FINAL REPORT

Bruce Head Shore-based Monitoring Program

2014-2017 Integrated Report

Submitted to:

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EXECUTIVE SUMMARY

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

A Project Certificate No. 005, amended by the Nunavut Impact Review Board (NIRB) on 27 May 2014, authorizes the Company to mine up to 22.2 million tonnes per annum (Mtpa) of iron ore from Deposit No. 1. Of this 22.2 Mtpa, the Company is currently authorized to transport 18 Mtpa of ore by rail to Steensby Port for year-round shipping through the Southern Shipping Route (via Foxe Basin and Hudson Strait), and 6.0 Mtpa of ore by truck to Milne Port for open water shipping through the Northern Shipping Route using chartered ore carrier vessels.

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

This report presents the results of shore-based monitoring of narwhal and vessel traffic in Milne Inlet near Bruce Head during the 2014 through 2017 open-water seasons. Initiated in 2013, the Bruce Head shore-based monitoring study was designed to specifically address Project Certificate (PC) conditions related to evaluating potential disturbance of marine mammals from shipping activities that may result in changes in animal distribution, abundance, and migratory movements in the study area. The primary objective of the shore-based study was to investigate narwhal response to shipping activities along the Northern Shipping Route in Milne Inlet.

Key findings from the 2014–2017 Bruce Head Monitoring Program include the following:

- Relative abundance and distribution (RAD):
  - The relative abundance of narwhal in the Bruce Head area has remained relatively constant over the four years of sampling (as shown by a lack of significant year effect on counts and fewer occurrences of zero counts in 2017) despite the relative increase in shipping during this period.
  - Model results indicated that vessel direction within Milne Inlet (south- vs northbound vessels) affected the response of narwhal relative to distance from large vessel. Conversely, the direction of vessel relative to the substrata (heading toward or away from substrata) was not a significant predictor of relative abundance.
- Spatial distribution within the SSA – GPS-tagged narwhal were shown to spend the least time in substratum ‘3’ and the most time in substratum ‘2’. This provides evidence that low RAD counts recorded in substratum ‘3’ are not solely due to reduced observation visibility.
- Group composition and behaviour:

- Group size — group sizes changed between years, but not in a manner consistent with the increase in vessel traffic between 2014 and 2017. Model results also did not suggest temporary effects of large vessel transits on narwhal group size within the BSA.
- Group composition — groups with calves/yearlings and groups with tusks were present in the BSA and SSA throughout the four sampling years. Model results indicated no effect of large vessel transits on presence of tusks or calves/yearlings in observed groups in the BSA. For both response variables, group size was the only significant predictor variable identified.
- Group spread — narwhal were more often observed in tight associations compared to loose associations under both vessel presence and vessel absence scenarios. During passage of a large vessel within 15 km from the BSA, loosely spread groups were more likely to occur when southbound or northbound vessels heading toward the BSA were 2–4 km away from the BSA, or when northbound vessels heading away from the BSA were near (≤2 km). In addition, the probability of observing a group in a loose spread significantly increased with group size.
- Group formation — narwhal were usually observed in parallel formation under both vessel presence and vessel absence scenarios. Models indicated no effect of vessel transits on group formation in the BSA (analyzed as presence/absence of non-parallel groups). The probability of observing a non-parallel formation increased significantly with group size.
- Group direction — narwhal groups were predominantly observed travelling south through the BSA. When northbound large vessels were within 15 km of the BSA, narwhal were most often observed travelling south, regardless of direction of the vessel relative to the BSA. In the presence of southbound vessels, narwhal groups travelled both north and south when the vessel was heading toward the BSA (model predictions were of a predominantly southward traveling direction). When the southbound vessel headed away from the BSA, narwhal groups were observed traveling predominantly north, unless the vessel was within close proximity (≤2 km). Narwhal tended to travel south in large groups and north in small groups.
- Travel speed – the majority of narwhal groups travelled at a medium speed, regardless of large vessel presence/absence. The probability of observing slowly-traveling groups increased when large vessels were south of the BSA (regardless of direction of travel and direction relative to the BSA) and in close proximity (≤3 km). When vessels were north of the BSA, the probability of observing slowly-traveling groups was low, especially for southbound vessels. The probability of observing slowly-traveling groups decreased with group size.
- Distance from Bruce Head shore - narwhal groups were observed more often at a distance <300 m of the Bruce Head shore compared to groups >300 m offshore under both vessel presence and vessel absence scenarios. Offshore groups were detected less frequently with increasing Beaufort scale values, indicating observer impediment with worsening sea state. Model results indicated that narwhal groups tended to be offshore when large vessels were 3–6 km away from the BSA, especially when vessels were heading toward the BSA (compared to vessels heading away from the BSA). When vessels were close, the model estimated that narwhal groups were concentrated inshore.

- *Ad libitum o*bservations collected throughout the four-year study period indicate the following:
  - The majority of narwhal recorded in the SSA during the four-year study period were engaged in travelling behaviour. Other behaviours observed in the SSA included nursing, rubbing, tusking, foraging, and mating. In all years, narwhal calves were commonly observed in the SSA, with observations of nursing behaviour recorded in 2015 (two occasions), 2016 (four occasions) and 2017 (two occasions). On 11 August 2016, the birth of a narwhal calf off Bruce Head was observed. Collectively, these observations lend support to the hypothesis that this part of Milne Inlet is important for calf rearing.
  - Narwhal occur most frequently south of the SSA in the vicinity of Koluktoo Bay and the entrance to Assomption Harbour (Milne Port). A similar distribution of narwhal has been reported during aerial surveys conducted in the Milne Inlet region (Thomas et al. 2015, 2016; Golder 2018b) affirming the importance of Koluktoo Bay as a refuge for narwhal during the open-water season.
  - Responses of narwhal to ore carrier traffic is variable, ranging from ‘no obvious response’ in which animals remain in close proximity to ore carriers as they transit through the SSA, to temporary and localized displacement and related changes in behaviour. However, no overall decrease in the abundance of narwhal in the area was observed.
  - During each survey year, narwhal were observed to respond to shooting by diving and increasing their swim speed. Despite repeatedly being shot at from the same location (i.e. the hunting camp below the observation platform), narwhal were always observed to return to the area at the base of Bruce Head, though the time until they returned was variable.
  - In 2016, narwhal were observed foraging on arctic cod schooling close to the Bruce Head shore on nine days during the first half of August. Mother-calf pairs were observed to engage in foraging behaviours although the majority of these feeding groups did not include calves or yearlings.

The following items should be considered with respect to future shore-based monitoring efforts:

- The primary narwhal behaviour in the current SSA consists of travel behaviour, which may make determination of narwhal responses to vessel transits more difficult than vessel transits in relation to more sedentary behaviour types (i.e., milling, foraging, etc.). Alternate locations for the observation platform should be assessed that might better survey the portion of the nominal shipping route closest to Koluktoo Bay, where travel does not appear to be the primary narwhal behaviour.
- Supplement visual observation with drone footage. This will provide a means to verify observation counts and will allow to correct for observation bias under conditions of low visibility or increased distance. In addition, drone footage may be helpful for filling in missing information on narwhal behaviour and composition in the BSA, where observers are not able to record certain aspects of group behaviour due to reduced sightability.
- Assess the potential effects of simultaneous transits of multiple large vessels on narwhal RAD and behaviour. At this time, it is unknown whether the effects of consecutive transits of a single large vessel are different than a single transit of multiple large vessels (travelling in SSA simultaneously).
- Integration of acoustic monitoring results with shore-based observer data to assess if and when narwhal alter their acoustic behaviour in response to vessel transits.

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ᐅᓇ ᓄᓘᔾᒃ ᐅᔭᕋᓐᓂᐊᕐᕕᒃ, ᐃᖏᕐᕋᓕᓚᐅᖅᑐᖅ ᒪᑐᐃᖓᔪᖅ ᓄᓇᒥ ᓴᕿᑦᔾᑉᓴᓂᒃ ᐅᔭᕋᓐᓂᐊᖅᑐᑦ ᑕᐅᕗᓃᑦᑐᖅ ᕿᑭᖅᑕᓂ ᓄᓇᕗᒻᒥ (ᓴᕿᔫᖅᑐᖅ 1-1). ᐸᕙᓀᓛᓐᑦ ᓴᕿᑦᔾᑉᓴᓂᒃ ᐅᔭᕋᓐᓂᐊᖅᑎᑦ ᑯᐊᐳᕆᓴᓐ ᓇᒥᓂᕆᔭᐅᔪᖅ ᐊᒻᒪᓗ ᐃᖏᕐᕋᑎᑦᑎᓕᖅᑐᑦ ᐅᔭᕋᓐᓂᐊᕐᕕᖕᒥᒃ. ᐅᓇ ᐃᖏᕐᕋᑎᑕᐅᕙᖅ ᐅᔭᕋᓐᓂᐊᕐᕕᖕᒥᑦ ᑲᑎᖓᓪᓗᒍ ᕿᑦᖑᐊᓄ (ᐃᒃᓴᕐᕕᖕᒍᑦ) ᑕᒪᐅᓐᓇ 100-ᑭᓚᑉᒦᑕ ᑕᑭᑎᒋᔪᖅ ᕿᑦᖑᐊᓄ ᐅᕐᑯᒪᐃᑦᑐᓄᑦ ᓄᓇᓯᐅᑎᓄᑦ ᐊᕐᑯᑎ. ᓯᕗᓂᒃᓴᑦᑎᓂ ᑭᓯᐊᓂ ᐃᓚᒃᓴᖏᑦ ᓴᓇᔭᐅᔪᓐᓇᓐᖏᑉᐸᑕ ᐅᔭᕋᓃᐊᕐᕕᒃ ᐃᓚᐊᖃᕐᓂᐊᖅᑐᖅ ᓂᒋᐊᓂᑦ ᓄᓇᓯᐅᑎᑰᑦᒃ ᐊᑕᔪᖅ ᕿᑦᖑᐊᓄᑦ ᓯᕗᓂᒃᓴᑦᑎᓂᓗ ᐃᒃᓴᕐᕕᒃᓴᖅ ᐃᒃᐱᑭᑦᑐᕐᔪᐊᖅ (ᐃᒃᓴᕐᕕᖓᓄᑦ).

ᐅᔭᕋᓐᓂᐊᕈᓐᓇᐅᖑᑎ ᓈᓴᐅᑖ 005, ᐋᕿᒋᐊᖅᑕᐅᓚᐅᖅᑐᖅ ᓄᓇᕗᒻᒥ ᐊᕙᑎᓕᕆᔾᒃᑯᑦ ᑲᑎᒪᔨᖏᓐᓂᑦ 27 ᒪᐃ 2014, ᐊᖓᔪᖅᓯᓪᓗᑎᒃ ᑲᒻᐸᓂ ᐅᔭᕋᓐᓂᐊᕈᓐᓇᖅᓱᓂ ᑎᑭᓪᓗᒍ 22.2 ᒥᓕᐊᓐ ᑕᓐᓵ ᐊᕐᕌᒍ ᐊᑕᐅᓯᖅ ᓴᕿᑦᔾᑉᓴᒥᒃ ᐅᔭᕋᓐᓂᐊᖅᓯᒪᓐᖏᑦᑐᖅ ᓈᓴᐅᑖ 1. ᑖᕙᖓᑦ 22.2 ᒥᓕᐊᓐ ᑕᓐᓵ ᐊᕐᕌᒍ ᐊᑕᐅᓯᖅ ᓴᕿᑦᔾᑉᓴᒥᒃ, ᑲᒻᐸᓂ ᒫᓐᓇ ᐊᖓᔪᖅᑕᐅᔪᒪᔪᖅ ᐊᓪᔭᖅᑐᕈᓐᓇᕐᓗᑎᒃ 18 ᒥᓕᐊᓐ ᑕᓐᓵ ᐊᕐᕌᒍ ᐊᑕᐅᓯᖅ ᓴᕿᑦᔾᑉᓴᒥᒃ ᓴᕿᖅᓴᒥᒃ ᓄᓇᓯᐅᑎᑰᒃᑯᑦ ᑕᐃᑯᐊ ᐃᒃᐱᑭᑦᑐᐊᕐᔪᒃ ᐊᕐᕌᒍᓕᒫᖅ ᐃᖏᕐᕋᓂᐊᖅᑐᒥᒃ ᐅᓯᑲᖅᑕᕐᓗᓂ ᑕᒪᐅᓐᓇ ᓂᒋᐊᓂᑦᓄᓇᖓᓂᖕᖑᖅᑐᖅ ᐊᕐᑯᑎ ᓄᓇᓯᐅᑎᑰᒃ (ᑕᐃᑰᓇ ᓴᓂᕋᔾᒃ ᐃᒪᖓᒍᑦ ᐊᒻᒪᓗ Hᐊᑦᓴᓐ ᓱᓪᓗᐊᓗᒃ), ᐊᒻᒪᓗ 6.0 ᑕᓐᓵ ᐊᕐᕌᒍ ᐊᑕᐅᓯᖅ ᓴᕿᑦᔾᑉᓴᒥᒃ ᓄᓇᓯᐅᑎᒃᑯᑦ ᕿᑦᖑᐊᓄ ᐃᒃᓴᕐᕕᖓᓄ ᐊᐅᔾᒃᑯᑦ ᓯᑯᖃᐅᖏᑎᓪᓗᒍ ᐃᒪᖓ ᑕᒪᐅᓐᓇ ᐅᐊᖕᓇᖓᓂ ᐅᓯᑲᖅᑕᖅᑐᖅ ᐊᕐᑯᑖᒍ ᓵᑕᖅᓯᓯᒪᓪᓗᑎᒃ ᓴᕿᑦᔾᑉᓴᓄᑦ ᐅᓯᑲᖅᑕᐅᑎᓂᒃ ᐅᒥᐊᕐᔪᐊᓂᒃ.

ᐅᓪᓗᒥᒨᑦ, ᐸᕙᓀᓛᓐᑦ ᐊᐅᓚᑎᑕᖓ ᑮᓇᐅᔭᓕᐅᕈᑎᒃᓴᓄᑦ ᐱᓕᕆᕙᓪᓕᐊᑎᓪᓗᒋᑦ ᐅᔭᕋᓐᓂᐊᕐᕕᒃ, ᐃᓚᖃᖅᑐᖅ ᐅᓯᑲᖅᑕᖅᑯᒋᑦ ᓴᕿᑦᔾᑉᓴᖅ ᑕᐃᑰᓇ ᕿᑦᖑᐊᑦ ᐃᒃᓴᕐᕕᖓᓂ ᐊᐅᔾᒃᑯᑦ ᓯᑯᖃᐅᖏᑎᓪᓗᒍ (ᔪᓚᐃ ᑎᑭᓪᓗᒍ ᐊᑑᓄᑦ ᐅᒃᑑᐸ). ᐅᓯᑲᖅᑕᖅᑐᑦ ᓴᕿᑦᔾᑉᓴᓂᒃ ᕿᑦᖑᐊᓂ ᑕᐅᕙᓂ ᑮᓇᐅᔭᓕᐅᕈᑎᒃᓴᓄᑦ ᐱᓕᕆᕙᓪᓕᐊᑎᓪᓗᒋᑦ ᐅᔭᕋᓐᓂᐊᕐᕕᒃ 2015-ᒥ ᐊᒻᒪᓗ ᓂᕆᐅᓚᓚᐅᖅᑐᖅ ᑲᔪᓯᓂᐊᕐᓗᓂ ᐅᔭᕋᓐᓂᐊᖅᑐᖅ (20+ ᐅᑭᐅᓄᑦ). ᑕᐃᑲᓂ ᓯᕗᓪᓕᖅᕿᖓᓂ ᐊᕐᕌᒍᒥ ᑮᓇᐅᔭᓕᐅᕈᑎᒃᓴᓄᑦ ᐱᓕᕆᕙᓪᓕᐊᑎᓪᓗᒋᑦ ᐅᔭᕋᓐᓂᐊᕐᕕᒃ ᐅᔾᔭᕋᓐᓂᐊᓕᓚᐅᖅᑐᑦ 2015, ᐸᕙᓀᓛᓐᑦ ᐅᓯᑲᖅᑕᓚᐅᖅᑐᖅ ~900,000 ᑕᓐᓵ ᑕᒪᐅᓐᓇ 13 ᐅᓯᑲᖅᑕᐅᑎᑦ ᐅᒥᐊᕐᔪᐊᑦ. ᐊᖏᑎᒋᓂᖓ ᓴᕿᑦᔾᑉᓴᖅ ᐅᓯᔭᐅᔪᖅ ᓯᑯᖃᖅᑎᓇᒍ ᐊᐅᔾᒃᑯᑦ ᐅᓄᖅᓯᒋᐊᖅᓯᒪᓕᖅᑐᖅ ᑎᑭᓪᓗᒍ ~4.2 ᒥᐊᓕᓐ ᑖᓐᓵ 2017-ᒥ, ᑕᒪᐅᓐᓇ 56 ᐅᑎᖅᑕᖅᑐᑦ ᓴᕿᑦᔾᑉᓴᓂᒃ ᐅᓯᑲᖅᑕᖅᑐᑦ ᐅᒥᐊᔪᐊᑦ.

ᐅᓇ ᐅᓂᒃᑳᖅ ᐅᖃᐅᓯᖃᖅᑐᖅ ᐋᕿᐅᑎᔪᓂᑦ ᓯᓪᔭᒥᑦ-ᐃᓕᓯᒪᔪᑦ ᒥᐊᓂᕆᔭᕐᑕᐅᔪᑦ ᑑᓕᓐᖏᓂᒃ ᕿᓚᓗᒐᕐᓂᒃ ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᓂᒃ ᐃᖏᕐᕋᔾᒃᑐᓂᒃ ᕿᑦᖑᐊᓄᑦ ᖃᓂᒋᔭᖓᓂ ᐃᓗᕙᓕᒃ ᑕᐃᑲᓂ 2014 ᑎᑭᓪᓗᒍ 2017 ᓯᑯᖃᖏᑎᓪᓗᒍ ᐊᐅᔾᒃᑯᑦ. ᐃᖏᕐᕋᓯᑎᑕᐅᓯᒪᔪᖅ 2013-ᒥ ᐃᓗᕙᓕᒃ ᓯᓪᔭᖓᓂ ᒥᐊᓂᕆᔪᑦ ᐃᓕᑦᑎᓇᓱᖕᑐᑦ ᓴᓇᓯᒪᓂᖓᓂ ᐱᓗᐊᖅᑐᒥᒃ ᐊᑐᖅᓯᓂᐊᕋᒥᒃ ᐅᔭᕋᓐᓂᐊᕈᓐᓇᐅᑎᖏᓐᓄᑦ ᒪᓕᒋᐊᓕᑦ ᐱᓪᓗᒍ ᖃᐅᔨᓇᓱᑦᑎᐊᕆᐊᖅᑲᕐᓂᖅ ᐸᒡᕙᔪᖃᕋᔭᕐᒪᖔᑦ ᐳᐃᔨᓂᒃ ᐅᓯᑲᖅᑐᓂᑦ ᐅᑯᐊᓗ ᐊᓱᑦᔨᒍᑎᒐᔭᖅᐸᑕ ᓂᕐᔪᑎᑦ ᓄᒦᖃᑦᑕᕐᓂᖏᓐᓄᑦ, ᐅᓄᕐᓂᖏᓐᓄᑦ, ᐊᒻᒪᓗ ᐊᑐᖃᑦᑕᖅᑕᖏᑦ ᓄᒃᑕᖅᓱᑎᒃ ᐃᓕᑕᐅᓇᓱᒃᓯᒪᔪᓂ. ᑐᑭᓕᐅᕈᑕᐅᕙᓪᓕᐊᔪᖅ ᓯᓪᔭᖓᓂ ᐃᓕᑦᑎᓇᓱᒃᑐᑦ ᖃᐅᔨᓂᐊᕐᒪᑕ ᑑᓕᓐᑦ ᕿᓚᓗᒐᐃᑦ ᖃᓄᖅ ᑭᐅᓯᖃᑦᑕᕐᒪᖔᑕ ᐅᒥᐊᕐᔪᐊᓂᒃ ᐅᓯᑲᖅᑐᓂᒃ ᑕᒫᓂ ᐅᑭᐅᖅᑕᖅᑐᒧᑦ ᐊᕐᑯᑎᖏᑦ ᐅᓯᑲᖅᓱᑎᒃ ᕿᑦᖑᐊᓄᑦ.

ᓇᓂᔭᐅᓯᒪᔪᑦ 2014-ᒥᑦ 2017-ᒧᑦ ᐃᓗᕙᓕᒃ ᒥᐊᓂᕆᕙᐅᔪᖅ ᐃᓚᖃᖅᑐᖅ ᐅᑯᓂᖓ ᐊᑖᓂ ᑎᑎᕋᖅᓯᒪᕗᑦ:

- ᐅᓄᓗᐊᓐᖏᑦᑑᔪᑦ ᐊᒻᒪᓗ ᓇᒧᖔᓯᒪᓂᖏᑦ
  - ᐅᓄᓗᐊᓐᖏᑦᑑᔪᑦ ᑑᓕᓐᑦ ᕿᓚᓗᒐᐃᑦ ᐃᓗᕙᓕᖕᒥ ᓱᓕ ᑕᐃᒪᓐᓇᐃᓕᖓᔪᑦ ᐅᖓᑖᓄᑦ ᑎᓴᒪᑦ (4) ᐅᑭᐅᓄᒃ ᖃᐅᔨᓴᕈᑎᑖᖑᖃᑦᑕᖅᑐᓂ (ᓇᓗᓇᐃᖅᓯᒪᔪᑦ ᐅᓄᓐᖏᓗᐊᖃᑦᑕᕐᓂᖏᓐᓂᒃ ᐊᕐᕌᒍᓕᐅᖅᑐᒥᑦ ᑕᐃᒪᖓᓂ ᓈᓴᖅᑕᐅᓕᒥᒃ ᐊᒻᒪᓗ ᐅᓄᓐᖏᓂᖅᓴᐅᕙᒃᑐᑦ 2017-ᒥᑦ) ᑕᒪᓐᓇ ᐅᓄᖅᓯᓚᓗᐊᖅᑐᑎᒃ ᐅᓄᖅᓯᓗᐊᕋᑎᒃ ᐅᒥᐊᕐᔪᐊᑦ ᐅᓯᑲᖅᑕᓇᐅᑎᓪᓗᒍ.

- ᖃᐅᔨᓴᕈᑕᐅᔪᖅ ᖃᐅᔨᓇᖅᓯᑎᑦᑎᓚᐅᖅᑐᖅ ᐅᑯᐊ ᐅᒥᐊᕐᔪᐊᑦ ᐊᑐᖅᑕᖏᑦ ᐃᒫᒍᑦ ᐃᓗᐊᓂ ᕿᑦᙳᐊᓂ (ᓂᒋᐊᓂᑦ-ᐱᓇᓂ-ᐅᐊᓐᓇᓕᐊᖅᑐᑦ ᐅᒥᐊᕐᔪᐊᑦ) ᐊᒃᑐᐃᔪᑦ ᑭᐅᓯᓪᓗᑎᒃ ᑑᓚᓕᑦ ᕿᓚᓗᑲᐃᑦ ᐅᖓᓯᑉᐸᓗᒃᑑᑲᓗᐊᒥᒃ ᐊᖏᔪᓄᑦ ᐅᒥᐊᕐᔪᐊᓄᑦ. ᐊᓯᕈᖅᑎᑕᐅᓯᒪᒍᓐᓇᖅᑐᖅ, ᓇᒧᖓᐅᓂᖏᑦ ᐅᒥᐊᕐᔪᐊᑦ ᑕᒪᐅᓐᓇ ᐊᖃᐅᒪᓪᓗᑎᒃ (ᐅᒥᐊᕐᔪᐊᓕᐊᖅᑐᑦ ᐅᕝᕙᓘᓐᓃᑦ ᕿᒫᕝᕙᐅᔪᑦ ᐊᖃᐅᒪᓪᓗᑎᒃ ᐃᑭᐊᖓᒍᑦ) ᐊᖏᔪᒥᒃ ᑲᑉᐱᐊᒋᓚᐅᖏᑕᖓ ᐅᓄᕋᓗᐊᕐᒪᑕ.

- ᐅᖓᓯᒋᔭᑲᓪᓚᖓᓄᑦ ᓇᒧᖔᑎᖅᑐᑦ ᐃᓗᐊᓂ SSA – ᑕᒻᒪᕖᑯᓯᖅᓯᒪᔪᑦ-ᓂᕙᖓᑖᖅᓯᒪᓪᓗᑎᒃ ᑑᓚᓕᑦ ᕿᓚᓗᑲᐃᑦ ᑕᑯᑎᑦᑎᓚᐅᖅᑐᑦ ᐊᑯᓂᐅᔪᒥᒃ ᑕᐅᕗᓃᑦᑐᑦ ᐃᒪᓂ '3' ᐊᒻᒪᓗ '2'-ᖓᓂ. ᐅᓇ ᑕᑯᑎᑦᑎᓯᒪᔪᖅ ᐊᑦᑎᒃᑑᓂᖏᓐᓂ ᐅᓄᓗᐊᓐᖏᑑᔪᑦ ᐊᒻᒪᓗ ᓇᒧᖓᖅᓯᒪᓂᖏᑦ ᓈᓴᖅᓯᒪᔪᑦ ᑎᑎᕋᖅᑕᐅᓯᒪᔪᓂ ᐃᒪᓂᑦ '3' ᐱᓯᒪᓐᖏᑦᑐᑦ ᑕᒍᔭᐅᖃᑦᑕᖅᑐᑦ ᐅᓄᕈᓐᓃᖅᓯᒪᔪᑦ.

- ᑲᑎᖓᔪᑦ ᐊᙳᑎᑦ ᐊᕐᓇᐃᑦ ᕿᓚᓗᖓᙳᕋᑖᕐᓂᑯᓪᓗ ᐊᒻᒪᓗ ᖃᓄᐃᓕᐅᕐᓂᖏᑦ:
  - ᑲᑎᖓᔪᑦ ᐊᖕᖏᓂᖏ - ᑲᑎᖓᔪ ᐊᖕᖏᓂᖏ ᐊᓯᑦᔨᖅᓯᒪᓕᖅᑐᑦ ᐊᕙᑖᓂᑦ ᐊᕐᕌᒍᓂ, ᑭᓯᐊᓂ ᑕᐃᒪᓐᓇᑦᑕᐃᓐᓇᐅᖏᓐᓇᖅᑐᖅ ᐅᓄᖅᓯᓚᓗᐊᖅᐳᑎᒃ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔭᒃᑐᑦ ᐊᕙᑖᓂᑦ 2014 ᐊᒻᒪᓗ 2017. ᖃᐅᔨᓴᕈᓯᑦ ᖃᐅᔨᑎᑦᑎᓯᒪᔪᑦ ᐊᓯᑦᔨᕈᑕᐅᓚᔭᓐᖏᑦᑐᑦ ᐊᖕᖏᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᑎᓪᓗᒋᑦ ᑑᓚᓕᓐᓄᑦ ᕿᓚᓗᑲᕐᓄᑦ ᐃᓗᐊᓂ BSA.
  - ᑲᑎᖓᔪᑦ ᓇᓕᐊᙳᒪᖔᑕ - ᐅᑯᐊ ᑲᑎᖓᔪᑦ ᐃᓅᕋᑖᑦ ᐊᒻᒪᓗ ᐊᐅᔭᒥ ᐃᓅᓰᑦ ᐊᒻᒪᓗ ᑲᑎᖓᔪ ᑑᓚᖃᕐᓂᖏ ᐃᑕᖃᖅᑐᑦ ᐃᓗᐊᓂ BSA ᐊᒻᒪᓗ SSA ᑕᒪᐅᓐᓇ ᑎᓴᒪᓄᖅ ᖃᐅᔨᓴᕈᑎᑖᕐᕕᐅᕙᓪᓗᑎᒃ ᐊᕐᕋᒍᓄᑦ. ᖃᐅᔨᓴᕈᓯᕐᓂᑦ ᐋᕿᐅᑎᔪᑦ ᐊᒃᑐᐃᓯᒪᓐᖏᑦᑐᑦ ᐊᖏᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᓪᓗᑎᒃ ᐱᑕᖃᖅᑎᓪᓗᒍ ᑑᓚᓕᓐᓂᒃ ᐅᕝᕙᓘᓐᓃᑦ ᐃᓅᓯᕐᓂᑯᓂᒃ ᑕᑯᔭᐅᓯᒪᔪᑦ ᖃᐅᔨᓴᖅᑐᓂᑦ ᑕᐃᑲᓂ BSA. ᑕᒪᐃᓐᓄᑦ ᑭᐅᓯᔪᑦ ᖃᓄᓇᑑᑕᐅᓂᖏᓐᓂᒃ, ᑲᑎᖓᔪᑦ ᐅᓄᖅᑎᒋᓂᖏᑦ ᐊᖏᓛᙳᓚᐅᖅᑐᖅ ᓄᙳᑕᐅᕙᓪᓕᖅᓯᒪᓂᖏᓐᓂᒃ ᓇᓗᓇᐃᖅᑕᐅᔪᓂ.
  - ᑲᑎᖓᔪᑦ ᓇᒥᑐᐃᓐᓈᓕᖅᐸᑦ — ᑑᓚᓕᑦ ᑕᑯᔭᐅᖃᑦᑕᓚᐅᖅᑐᑦ ᑲᑎᖓᔪ ᓇᒧᑐᐃᓐᓈᖅᓯᒪᓗᐊᓐᖏᓂᖅᓴᐅᓪᓗᑎᒃ ᐊᑖᓂ ᑕᒪᐃᓐᓄ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓪᓗᒍ ᐊᒻᒪᓗ ᐅᒥᐊᔪᐊᖅᑕᖃᖅᑎᓐᓇᒍ. ᑕᐃᑲᓂ ᓴᓂᖁᑕᐅᖃᑦᑕᖅᑎᓪᓗᒋᑦ ᐊᖏᔪᓂᑦ ᐅᒥᐊᕐᔪᐊᓂᑦ ᐃᓗᐊᓂ 15 ᑭᓚᒦᑕᔅ ᑕᐃᑲᖓᑦ BSA, ᓇᒧᖔᓚᐅᑲᓚᔭᖅᑐᑦ ᐊᓯᐊᓄᑦ ᐅᑯᐊᓗ ᐅᒥᐊᕐᔪᐊᑦ ᓂᒋᐊᒌᕈᑎᒃ ᐅᕝᕙᓘᓐᓃᑦ ᐅᐊᓐᓇᖓᖔᒌᕈᑎᒃ ᑕᐅᕘᖓᐅᔪᑦ BSA ᐅᖓᓯᒃᑎᒋᓚᐅᖅᑐᑦ 2-4 ᑭᓚᒦᑕ ᑕᐃᑲᖓᑦ BSA, ᐅᕝᕙᓘᓐᓃᑦ ᐅᐊᓐᓇᖓᔪᖓᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᕿᒪᒍᑎᓕᖅᑐᑦ BSA ᖃᓂᒋᔭᖓᓂ (≤2 ᑭᓚᒦᑕᔅ). ᐊᒻᒪᓗ, ᑕᐃᒪᓐᓇᐅᔫᓇᕐᒥᔪᖅ ᑕᒍᔭᐅᔪᑦ ᐊᒥᓱᓪᓗᑎᒃ ᓇᒥᑐᐃᓐᓈᕈᓐᓇᕐᒥᔪᑦ ᐅᓄᖅᑑᓪᓗᑎᒃ ᓇᒥᑐᐃᓐᓈᖅᐸᒃᑐᑦ.
  - ᑲᑎᖓᔪᑦ ᖃᓄᐃᓕᐅᓕᖅᐸᑦ— ᑑᓚᓕᑦ ᕿᓚᓗᑲᐃᑦ ᑕᒍᔭᐅᖃᑦᑕᓚᐅᖅᑐᑦ ᒪᓕᒃᑎᒦᒃᑐᑦ ᐊᑖᓂ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᖅᑎᓪᓗᒍ ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᑦ ᐱᑕᖃᓐᖏᑎᓪᓗᒋᑦ. ᖃᐅᔨᓴᕈᓯᑦ ᓇᓗᓇᐃᖅᓯᓯᒪᔪᑦ ᐊᒃᑐᐃᓐᖏᑦᑐᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐊᒥᓱᓂ ᓇᒧᖔᕙᒍᓯᖏᓐᖏᓂᒃ ᐃᓗᐊᓂ BSA (ᖃᐅᔨᓴᖅᑕᐅᓯᒪᔪᑦ ᐱᑕᖃᖅᑎᓪᓗᒋᑦ/ᐱᑕᖃᓐᖏᑎᓪᓗᒋᑦ ᒪᓕᒃᑎᒦᒍᓐᖏᑦᑐᓂᒃᑕᐅᖅ ᑲᑎᖓᔪᓂᒃ). ᓇᒥᑐᐃᓐᓇᖃᑦᑕᖅᑐᑦ ᑕᒍᔭᐅᔪᑦ ᐅᓄᖅᑐᑦ ᑲᑎᖓᓪᓗᑎᒃ ᐅᓄᕐᓂᖏᑦ ᒪᓕᒡᓗᒋᑦ.
  - ᑲᑎᖓᔪᑦ ᓇᒧᖓᐅᕙᑦ — ᑑᓚᓕᑦ ᕿᓚᓗᑲᐃᑦ ᑲᑎᖓᔪᑦ ᐅᓄᓛᑦ ᑲᑎᖓᔪᑦ ᑕᒍᔭᐅᓯᒪᔪᑦ ᐃᖏᕐᕋᔪᑦ ᓂᒋᐊᓄᑦ ᑕᒪᐅᓐᓇ BSA. ᑕᐃᑲᓂᓗ ᓂᒋᐊᓄᖓᐅᔪᑦ ᐊᖕᖏᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᓗᐊᓂ 15 ᑭᓚᒦᑕᔅ BSA, ᑑᓚᓕᑦ ᑕᒍᔭᐅᖏᓐᓇᖃᑦᑕᓚᐅᖅᑐᑦ ᓂᒋᐊᓄᖓᐅᔪᑦ, ᓇᒧᖓᐅᑐᐃᓐᓇᕋᓗᐊᕈᑎᒃ ᐅᒥᐊᕐᔪᐊᑦ ᑕᐃᒫᒃᑕᐅᖅ BSA-ᒧᑦ. ᐱᑕᖃᖅᑎᓪᓗᒋ ᓂᒋᐊᓄᖓᐅᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᑑᓚᓕᑦ ᑲᑎᖓᔪᑦ ᑕᒪᕐᒥᒃ ᐃᖏᕐᕋᔪᑦ ᐅᐊᓐᓇᖓᓄᑦ ᐊᒻᒪᓗ ᓂᒋᐊᓄᑦ ᑕᐃᑲᓂ ᐅᒥᐊᕐᔪᐊᑦ ᑕᐃᑯᖓᐅᑎᓪᓗᒋᑦ BSA (ᖃᐅᔨᓴᕈᓯᑦ ᑕᑯᑎᑦᑎᓯᒪᔪᑦ ᓂᐱᐅᓇᖅᑐᖅ ᐅᓄᕐᓂᖅᓴᐅᓚᐅᖅᑐᑦ ᓂᒋᐊᓄᖓᐅᔪᑦ). ᑕᐃᑲᓂ ᓂᒋᐊᓄᖓᐅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ ᕿᒪᒍᑎᓕᖅᐸᒃᑎᒃ BSA, ᑑᓚᓕᑦ ᕿᓚᓗᑲᐃᑦ ᑕᒍᔭᐅᓚᐅᖅᑐᑦ ᐃᖏᕐᕋᔪᖅ ᐅᐊᓐᓇᖓᓄᑦ, ᑭᓯᐊᓂ ᐅᒥᐊᕐᔪᐊᖅ ᐃᖏᕐᕋᔪᑦ ᑕᒪᕐᒥᐸᓗ ᐅᐊᓐᓇᖓᓄ, ᑭᓯᐊᓂ ᐅᒥᐊᕐᔪᐊᑦ ᖃᓂᒋᔭᖓᓃᓕᕈᑎᒃ (≤2 ᑭᓚᒦᑕᔅ). ᑑᓚᓕᑦ ᕿᓚᓗᑲᐃᑦ ᐃᖏᕐᕋᔭᓪᓗᑎᒃ ᓂᒋᐊᓄ ᑲᑎᖓᓪᓗᑎᒃ ᐊᒻᒪᓗ ᐅᐊᓈᖓᓄᑦ ᐅᓄᓗᐊᕋᑎᒃ.

- ᐃᖏᕐᕋᓂᖏᑕ ᓱᑲᓕᖏ– ᐅᓄᕈᖑᔪᑦ ᑑᒻᓕᑦ ᑲᑎᖓᔪᑦ ᐃᖏᕐᕋᕙᒃᑐᑦ ᓱᑲᓯᓗᐊᕋᑎᒃ, ᐅᒥᐊᕐᔪᐊᖅᑎᓪᓗᒍ/ ᐅᒥᐊᕐᔪᐊᖅᑕᖃᑎᖏᑎᓪᓗᒍ. ᐃᒻᒪᖅ ᑕᑯᔪᓐᓇᖅᑐᒍ ᓱᑲᐃᓈᕐᓂᖅᓴᐅᔪᑦ-ᐃᖏᕐᕋᓪᓗᑎᒃ ᑲᑎᖓᔪᑦ ᐅᓄᖅᓯᓯᒪᑎᓪᓗᒋᑦ ᐊᖏᔪᑦ ᐅᒥᐊᕐᔪᐊᑦ ᓂᒋᐋᑎᓪᓗᒋᑦ BSA (ᓇᓂᐊᖕᓄᑐᐃᓐᓇᖅ ᐃᖏᕐᕋᒐᓗᐊᕐᑯᑎᒃ ᐊᒻᒪᓗ ᓇᓃᓐᓂᖏᑦ ᑕᐃᑯᖓ BSA) ᐊᒻᒪᓗ ᖃᓂᓈᖅᑐᑦ (≤3 ᑭᓛᒦᑕᔅ). ᐅᒥᐊᕐᔪᐊᑦ ᐅᐊᖕᓇᖓᓃᑎᓪᓗᒋᑦ BSA, ᑕᑯᔪᓐᓇᓚᐅᖅᑐᒍᑦ ᓱᑲᐃᓵᖅᑐᑦ-ᐃᖏᕐᕋᔪᑦ ᑲᑎᖓᔪᑦ ᐱᑕᖃᓗᐊᓚᐅᖕᖏᑦᑐᑦ, ᐱᓗᐊᖅᑐᒥᒃ ᓂᒋᐊᓄᑦ ᐃᖏᕐᕋᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ. ᐃᒻᒪᖅ ᑕᑯᔪᓐᓇᖅᑐᑦ ᓱᒃᑲᐃᓵᖅᑐᓂᒃ-ᐃᖏᕐᕋᔪᑦ ᑲᑎᖓᓪᓗᑎᒃ ᐅᓄᓗᐊᕈᓃᖅᑐᑦ ᐅᓄᕈᓯᒋᕙᒃᑕᖏᓐᓂᑦ.
- ᐅᖓᓯᖕᓂᖓ ᐃᓗᕕᓕᖏᒥᑦ ᓯᒡᔭᖓᓂᑦ - ᑑᒻᓕᑦ ᕿᓚᓗᒐᐃᑦ ᑲᑎᖓᔪᑦ ᑕᑯᔭᐅᓯᒪᔪᑦ ᐊᒥᓱᐃᖅᑰᑎᒃ ᐅᖓᓯᑐᒦᑦᑐᑦ <300 ᒦᑕ ᐃᓗᕕᓕᒃ ᓯᒡᔭᖓᓂ ᑖᒃᑯᓇᖓᑦ ᖃᓅᑎᒋᓂᖏᓐᓂᓪᓕ ᑲᑎᖓᔪ <300 ᒦᑕ ᐃᒪᕙᖏᒥ ᐊᑖᒍᑦ ᑕᒪᕐᒥᒃ ᐅᒥᐊᕐᔪᐊᖅᑕᖅᖅᑎᓪᓗᒍ ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᖅ ᐱᑕᖃᖏᑎᓪᓗᒋᑦ. ᐃᒪᕙᖏᒥ ᐃᑎᔪᒥ ᑲᑎᖓᔪᑦ ᖃᐅᔮᔭᐅᓚᐅᖅᑐᑦ ᐊᑯᓚᐃᓐᓂᖅᓴᐅᖃᑦᑕᓕᖅᑐᑦ ᐊᖏᓪᓕᕙᓪᓕᐊᑎᓪᓗᒋᑦ ᐅᐊᓕᓂᐅᑉ ᑕᕆᐅᖓᓂ ᐊᖕᖏᔪ ᐊᑑᑎᖃᖅᑐᑦ, ᓇᓗᓇᐃᕈᑎᓚᐅᖅᑐᑦ ᑕᑯᔪᑦ ᐊᔪᖁᑎᖃᖅᑰᑎᒃ ᑕᕆᐅᖅ ᐊᔪᕐᓇᕐᑎᑦᑎᓂᖓᓄᑦ. ᖃᐅᔮᓴᕈᓯᕐᓂᑦ ᐋᕿᐅᑎᔪᑦ ᓇᓗᓇᐃᓚᐅᖅᑐᑦ ᐅᑯᐊ ᑑᒻᓕᑦ ᕿᓚᓗᒐᐃᑦ ᑲᑎᖓᔪᑦ ᐃᒪᕙᖑᐊᔾᑦᑐᑦ ᐱᑕᖃᖅᑎᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐃᓗᐊᓂ 3-6 ᑭᓛᒥᑕ ᑕᐃᑲᖓᑦ BSA, ᐱᓗᐊᖅᑐᒥᒃ ᐅᒥᐊᕐᔪᐊᑦ ᑐᕌᖅᑎᓪᓗᒋᑦ BSA (ᑖᒃᑯᓇᖓᓪᓕ ᐅᒥᐊᕐᔪᐊᑦ ᕿᒪᒍᑎᑦᑎᓪᓗᒋᑦ ᑕᐃᑲᖓᑦ BSA). ᑕᐃᑲᓂ ᐅᒥᐊᕐᔪᐊᑦ ᑲᓂᑐᒦᑎᓪᓗᒋᑦ, ᖃᐅᔮᓴᕆᑕᐅᔪᖅ ᓇᓚᐅᑖᓚᐅᖅᑐᖅ ᐅᑯᐊ ᑑᒻᓕᑦ ᕿᓚᓗᒐᐃᑦ ᓄᓇᖅᐸᓯᖏᒦᖅᑕᖅᑐᖅ ᑕᕆᐅᕐᒥ.

- ᐆᒪᔪᑦᑕᑯᔭᐅᔪᑦ ᓄᐊᑕᐅᔪᑦ ᑕᐃᒪᖓᓂ ᑎᓴᒪᓄᑦ-ᐅᑭᐅᓄᑦ ᐃᓕᑕᐅᓇᓱᒃᑐᑦ ᓇᓗᓇᐃᖅᓯᒪᔪᑦ ᐃᒪᓐᓇ ᐊᑖᓂ ᑎᑎᕋᖅᓯᒪᕗᖅ:
  - ᑕᒪᕐᒥᐸᓗᒃ ᑑᒻᓕᑦ ᕿᓚᓗᒐᐃᑦ ᑎᑎᕋᖅᑕᐅᔪᑦ ᑕᐃᑲᓂ SSA ᑕᐃᑲᓂ ᑎᓴᒪᓄᑦ-ᐅᑭᐅᓄᑦ ᐃᓕᑕᐅᓇᓱᒃᑎᓪᓗᒋᑦ ᐱᓕᕆᐊᖃᓚᐅᖅᑐᖅ ᐃᖏᕐᕋᓪᓗᑎᒃ ᖃᓄᐃᓕᐅᕐᓂᖏᓐᓂᒃ. ᐊᓯᖏᑦ ᖃᓄᐃᓕᐅᕈᓯᖏᑦ ᑕᑯᔭᐅᓚᐅᖅᑐᑦ ᑕᐃᑲᓂ SSA ᐃᓚᖃᖅᑐᑦ ᐊᒫᒪᒃᑎᑦᑎᔪᑦ, ᐊᒃᑐᐊᔪᑦ, ᑑᒐᕐᑎᒃ, ᓂᕆᔪᑦ, ᐊᒻᒪᓗ ᓄᓕᐊᖅᑐᑦ. ᑕᒪᖓᓂ ᐊᕐᕋᒍᓂ, ᑑᒻᓕᑦ ᕿᓚᓗᒐᐃᑦ ᐃᓅᓯᕐᓂᑯ ᑕᑯᔭᐅᕙᓚᐅᖅᑐᑦ ᑕᐃᑲᓂ SSA, ᑕᑯᔭᐅᕙᓪᓗᑎᓪᓗ ᐊᒫᒪᒃᑎᑕᐅᔪᑦ ᑎᑎᕋᖅᑕᐅᓯᒪᓚᐅᖅᑐᑦ 2015 (ᒪᕐᕈᐃᖅᓱᑎᒃ), 2016 (ᑎᓴᒪᐃᖅᓱᑎᒃ) ᐊᒻᒪᓗ 2017 (ᒪᕐᕈᐃᖅᓱᑎᒃ). ᑕᐃᑲᓂ 11 ᐋᒍᓯ 2016, ᐃᓅᔪᖃᓚᐅᖅᑐᖅ ᑑᒻᓕᖏᒥ ᓯᓚᑖᓂ ᐃᓗᕕᓕᒃ ᑕᑯᔭᐅᓚᐅᖅᑐᖅ. ᑕᐃᒪᓗ, ᑕᑯᔭᐅᖃᑦᑕᖅᑐᓄ ᐃᑲᔫᑎᔪᑦ ᐃᓱᒪᒋᔭᐅᓪᓗᓂ ᐅᓇ ᐃᓚᖓ ᕿᑦᖑᐊᑦ ᐱᒻᒪᕆᐅᒋᔭᐅᔪᖅ ᕿᑐᕐᖏᐅᕝᕙᐅᓪᓗᓂ,
  - ᑑᒻᓕᑦ ᕿᓚᓗᒐᐃᑦ ᐱᑕᖃᓗᔫᖑᔪᑦ ᓂᒋᐊᓂ SSA ᖃᓂᒋᔭᖓᓂ ᑯᓗᑑ ᐸᐃ ᐊᒻᒪᓗ ᐅᓯᓇᐊᕐᓂᕙᖓᓂ ᑭᑦᖑᐊᑕ ᐃᒃᓯᕙᖓᓄᑦ, ᑕᐃᒫᑦᑕᐅᖅ ᓇᓐᓂᖏᑦ ᑑᒻᓕᑦ ᕿᓚᓗᒐᐃᑦ ᐅᖃᐅᓯᐅᓯᒪᔪᑦ ᑕᐃᑲᓂ ᖃᖓᑕᓱᒃᑯᑦ ᓈᓴᖅᑕᐅᑎᓪᓗᒋᑦ ᐱᓕᕆᔭᐅᔪᑦ ᕿᑦᖑᐊᓂ ᓄᓇᖓᓐᓂ (ᑖᒪᔅ ᐊᓯᖏᓪᓗ 2015, 2016; ᒎᑐ 2018b) ᖃᐅᔨᓇᖅᓯᓚᐅᖅᑐᑦ ᐱᒻᒪᕆᐅᔪᖅ ᑯᓗᑑ ᐸᐃ ᕿᒫᕙᐅᖃᑦᑕᕐᒪᑦ ᑑᒻᓕᑦ ᕿᓚᓗᕐᓂᑦ ᓯᑯᖅᑎᓇᒍ ᐊᐅᔭᒃᑯᑦ.
  - ᑭᐅᓯᔾᔪᑎᖏᑦ ᑑᒻᓕᑦ ᕿᓚᓗᒐᐃᑦ ᑕᒪᑐᒧᖓ ᓴᕙᕋᔭᒃᓴᓂᒃ ᐅᓯᑲᖅᑕᖅᑐᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐊᔾᔨᒌᖏᑦᑐᑦ, ᑕᒫᒐ 'ᖃᐅᔨᓇᖅᑐᓂᑦ ᑭᐅᓯᔾᔪᑎᖃᕋᑎᒃ' ᑕᐃᒪᓗ ᐅᑯᐊ ᓂᕐᔪᑎᑦ ᓱᓕ ᖃᓂᒋᔭᖏᓐᓃᐸᒃᑐᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐅᓯᑲᖅᑕᖅᑐᑦ ᑭᐅᓯᓪᓗᑎᒃ ᑑᒻᓕᖕᓂᒃ ᑖᒃᑯᓄᖓ ᓴᕙᕋᔭᒃᓴᓂᒃ ᐅᓯᖃᑦᑕᖅᑐᑦ ᖃᓄᑐᐃᓐᓇᖅ ᐊᔾᔨᒌᓚᐅᖕᖏᑦᑐᑦ, ᑕᒫᖓ 'ᑭᐅᓯᖏᑦᑎᐊᒻᒪᕆᐋᕆᑎ' ᐅᑯᐊᓗ ᓂᕐᔪᑎᑦ ᓱᓕ ᖃᓂᒋᔭᖓᓄᐊᑦᑕᖅᑐᑦ ᓴᕙᕋᔭᒃᓴᓂᒃ ᐅᓯᑲᖅᑕᖅᑐᓄᑦ ᑕᐃᒪᓗ ᐃᖏᕐᕋᕙᒃᑲᒥᒃ ᑕᐃᑯᓇ SSA, ᐃᓖᓐᓂᓚᐅᓱᖓᒃᑯᑦ ᐊᒻᒪᓗ ᐅᐸᒃᓯᒪᔭᒥᖏᓐ ᓇᓕᖁᔮᓚᐅᕿᑦ ᐊᒻᒪᓗ ᒪᓕᒡᓗᒋᑦ ᐃᓕᖁᓯᖏᑦ ᐊᓯᑦᔮᖅᐸᒡᓗᑎᒃ. ᑕᐃᒪᓐᓇᐅᒐᓗᐊᖅᑎᓪᓗᒍ, ᐅᓄᓗᐊᕌᓗᓚᐅᖕᖏᑦᑐᑦ ᑑᒻᓕᑦ ᓄᓇᖓᓂ ᑕᑯᔭᐅᔪᓂ.
  - ᑕᐃᑲᓂ ᐊᑐᓂ ᖃᐅᔮᓴᕈᑎᓂ ᐊᕐᕌᒍᒥ, ᑑᒻᓕᑦ ᕿᓚᓗᒐᐃᑦ ᑕᑯᔭᐅᓚᐅᖅᑐᑦ ᑭᐅᓯᑎᓪᓗᒋᑦ ᖁᑭᖅᓴᖅᑐᓂᒃ ᐊᖅᑲᐅᒪᓕᖅᑯᑎᒃ ᐊᒻᒪᓗ ᓱᑲᓪᓗᑎᒃ ᐃᖏᕐᕋᓂᖏᑦ ᐊᖅᑲᐅᒪᓪᓗᑎᒃ. ᑕᒻᔭᐅᒐᓗᐊᕐᒪᑕ ᐊᒥᓱᐃᖅᑕᐅᓪᓗᓯᑎᒃ ᖁᑭᖅᓵᖑᔪᑦ ᑕᐃᑲᖓᑦᑕᐃᓐᓇᖅ (ᓱᕐᓗ ᐊᖑᓇᓱᒃᑲᖕᓂᑦ ᖁᕈᓂᑦ

ᖁᖏᐊᖅᑕᐅᓪᓗᑎᒃ), ᑑᒎᓕᑦ ᕿᓚᓗᒐᐃᑦ ᑕᑯᔭᐅᖃᑦᑕᓚᐅᖅᑐᑦ ᑕᐃᒪᖓᓂ ᐅᑎᕖᑦ ᓄᓇᒧᑦ ᑕᐃᑲᓂ ᐅᐸᒃᓯᒪᕕᒋᔭᒥᖕᓄᑦ ᐃᓗᕕᓕᖕᒥ, ᑕᐃᒪᓗ ᐊᔾᔨᒌᖕᖏᑦᑐᑦ ᖃᖓᒃᑯᑦ ᐅᑎᖅᐸᒍᓯᖏᑦ.

- 2016-ᒥ, ᑑᒎᓕᑦ ᕿᓚᓗᒐᐃᑦ ᑕᑯᔭᐅᓯᒪᔪᑦ ᓂᕆᔪᑦ ᐅᒐᕐᓂᒃ ᖃᓂᒋᔭᖓᓂ ᐃᓗᕕᓕᒃ ᓯᕙᔭᖓᓂ 9-ᐅᓪᓗᓄᑦ ᖁᕕᓂ ᐋᒍᓯ. ᐊᕐᓇᑦ ᕿᓚᓗᒐᐃᑦ ᒪᕐᑭᓕᖅᓱᑎᒃ ᓂᕆᖃᑎᒌᑦ ᐅᓄᖅᑐᓂᒃ ᓂᕆᑎᑦᑎᒐᒥᒃ ᐃᓅᓭᕐᓂᑯᓂᒃ ᐅᖕᓗᓐᓅᑦ ᐊᕐᕋᒍᑖᖅᓯᒪᔪᓂᒃ.

ᐊᑖᓂ ᑎᑎᕋᖅᓯᒪᔪᑦ ᐃᓱᒪᒋᔭᐅᓗᑎᒃ ᐃᒃᐱᒋᓪᓗᒍ ᓯᓀᓂᒃᓴᑦᑎᓂ ᓯᒡᔭᖓᓂ-ᐱᓯᒪᓗᑎᒃ ᒥᐊᓂᕆᓗᑎᒃ:

- ᐱᒋᐊᕐᓂᖓᓂᑦ ᑑᒎᓕᑦ ᖃᓄᐃᓕᐅᖃᑦᑕᖅᑐᑦ ᒫᓇᐅᔪᖅ SSA ᐃᖏᕐᕋᓪᓗᑎᒃ ᖃᓄᐃᓕᐅᖃᑦᑕᕈᓯᖏᑦ, ᐅᑯᐊᓗ ᖃᐅᔨᓇᓱᒡᓗᒋᑦ ᐱᔭᕐᓂᖕᖏᓂᖅᑕᐅᒐᔭᖅᑐᖅ ᑑᒎᓕᑦ ᕿᓚᓗᒐᐃᑦ ᑭᐅᓯᓂᖏᑦ ᐅᒥᐊᕐᔪᐊᓂ ᐃᖏᕐᕋᔪᓂᒃ ᑖᒃᑯᓇᖓᓪᓕ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᔪᓄᑦ ᐃᖃᖓᓂ ᐱᓯᒪᔪᓂ ᖃᓄᐃᓕᐅᖅᑎᑦᑎᒐᔭᕐᓂᖏ (ᓇᕐᓗ, ᓴᓇᕕᖏ, ᓂᕆᕕᖏᑦ ᐊᓯᖏᓪᓗ). ᐊᓯᐊᓂ ᐃᓂᖃᕈᑎᒃ ᑕᑯᓐᓇᖅᑐᑦ ᖃᐅᔨᔭᐅᓇᓱᑦᑎᐊᕐᒥᓗᑎᒃ ᖃᐅᔨᓴᕐᕕᒃᑖᑦᑎᐊᕐᓂᐊᕐᒪᑕ ᐃᓚᖓᓂ ᐅᒥᐊᕐᔪᐊᑦ ᐃᖏᕐᕋᕕᖏᑕ ᐊᕐᑯᑎᖏᓂ ᖃᓂᒐᔭᓂ ᑯᓗᑐ ᐸᐃ, ᑕᐃᑰᓇᖃᑦᑕᖅᑐᑦ ᑑᒎᓕᑦ ᖃᓄᐃᓕᐅᕐᕕᒋᓗᐊᕐᑰᔩᖏᓪᒪᒍ.
- ᐃᓚᓕᐅᑎᔪᑦ ᐅᑯᐊ ᑕᑯᔾᔪᑕᐅᔪᑦ ᖁᓕᒥᒎᓕᖑᐊᑦ ᐊᔾᔨᓕᐅᕈᑎᓕᑦ ᐃᓄᖃᖕᖏᑦᑐᑦ. ᐅᓇ ᐊᑐᖅᑕᐅᓯᒪᔪᖅ ᐊᑐᕈᓐᓇᖅᑕᒥᖕᓂᒃ ᐋᑎᖃᕈᒪᓪᓗᑎᒃ ᖃᐅᔨᓇᖅᓯᑦᑎᐊᕐᓂᐊᕐᒪᑕ ᑕᑯᓗᒋᑦ ᖁᕕᓂᑦ ᐊᑦᑎᒃᑐᒦᑦᑐᓂ ᑕᑯᔭᐅᔪᓐᓇᖕᖏᑦᑐᓂᑦ ᐅᖕᓗᓐᓅᑦ ᐅᐊᓯᒃᑐᓄᑦ. ᐊᒻᒪᓗ, ᖁᓕᒥᒎᓕᖑᐊᑦ ᐊᔾᔨᓕᐅᕈᑎᑦ ᓴᕿᑎᑕᖏᑦ ᐃᑲᔫᑎᒋᔭᖅᑐᑦ ᖃᐅᔨᒪᓚᐅᖕᖏᑕᖏᓐᓂᒃ ᖃᐅᔨᒪᓕᕈᑕᐅᓗᑎᒃ ᑑᒎᓕᑦ ᕿᓚᓗᒐᐃᑦ ᖃᓄᐃᓕᐅᕈᓯᖏᓐᓂᒃ ᐊᒻᒪᓗ ᓇᓕᐊᖑᒻᒪᖔᑕ ᑖᒃᑯᓇᖓᑦ BSA, ᑕᐃᑲᓂ ᑕᑯᔭᖅᑐᖅᓯᒪᔪᑦ ᑎᑎᕋᕈᓐᓇᕋᔭᓚᐅᖕᖏᑕᖏᓐᓂᒃ ᓇᓪᓕᐊᖕᓂᑦ ᑲᑎᖓᔪᑦ ᖃᓄᐃᓕᐅᕈᓯᖏᑦ ᐱᔾᔪᑎᒋᓪᓗᒍ ᑕᑯᔫᓇᕋᔭᓚᐅᖕᖏᑕᖏᓐᓂᒃ.
- ᖃᐅᔨᓇᓱᑦᑎᐊᖅᓱᒋᑦ ᐊᒃᑐᐃᔫᓇᖅᑐᑦ ᐊᑕᐅᑦᑎᒎᖅᑎᓪᓗᒋᑦ ᐃᖏᕐᕋᔪᑦ ᐅᓄᖅᑐᓪᓗ ᐊᖕᖏᔪᑦ ᐅᓯᑲᖅᑕᖅᑐᑦ ᐅᒥᐊᕐᔪᐊᑦ ᑖᒃᑯᓄᖓ ᑑᒎᓕᖕᓄᑦ ᐅᓄᓗᐊᖕᖏᑦᑐᑦ ᐊᒻᒪᓗ ᓇᒧᖔᑎᖅᓯᒪᓂᖏ ᐊᒻᒪᓗ ᖃᓄᐃᓕᐅᕈᓯᖏᑦ. ᑕᐃᑲᓂ ᒫᓇᐅᔪᖅ, ᖃᐅᔨᒪᔭᐅᖕᖏᑦᑐᖅ ᐊᒃᑐᐃᓂᖏᑦ ᐊᑕᐅᑦᑎᒍᕐᓗᑎᒃ ᐃᖏᕐᕋᓗᑎᒃ ᐊᑕᐅᓯᕐᒧᑦ ᐅᒥᐊᕐᔪᐊᒧᑦ ᐊᖏᔪᒧᑦ ᐅᓯᑲᖅᑕᖅᑐᒧᑦ ᐊᔾᔨᒋᖕᖏᑦᑕᖓ ᐊᑕᐅᓯᕐᒥᑦ ᐅᓄᖅᑐᓄᑦ.
- ᐃᓚᓕᐅᑎᓪᓗᒋᑦ ᓂᐱᖏᖕᓂᒃ ᒥᐊᓂᕆᓂᖅ ᓯᒡᔭᒥ-ᐃᓂᖃᕐᓗᑎᒃ ᑕᑯᓇᓱᒡᓗᑎᒃ ᖃᐅᔨᓴᕈᓯᕐᓂᒃ ᐊᑐᕐᓗᑎᒃ ᑕᐃᒪᓗ ᐊᒻᒪᓗ ᐱᑕᕈᓂ ᑑᒎᓕᒃ ᕿᓚᓗᒐᖅ ᐊᓯᑦᔨᖅᓯᒪᓗᓂ ᓂᐱᖓ ᖃᓄᐃᓕᐅᕈᓯᖓᓄ ᑭᐅᓯᓇᔭᖅᑐᖅ ᐅᒥᐊᕐᔪᐊᓄᑦ ᐃᖏᕐᕋᔪᓄᑦ.

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1.0 INTRODUCTION

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

1.1 Project Background

The Mary River Project (hereafter, "the Project") is an operating open pit iron ore mine located in the Qikiqtani Region of North Baffin Island, Nunavut (Figure 1-1). Baffinland Iron Mines Corporation (Baffinland) is the owner and operator of the Project. The operating Mine Site is connected to a port at Milne Inlet (Milne Port) via the 100-km long Milne Inlet Tote Road. 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 of the Project, which includes shipping up to 4.2 Mtpa of ore via Milne Port during July to late October, and the deferral of ore shipments from Steensby Port. Shipping of ore from Milne Inlet during the ERP began in 2015 and is expected to continue for the life of the Project (20+ years). During the first year of ERP Operations in 2015, Baffinland shipped ~900,000 tonnes of iron ore out of Milne Port involving 13 return ore carrier voyages. In 2017, the total volume of ore shipped out of Milne Port reached ~4.2 million tonnes involving 56 return ore carrier voyages.

The Bruce Head Shore-based Monitoring Program focuses on Project-related issues of primary concern with respect to narwhal, as identified through consultation with the applicable regulators, Project stakeholders, and local communities to date. Since 2013, regular community engagement meetings regarding the Project have been carried out in Arctic Bay, Clyde River, Hall Beach, Igloolik, and Pond Inlet. Primary concerns identified by the communities with respect to potential Project effects on marine mammals along the Northern Shipping Route include:

- Loss or alteration of narwhal habitat due to port construction and shipping.
- Injuries or mortality of marine mammals due to ship strikes.
- Disturbance effects on marine mammals from port construction and shipping noise, as well as close ship encounters (i.e., presence of ships), that may lead to changes in animal distribution, abundance, migration patterns, and subsequent availability of these animals for harvesting.

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

1.2 Study Objective

The objective of the Bruce Head shore-based monitoring study is to investigate narwhal response to shipping activities along the Northern Shipping Route in Milne Inlet, with data collected annually on relative abundance and distribution (RAD), group composition, and behaviour. Additional data were also collected on environmental conditions and anthropogenic activities (e.g., shipping and hunting activities) to distinguish between the potential effects of Project-related shipping activities and confounding factors which may also affect narwhal behaviour. The current study aims to evaluate the effect of Project-related vessel traffic on narwhal at Bruce Head through the analysis of the 2014–2017 dataset of RAD, group composition and behaviour data relative to the respective large vessel traffic data, environmental data, and sampling conditions.

LEGEND

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

0 125 250

1:5,000,000 KILOMETRES

REFERENCE(S)

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT – BRUCE HEAD MONITORING PROGRAM (2014-2017)

TITLE
PROJECT LOCATION

CONSULTANT

GOLDER

YYYY-MM-DD	2018-11-26
DESIGNED	SU
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	11000-08	0	1-1

2.0 NARWHAL BACKGROUND

2.1 Population Status and Abundance

Narwhal are endemic to the Arctic, occurring in deep Arctic waters, primarily in Baffin Bay, the eastern Canadian Arctic, and the Greenland Sea (Reeves et al. 2012). Seldom present south of 61º N latitude (COSEWIC 2004), two populations are recognized in Canadian waters; the Baffin Bay population and the northern Hudson Bay population (Watt et al. 2017). Of these, only the Baffin Bay population occurs seasonally along the Northern Shipping Route (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, Fisheries and Oceans Canada (DFO) has defined seven narwhal stocks (i.e., resource units subject to hunting) in Nunavut: Jones Sound, Smith Sound, Somerset Island, Admiralty Inlet, Eclipse Sound, East Baffin Island, and Northern Hudson Bay (Doniol-Valcroze et al. 2015). These stocks were selected based on tracking data indicating geographic segregation in summer (year-round segregation from the others in the case of the northern Hudson Bay stock) and also on evidence from genetic and contaminants studies that supported this stock partitioning. Subdividing the management units was recommended by DFO as a precautionary approach that would reduce the risk of over-exploitation of a segregated unit with site fidelity in summer (Richard et al. 2010). Previous management had been on the basis of two narwhal stocks comparable to those considered in the COSEWIC (2004) assessment: the High Arctic stock (also called Baffin Bay stock by the Joint Commission on Conservation and Management of Narwhal and Beluga [JCNB] working group and the Northern Hudson Bay stock.

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

The Canadian High Arctic Cetacean Survey conducted by DFO in August 2013 was the first complete survey of six major narwhal summering aggregations in the Canadian High Arctic (DFO 2015). The total abundance estimate, corrected for diving and observer bias, was 141,909 narwhal. Coefficients of variation ranged from

20%-65% for the different stocks and the corrected estimate for the Eclipse Sound area was 10,489 narwhal with a coefficient of variation of 24%. Annual variation in narwhal stock estimates between adjacent summering areas, Eclipse Sound and Admiralty Inlet, indicate that there is possible movement between these two summering ground locations (Thomas et al. 2015). Inuit Qaujimajatuqangit (IQ)[1] from northern Baffin Island communities suggests that narwhal numbers are increasing (Stewart 2001). For example, it was reported that, until the 1970s, narwhal in Clyde River were predominantly fall migrants; more recently, narwhal have been observed in this area from spring until fall (Stewart 2001). However, community workshop participants from Pond Inlet did not note any visible change to narwhal populations from year to year or changes to the abundance of narwhal in Eclipse Sound (JPCS 2017).

2.2 Geographic and Seasonal Distribution

Narwhal show high levels of site fidelity, annually returning to well-defined summering and wintering areas (Figure 2-1) (Laidre et al. 2004; Richard et al. 2014). During summer, narwhal tend to remain in deep-water coastal areas that are thought to provide protection from the wind (Kingsley et al. 1994; Koski and Davis 1994; Richard et al. 1994). In winter, narwhal move onto feeding grounds located in deep fjords and the continental slope where water depths are 1000 to 1500 m, and where upwelling increases biological productivity and supports abundant prey species including squid, flatfish (i.e., turbot), and Greenland halibut (Dietz and Heide-Jørgensen 1995; Dietz et al. 2001; Richard et al. 2014). IQ indicates that narwhal enter leads into Eclipse Sound in July with large males ahead of females and calves (JPCS 2017). Eclipse Sound is considered a particularly important summering area (Koski and Davis 1994; DFO 2015) and satellite tracking studies of narwhal summering in Tremblay Sound have shown that summering narwhal remain in a relatively small area including western Eclipse Sound and inlets during August (Dietz and Heide-Jørgensen 1995; Dietz et al. 2001). The distribution of narwhal in Eclipse Sound, Milne Inlet, Koluktoo Bay, and Tremblay Sound during summer is thought to be determined by the presence and distribution of ice and by the presence of killer whales (Kingsley et al. 1994).

Narwhal generally begin migrating out of their summering areas in late September (Koski and Davis 1994). IQ indicates that narwhal migrate in October and November through Eclipse Sound and Pond Inlet to overwintering areas in Baffin Bay and Davis Strait. Narwhal migratory routes to their overwintering grounds will change from year to year depending on ice conditions (JPCS 2017). Individuals exiting Eclipse Sound and Pond Inlet migrate down the east coast of Baffin Island in late September (Dietz et al. 2001). Individuals summering near Somerset Island enter Baffin Bay north of Bylot Island in mid- to late October (Heide-Jørgensen et al. 2003). By mid- to late October, narwhal leave Melville Bay and migrate southward along the west coast of Greenland in water depths of 500 to 1000 m (Dietz and Heide-Jørgensen 1995). Narwhal generally arrive at their wintering grounds in Baffin Bay and Davis Strait during November (Heide-Jørgensen et al. 2003) where they associate closely with heavy pack ice comprised of 90 to 99% ice cover (Koski and Davis 1994). Elders have indicated that while the majority of narwhal overwinter in Baffin Bay, some animals remain along the floe edges at Pond Inlet and Navy Board Inlet (DEIS 2010). Narwhal tracking data have identified two distinct wintering areas for the Baffin Bay population. 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

[1] Inuit Qaujimajatuqangit (IQ) refers to Inuit “Traditional Knowledge” that includes local and community-based knowledge, and ecological knowledge that encompasses the daily life of Inuit people (NIRB 2018).

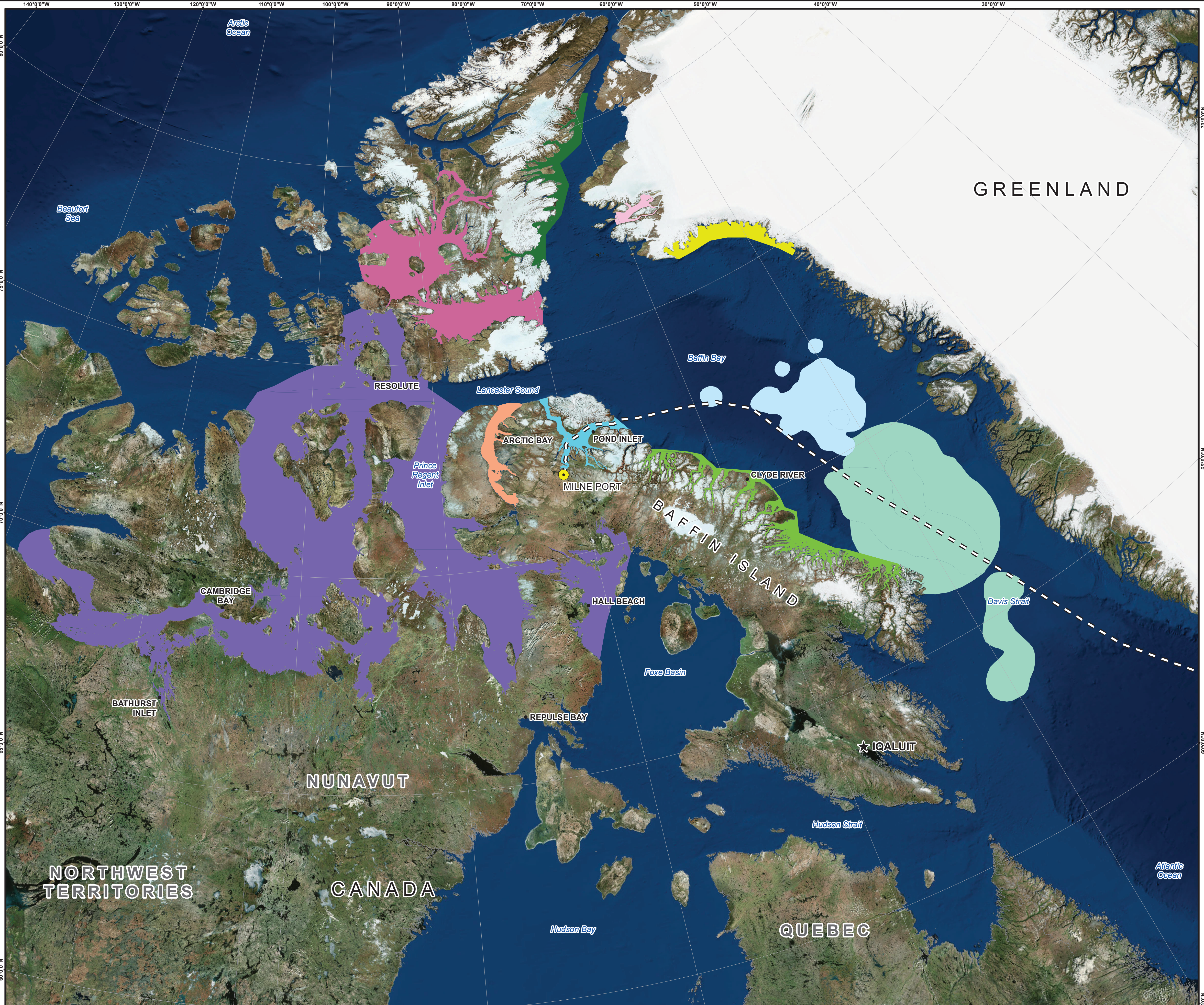
Eclipse Sound, and the Greenland narwhal stock from Melville Bay. The second wintering area is located in central Baffin Bay (referred to as the northern wintering area) and is used by narwhal from the Somerset Island summering stock (Richard et al. 2014).

IQ indicates that 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).

In Milne Inlet, narwhal are usually observed in small groups or clusters[2] but may occur in herds of up to several hundred individuals. Visual observations from Bruce Head indicate that narwhal travel in clusters averaging 3.5 individuals (range: 1 to 25), and that they generally enter Koluktoo Bay in larger clusters than when they exit the bay (Marcoux et al. 2009). Marcoux et al. (2009) counted up to 642 such clusters making up a herd, with an average number of 22.4 clusters/herd. These observations are similar to IQ that indicate narwhal travel in groups of 10-20 individuals (Furgal and Laing 2012).

Killer whales are well known to prey on narwhal. Laidre et al. (2006) observed an attack on tagged narwhal in Admiralty Inlet in August 2005 in which at least 4 narwhal were killed by 12-15 killer whales within 6 hours. Before the attack but in the immediate presence of killer whales, narwhal moved slowly and quietly, travelling close to the beach (often within 2 m of the shore) in very shallow water, and formed tight groups at the surface (Laidre et al. 2006). During the attack, narwhal beached themselves in sandy areas and made tail slaps. During the five days after the attack, the narwhal were widely dispersed and spatial use doubled from the pre-attack home ranges of 347 km^2 to 767 km^2. Shore observers determined that normal observable behaviour resumed approximately one hour after the killer whales left the area (Laidre et al. 2006). Similar results were observed for satellite telemetry tagged groups of killer whales (one tagged individual representing a group of 12-20 individuals) and narwhals (seven tagged individuals) in Admiralty Inlet in August 2009 (Breed et al. 2017). When the killer whale group entered the Inlet and was within approximately 100 km, narwhal maintained close proximity (within 500 m) to the shoreline. When the killer whale group retreated, narwhal moved offshore, generally between four and ten kilometers from the shoreline (Breed et al. 2017). Narwhal dive behaviour was affected when killer whales were present, with narwhal diving more frequently to deeper depths and for shorter durations than when killer whales were absent (Breed et al. 2017). Polar bears and sharks may also prey opportunistically on narwhal, as unsuccessful attacks by both species have been reported by Inuit (Stewart 2001).

[2] A cluster was defined as a group with no individual more than 10 body lengths apart from any other. The end of a herd was defined as the point when no narwhal were seen passing a shore-based observation point for 30 minutes (Marcoux et al. 2009).



LEGEND

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

SUMMER AGGREGATION AREA

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

WINTER AGGREGATION AREA

- NORTHERN WINTERING AREA
- SOUTHERN WINTERING AREA

REFERENCE(S)

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

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT – BRUCE HEAD MONITORING PROGRAM (2014-2017)

TITLE
NARWHAL SUMMERING AND WINTERING AREAS – BAFFIN BAY POPULATION

CONSULTANT
GOLDER

YYYY-MM-DD	2018-11-26
DESIGNED	SU
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	11000-08	0	2-1

2.3 Reproduction

Female narwhal are believed to reach sexual maturity at 8 to 9 years of age, while males are estimated to reach sexual maturity between the ages of 12 and 20 (Garde et al. 2015). Pond Inlet hunters reported that narwhal mating activity occurs in areas off the northern coast of Bylot Island and at the mouths of Navy Board and Pond Inlet at the floe edge. Eclipse Sound, Tremblay Sound, Milne Inlet, and Koluktoo Bay have also been reported as mating areas (Remnant and Thomas 1992). At least one presumed mating event was observed from the Bruce Head observation platform in southern Milne Inlet during the 2016 open-water season (Smith et al. 2017). Conception generally occurs between late March and late May but narwhal have also been observed mating in June at the Admiralty Inlet floe edge and in August in western Admiralty Inlet (Stewart 2001). Calving then takes place within inlets, bays, fjords, sounds, mouths of rivers, and the open water at the floe edge, however IQ indicates that calving can occur anywhere (Furgal and Laing 2012). Calving is known to occur in Pond Inlet, Navy Board Inlet, Eclipse Sound, Milne Inlet, and Koluktoo Bay (Remnant and Thomas 1992; JPCS 2017). On average, females are thought to produce a single calf approximately every three years until about 23 years of age (COSEWIC 2004), though many Inuit believe that narwhal give birth more frequently, perhaps annually (COSEWIC 2004). Gestation for narwhal is on the order of 14-15 months (COSEWIC 2004) with IQ suggesting 15 months based on fetuses observed (Furgal and Laing 2012). Newborn calves are primarily born between May and August each year and measure 140 to 170 cm in length, approximately 1/3 the body length of an adult female (Charry 2017). Typically, newborn calves travel less than one body length away from their mother and were found to travel in mean group sizes of five individuals (5.0 ± 3.03 Standard Deviation [SD]) in Eclipse Sound and in mean groups sizes of two individuals (2.0 ± 0.0 SD) in east Baffin Island (Charry 2017). Calves are generally weaned at 1–2 years of age (COSEWIC 2004).

2.4 Food Sources

Finley and Gibb (1982) surveyed the diet of 73 narwhal near Pond Inlet from June through September (1978-1979) and found food remains in 92% of the stomachs analyzed. Feeding was found to be most intensive at the floe edge and leads in spring with limited feeding occurring in fiords in late summer. Diet consisted of pelagic and benthic species including Arctic cod (*Boreogadus saida*) (found in 88% of 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). Tracking data from tagged narwhal show differences in narwhal diet and dive behaviour between the summering and wintering areas as well as between the two wintering areas. Surface dives (0 to 50 m) and the time spent at the surface is higher in the summering areas and lower in the wintering areas (Richard et al. 2014). In the northern wintering area, narwhal primarily dive to depths between 200 and 400 m and have a smaller proportion of Greenland halibut in their diet. In the southern wintering area, narwhal primarily dive to depths over 1000 m and have a larger proportion of their diet composed of Greenland halibut (Richard et al. 2014). As narwhal travel to the floe edge on their summer migration, stomachs contained mainly Arctic cod but there was a shift toward Greenland halibut as the narwhal moved through Pond Inlet (Finley and Gibb 1982).

Deep diving in marine mammals is energetically costly and requires lipid-rich prey or abundant food sources to support this activity (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 (Watt et al. 2015; 2017). Previous studies suggested that narwhal spend less time feeding while at their summering grounds compared to feeding in the winter or spring (Mansfield et al. 1975; Finley and Gibb 1982; Laidre et al. 2004; Laidre and Heide-Jørgensen 2005). Targeted deep dives in narwhal was used as a proxy to indicate important foraging areas or other important areas for other life-history traits in both summering and wintering areas (Watt et al. 2017). Watt et al. (2017) found that Eclipse Sound narwhal dives were deep dives in 75% of cases in their summer range, suggesting that foraging was occurring, countering the argument that narwhal spend limited time feeding during this time as evidenced from empty stomachs. Satellite tracking of 21 narwhal from both the Baffin Bay (whales tagged in Tremblay Sound in 2010 and 2011) and northern Hudson Bay (whales tagged in Lyon Inlet in 2006 and Repulse Bay in 2007) populations provided information on diving behaviour (Watt et al. 2017). A kernel density analysis indicated that important deep foraging areas for the Baffin Bay population are in Eclipse Sound in summer and in Davis Strait in winter. Important deep foraging areas for the northern Hudson Bay population are in northwestern Hudson Bay in summer and the eastern side of the Hudson Strait entrance in winter (Watt et al. 2017). The authors hypothesized that the Baffin Bay narwhal population would spend equal amounts of time at both mid-water and deep-water foraging locations; however, summering narwhal spent less time foraging in mid-water (approximately 15%) compared to deep zones (approximately 25%) with dives ranging from 75 to 100% of total bottom depth. Thus, narwhal spent some of their time foraging throughout their summering range as well as foraging in deep water. However, narwhal spent the majority of their time at the surface, likely recovering from deep dives (Watt et al. 2017) and engaging in other activities.

2.5 Narwhal Vocal Behaviour

Narwhal are a highly vocal species that produce a combination of pulsed calls, clicks, and whistles in order to communicate, navigate, and forage (Ford and Fisher 1978; Shapiro 2006; Marcoux et al. 2011; Rasmussen et al. 2015). Narwhal vocalization studies indicate that this species primarily vocalizes in the 300 Hz to 24 kHz range (Ford and Fisher 1978; Marcoux et al. 2011; Marcoux et al. 2012).

Pulsed sounds generated by toothed whales are characterized by short duration broadband signals (or ‘pulses’) whereas pure tone sounds are signals emitted at one single frequency of variable duration. For this reason, the following description of narwhal vocal behaviour is divided into pulsed sounds (including pulsed calls, echolocation clicks and buzzes) and pure tones (i.e., whistles). Although relatively little is known about narwhal acoustic communication given their remote Arctic distribution, recent studies continue to shed light on the specific call characteristics of narwhal and the potential context-specific variation among individuals and groups (Marcoux et al. 2012).

2.5.1 Pulsed Sounds / Clicks

According to Ford and Fisher (1978), pulsed sounds are a predominant form of narwhal vocalization and are comprised of pulsed tones and click series. Pulsed tones (or ‘pulsed calls’) possess pulsed repetition rates that vary irregularly over the series’ duration (Ford and Fisher 1978). They have distinct tonal properties and are highly variable in duration and pitch. For example, narwhal sounds ranging from high frequency ‘screams’ and ‘screeches’ to low frequency ‘grunts’ were all found to have pulsed components (Ford and Fisher 1978). According to Ford and Fisher (1978), the majority of repetitive pulsed tones emitted by narwhal have durations between 0.56 s and 1.34 s and are concentrated between 500 Hz and 5 kHz. Conversely, click series are often repeated several times at regular intervals and each tone exhibits a nearly identical pulse repetition rate and frequency structure, making these sounds easily discernable by ear (Ford and Fisher 1978).

Narwhal emit long series of pulses/clicks or ‘click trains’ (inter-click interval of 33 to 500 ms) associated with echolocation, as well as short bursts of broadband clicks or ‘burst pulse sounds/buzzes’ (shorter inter-click interval of 2.5 to 25 ms) (Miller et al. 1995). As an echolocating animal gets closer to its target, the rate at which it emits clicks becomes faster and the interval between clicks becomes shorter. This series of echolocation clicks leading up to a prey capture is commonly referred to as a ‘click train’. As the inter-click interval becomes sufficiently short, the click train often begins to sound like a ‘buzz’, thus resembling a burst-pulse sound. Narwhal click series repetition rates range from 4 to 370 clicks per second, with the majority occurring between 5 and 10 clicks per second and between 50 and 60 clicks per second (Ford and Fisher 1978). Most click series/trains emitted by narwhal are broadband and are concentrated between 12 and 24 kHz, though many click series with low repetition rates (< 15 clicks per second) resemble pulsed tones and are concentrated at lower frequencies between 500 Hz and 5 kHz (Ford and Fisher 1978), while high frequency echolocation clicks extend up to and beyond 150 kHz (Rasmussen et al. 2015). Narwhal echolocation clicks have source levels reaching 218 dB re 1 µPa (Mohl et al. 1990; Miller et al. 1995).

2.5.2 Pure Tones (Whistles)

Narwhal whistles (or ‘pure tones’) are narrow-band, frequency-modulated sounds that are generally emitted between 300 Hz and 10 kHz, though some tones have been found to reach frequencies as high as 18 kHz (Ford and Fisher 1978; Marcoux et al. 2011). Narwhal whistles resemble pulses but have extended durations ranging 0.05 to 6 s, with the majority of pure tones lasting between 0.5 and 1 s (Ford and Fisher 1978). Whistles are produced by narwhal far less frequently and more sporadically than pulsed sounds (Ford and Fisher 1978). They may be emitted at a constant frequency throughout their duration, may gradually increase or decrease in pitch, or fluctuate in frequency entirely (Ford and Fisher 1978). The source levels of narwhal whistles are not known (Marcoux et al. 2011).

2.6 Narwhal Hearing

As no behavioural or electrophysiological audiograms are available for narwhal specifically, little is known about their hearing ability (Rasmussen et al. 2015). Like beluga, narwhal are considered mid-frequency (MF) cetaceans with a functional hearing range likely occurring between 150 Hz and 160 kHz (Southall et al. 2007). Auditory response curves for MF cetaceans show 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).

2.7 Narwhal and Vessel Noise

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

Ship noise generally dominates ambient noise at low frequencies, with most energy occurring between 20 Hz to 300 Hz and some components extending into the 1 kHz to 5 kHz range (Richardson et al. 1995; McKenna et al. 2012). There is no evidence of hearing impairment occurring in marine mammals as a result of exposure to vessel-generated sound. Adverse effects are more likely to be linked to behaviour and acoustic communication. Research has demonstrated that vessel sound can elicit behavioural reactions in marine mammals and potentially result in masking of their communication space (Richardson et al. 1995). Acoustic responses to vessel sound include alteration of the composition of call types, the rates and duration of call production, and the actual acoustic structure of the calls. Observed behavioural responses include changes in respiration rate, dive patterns, and swim velocity. These responses have, in certain cases, been correlated with numbers of vessels and their proximity, speed, and directional changes. Responses have been shown to vary by species, gender and individual.

Several studies have documented avoidance and displacement behaviour in toothed whales following exposure to anthropogenic noise (Stone and Tasker 2006; Lucke et al. 2009; Miller et al. 2009; 2012; Teilman and Carstensen 2012; Decruiter et al. 2013), although this has been primarily associated with high-amplitude sound sources (e.g., sonar, seismic, acoustic harassment devices, offshore wind farms) which are not proposed as part of the Mary River Project. Little is known on how toothed whales respond to frequent disturbance from ship traffic over time. Many toothed whales show considerable tolerance of vessel traffic (Richardson et al. 1995). Although there is no clear evidence of toothed whales abandoning significant parts of their habitat range because of vessel traffic (full review in Richardson et al. 1995), vessel-related effects on abundance and behaviour have been observed for several odontocete species. Bejder et al. (2006) reported a decline in the relative abundance of bottlenose dolphins exposed to long-term disturbance by tourism vessels in Western Australia. Southern resident killer whales (SRKW) have been shown to increase the amplitude of their calls as background received levels increased due to vessel presence (Holt et al. 2009, 2011). There is also reports of killer whales increasing the duration of their vocalizations in response to increased vessel noise (Foote et al. 2004). Several recent studies conducted in support of the proposed Roberts Bank Terminal 2 Project in Vancouver, BC were undertaken to more accurately determine behavioural response thresholds of resident killer whale to continuous noise from ship transits (Williams et al. 2013; SMRU Canada Ltd. 2014). In each of these studies, behavioural responses were classified using published 'severity scores' developed by marine mammal behavioural specialists (Southall et al. 2007). These were used to develop fitted dose-response curves in conjunction with an appropriate hearing sensitivity filter for killer whales. Results indicated that southern resident killer whales were likely to exhibit 'moderate' severity behavioural responses up to 1.4 km from transiting ships, and 'low' severity behavioural responses up to 3.8 km from transiting ships (SMRU Canada Ltd. 2014).

Project shipping along the Northern Shipping Corridor overlaps with important summering grounds for the Baffin Bay narwhal population, including areas used for calving and mating. Mother-calf pairs traveling along the shipping corridor may be more sensitive to ship noise given their slower travel speeds and reduced manoeuvrability around vessel traffic. Although ore carriers are also slow moving (e.g. less than 10 knots), there are several narrow areas (<5 km) along the shipping route where narwhal are known to transit in large groups and where ships would have limited ability to alter course (e.g., channel width between Stephens Island and Baffin Island is approximately 2.5 km; channel width between Bruce Head and Poirier Island is approximately 3.2 km, channel width at the entrance to Milne Port is only 2.0 km). Although the majority of ship noise is emitted at frequencies at which narwhal have low hearing sensitivity, propeller cavitation on larger ships (i.e., bulk carriers and container ships) can emit sound in the mid- to higher frequency range, which can potentially interfere with narwhal communication (Veirs et al. 2016). There is therefore, concern that ship noise may elicit avoidance behaviour in narwhal including evasive maneuvers (diving) or changes in swim direction and/or speed.

Studies on the potential effects of ship traffic on narwhal are limited. Aerial-based photographic surveys conducted in Milne Inlet in 2015 analyzing potential narwhal response to large vessel transits along the Northern

Shipping Corridor were inconclusive (Thomas et al. 2016; Golder 2017). Since a pilot study in 2013, Baffinland has conducted shore-based monitoring at Bruce Head to study narwhal response to shipping traffic along the shipping route in Milne Inlet during the open-water season, with data collected on abundance, distribution, group composition, and behaviour (Smith et al. 2017). Most narwhal occurring along the shipping route near Bruce Head were shown to be in transit, with some evidence of nursing, mating and foraging behaviour also observed. Approximately 40% of the group sightings included calves or yearlings, supporting the hypothesis that Southern Milne Inlet is an important area for calf rearing. Results collectively indicate that narwhal do not respond to large vessels by fleeing; but rather remain in the area with some individuals showing temporary avoidance behaviour during active ship transits. Animals demonstrated a more pronounced avoidance behaviour to ships approaching from the south (Milne Port) than from the north. No changes in yearly relative abundance or distribution were observed, nor any evidence of long-term displacement or avoidance behaviour (Smith et al. 2017).

3.0 METHODS

3.1 Study Area

The 2014–2017 shore-based studies of narwhal relative abundance, distribution, and behaviour were based at an observation platform installed at Bruce Head, a high rocky peninsula on the western shore of Milne Inlet, Nunavut, overlooking the Project's Northern Shipping Route. The platform, located on a cliff at approximately 215 m above sea level (N 72° 4' 17.76", W 80° 32' 35.52") approximately 40 km from Milne Port, provided a mostly-unobstructed view of Milne Inlet from the southern tip of Stephens Island in the north, to the embayment south of Agglerojaq Ridge in the south. The portion of the Northern Shipping Route that is viewable from the observation platform is bounded by two islands in close proximity to Bruce Head: Poirier Island to the east and Stephens Island to the north. Also viewable from the observation platform is the mouth of Koluktoo Bay, just south of the Bruce Head Peninsula and extending approximately 16 km westward of the Northern Shipping Route.

The observation platform at Bruce Head consisted of a sheltered wooden (Photograph 3-1) structure and included an enclosed area for storing equipment. A weather station, mounted on the side of the observation platform, extended above the rooftop and consisted of a temperature probe and a wind monitor (further described in Section 3.3.2.3). The observation platform was located one kilometer from the Bruce Head camp, requiring a 30- to 45-minute hike between the two sites.

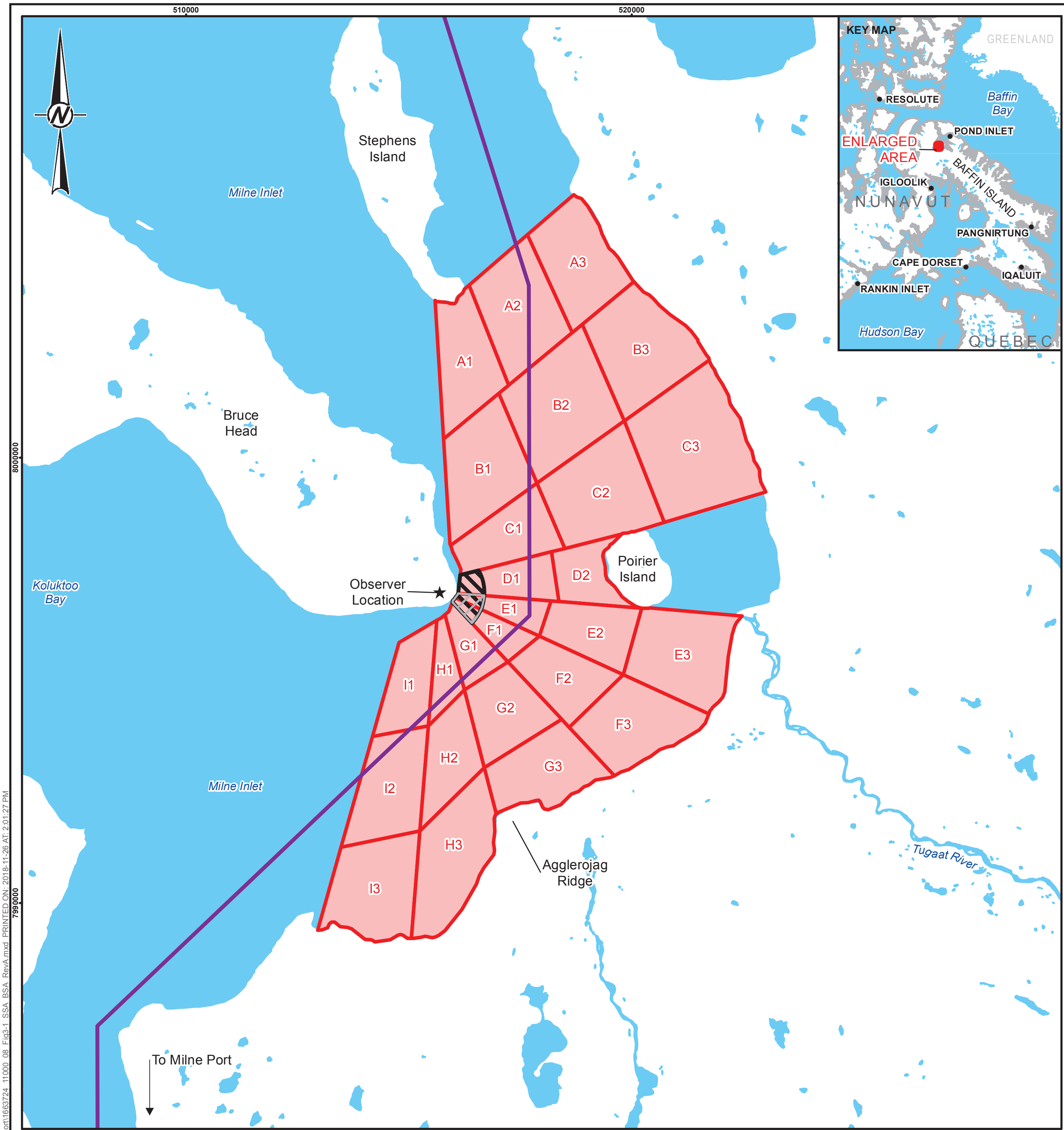
Two study areas were used for the 2014–2017 shore-based study depending on the applicable data collection protocol. This included a broader Stratified Study Area (SSA) and a smaller Behavioural Study Area (BSA), nested within the SSA (Figure 3-1).

3.1.1 Stratified Study Area

The SSA covers a total area of 82.5 km² and was designed for the collection of narwhal RAD data. The SSA is stratified into nine strata: strata A (northernmost stratum) through I (southernmost stratum). Each stratum is further subdivided into three substrata: substrata 1 through 3 (1 being closest to the Bruce Head shore/observation platform and 3 being the farthest away). There is a total of 26 substrata within the SSA as stratum D is comprised of only 2 substrata, 1 and 2 (substratum 3 is hidden behind Poirier Island and cannot be sampled from the observation platform). The substrata boundaries were visually defined in the field using definitive land marks on the far shore of Milne Inlet and nearby islands (Smith et al. 2015, 2016, 2017; Golder 2018a) and have remained unchanged since 2014.

3.1.2 Behavioural Study Area

The BSA covers an area closest to the Bruce Head observation platform. In 2014–2016, it was defined to cover portions of strata E and F, while in 2017 it was redefined to also include a portion of stratum D. Throughout the sampling years, only the area within 1 km of the shoreline below the Bruce Head observation platform was included in the BSA. The BSA spatial boundary was designed for the collection of narwhal group composition and behaviour data. The shoreline adjacent to the BSA is a common narwhal hunting camp for local Inuit.



LEGEND

- COMMUNITY
- OBSERVER LOCATION
- APPROXIMATE SHIPPING ROUTE
- 2014-2016 BEHAVIOURAL STUDY AREA (BSA)
- 2017 BEHAVIOURAL STUDY AREA (BSA)
- STRATIFIED STUDY AREA (SSA) SUBSTRATA
- WATERBODY

0 2.5 5

1:125,000 KILOMETRES

REFERENCE(S)

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

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT – BRUCE HEAD MONITORING PROGRAM (2014-2017)

TITLE
STRATIFIED STUDY AREA (SSA) AND BEHAVIOURAL STUDY AREA (BSA)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-11-26
DESIGNED	SU
PREPARED	AA
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APPROVED	PR

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25mm

Photograph 3-1: Observer at Bruce Head platform completing scan surveys (2 August 2017).

3.2 Data Collection

Visual survey data collected during the 2014–2017 Bruce Head shore-based monitoring program included information on (1) narwhal RAD; (2) narwhal group composition and behaviour; and (3) vessel traffic and other anthropogenic activities. During each daily shift, the study team was split into two separate groups. The first group, composed of two observers, was exclusively responsible for collecting RAD data in the SSA. The second group, composed of three to four observers, was responsible for collecting data on group composition and behaviour in the BSA, as well as tracking vessels and recording anthropogenic activities in the SSA. Both teams also collected data on environmental conditions during their respective survey efforts. In order to minimize potential observer fatigue, study team members rotated between observer and recorder roles throughout each daily shift. Detailed descriptions of data collection and survey methods employed during the 2014–2017 shore-based studies are provided in the respective annual reports (Smith et al. 2015, 2016, 2017; Golder 2018a).

3.2.1 Relative Abundance and Distribution

RAD surveys were conducted throughout the SSA. 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 recorded, the observer moved on to the next substratum. Where the majority of narwhal were travelling in one direction (e.g., north → south), the observer would begin counting strata from the opposite direction (e.g., south → north) in order to avoid /minimize the potential of double counting groups. During large vessel transits through the SSA, counting commenced in the stratum closest to the incoming vessel. During the 2014–2016 surveys, RAD counts were conducted throughout the SSA at the start of each daily observation period and every hour, on the hour. In addition, RAD counts were conducted just before a large vessel entered the SSA at either the northern or southern border of the SSA, when the large vessel was roughly in the centre of the SSA, and just after a large vessel exited the SSA. During the 2017 survey, RAD counts were conducted throughout the SSA at the start of each daily observation period and every hour, on the hour, as well as continuously whenever a large vessel was present within the SSA, followed by a final RAD survey conducted upon departure of the vessel from the SSA.

3.2.2 Group Composition and Behaviour

Group composition and nearshore behavioural data were collected on all narwhal observed within the BSA (<1 km from shore). Survey and scan sampling protocols (Mann 1999) were used to record group-specific data (Table 3-1) before moving onto the next sighting. Observations were made using a combination of Big Eye binoculars (25 x 100), 10 x 42 and 7 x 50 binoculars, and the naked eye. When large herding events took place and RAD team members were not conducting a RAD count, the RAD team assisted in collecting group composition data in the BSA. The data collection protocols were similar across the four years of sampling (2014-2017).

Table 3-1: Group composition and behavioural data collected in the BSA

Recorded Data	Description
Time of sighting	Time of initial observation within the BSA
Sighting number	A sighting number was used as a unique identifier for each single whale or group of whales
Marine mammal species	All marine species observed were recorded as a separate sighting
Group size[1]	Number of narwhal within one body length of one another
Number of narwhal by tusk classification	■ Number of narwhal with tusks ■ Number of narwhal without tusks ■ Number of narwhal with unknown tusks (i.e., head not visible)
Number of narwhal by age category	Adult, juvenile, yearling, calf, unknown life stage
Spread of group	■ Tight: narwhal ≤ 1 body width apart ■ Loose: narwhal >1 body width apart
Group formation	■ Linear ■ Parallel ■ Cluster/Circular ■ Non-directional line ■ No formation
Direction of travel	North, South, East, West
Speed of travel	■ Fast / Porpoising ■ Medium ■ Slow ■ Not travelling / Milling
Distance away from shore	■ Inner: <300 m ■ Outer: >300 m
Primary and secondary behaviour	See Table 6 (Behavioural Data) in Training Manual (Appendix A) of Golder (2018a) for lists of primary and secondary behaviours recorded

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

3.2.3 Vessel Transits

Vessel transits within the SSA in all sampling years were tracked and recorded using a combination of shore-based and satellite-based Automated Identification System (AIS) data to provide accurate real-time data on all large vessels transiting through Milne Inlet. AIS transponders are mandatory on all commercial vessels >300 gross tonnage and on all passenger ships. Information provided by the AIS includes vessel name and unique identification number, vessel size and class, position and heading, course, speed of travel, and destination port. The two 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. The satellite-based AIS data was lower resolution but provided coverage of the entire Northern Shipping Route.

The study teams also visually recorded vessel traffic in the SSA during daily observation periods. Vessels were classified by size (small <50 m, medium 50-100 m, and large >100 m in length), type of vessel, and general travel direction. Small vessels were modeled as total count of small vessels present during the RAD count.

3.2.4 Non-vessel Anthropogenic Activity

A hunting camp is located directly below the Bruce Head observation platform. This camp is used intermittently by local Inuit. Over the course of the 2014-2017 field programs, active shooting events associated with hunting were regularly witnessed by the study team both visually and acoustically from the observation platform. All hunting (i.e., shooting) events were recorded during each daily observation period, including the time and duration of the event, number of shots fired, and target species.

3.2.5 Ad Lib Observations

In addition to the collection of RAD and group composition and behaviour data, general observation (*ad libitum*) of narwhal activity were recorded by the observers throughout the four-year study.

3.2.6 Environmental Conditions

Environmental conditions were recorded at the start of the observation period, every hour, and whenever weather conditions changed. For the entire SSA, cloud cover (%), precipitation, and ice cover (%) were recorded. Beaufort scale, sun glare, and an overall assessment of sightability were recorded for each substratum within the SSA and also in the BSA. In all years, modeled tidal data for Bruce Head were obtained from WebTide Tidal Prediction Model (v.0.7.1). These tide 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.

3.2.7 Data Management

At the end of each observation shift, datasheets were checked for completeness and accuracy, and photographed to create a digital backup. Data logger files and photos were downloaded onto the project laptop computer back at camp. In 2014–2016, data were entered into Microsoft® Excel® spreadsheets. In 2017, a Microsoft Access© database customized for the 2017 shore-based study was used. Throughout the 2014–2017 program, all files were backed up onto multiple hard drives on a daily basis.

3.3 Data Analysis

3.3.1 Data Integration between Sampling Years

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

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

For the 2014 and 2015 RAD surveys, there was no information recorded on herding events. Herding event data were therefore compiled based on the verbal description of timing of events, provided in Smith et al. (2015, 2016). In both 2016 and 2017 sampling years, herding events were marked directly on the RAD datasheets, and the information was therefore readily available.

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

For BSA surveys conducted in 2014, 2015 and 2016, sightings data were limited to substrata E1 and F1 (within 1 km from shore). For BSA surveys conducted in 2017, sightings data also included substrata D1 (within 1 km from shore). The expanded 2017 BSA study area should have no effect on the main variables of interest (group size, composition, spread, formation, direction, speed, and distance from shore), although it could bias the number of narwhal groups observed, due to the larger survey area. To account for this discrepancy and other potential inter-annual effects, the year of sampling was included as a covariate in the BSA models.

3.3.2 Data Post-Processing

3.3.2.1 Automatic Identification System Data

Satellite-based AIS data was used to supplement vessel location information for periods when there were gaps in the shore-based AIS data. The temporal resolution of the shore-based AIS data was approximately five seconds, whereas the satellite-based AIS data exhibited longer interposition times (ten minutes on average), resulting in a comparatively lower spatial and temporal resolution with respect to vessel position. To best represent vessel movement in the SSA during periods when only satellite-based AIS was available, vessel position was interpolated at one-minute intervals.

For the RAD analysis, distance and angle were calculated between each vessel location point (relative to the ship’s bow) and the centroid of each of the 26 substrata (Figure 3-2). The resulting distances were used as continuous predictors of narwhal response to vessel traffic. To account for the orientation of the vessel relative to the substrata, a vessel was classified as ‘Heading toward’ a substratum when its travel angle was >270º and <90º (relative to the substrata centroids); and classified as ‘heading away’ when its travel angle was >90º and <270º (relative to the substrata centroids). For analysis of group composition and behaviour, distance and angle were calculated in the same manner but using the BSA centroid as the reference point. It should be noted that the BSA centroid position differed slightly in 2017 than in previous years, as the BSA boundary in 2017 expanded slightly northward to include a portion of substratum D1.

A 15-km cut-off (relative to the substrata and BSA centroids) was selected for integration of vessel position in the multi-year analysis as this captured the maximum zone of acoustic disturbance based on acoustic modelling results completed for the Mary River Project (Quijano et al. 2017). In other words, any vessel beyond the 15-km cut-off was considered non-influential on narwhal abundance, distribution and behaviour within the SSA.

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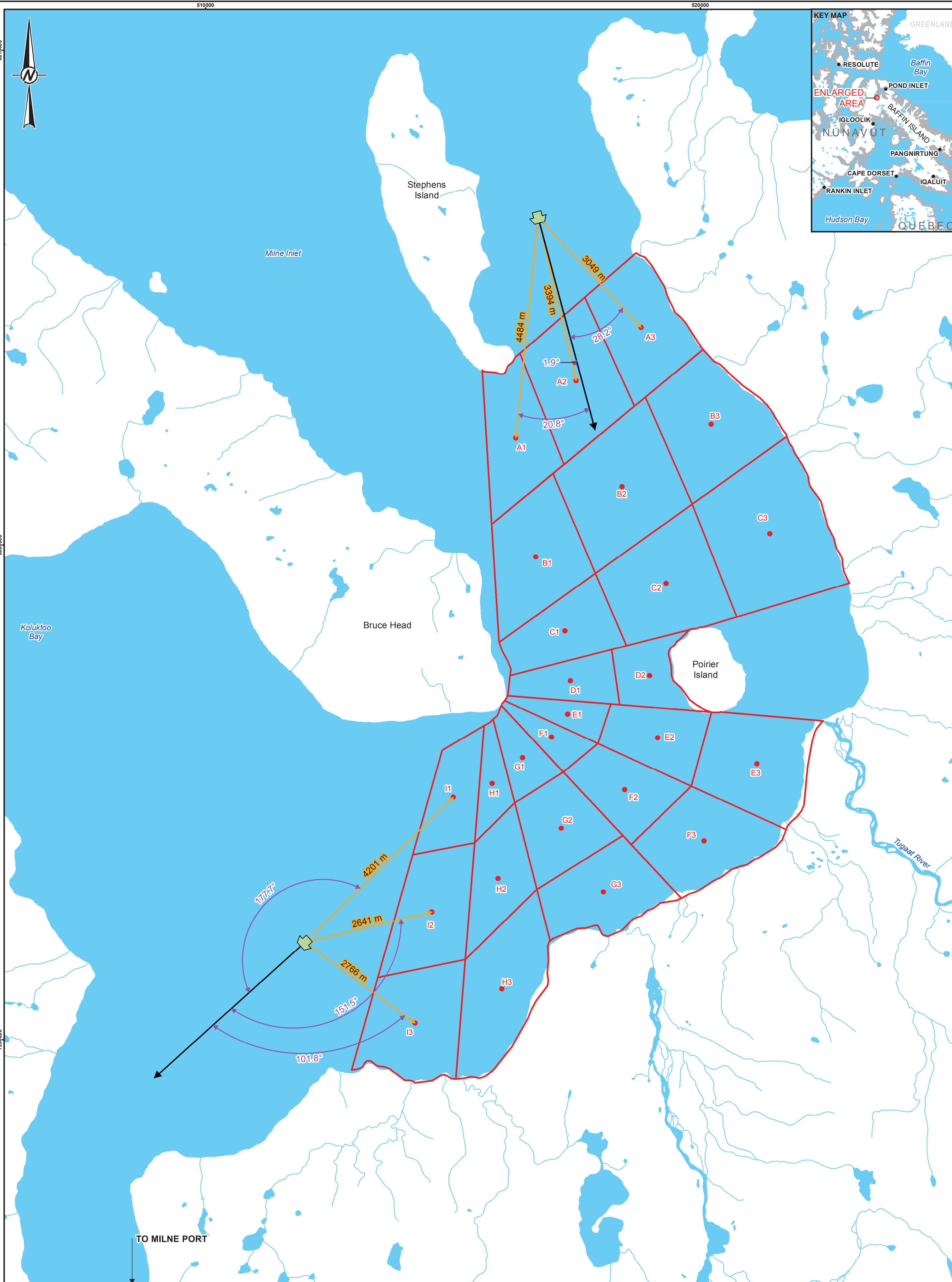

LEGEND

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

0 2 4

1:75,000 KILOMETRES

REFERENCE(S)

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

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT – BRUCE HEAD MONITORING PROGRAM (2014-2017)

TITLE
VESSEL DISTANCE AND TRANSITING ANGLE RELATIVE TO SURVEY SUBSTRATA

CONSULTANT

GOLDER

YYYY-MM-DD	2018-11-26
DESIGNED	SU
PREPARED	AA
REVIEWED	PR
APPROVED	PR

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3.3.2.2 Anthropogenic Activity other than Large Vessels

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. For each RAD survey, the time since last shooting (in minutes) was calculated. The period between the onset of each RAD survey and a discrete shooting event was classified as ‘no hunting activity`. Small vessel traffic was expressed as the number of small vessels present within the SSA and BSA during the RAD and group composition/behaviour surveys, respectively.

3.3.2.3 Environmental Conditions

No post-processing of environmental variables was required for the multi-year analysis, with the exception of merging ‘medium’ and ‘low’ glare categories together in the 2016 dataset, in an effort to standardize glare categories throughout years (medium glare was a unique category in 2016).

3.3.2.4 Data Filtering

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

1) Sightings collected during periods of ‘impossible’ sightability and cases with Beaufort scale value of 6 or higher (428 cases representing 1.7% of total RAD counts). These accounted for conditions of fog or ice cover, which would not be reflected in Beaufort scale or glare value, and therefore had to be removed from the modeling dataset.).
2) Cases when more than one vessel was present in the study area (197 cases representing 0.8% of total RAD counts) – multiple vessel presence may affect narwhal response and will therefore introduce bias into the analysis.).
3) Cases where the line of sight between the vessel and substratum centroid included a landmass (658 cases representing 2.6% of total RAD counts) – the presence of landmass is likely to affect vessel noise propagation. Landmass was present when vessels were farther away (mean distance between vessels and centroids of 11.0 km, compared to 6.3 km when landmass was absent). Therefore, the inclusion of all data, regardless of landmass presence, may bias results collected on vessel data at larger distances).
4) Cases with 200 or more narwhal within substratum (2 cases, <0.01% of total RAD counts) – these were removed to resolve model convergence issues.

Note that some of these cases overlapped. For example, in 83 RAD counts, more than one vessel was present in the SSA and a landmass was between the line of sight separating the substratum centroid and one of the vessels.

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

1) Observations collected during periods of ‘impossible’ sightability (eight observations representing 0.2% of total observations).
2) Cases where group size was >20 narwhal (nine cases overall representing 0.2% of total observations).

3) Cases when more than one vessel was present in the study area (65 observations representing 1.7% of total observations).

4) Cases where the line of sight between the vessel and substratum centroid included a landmass (202 observations, 5.4% of total observations).

In cases when one or more large vessel was present (case #3 above), data were omitted to avoid biasing the modeling results. Since it is not possible to account for any increased effect on narwhal due to presence of more than one vessel in the current models, it was necessary to exclude these cases, as was previously performed for the 2014-2016 (Smith et al. 2017) and for the 2017 analysis (Golder 2018).

As in the case of the RAD data, some of these cases overlapped. For example, in 46 observations, more than one vessel was present at the SSA and a landmass was between the line of sight separating the BSA centroid and one of the vessels.

3.3.3 Analytical Approach

3.3.3.1 Fixed Effect Predictors

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

1) Glare (within SSA strata or BSA, as applicable) — discrete variable with the following categories: None (N), Low (L), Medium (M), and Severe (S).

2) Beaufort scale (within SSA strata or BSA, as applicable) — discrete variable, with categories ranging from 0 to 7.

3) Tidal effect — multiplicative effect of tide height (m) and change in depth (m); see Section 3.2.6). In some cases, the tidal effect had to be simplified to an additive effect of tide height and change in depth due to spurious effects.

4) Distance from vessel — continuous variable (in km) calculated between vessel location and each of the SSA substratum (and BSA) centroids.

5) Relative position between vessel and centroids — whether the vessel was heading toward or away from the observation area.

6) Vessel direction — discrete variable with two categories: ‘northbound’ and ‘southbound’.

7) Interaction between vessel distance and relative position of vessel.

8) Interaction between vessel distance and vessel direction.

9) Interaction between vessel direction and relative position of vessel.

10) Vessel presence within 15 km of the substratum/BSA centroid — discrete variable with two categories: 'vessel present within 15 km' and 'no vessel present within 15 km'.

11) Time since last shot fired — continuous variable (in min).

12) Whether hunting occurred within a pre-defined window prior to a sighting — discrete variable with two categories: 'hunting occurred' and 'no hunting occurred'. For the RAD analysis, 12.5 hours was selected as the pre-sighting cut-off limit for a hunting activity, to maintain consistency with previous survey years (Smith et al. 2017). For group composition and behavioural analysis within the BSA, six hours was selected as the pre-sighting cut-off limit for a hunting activity due to limited data beyond this interval.

13) Number of small vessels in the SSA/BSA during the observation — continuous variable.

14) Day of year — continuous variable, where January 1 of each year is assigned a value of 1. Usually entered as a multiplicative effect with year (unless model convergence issues were encountered).

15) Year — discrete variable with four categories: 2014, 2015, 2016, and 2017.

The effects of tide height, day of year, time since last shooting event, and distance between large vessels and centroids were expressed as third-degree polynomials. For some analyses, it was necessary to simplify the model structure because of convergence issues or spurious effects. In those cases, second-degree polynomials were used. In the analysis of group spread (loose vs. tight groups) and group formation (parallel vs. non-parallel), the effect of depth was modelled as a linear effect. Similarly, the interactions between tide height and depth change, and between day of year and survey year, had to be removed in a few cases where the interactions caused convergence problems or spurious effects. 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 variance inflation factors (VIFs) were calculated; all values were below 3.0, indicating no collinearity in the fixed factors (Zuur et al. 2009).

3.3.3.2 Relative Abundance and Distribution

Narwhal RAD data collected in the SSA were analyzed as the total number of narwhal observed in each substratum during each RAD count completed throughout the four-year survey period. The generalized mixed linear model with a zero-inflation component evaluated how the relative abundance of narwhal (expressed as total narwhal count per substratum) was affected by the various predictor variables. In addition to the variables listed in Section 3.3.3.1, the RAD model included also the effects of stratum (A to I) and substratum (1, 2, or 3), as well as two-way interactions between variables related to large vessel traffic (distance from vessel, direction of vessel within Milne Inlet, and direction of vessel relative to SSA centroids). The considerably larger size of the RAD dataset relative to the behavioural dataset (24,316 and 3,471 data points, respectively) allowed for this increase in model complexity. Note that in all models, substratum was not nested within stratum, since substratum was treated as a proxy for distance between observer and each sampled substratum.

The selected modelling framework was a zero-inflated negative binomial model with a random effect of day (where each sampling day within the four-year period had a unique value) and a spatial autocorrelation within each sampling day. The zero-inflation portion of the model was modelled to depend on stratum, substratum, Beaufort scale, and year, thus reflecting the unequal distribution of zero counts between different categories of these variables. Likelihood ratio tests (alpha of 0.05) were used to determine the importance of the zero-inflation component of the model. The full zero-inflated model was tested relative to a zero-inflated model with an intercept-only zero-inflation component and relative to a negative binomial model without zero-inflation.

The selected analytical approach allowed for analysis of count data with a high occurrence of zeroes, while specifying an explicit spatial autocorrelation — i.e., accounting for the fact that narwhal are not randomly distributed and that counts in adjacent substrata will likely be more similar than counts in spatially segregated substrata. The models were used for inference of statistical significance based on *P* values of coefficients, and population-level model predictions 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 narwhal counts (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 large vessels or shooting events), or, when possible, their average values (e.g., tide height and depth change). The following predictor values were used to visualize model predictions: stratum F, substratum 2, Beaufort scale of 2, survey year 2017, day of year 224 (12 August), and glare value 'N'. All analyses were performed using the package glmmTMB (Brooks et al. 2017) in the statistical package R v.3.5.1 (R 2018).

3.3.3.3 Spatial Distribution in the SSA

In order to investigate if the low number of narwhal sightings recorded in substrata 3 was due to a reduced ability to detect animals at greater distances, or reflective of lower animal densities in the eastern portion of the channel, a subset of the narwhal satellite tagging data collected in 2017 as part of DFO's Tremblay Sound Tagging Program was analyzed. High-resolution location data from five narwhal fitted with GPS Fasloc tags were used to evaluate spatial distribution and habitat use patterns by the tagged narwhal during their occurrence within the SSA. Proportions of daily GPS fixes in each of the three substrata were calculated for each day and each tagged narwhal, with results plotted as a time series.

To estimate spatial preference, substratum number (1, 2, or 3) was used to construct a multinomial mixed-effects model, with a fixed effect of stratum. Stratum was used as a predictor due to the spatial preference of some strata (Smith et al. 2017; Golder 2018a), and since larger substrata were more likely to contain more GPS locations than smaller substrata. The random effects consisted of random intercepts of narwhal to account for individual variability and the repeated-measures nature of the dataset. The analysis was performed in the statistical package R v.3.5.1 (R 2018) using the library 'brms' (Bürkner 2017).

3.3.3.4 Group Composition and Behaviour

Narwhal group composition and behavioural data were plotted as time series, and also as a function of group size in relation to proximity and orientation of large vessels.

Following the classification used in 2016 (Smith et al. 2017), groups of known composition (i.e., where no 'unknown' life stages were part of the group) were classified using the following six categories:

- Group 1 — no observed tusks (adults or juveniles without tusks), no calves or yearlings
- Group 2 — no observed tusks (adults or juveniles without tusks), yes calves or yearlings
- Group 3 — mixed tusks (adults or juveniles, with and without tusks), no calves or yearlings
- Group 4 — mixed tusks (adults or juveniles, with and without tusks), yes calves or yearlings
- Group 5 — yes tusks (adults or juveniles with tusks), no calves or yearlings
- Group 6 — yes tusks (adults or juveniles with tusks), yes calves or yearlings
- Other — all other groups

The compiled 2014–2017 data were used to construct a set of models to describe the variables of interest, similar to those identified in Golder (2018a). The models developed for analysis of group composition and behavioural data examined changes in group size, group composition, spread, formation, direction, speed, and distance from shore. The explanatory variables used for these analyses were similar to those used for RAD models (see Section 3.3.3.1). The models were examined for significant effects, and estimated predictions were plotted against the explanatory variables to visualize patterns. To reduce spurious effects, nine cases where recorded group size was >20 narwhal were removed from analysis; of these, three were from 2014, five were from 2015, and one was from 2017. The majority (seven cases) were recorded when no large vessel was within 15 km of the BSA. Since group size was used as a covariate in all models of group composition and behaviour, these cases were removed from all analyses. All models had a random intercept of day of survey (unique value for each day of survey throughout 2014–2017) to account for the inter-day variability in group sizes. Since observations were often close in time, autocorrelation for irregular time steps was added to the models. The models were used for inference of statistical significance based on *P* values of coefficients, and population-level model predictions were plotted against observed data to visualize the estimated relationships between narwhal group composition and behaviour and the various explanatory variables. Similar to the RAD model, predictions of group composition and behaviour for plotting model results were calculated on a grid of constant values of all other predictors (day of year 227 [15 August], year 2017, group size of 3 narwhal, average tide height and depth change, no large vessel present, no hunting event occurred, no small vessel present, no glare, and a Beaufort scale value of 1).
All modeling was performed using the package glmmTMB (Brooks et al. 2017) in the statistical package R v.3.5.1 (R 2018).

3.3.3.4.1 Group Size

The analysis of group size included all predictor variables listed in Section 3.3.3.1. The interaction between day of year and survey year was removed to assist with convergence. A generalized mixed linear model was used to estimate the effect of the various fixed variables on group size. The effect of day of year on group size was estimated using a third-degree polynomial to account for the increase in group sizes observed at the end of the survey periods in 2015 and 2016. Group size was assumed to have a negative binomial distribution, and a random intercept of day of survey (unique value for each day of survey throughout 2014–2017) was used to account for the inter-day variability in group sizes.

3.3.3.4.2 Group Composition

3.3.3.4.2.1 Presence of Tusks

The analysis of presence of tusks in observed groups included all predictor variables listed in Section 3.3.3.1. Group size was also used as a covariate. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on presence of tusks. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017) was used to account for the inter-day variability in presence of tusks.

3.3.3.4.2.2 Presence of Calves or Yearlings

The analysis of presence of calves or yearlings in observed groups was simplified relative to the list of all predictor variables listed in Section 3.3.3.1. To assist with model convergence, both tide height and change of depth were removed from analysis. Group size was used as a covariate in the model. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on presence of calves or yearlings in the observed groups. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017) was used to account for the inter-day variability in presence of calves and yearlings.

3.3.3.4.3 Group Spread

The analysis of group spread (loose vs tight groups) included all predictor variables listed in Section 3.3.3.1. Group size was also used as a covariate. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group spread. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017) was used to account for the inter-day variability in group spread.

3.3.3.4.4 Group Formation

The analysis of group formation was simplified to a logistic regression by analysing whether the observed group formation was parallel or not (instead of analyzing each individual observed formation). Since parallel formation was by far the most common (67% of all data), the parallel formation was assumed to be the baseline formation. Therefore, the logistic analysis will provide insight into the effect of the predictor variables and deviations from the baseline parallel formation.

The analysis included all predictor variables listed in Section 3.3.3.1 with the exception of the interaction between day of year and survey year due to convergence issues. Group size was also used as a covariate. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group formation. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017) was used to account for the inter-day variability in group formation.

3.3.3.4.5 Group Direction

The analysis of group direction was simplified to a logistic regression by removing cases of west- or east-traveling groups (a total of 101 groups representing 3% of the data). The resulting dataset contained only north- or south-traveling groups. The analysis of travel direction was simplified relative to the full list of all predictor variables listed in Section 3.3.3.1. To assist with model convergence, the interaction between tide height and change of depth was removed from analysis. In addition, the effect of day of year (and as a result its interaction with survey year) was also removed from the model. All two- and three-way interactions between vessel distance, vessel position relative to the BSA, and vessel direction (north- or southbound) was added to the model to assist with convergence and adequately model the observed patterns. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group direction. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017) was used to account for the inter-day variability in group direction.

3.3.3.4.6 Travel Speed

The analysis of travel speed was performed using two logistic models — one of fast vs medium speeds, and another of slow vs medium speeds. In both cases, medium travel speeds were assumed to be the baseline values, since medium travel speeds were the most common (63% of the data). A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group travel speed. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017) was used to account for the inter-day variability in speed.

The analysis of slow vs. medium speeds included all predictor variables listed in Section 3.3.3.1 (except the interaction between day of year and survey year due to convergence issues), in addition to group size that was used as a covariate. Similar to the analysis of group direction, additional interaction terms were included in the model to adequately represent the observed patterns — an interaction between vessel position relative to the BSA and vessel direction (north- or southbound) and a three-way interaction between vessel distance, vessel position relative to the BSA, and vessel direction (north- or southbound).

The analysis of fast vs. medium speeds included all predictor variables listed in Section 3.3.3.1. Group size was also used as a covariate.

3.3.3.4.7 Distance from Bruce Head Shore

The analysis of whether narwhal groups were close to shore (<300 m) or far from shore (>300 m) included all predictor variables listed in Section 3.3.3.1 with the exception of the interaction between day of year and survey year due to convergence issues. Group size was also used as a covariate. A generalized mixed linear model with a logit link (for binomial data) was used to estimate the effect of the various fixed variables on group distance from shore. A random intercept of day of survey (unique value for each day of survey throughout 2014–2017) was used to account for the inter-day variability in distance from shore.

4.0 RESULTS

4.1 Observer Effort and Environmental Conditions

Each yearly shore-based study was timed to extend over an approximate five-week period, coinciding with the peak open-water season (Table 4-1, Figure 4-1). In general, the study area was ice-free during the study periods, with occasional presence of drifting ice floes in the SSA. Observer effort varied between survey years (Figure 4-1); this was largely dependant on weather conditions and the number of observer shifts used during each survey. Inclement weather occasionally impeded survey effort throughout the multi-year program (Table 4-1). In 2014 and 2015, the timing of sampling was highly variable between days. Sampling effort was more standardized in 2016 and 2017. In 2017, sampling effort was lower than in previous years due to only having a single 10-h observer shift (previous years consisted of two rotating 8-h shifts).

Table 4-1: Number of narwhal and vessel transits recorded during RAD survey effort (2014–2017)

Statistic	Survey year				Total
	2014	2015	2016	2017	
Survey dates	3 Aug–5 Sept	29 July–5 Sept	30 July–30 Aug	31 July–29 Aug	-
No. of active survey days	23	29	27	26	105
No. of survey days lost to weather	14	9	11	2	36
No. of observer hours (total)	103.2	148.7	159.3	97.3	508.5
Average daily survey effort (h)	7.8	10.8	11.9	6.2	9.3
No. of attempted RAD surveys	179	314	321	160(1)	974
No.of complete RAD surveys	166	313	311	109	899
Number of RAD surveys with zero narwhal counts	74	164	127	35	400
No. of narwhal sightings (total)	10,463	14,599	28,309	11,862	65,233
No. of narwhal excluding ‘impossible’ sightability	10,463	14,599	28,309	11,831	65,202
No. of narwhal excluding ‘impossible’ sightability, standardized by effort (narwhal / h)	101.4	98.2	178.0	121.8	128.3
No. of large vessel transits during RAD effort	5	12(2)	23(2)	22	62
No. of RAD surveys with >1 large vessel transiting	0	0	3	5	8

(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) = counts of large vessel transits differ from those presented in Table 4-2 due to transits occurring outside of a RAD count or the vessel being farther than 15 km from relevant substrata during the RAD count.

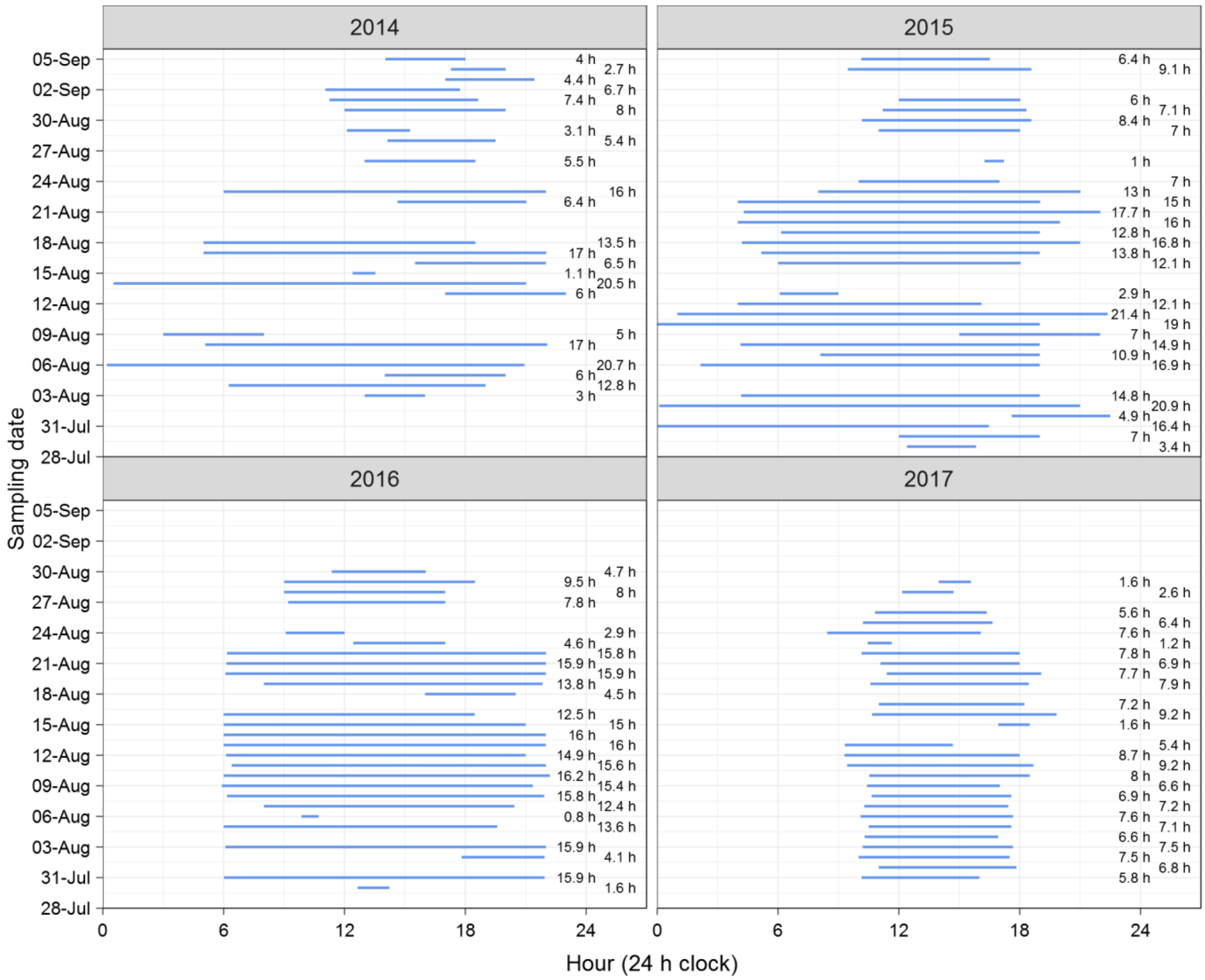


Figure 4-1: Observer effort (h) by survey day (2014-2017)

In 2014, weather conditions were recorded manually by the observers during their watches at the platform, resulting in an intermittent weather record for that survey period. Automated weather instrumentation installed at the platform during 2015–2017 allowed for a continuous weather record in those years (Figure 4-2). Coldest average temperatures during the four-year study period occurred in 2015. Mean daily air temperature was generally highest (maximum daily values of up to 12ºC) during the first two weeks of observation within each year, followed by a slow reduction in temperature to approximately 2.5ºC by early September during 2015–2017 (Figure 4-2). In 2014, warmer than average temperatures persisted into early September compared to other years.

Mean daily wind speed was highly variable between days within the same sampling year (Figure 4-2). Mean daily wind speeds in 2015–2017 generally ranged from approximately 1.1–1.5 m/s to approximately 13–17 m/s, depending on the year. In comparison, in 2014, mean daily wind speeds ranged between 0.1 m/s and 1.5 m/s. The discrepancy in average wind speed observed in 2014 compared to later years may have been associated with the different measurement technique in that year and the fact that wind measurements were only taken when observers were at the observation platform in 2014 (i.e., no wind measurements were recorded during extreme wind events when observers were not at the observation platform). Of the three years with consistent measurements, 2017 was generally the least windy (median of 4.5 m/s, as compared to 6.1 m/s in 2016 and 6.3 in 2015). Prevailing wind direction differed greatly between years (Figure 4-3) and was likely affected by the placement of the weather vane on the observation platform, which was not the same each year also varied among years.

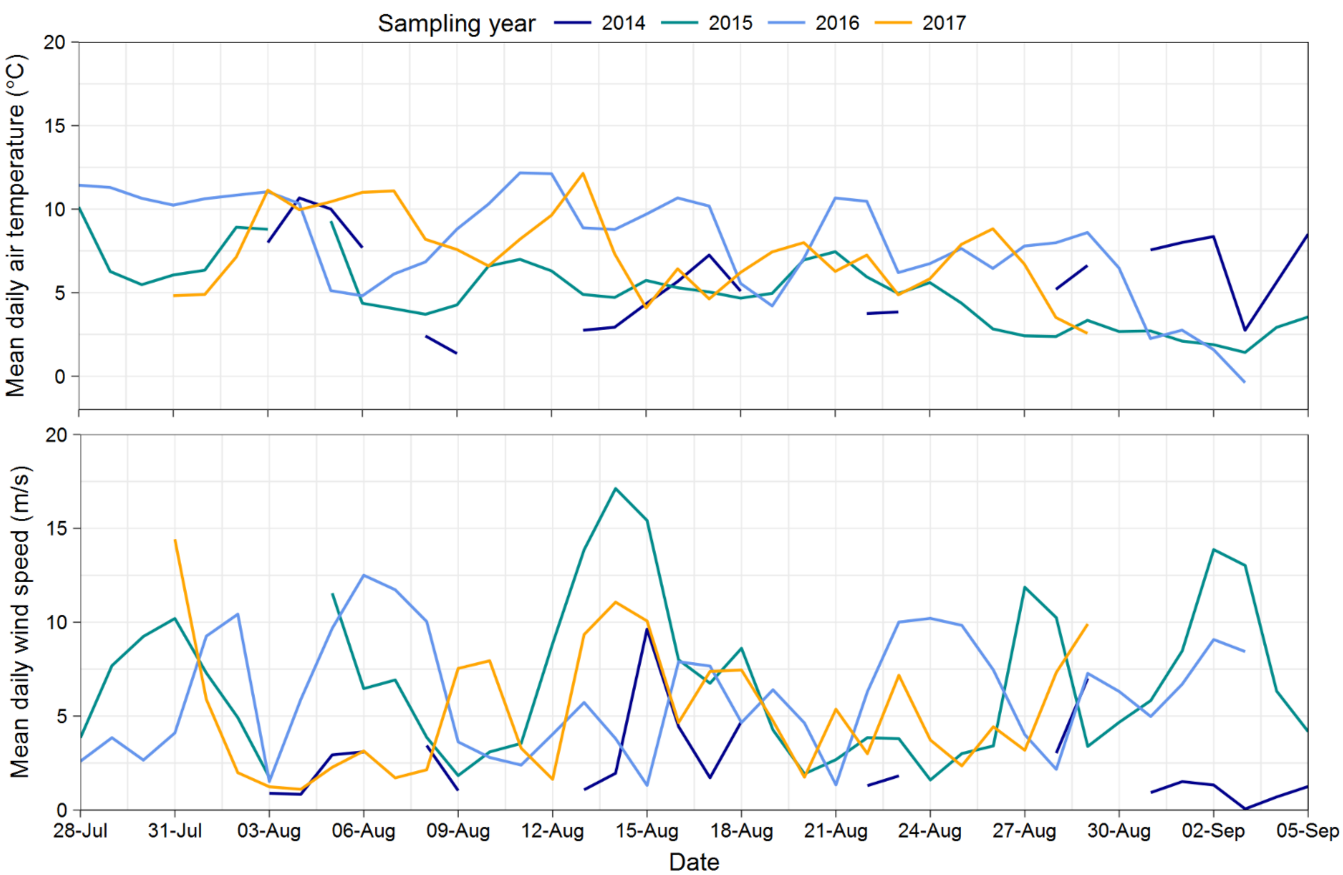


Figure 4-2: Mean daily air temperature (°C) and wind speed (m/s) recorded at Bruce Head (2014–2017)

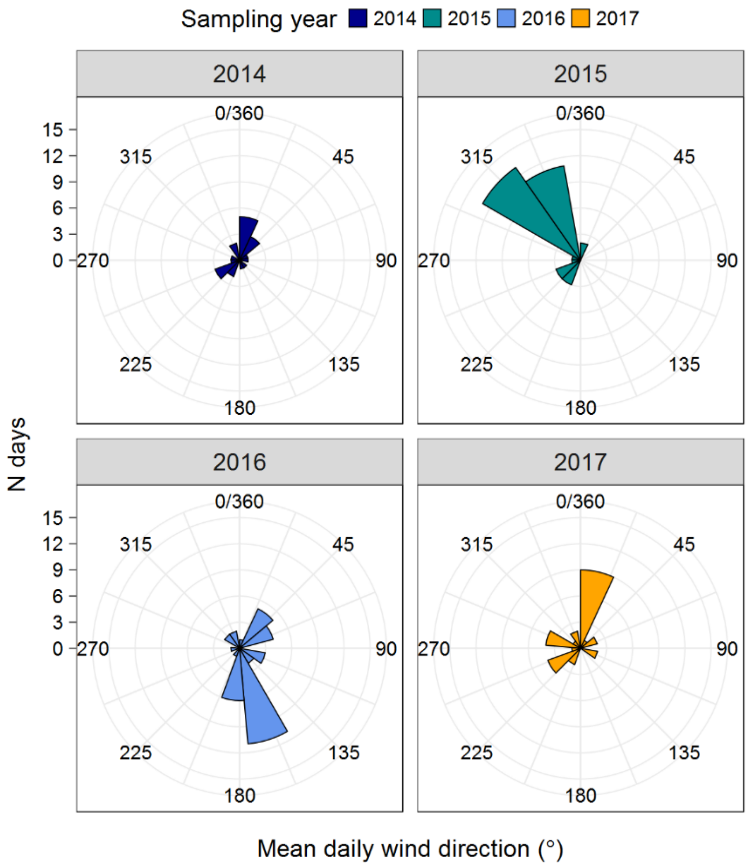


Figure 4-3: Mean daily wind direction (º) recorded at Bruce Head (2014–2017)

Following a review of the multi-year dataset, it was deemed that sightability was a subjective value that had been inconsistently assigned over the course of the four-year study. Specifically, in substrata 3, sightability was often assigned as ‘medium’, even under conditions of higher Beaufort scale values (Figure 4-4). Due to inconsistencies in how sightability was assessed between survey years (particularly in substrata 3), the effect of sightability on RAD and group composition / behavioural data was replaced with Beaufort scale values, glare levels, and substratum value (which would account for distance from the observation platform), since these variables were recorded in a similar manner between survey years. Across the four-year study period, sightability was shown to decrease with increasing wind levels, and with increasing stratum distance relative to the platform (e.g., substratum 3 was generally associated with reduced sightability compared to substratum 1; Figure 4-4). All sightings made during ‘impossible’ sighting conditions or during wind conditions of Beaufort value 6 or higher were removed from the multi-year analysis, equivalent to 428 rows of RAD data (1.7% of the total 2014–2017 dataset).

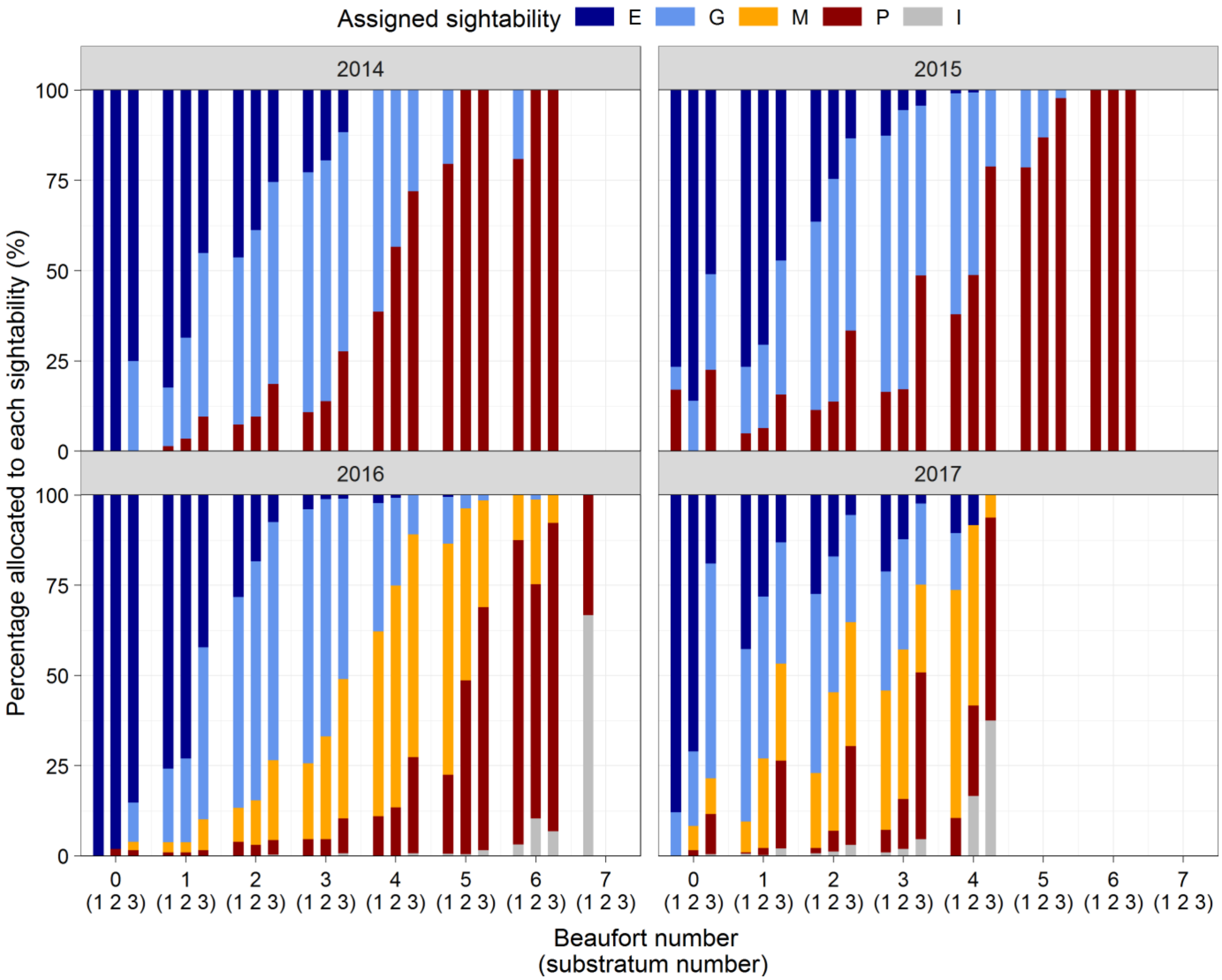


Figure 4-4: Sightability conditions during the 2014–2017 RAD surveys in the SSA based on Beaufort Wind Scale and substratum location (plotted by year)

4.2 Anthropogenic Activity

4.2.1 Large and Medium Vessel Traffic

The total number of one-way large vessel transits LVTs) that passed through the SSA each year is summarized in Table 4-2 and Figure 4-5. Overall, sightings data were recorded during 47% of these events. Large vessels in the SSA consisted primarily of Project-related bulk (ore) carriers (n = 92); accounting for 59%, 84%, and 74% of the one-way transits in 2015, 2016 and 2017, respectively (no ore carriers were present in 2014). Other large Project-related vessels included general cargo vessels and fuel tankers. Passenger vessels represented the only non-Project-related large vessels recorded in the SSA. Recorded tracklines of all LVTs in the SSA throughout the four-year study period are presented in Figure 4-6.

Table 4-2: Number of Large Vessel Transits (LVTs) in SSA per survey year

Survey Year	No. of 1-way LVTs in SSA (No. of Project-related LVTs)	No. and (%) of 1-way LVTs Recorded by Observers
2014	10 (5)	5 (50%)
2015	22 (20)	13 (59%)
2016	43 (40)	22 (51%)
2017	58 (55)	22 (38%)
Total	133 (120)	62 (47%)

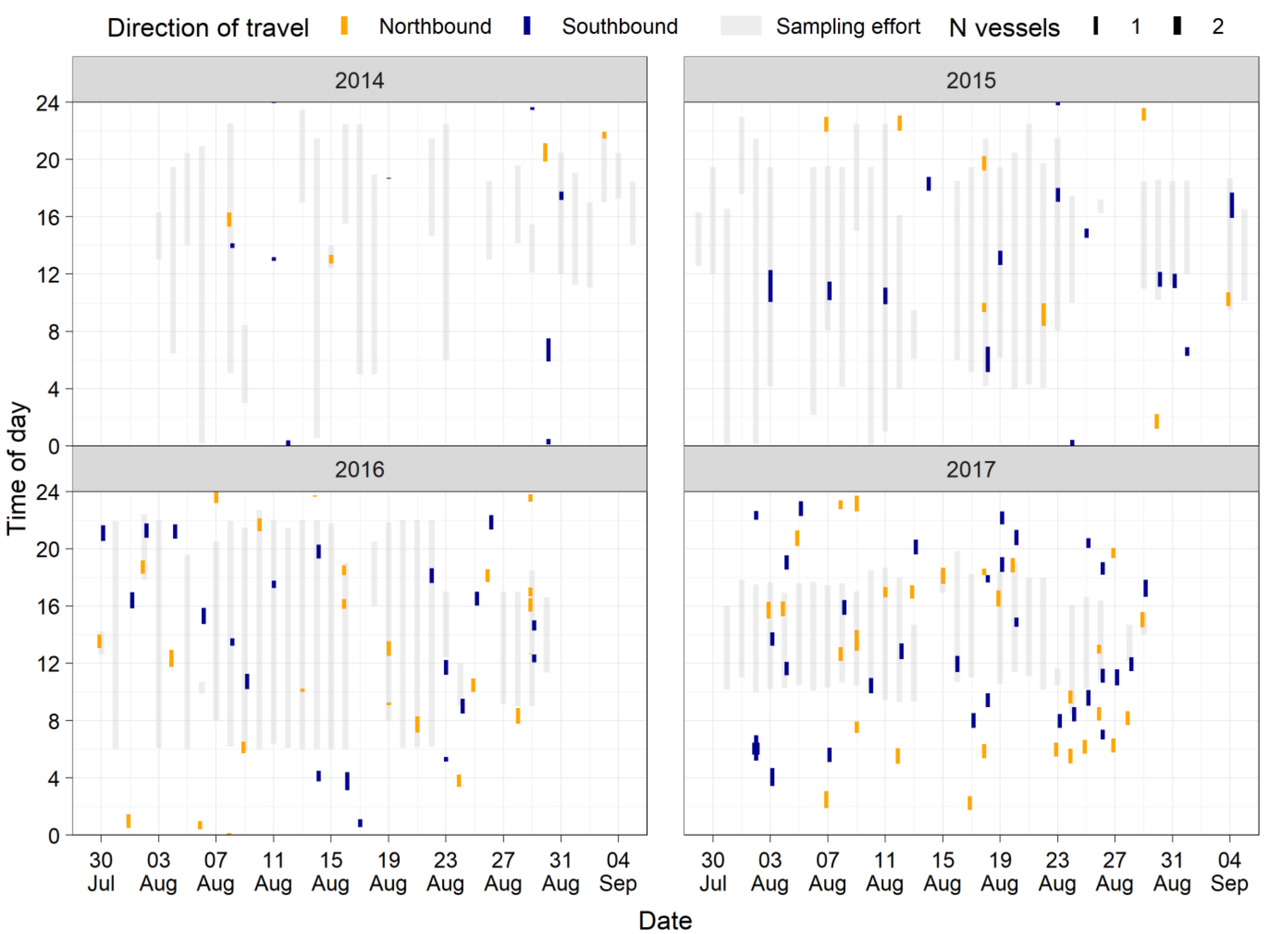
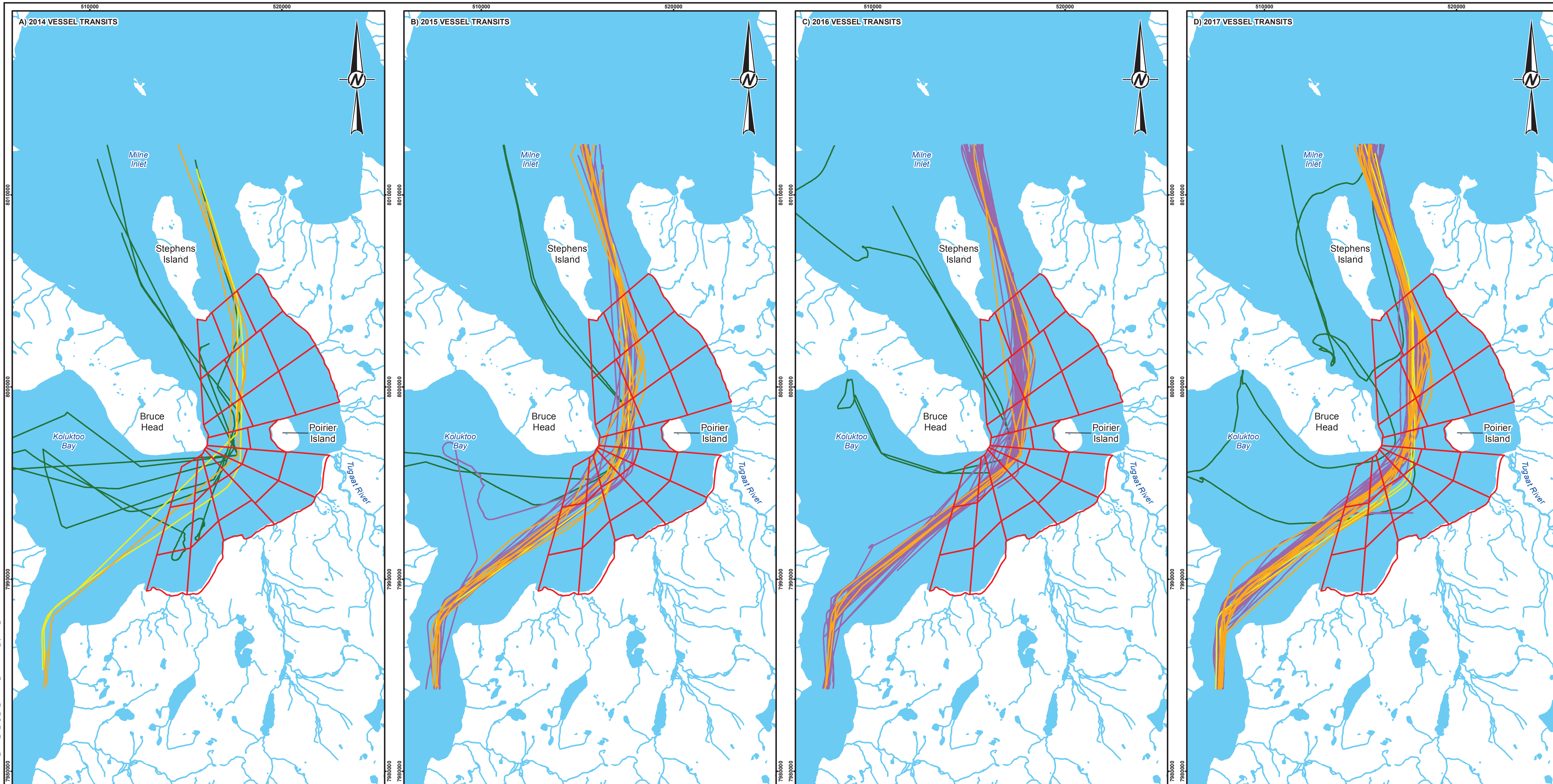


Figure 4-5: Daily summary of LVTs in SSA with associated survey effort. Grey boxes indicate daily observation periods



LEGEND

WATERCOURSE

VESSEL TRANSIT ROUTES BY CLASS

BULK (ORE) CARRIER

CARGO CARRIER

FUEL TANKER

PASSENGER VESSEL

STRATIFIED STUDY AREA (SSA) SUBSTRATA

WATERBODY

0 5 10

1:200,000 KILOMETRES

REFERENCE(S)

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

PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

MARY RIVER PROJECT – BRUCE HEAD MONITORING PROGRAM (2014-2017)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-11-26
DESIGNED	SU
PREPARED	AA
REVIEWED	PR
APPROVED	PR

TITLE

TRACKLINES OF LARGE VESSEL TRANSITS (LVTS) IN SSA (2014-2017)

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	11000-08	0	4-6

Vessel speeds were plotted by vessel type for the four-year study period (Figure 4-7). As part of Baffinland's vessel management practices, a maximum vessel speed limit of nine knots along the Northern Shipping Route. In general, ore carriers transiting in the SSA rarely exceeded 10 knots during the 4-year study period (mean = 8.2 knots; range = 4.0 to 12.4 knots). Of the 92 ore carrier transits recorded in the SSA during this period, 36 vessels (39%) transited at speeds ≥ 9 knots; and three vessels (14%) transited at speeds ≥ 10 knots. The average travel speed of 'other' Project-related large vessels (e.g., cargo ships and fuel tankers) in the SSA was 12.1 knots, ranging from 6.2 knots (*Federal Tiber* in 2015) to 14.5 knots (*Claude A. Desgagnés in* 2014).

Travel speeds of large passenger vessels (non-Project) during the four-year study period ranged from 6 knots (*Akademik Ioffe* in 2015) to 15.9 knots (*Le Boreal* in 2017). The average maximum travel speed in 2014–2015 (8.7 knots, n = 5) was considerably lower than in 2016–2017 (13.7 knots, n = 6). Passenger vessels often travelled close to the shore near Bruce Head and occasionally entered Koluktoo Bay.

A total of four medium-sized (50 to 100 m in length) non-Project-related vessels were recorded in the SSA during the 2014–2017 study period (*Sedna IV* in 2014, *Rosehearty* in 2016, *Galileo G.* in 2016, and *Archimedes* in 2017). *Archimedes* travelled at speeds < 9.0 knots, while the maximum travel speed of the three other vessels ranged from 10 knots (*Sedna IV* in 2014) to 12.0 knots (*Galileo G.* in 2016).

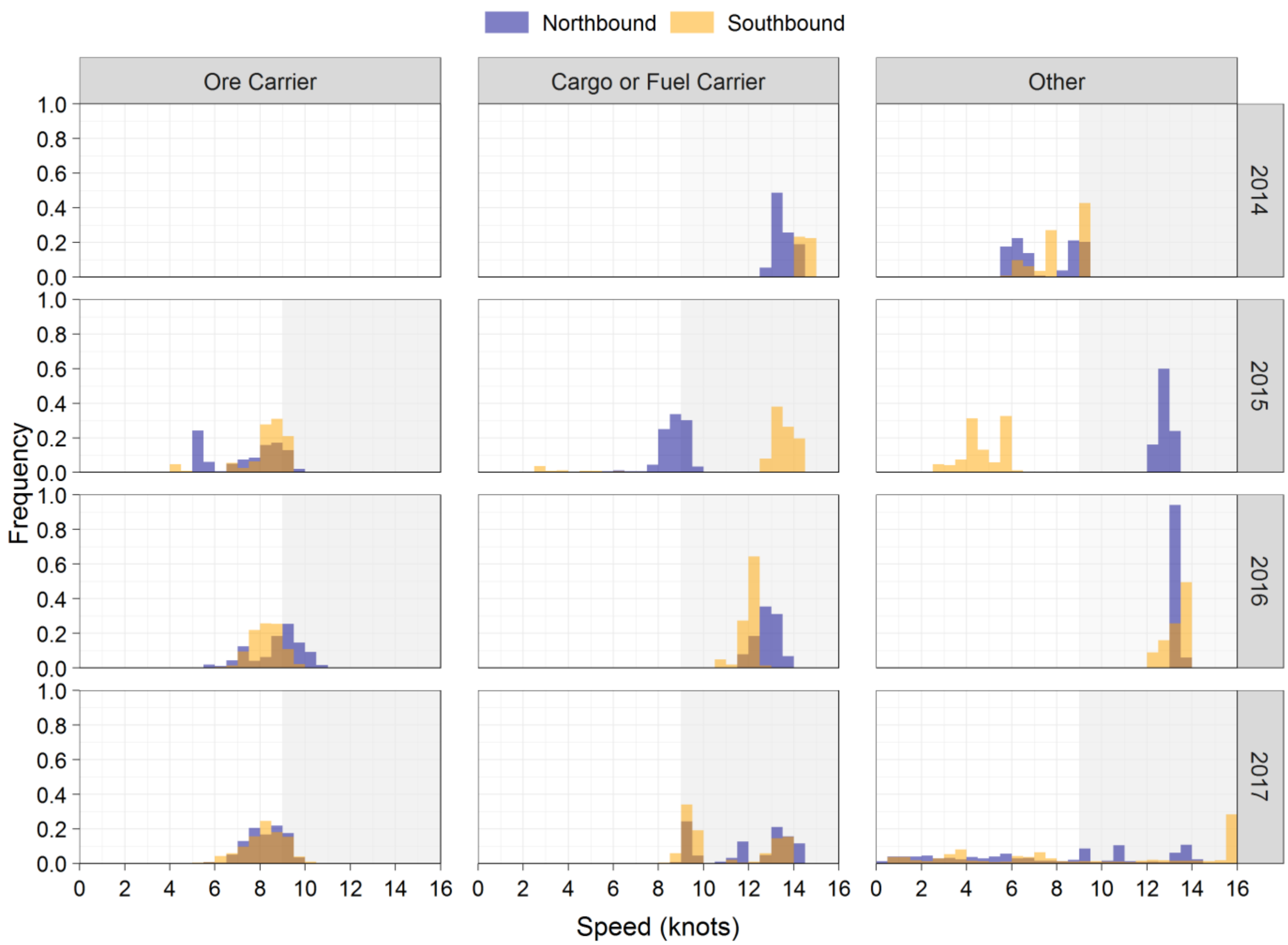


Figure 4-7: Travel speed (knots) of large vessels in the SSA during the 2014–2017 survey periods. Shaded area represents speeds > 9 knots

4.2.2 Small Vessel Traffic

Small vessels (< 50 m in length) recorded in the SSA were mostly aluminum skiffs or canoes with outboard motors, operated by local Inuit for hunting, fishing, and camp access. These vessels were generally passing through the SSA in transit to other locations, although several small vessels were recorded pulling ashore or moored to rocks on the shore below the Bruce Head observation platform.

Few small vessels were recorded in the SSA during active RAD surveying. In each of the sampling years, the majority of RAD surveys (73–85%) had no presence of small vessels within the SSA. Only 12–21% of surveys had one small vessel within the SSA (12% in 2015 and 21% in 2017), 2%–6% of surveys had two small vessels (2% in 2014 and 6% in 2017), and only 2015 and 2016 had three small vessels within the SSA during RAD surveys (<1% of surveys for each year).

4.2.3 Hunting

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. For example, during the 2017 survey period, the hunting camp was occupied during 20 of the 27 survey days. Hunting activity occurred frequently during the daily surveys, with one or more shots being fired within a short time period (Smith et al. 2017). For the majority of RAD surveys (60–86%, depending on the year), no hunting activity was recorded during or prior to the survey (designated as ‘no hunting’ in Figure 4-8). Of the remaining RAD surveys, the majority occurred within one hour of a shooting event (4–14% of all surveys, depending on year).

Generally, shooting events targeted either narwhal or seal. Shooting events in the air were indirectly targeting narwhal as the local Inuit observers explained that the intent was for the bullet to fall on the offshore side of the narwhal, spooking the animal so that it would flee towards the Bruce Head shoreline, closer to the hunters (A. Ootova per. comm. 2017).

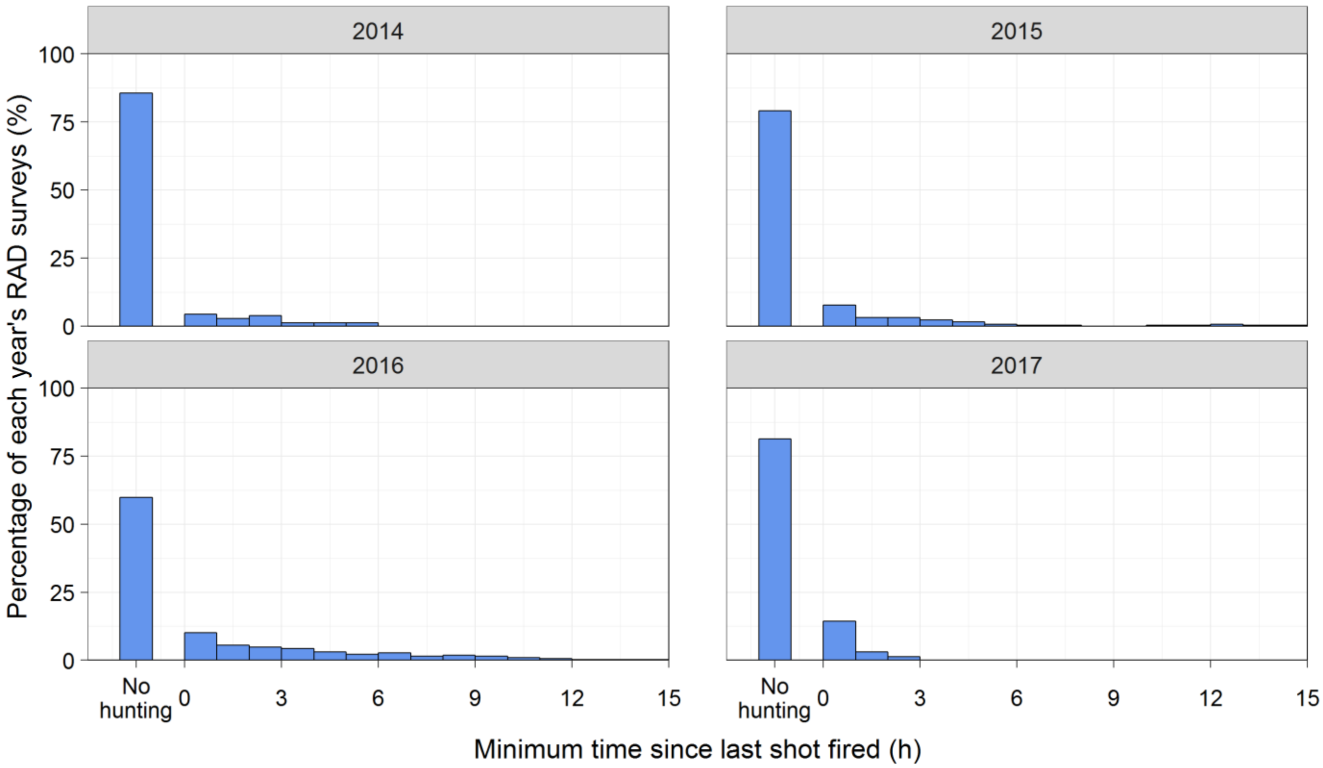


Figure 4-8: Distribution of each year's minimum time since shooting occurred, calculated for each RAD survey

4.3 Relative Abundance and Distribution

The number of RAD surveys completed per year ranged from 160 to 321 (see Table 4-1). The average number of RAD surveys per day ranged from 6.2 in 2017 to 11.9 in 2016. The lower number of RAD surveys in 2017 reflected the reduction in survey effort that year (one observation shift vs. two rotating observing shifts). Analysis of the RAD data excluded sightings made during 'impossible' sightability conditions and exclude an entire RAD survey conducted on 11 August 2017 in which counts were made in the same direction as a herding event and therefore had high potential of double-counting animals.

The majority of the RAD surveys with sightability not classified as 'impossible' were completed resulting in counts being conducted for all nine strata (26 substrata). In the four years of RAD surveys, completed surveys accounted for 93% of the surveys in 2014, 99% in 2015, 97% in 2016, and 69% in 2017. The proportion of complete surveys was extremely high in 2014–2015 due to lack of 'impossible' sightability values (see Figure 4-4). The lack of 'impossible' sightability values in 2014–2015 and the sparse use of 'impossible' sightability in 2016 (e.g., at Beaufort number of 6, in the farthest substrata; see Figure 4-4) further emphasized the need for an objective classification of sightability. Throughout the analysis, cases where sightability was listed as 'impossible' were removed from the dataset.

A total of 65,202 narwhal were observed in the SSA over the course of the 2014–2017 shore-based programs (see Table 3-1). The annual counts ranged from 10,463 narwhal (2014) to 28,309 narwhal (2016), reflecting both narwhal density and survey effort. Mean number of narwhal counts per RAD survey ranged from 46.5 narwhal/survey in 2015 to 88.2 narwhal/survey in 2016. When standardized by effort (i.e., survey counts divided by length of survey [h]), mean annual values ranged from 84.2 narwhal/h in 2015 to 156.4 narwhal/h in 2016 (Figure 4-9). Since mean values are strongly influenced by both zero counts and very high counts (as recorded in 2016; Figure 4-9), median values were also calculated. Median values of standardized counts ranged from 35.9 narwhal/h (in 2014) to 106.0 narwhal/h (in 2017).

Standardized daily counts of narwhal (narwhal/h) were bimodal in 2014, with a main peak (503 narwhal) on August 16 and a secondary peak (272 narwhal) on August 31 (Figure 4-9). In 2015, values of daily standardized counts were generally low (20 out of 29 survey days with values <70 narwhal/h). However, high values of daily standardized counts (>150 narwhal/h) were recorded on multiple days throughout the survey period (six days in August and one day in September). In 2016, daily standardized counts and their temporal distribution were similar to those recorded in 2014, with multiple high daily values (>150 narwhal/h) and two peaks in counts – in mid- and late-August. In 2017, no counts with numbers greater than 400 narwhal/h were recorded. On average, daily counts values in 2017 were between the relatively low values recorded in 2015 and the higher values recorded in 2014 and 2016.

In all years, multiple RAD surveys were conducted during which the total number of observed narwhal was zero (see Table 4-1). The proportion of zero-count RAD surveys varied from 41% of RAD surveys in 2014 to 52% in 2015, 40% in 2016, and only 22% in 2017. This variation strongly affected the annual median values.
The 2014-2016 median of daily standardized values ranged between 35.9 narwhal/h (in 2014) to 75.4 narwhal/h (in 2016) and increased to 106.0 narwhal/h in 2017 (Figure 4-9).

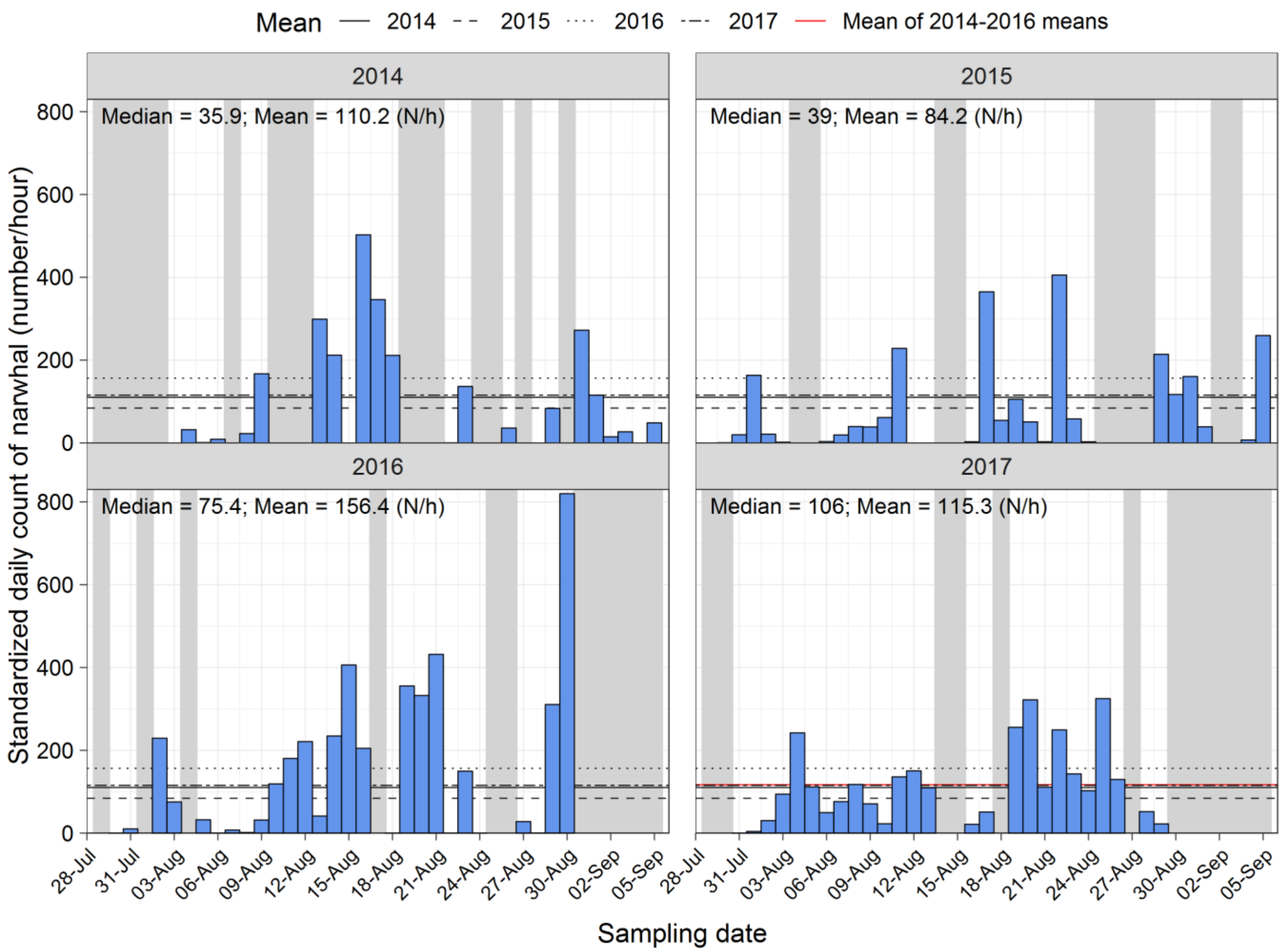


Figure 4-9: Standardized daily number of narwhal observed in the SSA from 2014–2017

Note: Horizontal lines depict each year's mean standardized value (black lines), as well as the average value of the combined 2014–2016 annual means (red line, shown on 2017 panel only). Grey areas delineate days with no sampling effort. Mean and median values of daily standardized counts (narwhal/h) are provided for each year.

In general, stratum narwhal counts increased from north to south, as described in the 2014–2017 annual reports (Smith et al. 2015, 2016, 2017; Golder 2018a). Each survey year, strata G, H, and I had the highest proportion of narwhal counts (Figure 4-10). Strata G, H, and I accounted for 62–72% of total counts in 2014–2017, while strata A, B, and C only accounted for 5–11% of total annual counts. Narwhal numbers also varied with substratum distance from the observation platform (Figure 4-10). Each year, substrata '2' had the highest percentage of total annual counts, accounting for 48–56% of total annual narwhal observations.

In addition to stratum and substratum, sightability also affected narwhal counts (Figure 4-10). Narwhal counts per RAD survey were considerably higher during periods when the sightability was considered 'excellent' and 'good', with 'excellent' sightability counts ranging between 21 narwhal/survey in 2014 and 63 narwhal/survey in 2016 and 'good' sightability counts ranging from 22 narwhal/survey in 2015 to 42 narwhal/survey in 2016. In comparison, 'medium' sightability counts only ranged from 12 narwhal/survey in 2016 to 23 narwhal/survey in 2017 (the only two years when 'medium' sightability was recorded) and 'poor' sightability counts ranged from four narwhal/survey in 2016 to 19 narwhal/survey in 2014 (before 'medium' sightability was used and thus when 'poor' sightability also likely included some 'medium' conditions).

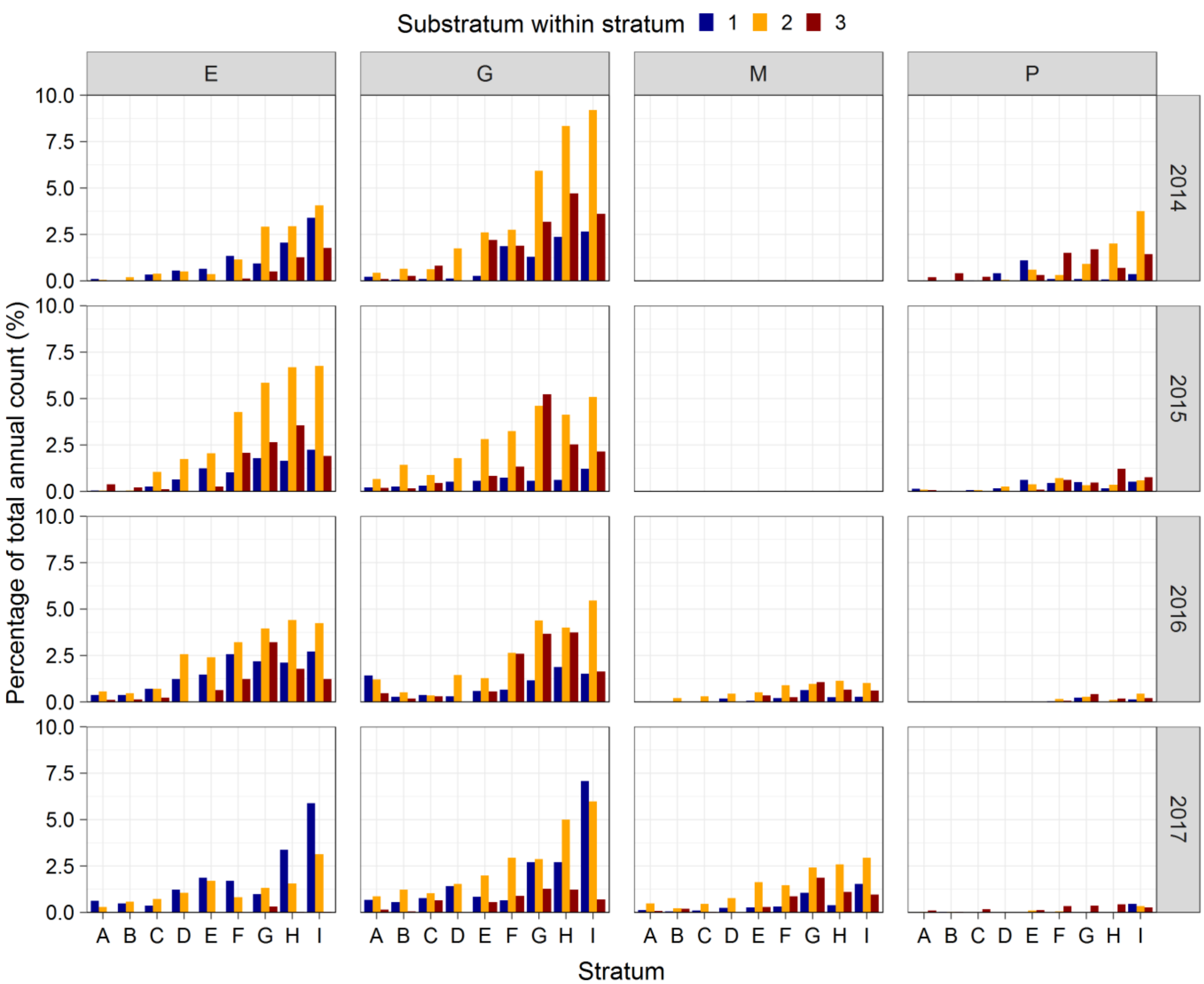


Figure 4-10: Percentage of narwhal counted in each substratum and sightability out of total narwhal counted in 2014-2017

In 2014–2017, the proportion of narwhal observed in the presence of at least one large vessel within 15 km of the substratum centroids increased from 0.6% in 2014 to 11% in 2015, 18% in 2016, and 30% in 2017. Of the narwhal counts recorded during periods when a single large vessel present within 15 km, the majority of counts was recorded when vessels were northbound (93.2%, 67.4%, 86.1%, and 64.5% in 2014–2017, respectively).

In the combined 2014–2017 RAD dataset, the majority of narwhal counts were recorded when no large vessels were present within 15 km of the BSA (n = 21,822 narwhals), at which time mean number of narwhal per substratum was 2.5 individuals (across-year standard deviation = 0.6 individuals; Figure 4-11). When a large vessel was within 15 km of the SSA centroids, a total of 2,497 narwhal were recorded, with mean count per substratum of 3.6 individuals (across-year SD = 1.7 individuals). When large vessels were present within 15 km of the SSA centroids, mean narwhal count per substratum varied in relation to 1) distance from the vessel transiting through the SSA and 2) direction of vessel and relative position of vessel to the SSA. Mean narwhal counts were generally lower when southbound vessels passed through the SSA (1.0 and 1.4 individuals per substratum when a vessel headed toward or away from the centroid, respectively) and higher when northbound vessels passed through the SSA (5.2 and 2.7 individuals per substratum when a vessel headed toward or away from the centroid, respectively). Narwhal counts in close proximity to large vessels (distance ≤2 km) were generally lower than counts at a larger distance (3–15 km) for northbound vessels, but not southbound vessels (especially southbound vessels heading toward the substrata).

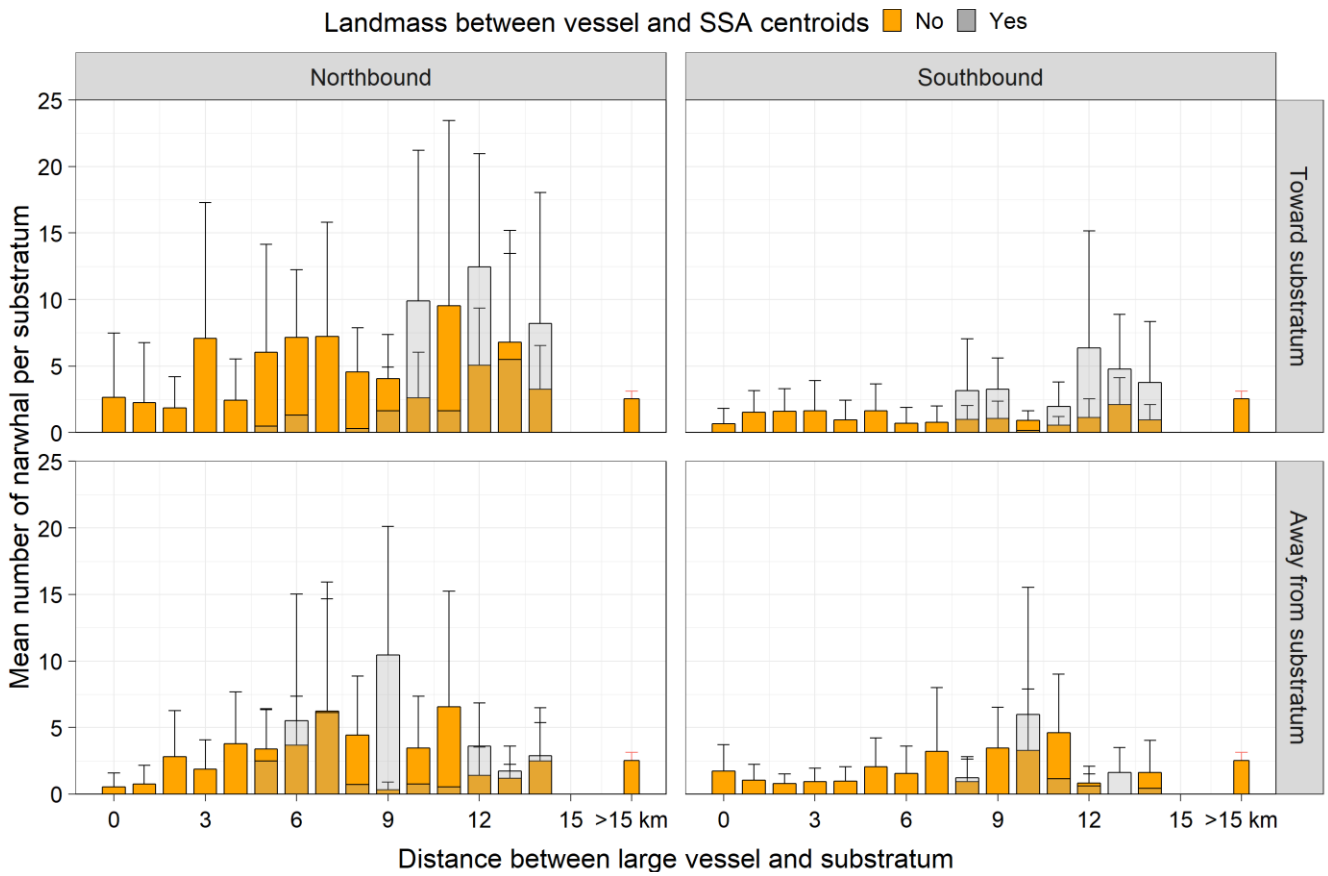


Figure 4-11: Mean narwhal counts in SSA relative to distance from vessel, binned to 1 km (2014–2017)

Notes: Observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant). One bar, of 36 narwhal/substratum at a distance of 4 km, with a landmass between vessel and SSA centroids was removed from the bottom left panel of the plot for visualization.

4.3.1 RAD Modeling

Of the compiled 25,166 substratum counts, a total of 3,344 had a vessel present within 15 km from the relevant substratum centroid. In 653 cases (20% of all cases with vessel presence), there was a landmass in the line of sight between the vessel and centroid, which is likely to affect noise propagation. As expected, landmasses in the line of sight between the vessel and substratum centroid were predominantly present when vessels were farther from the SSA. Mean distances between vessel and centroid with and without landmass in the line of sight were 11.0 and 6.25 km, respectively. All cases with a landmass present in the line of sight between the vessel and substratum centroid were removed from the modelling to reduce bias associated with reduced noise propagation.

The full model of RAD counts had a zero-inflation component that depended on stratum, substratum, year, and Beaufort scale. The full model was preferred over a model with an intercept-only zero-inflation ($P<0.001$) and over a negative binomial model with no zero inflation ($P<0.001$). This indicates that these four fixed effect predictors affect not only narwhal counts, but also the probability of recording narwhal presence – whether due to sighting conditions (Beaufort scale effect and distance of the substratum), spatial (stratum) distribution within the SSA or interannual differences in narwhal distribution. All four effects were highly significant (<0.001) predictors in the zero-inflation component of the full mixed model (Table 4-3).

In the mixed model of narwhal counts in the SSA, effects of sampling (stratum, substratum, Beaufort scale, and glare), environmental variables (tide height and interaction between tide height and change in depth) and anthropogenic activity (large vessel traffic and hunting) had statistically significant effects on narwhal counts ($P<0.05$; Table 4-5).

Mean narwhal counts were estimated to increase over the course of the sampling period, with a peak in late August (Figure 4-12, panel A). At the end of August and in early September, estimated mean counts were higher than in the beginning of the sampling period, however the uncertainty associated with these estimates was also considerably higher than in early August. Mean narwhal counts were estimated to increase throughout the strata, from the lowest estimate at stratum A to the highest estimate in stratum I, as well as throughout the substrata, with the lowest estimate at substratum '3' and the highest at substratum '2' (Figure 4-12, panel B). For example, at the predictor levels used for visualization of model results (year = 2017, date = 12 August, Beaufort value of 2, glare = 'none', no large vessel present, and no hunting activity), narwhal predictions increased from 0.31 narwhal/count in substratum A2 to 3.28 narwhal/count in substratum I2. Similarly, for the same predictor values and for stratum F, narwhal count predictions increased from 0.64 narwhal/count in substratum '3' to 0.88 narwhal/count in substratum '1', and to 1.44 narwhal/count in substratum '2'.

Time since last hunting period was estimated to have a significant effect on mean narwhal counts (Table 4-3). The effect was modeled as a third-degree polynomial to account for temporal trends in narwhal counts with time since last shooting event. The resulting trend was estimated to have decreasing narwhal counts over time, from 2.66 narwhal/count at 0 h after shooting to 1.48 narwhal/count at 3.5 h after shooting. From 3.5 h post shooting, narwhal counts increased, peaking at 11 h after a shooting event (Figure 4-12, panel C). In comparison, when no hunting occurred, the model predicted a mean narwhal count of 1.85 narwhal/count was estimated.

Increasing Beaufort scale values were predicted to result in decreasing estimates of narwhal counts (Figure 4-12, panel D), decreasing from a mean estimated value of 2.36 narwhal/count at a Beaufort scale value of 0 to 0.73 narwhal/count at a Beaufort scale value of 5. However, only Beaufort values of 2 or higher were estimated to have a significantly different effect than a Beaufort value of 0 (dead calm water). Increasing glare (from none to low) resulted initially in an increase in narwhal counts (from 1.44 narwhal/count to 1.67 narwhal/count), reflecting the increase in mean observed narwhal. Further increase to severe glare resulted in a reduction in estimated narwhal counts to 0.88 narwhal/count at severe glare (Figure 4-12, panel E).

Table 4-3: Summary table of generalized mixed linear model of narwhal counts in the SSA

Parameter	X^2 value	df	P-value
Negative binomial component of model			
Day of year	15.136	2	0.001
Year	4.613	3	0.202
Stratum	277.230	8	<0.001
Substratum	186.520	2	<0.001
Glare	47.233	2	<0.001
Beaufort scale	126.254	5	<0.001
Tide height	32.226	2	<0.001
Change in depth	0.285	1	0.593
Vessel distance	0.740	3	0.864
Vessel direction relative to SSA centroids	0.505	1	0.477
North- or southbound vessel	24.021	1	<0.001
Large vessel presence within 15 km from SSA	16.867	1	<0.001
Time since last shooting event	66.597	3	<0.001
Hunting event within 12.5 h prior to observation	8.373	1	0.004
Number of small vessels within the SSA	0.241	1	0.623
Tide height: Change in depth	6.129	2	0.047
Vessel distance: Vessel direction relative to SSA centroids	2.955	3	0.399
Vessel distance: North- or southbound vessel	8.206	3	0.042
Vessel direction relative to SSA centroids: North- or southbound vessel	3.343	1	0.068
Zero-inflation component of model			
Stratum	49.926	8	<0.001
Substratum	59.289	2	<0.001
Year	91.243	3	<0.001
Beaufort scale	23.227	6	<0.001

The effect of tide height on mean narwhal counts was subtle and was predicted to reverse between falling and rising tides (Figure 4-13). At falling tide, mean counts were estimated to decrease when tide height was near average. Conversely, at rising tide, mean counts were estimated to increase when tide height was near average. The effect was slight — at average tide height, predicted narwhal counts increased from 1.73 narwhal/count at falling tide to 1.99 narwhal/count at rising tide.

The effect of vessel distance from SSA centroids was estimated to change based on the direction of the vessel within Milne Inlet (*P* value of interaction between vessel distance and vessel direction = 0.042). The direction of the large vessel relative to the SSA centroids was not significant in either main effect or interaction terms.
The model predicted low counts of narwhal when a northbound large vessel was near the substrata (0.72-1.2 narwhal/count at distance of 0 km, depending on vessel direction relative to the substrata) and a peak in narwhal counts when vessels were 6–7 km from the substrata (2.1–2.8 narwhal/count, depending on distance vessel direction relative to the substrata; Figure 4-14). In contrast, for southbound vessels, the model predicted an increase in narwhal counts when vessels were near (1.85–2.1 narwhal/count at distance of 0 km) and a decrease in counts when vessels were farther away (e.g., 1.2–1.3 narwhal/count at a distance of 6 km). Mean narwhal counts at the absence of large vessels within 15 km from the substrata were estimated to be 1.85 narwhal/count.

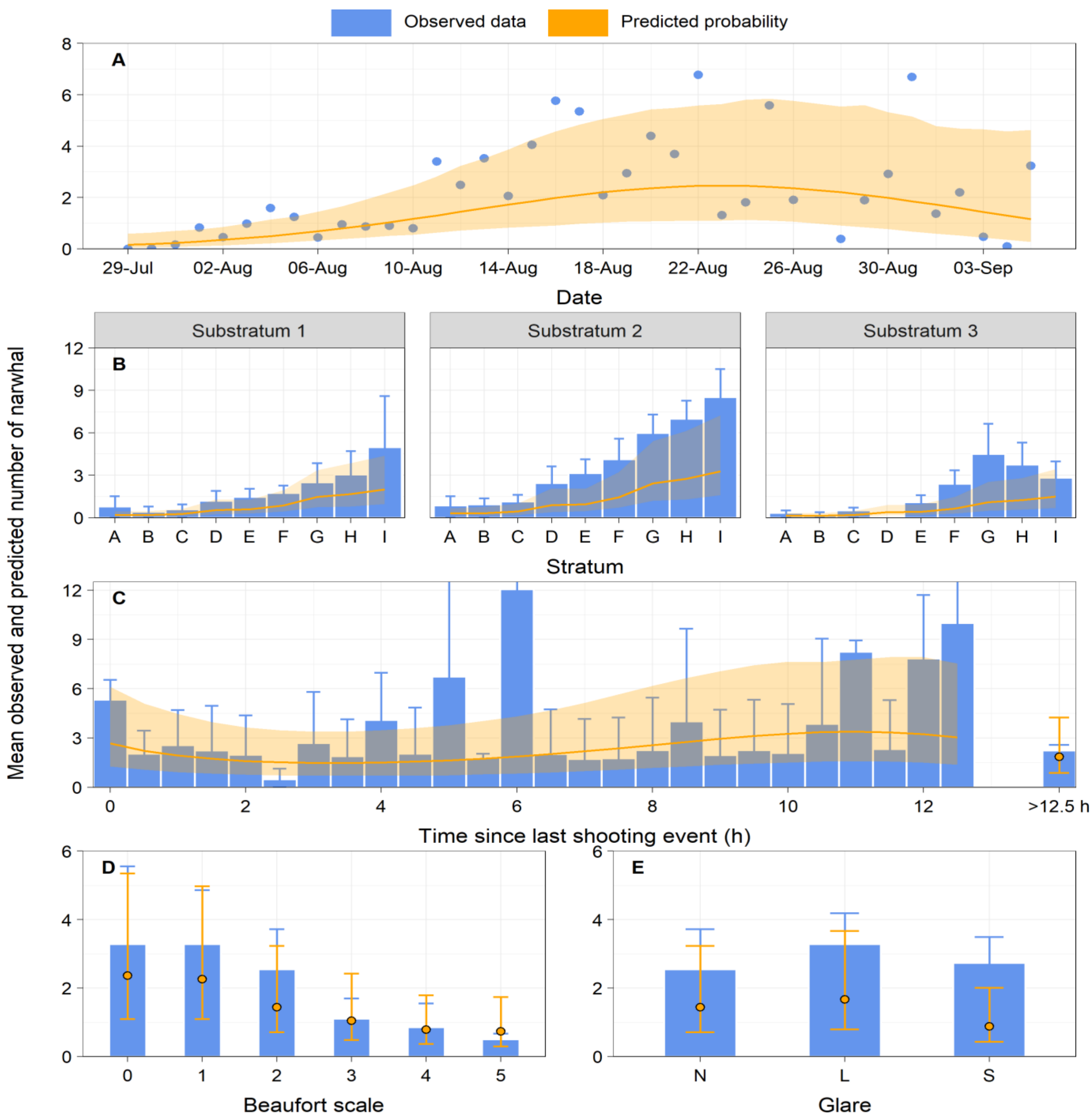


Figure 4-12: Mean observed and predicted narwhal counts in the SSA relative to sampling date, stratum, substratum, hunting activity, Beaufort scale, and glare

Notes: Observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Y-axis scale in panel C was reduced to improve visibility of predictions.

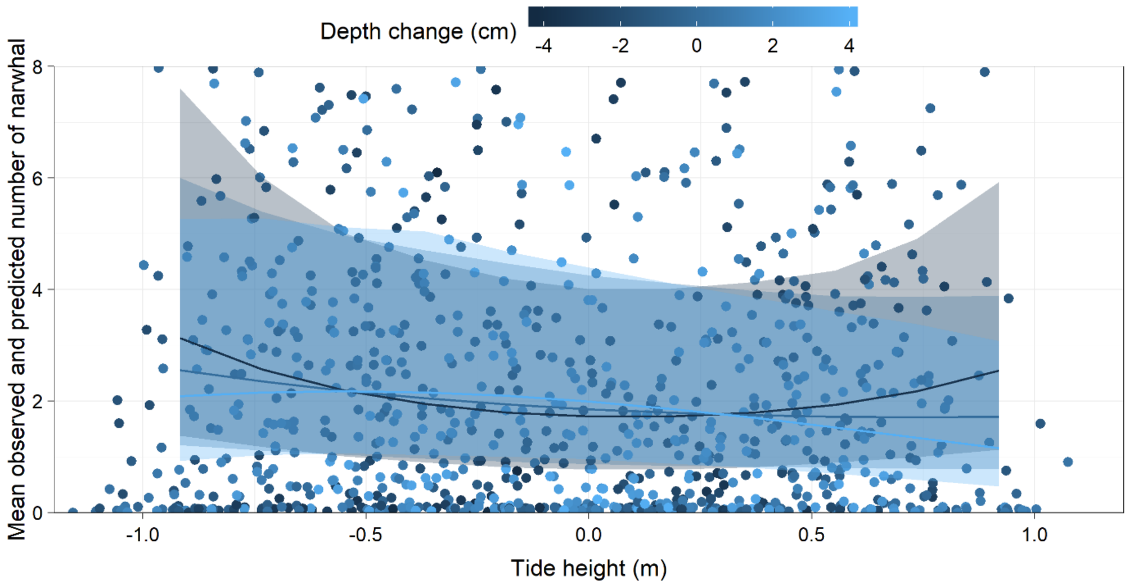


Figure 4-13: Observed (points) and mean predicted (line and ribbon) narwhal counts in the SSA relative to sampling date, stratum, substratum, hunting activity, Beaufort scale, and glare. Predictions are shown for falling (minimum), slack (mean), and rising (maximum) tides.

Notes: predicted data depict mean and 95% confidence intervals, holding all other variables constant.

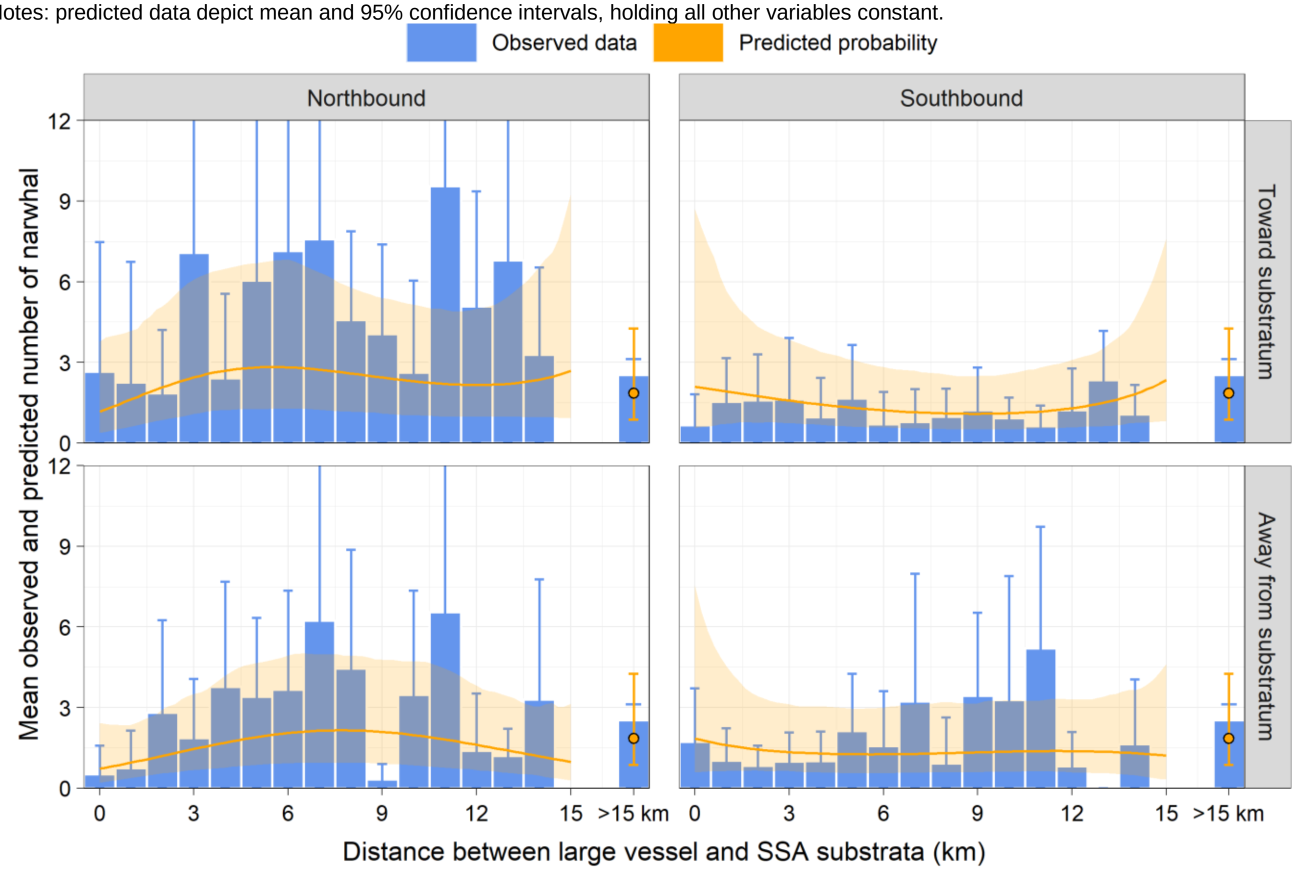


Figure 4-14: Mean observed and predicted narwhal counts in the SSA relative to distance from large vessels in transit, vessel direction in Milne Inlet, and direction relative to the BSA (2014–2017)

Notes: Observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant. Y-axis scale was reduced to improve visibility of predictions.

4.3.2 Spatial Distribution in the SSA

The use of substrata ‘3’ varied both with time and between narwhal (Figure 4-15; Figure 4-16). The number of GPS fixes used in this analysis ranged from 138 (narwhal #5) to 211 (narwhal #2). While narwhal #1 and #2 used substrata ‘3’ repeatedly and on multiple days, narwhal #4 and #5 had very few fixes in those substrata. Overall, the use of substratum ‘3’ by the five narwhal GPS-tagged monitored in August 2017 was uncommon. Narwhal #2 used substratum ‘3’ relatively heavily in late August, with up to 100% of the daily GPS fixes (although only 2 and 9 GPS fixes were recorded on those days).

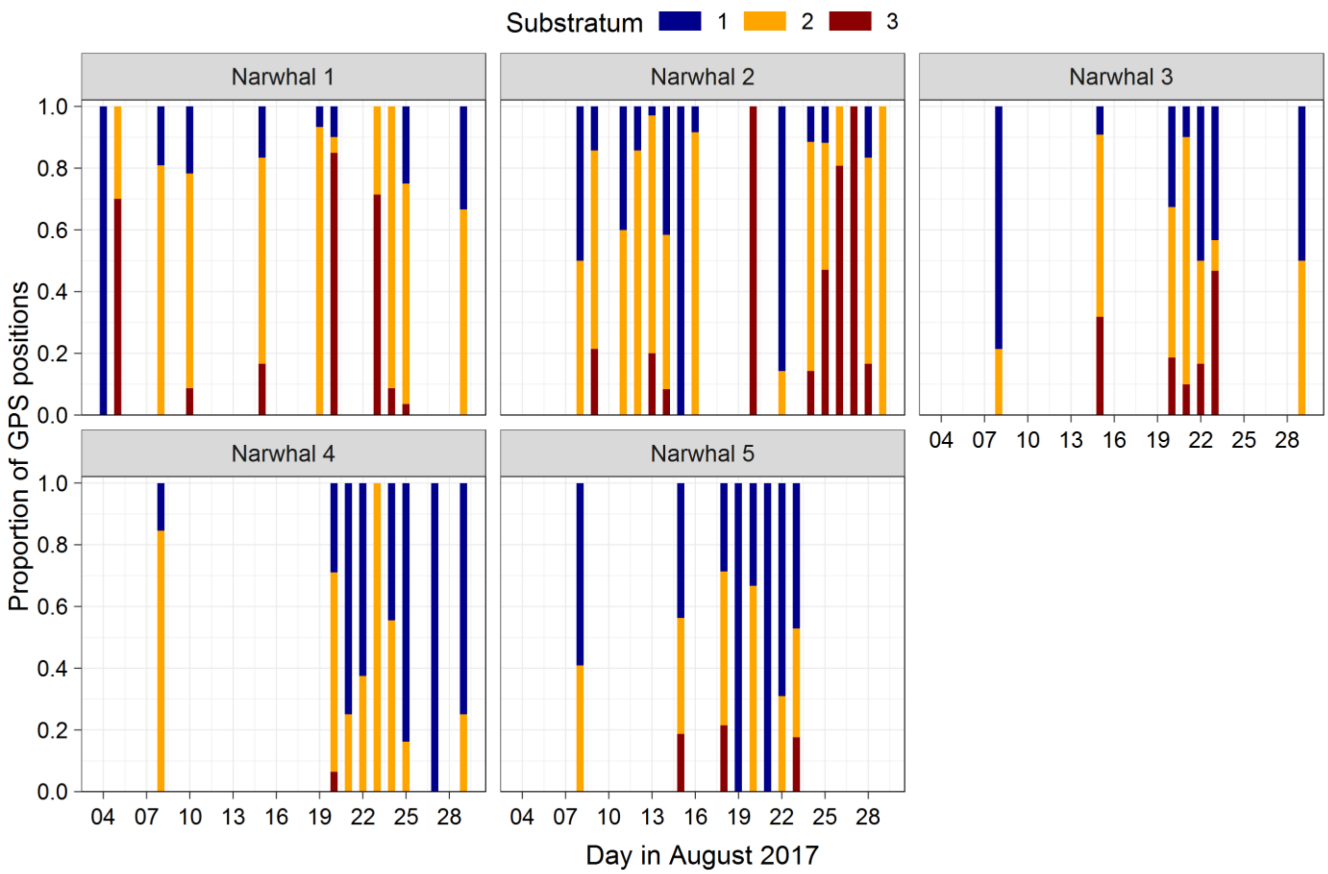
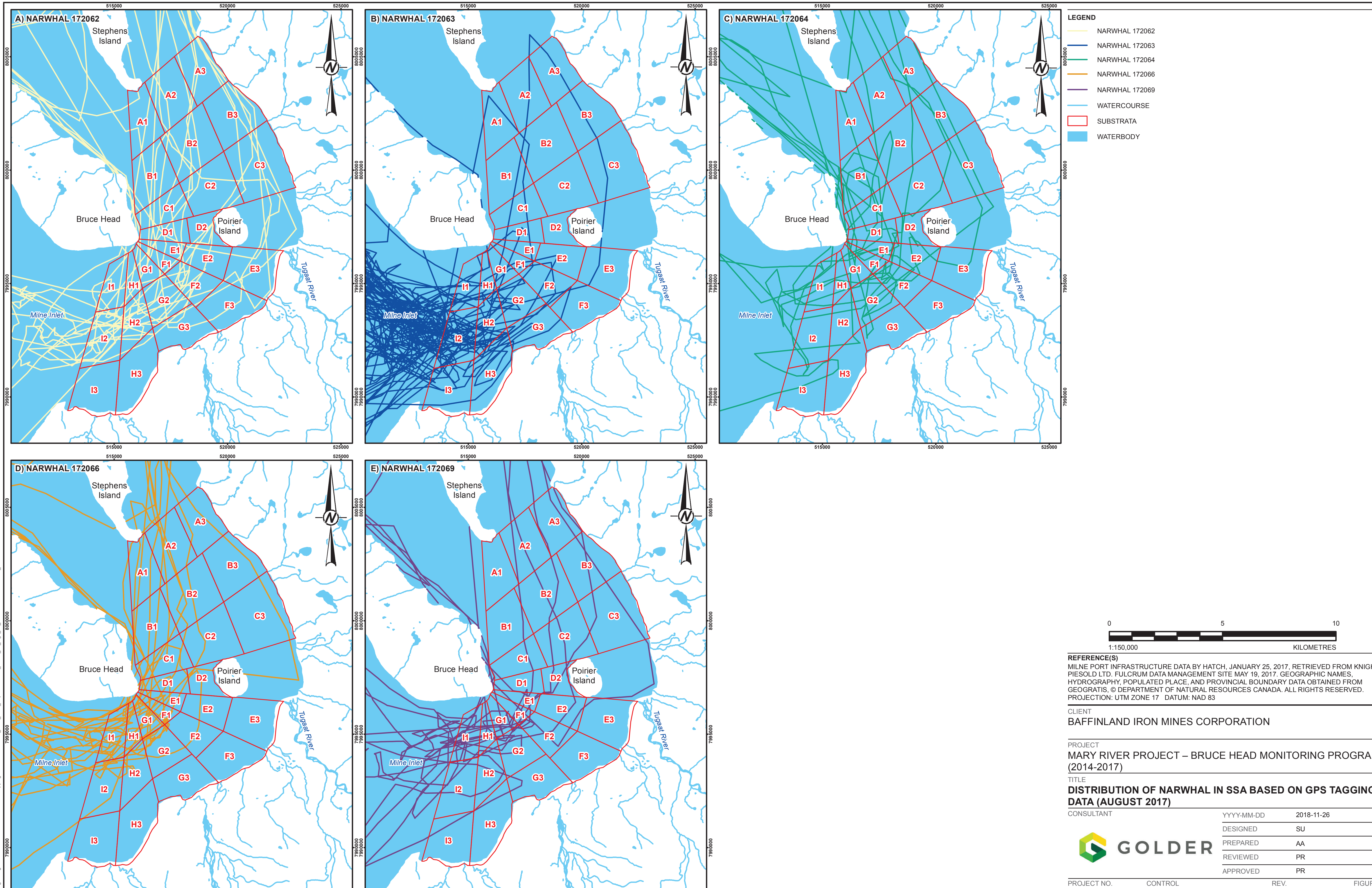


Figure 4-15: Observed use of substrata by five GPS-tagged narwhal in August 2017, plotted by date



0 5 10

1:150,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. GEOGRAPHIC NAMES, HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT

BAFFINLAND IRON MINES CORPORATION

PROJECT

MARY RIVER PROJECT – BRUCE HEAD MONITORING PROGRAM (2014-2017)

TITLE

DISTRIBUTION OF NARWHAL IN SSA BASED ON GPS TAGGING DATA (AUGUST 2017)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-11-26
DESIGNED	SU
PREPARED	AA
REVIEWED	PR
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
1663724	11000	0	4-16

Predicted probability of use of substratum ‘3’ was low in all strata except for stratum A (Figure 4-17). Throughout strata B to E, the probability of use of substrata ‘1’ was similar or higher than the use of substrata ‘2’. In comparison, in strata F through I, the probability of using substratum ‘2’ was substantially higher than the probability of use of substratum ‘1’. Individual use of the three substrata (as indicated by thin lines in Figure 4-17) varied greatly, with some individuals using certain substrata considerably more than others. Overall, the five tagged narwhal spent less time in substrata ‘3’ in the SSA, with substantial individual and temporal variability.

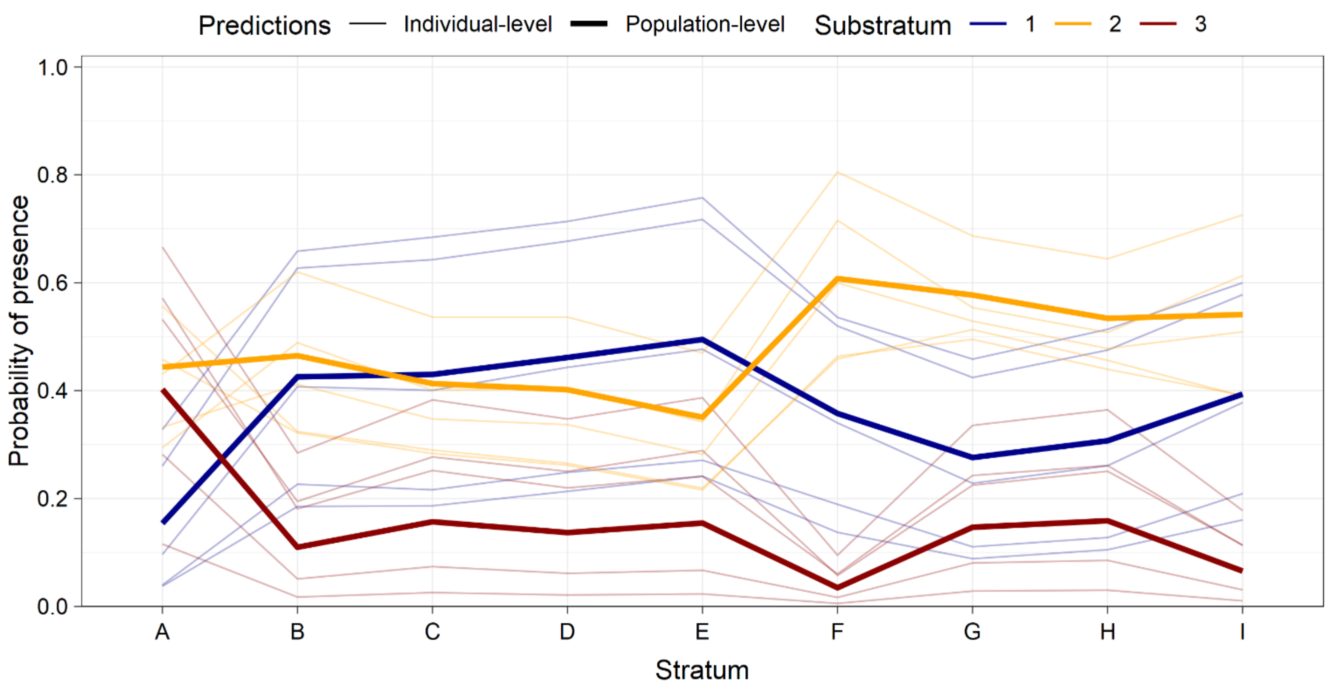


Figure 4-17: Predicted use of substrata in August 2017, plotted by stratum (A to I) and prediction level – individual (thin lines, representing each of the five tagged narwhal) and population-level (thick lines)

Overall, the predicted population-level estimates of substratum use base on GPS track data correlated with substratum use based on summarized 2017 Bruce Head data (Figure 4-18). Both Bruce Head data and GPS-based model estimates estimated high use of substratum ‘2’ throughout the strata, intermediate use of substratum ‘1’ and low use of substratum ‘3’. Observed and estimated values differed for substrata A1 and A3 – while Bruce Head data indicated high use of substratum A1 (approximately 40% of narwhal counts in stratum A), the model estimated only 15% use for the substratum. The reverse was observed in substratum A3. This is likely due to the GPS data of narwhal #1, which was recorded multiple times in substratum A3 (Figure 4-16), increasing the overall use of the substratum in the model of GPS positions.

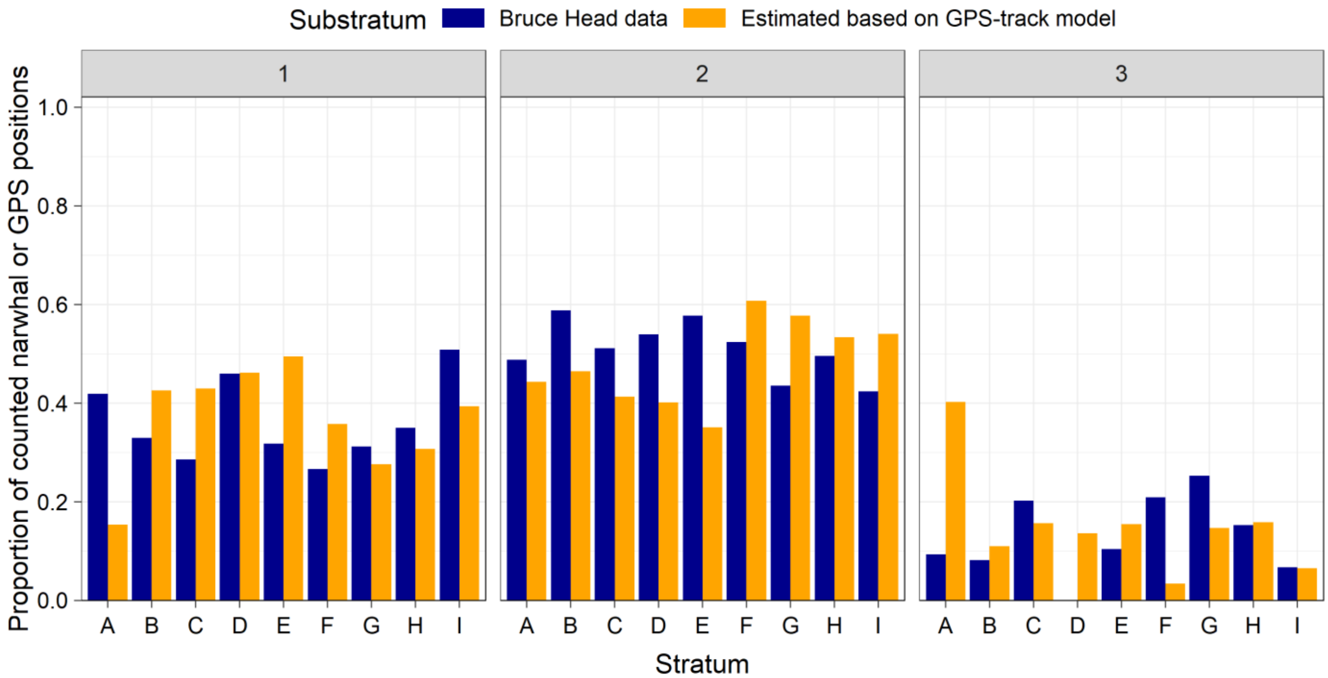


Figure 4-18: Predicted use of substrata in August 2017, plotted by stratum, substratum (1 to 3), and data source (observed Bruce Head data and modeled population-level estimates shown in Figure 4-17)

4.4 Group Composition and Behaviour

The total number of sampling days in which data on narwhal group composition and behaviour were collected within the BSA ranged from 11 days in 2014 to 27 days in 2017 (Table 4-4). The number of narwhal groups observed during these days ranged from 250 groups (totalling 1,086 narwhal) in 2014 to 2,416 groups (totalling 8,913 narwhal) in 2017 (Table 4-4). A total of 8 and 23 groups in 2016 and 2017, respectively, were recorded under 'impossible' sightability conditions and were excluded from further analyses. The proportion of narwhal groups recorded in the BSA during periods of 'no anthropogenic activity[3]' decreased from 91% in 2014 to 56% in 2015, and to 42% in both 2016 and 2017.

Table 4-4: Number of narwhal recorded in BSA during group composition / behaviour surveys (2014–2017)

Survey Year	# Sampling Days	# Narwhal Groups	# Narwhal
2014	11	250	1,086
2015	17	287	1,568
2016	26	702	2,171
2017	27	2,416	8,913

Note: data collected under 'impossible' sightability conditions were omitted from this table and the multi-year analysis.

[3] large and small vessel transits, active shooting events

When standardizing the yearly data for hourly observer effort, the daily number of narwhal observed in the BSA between 2014 and 2017 differed substantially among years, as well as within individual years, with no apparent within-year temporal patterns (Figure 4-19). Overall, the 2016 survey recorded the lowest standardized number of narwhal per hour of observation (mean = 8.4 narwhal/h) while the 2017 survey recorded the highest standardized number of narwhal per hour of observation (mean = 59.8 narwhal/h). The standardized number of narwhal per hour of observation recorded in 2014 and 2015 were closer to the numbers observed in 2017 than 2016 with means of 47.1 and 40.8 narwhal/h observed, respectively (Figure 4-19). It should be noted that higher narwhal counts in 2017 may have been influenced by the slightly larger BSA boundary used that year compared to previous years. In 2017, the BSA was defined to include portions of substrata D1, E1, and F1 up to 1,000 m from shore, whereas it only included portions of substrata E1 and F1 up to 1,000 m from shore in 2014–2016.

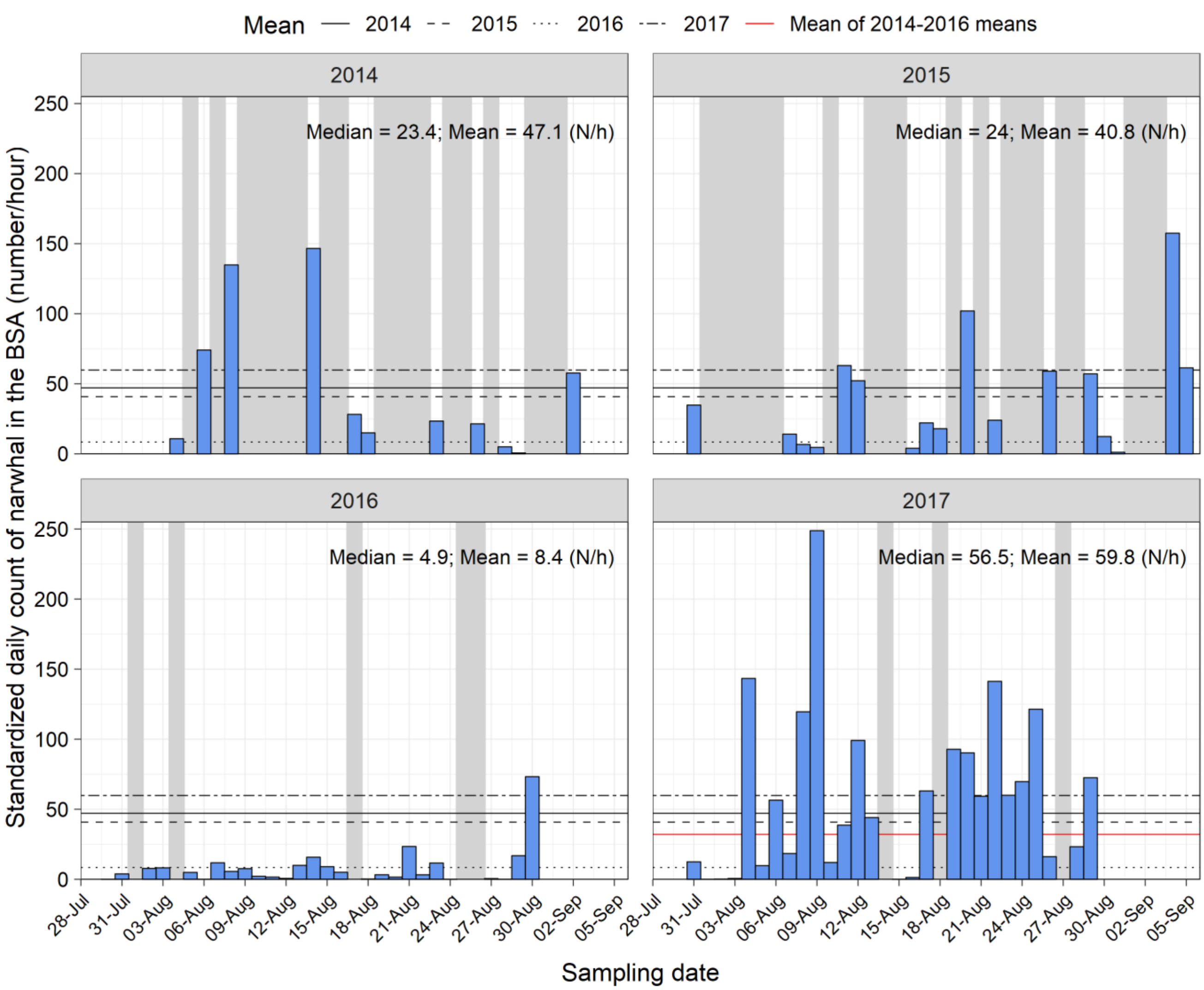


Figure 4-19: Standardized daily number of narwhal observed per hour of observation in the BSA (2014–2017)

Note: Horizontal lines depict each year's mean standardized value (black lines), as well as the average value of the combined 2014–2016 annual means (red line, shown on 2017 panel only). Grey areas delineate days with no sampling effort. Mean and median values of daily standardized counts (narwhal/h) are provided for each year.

The majority of narwhal groups in the BSA were recorded during ‘excellent’ sightability conditions in 2014, 2015, and 2017; and during ‘good’ sightability conditions in 2016 (Figure 4-20). The proportion of narwhal groups recorded during ‘poor’ sightability conditions was relatively high in 2015 (21%). This was likely an artefact of merging ‘poor’ and ‘medium’ sightability categories that year for standardization purposes.

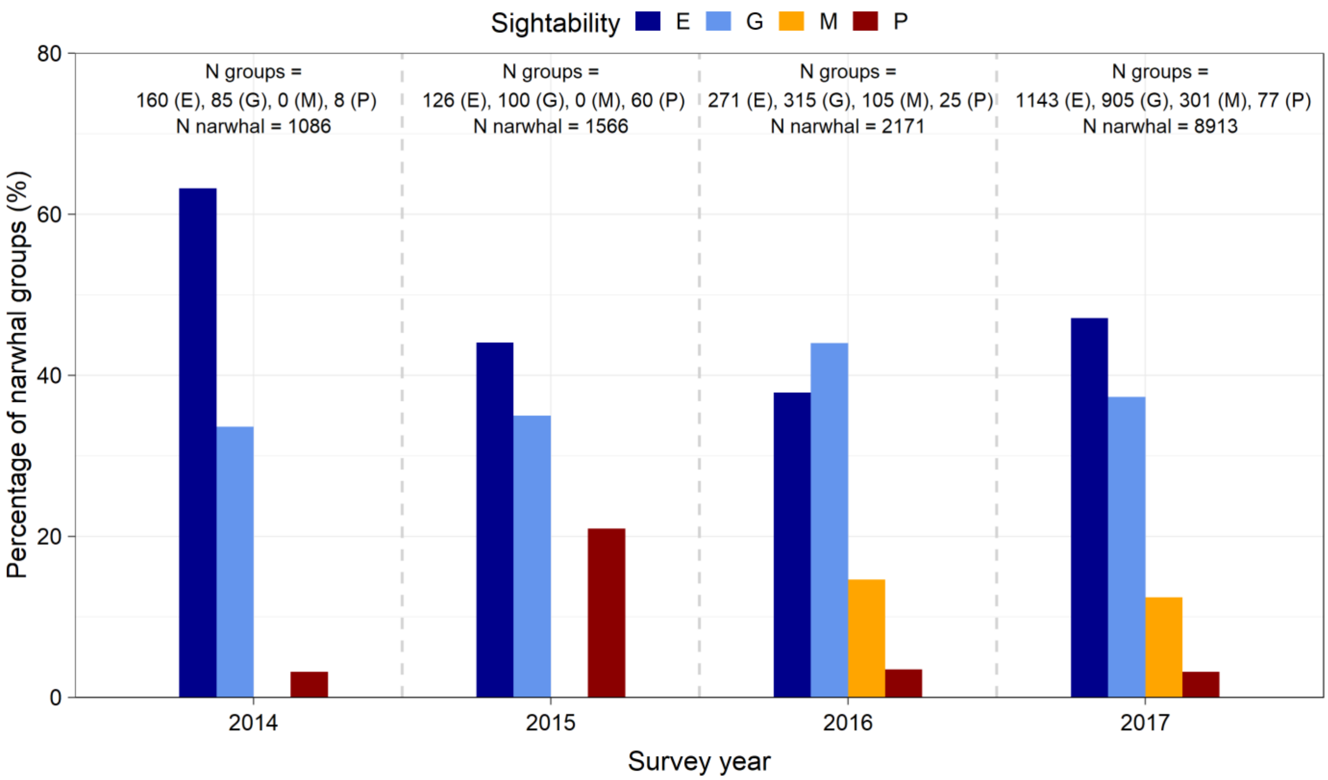


Figure 4-20: Percentage of narwhal groups in the BSA by sightability conditions

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

4.4.1 Group Size

Throughout the four-year study, the number of narwhal observed per group was relatively small, generally between one and five individuals (Figure 4-21). Groups larger than 25 individuals were only recorded once in 2014 and three times in 2015 (with group sizes up to 45 individuals). Mean group size in the BSA was 4.3 in 2014, 5.5 in 2015, 3.1 in 2016, and 3.7 in 2017.

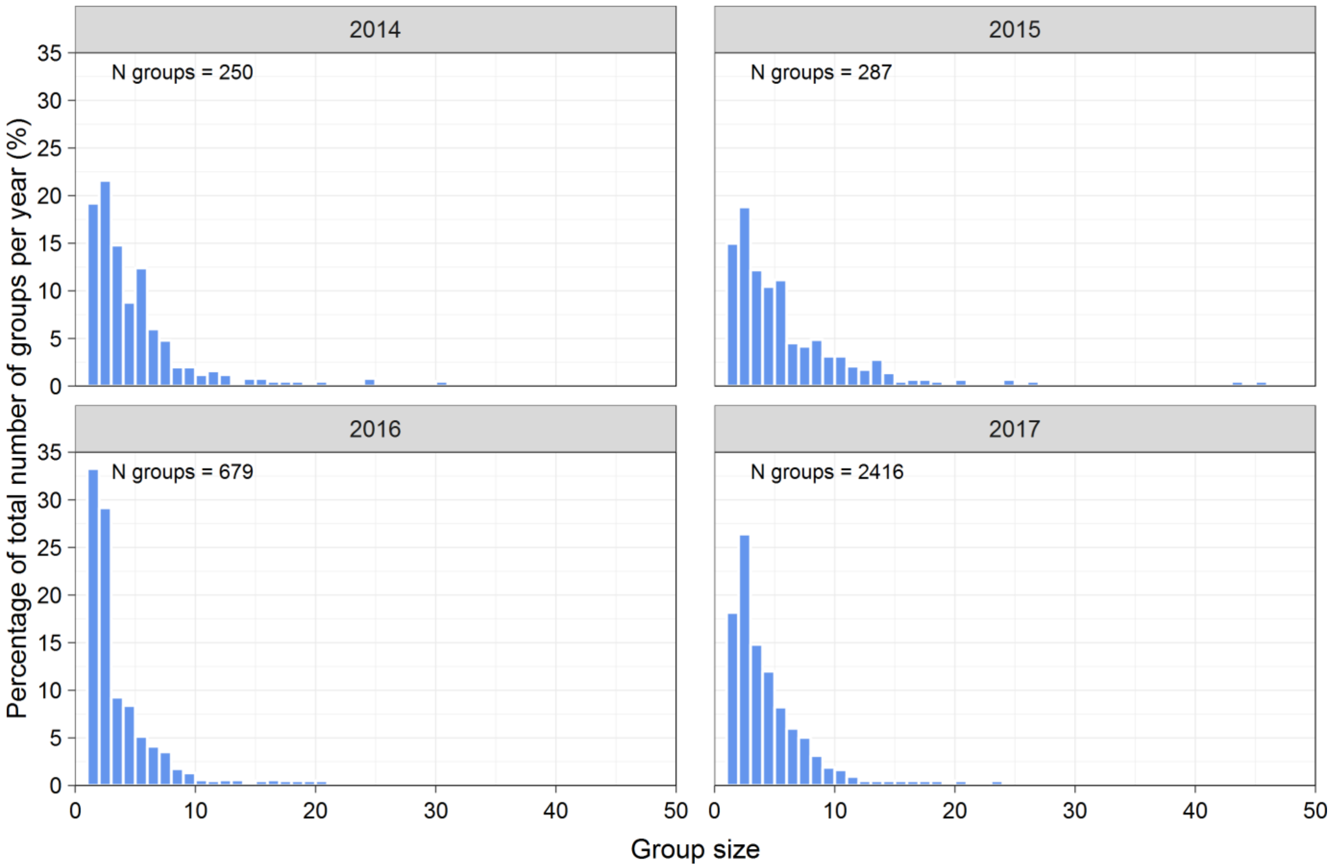


Figure 4-21: Distribution of group size observed in BSA (2014–2017)

In the combined 2014–2017 dataset, most narwhal sightings in the BSA occurred when no large vessels were present within 15 km of the BSA (n = 2,908), at which time mean group size was 3.7 individuals (across-year standard deviation = 2.9 individuals). When large vessels were present within 15 km of the BSA, mean narwhal group size varied in relation to 1) distance from the vessel transiting through the SSA and 2) direction of vessel and relative position of vessel to the BSA. When a large vessel was within 15 km of the BSA, a total of 572 narwhal groups were sighted with mean group size of 3.6 individuals (SD = 3.0 individuals). Of these, 152 and 160 groups were recorded when a vessel was northbound and heading toward or away from the BSA, respectively, and 110 and 148 cases were recorded when a vessel was southbound and heading toward or away from the BSA, respectively. Mean group size of narwhal observed under these four vessel passage scenarios ranged from 2.7 (northbound vessel heading toward the BSA) to 4.6 (southbound vessel heading toward the BSA; Figure 4-22).

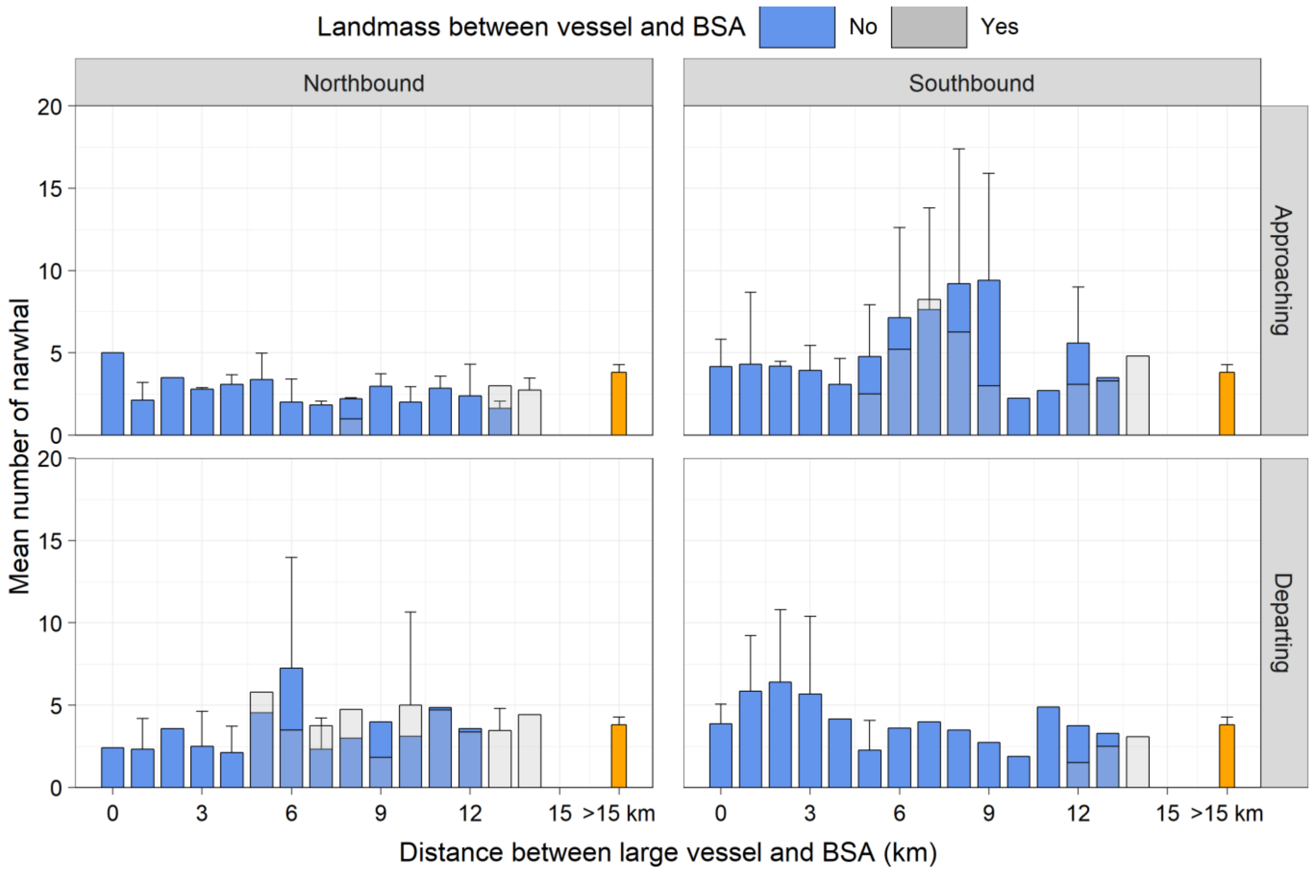


Figure 4-22: Mean group size in BSA relative to distance from vessel, binned to 1 km (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

In the mixed model for group size, only the effects of glare and survey year were statistically significant (*P*<0.05; Table 4-5). Anthropogenic activity, including large vessel transit, did not have a significant effect on group size. Group sizes were estimated to be on average similar when there was no glare or when glare was low, but larger at severe glare (when smaller groups are harder to notice; Figure 4-23). Since ‘medium’ glare was only used in 2016 (and was combined with ‘low’ glare for analysis), it is not currently possible to estimate how `medium` glare affects group size estimates. Estimated mean group sizes were smallest in 2016 and largest in 2015.

Table 4-5: Summary table of generalized mixed linear model of group size

Parameter	X^2 value	df	P-value
Day of year	7.011	3	0.072
Year	15.938	3	0.001
Glare	6.434	2	0.040
Beaufort scale	2.339	4	0.674
Tide height	7.096	3	0.069
Change in depth	1.750	1	0.186
Vessel distance	1.175	3	0.759
Vessel direction relative to BSA	2.374	1	0.123
North- or southbound vessel	0.145	1	0.703
Large vessel presence within 15 km from BSA	0.385	1	0.535
Time since last shooting event	7.535	3	0.057
Hunting event within 6 h prior to observation	0.027	1	0.870
Number of small vessels within the SSA	0.850	1	0.356
Vessel distance:Vessel direction relative to BSA	0.947	3	0.814
Vessel distance:North- or southbound vessel	0.318	3	0.957

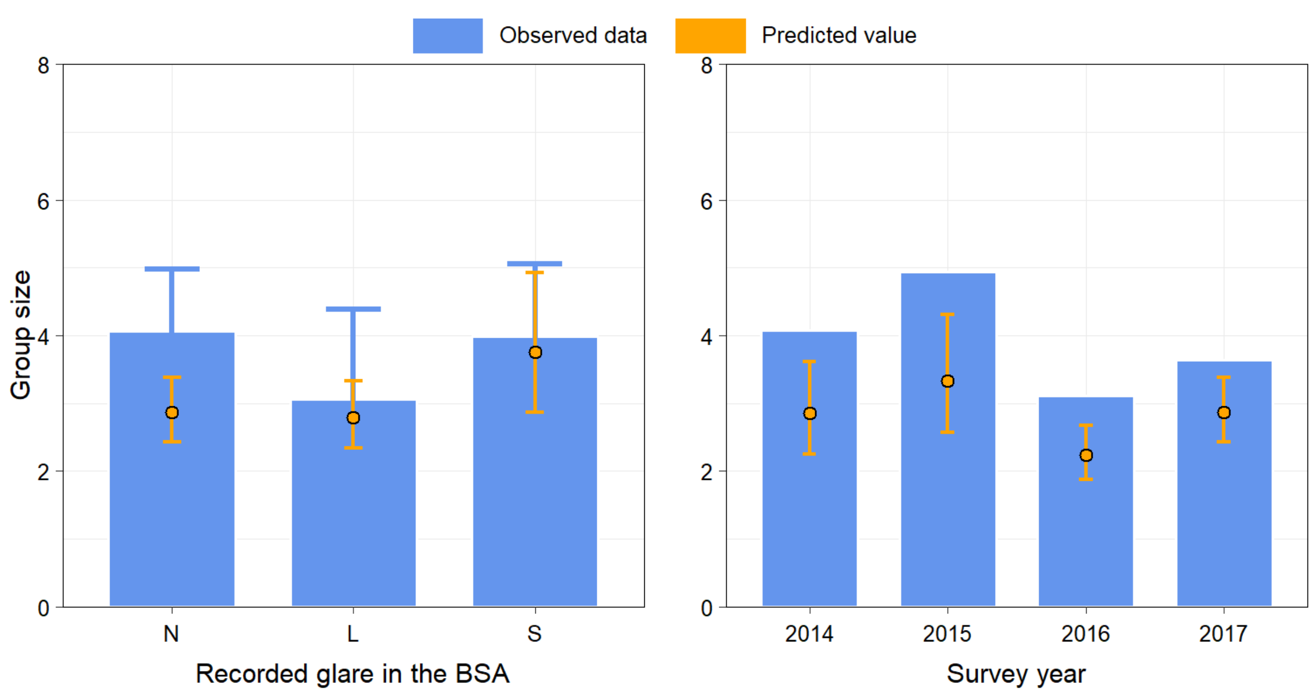


Figure 4-23: Mean narwhal group size in BSA relative to Beaufort scale and survey year (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant

4.4.2 Group Composition

Based on the group composition classification used in Smith et al. (2017) as described in Section 3.3.3.4, the most common group composition observed throughout the four-year study period were groups with ‘no observed tusks’, whether with or without calves or yearlings (Figure 4-24). When ‘Other’ groups were omitted from the analysis to focus on groups of known composition, groups with ‘no observed tusks’ accounted for a total of 61% of all narwhal groups observed in 2014-2017. Groups with ‘no calves or yearlings’ accounted for 52% of all observed groups with known composition.

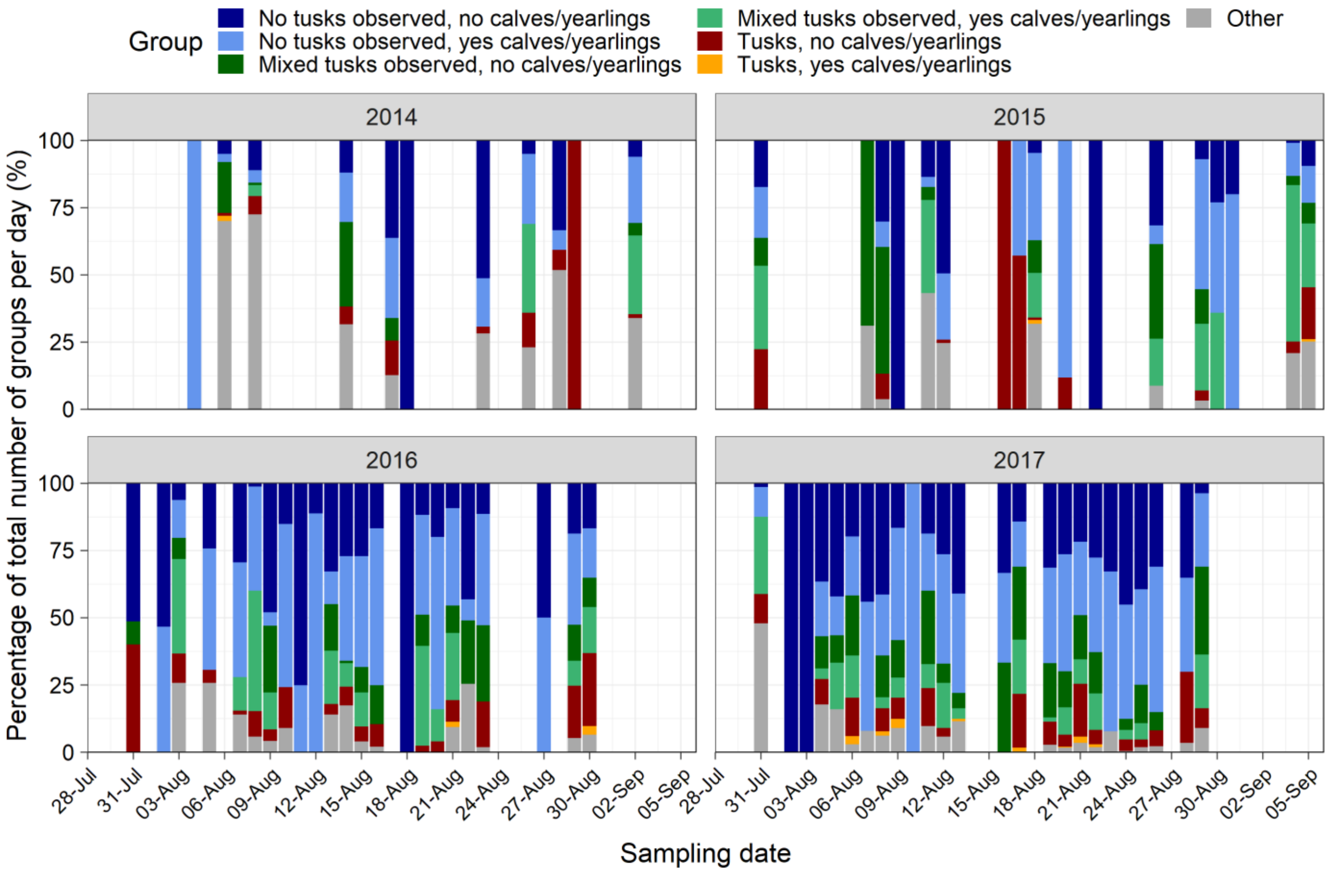


Figure 4-24: Daily distribution of narwhal group composition in BSA (2014–2017)

The six group types of known composition (shown in Figure 4-24) were grouped further for analysis. To provide results that can be compared with analyses presented in Smith et al. (2017), two analyses were conducted – 1) presence/absence of groups with calves or yearlings; and 2) presence/absence of tusks in observed groups. The results of these two analyses are provided below.

4.4.2.1.1 Presence of Tusks

In the mixed model for presence/absence of tusks in groups, only group size was found to be a statistically significant ($P<0.05$) predictor (Table 4-6). The probability of observing tusks increased with group size, from approximately 0.1 for a group size of n = 1 to approximately 0.9 for a group size of n = 20 (Figure 4-26). None of the large vessel traffic variables were found to be significant (distance, vessel direction, and vessel position relative to the BSA), suggesting no effect of vessel traffic on tusk presence within the BSA.

In the combined 2014–2017 dataset, the majority of 'tusks present' observations were recorded when no large vessels were present within 15 km of the BSA (n = 2,648), of which 28% had at least some tusks present (yearly proportion ranged from 25% in 2017 to 42% in 2015). Mean narwhal group size was larger for groups with tusks than for groups with no tusks observed (5.0 and 3.1 individuals, respectively; Figure 4-25).

When large vessels were present within 15 km from the BSA, 526 groups with and without tusks were recorded. Groups with tusks were more common when southbound vessels were heading toward the BSA (33% of groups) and overall similar in the other three large vessel scenarios (percentages ranging between 23% and 27%). Similar to when no vessels were present within 15 km from the BSA, groups with tusks present were on average larger (mean of 5.5 individuals) than groups without observed tusks (mean of 2.9 individuals).

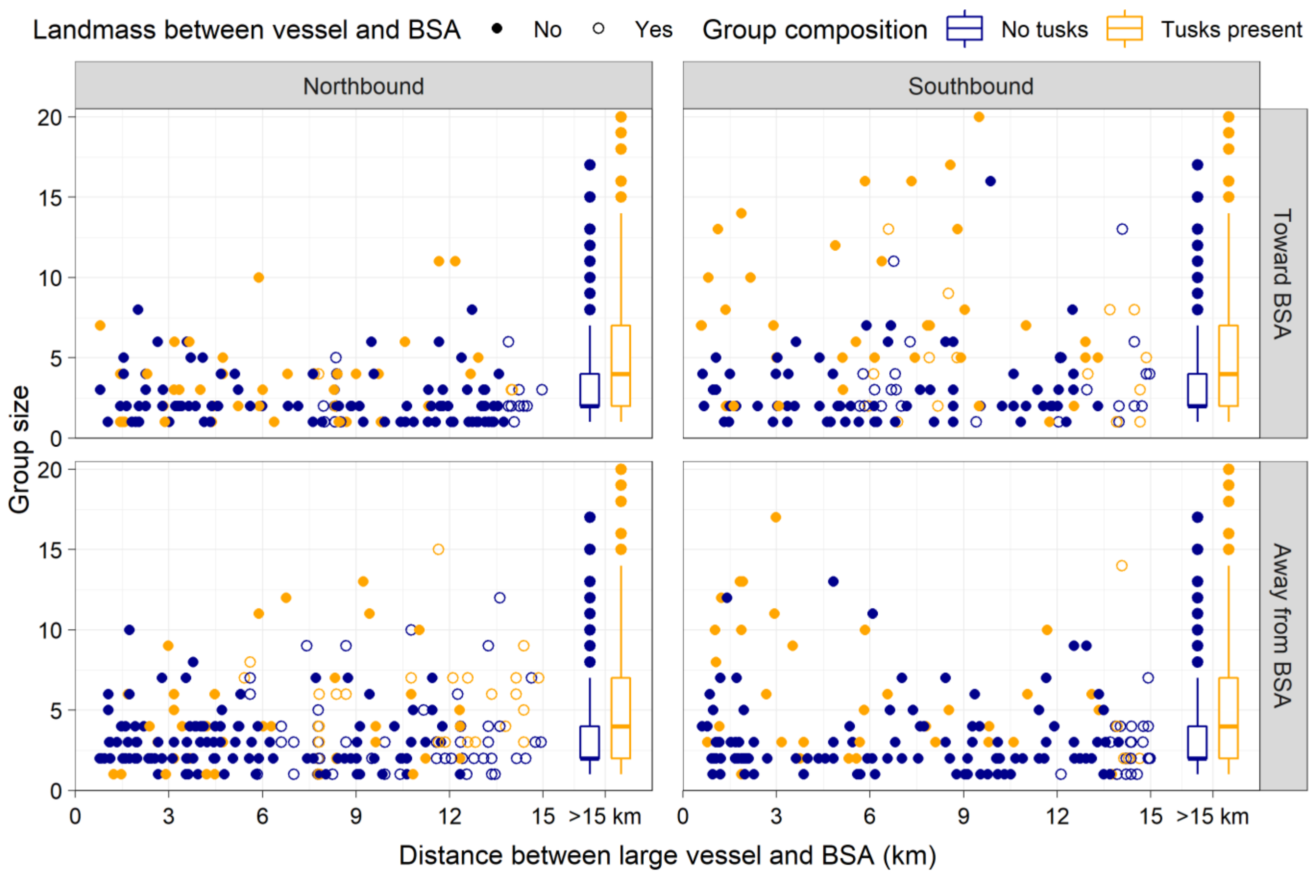


Figure 4-25: Presence/absence of tusks in narwhal groups recorded in BSA relative to distance from large vessels transiting through the SSA (2014–2017)

Table 4-6: Summary table of generalized mixed linear model of presence of tusks in observed groups

Parameter	X^2 value	df	P-value
Day of year	5.789	2	0.055
Year	5.981	3	0.113
Group size	181.906	1	<0.001
Glare	0.922	2	0.631
Beaufort scale	9.474	4	0.050
Tide height	2.392	2	0.302
Change in depth	0.003	1	0.960
Vessel distance	2.858	3	0.414
Vessel direction relative to BSA	0.415	1	0.520
North- or southbound vessel	1.146	1	0.284
Large vessel presence within 15 km from BSA	3.789	1	0.052
Time since last shooting event	1.519	3	0.678
Hunting event within 6 h prior to observation	0.414	1	0.520
Number of small vessels within the SSA	1.682	1	0.195
Day of year: Year	5.142	6	0.526
Tide height: Change in depth	0.257	2	0.879
Vessel distance: Vessel direction relative to BSA	3.845	3	0.279
Vessel distance: North- or southbound vessel	1.737	3	0.629

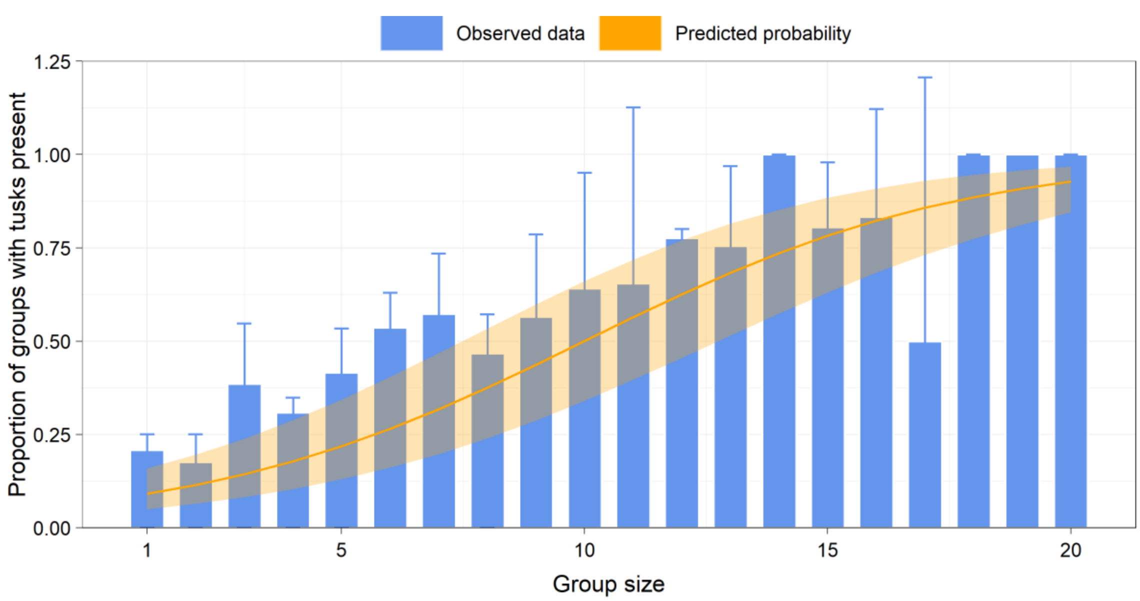


Figure 4-26: Proportion of narwhal groups with tusks present relative to group size (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

4.4.2.1.2 Presence of Calves or Yearlings

In the combined 2014-2017 dataset, the majority of group composition observations were recorded when no large vessels were present within 15 km of the BSA (n = 2,648), of which 39% had calves or yearlings (annual percentage ranging between 29% in 2014 and 40% in 2017). Mean narwhal group size was larger for groups with calves or yearlings than for groups without calves or yearlings (4.4 and 3.1 individuals, respectively; Figure 4-27).

When large vessels were present within 15 km from the BSA, 526 groups with and without calves or yearlings were recorded. Groups with calves or yearlings were least common when a northbound vessel was heading toward the BSA (36% of groups) and most common when a southbound vessel was heading toward the BSA (50% of groups). Similar to when no vessels were present within 15 km from the BSA, groups with calves or yearlings were on average larger (mean of 4.2 individuals) than groups without tusks or yearlings (mean of 3.0 individuals).

In the mixed model of presence/absence of calves or yearlings, only group size was found to be a statistically significant (*P*<0.05) predictor (Table 4-7). The probability of calves or yearling presence in groups increased with group size, from approximately 0.3 at group size of two narwhal to approximately 0.9 at a group size of 20 (Figure 4-28).

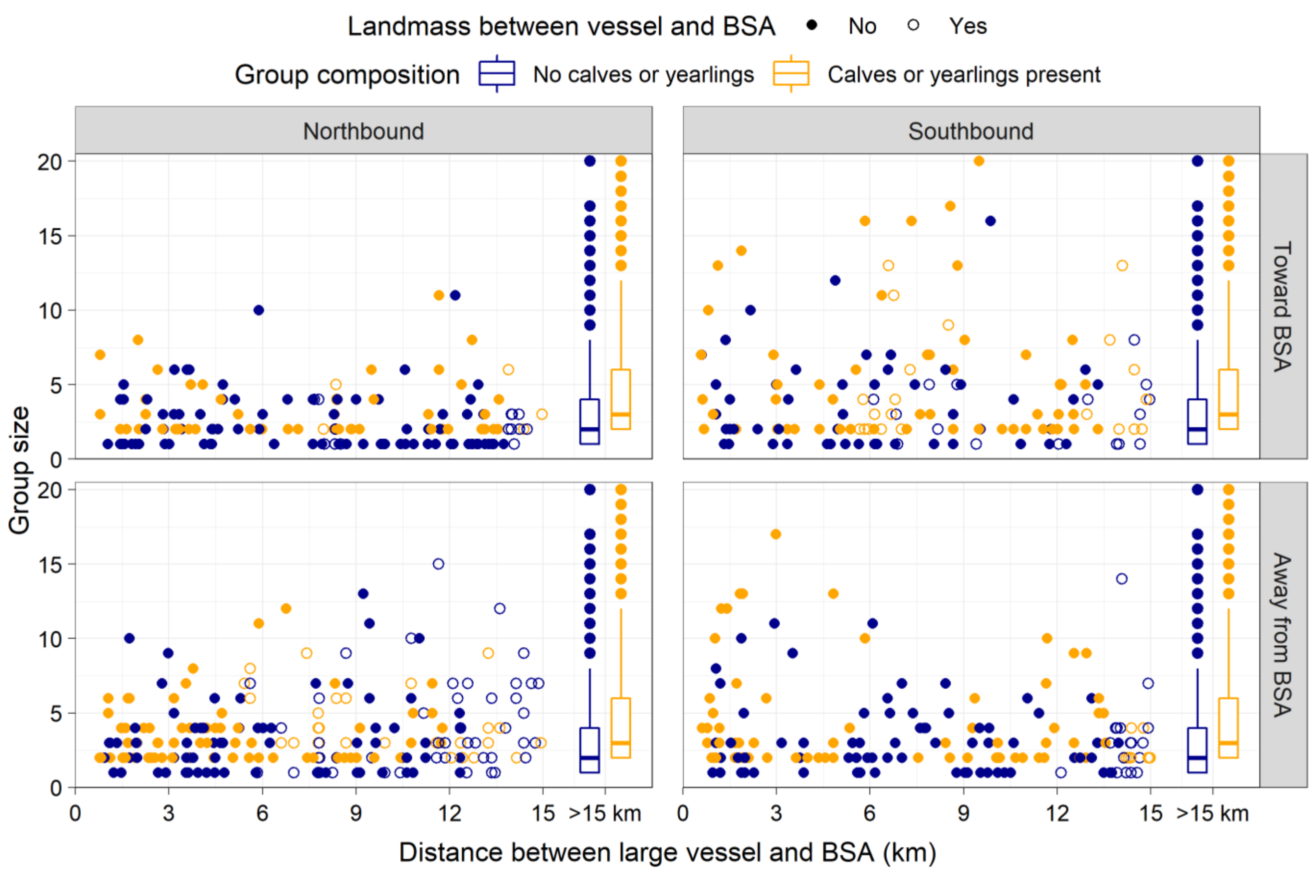


Figure 4-27: Presence/absence of groups with calves and yearlings in narwhal groups recorded in BSA relative to distance from large vessels transiting through the SSA (2014–2017)

Table 4-7: Summary table of generalized mixed linear model of presence of calves

Parameter	X^2 value	df	P-value
Day of year	2.415	2	0.299
Year	6.318	3	0.097
Group size	109.269	1	<0.001
Glare	1.122	2	0.571
Beaufort scale	5.979	4	0.201
Vessel distance	3.569	3	0.312
Vessel direction relative to BSA	0.018	1	0.893
North- or southbound vessel	0.129	1	0.720
Large vessel presence within 15 km from BSA	0.132	1	0.717
Time since last shooting event	0.843	2	0.656
Hunting event within 6 h prior to observation	0.002	1	0.963
Number of small vessels within the SSA	0.225	1	0.635
Day of year: Year	9.681	6	0.139
Vessel distance: Vessel direction relative to BSA	4.077	3	0.253
Vessel distance: North- or southbound vessel	5.052	3	0.168

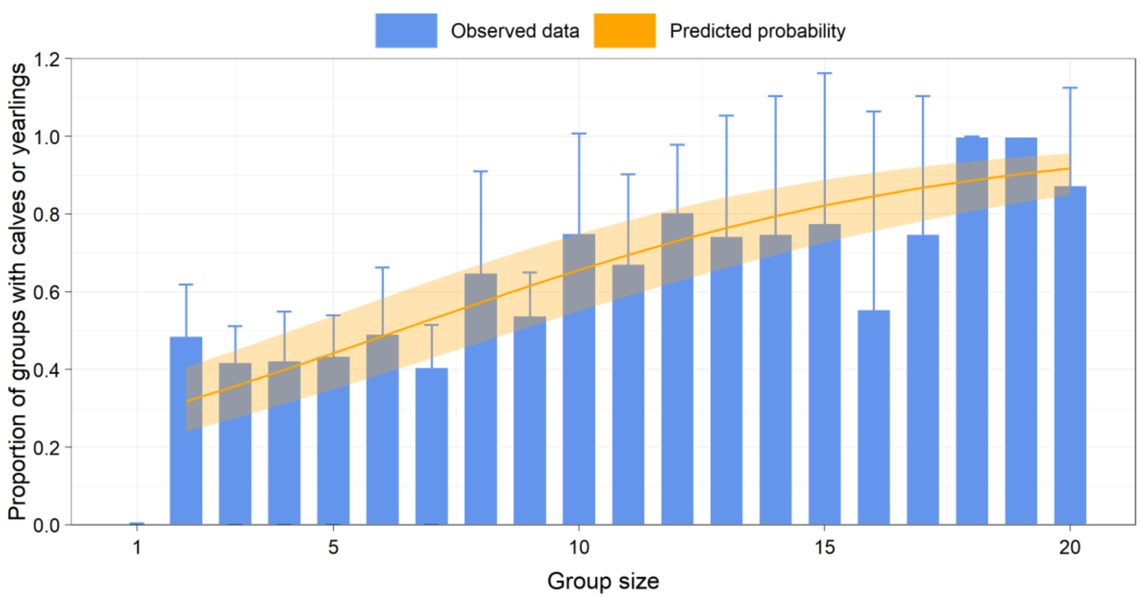


Figure 4-28: Proportion of narwhal groups with tusks present relative to group size (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

4.4.3 Group Spread

Narwhal groups of two or more individuals observed in the BSA during 2014–2017 sampling years were classified as tight (i.e., individuals ≤1 body width apart) or loose (i.e., individuals >1 body width apart) based on the physical proximity of individuals to one another. Throughout the four years of sampling, narwhal were more often observed in tight groups than in loose groups (Figure 4-29), regardless of whether individuals were exposed to anthropogenic activity (Smith et al. 2017; Golder 2018a).

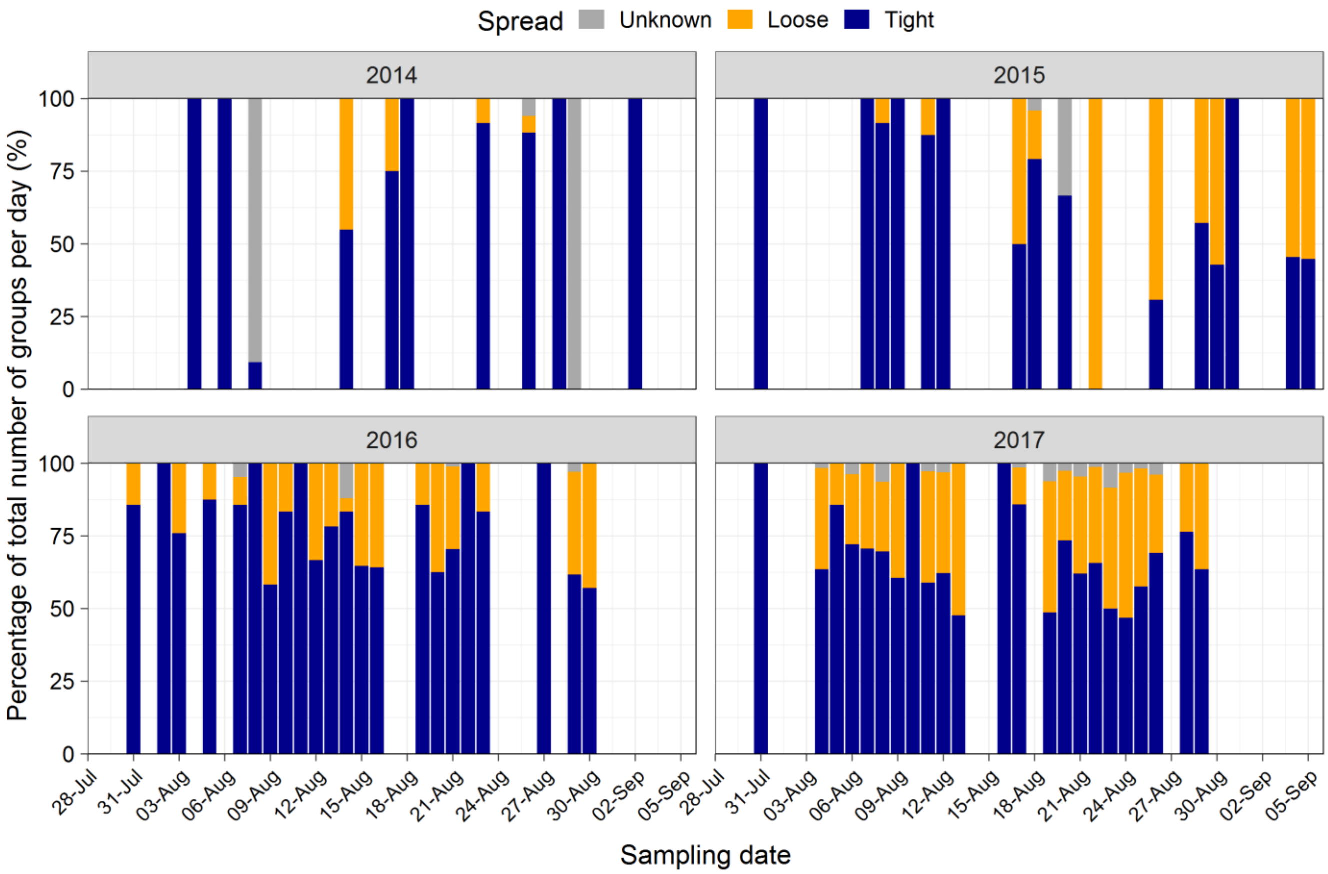


Figure 4-29: Daily distribution of groupings of narwhal group spread (2014–2017)

In the combined 2014–2017 dataset, the majority of narwhal group spread observations were recorded when no large vessels were present within 15 km of the BSA (n = 2,190), of which 34% were in loose spread (annual percentage ranging from 23% in 2014 to 37% in 2015 and 2017). Mean narwhal group size was larger for loose-spread groups than for tight groups (4.7 and 4.3 individuals, respectively; Figure 4-30).

When large vessels were present within 15 km from the BSA, 445 groups with a known spread were recorded. Groups in loose spread were more common when vessels headed away from the BSA (38% for northbound vessels and 30% for southbound vessels) than when vessels were heading toward the BSA (28% for northbound vessels and 23% for southbound vessels). Similar to when no vessels were present within 15 km from the BSA, loose groups were on average larger (mean of 5 individuals) than tight groups (mean of 3.9 individuals).

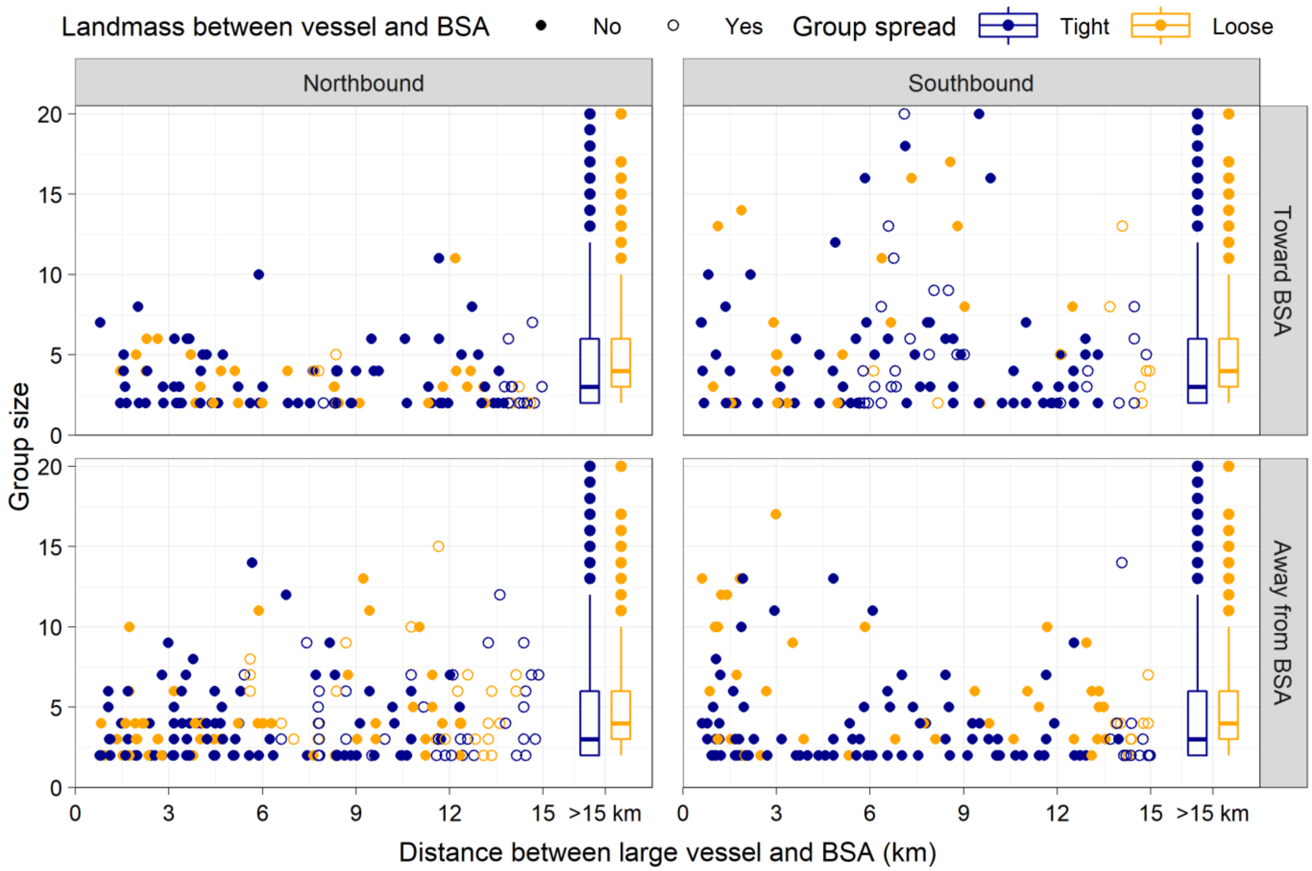


Figure 4-30: Group spread of narwhal groups observed in BSA relative to distance from large vessels transiting through the SSA (2014–2017)

In the mixed model of group spread, both anthropogenic and sampling variables had a significant effect on the probability of observing a group in a loose spread (Table 4-8). The significant anthropogenic effect on group spread was the interaction between vessel distance from the BSA and whether the vessel was heading toward or away from the BSA (*P* = 0.018). When large vessels headed toward the BSA, narwhal groups were more likely to be in a tight spread when vessels were 3-4 km away from the BSA (Figure 4-31). In comparison, when large vessels were headed away from the BSA (especially northbound vessels), groups were most likely to be in a loose spread when vessels were within 3 km from the BSA.

Increased group size resulted in an increased probability of observing narwhal groups in loose formation (Figure 4-32), with the probability increasing from 0.4 for a group of size of two, to 0.7 for a group size of 20. Both day of year and group size were estimated to have a significant effect on narwhal group spread (Table 4-8). In both 2015 and 2017, the probability of observing loose groups was highest in mid-August, whereas in 2016, the probability of observing loose groups was highest in late August and early September (Figure 4-32). Overall, the effect of day appears to be spurious and likely attributed to the low proportions of loose groups recorded in the BSA during early August 2016 and late August 2014.

Table 4-8: Summary table of generalized mixed linear model of group spread

Parameter	X^2 value	df	P-value
Day of year	14.228	2	0.001
Year	19.455	3	<0.001
Group size	23.793	1	<0.001
Glare	0.463	2	0.794
Beaufort scale	3.906	4	0.419
Tide height	0.095	1	0.757
Change in depth	0.217	1	0.641
Vessel distance	4.842	3	0.184
Vessel direction relative to BSA	1.307	1	0.253
North- or southbound vessel	1.131	1	0.288
Large vessel presence within 15 km from BSA	0.110	1	0.740
Time since last shooting event	3.223	2	0.200
Hunting event within 6 h prior to observation	1.486	1	0.223
Number of small vessels within the SSA	0.376	1	0.540
Day of year: Year	20.997	6	0.002
Tide height: Change in depth	0.931	1	0.335
Vessel distance: Vessel direction relative to BSA	10.038	3	0.018
Vessel distance: North- or southbound vessel	1.827	3	0.609

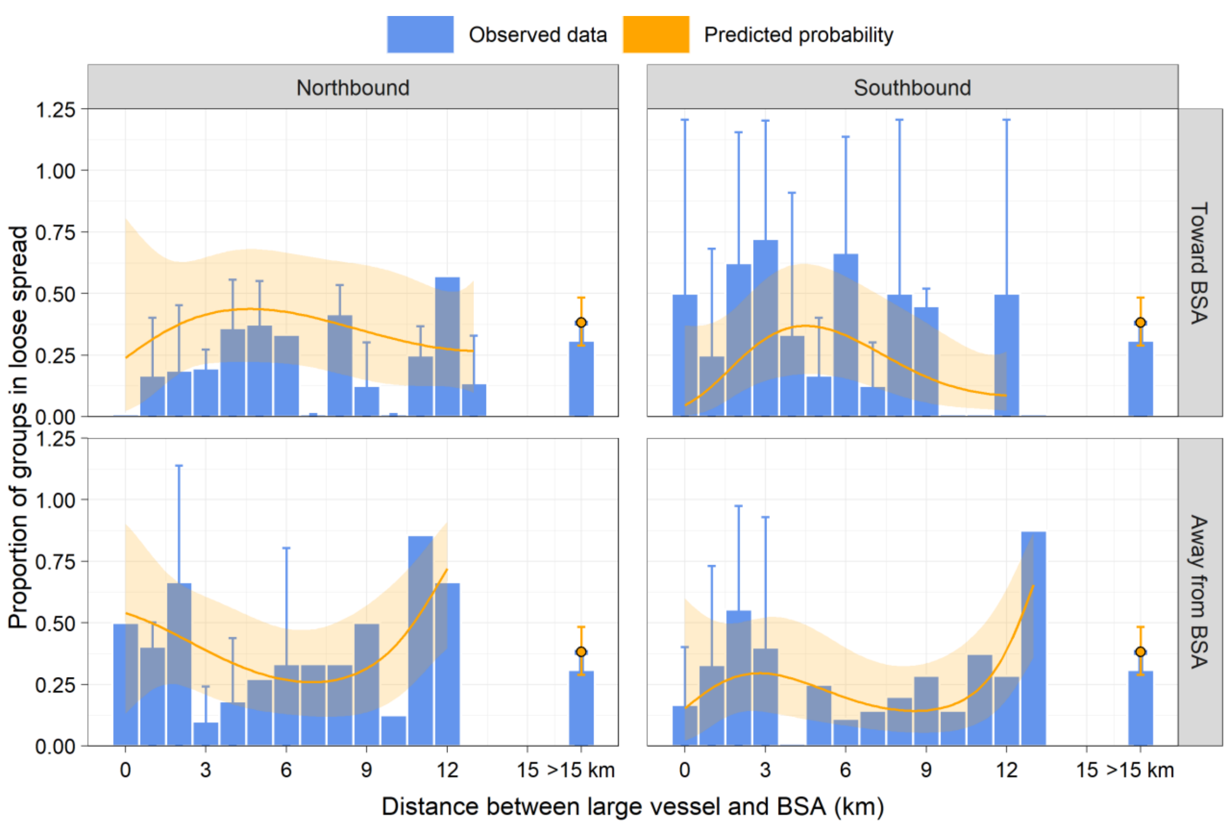


Figure 4-31: Proportion of narwhal groups observed in a loose spread relative to distance from large vessels in transit, vessel direction in Milne Inlet, and direction relative to the BSA (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

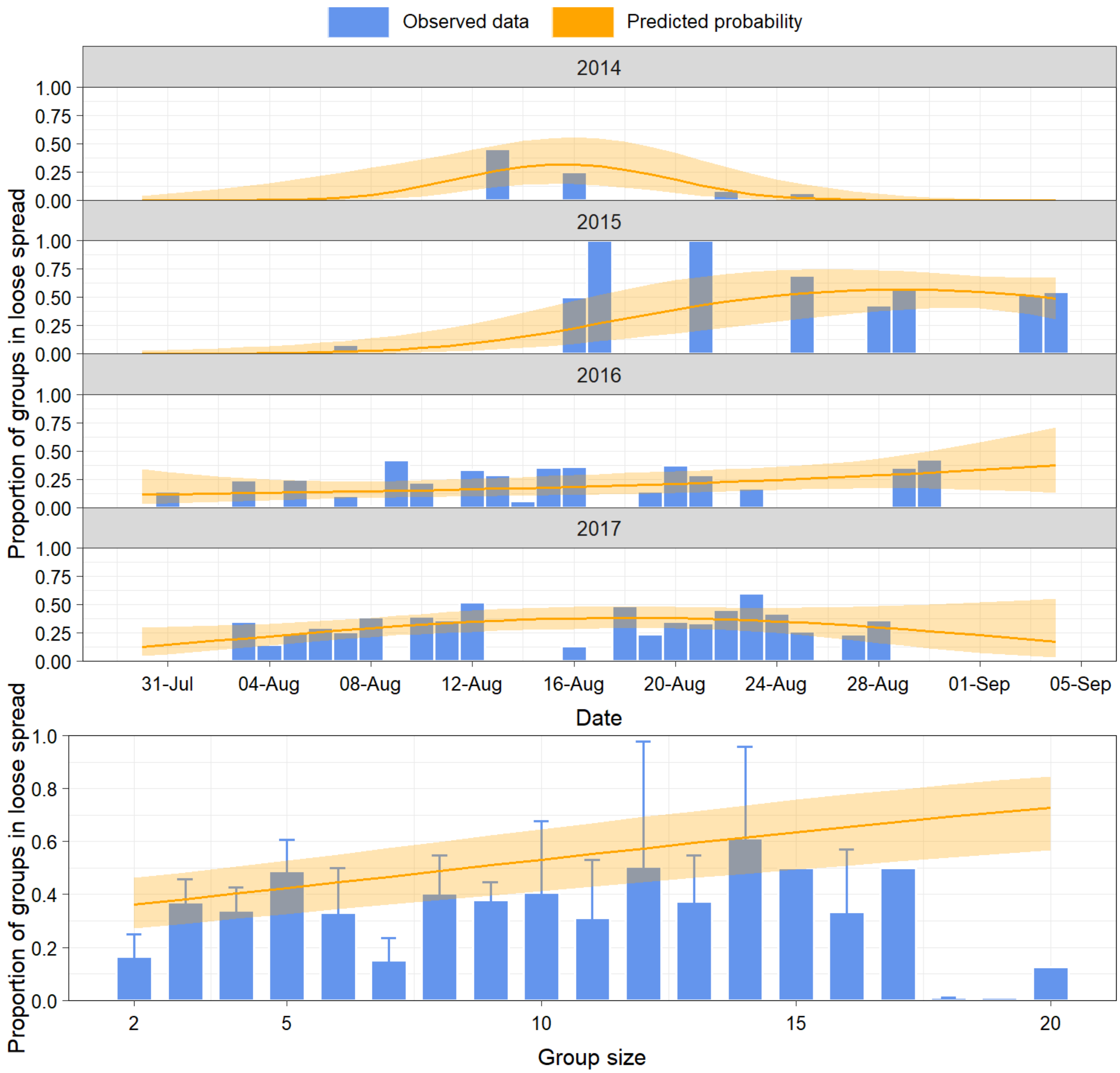


Figure 4-32: Proportion of narwhal groups observed in a loose spread relative to sampling date and group size (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant

4.4.4 Group Formation

The formation of narwhal groups of two or more individuals observed in the BSA during 2014–2017 sampling years was classified as linear, parallel, cluster, non-directional line, or no formation. The majority of recorded groups in the four years of sampling were in the parallel formation, follower by cluster formation (Figure 4-33), regardless of whether individuals were exposed to anthropogenic activity (Smith et al. 2017; Golder 2018a). Parallel groups comprised at least 12%, 34%, 33%, and 49% of all daily recorded groups of two or more individuals in 2014–2017, respectively. Cluster groups comprised 7%-11% of all daily groups, depending on year. Conversely, linear groups comprised only up to 10%, 33%, and 17% of all daily groups in 2014, 2016, and 2017 (with a single day in 2015 with 100% linear formation, where only one group of narwhal with two or more individuals was recorded in the BSA).

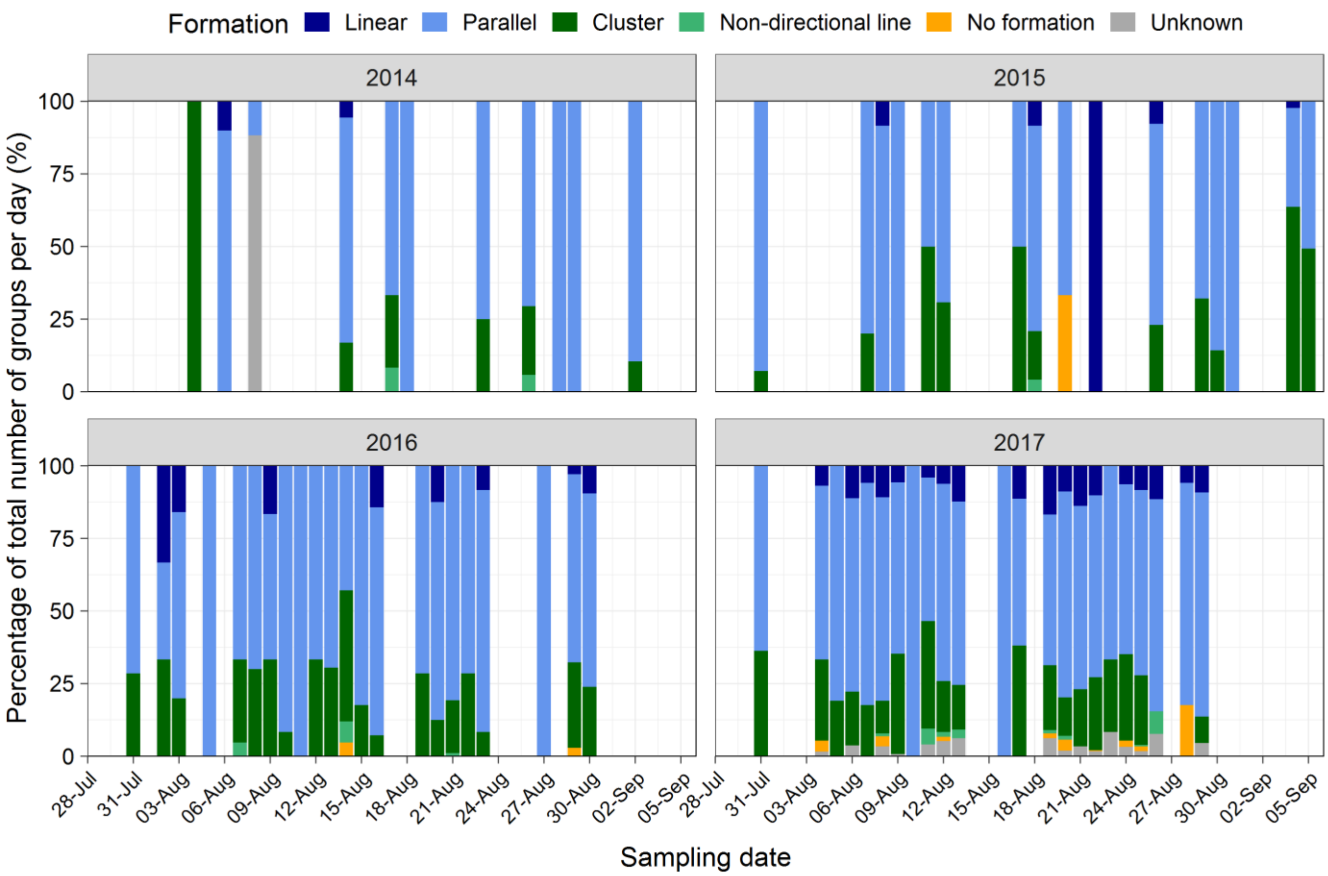


Figure 4-33: Daily distribution of groupings of narwhal group formation (2014–2017)

In the combined 2014–2017 dataset, the majority of narwhal group formation observations were recorded when no large vessels were present within 15 km of the BSA (n = 2,202), of which 34% were in non-parallel formation (annual percentage ranging from 19% in 2014 to 37% in 2017). Mean narwhal group size was larger for non-parallel groups than for groups in parallel formation (5.7 and 3.8 individuals, respectively; Figure 4-34).

When large vessels were present within 15 km from the BSA, 439 groups with a known formation were recorded. The percentage of groups in non-parallel formation was similar between north- or southbound vessels, as well as between vessels heading toward or away from the BSA. The percentage ranged from 24.8% (southbound vessels heading away from the BSA) to 28.9% (southbound vessels heading toward the BSA). Similar to when no vessels were present within 15 km from the BSA, non-parallel groups were on average larger (mean of 6.2 individuals) than groups in parallel formation (mean of 3.5 individuals).

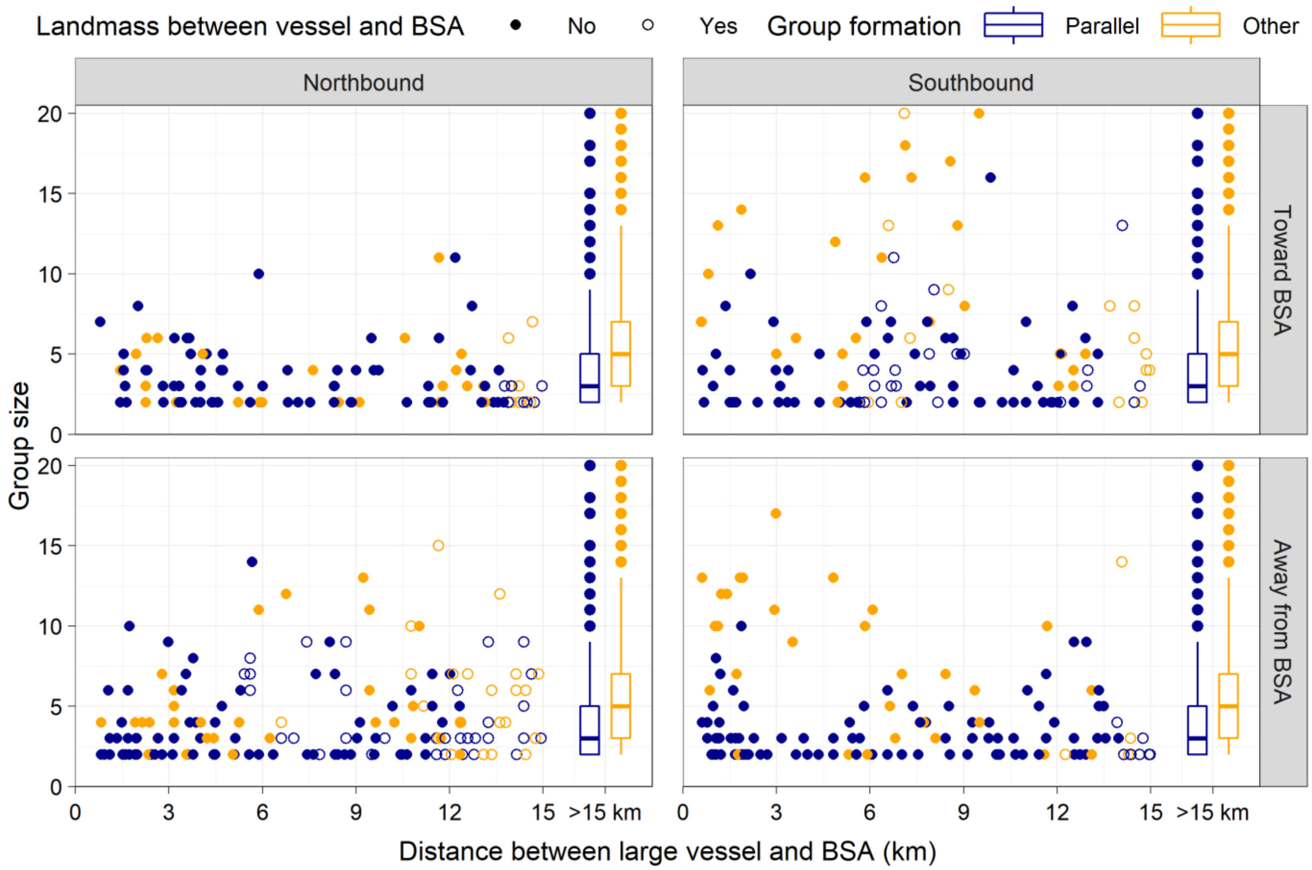


Figure 4-34: Group formation of narwhal recorded in BSA relative to group size and distance from large vessels transiting through the SSA (2014–2017)

In the mixed model of group formation, the response variable was simplified to whether the group was parallel (most common state and considered baseline) or non-parallel (less common and therefore likely to represent a behavioural reaction to disturbance). In the analysis, anthropogenic variables had no significant effect on group formation (*P*>0.05; Table 4-9). Only sampling variables and group size had a significant effect on the probability of observing a southbound group (Table 4-9). Estimated effect of Beaufort scale on observed narwhal group formation suggested that the probability of observing a group in non-parallel formation was lowest at Beaufort scale value of 3 or higher (Figure 4-35). Conversely, the probability of observing a non-parallel group was highest under severe glare (Figure 4-35). These two results suggest that either sea state and glare influence observer efficiency differently in relation to group formation identification, or the results are spurious. Survey year had a significant effect on the probability of observing groups in non-parallel formation (*P* = 0.001), with an increase in estimated probability with each passing year. That said, the probability of observing groups in non-parallel formation in 2015 was underestimated relative to the observed proportions (Figure 4-35).

Group size had a strong effect on the probability of observing groups in non-parallel formation (Figure 4-35). The probability of non-parallel formation increased with group size, increasing from approximately 0.2 for a group size of two, to almost 1.0 for a group size of 20.

Table 4-9: Summary table of generalized mixed linear model of group travel direction

Parameter	X^2 value	df	P-value
Day of year	6.162	3	0.104
Year	16.900	3	0.001
Group size	208.908	1	<0.001
Glare	8.389	2	0.015
Beaufort scale	13.398	4	0.009
Tide height	1.838	1	0.175
Change in depth	0.113	1	0.737
Vessel distance	3.615	3	0.306
Vessel direction relative to BSA	0.318	1	0.573
North- or southbound vessel	0.013	1	0.908
Large vessel presence within 15 km from BSA	0.730	1	0.393
Time since last shooting event	2.929	3	0.403
Hunting event within 6 h prior to observation	1.436	1	0.231
Number of small vessels within the SSA	0.558	1	0.455
Tide height: Change in depth	0.122	1	0.727
Vessel distance: Vessel direction relative to BSA	1.633	3	0.652
Vessel distance: North- or southbound vessel	0.820	3	0.845

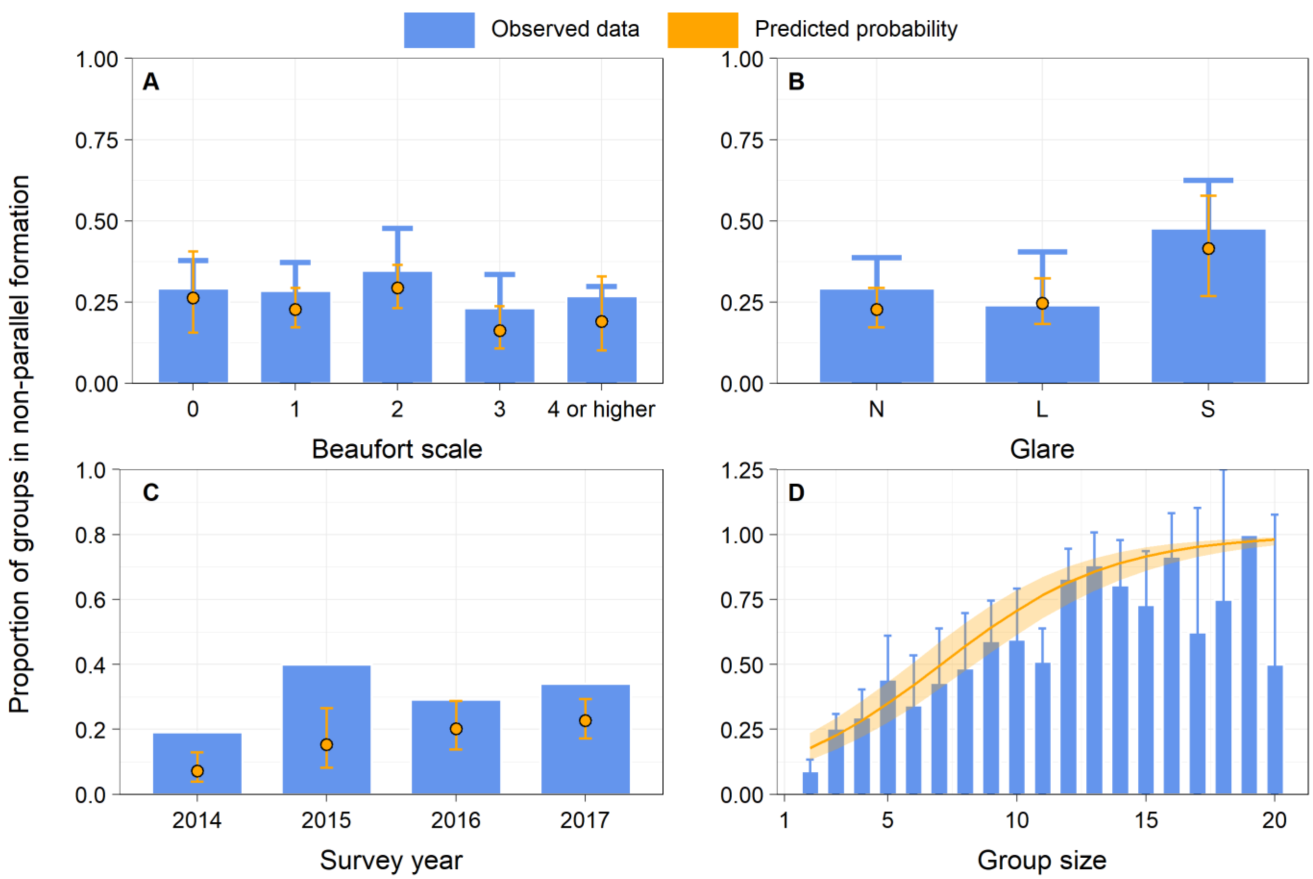


Figure 4-35: Proportion of narwhal groups observed traveling in non-parallel formation relative to Beaufort scale, glare, survey year, and group size (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

4.4.5 Group Direction

The majority of narwhal groups observed in the BSA during 2014–2017 sampling years traveled in the south direction (Figure 4-36), with annual averages of daily percentages of south-traveling groups ranging between 63% (in 2016) and 90% (in 2015). Annual averages of daily percentages of north-traveling groups ranged between 40% (in 2017) and 60% (in 2014). Both east and west travel directions were rare, with annual averages between 2% and 15%, depending on direction and year.

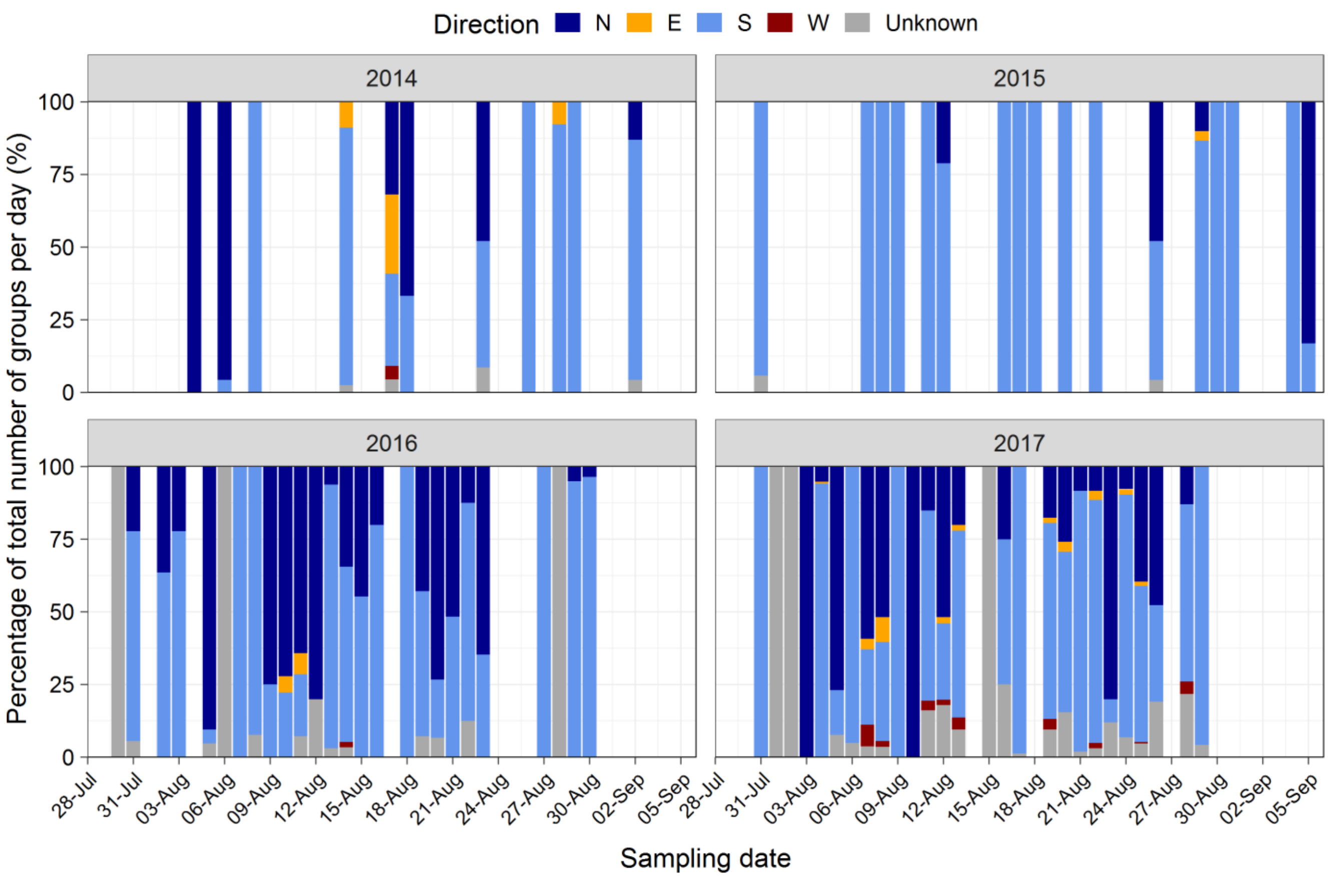


Figure 4-36: Daily distribution of narwhal group travel direction in BSA (2014–2017)

In the combined 2014–2017 dataset, the majority of narwhal group direction observations (filtered to north/south travel only) were recorded when no large vessels were present within 15 km of the BSA (n = 2,688), of which 72% were traveling south (annual percentage ranging from 61% in 2015 to 80% in 2014). Mean narwhal group size was larger for south-traveling groups than for groups traveling north (4.2 and 2.5 individuals, respectively; Figure 4-37).

When large vessels were present within 15 km from the BSA, 506 groups with a known travel direction (filtered to north/south travel only) were recorded. The percentage of groups traveling south varied with vessel direction and position relative to the BSA. The highest percentage of south-traveling groups was recorded when northbound vessels were heading away from the BSA (95%), and the lowest percentage was recorded when southbound vessels were heading away from the BSA (29%). Similar to when no vessels were present within 15 km from the BSA, non-parallel groups were on average larger (mean of 4.1 individuals) than groups in parallel formation (mean of 2.9 individuals).

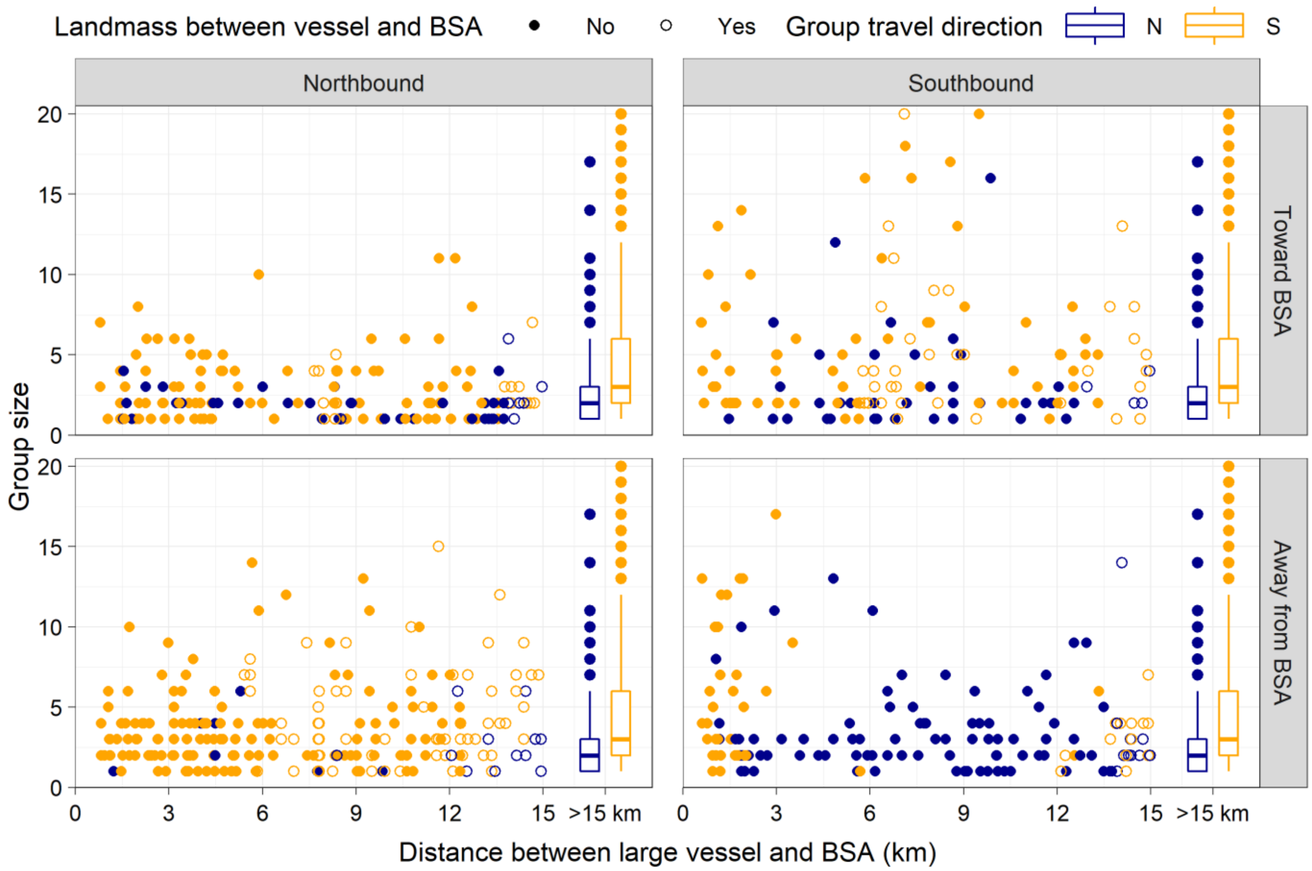


Figure 4-37: Travel direction of narwhal groups recorded in BSA relative to group size and distance from large vessels transiting through the SSA (2014–2017)

In the mixed model for group travel direction, both anthropogenic and sampling variables had a significant effect on the probability of observing a southbound group (Table 4-10). The significant anthropogenic effect on group direction was the interaction between vessel direction within Milne Inlet (north- or southbound) and whether the vessel was heading toward or away from the BSA (P = 0.03). Generally, narwhal were most likely to travel southward regardless of vessel distance from the BSA, vessel direction within Milne Inlet, or vessel direction relative to the BSA (Figure 4-38). However, when large southbound vessels were heading away from the BSA, narwhal were observed traveling northward more often, especially when vessels were far from the BSA. The uncertainty around the estimated probabilities was extremely wide, reflecting data variability.

Estimated effect of Beaufort scale on observed narwhal travel direction suggested an increase in the probability of recording a southbound group of narwhal with an increase in Beaufort scale values (Figure 4-39), likely due to observer bias. Of the four survey years, 2016 had the lowest estimated probability of observing southbound narwhal groups, while both 2014 and 2015 had extremely high probabilities of observing southbound groups of narwhal. The effect of ‘time since last shooting’ was not significant (P = 0.08) while the effect of hunting overall was significant (P = 0.018), likely due to the decrease in southbound groups up to four hours after a shooting event occurred (Figure 4-39). Increased group size resulted in an increased probability of observing southbound narwhal groups (Figure 4-39). The predicted probability of southbound travel was highest at an average tide height and lowest at both low and high tide (Figure 4-40).

Overall, the model predictions of group travel direction had wide confidence intervals due to the high uncertainty and little available data on south-traveling groups when southbound vessels were heading away from the BSA (Figure 4-37). The almost perfect separation of group travel direction when northbound vessels were heading away from the BSA resulted in an unstable model and predicted probabilities of observing southbound groups of narwhal that were very close to 1.0.

Table 4-10: Summary table of generalized mixed linear model of group travel direction

Parameter	X^2 value	df	P-value
Year	11.500	3	0.009
Group size	7.386	1	0.007
Glare	1.689	2	0.43
Beaufort scale	15.992	3	0.001
Tide height	6.246	2	0.044
Change in depth	0.132	1	0.717
Vessel distance	3.469	1	0.063
Vessel direction relative to BSA	0.041	1	0.839
North- or southbound vessel	2.482	1	0.115
Large vessel presence within 15 km from BSA	1.493	1	0.222
Time since last shooting event	6.778	3	0.079
Hunting event within 6 h prior to observation	5.587	1	0.018
Vessel distance: Vessel direction relative to BSA	0.137	1	0.711
Vessel distance: North- or southbound vessel	0.003	1	0.958
Vessel direction relative to BSA: North- or southbound vessel	4.704	1	0.030
Vessel distance:Vessel direction relative to BSA:North- or southbound vessel	0.287	1	0.592

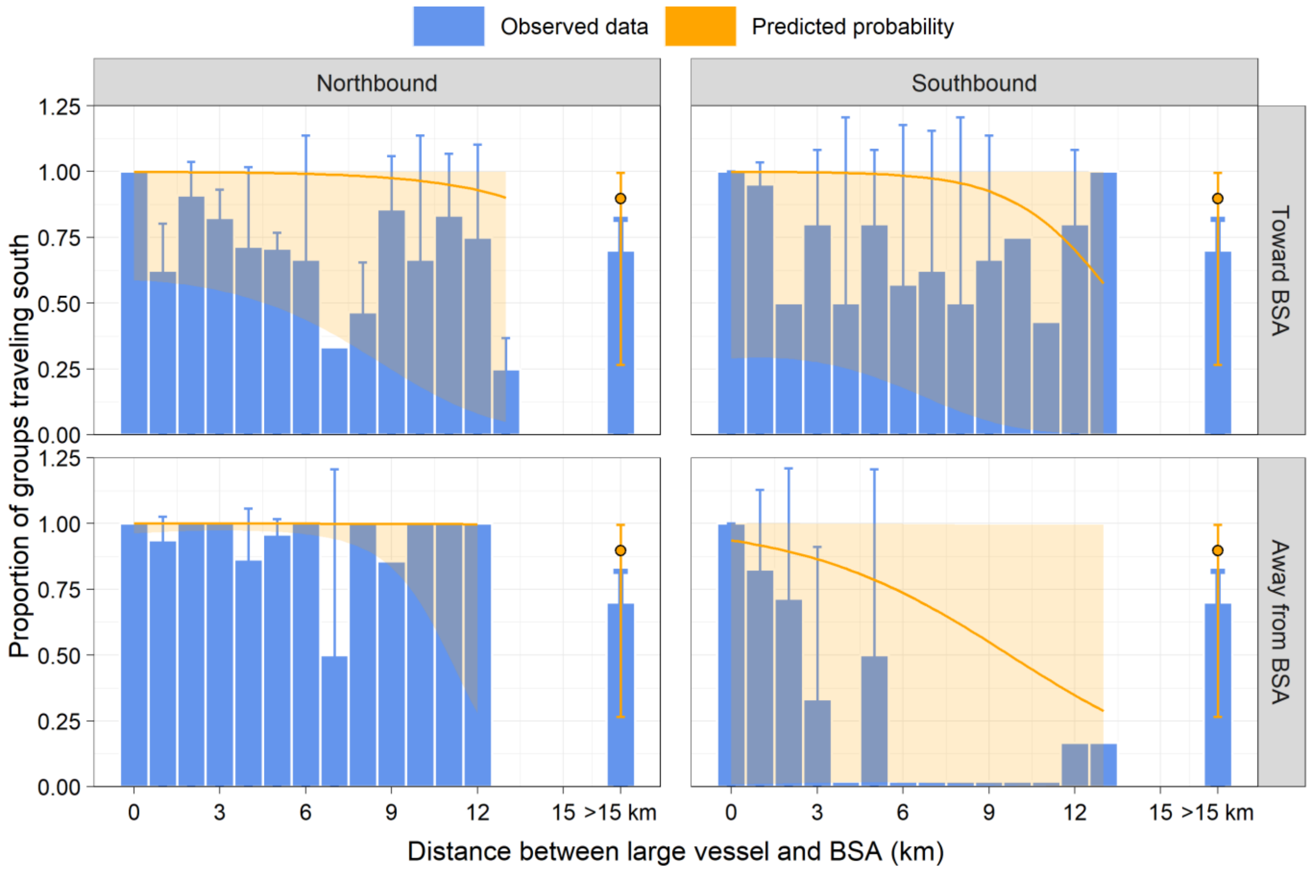


Figure 4-38: Proportion of narwhal groups in BSA traveling south relative to distance from large vessels in transit, vessel direction in Milne Inlet, and direction relative to the BSA (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

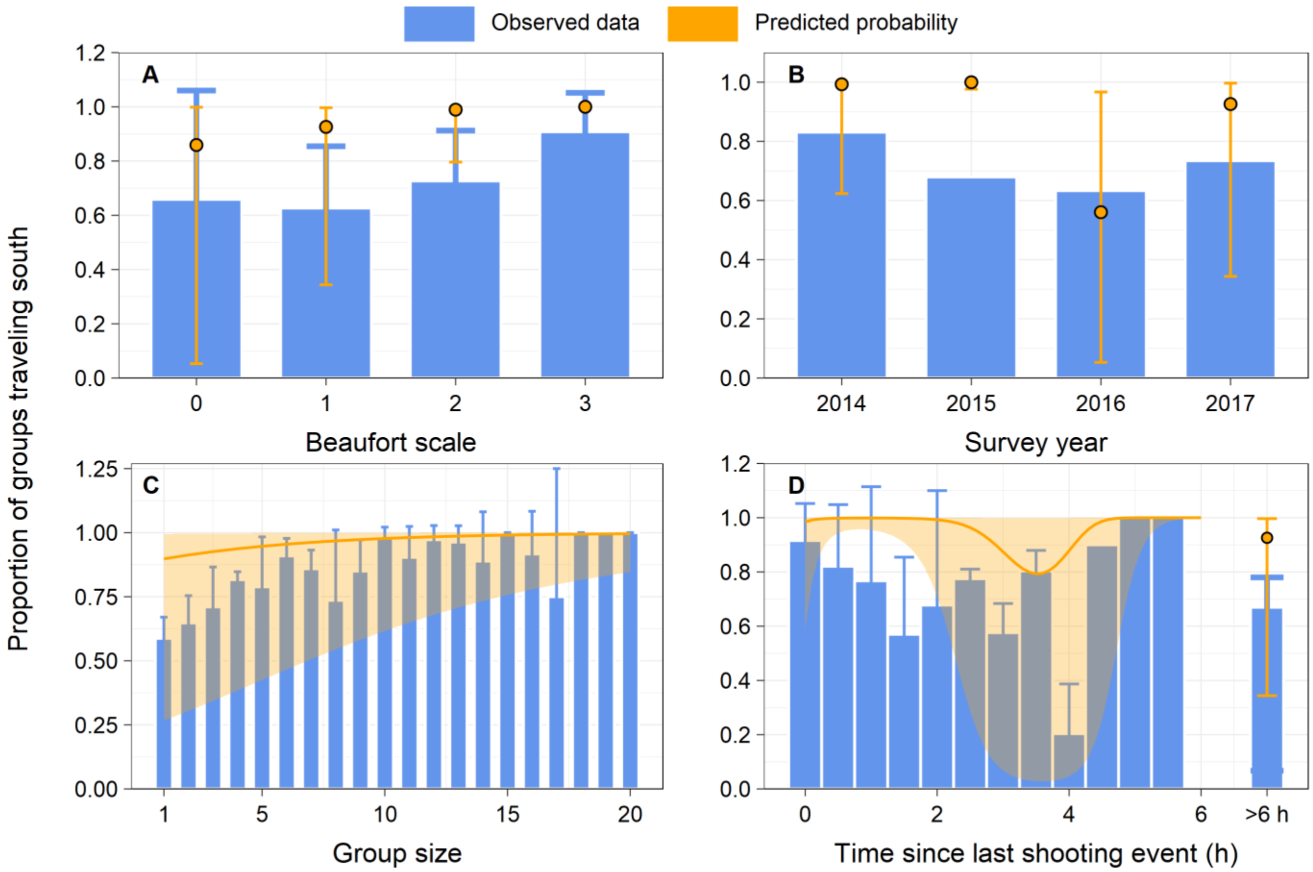


Figure 4-39: Proportion of narwhal groups in BSA traveling south relative to Beaufort scale, survey year, time since last shooting event, and group size (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

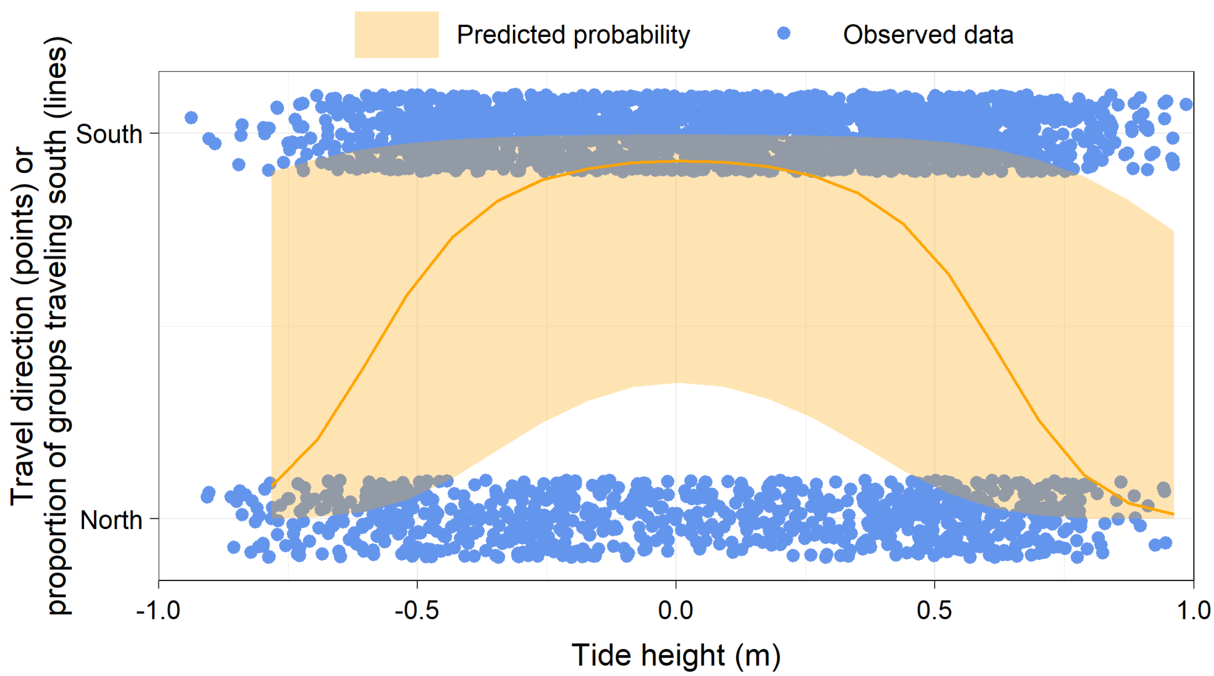


Figure 4-40: Proportion of narwhal groups in BSA traveling south relative to tide height (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant

4.4.6 Travel Speed

The majority of narwhal groups observed in the BSA during 2014-2017 sampling years traveled in a medium speed, followed by slow speed (Figure 4-41). Annual averages of daily percentages of groups travelling at a medium speed ranged between 57% (in 2016) and 80% (in 2014). Annual averages of daily percentages of slow-speed groups ranged between 30% (in 2017) and 46% (in 2015). Fast-traveling groups were relatively rare, with annual averages of 9%, 57%, 24%, and 16% in 2014-2017, respectively.

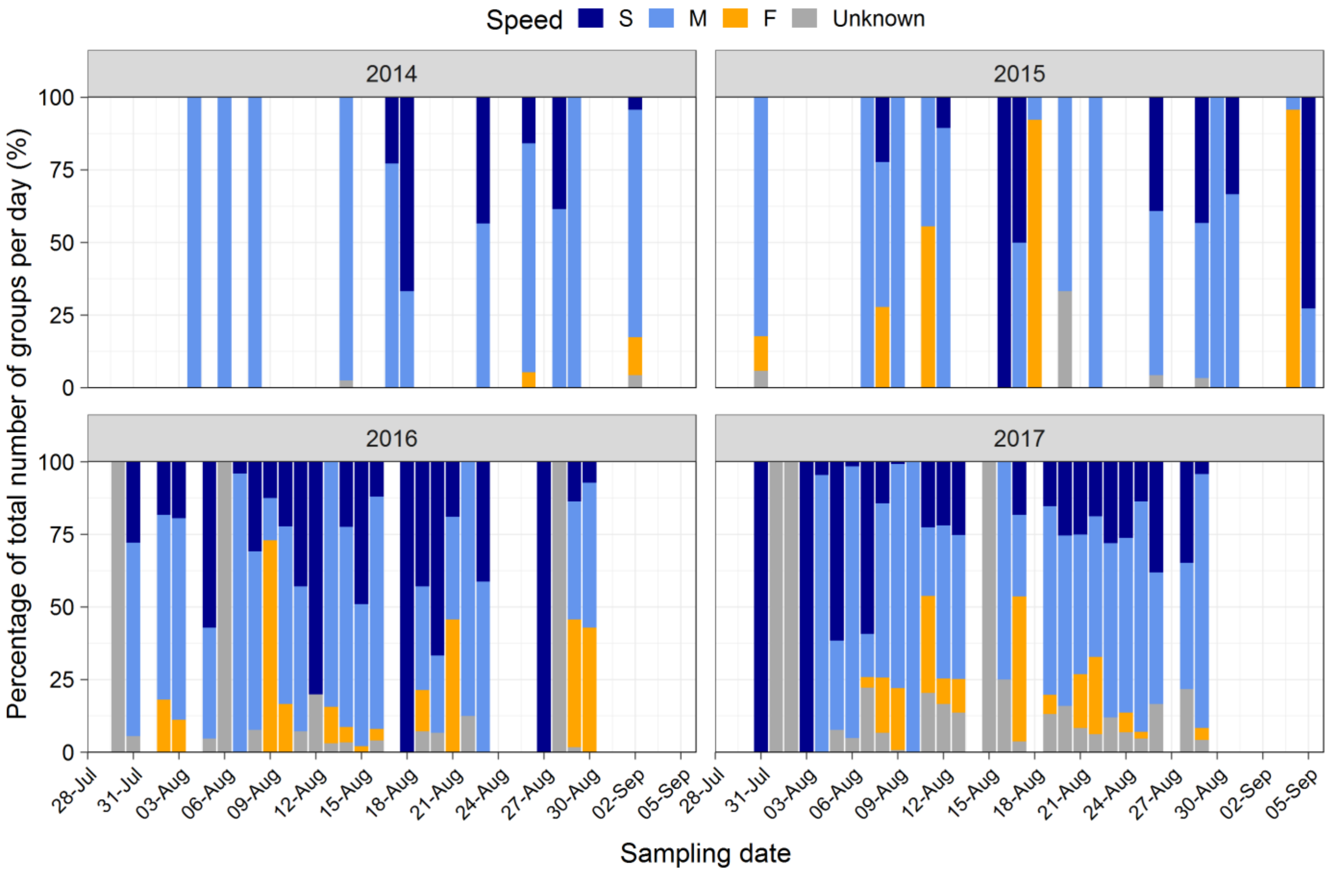


Figure 4-41: Daily distribution of narwhal group travel speed in BSA (2014–2017)

In the combined 2014-2017 dataset, the majority of narwhal group speed observations were recorded when no large vessels were present within 15 km of the BSA (n = 2,727), of which 64% were traveling at a medium speed, 22% were traveling slowly, and 14% were traveling fast. Mean narwhal group size was smallest for slow groups (2.7 individuals), intermediate for medium-speed groups (4.0 individuals), and largest for fast groups (4.4 individuals). larger for south-traveling groups than for groups traveling north (4.2 and 2.5 individuals, respectively; Figure 4-42).

When large vessels were present within 15 km from the BSA, 523 groups with a known travel speed were recorded. The percentage of groups traveling slowly varied with vessel direction and position relative to the BSA, ranging from 12% for northbound vessels heading away from the BSA to 22% for southbound vessels heading toward the BSA. The percentage of groups traveling at a fast speed ranged from 5% for northbound vessels heading toward the BSA to 31% for southbound vessels heading toward the BSA. Similar to when no vessels were present within 15 km from the BSA, travel speed and group size were positively related, with mean group size increasing from 2.6 individuals for slow groups to 3.4 individuals for medium-speed groups to 5.3 individuals for fast groups.

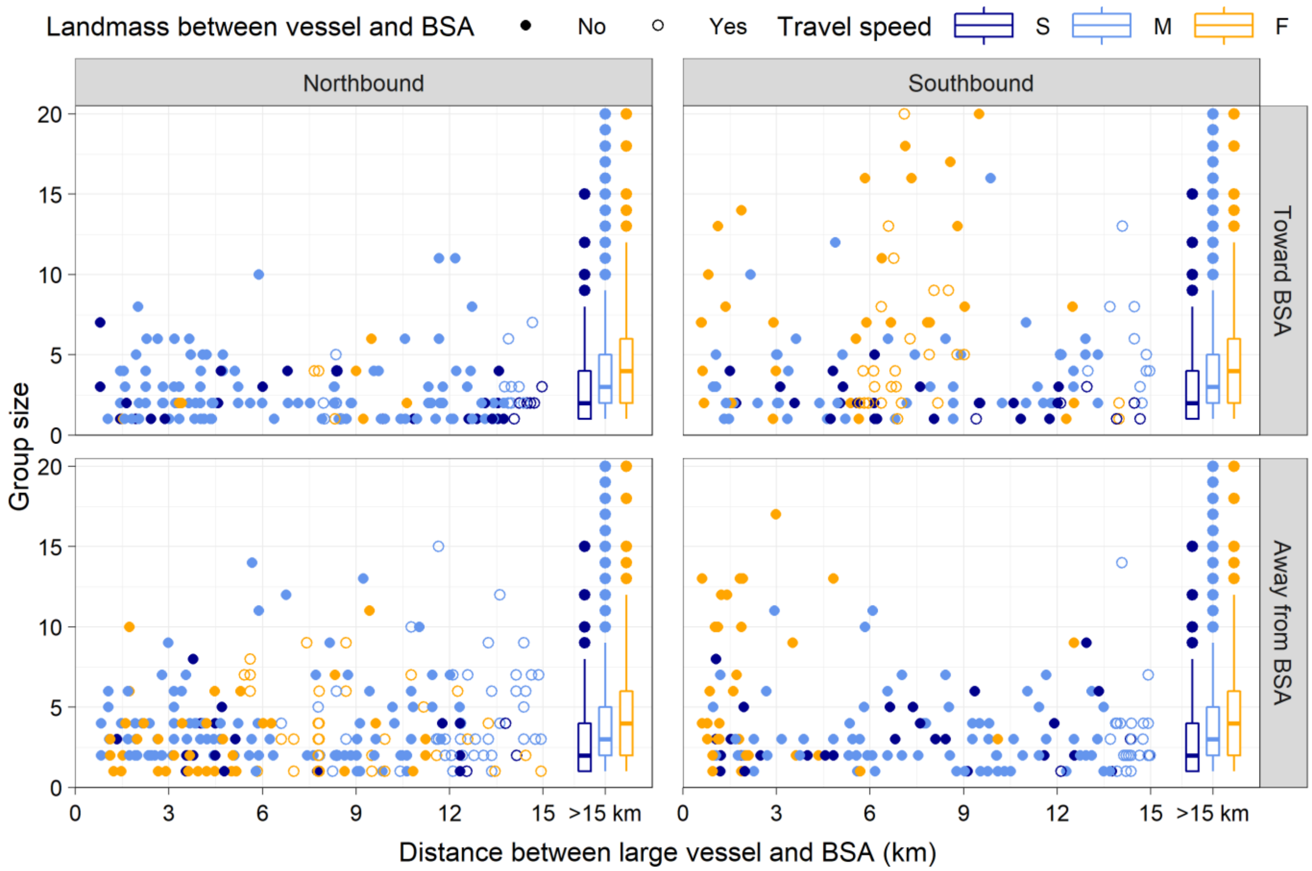


Figure 4-42: Travel speed of narwhal groups recorded in BSA relative to distance from large vessels transiting through the SSA (2014–2017)

4.4.6.1 Slow-traveling groups

In the mixed model for group travel speed, both anthropogenic and sampling variables had a significant effect on the probability of observing a group traveling slowly (rather than at medium speed; Table 4-11). The anthropogenic effects on group distance from shore included the interaction between vessel distance from the BSA, vessel direction, and position relative to the BSA (*P* = 0.027). The effect of distance of large vessel form the BSA differed between the modeled scenarios (Figure 4-43). The probability of observing slowly-swimming groups was shown to be higher when large vessels were close to the BSA (within 2–3 km) and were located south of the BSA, whether they were northbound and heading toward the BSA, or southbound and heading away from the BSA. When large vessels were close (within 2-3 km) and north of the BSA, the probability of observing slowly-swimming groups was lower. The uncertainty associated with estimated effects was high, reflecting data variability and data gaps (e.g., for northbound vessels heading away from the BSA). Overall, the reversal of vessel effect of distance when vessels were found north or south of the BSA is likely to be spurious.

Survey year, group size, and tide were estimated to have a significant effect on the distance of narwhal from Bruce Head shore (Table 4-11). Small groups were much more likely to travel slowly (rather than at medium speed) compared to large groups, with probabilities decreasing from approximately 0.55 at group size of 1 to less than 0.05 at group size of 20 (Figure 4-44). The probability of observing groups traveling slowly were estimated to increase with each survey year (Figure 4-44), although estimates were highly uncertain and overestimated observed values for 2016 and 2017.

The estimated effect of tide on group travel speed depended both on tide height and change in depth (Table 4-11; Figure 4-45). When tide was rising (i.e., positing depth changes), the probability of slowly-traveling groups was highest when tide height was near average and low at low and high tide. When tide was falling, the estimated effect was reversed, with slowly-traveling groups more likely to occur at low and high tide. The effect was uncertain, resulting in wide 95% confidence intervals.

Table 4-11: Summary table of generalized mixed linear model of group travel speed (comparing slow and medium speeds only)

Parameter	X^2 value	df	P-value
Day of year	2.071	2	0.355
Year	8.208	3	0.042
Group size	34.212	1	<0.001
Glare	3.920	2	0.141
Beaufort scale	7.180	3	0.066
Tide height	2.144	2	0.342
Change in depth	0.048	1	0.827
Vessel distance	0.877	2	0.645
Vessel direction relative to BSA	0.077	1	0.781
North- or southbound vessel	4.894	1	0.027
Large vessel presence within 15 km from BSA	3.891	1	0.049
Time since last shooting event	7.691	3	0.053
Hunting event within 6 h prior to observation	1.835	1	0.176
Number of small vessels within the SSA	0.209	1	0.647
Tide height:Change in depth	8.536	2	0.014
Vessel distance: Vessel direction relative to BSA	1.178	2	0.555
Vessel dstance: North- or southbound vessel	2.842	2	0.241
Vessel direction relative to BSA: North- or southbound vessel	1.645	1	0.200
Vessel distance: Vessel direction relative to BSA:North- or southbound vessel	7.254	2	0.027

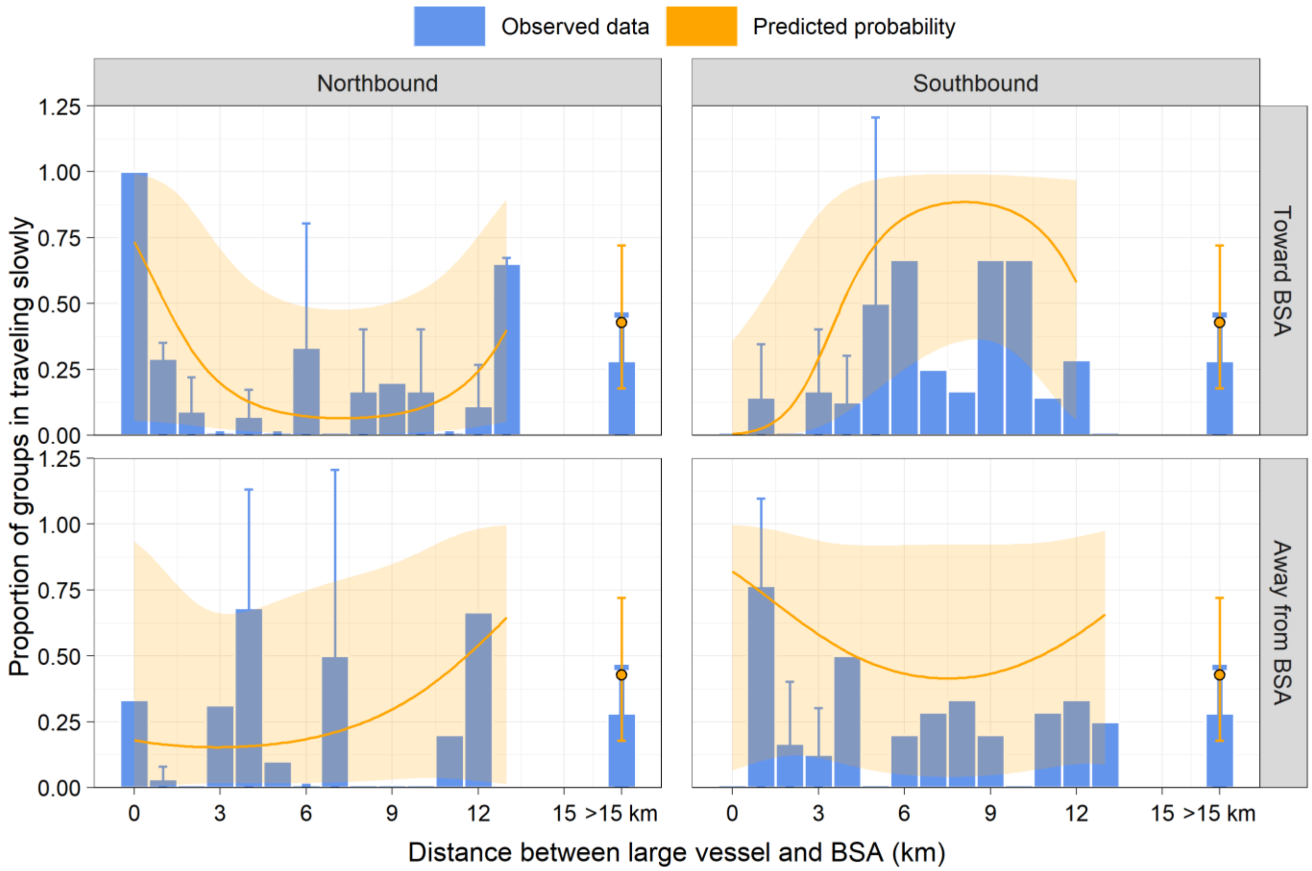


Figure 4-43: Proportion of narwhal groups recorded traveling slowly (rather than at medium speed) relative to distance from large vessels in transit, vessel direction in Milne Inlet, and direction relative to the BSA (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

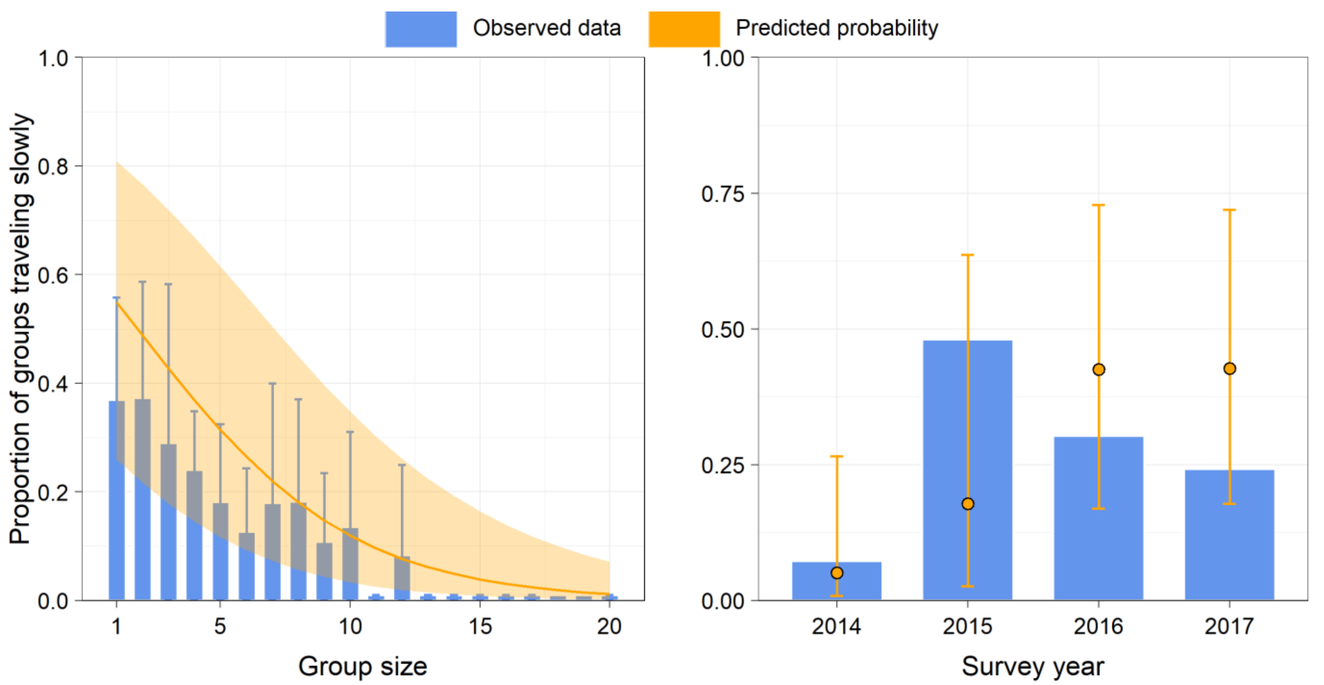


Figure 4-44: Proportion of narwhal groups observed traveling slowly (rather than at medium speed) relative to group size and survey year (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

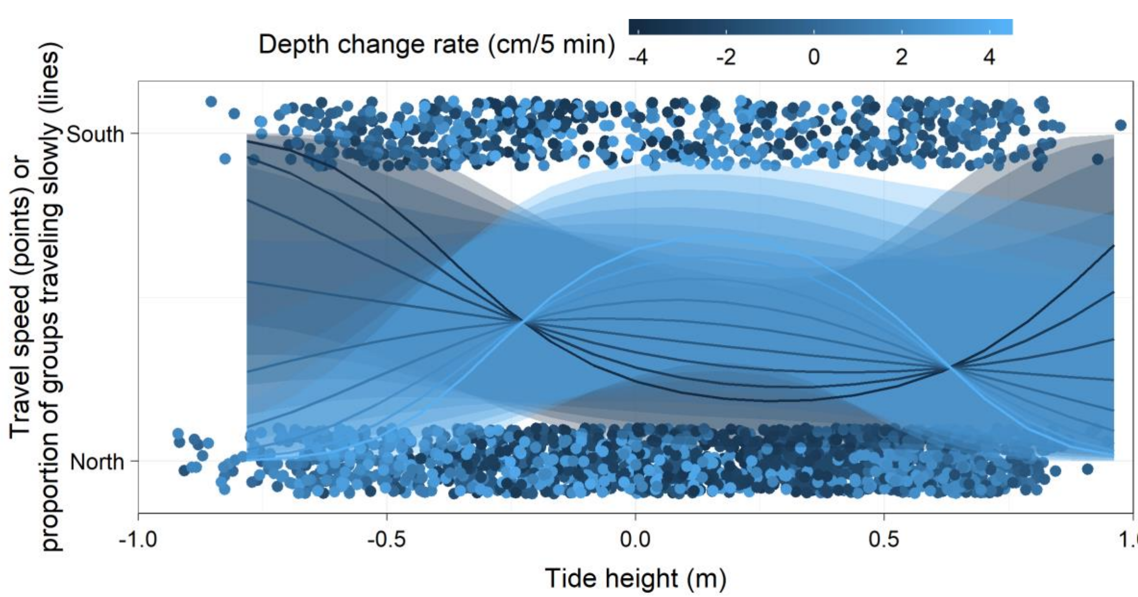


Figure 4-45: Proportion of narwhal groups observed traveling slowly (rather than at medium speed) relative to tide height and change in depth (2014–2017)

Notes: observed data depict raw data (jittered for visualization); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

4.4.6.2 *Fast-traveling groups*

The mixed model of group travel speed did not converge, whether as full model or as simplified model structures. Convergence was only achieved after removal of the autocorrelation term. However, since approximately 50% of periods between observations were within one minute, the removal of temporal autocorrelation would likely result in overly narrow confidence intervals, leading to an erroneously large number of statistically significant findings. The data were therefore not modeled.

4.4.7 Distance from Bruce Head Shore

The majority of narwhal groups observed in the BSA during 2014–2017 sampling years were recorded close to shore (<300 m distance classification; Figure 4-46). At least 22%, 61%, 25%, and 33% of the daily groups were recorded close to shore in 2014–2017, respectively. Annual averages of daily percentages of groups recorded farther from shore ranged between 22% (in 2015) and 50% (in 2014).

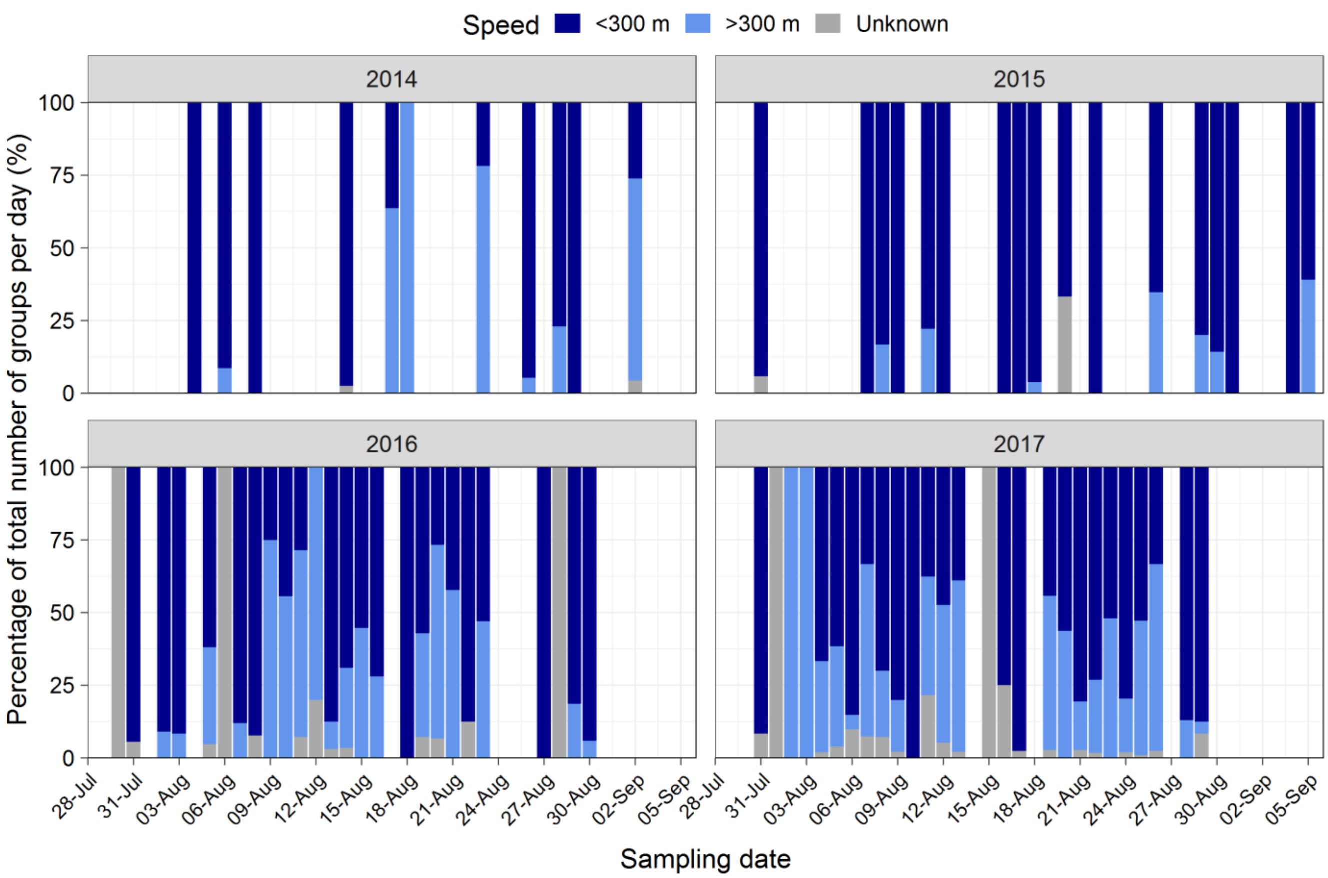


Figure 4-46: Daily distribution of narwhal distance from shore (2014 – 2017)

The distance of narwhal groups from the Bruce Head shore was analyzed in relation to proximity and orientation of transiting large vessels (Figure 4-47).

In the combined 2014–2017 dataset, the majority of observations of narwhal distance from Bruce Head shore were recorded when no large vessels were present within 15 km of the BSA (n = 2,833), of which 33% were more than 300 m away from shore (annual percentage ranging from 23% in 2014 to 35% in 2017). Mean narwhal group size was larger for groups found closer to shore than for groups more than 300 m from shore (4.1 and 2.9 individuals, respectively; Figure 4-47).

When large vessels were present within 15 km from the BSA, 553 groups with a known distance from shore were recorded. The percentage of groups found more than 300 m from shore varied with vessel direction and position relative to the BSA. The percentage was lowest for vessels heading away from the BSA (25% for northbound and 22% for southbound vessels), intermediate for southbound vessels heading toward the BSA (32%) and highest for northbound vessels heading toward the BSA (53%).

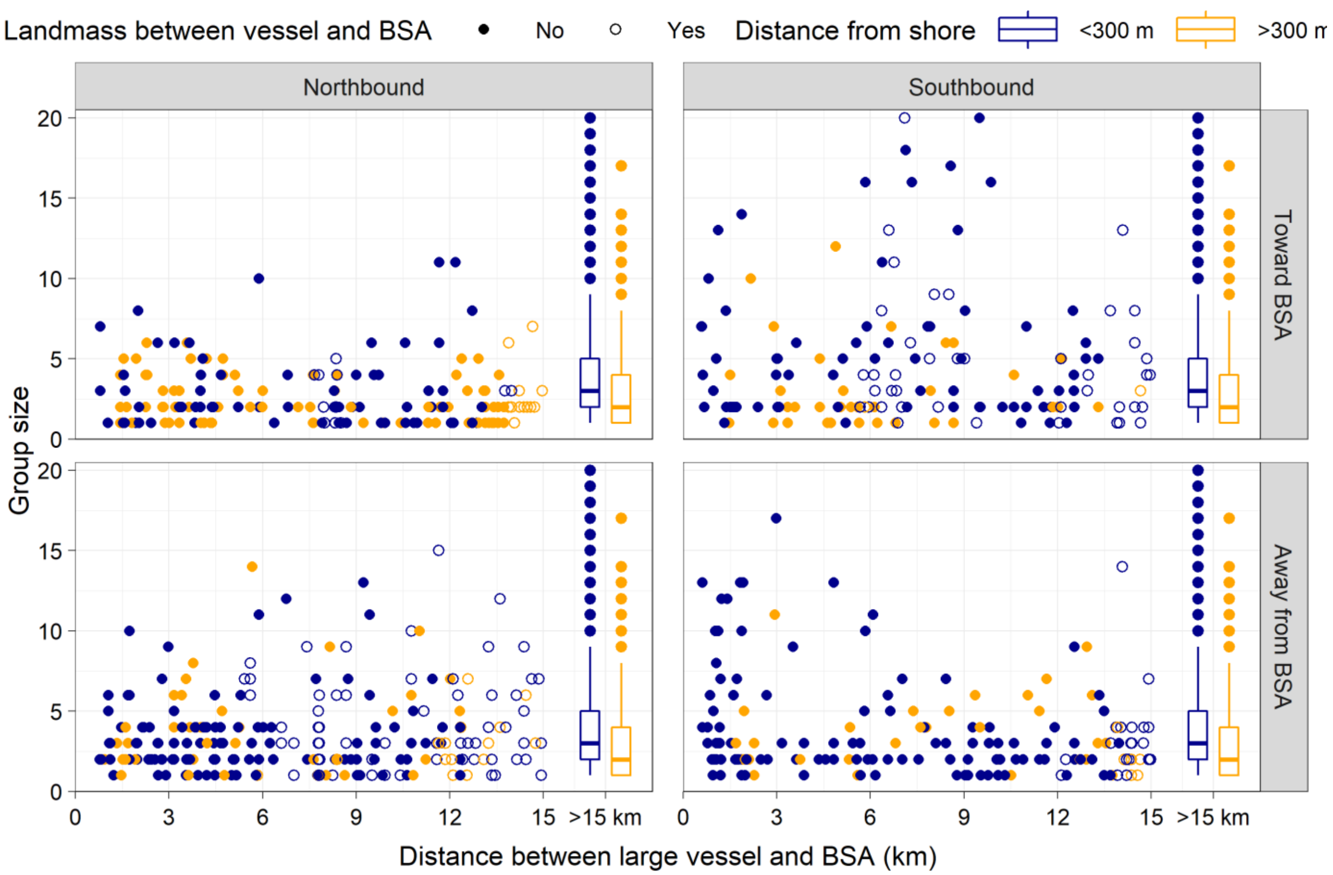


Figure 4-47: Distance from shore for narwhal groups recorded in BSA relative to distance from large vessels transiting through the SSA (2014–2017)

In the mixed model for group distance from shore, both anthropogenic and sampling variables had a significant effect on the probability of observing a group offshore (>300 m; Table 4-12). The anthropogenic effects on group distance from shore included vessel distance from the BSA (*P* = 0.021), whether the vessel was heading toward or away from the BSA (*P* = 0.007), and the time since last shooting occurred (*P* = 0.005). The effect of distance of large vessel form the BSA (estimated using a third-degree polynomial) indicated that narwhal were most likely to be offshore when large vessels were approximately 3–6 km away from the BSA and generally not likely to be offshore when large vessels were within 3 km from the BSA (Figure 4-48). The effect of vessel distance on the probability of observing offshore groups was larger when vessels were heading toward the BSA when compared to vessels heading away from the BSA.

In addition to large vessel passage, time since last shooting event was also found to have a significant effect on narwhal distance from shore. Specifically, the probability of offshore narwhal groups was highest 1.5–2 h post shooting (Figure 4-49). The lower probability of offshore groups immediately after a shooting event is likely an artifact, since much of the hunting took place from the hunting camp on the shore of Bruce Head (below the platform), and therefore hunting was more likely to occur when narwhal were closer to shore.

Both day of year and Beaufort scale were estimated to have a significant effect on the distance of narwhal from Bruce Head shore (Table 4-12). The modeled results indicated a reduction in the probability of observing narwhal offshore with every increase in Beaufort scale value (Figure 4-49), although the difference was significant only in the comparison of Beaufort scale value of ‘3’ to ‘0’. The effect of day of year on narwhal distance from shore indicated a higher probability of narwhal remaining offshore in mid-August than in either late July or early September (Figure 4-49). The interaction with survey year was omitted due to convergence issues, therefore it is not known whether the effect of day of year differed between years.

Table 4-12: Summary table of generalized mixed linear model of group distance from Bruce Head shore

Parameter	X^2 value	df	P-value
Day of year	6.963	2	0.031
Year	5.462	3	0.141
Group size	3.112	1	0.078
Glare	3.625	2	0.163
Beaufort scale	9.255	3	0.026
Tide height	1.794	3	0.616
Change in depth	0.810	1	0.368
Vessel distance	9.712	3	0.021
Vessel direction relative to BSA	7.310	1	0.007
North- or southbound vessel	0.043	1	0.835
Large vessel presence within 15 km from BSA	1.394	1	0.238
Time since last shooting event	10.447	2	0.005
Hunting event within 6 h prior to observation	0.026	1	0.871
Number of small vessels within the SSA	2.817	1	0.093
Tide height: Change in depth	2.043	3	0.563
Vessel distance: Vessel direction relative to BSA	5.978	3	0.113
Vessel distance: North- or southbound vessel	1.355	3	0.716

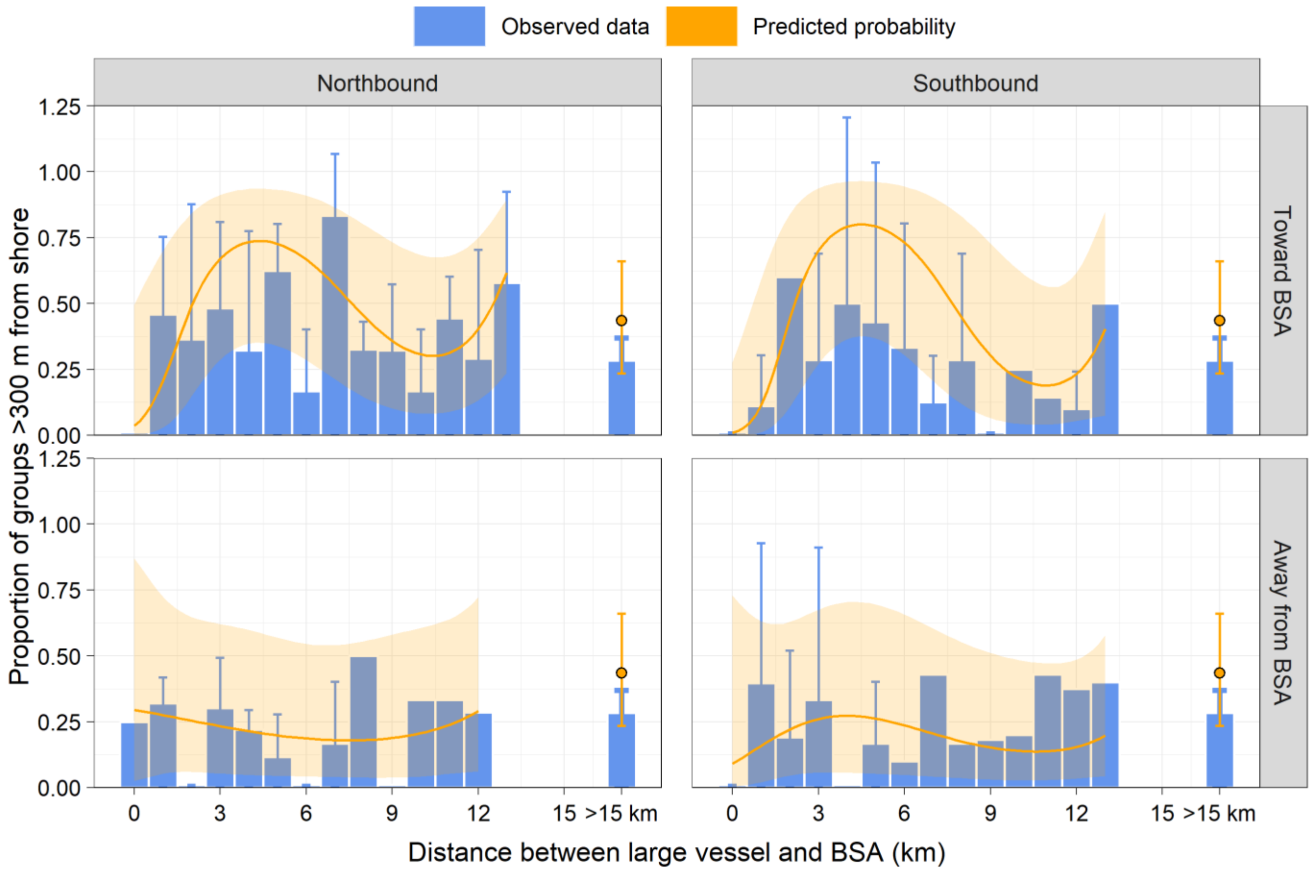


Figure 4-48: Proportion of narwhal groups observed >300 m from shore relative to distance from large vessels in transit, vessel direction in Milne Inlet, and direction relative to the BSA (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

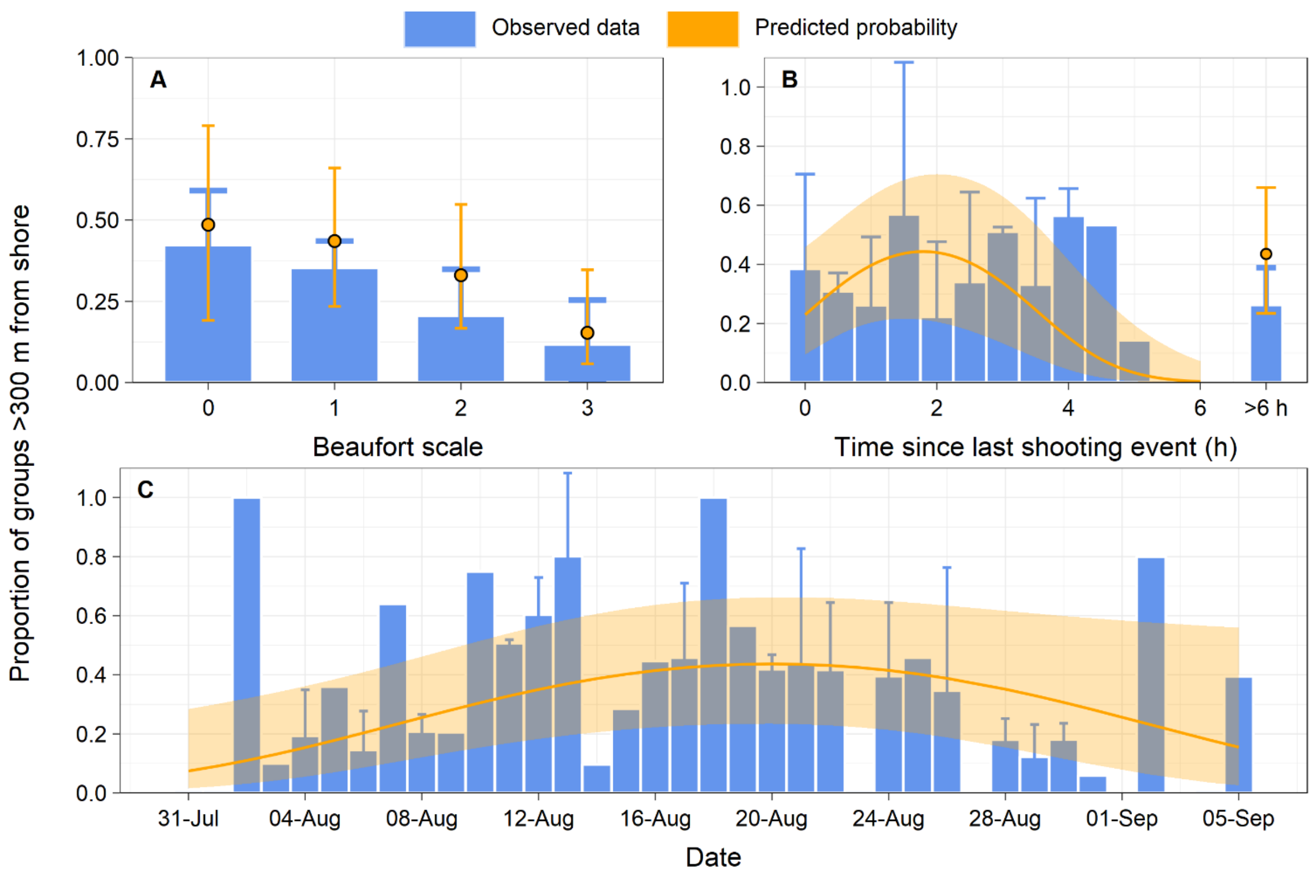


Figure 4-49: Proportion of narwhal groups observed >300 m from shore relative to Beaufort scale, sampling date, and time since last shooting event (2014–2017)

Notes: observed data depict mean and standard deviations of annual means for each x-axis value (all other variables are not held constant); predicted data depict mean and 95% confidence intervals, holding all other variables constant.

4.5 *Ad Lib* Observations

Narwhal were frequently observed south of the SSA in the general vicinity of Koluktoo Bay and the entrance to Assomption Harbour (Milne Port). Similar distribution of narwhal in this area has been reported during aerial surveys (Thomas et al. 2015, 2016; Golder 2018b) affirming the importance Koluktoo Bay may serve as a refuge for narwhal during the shipping season.

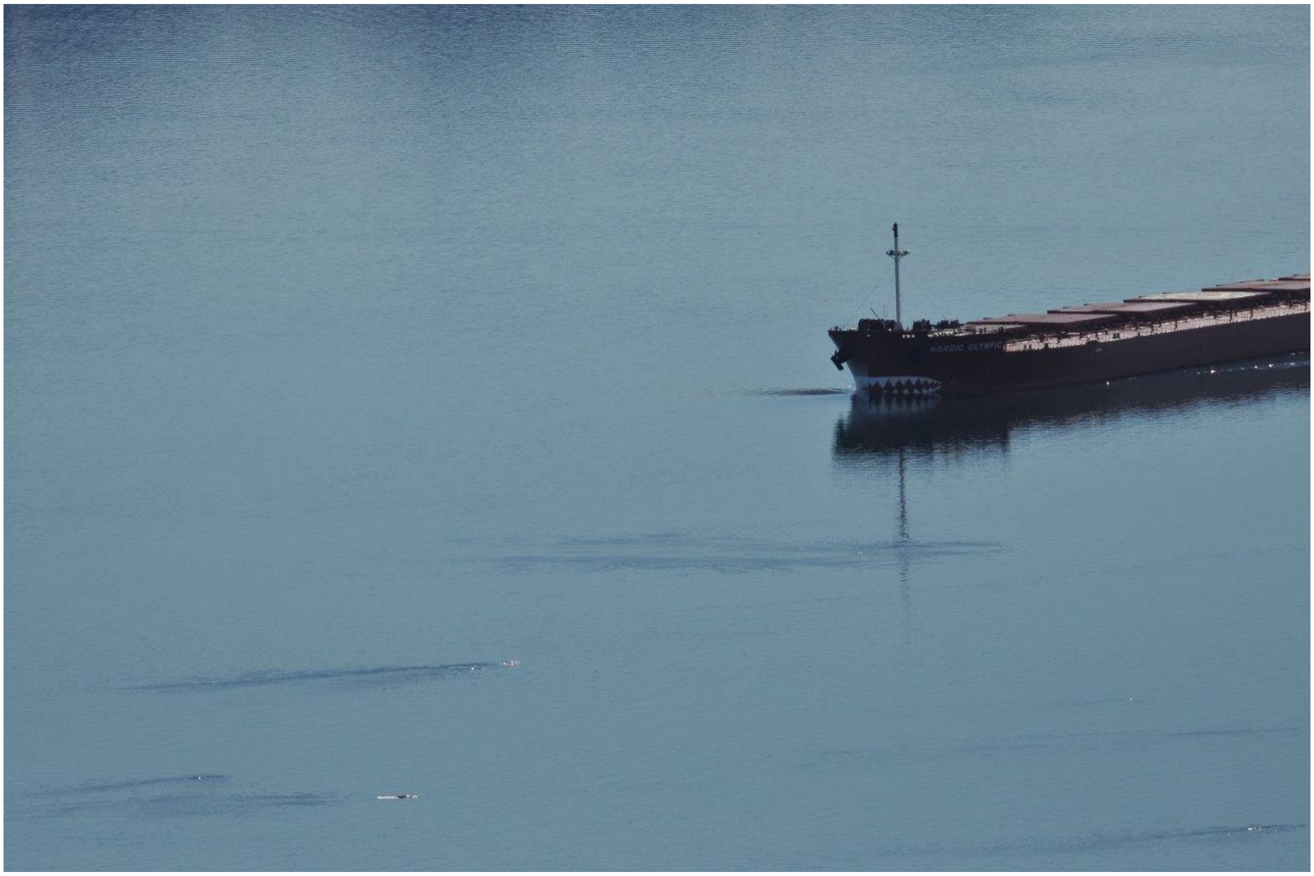
The majority of narwhal recorded in the SSA during the four-year study period were engaged in travelling behaviour. Other behaviours observed in the SSA included nursing, rubbing, tusking, foraging, and mating. In all years, narwhal calves were commonly observed in the SSA, with observations of nursing behaviour recorded in 2015 (two occasions), 2016 (four occasions) and 2017 (two occasions). On 11 August 2016, the birth of a narwhal calf off Bruce Head was observed. Collectively, these qualitative observations lend further support to the hypothesis that this part of Milne Inlet is important for calf rearing.

In 2016, narwhal were observed foraging on arctic cod near the Bruce Head shore on several days in early August (Smith et al. 2017). The foraging groups included mother-calf pairs, although these were not commonly observed feeding. Narwhal stomach contents performed in the 1960s indicated that narwhal consume arctic cod in the area. However, most narwhal foraging is thought to occur during winter in Davis Strait.

In 2016 and 2017, despite increased shipping traffic in these years, narwhal were regularly observed in the SSA and adjacent areas of Milne Inlet throughout the open-water study period (Smith et al. 2016; Golder 2018a). *Ad lib* observations made by the observers suggested that the response of narwhals 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 (Photographs 4-1 and 4-2), to temporary and localized displacement and related changes in behaviour. However, no overall decrease in the abundance of narwhal in the area was observed.

During each year of this shore-based study, narwhal were observed to respond to shooting by diving and increasing their swim speed. Despite repeatedly being shot at from the same location (i.e., the hunting camp below the observation platform), narwhal were always observed to return to the area at the base of Bruce Head, though the time until they returned was variable.

Photograph 4-1: Narwhal recorded in close proximity to southbound ore carrier transiting in SSA during the 2017 RAD surveys



Photograph 4-2: Narwhal recorded in close proximity to northbound ore carrier transiting in SSA during the 2017 RAD surveys

5.0 DISCUSSION

5.1 Vessel Traffic and Other Anthropogenic Activities

A total of 133 one-way large vessels transits occurred along the Northern Shipping Route in the Bruce Head SSA during the 2014–2017 open-water seasons. Mitigation measures established by Baffinland to minimize vessel-related impacts to marine mammals along the Northern Shipping Route included a maximum speed limit imposed for Project-related ore carrier traffic. Of note, ore carriers travel speed was set at a maximum of 7-10 knots upon entering Pond Inlet and 5 knots when entering Milne Port. According to satellite and shore-based AIS data, the majority of the ore carrier travel speeds recorded in Milne Inlet were in general compliance with speed restriction (rarely exceeding 10 knots). However, multiple Project-related cargo ships and fuel tankers were shown to travel exclusively in the 10 to 15 knot range while transiting in Milne Inlet.

Small vessel (<50 m) traffic in the SSA ranged from none (79% of RAD cases) to three small vessels within the SSA (0.3% of RAD cases). Small vessel traffic was slightly higher in 2017 compared to previous years (only 72% of RAD counts collected without a small vessel present in the SSA, compared to 78-84% in 2014-2016). Small vessel traffic in the SSA was considered as a confounding variable when assessing narwhal behavioural response to large vessel traffic.

During the 2017 Program, the hunting camp at the base of the cliff below the Bruce Head observation platform was occupied during 20 of the 27 survey days. This occupancy rate is similar to the 2016 Program, when the hunting camp was occupied during 22 of the 27 survey days. In comparison, during the 2015 Program, the hunting camp was occupied during 16 of the 30 survey days. Hunting of narwhal in the SSA was considered as a confounding variable when assessing narwhal behavioural response to vessel traffic.

5.2 Relative Abundance and Distribution

The southern portion of Milne Inlet is a preferred summering ground for narwhal, with evidence from previous and current surveys suggesting that it is an important area for rearing of young based on observations of mother calf nursing, mating, and foraging behaviour (Smith et al. 2017). During the 2014–2017 survey years, a total of 65,233 narwhal were observed with the SSA, with mean annual standardized counts ranging from 84.2 narwhal/h (in 2015) to 156.4 narwhal/h (in 2016). Due to the uneven temporal and spatial distribution of narwhal, the dataset contained many counts of zero narwhal (from 72% of substratum counts in 2017 to 88% in 2015). In general, narwhal counts in the SSA increased from north to south (stratum A to I), with low counts in substrata ‘1’ and ‘3’ and high counts in substrata ‘2’. The relative abundance and distribution of narwhal was observed in response to 62 transits of large vessels. The majority of narwhal observations in the SSA, however, occurred when no large vessels were present within 15 km of a given substratum.

5.2.1 RAD Modelling

The statistical model of RAD data included all two-way interactions between three vessel-related variables: 1) vessel distance from a given substratum; 2) whether the vessel was heading toward or away from a substratum; and 3) whether the vessel was north- or southbound. Of these three interactions, only the interaction between vessel distance and its direction within Milne Inlet (north- or southbound) was significant. That is, the effect of vessel distance from SSA centroids was estimated to change based on the direction of the vessel within Milne Inlet. The model predicted low counts of narwhal when a northbound large vessel was near the substrata and a peak in narwhal counts when vessels were 6–7 km from the substrata. In contrast, for southbound vessels, increased counts were predicted when vessels were near. The direction of the large vessel relative to the SSA centroids (vessel heading toward or away from centroid) was not significant in either main effect or interaction terms.

The results of the combined 2014–2017 analysis differ from those of the 2017 dataset analysis (Golder 2018a) and partly support the results of the 2014–2016 analysis (Smith et al. 2017). Specifically, the analysis of data collected in 2017 only suggested an effect of the direction of large vessels relative to the SSA centroids (i.e., whether vessel was heading toward or away from the substratum), but no effect of vessel direction within Milne Inlet (north- or southbound vessel). Conversely, the analysis of 2014–2016 dataset found that narwhal counts were significantly different when northbound vessels were heading away from a substratum than in all other scenarios. Based on the analysis of the combined dataset, the direction of vessel within Milne Inlet is indeed a significant factor affecting narwhal relative abundance. It is possible that the difference in narwhal response to north- and southbound vessels is due to the difference in vessel noise propagation, combined with the spatial distribution of narwhal. Specifically, the noise of northbound vessels propagates without an impediment throughout the opening of Koluktoo Bay and the southern strata of the SSA, where the majority of narwhal are usually located. Conversely, the noise of a southbound vessel north of Poirier Island is impeded by the Bruce Head peninsula, resulting in a different response of narwhal in the southern strata and Koluktoo Bay.

When a northbound vessel headed toward the substrata, narwhal abundance increased when the vessel was 6-7 km away from the substratum centroids relative to when the vessel was 9–15 km away. It is possible that the narwhal in Koluktoo Bay, outside of the SSA, act as a reservoir of animals that are displaced into the SSA by northbound traffic, resulting in increased counts relative to counts in the absence of vessels or when southbound vessels are present. Expansion of the study area to cover more of Koluktoo Bay may help illuminate whether this is indeed the behavioural response underlying the apparent difference in abundance.

Once a northbound vessel passed the SSA and started heading away from it, narwhal abundance gradually increased until the vessel was 6–7 km away. This pattern could represent a refractory period during which narwhal reoccupy the SSA after their initial displacement. The pattern in narwhal abundance relative to southbound vessel distance is less apparent and may actually suggest that narwhal abundance could increase when vessels are at closer distances to the substrata. One explanation could be that narwhal are pushed ahead of the vessel but remain close to the vessel and do not leave the SSA, resulting in an accumulation of narwhal ahead of the vessel. The increase in narwhal abundance as southbound vessels heading away from the SSA are at 6–11 km may be related to the pattern of narwhal travel direction observed for that scenario of large vessel transit, where narwhal were more likely to travel north when southbound vessels were heading away from the BSA. That is, as large vessels clear the study area, narwhal move north and repopulate the study area. It is not clear whether the different patterns in relative abundance between south- and northbound vessels are due to chance (i.e., spurious finding) or are an actual behavioural response.

5.2.2 Spatial Distribution in the SSA

The analysis of movements of GPS-tagged narwhal in the SSA in summer 2017 suggested that overall, the five tagged narwhal spent less time in substrata ‘3’, with substantial individual and temporal variability. The use of substrata ‘3’ also depended on the stratum, with higher use in stratum A and low use in strata B-I. These results suggest that the low counts of narwhal recorded in substrata ‘3’ throughout the 2014–2017 RAD surveys (Smith et al. 2015, 2016, 2017 and Golder 2018a) may be due to spatial distribution, rather than simply reduced visibility in the farthest substrata. To quantify the effect of reduced visibility on RAD counts, additional work is required, which would combine visual surveys with concurrent counts via drone footage to estimate the difference between actual and observed counts of narwhal.

5.3 Group Composition and Behaviour

5.3.1 Group Size

Model results for the 2014–2017 dataset indicated that for narwhal observed within 15 km of a large vessel, vessel distance from the BSA did not have a significant effect on group size. Mean group sizes for narwhal observed in the 2014–2017 dataset were not significantly different when large vessels were present within 15 km of the BSA compared to when no large vessels were present. The analysis of 2014–2016 data (Smith et al. 2017) indicated that mean narwhal group size increased in the presence of large vessels. However, the analysis was based on a simple ANOVA based on whether large vessels or small vessels were present, or shooting events occurred, and did not take into account all confounding variables considered in this report. The analysis performed on 2017 data (Golder 2018a) resulted in a significant effect of whether a vessel was heading toward or away from the BSA and whether a vessel was present within 15 km from the BSA centroid, but no significant effect of distance between vessel and the BSA. This result was considered a spurious finding (Golder 2018a), which is supported by the analysis of the combined 2014–2017 dataset presented in this report. Overall, only year and glare had a significant effect on group size determination.

5.3.2 Group Composition

Milne Inlet is an important summering ground for narwhal of all life stages, including adults, juveniles, yearlings, and calves. Group composition was similar throughout 2014–2017, with adult narwhal as the primary age class observed followed by yearling/juvenile and calf. Variation in group composition did not have obvious trends over the open-water season (end of July to end of August), and all narwhal age classes were recorded in the SSA and BSA throughout the duration of the four-year program. Mother-calf pairs were observed on multiple occasions in the BSA and, in some cases, the calves were likely only hours to one day old (Golder 2018a), which is supported by previous identification of Milne Inlet near the Bruce Head peninsula as an important calf rearing area (Smith et al. 2015, 2016, 2017).

The analysis of presence / absence of tusks or yearlings / calves did not find significant effects of vessel traffic (or other anthropogenic activity). Group size was the only significant predictor of whether a group would have an individual with a tusk (or whether calves or yearlings would be present). For both analyses, the probability of observing the response variable (tusk presence or presence of calves/yearlings) increased with group size. The analysis of 2014–2016 data also indicated lack of effect of anthropogenic activity on presence/absence of calves or yearlings (Smith et al. 2017). On the other hand, the 2014–2016 results suggested that the presence of tusked animals differed in the presence of large vessels (when compared to presence of small vessels) and in the presence of small vessels (when compared to observations without anthropogenic activity; Smith et al. 2017). However, as detailed for the 2014-2016 group size analysis, the 2014–2016 analysis of group composition did not account for other confounding variables that were included in the integrated 2014–2017 models presented in this report.

5.3.3 Group Spread

Throughout the 2014–2017 sampling program, narwhal were more often observed in tight associations compared to loose associations under both vessel presence and vessel absence scenarios. The analysis of the integrated 2014–2017 dataset indicated that group size, year, day of year, and vessel distance (depending on whether the vessel was heading toward or away from the BSA) had a statistically significant effect on group spread. The analysis of 2014–2016 dataset (Smith et al. 2016) suggested that loose groups were more common in the presence of large vessels. The significant effects of vessel presence on group spread presented in this report support that finding. Similar to the results presented in Smith et al., hunting and the number of small vessels in the SSA did not have a significant effect on group spread in the integrated 2014–2017 analysis.

It is believed that some cetacean species aggregate more closely together during periods of disturbance and/or stress as a strategy to better detect the subtle queues of group members and increase ability to respond to a potential threat (Mann et al. 2000). Narwhal, however, are a gregarious species and are closely associated with one another by nature (Marcoux et al. 2009), meaning that the reduced estimated probability of observing a group in loose spread when vessels were near the BSA (except for northbound vessels heading away from the BSA) is not necessarily indicative of animals responding to a perceived threat (i.e., a transiting vessel).

5.3.4 Group Formation

The majority of narwhal groups of two narwhal or more observed throughout 2014–2017 were in a parallel formation, followed by cluster, linear, and non-directional line formations. The model of the combined 2014–2017 dataset indicated that anthropogenic activity did not affect the probability of narwhal groups occurring in non-parallel formation. The effects of year, group size, glare, and Beaufort scale were the only variables that had a statistically significant effect on group formation. Of these, glare and Beaufort scale effects are likely related to a change in the observers' ability to either see groups in different formations or accurately identify different formations under different visibility conditions. Interestingly, an increase in Beaufort scale values was predicted to decrease the probability of observing non-parallel groups, whereas an increase in glare had the opposite results.

The analysis of the 2014–2016 dataset (Smith et al. 2017) did not find strong effects of anthropogenic activity on group formation (only that the proportion of groups in circular formation arguably increased when large vessels were present). Analysis of the 2017 survey data alone suggested an effect of large vessel transits on group formation (i.e., probability of observing linear and parallel formations). However, this effect was not statistically significant following the integration of 2014–2016 data to the 2017 dataset and subsequent refinement of the model.

5.3.5 Group Direction

Narwhal groups were predominantly observed travelling south through the BSA during the four-year study period, with animals tending to travel south in large groups and north in small groups. The integrated 2014–2017 modeling results indicated a significant effect of group size (larger groups were more likely to travel south), year, Beaufort scale, tide, hunting activity, and large vessel transit. Specifically, travel direction depended on the interaction between vessel direction and position relative to the BSA, due to the strongly reduced proportion of south-traveling groups in the presence of a southbound vessel heading away from the BSA. The distance between vessel and the BSA did not have a significant effect on the probability of observing narwhal groups traveling south, which usually suggests a spurious effect, since vessel effects are expected to be distance-dependent. However, the change in the proportion of south-traveling groups under the presence of southbound vessels heading away from the BSA is too strong to be considered a spurious finding. In the presence of large vessels, south-traveling groups were most common when northbound vessels were heading away from the BSA and least common when southbound vessels were heading away from the BSA. That is, narwhal groups were less likely to swim in the direction of a vessel that passed through the BSA.

The integrated modelling results for group direction are similar to the results presented by Smith et al. (2016) in their analysis of the 2014–2016 dataset, in which a significant effect of large vessel presence on narwhal swimming direction was identified. The results are also similar to the model estimates presented for the 2017 dataset (Golder 2018a), where the interaction between vessel direction and position relative to the BSA was significant ($P<0.001$), also reflecting the decrease in south-traveling groups when southbound vessels were heading away from the BSA.

In general, travel north was primarily observed when narwhal groups were smaller and at greater distances from a large vessel, or when a southbound vessel was heading away from the BSA. However, due to the almost complete separation in the data, the model was unstable and the resulting estimate uncertainty was high.

5.3.6 Travel Speed

The majority of narwhal groups recorded in the BSA during the four-year study period travelled at a medium speed, regardless of large vessel presence/absence. Group traveling speed generally increased with group size, with a lower probability of observing slowly-traveling groups as group size increased. Distance between vessel and the BSA had a significant effect on the presence of slowly-traveling groups, however the effect depended on the direction of the vessel within Milne Inlet (northbound vs. southbound) and the direction of the vessel relative to the BSA (approaching vs. moving away from the BSA). Based on predictions of the model, narwhal were more likely to travel slowly when a vessel was near (within 3 km) and to the south of the BSA, regardless of whether the vessel was north- or southbound or if it was heading toward or away from the BSA. The reverse effect was predicted when a large vessel was near and north of the BSA. This finding suggests the possibility that when a large vessel is present to the south of the BSA (and possibly inhibiting narwhal from entering into Koluktoo Bay), narwhal swim slowly in the BSA while waiting for the vessel to pass. Since the models of fast travel did not converge, it was not possible to analyze the 2014-2017 dataset for presence/absence of fast-traveling narwhal groups. Plots of raw data indicated that fast-moving groups were on average larger than groups traveling at a slow or medium speed. Previous analysis, performed on the 2014–2016 dataset, suggested that fast-traveling narwhal groups were significantly more common in the presence of large vessels than in the presence of small vessels or following a shooting event (Smith et al. 2017).

5.3.7 Distance from Bruce Head Shore

Throughout 2014–2017 sampling, the majority of narwhal groups in the SSA were observed inshore (<300 m from the Bruce Head shore). Generally, inshore groups were larger than offshore groups, regardless of large vessel presence within 15 km from the BSA. The mixed model of group distance suggested that the presence of offshore groups was significantly affected by large vessel distance from the BSA and the vessel's direction relative to the BSA. The probability of observing offshore narwhal groups was lower when large vessels headed away from the BSA than when vessels were heading toward the BSA. That is, vessel passage resulted in a temporary displacement of narwhal closer to the Bruce Head shore.

The significant effect of vessel passage supports the results reported in Smith et al. (2017) for the 2014–2016 data, where inshore narwhal groups were significantly more common in the presence of large vessels than in the presence of small vessels, shooting events, or no anthropogenic activity.

As narwhal tend to move close to shore when attempting to escape predation by killer whales (Steltner et al.1984; Marcoux et al. 2009; Breed et al. 2017), it is conceivable that narwhal may also move closer to shore when exposed to other perceived threats (i.e., large vessel traffic). Monitoring of narwhal distance from shore is therefore an appropriate metric to assess habitat use and whether the proportion of inshore vs. offshore narwhal groups is dependant on anthropogenic activity.

6.0 CONCLUSIONS

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

- Condition No. 99 and 101 — "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"[4]
- Condition No. 109 (for Milne Inlet specifically) — "The Proponent shall conduct a monitoring program to confirm the predictions in the FEIS with respect to disturbance effects from ships noise on the distribution and occurrence of marine mammals. The survey shall be designed to address effects during the shipping seasons, and include locations in Hudson Strait and Foxe Basin, Milne Inlet, Eclipse Sound, and Pond Inlet. The survey shall continue over a sufficiently lengthy period to determine the extent to which habituation occurs for narwhal, beluga, bowhead and walrus".
- Condition No. 111 — "The Proponent shall develop clear thresholds for determining if negative impacts as a result of vessel noise are occurring".

Key findings from the 2014–2017 Bruce Head Monitoring Program include the following:

- Relative abundance and distribution (RAD):
  - The relative abundance of narwhal in the Bruce Head area has remained relatively constant over the four years of sampling (as shown by a lack of significant year effect on counts and fewer occurrences of zero counts in 2017) despite the relative increase in shipping during this period.
  - Model results indicated that vessel direction within Milne Inlet (south- vs northbound vessels) affected the response of narwhal relative to distance from large vessel. Conversely, the direction of vessel relative to the substrata (heading toward or away from substrata) was not a significant predictor of relative abundance.
- Spatial distribution within the SSA – GPS-tagged narwhal were shown to spend the least time in substratum '3' and the most time in substratum '2'. This provides evidence that low RAD counts recorded in substratum '3' are not solely due to reduced observation visibility.
- Group composition and behaviour:
  - Group size — group sizes changed between years, but not in a manner consistent with the increase in vessel traffic between 2014 and 2017. Model results also did not suggest temporary effects of large vessel transits on narwhal group size within the BSA.

[4] The 2014-2017 Bruce Head Shore-based Monitoring Program currently satisfies this condition.

  - Group composition — groups with calves/yearlings and groups with tusks were present in the BSA and SSA throughout the four sampling years. Model results indicated no effect of large vessel transits on presence of tusks or calves/yearlings in observed groups in the BSA. For both response variables, group size was the only significant predictor variable identified.
  - Group spread — narwhal were more often observed in tight associations compared to loose associations under both vessel presence and vessel absence scenarios. During passage of a large vessel within 15 km from the BSA, loosely spread groups were more likely to occur when southbound or northbound vessels heading toward the BSA were 2–4 km away from the BSA, or when northbound vessels heading away from the BSA were near (≤2 km). In addition, the probability of observing a group in a loose spread significantly increased with group size.
  - Group formation — narwhal were usually observed in parallel formation under both vessel presence and vessel absence scenarios. Models indicated no effect of vessel transits on group formation in the BSA (analyzed as presence/absence of non-parallel groups). The probability of observing a non-parallel formation increased significantly with group size.
  - Group direction — narwhal groups were predominantly observed travelling south through the BSA. When northbound large vessels were within 15 km of the BSA, narwhal were most often observed travelling south, regardless of direction of the vessel relative to the BSA. In the presence of southbound vessels, narwhal groups travelled both north and south when the vessel was heading toward the BSA (model predictions were of a predominantly southward traveling direction). When the southbound vessel headed away from the BSA, narwhal groups were observed traveling predominantly north, unless the vessel was within close proximity (≤2 km). Narwhal tended to travel south in large groups and north in small groups.
  - Travel speed – the majority of narwhal groups travelled at a medium speed, regardless of large vessel presence/absence. The probability of observing slowly-traveling groups increased when large vessels were south of the BSA (regardless of direction of travel and direction relative to the BSA) and in close proximity (≤3 km). When vessels were north of the BSA, the probability of observing slowly-traveling groups was low, especially for southbound vessels. The probability of observing slowly-traveling groups decreased with group size.
  - Distance from Bruce Head shore - narwhal groups were observed more often at a distance <300 m of the Bruce Head shore compared to groups >300 m offshore under both vessel presence and vessel absence scenarios. Offshore groups were detected less frequently with increasing Beaufort scale values, indicating observer impediment with worsening sea state. Model results indicated that narwhal groups tended to be offshore when large vessels were 3–6 km away from the BSA, especially when vessels were heading toward the BSA (compared to vessels heading away from the BSA). When vessels were close, the model estimated that narwhal groups were concentrated inshore.
- *Ad libitum o*bservations collected throughout the four-year study period indicate the following:
  - The majority of narwhal recorded in the SSA during the four-year study period were engaged in travelling behaviour. Other behaviours observed in the SSA included nursing, rubbing, tusking, foraging, and mating. In all years, narwhal calves were commonly observed in the SSA, with observations of nursing behaviour recorded in 2015 (two occasions), 2016 (four occasions) and 2017 (two occasions).

On 11 August 2016, the birth of a narwhal calf off Bruce Head was observed. Collectively, these observations lend support to the hypothesis that this part of Milne Inlet is important for calf rearing.

- Narwhal occur most frequently south of the SSA in the vicinity of Koluktoo Bay and the entrance to Assomption Harbour (Milne Port). A similar distribution of narwhal has been reported during aerial surveys conducted in the Milne Inlet region (Thomas et al. 2015, 2016; Golder 2018b) affirming the importance of Koluktoo Bay as a refuge for narwhal during the open-water season.
- Responses of narwhal to ore carrier traffic is variable, ranging from ‘no obvious response’ in which animals remain in close proximity to ore carriers as they transit through the SSA, to temporary and localized displacement and related changes in behaviour. However, no overall decrease in the abundance of narwhal in the area was observed.
- During each survey year, narwhal were observed to respond to shooting by diving and increasing their swim speed. Despite repeatedly being shot at from the same location (i.e. the hunting camp below the observation platform), narwhal were always observed to return to the area at the base of Bruce Head, though the time until they returned was variable.
- In 2016, narwhal were observed foraging on arctic cod schooling close to the Bruce Head shore on nine days during the first half of August. Mother-calf pairs were observed to engage in foraging behaviours although the majority of these feeding groups did not include calves or yearlings.

7.0 RECOMMENDATIONS

The following items should be considered with respect to future shore-based monitoring efforts:

- Data collection:
  - The primary narwhal behaviour in the current SSA consists of travel behaviour, which may make determination of narwhal responses to vessel transits more difficult than vessel transits in relation to more sedentary behaviour types (i.e., milling, foraging, etc.). Alternate locations for the observation platform should be assessed that might better survey the portion of the nominal shipping route closest to Koluktoo Bay, where travel does not appear to be the primary narwhal behaviour.
  - Supplement visual observation with drone footage. This will provide a means to verify observation counts and will allow to correct for observation bias under conditions of low visibility or increased distance. In addition, drone footage may be helpful for filling in missing information on narwhal behaviour and composition in the BSA, where observers are not able to record certain aspects of group behaviour due to reduced sightability.
- Analysis:
  - Assess the potential effects of simultaneous transits of multiple large vessels on narwhal RAD and behaviour. At this time, it is unknown whether the effects of consecutive transits of a single large vessel are different than a single transit of multiple large vessels (travelling in SSA simultaneously).
  - Integration of acoustic monitoring results with shore-based observer data to assess if and when narwhal alter their acoustic behaviour in response to vessel transits.
- Linkage with other narwhal studies in the region:
  - The Bruce Head observation point provides a convenient platform for conducting narwhal surveys. However, the surveys are often impeded by weather (e.g., high wind events), reduced sightability conditions due to fog, glare, or sea state, and observer ability to identify and enumerate narwhal at a distance. A comprehensive analysis of narwhal movement and dive behavior using data collected during the 2017 Tremblay Sound Narwhal Tagging Program, will provide complementary information on narwhal responses to large vessel traffic in the wider context of Milne Inlet.

8.0 CLOSURE

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

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Date of Comment Submission: 19/12/2018

#	Document Name	Section Reference	Comment	Baffinland Response
1	Bruce Head shore Based Monitoring Program (2014-2017)	Page 11. Paragraph 2	"There is no evidence of hearing impairment occurring in marine mammals as a result of vessel sound" Assumptions such as this can be problematic, especially given the lack of extensive research in narwhal.	Noted. However, there has been extensive work conducted to date to establish acoustic injury thresholds for both toothed whales and baleen whales when exposed to non-impulsive noise sources, including vessel noise (NFFS 2013a, 2013b, 2016; NOAA 2015, 2016. 2018). As source levels for ore carriers and fuel tankers are below the established injury thresholds for toothed whales (i.e. narwhal, beluga, killer whale), hearing impairment effects are not expected from vessel noise exposure. This is further supported by acoustic monitoring results from the 2018 Passive Acoustic Monitoring Program, in which Project vessel noise levels did not reach the NMFS (2018) thresholds for hearing injury at any of the five acoustic monitoring locations near Bruce Head (Frouin-Mouy et al. 2019). Frouin-Mouy, H., E.E. Maxner, M.E. Austin, and S.B. Martin. 2019. Baffinland Iron Mines Corporation - Mary River Project: 2018 Passive Acoustic Monitoring Program. Document 01720, Version 3.0. Technical Report by JASCO Applied Sciences for Golder Associates Ltd. National Marine Fisheries Service (NMFS). 2013a. Marine Mammals: Interim Sound Threshold Guidance. National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

#	Document Name	Section Reference	Comment	Baffinland Response
				NFMS. 2013b. Draft guidance for assessing the effects of anthropogenic sound on marine mammal acoustic threshold levels for onset of permanent and temporary threshold shifts. NMFS, NOAA and U.S. Department of Commerce. NMFS. 2016. Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-55. 178 pp. National Oceanic and Atmospheric Administration (NOAA). 2015. Draft guidance for assessing the effects of anthropogenic sound on marine mammal hearing: Underwater acoustic threshold levels for onset of permanent and temporary threshold shifts, July 2015, 180 pp. Silver Spring, Maryland: NMFS Office of Protected Resources. NOAA. 2016. Overview of NMFS 2016 Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing. BOEM: Best Management Practices Workshop for Atlantic Offshore Wind Facilities. National Marine Fisheries Service, National Oceanic and Atmospheric Administration, US Department of Commerce. NOAA. 2018. Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts.

#	Document Name	Section Reference	Comment	Baffinland Response
2	Bruce Head shore Based Monitoring Program (2014-2017)	3.3.2.4 #2	"Cases with more than one vessel in the study area were omitted-multiple vessel presence may impact narwhal response and bias the data." It is of great interest to Parks Canada that a statistical method is found in which the impact of multiple vessel vs. single vessel transits on narwhals can be examined.	This analysis cannot be easily performed using the same approach / analyses as was used in the Bruce Head Integrated Program because vessel effect was expressed as a distance between narwhal and vessel, which is difficult to extend to more than one vessel. Instead, the analysis of the effect of multiple vessels on narwhal would have to examine whether narwhal behavior is affected by the number of vessels within the exposure zone, in addition to potential covariates such as minimum or maximum distance from either of the vessels. Baffinland will consider incorporating into its 2019 study design an approach for testing the effect of simultaneous vessel transits on narwhal behaviour. If possible, relevant data from the 2014-2017 shore-based study will be incorporated into this study component and associated analyses.
3	Bruce Head shore Based Monitoring Program (2014-2017)	3.3.3	As previously suggested, efforts should be made to include the different classes of vessel (i.e. ore carrier vs. fuel ship) in the analysis of narwhal responses to vessel traffic.	Based on a recent study that analyzed source levels of different types of oceangoing vessels (VFPA 2018), the variability between vessels within a single vessel class is likely to be greater than any systematic differences between different vessel types, provided the vessels are comparable in size and travel speed. Relative to this study, ore carriers would fall into the 'Bulker' category and fuel vessels would fall in the 'Tanker' category (see Table 6 of VFPA 2018 under 'Control' entries). Results of this study suggest that the sound profile of a ship is more related to its size (i.e. overall length) and travel speed (and not vessel type). Further to this, 'ship type' could not be included as a control variable in the integrated analysis due to the overall low number of fuel tanker transits occurring each year (i.e., sample size limitations prevented any meaningful statistical analyses). Vancouver Fraser Port Authority (VFPA). 2018. Voluntary Vessel Slowdown Trial Summary Findings. ECHO Program. Port of Vancouver. June

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				2018. Available at: https://www.flipsnack.com/portvancouver/echo-haro-strait-slowdown-trial-summary/full-view.html
4	Bruce Head shore Based Monitoring Program (2014-2017)	Figure 4-7 & Section 5.1.	Speed restrictions of project related ore traffic appears to be largely followed. Is this restriction in place for other projected related cargo and fuel vessels? If so, why is the speed performance of these vessels much worse? (i.e. 10-15 knots)	One of the additional adaptive management measure implemented during the 2018 shipping season included Baffinland providing all Project-related vessels, including fuel and freight carriers with a copy of the Standing Instruction to Mariners (STIM), which describes the speed restrictions throughout the Inlet. In 2018, Baffinland also used AIS monitoring to track speeds of all Project-related vessels and enhanced live communications with owners and operators when vessels were travelling at speeds greater than 9 knots.
5	Bruce Head shore Based Monitoring Program (2014-2017)	Section 7.0	As suggested in previous monitoring report commenting opportunities, the use of drones would greatly improve the size and accuracy of the narwhal monitoring program. Particularly in regards to expanding the visible narwhal behavioral zone. Care must be taken in drone selection as narwhal often exhibit dive behavior in response to lower flying drones.	Noted. A shore-based narwhal monitoring program with integrated passive acoustic monitoring is proposed in Milne Inlet during summer 2019 and in future years. As part of this program, Baffinland will consider the use of drones to assess the accuracy of narwhal detection at different distances and to augment observational data over an expanded behavioral study area that overlaps with the shipping lane, as well as Koluktoo Bay. In the past, Transport Canada regulations have limited the ability to conduct unmanned aerial system (UAS) or drone flights beyond visual line-of-sight (1.5 km). The 2019 program is contingent on securing a Beyond Visual Line-of-Sight (BVLOS) Special Flight Operator Certificate (SFOC). The SFOC application is in progress for this purpose and early discussion with the regulators suggest that this may be a possibility for 2019.

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6	Bruce Head shore Based Monitoring Program (2014-2017)	Section 7.0	As suggested in previous monitoring report commenting opportunities, the inclusion of acoustic information regarding the impacts of vessel noise on the frequency and range of narwhal vocalizations would be useful.	A passive acoustic monitoring program was conducted at Bruce Head during the 2018 open-water season. The technical data report for this program will be submitted to MEWG members in Q1 2019. A shore-based narwhal monitoring program with integrated passive acoustic monitoring is proposed for Bruce Head during summer 2019 and future years.

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Date of Comment Submission: 21 December 2018

#	Document Name	Section Reference	Comment	Baffinland Response
1	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	General	Protected PDF files make reviewing draft reports more difficult and time-consuming. QIA raised this during review of the 2017 draft Bruce Report report (in March 2018), and the response was that since "MEWG members are often privy to draft reports and/or information that has not yet been released to the general public, information shared will be sent in locked PDFs to ensure data integrity." However, draft reports submitted to the TEWG (e.g., draft annual monitoring report) are not protected, allowing reviewers to copy/paste relevant text, and there haven't been any issues with respect to data integrity.	Comment noted.
2	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 2.1, p. 4	COSEWIC (2004) does not recognize an "Eastern High Arctic-Baffin Bay" narwhal stock. This is the name of the beluga stock in the north Baffin region. COSEWIC recognized "Baffin Bay" and "Hudson Bay" populations (but assessed status of a combined Designatable Unit).	Comment noted. The text in the revised report has been updated accordingly.

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3	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 2.1, p. 4	"Confidence intervals for the years were large, however, and an abundance estimate of approximately half as many narwhal is 2013 (n = 10,489) was likely not representative of actual numbers." What evidence is there to support the survey results not being representative? The Admiralty Inlet estimate went up by approximately the same number that the Eclipse Sound estimate went down, and narwhal are known to move between the two areas.	The text has been revised to read: "The 2013 Eclipse Sound population estimate is not likely representative of a change in the actual stock size, but of year to year variation in distribution of that stock."
4	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 2.2, p. 6 (and also elsewhere)	Breed et al. (2017a) and (2017b) are cited, but there is only one paper in the references (which is the only relevant paper to narwhal response to killer whale presence).	Noted. Multiple reference names for Breed et al. have been corrected in the revised report.
5	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 2.3, p. 8	COSEWIC (2004) is cited for information on narwhal age at sexual maturity. Newer research is available that should be consulted. Garde et al. (2015) estimated age at sexual maturity to be 8–9 years for females and 12–20 years for males (cf 5-8 and 11-16 years, respectively, in COSEWIC 2004). Garde, E., S. H. Hansen, S. Ditlevsen, K. B.Tvermosegaard, J. Hansen, K. C. Harding, and M. P. Heide-Jørgensen. 2015. Life history parameters of narwhals (*Monodon monoceros*) from Greenland. Journal of Mammalogy 96(4): 866-	Noted. Text in the report has been revised to include this more recent reference for age of sexual maturity.

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			879. https://doi.org/10.1093/jmammal/gyv110	
6	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 2.5, pp. 9-10	Re: narwhal vocalizations, information from Shapiro (2006) could be included. Shapiro, A. D. 2006. Preliminary evidence for signature vocalizations among free-ranging narwhals (*Monodon monoceros*). The Journal of the Acoustical Society of America 120(3):1695-1705. DOI: 10.1121/1.2226586	Noted. Text in the report has been revised to also include the Shapiro (2006) reference.
7	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.1.2, p. 13	The Behavioural Study Area (BSA) was enlarged in 2017 to include a portion of stratum D (compared to portions of strata E and F only in 2014-2016). Having year included as a covariate in BSA models is useful, but it would be be interesting to see analyses re-done with data from stratum D (2017) removed, to see how sensitive results are to sample size. Also see comment #34.	The narwhal sightings recorded within the 2017 BSA study area were not further identified to strata. Therefore, the data can not be clipped to reflect the smaller BSA of earlier field seasons. Assuming that animal behavior does not differ strongly between D1 and E1, it is not expected that results would be skewed.

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8	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.2.1, p. 15-16	Methodology for RAD (Relative Abundance and Distribution) counts changed from 2014-2016 to 2017 (with more data collected in 2017 as it was collected continuously during ship transits versus a spot-sampling approach in previous years with counts taken as a vessel entered the SSA, exited the SSA, and at the approximate centre of the SSA). How did the analysis consider this change in methodology?	A full RAD survey can take between 27 minutes and an hour, which degrades the relevance of the entering/middle/exiting terminology when applied to strata or sub-strata. The modelling approach applied here (continuous time and distance) is considered a more precise analysis of a similar dataset. Although a greater effort was placed on collecting RAD data in 2017, this should not have skewed the results.
9	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.2.1, p. 16, Table 3-1	It would be useful to have the primary and secondary behaviour categories included as an Appendix in this report, rather than requiring readers to refer to the Training Manual in the Appendix of Golder (2018a).	Comment noted.
10	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.1, p. 18	How did number of herding events in 2014 and 2015 (post-hoc assessment based on ad lib and descriptive data) compare with 2016 and 2017 when herding events were directly recorded? This could provide insight into how well the post-hoc analyses of 2014 and 2015 data captured the frequency of herding events.	LGL stated that herding events "were not well captured by the data collection protocols" for the 2014, 2015 and 2016 survey years, indicating no focused effort to collect the herding data (Smith et al. 2015, 2016, 2017). Given the sporadic timing and varying size of herding events, it is not possible to deduce to what extent herding events were undercounted in study years prior to 2017.

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11	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.2.1, pp. 18-19	The temporal resolution of shore-based AIS data was ca. 5 seconds, versus ca. 10 minutes on average for satellite-based. Vessel-position data (when only satellite-based data were available) was interpolated at 1-minute intervals. What is the sensitivity of the results to use of different interpolation? E.g., 2-minute intervals? How does higher-resolution data compare to interpolated data, and can it be used to inform interpolation, i.e., best temporal interval?	Given that the sub-stratum RAD counts took at least one minute to complete, it was felt that one minute was also an appropriate level of precision for interpolation of AIS data. As no benefit was perceived for the use of a lower temporal resolution for AIS interpolation, this was not investigated.
12	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.2.1, p. 19	What substratum was the BSA centroid in? Was it different in 2017 than in previous years?	The 2017 BSA centroid was in sub-stratum E1. In years prior to 2017, the BSA centroid was in the F1 sub-stratum, 16 m from the E and F strata boundary. The distance between the differing BSA centroids was 224 m.
13	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.2.1, p. 19	A 15 km distance cut-off used for vessel presence. How sensitive are results to cut-off choice, e.g., if 10 or 20 km is used instead? Could models instead use distance to vessel(s) as a continuous variable?	Distance was used as a continuous variable, as long as the distance between vessel and substratum was within 15 km (3.3.2.1, page 19). The 15 km cut-off was based on the maximum range for acoustic disturbance based on modelling results of the 120 dB µPa SPL disturbance threshold (Quijano et al. 2018). Multiple cut-off distances were not tested.

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14	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s.3.3.2.4, pp. 21-22	Filtering out RAD counts and group composition and behaviour observations made with more than one vessel present is a deficiency in the analysis, as the presence of multiple vessels may have a cumulative effect on narwhal response (as noted in the report). Accurate assessment of shipping-related impacts on narwhal requires assessment of actual conditions, which includes the presence of multiple vessels.	Comment noted. As stated in s.3.3.2.4, pp.22, *"Since it is not possible to account for any increased affect on narwhal due to the presence of more than one vessel in the current models, it was necessary to exclude these cases, as was previously performed for the 2014-2016 (Smith et al. 2017) and for the 2017 analysis (Golder 2018)."* An analysis of multiple simultaneous vessel transits cannot be easily performed using the same approach as for single vessels (using the current model) because vessel effect was expressed as a distance between narwhal and vessel, which is difficult to extend to more than one vessel. Instead, the analysis of the effect of multiple vessels on narwhal would have to examine whether narwhal behavior is affected by the number of vessels within the exposure zone, in addition to potential covariates such as minimum or maximum distance from either of the vessels. Baffinland will consider incorporating into its 2019 study design an approach for testing the effect of simultaneous vessel transits on narwhal behaviour.

#	Document Name	Section Reference	Comment	Baffinland Response
15	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s.3.3.2.4, pp. 21-22 (also s. 5.2.1, pp. 89-90)	The presence of landmasses and potential effect on vessel noise propagation needs to be considered in monitoring and the development of mitigation strategies if necessary. The existing PAM data (Greeneridge) should be analyzed to provide insight (only a subset of the data has been reported to date). There is some information available in past reports (e.g., 2015 Greeneridge acoustic monitoring report which suggests that local headlands appear to block the transmission of sound from ore carriers in Milne Inlet), but additional analyses are warranted. Also see comment #46.	One of the objectives of the 2018 Passive Acoustic Monitoring Program was to collect data to evaluate the potential shielding effect of headlands on vessel traffic noise. A collaborative study between Baffinland, Golder, JASCO, and the University of New Brunswick (using the 2018 acoustic data) is underway to address this identified gap.
16	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s.3.3.2.4, p. 21	Items 4 and 5 refer to the same data, but only one notes convergence issues. Were these data removed a priori, or after initial model runs?	Item 5 is a copy of item 4 and has been removed from the table; the two cases noted were removed after initial model runs.
17	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s.3.3.2.4, p. 22; s. 3.3.3.4, p. 25	Why were cases with group size > 20 narwhals removed from the group composition and behaviour dataset? s. 3.3.3.4 (p. 25) states that cases with > 20 narwhal were removed from all analyses to reduce spurious effects. What is it about groups of 20+ animals that lead to issues? Difficulty in identifying each individual? In these nine cases, were observers uncertain that all individuals were accurately classified? If group size was used a	Group size was included as a continuous covariate in BSA models. Since groups larger than 20 individuals were so rare (99.7% of the recorded groups were 20 individuals or fewer), large groups resulted in being influential cases, skewing model results. These nine cases were therefore removed, to capture the patterns of the overall dataset.

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			covariate, couldn't these larger groups still be included?	
18	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s.3.3.2.4, p. 22	Why is it "not possible to account for any increased effect on narwhal due to presence of more than one vessel in the current models"? Because these observations were removed a priori?	As distance was a single continuous variable, there was no provision for including another measurement of distance in the model.
19	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.3.1, p. 22	What were the spurious effects that led to tidal effect having to be simplified to an additive effect "[i]n some cases"? What cases? Model runs? Individual RAD/composition counts? More detail is required.	When model outputs were plotted relative to tide conditions, the outputs produced strong polynomial patterns that did not reflect the observed data.
20	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.3.1, p. 23	Was the interaction between vessel direction and relative position not included in models? (see s. 3.3.3.2, p. 23; s. 3.3.3.4.6, p. 27; s. 5.2.1, p. 89, which indicates it was - it could be clearer here).	The interaction was included; the text in Section 3.3.3.1 has been revised accordingly.
21	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.3.1, p. 23	Why was day of year included in the "time since last shot fired" variable?	It was not – the list numbering was incorrect; items a-d should have been listed as 11-14 and not been offset. The text and bullet numbers have been revised accordingly.

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22	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.3.1, p. 23	What spurious effects led to simplifying model structure in regards to variables that were expressed as third-degree polynomials?	These spurious effects are common with polynomials that are too complex – the "tails" of the predictions would have a strong, unrealistic pattern. For example, when using a third-degree polynomial to describe a parabolic effect, predicted values on the extremes of the x-axis would be very high or very low (depending on the direction of the effect), whereas the observed data would not have such patterns. The simplification of the model to a second-degree polynomial (i.e., parabola) removes these effects and correctly accounts for the patterns observed in the data.
23	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.3.2, p. 23 (and s. 4.1, p. 31)	It isn't clear that substratum was not nested within stratum (it is elsewhere, e.g., s. 4.1 where it is noted that it is essentially a measure of distance). Could be specifically noted here.	Substratum was indeed not nested in stratum. Section 3.3.3.2 has been edited to reflect this.
24	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.3.2, p. 24 (and Results, etc.)	During review of the draft 2017 report (March 2018), QIA suggested (comment #27) that a zero-inflated model that allows for two different processes that can produce a zero count could be used instead of a hurdle model that assumes that zero counts can only be produced by a single process. QIA asked whether a zero-inflated model could consider availability bias (i.e., animals present in the search area are not available for detection). The combined 2014-2017 analysis uses a zero-inflated	Perception bias is accounted for in the zero-inflated model, since both distance (as substratum) and Beaufort scale were included as predictors for the zero-inflation part of the model. Availability bias, on the other hand, cannot be derived from this dataset.

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			model instead of the hurdle model used in the 2017 (only) analysis. Is it possible to interpret model results in a manner that provides information on availability bias via the negative binomial model that predicts the counts for sampling events that are not "certain zeros" (i.e., narwhals present but missed, versus the logit model portion generated for the "certain zero" cases, i.e., counts in which no narwhal were present)? In s. 5.2.2 (p. 90) the report notes that additional work is required to quantify the effect of reduced visibility on RAD counts, e.g., combining visual surveys with concurrent counts via drone footage. Can the two different model components provide any preliminary information on partitioning availability and perception bias?	
25	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.3.2, p. 24 (and elsewhere)	In some cases where the zero-inflated negative binomial model fails to converge, it may be that a zero-inflated Poisson model is better suited for the modeling situation at hand.	The count data are highly overdispersed, which is not well-suited for a Poisson model. In the preliminary model runs, quasipoisson models were attempted as an alternative to negative binomial models, since both quasipoisson and negative binomial distribution allow for overdispersion in the data.

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26	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.3.3, p. 24	The 'brms' R library (Bürkner 2017) is for Bayesian multilevel models. Is the package appropriate for non-Bayesian modeling?	The analysis of substratum use was performed as a Bayesian analysis of mixed ordinal data.
27	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 3.3.3.4.2.2, p. 26 (and elsewhere)	Were models run (or attempted) with only one of tide height and change of depth removed to determine if convergence issues could be addressed without having to remove both variables? (Note, this comment refers to all cases in which multiple variables were removed).	In this specific case, both tide variables were removed, since both were needed to fully describe the condition of tide. In cases where multiple variables were removed and they were not tide-related, removal of variables proceeded as suggested – by removing one variable at a time.
28	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 4.2.1, pp. 32-33	Text on p. 32 says 48% of large vessel transits had corresponding sighting data, versus 47% in Table 4-2 on p. 33 (47% is correct).	Comment noted. Text has been revised in the report with the correct value of 47% (as stated in Table 4-2).
29	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 4.2.1, p. 34, Figure 4-6	Why did an ore carrier enter Koluktoo Bay in 2015?	No details are provided in the 2015 Bruce Head Shore-based Monitoring Report (Smith et al. 2016) other than the M/V *Nordic Odin* passed through the SSA on August 7 and 12, 2015. It is presumed that the vessel was required to wait until an anchorage in Milne Port opened up. Since this event, Koluktoo Bay has been identified in Baffinland's Standing Instructions to Masters

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				(SITM) (navigational instructions to chartered Project vessels) as a no-go zone / restricted area.
30	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 4.3, p. 40	The vast majority of observed vessel transits were northbound (64.5 to 93.2% per year), could this skew model results?	Yes. This is related to the statement addressed in comment #41. The 2019 Bruce Head Shore-based Monitoring Program will expand the sampling hours to capture a more balanced proportion of vessel transit directions.
31	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 4.3.1, p. 45, Figure 4-13	It isn't clear which variables the different lines and ribbons refer to.	The three lines are provided for falling (minimum), slack (mean), and rising (maximum) tides; the caption will be updated to reflect this detail.
32	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 4.3.2, p. 49, Figure 4-17	The y-axis refers to points and lines, but it appears that there are only lines in the figure.	Correct – text for the y-axis has been updated in the revised report to only refer to lines.

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33	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 4.4, p. 50	"The proportion of narwhal groups recorded in the BSA during periods of 'no anthropogenic activity' decreased from 91% in 2014 to 56% in 2015, and to 42% in both 2016 and 2017." This is presumably related to increasing numbers of ore carrier transits? Any other factors?	Yes, this is related to an increased number of ore carriers in combination with presence of small hunting vessels and hunting activities.
34	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 4.4, p. 51	"It should be noted that higher narwhal counts in 2017 may have been influenced by the slightly larger BSA boundary used that year compared to previous years." Analysis could explore sensitivity of model results to this by excluding 2017 counts from the portion of substratum D1. Also see comment #7.	See response to comment #7
35	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 4.4.1, p. 55, Figure 4-23	Model predictions consistently underestimate group size across all years. Why?	This is due to the varying relationship between group size and glare. In 2014/2015, group sizes were larger under no glare than under low or severe glare. In 2016/2017, group sizes were smallest under no glare. Since the majority of the data in the dataset is from 2016/2017, the model predicted small group sizes under no-glare scenario. To produce the plot of predicted group size vs year, we had to hold the glare variable constant at “no glare”, since that is the most common category (69%). Therefore, the predictions are underestimating the overall observed annual means.

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36	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	p. 56, s. 4.4.2	Reference to "Section 0", presumably missing rest of section reference.	Typo. The section reference should be 3.3.3.4. Text has been revised accordingly.
37	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 4.4.4, p. 68	"... the probability of observing groups in non-parallel formation in 2016 was underestimated relative to the observed proportions (Figure 4-35)." Figure 4-35 (p. 70), panel C indicates that probability was underestimated in all years, and 2015 in particular? Should the 2016 reference in text refer to 2015?	Yes, the text reference should refer to 2015, not 2016. Text has been revised accordingly.
38	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 4.4.5, p. 76	Figure 4-40 is not cited in text.	Noted. Text has been revised accordingly (which refers to Figure 4-40).
39	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 4.5, p. 86	These observations of nursing, mating and a calf birth are worth publishing as a note in the peer-reviewed literature.	Comment noted.

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40	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 5.2.1 and s. 5.2.2 , p. 90	"It is possible that the narwhal in Koluktoo Bay, outside of the SSA, act as a reservoir of animals that are displaced into the SSA by northbound traffic, resulting in increased counts relative to counts in the absence of vessels or when southbound vessels are present. Expansion of the study area to cover more of Koluktoo Bay may help illuminate whether this is indeed the behavioural response underlying the apparent difference in abundance." What options are available for expanding the study area? Shore-based platform(s)? Community-based monitoring, or aerial surveys/drones (see s. 5.2.2)? The regularly scheduled aerial surveys flown by LGL were designed to address this issue, to some extent (with variable success).	The logistical difficulties and costs of manned aerial-survey platforms are not warranted if only the photographic results will be analysed in areas of high narwhal abundance (i.e. Koluktoo Bay). Therefore, Baffinland is considering conducting repeated UAV photographic surveys in 2019 to expand the study area into Koluktoo Bay and attempt to evaluate the differences in narwhal behaviour between north and southbound vessel transits. Moving forward on this study component is pending approval by Transport Canada for a Beyond-Line-of-Sight permit for drone operation in the expanded study area.
41	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)		s. 5.2.1, p. 90 - "It is not clear whether the different patterns in relative abundance between south- and northbound vessels are due to chance (i.e., spurious finding) or are an actual behavioural response." Are additional analyses possible to tease this out? Different statistical model(s), etc?	The data could be re-sampled using a different statistical approach such as bootstrapping applied to a subset of the data (e.g., resampling the data using the same number of northbound transits as southbound transits). However, this re-analysis would be based on a limited dataset that is unlikely to clarify whether the result is spurious or an actual behavioural response tied to vessel direction. For this analysis to be warranted, we recommend waiting for additional data to be collected in 2019 and using the multi-year Bruce Head dataset for this analysis so that the ratio of northbound vs. southbound vessel passages is not as skewed.

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42	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 5.3, pp. 90-93	It would be useful to have a summary table of all the different variables and their significance (i.e., significant or not-significant) for each modelled parameter (the table wouldn't need P-values, df, etc. as they are reported in the original tables). (Also p. 94-95 - effective summary, but a table would help summarize findings re: composition and behaviour).	Comment noted. This type of summary table can be included in the 2019 Bruce Head Shore-based Monitoring Report.
43	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s. 5.3.7, p. 93	"Monitoring of narwhal distance from shore is therefore an appropriate metric to assess habitat use and whether the proportion of inshore vs. offshore narwhal groups i[s]dependant on anthropogenic activity." What role could a community-based monitoring (CBM) program play here?	In order to resolve how narwhal use habitat in the Bruce Head area when they are not influenced by anthropogenic factors or predation pressure, the Bruce Head shore-based study would need to have reliable concurrent data on: • narwhal sightings • ship movements • hunting activities • killer whale occurrences in or near the study area. Currently, the Bruce Head study captures the first two bullets effectively, but data for the other two components are limited at the regional and local (study area) scale.
44	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s.7.0, p. 97	Re: the recommendation to assess alternate locations for the observation platform that might allow for better surveys of the portion of the nominal shipping route closest to Koluktoo Bay. This should be discussed, but data continuity and comparability would need to be carefully considered.	Alternate survey platform locations, around the perimeter of the Bruce Head and Koluktoo Bay area, were considered for the 2019 field season. When considering observer altitude and viewing area, distance to nominal shipping route, and narwhal density (i.e. tagging data) in relation to observer distance limitations, it was determined that alternate locations would compromise the ability of observers to record activity relative to the shipping route and/or would

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				focus on areas with lower narwhal densities. As such, the preference was to keep the observer platform at Bruce Head. Baffinland is considering conducting repeated UAV photographic surveys in 2019 to expand the study area into Koluktoo Bay and attempt to evaluate the differences in narwhal behaviour between north and southbound vessel transits. Moving forward on this study component is pending approval by Transport Canada for a Beyond-Line-of-Sight permit for drone operation in the expanded study area.
45	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s.7.0, p. 97	In regards to the recommendation to "[a]ssess the potential effects of simultaneous transits of multiple large vessels on narwhal RAD and behaviour", existing data could be used for preliminary analyses.	Comment noted. An analysis of multiple simultaneous vessel transits cannot be easily performed using the same approach as for single vessels (using the current model) because vessel effect was expressed as a distance between narwhal and vessel, which is difficult to extend to more than one vessel. Instead, the analysis of the effect of multiple vessels on narwhal would have to examine whether narwhal behavior is affected by the number of vessels within the exposure zone, in addition to potential covariates such as minimum or maximum distance from either of the vessels. Baffinland will consider incorporating into its 2019 study design an approach for testing the effect of simultaneous vessel transits on narwhal behaviour.

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46	Bruce Head Shore-based Monitoring Program: 2014-2017 Integrated Report (file name: "2014-2017 In[t]egrated Data_Bruce Head Monitoring Report_27NOV_18_dft.pdf)	s.7.0, p. 97	In regards to the recommendation for "[i]ntegration of acoustic monitoring results...", data collected by Greeneridge could be analyzed to a greater extent than has been done to date. These data could provide important information on narwhal vocal behaviour and ship noise (e.g., differences in south- vs northbound transits, effect of land features on noise propagation). Also see comment #15.	A collaborative study between Baffinland, Golder, JASCO, and the University of New Brunswick is underway to address this identified gap. Detailed results will be available in Q3 2020 with preliminary results available as early as Q4 2019.

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