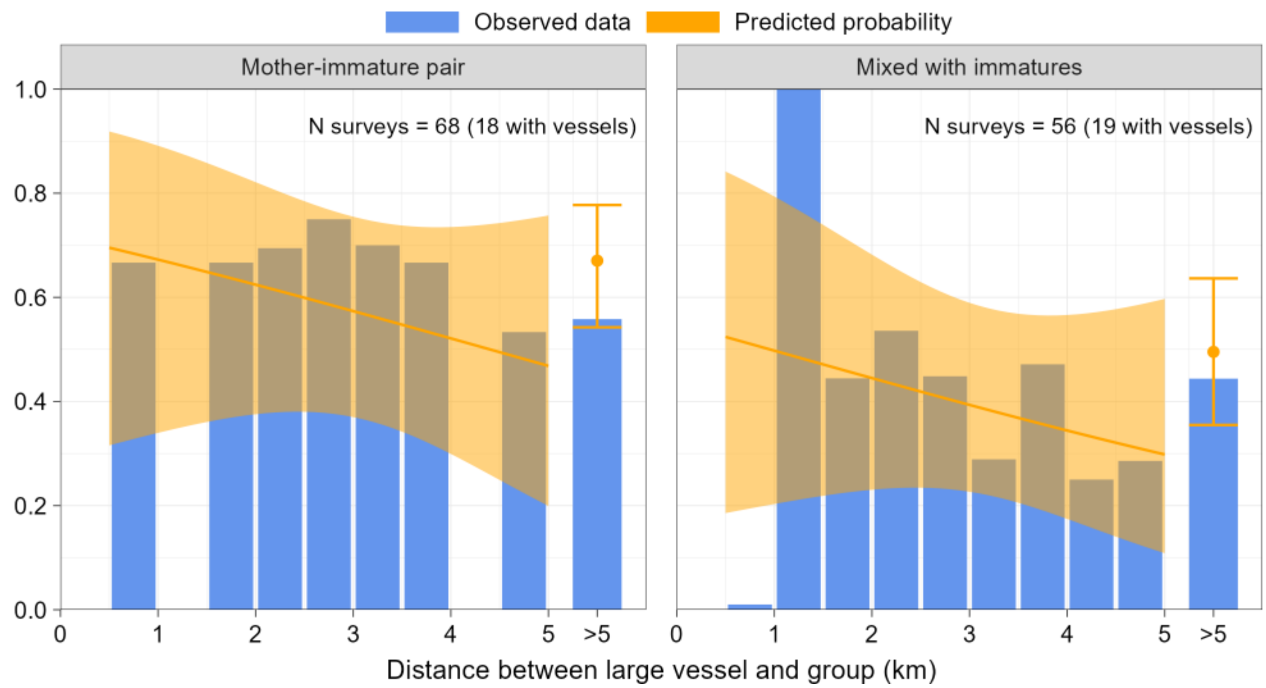



**Figure 5-46: Proportion of time immatures were observed under their mother as a function of distance (rounded up to nearest 0.5 km value) from vessel, plotted by group type.**

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

### 5.6.5 Group Formation

Of the followed groups (with group size ≥2), the most frequently observed group formation was parallel (39% of time), similar to the predominant formation recorded by shore-based observers between 2014 and 2022 in the BSA. This was followed by cluster formation (29% of the time) and linear formation (18% of the time; Figure 5-47). In the absence of vessels, the proportion of groups in parallel formation (38% of the time) was similar to when vessels were present (42%). In contrast, the proportion of groups in linear formation was higher in the absence of vessels (21%) relative to when vessels were present 10%). The proportion of groups in cluster formation was lower when a vessel was absent compared to when a vessel was present (27% and 36%, respectively).

Mother-immature pairs were generally observed in linear formation, whether in the absence of vessels (52% of the time) or the presence of vessels (27 - 67% of the time, depending on distance; Figure 5-48). This finding should be interpreted with caution, however, as an immature located either above or underneath of its mother would be classified as linear, thereby inflating the likelihood of observing linear formation in strictly mother-immature groups. In comparison, mixed groups with immatures were mostly observed in parallel formation, whether in the absence of vessels (46%) or the presence of vessels (22 to 100% of the time, depending on distance). Mixed groups without immatures were also most likely to be in parallel formation both in the absence of vessels (46%) and in the presence of vessels (17 to 58%, depending on distance from vessel). Adult-only groups were often groups comprised of a single animal when vessels were absent (51% of the time) or present (28 to 70% of the time, depending on distance from vessel). When adult-only groups had at least two individuals, groups were most commonly recorded in cluster formation when vessels were absent (39% of time) and in parallel formations when vessels were present (43 to 61% of time, depending on distance from vessel). Lone immatures were usually in a group comprised of a single individual (82% of the time in absence of vessels and 82 to 100% of the time in presence of vessels).

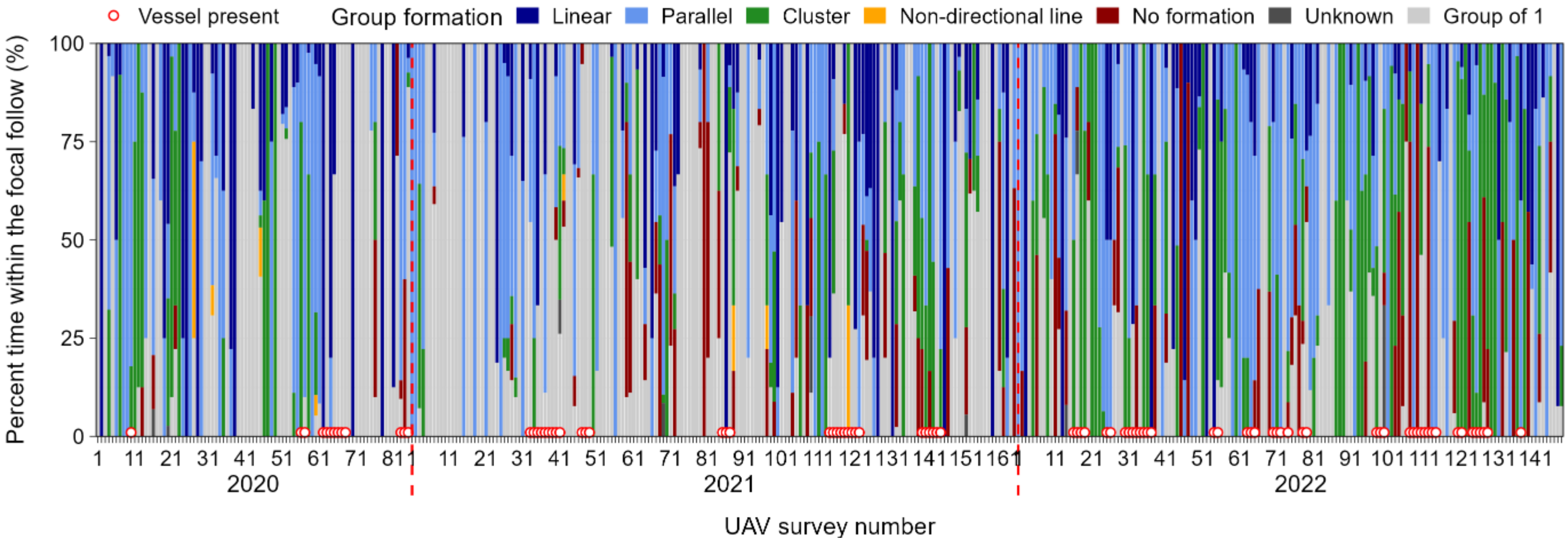



**Figure 5-47: Group formation recorded during focal follow surveys, 2020-2022.**

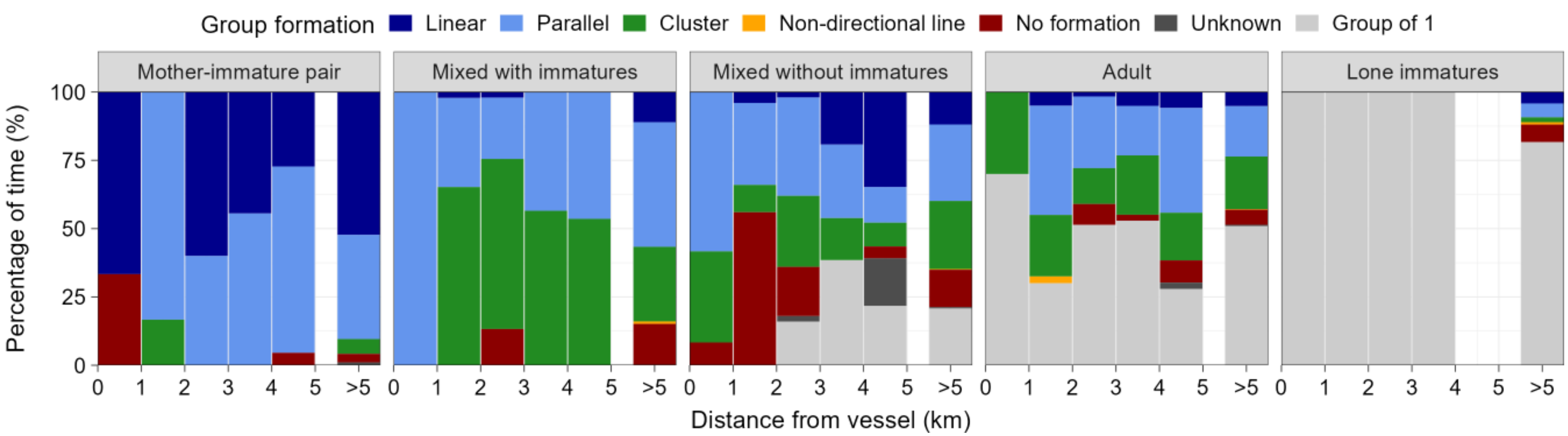



**Figure 5-48: Percentage of time narwhal groups spent in each formation relative to distance from vessel, presented by group type.**

In the analysis of group formation, formations were binned into the following two categories: ‘parallel’ and ‘linear, cluster, non-directional line and/or no formation’. In the model, the interaction between distance from vessel and group type, as well as the main effect of distance from vessel were not significant (*P*>0.1 for both). Effect sizes were estimated to be +19% for mother-immature pairs, -35% for mixed groups with immatures, -27% for mixed groups without immatures, and -98% for adult groups (Figure 5-49). However, adult-group data at distances closer than 1 km were obtained from a single focal follow survey which may affect the adult-group response at close proximity to vessels. The main effect of group type was also not significant (*P*=0.2). The effect of group size was, however, found to be significant (*P*<0.001), with larger groups being significantly less likely to be found in parallel formation (Figure 5-50), though data on large groups came from a limited set of focal follow surveys (with only 19 surveys having group sizes larger than ten narwhal, and only seven surveys having groups sizes larger than 15 narwhal).

At close proximity to vessels, estimated spatial extents of effects differed between group types. For mother-immature pairs, effect sizes of vessel at 0.5 km, 1.0 km, and 2.0 km from the group were +19%, +11%, and +2%, respectively, suggesting a potential small effect (i.e., >10% change in group formation) may exist, with a spatial extent of less than 2 km from a vessel. For mixed groups with immatures, effect sizes of vessel at 0.5 km, 1.0 km, 2.0 km, and 3.0 km from the group were -35%, -29%, -12%, and +14%, respectively, suggesting a potential medium-sized effect (i.e., >25% change in group formation) may exist, with a spatial extent of less than 3 km from a vessel. For mixed groups without immatures, effect sizes of vessel at 0.5 km and 1.0 km from the group were -27% and -5%, respectively, suggesting a potential medium-sized effect (i.e., >25% change in group formation) may exist, with a spatial extent of less than 1 km from a vessel. Finally, for adult groups, effect sizes of vessel at 0.5 km, 1.0 km, 2.0 km, and 3.0 km from the group were -98%, -94%, -60%, and +16%, respectively, suggesting a potential large effect (i.e., >50% change in group formation) may exist, with a spatial extent of less than 3 km from a vessel. Overall, three of the four group types were estimated to have a medium to large decrease in odds of a parallel formation, with a spatial extent of less than 3 km from a vessel. The increase in odds of a parallel formation for mother-immature pairs, while the odds decreased for all other groups, may be due to low sample size at close proximity to vessels.

The statistical power to estimate the observed effect sizes of distance from vessel (ranging between -98% and +16%) was low (<0.6; Appendix A). That is, the observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model only had sufficient power (≥0.8) to detect an effect size >1,100% (Appendix A). This effect size corresponded to the increase in probability of parallel formation of a group from 0.201 to 0.759 for mother-immature pairs, from 0.266 to 0.819 for mixed groups with immatures, from 0.334 to 0.862 for mixed groups without immatures, and from 0.343 to 0.867 for adult groups.

**In summary, results suggest that narwhal may alter their group formation when in close proximity to vessel traffic, with the majority of group types decreasing the proportion of time that they spend in parallel formation when within 1 to 3 km of vessels. Conversely, mother-immature pairs were the only group type to increase the proportion of time that they spent in parallel formation when within 2 km of vessels, however the effect size was small. These findings are based on a small sample size and should therefore be interpreted with caution.**

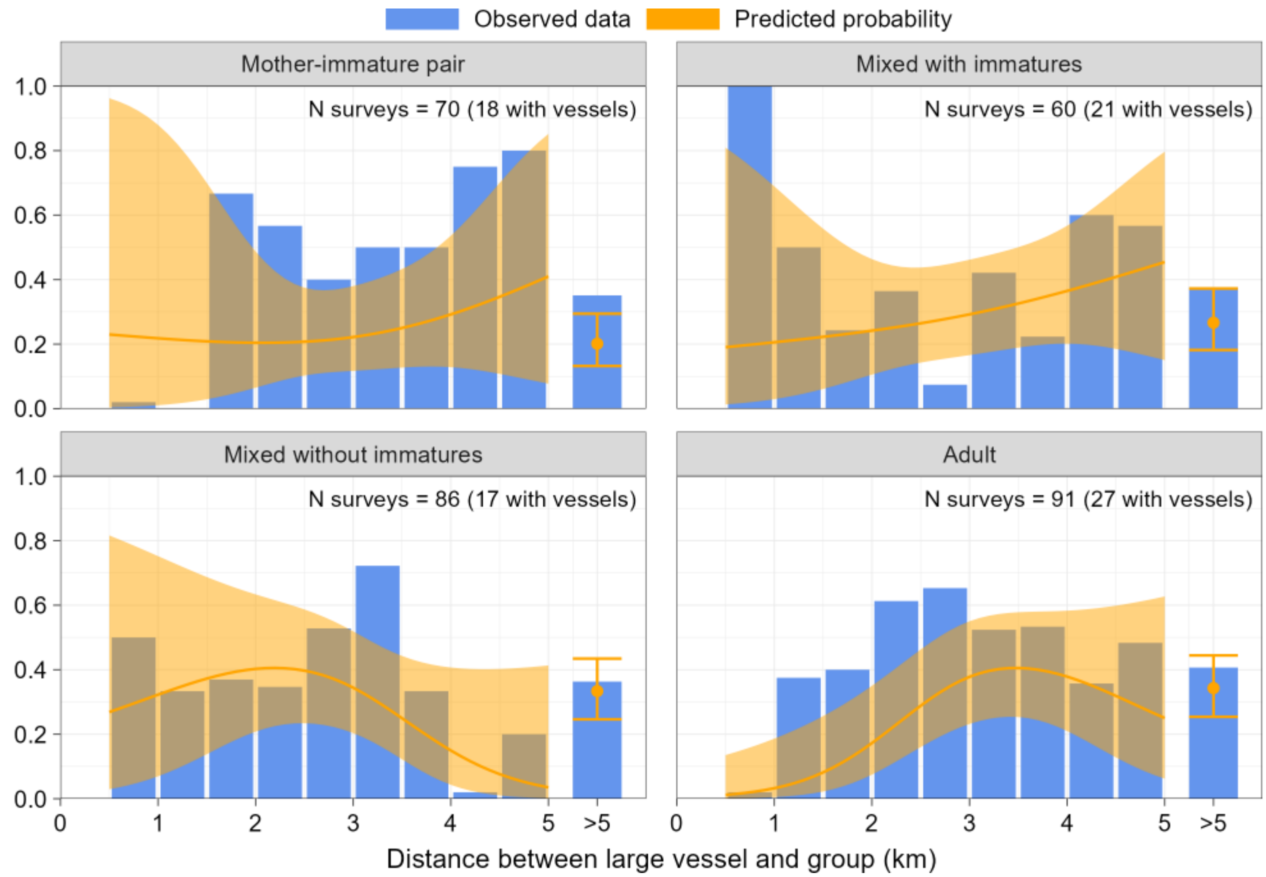



**Figure 5-49: Proportion of time narwhal groups were observed in parallel formation as a function of distance (rounded up to nearest 0.5 km value) from vessel, presented by group type.**

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

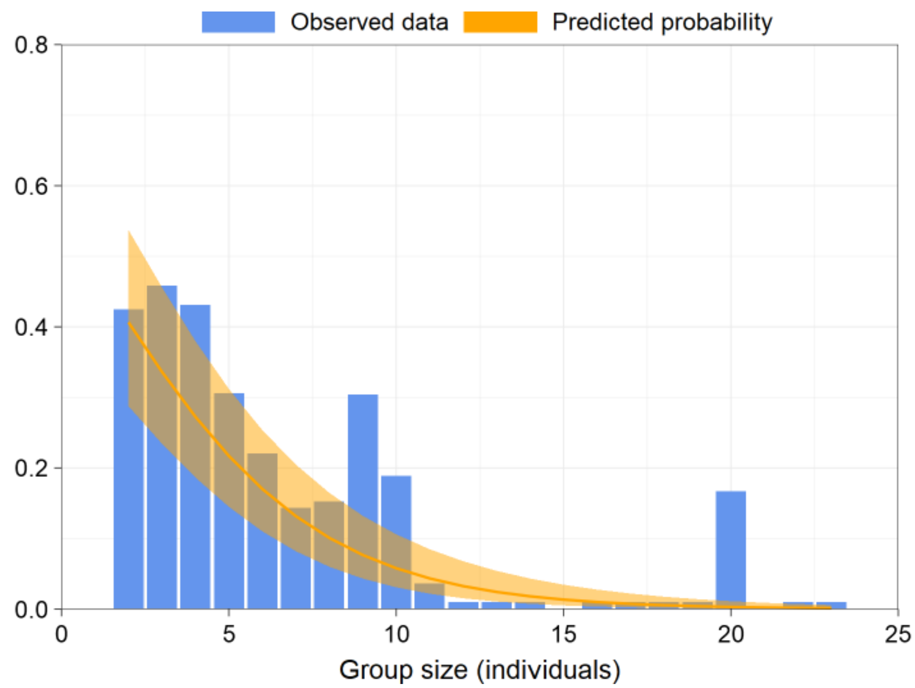



**Figure 5-50: Proportion of time narwhal groups were observed in parallel formation as a function of group size.**

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

## 5.6.6 Group Spread

Narwhal groups tended to spend less time tightly associated with one another compared to loosely associated (44% and 56% of the time, respectively; Figure 5-51). During vessel exposure periods, narwhal tended to spend similar time in tightly associated groups (40%) compared to non-exposure periods (45% of the time). This finding was inconsistent with results obtained from the integrated shore-based monitoring dataset between 2014 and 2021 which found that narwhal formed tighter groups in close proximity (≤2 km) to vessels (Golder 2022).

For groups containing vulnerable life stages, mother-immature pairs were generally observed tightly associated, whether in the absence (79% of the time) or presence of vessels (63 to 96% of the time, depending on distance (Figure 5-52). In comparison, mixed groups with immatures were mostly observed loosely associated, whether in the absence (71%) or presence of vessels (50 to 100% of the time, depending on distance). Lone immatures were usually in a group of a single individual (82% of time when vessels were absent and 100% of time when vessels were present, although sample size was limited to four focal follows). When groups of two or more immatures were recorded, they were most commonly recorded to be tightly associated (53% of time when vessels were absent); groups of two or more immatures were not recorded during vessel exposure periods.

For groups without vulnerable life stages, mixed groups comprised of two or more individuals without immatures were most likely to be loosely associated in the absence of vessels (54%), but their spread varied in the presence of vessels (26 to 67% loosely associated, depending on distance from vessel). Adult-only groups were often groups comprised of a single animal (51% of the time when vessels were absent and 28 to 70% 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 loosely associated with one another (70% of time when vessels were absent and 60 to 100% of the time when vessels were present, depending on distance from vessel).

In the analysis of group spread, the effect of distance from vessel was not significant (*P*=0.058). Due to the nonlinear nature of the logistic function, while the difference in probability of a tight association between narwhal changed little between when a vessel was at 0.5 km and when no vessels were present (decrease in probability ranging between 0.065 and 0.132 on the probability scale), the odds of narwhal being tightly associated when within 0.5 km of a vessel were 46% lower than when no vessels were present within 5 km from a group.

The effect of group type was found to be significant (*P*<0.001), with mother-immature pairs estimated to be significantly more likely to be tightly associated than mixed groups with immatures, mixed groups without immatures, or adult groups (*P*<0.001 for all comparisons). This finding was likely due to the nature of the group type 'mother-immature pairs' which are known to typically associate in a tightly associated echelon position. No significant difference was found between mixed groups with immatures and mixed groups without immatures, as well as between mixed groups with immatures and adult groups (*P*>0.1 for both comparisons).

At proximity to vessels, estimated effect sizes for a vessel at 0.5 km, 1.0 km, 2.0 km, and 3.0 km from the group were -54%, -44%, -19, and +18%, respectively. These effect sizes suggest a potential large effect (i.e., >50% change in group spread – as detailed in Section 4.3.2.1) may exist, with a spatial extent of less than 3 km from a vessel.

The statistical power to estimate the observed effect was low (<0.2; Appendix A). That is, the observed effect size was smaller than the effect size required to achieve sufficient statistical power (≥0.8). The model only had sufficient power (≥0.8) to detect an effect size >700% (Appendix A). This effect size corresponded to the increase in probability of tight spread of a group from 0.867 to 0.981 for mother-immature pairs, from 0.156 to 0.597 for mixed groups with immatures, from 0.295 to 0.770 for mixed groups without immatures, and from 0.131 to 0.546 for adult groups.

**In summary, results suggest that narwhal may associate less tightly with one another when within 3 km of vessels for all group types, although modelling results indicated that this effect was not statistically significant despite a large effect size. The lack of a statistically significant effect may be associated with the low sample size and high data variability. As a result, the above findings should be interpreted with caution. Additional focal follow monitoring is recommended to increase overall sample size and the robustness of the corresponding analysis.**

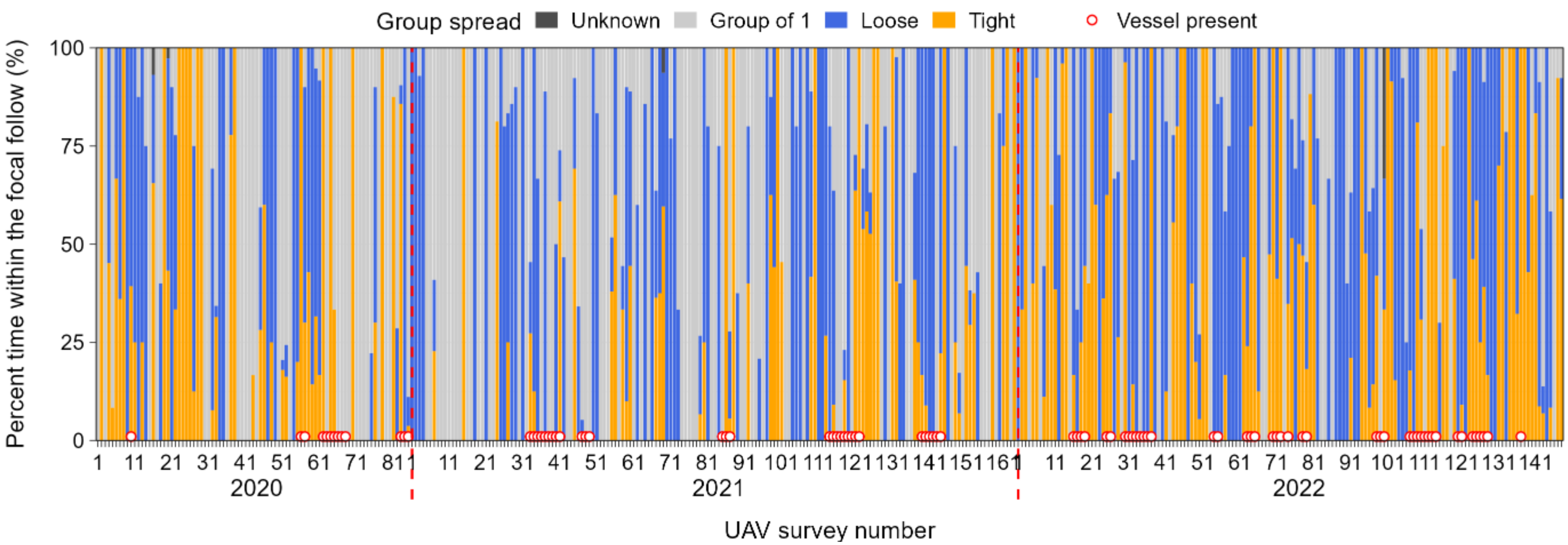



**Figure 5-51: Group spread recorded during focal follow surveys, 2020-2022.**

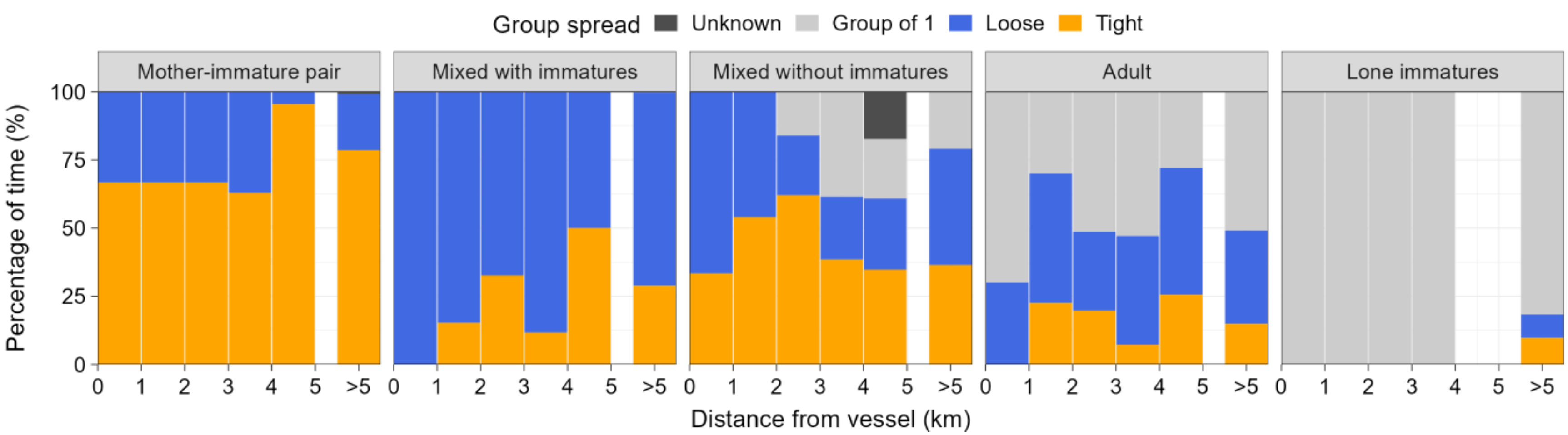



**Figure 5-52: Percentage of time narwhal groups tightly associated relative to distance from vessel, presented by group type.**

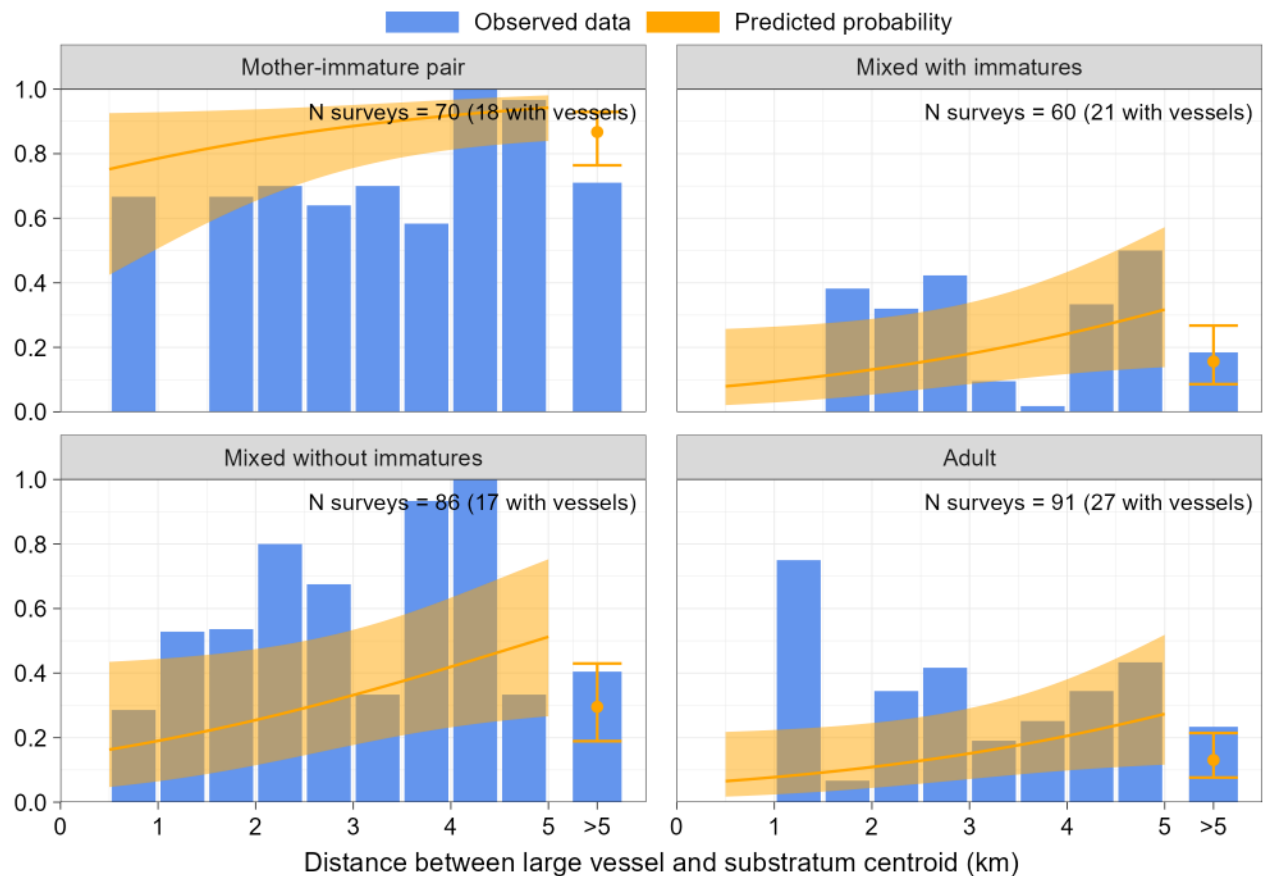



**Figure 5-53: Proportion of time narwhal groups were observed tightly associated (rather than loosely associated) as a function of distance from vessel, presented by group type.**

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

## 5.6.7 Group Size

The majority of the focal follow surveys conducted consisted of small group sizes (Figure 5-55). Focal groups comprised of two or fewer individuals accounted for 202 of the 397 focal follow surveys conducted (51%). Groups comprised of two or fewer individuals accounted for 167 of the 321 surveys undertaken when vessels were not present within the 5 km exposure cut-off (52%), and for 40 of the 86 surveys that were undertaken when no vessels were present (47%). Note that because vessel exposure is limited to a defined spatial zone (i.e., <5 km from the focal group), many of the focal follow surveys collected data during both vessel exposure and non-exposure periods. Groups larger than ten narwhal were recorded during 19 of the focal follow surveys; four in 2020 (maximum group sizes of 11 [two follows] and 13 [two follows]), three in 2021 (maximum group sizes of 11, 12, and 18 individuals), and 12 in 2022 (maximum group sizes ranging between 11 [five follows] and 23 [two follows]). In the absence of vessels, the median value of maximal group size was two narwhal, and the mean group size was 3.5 narwhal (SD of 3.3 narwhal). When vessels were present, the median value of maximal group size was three narwhal, and the mean group size was 3.7 narwhal (SD of 3.6 narwhal). In 2022, recorded group sizes were larger than those recorded in both 2020 and 2021, with four focal follow surveys having group sizes >18 individuals. More groups of larger sizes (≥7 narwhal) were recorded in 2021 compared to 2020. These results should be interpreted with caution, however, due to non-random selection of focal groups (i.e., from 2021 onward, focus was placed on following mother-immature pairs) and due to the statistics above not being summarized by group type. The statistical analysis of group size below did incorporate a group type effect, and hence was not affected by the non-random selection of groups.

Mixed groups with immatures tended to be larger than other group types, followed by mixed groups without immatures, mother-immature pairs and adult-only groups (Figure 5-55). In the absence of vessels, mixed groups with immatures had an average maximum group size of 5.5 individuals, compared with 4.5 individuals for mixed groups without immatures, 2.3 individuals for mother-immature pairs, and 2.5 individuals for adult-only groups. Maximum group size of adult groups increased slightly with vessel distance (for example, increasing from 2.3 individuals at 1 to 2 km to 3.2 individuals at 4 to 5 km). In comparison, maximum group size of mixed groups without immatures decreased with distance from vessel, from 3.8 individuals at 1 to 2 km to 2.4 individuals at 4 to 5 km from vessels. Lone immature focal follow surveys were typically comprised of a single immature (36 of 39 focal follow surveys with lone immatures).

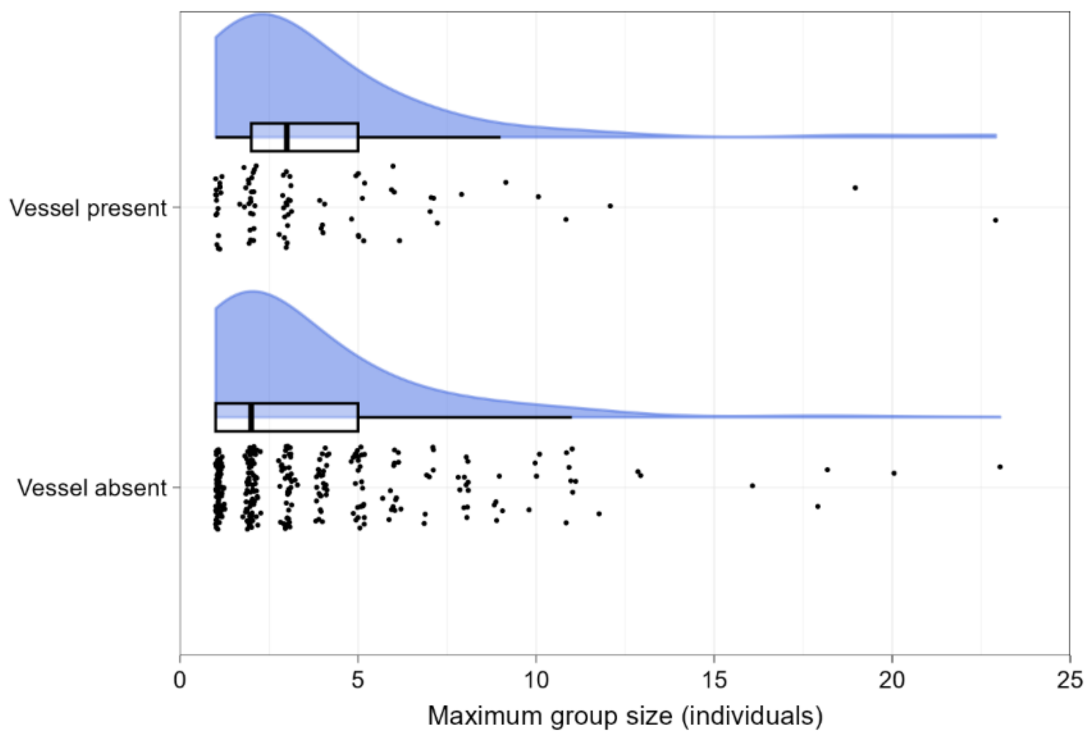



**Figure 5-54: Maximum narwhal group size during focal follow surveys relative to vessel presence, 2020-2022.**

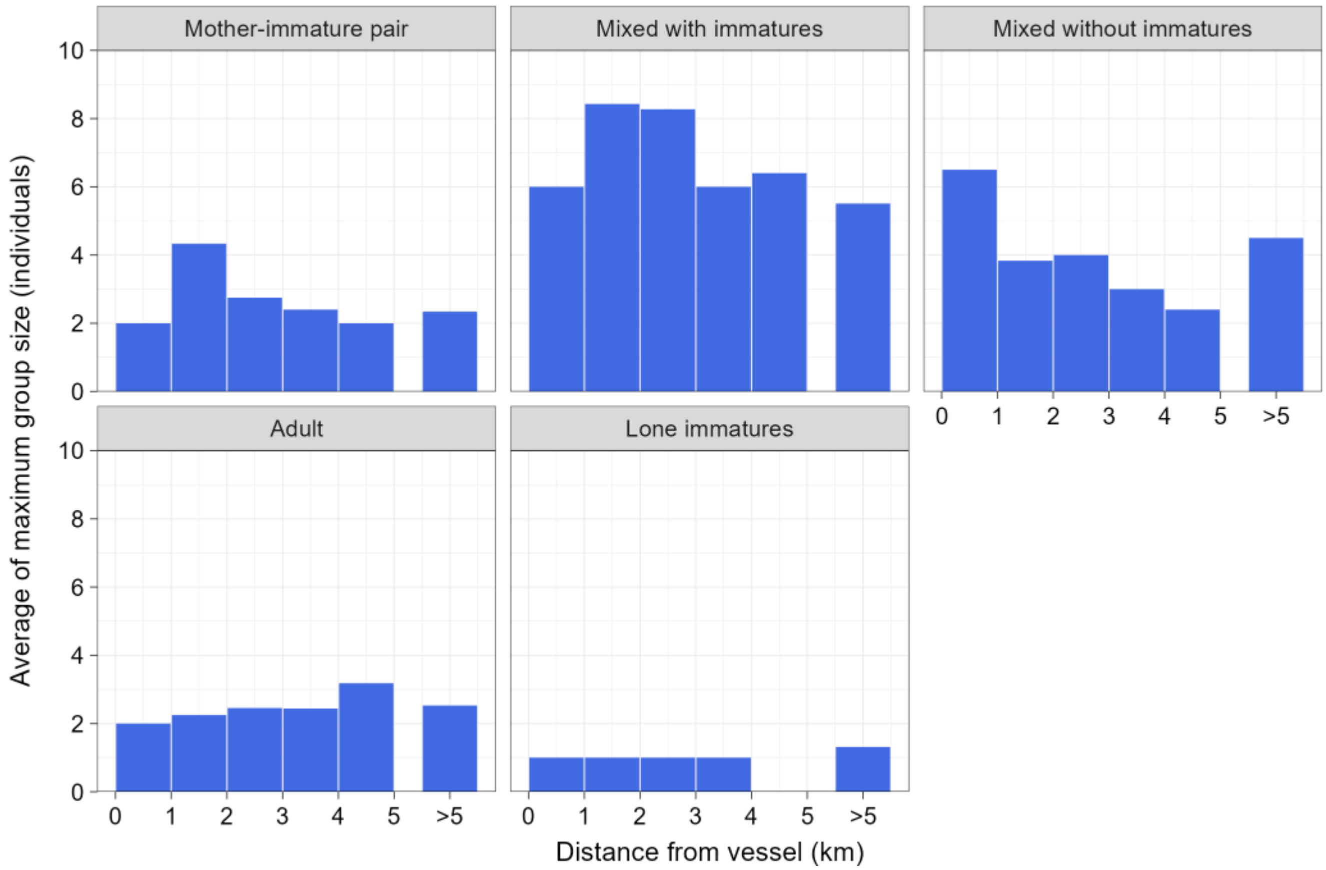



**Figure 5-55: Average of maximum narwhal group size during focal follow surveys relative to distance from vessel in 2020-2022, presented by group type.**

The analysis of group size was performed separately for each the following group types: mother-immature pairs, mixed groups with immatures, mixed groups without immatures, and adult groups (lone immatures were removed from analysis). The effect of distance from vessel was not significant for any of the groups ($P$=0.2 for mother-immature pairs, $P$=0.08 for mixed groups with immatures, $P$=0.4 for mixed groups without immatures, and $P$=0.9 for adult groups).

Observed effect sizes at close proximity were small (<18% absolute value) for all group types, except for mother-immature pairs with more than two narwhal, where the effect size was estimated to be 126% (Figure 5-56). This effect size corresponded to the increase in the group size of mother-immature pairs with more than two narwhal from 2.9 individuals when no vessels were present to 6.6 narwhal at 0.5 km from vessels. However, data on mother-immature pair groups comprised of more than two narwhal in the presence of vessels were limited to distances greater than 1.6 km, and the estimation of an effect size at a distance of 0.5 km from a vessel was based solely on modeling estimates. Effect size for mother-immature pairs with only two narwhal was small (2%), and for these groups, data were collected in close proximity to vessels (0.66 km). That is, vessel distance data were available for mother-immature groups with only two individuals, which accounted for most of the mother-immature pair data (67% of all mother-immature pair focal follow surveys).

In proximity to vessels, estimated spatial extents of effects differed between group types. For mother-immature pairs, effect sizes of vessel between 0.5 km and 4.0 km decreased between 126% and -2%, respectively, suggesting a potential large effect (i.e., >50% change in group size) may exist, with a spatial extent of less than 4 km from a vessel. While no data were available for mother-immature pairs larger than two narwhal at distances <1.6 km, the estimated effect size at 2 km from vessels was 44% (i.e., still in the medium range of effect sizes). This effect size corresponded to a change in group size from 2.9 narwhal when no vessels were present to 4.1 narwhal. For mixed groups with immatures, effect sizes of vessel between 0.5 km and 4.0 km decreased from 13.0% to 0.2%, respectively, after peaking at +36.0% at 2 km, suggesting a potential medium-sized effect (i.e., >25% change in group size) may exist, with a spatial extent of less than 4 km from a vessel. The +36% corresponded to a change in group size from 4.2 narwhal when no vessels were present to 5.7 narwhal. For mixed groups without immatures, effect sizes of vessel at 0.5 km and 1.0 km from the group were +14% and +9%, respectively, suggesting a potential small effect (i.e., >10% change in group size) may exist, with a spatial extent of less than 1 km from a vessel. Finally, for adult groups, effect sizes of vessel at 0.5 km and 1.0 km were 6% and 1%, respectively, suggesting no effect of vessel distance on group size. Overall, three of the four group types were estimated to have an increase in group size in proximity to vessels, with a spatial extent of less than 4 km from a vessel.

Statistical power was sufficient to detect large effect sizes (>50%) for adult groups, but not for other group types, where effect sizes of 200 to 300% were required for sufficient power (<0.2; APPENDIX A). While statistical power was low, so were most effect sizes in the analysis, indicating low, if any, effect of vessel distance on group sizes for mixed groups with immatures, mixed groups without immatures, and adult groups. Additional data collected for mother-immature pair groups in close proximity to vessels will be required to confirm effect size of this group type with group size larger than two.

**In summary, results suggest that mixed groups with immatures may associate in slightly larger groups when within 4 km of vessels. For the other group types, effect sizes were small and do not suggest a biologically significant effect. The large effect size associated with mother-immature pairs was not substantiated by data in close proximity to vessels. Therefore, further surveys are required to increase sample size, thereby allowing for a more robust analysis.**

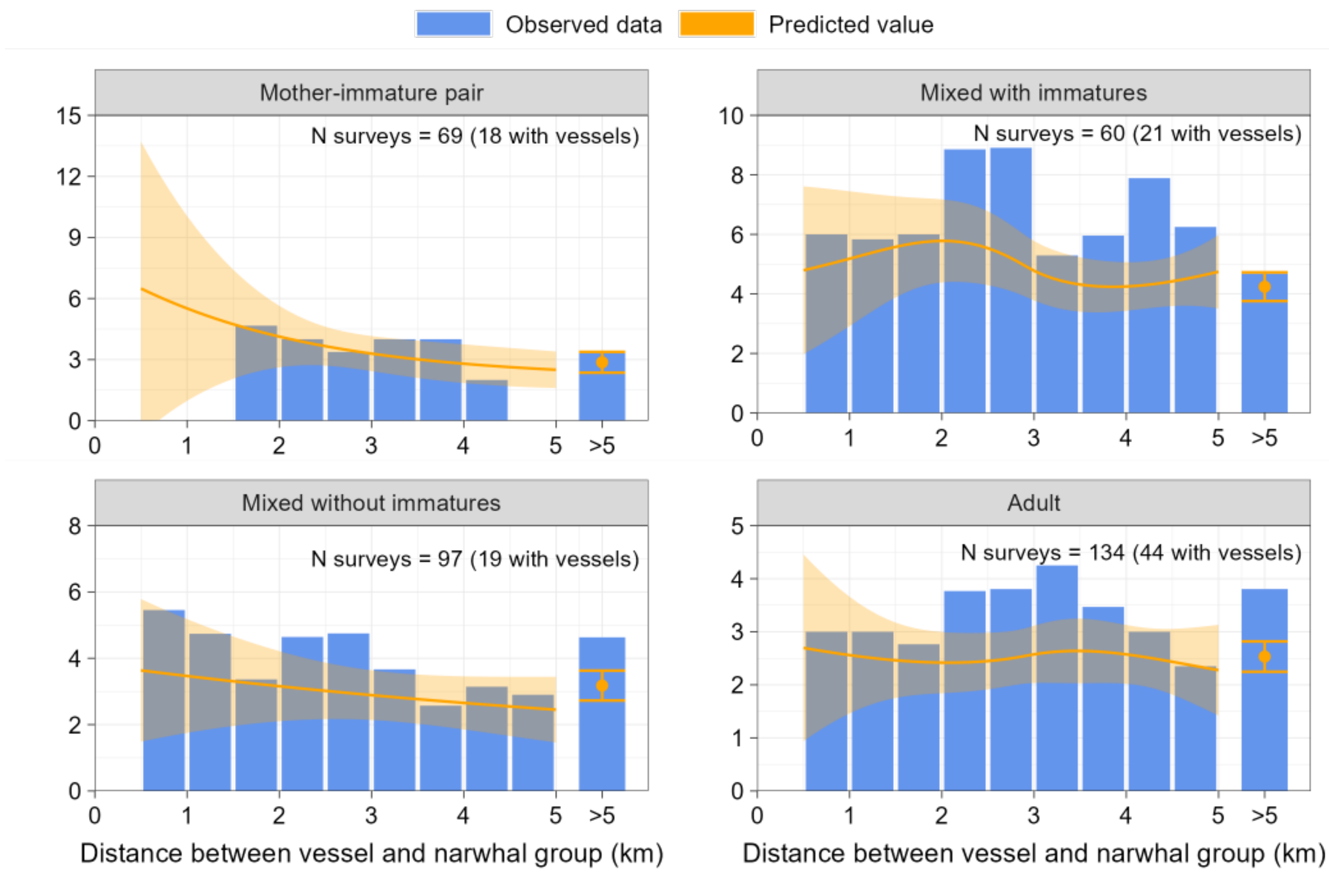



**Figure 5-56: Mean group size for groups larger than minimum size for the group type as a function of distance (rounded up to nearest 0.5 km value) from vessel, presented by group type.**

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

### 5.6.8 Group Travel Speed

Narwhal travel speed calculated for each time segment within the focal follow surveys ranged from 0 m/s to 2.5 m/s (mean of 0.9 m/s and SD of 0.5 m/s). For data visualization, these speeds were averaged within each survey, to provide a single travel speed for each focal follow. Mean speed calculated for individual focal follows ranged from 0.2 m/s to 2.1 m/s (mean of 1.0 m/s, SD = 0.4 m/s; Figure 5-57). When vessels were absent, mean travel speed of narwhal groups was 1.0 m/s (min = 0.3 m/s, max = 2.1 m/s, SD = 0.5). When vessels were present within 5 km from groups, mean travel speed was 1.0 m/s (min = 0.2, max = 1.9, SD = 0.4). Overall, of the assessed group types, travel speed was lowest for lone immatures and highest for adult groups (Figure 5-58).

For groups with immatures, mother-immature pairs travelled at an average speed of 0.98 m/s in the absence of vessels and at speeds ranging from 0.50 m/s to 1.20 m/s when vessels were present, depending on distance (Figure 5-58); for these groups, no data were available for distances closer than 1.6 km from vessels. Mixed groups with immatures travelled at an average speed of 1.00 m/s in the absence of vessels and at speeds ranging from 0.80 m/s to 1.10 m/s when vessels were present, depending on distance. Lone immatures travelled at an average speed of 0.90 m/s in the absence of vessels and at speeds ranging from 0.70 m/s to 1.00 m/s when vessels were present, depending on distance, however only limited data were available for lone immature travel speed in presence of vessels.

For groups without immatures, mixed groups without immatures travelled at an average speed of 0.90 m/s in the absence of vessels and at speeds ranging from 0.90 m/s to 1.30 m/s when vessels were present, depending on distance. Finally, adult-only groups travelled at an average speed of 1.20 m/s in the absence of vessels and at speeds ranging from 1.10 m/s to 1.30 m/s when vessels were present, depending on distance.

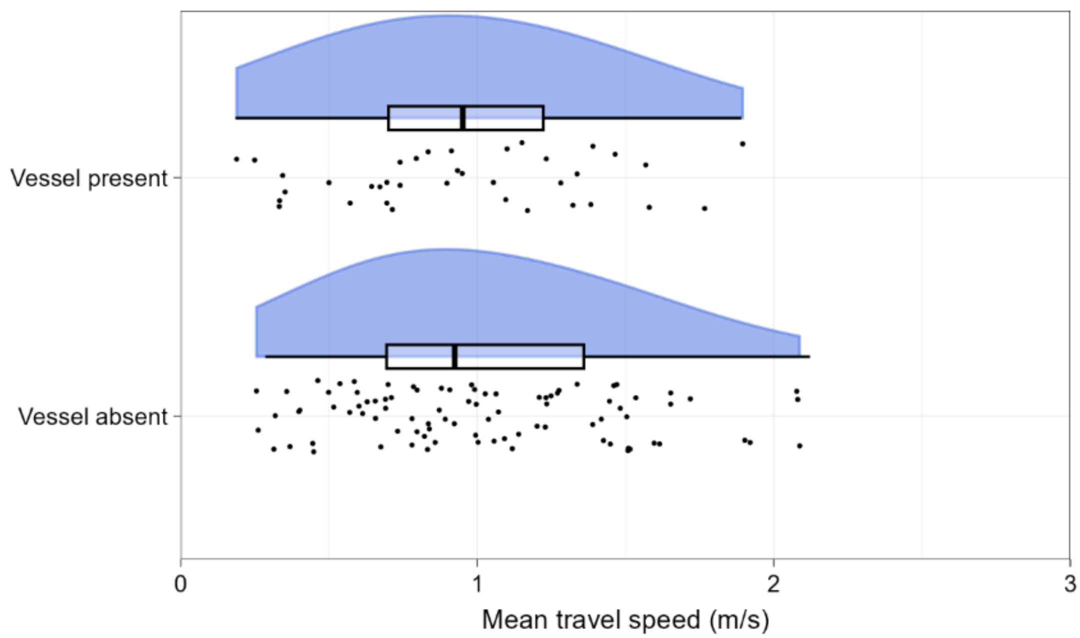



**Figure 5-57: Mean travel speed of narwhal focal groups relative to vessel presence, 2020-2022.**

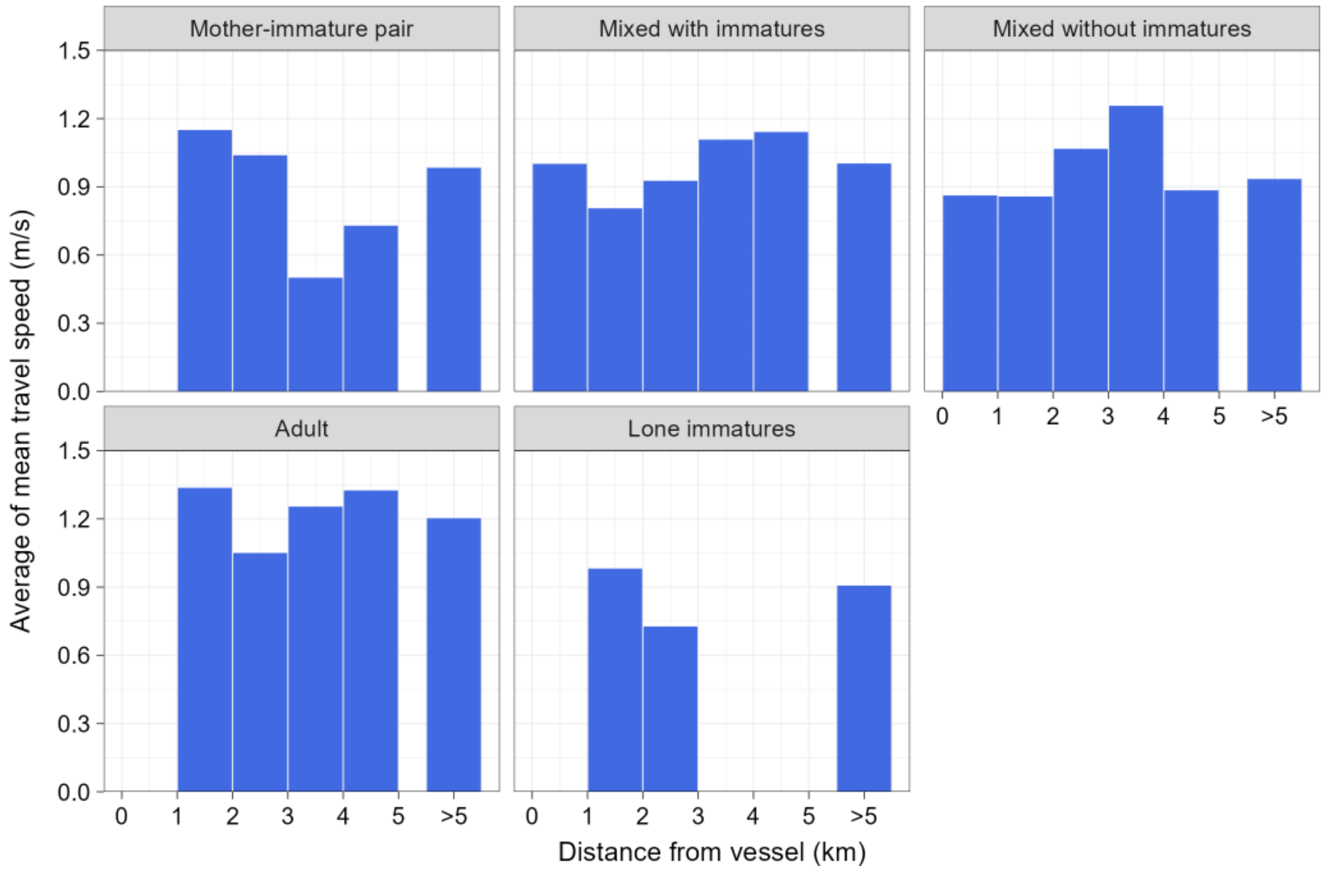



**Figure 5-58: Travel speed of narwhal focal groups relative to vessel presence, by group type, 2020-2022.**

In the analysis of group travel speed, the effect of group type was found to not be significant (*P*=0.14). The interaction between distance from vessel and group type, as well as the main effect of distance from vessel were not significant (*P*>0.7 for both). Observed effect sizes were small for all group types, ranging between -20% (for mixed groups with immatures) and -0.1% (for adult groups; Figure 5-59). Note that the effect size for mother-immature pairs was estimated as an extrapolation of the model, since no data were available for mother-immature groups at distances closer than 1.6 km.

At proximity to vessels, estimated effect sizes for mother-immature groups, mixed groups without immatures, and adult groups were all <10% at distances of 0.5 to 4.0 km, suggesting no effect of distance from vessel on group travel speed. For mixed groups with immatures, effect sizes at 0.5 km, 1.0 km, 2.0 km, and 3.0 km from the group were -20%, -17%, -10%, and -4%, respectively. These effect sizes suggest a potential small effect (i.e., <25% change in group travel speed – as detailed in Section 4.3.2.1) may exist, with a spatial extent of less than 3 km from a vessel. Overall, given the <10% effect size for three group types and the small effect size for the remaining group type, the analysis suggests that vessel traffic does not affect group travel speed.

The statistical power to estimate the observed effect was sufficient (≥0.8) to detect effect sizes of ±27% (Appendix A). This effect size corresponded to a 27% increase or decrease in travel speed relative to values when no vessels were present within 5 km from a group – 1.0 m/s for mother-immature pairs and mixed groups with immatures, 0.9 m/s for mixed groups without immatures, and 1.1 for adult groups.

**In summary, the results indicate that there was no statistically significant change in narwhal travel speed in response to vessel traffic. As discussed in Section 3.0, a change in energy expenditure (e.g., change in travel speed) by narwhal would be consistent with a moderate severity behavioural response, though no such change was evident. The lack of response was supportive of impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.**

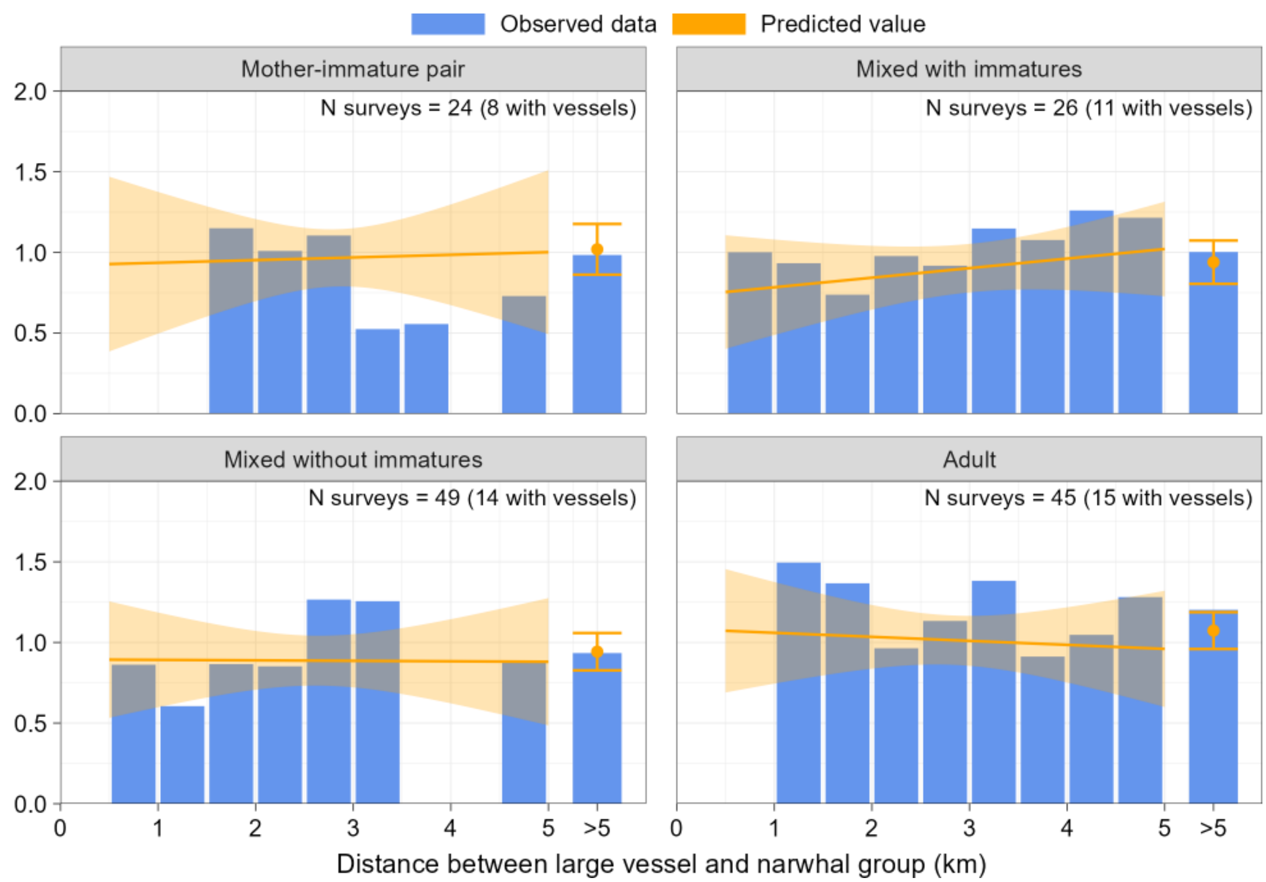



**Figure 5-59: Mean group travel speed as a function of distance (rounded up to nearest 0.5 km value) from vessel, plotted by group type.**

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

## 5.7 General Observations

Narwhal were frequently observed south of the SSA in the general vicinity of Koluktoo Bay and near the entrance to Assomption Harbour. Similar distribution of narwhal in this area has been reported during aerial surveys (Thomas et al. 2015, 2016; Golder 2018b, 2020c, 2021a, 2022a) affirming the importance of Koluktoo Bay as a summering ground for narwhal during the open-water season.

The majority of narwhal observed over the eight years of data collection were engaged in travelling behaviour. Other behaviours observed by narwhal included nursing, rubbing, tusking, foraging, socializing and mating. In all years of the Program, narwhal calves have been commonly observed, with evidence of nursing behaviour recorded in 2015 (two occasions), 2016 (four occasions), 2017 (two occasions) and 2019 (seven occasions). With the introduction of the UAV Program in 2020, nursing behaviour was observed during 12 focal follow surveys in 2020, 12 focal follow surveys in 2021, and six focal follow surveys in 2022. On 11 August 2016, the birth of a narwhal calf off Bruce Head was observed. Collectively, these qualitative observations lend further support to the importance of southern Milne Inlet as an important area for calf rearing, and that these functions are continuing year-over-year in the presence of vessels.

*Ad lib* observations made throughout the multi-year program suggest that the response of narwhal to ore carrier traffic was variable, ranging from ‘no obvious response’ in which animals remained in close proximity to ore carriers as they transited through the SSA, to temporary and localized displacement and related changes in behaviour.

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

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

### 5.7.1 Other Cetacean Species

Several other cetacean species were observed in the SSA during the 2022 field season at Bruce Head (Table 5-9). Of note, 120 beluga (*Delphinapterus leucas*) were present in the SSA on 29 July 2022 when the field team first arrived at Bruce Head and prior to the start of shipping operations that summer. Beluga were frequently observed in small groups throughout the SSA and the BSA between 1 August and 16 August 2022, with one larger group comprised of ten individuals observed in the SSA on 6 August 2022.

Bowhead whale (*Balaena mysticetus*) were observed sporadically in the study area, with five sightings documented throughout the 2022 field season. While killer whale (*Orcinus orca*) have been observed in the study area at least once during every prior field season, there were no killer whales observed in the study area in 2022.

In addition to the typically observed ringed seals and bearded seals, a single juvenile walrus (*Odobenus rosmarus*) was observed on 12 August 2022.

**Table 5-9: Other cetacean species observed in the SSA during the 2022 Bruce Head Program**

| Species | Date of Record | Number of Individuals |
|---|---|---|
| Beluga whale (*Delphinapterus leucas*) | 29 July 2022 | 120 |
| | 1 August 2022 | 2 |
| | 2 August 2022 | 2 |
| | 6 August 2022 | 10 |
| | 9 August 2022 | 3 |
| | 10 August 2022 | 2 |
| | 11 August 2022 | 1 |
| | 15 August 2022 | 1 |
| | 16 August 2022 | 1 |
| Bowhead whale (*Balaena mysticetes*) | 7 August 2022 | 1 |
| | 9 August 2022 | 1 |
| | 10 August 2022 | 1 |
| | 17 August 2022 | 1 |
| | 20 August 2022 | 1 |

# 6.0 DISCUSSION

## 6.1 Relative Abundance and Distribution – Stratified Study Area

The relative abundance of narwhal (total number of narwhal corrected for survey effort) in the SSA was higher in 2022 (84.9) than in 2020 and 2021 (47.5 and 29.4, respectively) and approaching the 2015 baseline level (98.2). However, narwhal relative abundance in 2022 was lower than the 2014 baseline level (131.4) and lower than levels observed in 2016 (178.0), 2017 (121.8) and 2019 (127.2). These findings indicate that narwhal numbers in the RSA appear to be increasing from the low numbers observed in 2020/2021 but have not yet reached levels observed during the initial shipping years (2016, 2017) or those observed in 2019.

Over the combined 2014-2022 monitoring period, the second highest relative abundance estimate at Bruce Head was recorded in 2019, when shipping levels in the RSA were the highest to date and Project icebreaking occurred during the early shoulder season for the third consecutive year (2018-2020). In contrast, the lowest relative abundance estimates at Bruce Head were recorded in 2020 and 2021, when shipping levels were similar to 2016. Icebreaking operations took place during the 2020 early shoulder season but not in 2021. These results suggest that the annual volume of Project shipping in the RSA is not a reliable predictor of narwhal relative abundance at Bruce Head in the same year. The 2022 results support the theory that some degree of natural exchange likely occurs between the two putative narwhal summer stock areas and, while shipping cannot be ruled out as a contributing factor, that the regional distribution and movement of narwhal off North Baffin Island during the summer is likely influenced by other external factors (e.g., local ice conditions, water temperature, prey availability, predation pressure, etc.

In comparing these findings with the 2022 aerial survey results obtained by WSP on 17 and 21 August, the narwhal abundance estimate for Eclipse Sound stock alone was 4,592 narwhal (CV = 0.10, 95% CI of 3,754–5,617, WSP 2023a) which was statistically higher than the 2021 estimate of 2,595 (CV = 0.33, 95% CI of 1,369–4,919; Golder 2022a) (t-test = 2.02, p = 0.049). Based on aerial surveys conducted on 17 and 18 August 2022, the combined abundance estimate for the combined Eclipse Sound and Admiralty Inlet stocks was 46,408 narwhal (CV = 0.13, 95% CI of 36,129–59,611, WSP 2023a), which was statistically lower than the 2021 combined stock estimate of 75,177 (CV = 0.08, 95% CI of 63,795–88,590) (t-test = 3.317, p = 0.001), but not statistically different than the abundance calculated during the previous DFO survey conducted in August 2013 (45,532 narwhal, CV = 0.33, 95% CI of 22,440–92,384) (t-test = 0.054, p = 0.957), the 2019 Baffinland estimate of 38,677 (CV = 0.11, 95% CI of 31,155–48,015) (t-test = 1.011, p = 0.316), or the 2020 Baffinland estimate of 36,044 (CV = 0.12, 95% CI of 28,267–45,961) (t-test = 1.390, p = 0.170).

If it was determined that the changes in narwhal numbers in the RSA were a result of Project-related activities, this would be consistent with a high severity response and would be considered a significant alteration of natural behavioural patterns of narwhal in the RSA and/or disruption to their daily routine (see Section 3.0) (Southall et al. 2021). However, findings from Bruce Head were consistent with results obtained via aerial surveys conducted in 2022, suggesting that narwhal numbers in the RSA (i.e., Eclipse Sound summer stock area) appear to be increasing from the low numbers observed in 2021.

Other Considerations:

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

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

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

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

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

## 6.2 Density

Based on statistical analyses of the RAD data, the effect of 'distance from vessel' was shown to have a significant effect of narwhal density, while 'vessel travel direction' did not. 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), with effect sizes for northbound vessels that suggest that there may be a moderate biologically significant effect up to a distance of 2 km from northbound vessels. Once a northbound vessel passed through the SSA, heading away from the strata, narwhal density was shown to gradually increase as the vessel moved away. The same pattern was observed for a southbound vessel moving away from the substrata, although the observed increase was smaller, mirroring the smaller decrease in density when a southbound vessel approached the substrata, compared to a northbound vessel. This pattern could represent a refractory period during which narwhal reoccupy the SSA after their initial avoidance of the vessel.

The observed effect was equivalent to a maximum period of 14 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). During the Program (31 July to 23 Aug 2022), there were approximately two vessel transits per day in the SSA (56 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 min. These findings were consistent with previous years' findings and with behavioural results from the narwhal tagging study (Golder 2020a), which indicated that narwhal density in the SSA was influenced by vessel traffic, but limited to close distances (i.e., within 2 km of a northbound vessel). Localized avoidance of the sound source (i.e., the vessel) by narwhal was consistent with a moderate severity behavioural response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., 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 were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal are anticipated to be limited to temporary, localized avoidance behaviour.

## 6.3 Group Composition - Behavioural Study Area

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

Two vital rates previously assessed in Booth et al. (2020) have been shown to be sensitive to changes in fertility and calf survival, including the ratio of calves/pups to mature females and the proportion of immature animals in a population. Based on PCoD (population consequences of disturbance) models, the study confirmed that demographic characteristics such as the proportion of immature animals in a population were appropriate indicators of population decline (Booth et al. 2020). This conclusion has been supported by other studies that have investigated the potential effects of disturbance on reproductive success, where disturbance resulted in a large reduction in the proportion of calves reaching weaning age in long-finned pilot whales (*Globicephala melas*;

Hin et al. 2019) and Blaineville's beaked whales (*Mesoplodon densirostris*; Moretti et al. 2019). These studies suggest that a decline in the proportion of immatures was an appropriate early warning indicator (EWI) for identification of population decline in the Eclipse Sound narwhal stock. As discussed in Baffinland (2023), early detection of a decline in the proportion of immatures, combined with detection of prolonged adverse behavioural responses by narwhal to vessel traffic, would suggest that Project-related shipping may be a contributor to the observed population-level effect on narwhal.

Findings from the combined multi-year dataset indicated that the relative proportion of immature narwhal observed in the BSA in 2022 (0.105) was significantly lower than pre-shipping values in 2014 and 2015 (0.152 and 0.167, respectively), representing a 32% decrease from the baseline condition. This was similar to 2021 results, in which the relative proportion of immature narwhal observed in the BSA in 2021 (0.102) was significantly lower than the baseline condition. The 2021 and 2022 results indicated an exceedance of the Moderate Risk threshold for this specific indicator, as per the Marine Mammal TARP (Baffinland 2021c), and that the Risk Status / Threshold trigger has now been observed in at least two consecutive monitoring years. The pre-defined response for exceedance of a moderate risk indictor includes the following: 1) investigate trend over time and consider any uncertainties (i.e., changes in operational processes, potential sources, confounding influences) in a formal Response Plan; and 2) initiate component specific targeted studies as part of the response planning. Based on prior monitoring results for narwhal, Baffinland proactively developed and implemented a Narwhal Adaptive Management Response Plan (Baffinland 2022), which included a follow-up investigation on the EWI through EWI analysis of 2020-2022 aerial survey data using dedicated 1000 ft. survey data. Findings from the EWI analysis of 2022 aerial survey data indicated that the proportion of immature narwhal in the Eclipse Sound stock (0.124) was not significantly different from 2020 (0.117) or 2021 (0.128) estimates (P=0.3), though this dataset was associated with high variability and low sample sizes, resulting in high uncertainty of the EWI estimates (WSP 2023b). The 2020, 2021, and 2022 proportions of immature narwhal fell within the range of the baseline condition in 2014 and 2015 (0.150 and 0.110, respectively) (WSP 2023b).

In summary, while the EWI data collected at Bruce Head suggested a localized change in narwhal group composition, the equivalent EWI analysis derived from the spatially broader aerial survey dataset provided no indication that the proportion of immature narwhal had declined in the broader RSA since the 2014/2015 baseline condition. Ongoing monitoring through both programs is therefore recommended.

## 6.4 Behaviour - UAV-based Focal Follow Surveys

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

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

### 6.4.1 Primary Behaviour

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

Findings based on the three-year UAV dataset provide possible, though conflicting, support that narwhal groups may change the proportion of time that they engage in critical activities when in the immediate presence of vessels. Specifically, group types with immatures (i.e., mother-immature pairs and mixed groups with immatures) and adult groups were shown to decrease the proportion of time that they engage in resting, milling, or social behaviour when within 5 km and 4 km of vessels, respectively. Conversely, mixed groups without immatures were shown to increase the proportion of time that they engage in such behaviours when within 3 km of vessels. While these findings suggest that vessel traffic may have some effect on the ability of narwhal to carry out these critical behaviours, the conflicting trends among group types suggest that the results should be interpreted with caution. Additional monitoring is recommended to increase overall sample size of the corresponding dataset.

As discussed in Section 3.0, a change in behavioural state (e.g., change in primary behaviour) by narwhal would be consistent with a low to moderate severity behavioural response, depending on the duration for which the response was sustained. Given the temporary and uncertain nature of the effect observed (i.e., conflicting trends in proportion of time engaged in resting, milling or social behaviour among group types, all within 3 to 5 km of vessels), combined with the lack of “flight” behaviour observed by narwhal (i.e., no increase in travel speed observed; see section 5.6.8), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the broader RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 21 to 35 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

### 6.4.2 Unique Behaviours

Unique behaviours that would not be expected under stressful conditions, such as nursing, social rubbing, sexual displays, and rolling (either vertically in the water column or horizontally) were recorded throughout many of the focal follow surveys conducted between 2020 and 2022, both in the presence and in the absence of vessel traffic. Findings based on the combined multi-year dataset suggest that unique behaviour displays by narwhal tended to occur less frequently by all narwhal group types in close proximity (≤2 km) to transiting vessels, although the observed decrease was not shown to be significant. The lack of significance may have been associated with the low sample sizes and high data variability at close range (<2 km) to vessels. The results suggest that social behaviours such as rubbing, rolling, nursing, and sexual displays may potentially be disrupted in close proximity (<2 km) to vessel traffic, though this finding is based on a very small sample size at close range to vessels. Additional monitoring is therefore recommended to increase overall sample size and the robustness of the corresponding analysis.

Several anecdotal observations of narwhal unique behaviours are noteworthy to discuss as being novel to the 2022 Program. Of note, there was one event (FFID 47) in which two male narwhal of similar size and tusk length were observed slowly circling one another, interspersed with sudden and directed movement toward one another, and then deviating from their course immediately before colliding with one another, at which point they began rubbing. The biological significance of this behaviour and the relationship between the two males is unknown, but was likely social in nature. During another survey (FFID 73), a tusked adult was observed foraging for small fish at the water’s surface, using its tusk to swipe and stun the prey before it appeared to consume it. Sexual displays were observed during three separate surveys in 2022, all between a tusked adult and a juvenile. In one of the surveys, the juvenile had a tusk (FFID 124), and in two surveys the juvenile had no tusk (FFID 62 and 119).

On 12 August 2022, three focal follow surveys were conducted (FFID 103, 104, 107) in which novel and unusual behaviour was observed, with a small group of adult males appearing to try to separate a calf from its presumed mother. A group of two adult females with one calf were first observed around 13:30, after which they were joined by four males that appeared to chase them and separate the calf from the adult females (FFID 103 and 104). Successful separation finally occurred when one male forced himself between the presumed mother and the calf, at which point the calf was kept very close to one or more of the males, and the male would frequently swim in front of the calf to coerce its movement. Despite this seemingly aggressive behaviour, the event also included occasions when the males appeared to socially rub against the calf. The mother and the other female were intermittently observed nearby, moving quickly, often circling the calf and the male(s), but keeping their distance from the male-dominated group. There were several instances where the calf attempted to escape and re-join the presumed mother, though the males consistently resumed their chase until the calf was again separated. At 16:30 (during FFID 107), the group was resighted and the same behaviour was again observed, almost three hours after the behaviour was initially observed. It is unclear if the harassment of the mother calf pair continued throughout the time between focal follow surveys.

As discussed in Section 3.0, a decrease in the display of unique behaviours by narwhal would be consistent with a low to moderate severity behavioural response, depending on the duration for which the response was sustained. Given the temporary nature of the effect (i.e., unique behaviours displayed less frequently within 2 km of vessels), this finding was not anticipated to be a biologically significant behavioural response and would not be expected to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 14 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

### 6.4.3 Association of Immatures with Presumed Mother

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

Like many other odontocete species, it should be noted that narwhal appear to exhibit alloparental care, meaning that dependent young observed at the surface are often accompanied by another non-parent whale during foraging excursions by their mother. This behaviour has been directly observed during multiple focal follow surveys conducted near Bruce Head (Golder 2022b). Therefore, all associations discussed herein are between immatures and their *presumed* mother.

#### *6.4.3.1 Presence of Nursing Behaviour*

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

Findings based on the combined multi-year UAV dataset suggest that immature narwhal engaged in nursing less often when in the presence of vessel traffic (vessel within 5 km of the focal group); although modelling results indicated that this effect was not significant despite an effect size of -69%. The lack of a significant effect may have been associated with the low sample size and high data variability available at close ranges to the vessel. The model was based on limited and unbalanced data; specifically, only four of the 28 surveys involving active nursing occurred in the presence of vessels (<5 km). As a result, the above findings should be interpreted with caution. Additional monitoring is recommended to increase overall sample size and the robustness of the corresponding analysis.

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

FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

#### 6.4.3.2 Relative and Distal Positioning of Immatures

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

Findings based on the combined multi-year UAV dataset suggest that immature narwhal may change their positional association with their mother when in close proximity to vessel traffic, for both mother-immature pairs and for mixed groups with immatures. That is, immature narwhal tended to favour the underside of their mother over other relative positions when within 1 km of vessels (though this finding is based on a small effect size) and they associated more tightly with their mother when within 5 km of vessels. The full spatial extent of the latter finding may be a modelling artefact and the effect may only extend up to 3 km from a vessel. Further surveys are therefore recommended to increase sample size, thereby allowing for a more robust analysis**.**

As discussed in Section 3.0, a change in group cohesion between a mother and its dependent young would be consistent with a moderate severity response. However, it is important to note that immatures, especially calves, are afforded significant locomotive advantages when swimming tightly associated with their mothers (Noren 2008). This suggests that there is a natural incentive to remain closely associated with one another as a looser association may result in higher energetic costs for the immature. Therefore, the finding related to distal association (i.e., immature narwhal associate more tightly with their mother within 3 to 5 km of vessels) should be interpreted with caution as it may not signify a perceived threat by narwhal but may simply be the result of being more energetically advantageous. In regard to the finding that immature narwhal tended to favour the underside of their mother when within 1 km of a vessel, the temporary nature of the effect suggests that it was likely not biologically significant. That is, the response was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted responses were shown to be short in duration, with a change in distal association equivalent to a maximum period of 21 to 35 min per vessel transit and a change in relative association equivalent to a maximum period of 7 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel; exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that ship noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

### 6.4.4 Group Formation

Findings based on the combined multi-year UAV dataset suggest that narwhal may alter their group formation when in close proximity to vessel traffic, with the majority of group types decreasing the proportion of time that they spent in parallel formation when within 1 to 3 km of vessels. Conversely, mother-immature pairs were the only group type to increase the proportion of time that they spent in parallel formation when within 2 km of vessels, however this finding was based on a small effect size and should therefore be interpreted with caution. These findings together were consistent with previous studies that demonstrated certain cetacean species respond to disturbance by changing their group formation (Irvine et al. 1981; Au and Perryman 1982) but were inconsistent with shore-based results obtained from previous years at Bruce Head, in which narwhal did not significantly alter their group formation in response to vessel traffic (Golder 2022b). Consistent with shore-based findings from previous years, narwhal groups were most often observed in parallel formation under both vessel presence and vessel absence scenarios.

In general, narwhal groups frequently shifted their formations between parallel, linear, and cluster throughout a given focal follow survey, both in the presence and in the absence of vessels. The biological purpose of these formations in narwhal groups is not well understood and there remains uncertainty regarding how these formations relate to internal group cohesion of narwhal specifically. Therefore, further monitoring of narwhal group formation may contribute to a better understanding of the context and function (if any) of narwhal aggregations and whether a given formation is indicative of a potential response to a perceived threat (i.e., a transiting vessel).

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

### 6.4.5 Group Spread

Cetaceans have been shown to form tight groups in situations of perceived threat or when surprised (Johnson and Norris 1986; Cosens and Dueck 1988, 1991, 1993; Finley et al. 1990; Nowacek et al. 2001; Visser et al. 2016; Golder 2021a), potentially as a mechanism to provide increased protection for individuals within the group. Cetaceans have also been shown to form tight pods in the presence of vessels (Irvine et al. 1981; Au and Perryman 1982; Finley et al. 1990; Blane and Jaakson 1994; Bejder et al. 1999, 2006a; Nowacek et al. 2001) and when exposed to navy sonar activity (Visser et al. 2016). There is also evidence that cetacean response to perceived threats such as vessel noise, predation, and hunting, may depend on whether calves are present. For example, dolphin groups containing calves have been found to alter their space use patterns by forming tighter groups, with mothers and calves centrally located (Johnson and Norris 1986). Conversely, Guerra et al. (2014) studied the effects of tour boats on group structure of bottlenose dolphins in Doubtful Sound, New Zealand and found that dolphin groups containing mother-calf pairs increased their distance from the rest of the group in the presence of tour boats and associated noise. Though these accounts were not considered avoidance responses directly, it was acknowledged that disruptions to normal behaviour can lead to increased energetic challenges with the potential for population level consequences, particularly to small or vulnerable populations (Lusseau and Bejdger 2007).

In the eastern Canadian High Arctic, narwhal have been observed forming tight groups in response to killer whales (Steltner et al. 1984; Laidre et al. 2006; Breed et al. 2017; Golder 2021a) and vessel traffic (Cosens and Dueck 1988, 1993; Finley et al. 1990). These results were in agreement with other studies that suggest cetaceans form tighter groups in situations of perceived threat (e.g., as an anti-predator response). Finley et al. (1990) conducted aerial surveys of beluga and narwhal and found that the two species reacted very differently to icebreaking activities; with beluga demonstrating herd formation and a loss of pod integrity while narwhal huddled together often engaging in physical contact. These differences in responses fit with Inuit descriptions of beluga and narwhal behaviour in response to killer whales (Gonzales 2001). During aerial surveys conducted by Golder in 2020, a large group of killer whales (60+ individuals) was observed herding 150 to 200 narwhal into Fairweather Bay near Milne Inlet (Golder 2021a). The killer whales travelled quickly into the bay swimming abreast of each other in two lines as the narwhal swam in tightly associated groups and clustered near the shoreline. As the killer whales neared the narwhal, the killer whales dispersed into smaller groups and were observed killing two narwhal calves and two adults, including an adult male that was observed floating motionless near shore and one probable adult female, potentially the mother to one of the killed calves (Golder 2021a).

Findings based on the combined multi-year UAV dataset suggest that narwhal did not congregate in more tightly associated groups but actually loosened their association with one another when in close proximity (≤ 3 km) to vessel traffic, although modelling results indicated that this effect was not significant despite a large effect size. This finding was true for all group types and was contrary to shore-based results obtained from previous years at Bruce Head, in which narwhal were shown to congregate into tightly associated groups when in close proximity (≤ 2 km) to vessels (Golder 2022b). One theory for why the present UAV results may differ from the previously obtained shore-based results is that narwhal in the BSA were typically observed travelling either toward or away from Koluktoo Bay and were geographically constrained by the Bruce Head peninsula, causing them to associate more tightly with one another, while narwhal observed throughout the broader SSA did not typically appear to be as direction-oriented and were not geographically constrained by land masses. Therefore, the differing space use patterns by narwhal observed in close proximity to vessels may be influenced by where in the inlet the group is located during land-based (BSA) or UAV-based (broader SSA) surveys.

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

### 6.4.6 Group Size

Cetaceans have been shown to change group size in response to predators (Mattson et al. 2005; de Stephanis 2014; Visser et al. 2016) and anthropogenic disturbance such as vessels and navy sonar (Curé et al. 2012; Curé et al. 2016). For example, in the presence of tourism and shipping vessels, bottlenose dolphins (*Tursiops truncatus*) have been found to reduce their group size, spreading out into multiple smaller groups (Arcangeli and

Crosti 2009; Pennacchi 2013). Conversely, cetaceans have also been shown to increase their group size in the presence of potential threats. In one study by Mattson et al. (2005), bottlenose dolphins were shown to occur in larger group sizes when in the presence of vessels, including multiple different vessel types (i.e., dolphin tour boats, motorboats, shrimp boats). In another study, long-finned pilot whales (*Globicephala melas*) were shown to form larger groups in response to three types of disturbance (i.e., killer whale sound playbacks, tagging, and naval sonar), with the most significant increase in group size occurring during and after sonar playback exposure, followed by satellite tagging and killer whale sound playbacks (Visser et al. 2016). The pilot whales also appeared to be attracted to the source and actively approached it. As pilot whales are known to use social defence strategies when detecting and responding to a threat (Curé et al. 2012; de Stephanis 2014), it is plausible that this behaviour may be a form of social defence through mobbing (Visser et al. 2016). Based on these findings, it is evident that cetacean species do not all respond to perceived threats in the same way. One example of species-specific strategies to altering group size is evident in Finley et al. (1990), in which responses were compared of narwhal and beluga to ice-breaking ships in the eastern Canadian Arctic over a three-year period. Of note, beluga were observed forming larger herds and fleeing while narwhal did not form larger herds and tended to freeze (Finley et al. 1990).

Findings based on the combined multi-year UAV dataset suggest that mixed groups with immatures were the only group type that may associate in slightly larger groups when within 4 km of vessels. For the other group types, effect sizes were small and did not suggest a biologically significant effect. The large effect size associated with mother-immature pairs was not substantiated by data in close proximity to vessels. This finding was loosely consistent with shore-based results obtained from previous years at Bruce Head, in which narwhal were shown to associate in marginally larger groups when in close proximity (≤ 1 km) to vessels (Golder 2022b), 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 this year and during previous years (<1 individual) to support this theory. The small increase in narwhal group size observed previously in close proximity to vessels was 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 cohesion (e.g., change in group size) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect (i.e., increase in group size for mixed groups with immatures when within 4 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 28 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

### 6.4.7 Group Travel Speed

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

Findings based on the combined multi-year UAV dataset suggest that narwhal did not significantly alter their travel speed in response to vessel traffic, regardless of group type. While many studies have demonstrated an increase in travel speed by cetacean groups in response to vessel disturbance (Kruse 1991; Nowacek et al. 2001; Williams et al., 2002; Ribeiro et al. 2005; Bejder et al. 2006a; Laidre et al. 2006; Miller et al. 2008; Matsuda et al., 2011; Erbe et al. 2019), narwhal specifically have shown no increase in travel speed when in the presence of ice-breaking vessels, but have been reported to instead demonstrate a “freeze” response (Finley et al. (1990). This latter finding has been supported by analysis of movement data obtained through the narwhal tagging study (Golder 2020a), in which no significant increase in travel was detected for narwhal in the presence of vessels compared to periods when no vessels were present. As Milne Inlet has seen the regular transits of ore-carrier traffic through the area since 2015, it is plausible that narwhal did not respond to vessel traffic by fleeing as they may be experiencing some level of habituation.

As discussed in Section 3.0, a change in energy expenditure (e.g., change in travel speed) by narwhal would be consistent with a moderate severity behavioural response, though no such change was evident. The lack of response was supportive of impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

## 6.5 General Observations

The use of UAV surveys at Bruce Head in 2022 yielded further insights into narwhal group composition and behaviour, building on the data collected in 2020 and 2021. Similar to previous years, evidence of nursing was readily observed, and immatures were often seen on their own or with non-parental associations. The UAV team was able to increase the number of focal follow surveys conducted, particularly in the presence of shipping, with more surveys completed in the presence of vessel traffic during the present year than in 2020 and 2021 combined. The relatively good weather and increased presence of narwhal in the inlet contributed to the UAV team’s ability to increase the number of surveys conducted in the presence of vessels. The present sampling year was also characterized by reduced hunting and killer whale activity in the inlet relative to 2020 and 2021, allowing for an increased number of focal follow surveys to be carried out in the absence of other confounding stimuli. Despite this increased effort, additional focal follow surveys in the presence of vessels are recommended to increase the sample size for effective quantitative analysis.

# 7.0 SUMMARY OF KEY FINDINGS

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

## Relative Abundance and Distribution

- Interannual variation in relative abundance: The relative abundance of narwhal (total number of narwhal corrected for survey effort) in the Stratified Study Area (SSA) was higher in 2022 (84.9) than in 2020 and 2021 (47.5 and 29.4, respectively) and approaching the 2015 baseline level (first year of operations; 98.2). However, narwhal relative abundance in 2022 (84.9) was lower than the 2014 baseline level (131.4) and lower than levels observed in 2016 (178.0), 2017 (121.8) and 2019 (127.2). These findings indicate that narwhal numbers in the Regional Study Area (RSA) appear to be increasing from the numbers observed in 2020/2021 but have not yet reached levels observed during the initial shipping years (2016, 2017) or those observed in 2019. Over the combined 2014 to 2022 monitoring period, the second highest relative abundance estimate at Bruce Head was observed in 2019, when shipping was highest and Project icebreaking occurred during the early shoulder season for the third consecutive year (2018 to 2020). In contrast, the lowest relative abundance estimates at Bruce Head were recorded in 2020 and 2021, when shipping levels were similar to 2016. Icebreaking operations took place during the 2020 early shoulder season but no icebreaking took place in the RSA during 2021. These results suggest that the annual volume of Project shipping in the RSA is not a reliable predictor of narwhal relative abundance at Bruce Head in the same year. The 2022 results support the theory that some degree of natural exchange likely occurs between the two presumed narwhal summer stock areas and, while shipping cannot be ruled out as a contributing factor, that the regional distribution and movement of narwhal off North Baffin Island during the summer was likely influenced by other external factors (e.g., local ice conditions, water temperature, prey availability, predation pressure, etc.).

- Density: Vessel exposure was shown to result in a statistically significant temporary decrease in narwhal density in the SSA compared to when no vessels were present; this decrease was limited to when narwhal were in close proximity (≤2 km) to approaching northbound vessels, after which narwhal densities were shown to increase as northbound vessels transited away from the SSA (i.e., temporary effect). This was equivalent to a maximum period of 14 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). During the 2022 Program (31 July to 23 Aug), there were approximately two vessel transits per day in the SSA (56 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 min. These findings were consistent with previous years' findings and with behavioural results from the narwhal tagging study (Golder 2020a), indicating that narwhal density in the SSA was temporarily influenced by vessel traffic, with the decrease limited to close distances (i.e., within 2 km of a northbound vessel). Localized avoidance of the sound source (i.e., the vessel) by narwhal was consistent with a moderate severity behavioural response (Southall et al. 2021). However, given the temporary nature of the effect (i.e., 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 were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the Final Environmental Impact Statement (FEIS) for the Early Revenue Phase (ERP), in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

## Group Composition

- Group Composition: The number of narwhal groups in the BSA in 2022 was the second highest observed since the start of the eight-year study period, with 1,523 narwhal groups (comprising 5,864 individuals) recorded. All narwhal life stage categories (adults, juveniles, yearlings, and calves) were recorded in the BSA throughout the eight-year sampling program, with the majority of the sightings consisting of adult narwhal, followed by juveniles, calves, and yearlings.
- Proportion of Immatures (Early Warning Indicator; 'EWI'): Findings from the combined multi-year dataset indicated that the relative proportion of immature narwhal observed in the BSA in 2022 (0.105) was significantly lower than the 2014/2015 baseline condition (0.152 in 2014 and 0.167 in 2015). This was similar to the 2021 EWI results, in which the relative proportion of immature narwhal observed in the BSA in 2021 (0.102) was significantly lower than the 2014/2015 baseline condition. The 2021 and 2022 results indicate an exceedance of the Moderate Risk threshold for this specific indicator, as per the Trigger Action Response Plan (TARP) for marine mammals (Baffinland 2021c), and that the Risk Status / Threshold trigger has been observed in at least two consecutive monitoring years. The pre-defined response for exceedance of a moderate risk indicator includes the following: 1) investigate trend over time and consider any uncertainties (i.e., changes in operational processes, potential sources, confounding influences) in a formal Response Plan; and 2) initiate component-specific targeted studies as part of the response planning. Based on prior monitoring results for narwhal, Baffinland proactively refined and implemented the 2022 Narwhal Adaptive Management Response Plan (NAMRP; Baffinland 2022), which included a follow-up investigation involving an EWI analysis of 2020 to 2022 aerial survey data using dedicated 1,000-feet (305 m) aerial survey data (WSP 2023b). Findings from the aerial EWI indicated that the proportion of immature narwhal in Eclipse Sound in 2022 (0.124) was within the range of the 2014/2015 baseline condition (0.150 in 2014 and 0.110 in 2015), although a statistical analysis was not possible since the raw data from 2014/2015 aerial surveys were not available. Both Bruce Head and aerial-based EWI datasets were associated with high variability and low sample sizes, resulting in high uncertainty in the EWI estimates. In summary, while the EWI data collected at Bruce Head suggested a localized change in narwhal group composition, the equivalent EWI analysis derived from the spatially broader aerial survey dataset provided no indication that the proportion of immature narwhal had declined in the broader RSA since the start of shipping operations (2014/2015) (WSP 2023b). Ongoing EWI monitoring through both the Bruce Head Shore-based Monitoring Program and Marine Mammal Aerial Survey Program is therefore recommended.

The following summarizes key findings pertaining to narwhal responses to ship traffic at Bruce Head based on three years (2020-2022) of drone-based focal follow imagery collected in Milne Inlet:

## Behaviour - UAV-based Focal Follow Surveys

- Primary behaviour: Findings based on the three-year UAV dataset provide possible, though conflicting, support that narwhal groups may change the proportion of time that they engage in critical activities (i.e., resting, milling, and social behaviours) when in the presence of vessels. Specifically, group types with immatures (i.e., mother-immature pairs and mixed groups with immatures) and adult groups were shown to decrease the proportion of time that they engage in critical activities when within 5 km and 4 km of vessels, respectively. Conversely, mixed groups without immatures were shown to increase the proportion of time that they engaged in critical activities when within 3 km of vessels. While these findings suggest that vessel traffic may have some effect on the ability of narwhal to carry out these critical life functions, the conflicting trends among group types suggest that the results should be interpreted with caution. Additional focal follow monitoring is recommended to increase overall sample size of the corresponding dataset.

- Unique behaviours: Unique behaviours were displayed less frequently by all narwhal group types in close proximity (<2 km) to transiting vessels, although comparisons relative to vessel absence scenarios were not significant despite large effect sizes at 0.5 km and 1.0 km from vessels. The lack of statistical significance was likely due to the low sample size and high data variability at close range (<2 km) to vessels. The results suggest that unique behaviours such as rubbing, rolling, nursing, and sexual displays may be temporarily disrupted in close proximity (<2 km) to vessel traffic, though this finding was based on a limited sample size at close range to vessels. Additional focal follow (UAV-based) monitoring is therefore recommended to increase overall sample size and the robustness of the corresponding analysis.

- Association of immatures with presumed mother: Immature narwhal were recorded in 148 of the 397 (37%) focal follow surveys conducted to date. Of these, immature narwhal occurred on their own in 35 of the surveys, with their presumed mother in 64 of the surveys, and in mixed groups in 49 of the surveys. Nursing behaviour was recorded during 30 of the surveys, of which five coincided with a vessel being present within 5 km of the focal group.

  - Presence of nursing behaviour: Immature narwhal engaged in nursing less often when in the presence of vessel traffic (vessel within 5 km of the focal group), although this effect was not statistically significant despite a large effect size (-69%). The lack of a statistically significant effect was likely due to low sample size and high data variability. As a result, these findings should be interpreted with caution. Additional focal follow monitoring is recommended to increase overall sample size and the robustness of the corresponding analysis.

  - Relative and distal positioning of immatures: Immature narwhal were found to change their association with their mother when in close proximity to vessel traffic, for both mother-immature pairs and for mixed groups with immatures. That is, immature narwhal tended to favour the underside of their mother over other relative positions when within 1 km of vessels (though this finding was based on a small effect size) and they associated more tightly with their mother when within 5 km of vessels. The full spatial extent of the latter finding may be a modelling artefact and the effect may only extend to <3 km from a vessel. Additional focal follow surveys are required to increase sample size, thereby allowing for a more robust analysis.

- Group formation: Narwhal groups were shown to alter their group formation when in close proximity to vessels, with the majority of group types decreasing the proportion of time that they spend in parallel formation when within 1 to 3 km of vessels. Conversely, mother-immature pairs were the only group type to increase the proportion of time that they spend in parallel formation when within 2 km of vessels, however the effect size was small. These results were based on a limited sample size and should therefore be interpreted with caution. As discussed in Section 3.0, a change in group cohesion (e.g., change in group formation) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect (i.e., change in group formation within 3 km of a vessel), this finding was not anticipated to result in a biologically significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 21 min per vessel transit (based on a 9 knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

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

- Group size: Of the different narwhal group types, only mixed groups with immatures were shown to temporarily associate in slightly larger groups when within 4 km of vessels. For the other group types, effect sizes were small and did not suggest a biologically significant effect. While mother-immature pairs had a large effect size, data in close proximity to vessels were limited, and additional focal follow surveys are recommended to increase sample size. As discussed in Section 3.0, a change in group cohesion (e.g., change in group size) by narwhal would be consistent with a moderate severity behavioural response. Given the temporary nature of the effect evident for only mixed groups with immatures (i.e., increase in group size when within 4 km of a vessel), this finding was not anticipated to result in a significant alteration of natural behavioural patterns by narwhal in the RSA or disruption to their daily routine. The noted response was shown to be short in duration, equivalent to a maximum period of 28 min per vessel transit (based on a 9-knot travel speed, assuming narwhal remained stationary during exposure), with animals returning to their pre-response behaviour shortly following the initial vessel exposure (i.e., a temporary effect). Accordingly, no effects were anticipated on the individual fitness and/or vital rates of narwhal in the RSA, which may ultimately affect population parameters. This response was in line with impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

- Group travel speed: Narwhal did not significantly alter their travel speed in response to vessel traffic. As discussed in Section 3.0, a change in energy expenditure (e.g., change in travel speed) by narwhal would be consistent with a moderate severity behavioural response, though no such change was evident. The lack of response was supportive of impact predictions made in the FEIS for the ERP, in that vessel noise effects on narwhal were anticipated to be limited to temporary, localized avoidance behaviour.

# 8.0 RECOMMENDATIONS

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

- Continue to increase program emphasis on UAV surveys, given the valuable insight this tool provides with respect to monitoring changes in group composition and fine scale behaviours in the presence of shipping (Broker et al. 2019). UAV surveys provide a detailed and permanent record of key narwhal behaviours (i.e., nursing, resting, territorial behaviour) that may not otherwise be quantifiable by shore-based visual methods. For example, one of the benefits of the focal follow surveys is an enhanced ability to monitor for moderate to high severity responses such as change in nursing behaviour should they occur.
- Continue to undertake additional analysis of the aerial survey data (as available) for specific evaluation of the EWI metric (using the dedicated 1,000 ft survey data which was collected for this purpose) to support findings regarding the proportion of immature narwhal in the RSA.
- Where possible, conduct UAV-based focal follow surveys of narwhal when in the presence of other external and confounding stimuli such as killer whales or hunting given the known influence these activities have on narwhal behaviour (Laidre et al. 2006).

# 9.0 CLOSURE

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

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**APPENDIX A**

# Power Analysis

**APPENDIX B**

# Vessel Track Information

**APPENDIX C**

# Test Statistics and Coefficients

**APPENDIX D**

# Model Diagnostics

**APPENDIX E**

# Focal Follow Survey Tracks Relative to Vessels

**APPENDIX F**

# Focal Follow Survey Descriptions in the Presence of Vessels

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