REPORT

Mary River Project

2023 Marine Mammal Aerial Survey Program (MMASP) - Technical Report

Submitted to:

Baffinland Iron Mines Corporation

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Distribution List

Baffinland Iron Mines Corporation

Executive Summary

In 2023, WSP Canada Inc. (WSP), on behalf of Baffinland Iron Mines Corporation (Baffinland), completed a Marine Mammal Aerial Survey Program (MMASP) designed to assess narwhal distribution and abundance in the Regional Study Area (RSA) and Admiralty Inlet. The 2023 MMASP was staged in three separate legs. Leg 1 targeted a 15-day window during the early shoulder shipping season (late July) to collect data on the presence/absence and distribution of marine mammals in the RSA relative to ice conditions at that time of year and prior to the start of shipping operations. Leg 2 targeted a three-week window in peak summer (August) to obtain an annual abundance estimate for the Eclipse Sound and Admiralty Inlet narwhal summer stocks during the open-water season. Leg 3 targeted a two-day window at the end of the shipping season in late October to conduct a visual clearance survey to document if narwhal entrapment events occurred in the RSA following completion of Baffinland's 2023 shipping operations along the Northern Shipping Route. Survey design and data collection methodology previously developed by Fisheries and Oceans Canada (DFO) (Matthews et al. 2017; Marcoux et al. 2016; Doniol-Valcroze et al. 2015a; Asselin and Richard 2011) and implemented by Golder Associates Ltd. (amalgamated in January 2023 under WSP Canada Inc.) in 2019 (Golder 2020a), 2020 (Golder 2021a), 2021 (Golder 2022a) and 2022 (WSP 2023a) was adopted to allow for interannual comparison of the annual abundance estimates.

Early Shoulder Season (Leg 1) Surveys

The 2023 early shoulder season (Leg 1) surveys were conducted in the RSA (i.e., Eclipse Sound survey grid) on 23–30 July and in Admiralty Inlet on 29 and 31 July, with a total of nine surveys flown during this period. Landfast ice was present in the RSA for the full duration of the Leg 1 surveys. During the first week of the surveys (23 to 28 July), landfast ice extended across Eclipse Sound and north Milne Inlet, with no visible leads present in the ice. Areas bordering the landfast ice (Pond Inlet and south Navy Board Inlet) were comprised of consolidated / very close pack ice (9/10 to 10/10 concentration). Open-water areas (1/10 to 3/10 concentration) at this time were limited to south Milne Inlet, north Navy Board Inlet and Baffin Bay.

Towards the end of the Leg 1 surveys (29-31 July), ice conditions in the RSA began to break-up with landfast cover now limited to central Eclipse Sound and consolidated / very close pack ice (9/10 to 10/10) extending across western and eastern Eclipse Sound, north Milne Inlet and south Navy Board Inlet. Open-water areas (0/10 to 3/10) at this time were limited to south Milne Inlet, north Navy Board Inlet and Baffin Bay.

In Admiralty Inlet, ice conditions during the Leg 1 aerial surveys ranged from close pack ice (7/10 to 8/10) in the north to consolidated / very close pack ice (9/10 to 10/10) in the central portion of the inlet with some open-water areas in south Admiralty.

A total of 4,499 km of survey effort (3,688 km of systematic transects and 811 km of dedicated transects) was undertaken for the Leg 1 surveys completed in the RSA and Admiralty Inlet. Eight different marine mammal species were recorded during Leg 1 (narwhal, beluga, bowhead, ringed seal, harp seal, bearded seal, hooded seal and polar bear) resulting in a total of 2,886 sightings (comprising 8,668 individuals). Narwhal were the most abundant species observed during Leg 1, with 0.79 animals/km recorded during the systematic surveys and 1.94 animals/km recorded during the dedicated transects. A total of 357 mother/calf pairs (227 mother/calf pairs in RSA and 130 mother/calf pairs in Admiralty Inlet grid) and 80 lone calves (37 lone calves in RSA and 43 lone calves in Admiralty Inlet grid) were recorded during the Leg 1 surveys.

In the RSA, a total of 1,696 narwhal sightings (comprising 4,184 individuals) were recorded during Leg 1, with narwhal distributed in two distinct areas; north Navy Board Inlet and eastern Eclipse/Pond Inlet/Baffin Bay. The extensive landfast ice in western Eclipse Sound effectively isolated the two distribution areas from one another. In the Eclipse Sound/Pond Inlet/Baffin Bay strata, narwhal relative abundance remained consistently high throughout the Leg 1 surveys. In the Navy Board Inlet stratum, narwhal relative abundance remained consistently high for the first three surveys, but then dropped to very low numbers on the last survey (30 July). Survey results generally indicated that narwhal in the Eclipse Sound/Pond Inlet/Baffin Bay stratum remained in the RSA for the duration of the Leg 1 surveys, while narwhal in the Navy Board Inlet strata appeared to have departed the RSA sometime after 27 July (presumably through Lancaster Sound). Once landfast ice in Eclipse Sound began to break-up near the end of Leg 1 (27-28 July), several narwhal sightings were recorded in ice leads present in western Eclipse Sound. However, no narwhal were observed in Milne Inlet or Tremblay Sound during any of the Leg 1 surveys, presumably due to local ice conditions impeding access to these areas or narwhal preference to remain in areas of high ice concentration.

In Admiralty Inlet, a total of 578 narwhal sightings (comprising 1,152 individuals) were recorded during Leg 1, with sightings limited to north Admiralty. No narwhal sightings were recorded south of the area of consolidated pack ice (9/10 to 10/10 ice concentrations) present in the middle portion of the inlet, presumably due to local ice conditions impeding access to south Admiralty Inlet or narwhal preference to remain in areas of high ice concentration.

Open-water (Leg 2) Abundance Surveys

The Leg 2 aerial surveys in 2023 provided an updated estimate of narwhal abundance for the Eclipse Sound summer stock, the Admiralty Inlet summer stock, and the combined Eclipse Sound and Admiralty Inlet stocks. Two types of aerial surveys were flown: a visual-based survey in which marine mammal sightings were collected along established line transects using a double-platform approach with Marine Mammal Observers (MMOs) stationed at independent observation platforms at the front and rear of the aircraft, and a photographic-based survey in which medium format mirrorless cameras were installed on the aircraft to collect high definition photographic images of the survey area directly below the aircraft. Photographic surveys were flown in areas of high narwhal concentrations where accurate counts would be difficult to obtain using visual means. A total of two surveys were conducted in the Eclipse Sound survey grid and one survey was conducted in the Admiralty Inlet survey grid during Leg 2. Complete coverage (excluding fjords) was achieved for the first survey in Eclipse Sound (12-13 Aug) and partial coverage was obtained for the second survey in Eclipse Sound (23-25 Aug) and the single survey in Admiralty Inlet (19-20 Aug).

A total of 4,376 km of survey effort was undertaken for the Leg 2 aerial surveys (including both visual and photographic surveys), encompassing 3,345 km in the RSA and 1,031 km in Admiralty Inlet. During the visual surveys, a total of six different marine mammal species were recorded (narwhal, bowhead, ringed seal, harp seal, bearded seal and polar bear) resulting in a total of 271 sightings (comprising 648 individuals) in the RSA and 417 sightings (comprising 893 individuals) in Admiralty Inlet. Narwhal were the most abundant species observed during the Leg 2 aerial surveys, with 140 sightings (comprising 353 individuals) in the RSA (including reconnaissance flights) and 348 sighting (comprising 690 individuals) in Admiralty Inlet. For the photographic surveys, a total of 9,501 sightings (comprising 17,675 individuals) were identified during the photographic analysis (all surveys combined). Photographic surveys were conducted in high density areas of Milne Inlet, Tremblay Sound and Admiralty Inlet. Two different species were recorded during the photographic surveys: narwhal (9,496 sightings totalling 17,668 individuals) and bowhead whale (five sightings totalling 7 individuals).

The 2023 Eclipse Sound narwhal summer stock was estimated at 10,492 animals (CV= 0.05; CI = 9,578-11,494) which was not significantly different than the 2013 baseline condition (10,489 animals; CV = 0.24; CI = 6,342 – 17,347; Doniol-Valcroze et al. 2015a), the 2016 abundance estimate (12,039 animals; CV = 0.23; CI = 7,768-18,660; Marcoux et al. 2019) or the 2019 abundance estimate[1] (9,931 animals, CV = 0.05, 95% CI of 9,009–10,946; Golder 2020a). The 2023 Eclipse Sound abundance estimate was significantly higher than the three preceding years (2020-2022; Golder 2021a, 2022a, WSP 2023a). The increase in 2023 was observed despite 2023 having the highest volume of iron ore shipped out of Milne Port since the start of shipping operations and despite the introduction of larger Capesize ore carriers to shipping operations in 2023. Collectively, survey results to date indicate a poor correlation between annual shipping levels and narwhal abundance in the RSA.

The 2023 Admiralty Inlet narwhal summer stock was estimated at 30,214 narwhal (CV = 0.15; CI = 22,559–40,467) which was not statistically different than the 2013 abundance estimate (35,043 animals; CV = 0.42; CI = 14,188–86,553; Doniol-Valcroze et al. 2015a), the 2019 abundance estimate (28,746 animals; CV = 0.15; CI = 21,545–38,354; Golder 2020a), the 2020 abundance estimate (31,026 animals; CV = 0.14; CI = 23,406–41,126; Golder 2021a) or the 2022 abundance estimate (43,042 animals; CV = 0.15; CI = 32,218–57,502; WSP 2023a). The 2023 abundance estimate was shown to be statistically lower than the 2021 abundance estimate of 72,582 animals (CV = 0.09; CI = 61,333–85,895; Golder 2022a).

The 2023 abundance estimate for the combined Eclipse Sound and Admiralty Inlet narwhal stocks was 40,706 animals (CV = 0.11; CI = 32,711–50,655), which was not statistically different than the 2013 abundance estimate (45,532 animals; CV = 0.33; CI = 22,440–92,384; Doniol-Valcroze et al. 2015a), the 2019 abundance estimate (38,677 animals; CV = 0.11; CI = 31,155–48,015; Golder 2020a), the 2020 abundance estimate (36,044 animals, CV = 0.12, CI = 28,267–45,961; Golder 2021a) or the 2022 abundance estimate (46,408 animals, CV = 0.13, CI = 36,129–59,611; WSP 2023a). The 2023 abundance estimate was shown to be statistically lower than the 2021 abundance estimate (75,177 animals; CV = 0.08; CI = 63,795–88,590; Golder 2022a). Collectively, aerial survey results indicate that the combined stock size appears to be stable since the start of Baffinland shipping operations and relative to baseline levels. Results further indicate that some level of animal exchange occurs between the two putative stock areas but this does not appear to be related to Project shipping levels in the RSA.

Late Shoulder Season (Leg 3) Surveys

An aerial clearance survey was flown in the RSA at the end of the shipping season on 31 October 2023 to monitor the shipping corridor and adjacent areas for potential narwhal entrapment events following the completion of Baffinland's 2023 shipping operations in the RSA. No narwhal sightings were recorded during the survey. Results of the end of season aerial clearance survey indicate that no entrapments occurred in 2023 as a result of Project icebreaking and shipping activities in the RSA.

[1] High-risk threshold in Marine Mammal Trigger Action Response Plan (TARP) = >25.0% decrease in Eclipse Sound narwhal abundance relative to the 2019 aerial survey abundance.

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ᓯᑯᐃᓕᓵᖅᑎᓪᓗᒍ (ᖃᖕᒐᑕᓂᖅ 1) ᖃᐅᔨᓴᕐᓂᖅ

2023-ᒥ ᓯᑯᐃᓕᓵᖅᑎᓪᓗᒍ (ᖃᖕᒐᑕᓂᖅ 1) ᖃᐅᔨᓴᕐᓃᑦ ᐱᓕᕆᐊᖑᓚᐅᖅᑐᑦ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᒥ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ (ᓱᕐᓗ ᑕᓯᐅᔭᒥ ᖃᐅᔨᓴᕐᓂᕐᓄᑦ ᐋᖅᑭᒃᓱᖅᑕᐅᓯᒪᔪᑦ) 20-30 ᔫᓚᐃᒥ ᐊᒻᒪᓗ ᐃᑉᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ 29 ᐊᒻᒪᓗ 31 ᔪᓚᐃᒥ, ᑲᑎᕆᓯᑦ ᖁᓕᖃᖖᒋᑐᐃᓐᓇᖅᑐᑦ ᖃᐅᔨᓴᕐᓃᑦ ᖃᖕᒐᑕᔭᐅᓪᓗᑎ ᑕᒪᓐᓇ ᐊᑐᖅᑎᓪᓗᒍ. ᑐᕌᖅᑕᖃᓚᐅᖅᑐᑦ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᒥ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ ᖃᖕᒐᑕᓂᓗᒃᑖᖏᓐᓂ 1-ᒥ ᖃᐅᔨᓴᕐᓂᕐᓂ. ᓯᕗᓪᓕᖅᐹᖓᓂ ᐱᓇᓱᐊᕈᓯᕐᒥ ᖃᐅᔨᓴᕐᓂᕐᓂ (23-ᒥᑦ 28-ᒧᑦ ᔪᓚᐃ), ᑐᕋᖃᓚᐅᖅᑐᑦ ᑕᐅᓵᓇᓗᒃᑖᖅ ᑕᓯᐅᔭᒃᑯᑦ ᐊᒻᒪᓗ ᐅᐊᖕᓇᖕᓛᖕᒐᒍᑦ ᕿᒻᒧᐊᑕ, ᓴᖅᑮᔭᖅᑐᖃᖖᒋᕈᓂ ᐋᔪᕋᕐᓂᒃ ᓯᑯᒥ. ᐊᕙᑎᖏᑦ ᑐᕙᐅᑉ (ᒥᑦᑎᒪᑕᓕᖕᒥᑦ ᓂᕆᐊᓄᑦ ᐃᓗᐊᑕ ᑲᖏᖅᓱᐊᒍᑦ) ᓯᑯᓕᒪᓇᐅᓚᐅᖅᑐᑦ / ᖃᓂᒋᒃᑕᖅᑑᑕᐅᓪᓗᑎᒃ ᓯᑯᐃᑦ (9/10-ᒥᑦ 10/10-ᒧᑦ ᓯᑯᖃᕐᓂᖃᖅᑐᓂ). ᐃᒪᐅᓂᖓ (1/10–ᒥᒃ 3/10-ᒧᑦ ᓯᑯᖃᕐᓂᖃᖅᑐᓂ) ᑭᒡᓕᖃᓚᐅᖅᑐᒍᑦ ᓂᕆᐊᓄᑦ ᕿᒻᒧᐊᑕ, ᐊᒻᒪᓗ ᐅᐊᖕᓇᖕᓛᖕᒐᓄᑦ ᐃᓗᐊᑕ ᑲᖏᖅᓱᐊᓄᑦ ᐊᒻᒪᓗ ᕿᑭᖅᑖᓗᒃ ᐃᑭᖓᓂ.

ᐃᓱᓕᑉᐸᓕᐊᓕᖅᑎᓪᓗᒍ ᖃᖕᒐᑕᓂᖅ 1 ᖃᐅᔨᓴᕐᓂᕐᓂᑦ (29-31 ᔪᓚᐃ), ᓯᑯᐃᑦ ᖃᓄᐃᓕᖓᓂᖏᑦ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ ᐲᔭᖅᐸᓪᓕᐊᓕᓚᐅᖅᑐᑦ ᑐᕙᖕᒥ ᑭᒡᓕᖃᓕᖅᑐᓂ ᕿᑎᐊᓄᑦ ᑕᓯᐅᔭᐅᑉ ᐊᒻᒪᓗ ᓯᑯᖃᐅᕐᓂᖓ / ᖃᓂᒋᒃᑕᖅᑑᑎᑦ (9/10-ᒥᑦ 10/10-ᒧᑦ) ᑕᐅᓵᓇᓗᒃᑖᖅ ᐱᓇᖕᓇᖕᒐᒍᑦ ᐊᒻᒪᓗ ᑲᓇᖕᓇᖕᒐᒍᑦ ᑕᓯᐅᔭᐅᑉ, ᐅᐊᖕᓇᖕᒐᒍᑦ ᕿᒻᒧᐊᑕ ᐊᒻᒪᓗ ᓂᕆᐊᒍᑦ ᐃᓗᐊᑕ ᑲᖏᖅᓱᐊᓄᑦ. ᐃᒪᐅᓂᖓ (0/10-ᒥᑦ 3/10-ᒧᑦ) ᑕᐃᑦᓯᒪᓂ ᑭᒡᓕᖃᓚᐅᖅᑐᑦ ᓂᕆᐊᓄᑦ ᕿᒻᒧᐊᑕ, ᐅᐊᖕᓇᖕᒐᒍᑦ ᐃᓗᐊᑕ ᑲᖏᖅᓱᐊᒍᑦ ᐊᒻᒪᓗ ᕿᑭᖅᑖᓕᑉ ᐃᑭᖓᓄᑦ.

ᐃᑉᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ, ᓯᑯᐃᑦ ᖃᓄᐃᓕᖓᓂᖏᑦ ᖃᖕᒐᑕᓂᖅ 1-ᒥ ᖃᖕᒐᑕᓲᒃᑯᑦ ᖃᐅᔨᓴᕐᓂᕐᒥᑦ ᐊᔾᔨᒌᓚᐅᖏᑦᑐᑦ ᐊᑯᓐᓂᖃᓗᐊᖏᑦᑐᒥᑦ (7/10-ᒥᑦ 8/10-ᒧᑦ) ᐅᐊᖕᓇᖓᓂ ᓯᑯᓕᒪᓇᐅᓪᓗᓂ / ᖃᓂᒋᒃᑕᖅᑏᑦ (9/10-ᒥᑦ 10/10-ᒧᑦ) ᕿᑎᐸᓗᐊᓂ ᑲᖏᖅᓲᑉ ᐃᒪᐅᓂᖃᕋᓛᒃᑐᓂ ᓂᕆᐊᒍᑦ ᐃᑉᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ.

ᑲᑎᓪᓗᒃᑖᖅᑐᒋᑦ 4,499 ᑭᓛᒥᑕᓂ ᖃᐅᔨᓴᕐᓂᖃᕋᓯᓚᐅᖅᑐᑦ (3,688 ᑭᓛᒥᑕᑦ ᐋᖅᑭᒃᓱᖅᓯᒪᔪᑦ ᑐᑭᓕᐅᑦ ᐊᒻᒪᓗ 811 ᑭᓛᒥᑕᐃ ᑖᒃᑯᓇᖓᓪᓚᑦᑖᖅ ᑐᑭᓕᐅᑦ) ᐱᓕᕆᐊᖑᓚᐅᖅᑐᑦ ᖃᖕᒐᑕᓂᖅ 1 ᖃᐅᔨᓴᕐᓂᕐᒥ ᐱᔭᕇᖅᑕᐅᓪᓗᑎᒃ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ ᐊᒻᒪᓗ ᐃᑉᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ. ᑎᓴᒪᐅᔪᖅᑐᑦ ᐊᔾᔨᒌᖏᑦᑐᑦ ᑕᓇᐅᒥ ᐳᐃᔩᑦ ᑎᑎᕋᖅᑕᐅᓚᐅᖅᑐᑦ ᖃᖕᒐᑕᓂᖅ 1-ᒥ (ᑑᒑᓖᑦ, ᕿᓚᓗᒐᑦ ᖃᑯᖅᑕᑦ, ᐊᕐᕕᖅ, ᓇᑦᑎᖅ, ᖃᐃᕈᓕᒃ, ᐅᒡᔪᒃ, ᐊᐸ ᐊᒻᒪᓗ ᓇᓄᖅ) ᓴᖅᑮᓪᓗᑎ ᑲᑎᓪᓗᒃᑖᖅᑐᒋᑦ 2,886-ᓂᒃ ᑕᑯᓪᓗᑎ (ᐱᑕᖃᖅᑐᖅ 8,668 ᐃᓛᒃᑰᖅᑕᖅᑐᑦ). ᑑᒑᓖᑦ ᐱᑕᖃᓛᖑᓚᐅᖅᑐᑦ ᐅᔾᔨᕆᔭᐅᓪᓗᑎᒃ ᖃᖕᒐᑕᓂᖅ 1-ᒥ, 0.79 ᓂᕐᔪᑏᑦ/ᑭᓛᒥᑕᒧᑦ ᑎᑎᕋᖅᑕᐅᓯᒪᔪᑦ ᐋᖅᑭᒃᓱᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᓂᐅᔪᓂ ᐊᒻᒪᓗ 1.94 ᓂᕐᔪᑏᑦ/ᑭᓛᒥᑕᒧᑦ ᑎᑎᕋᖅᑕᐅᓯᒪᓪᓗᑎ ᑖᒃᑯᓇᖓᓪᓚᑦᑖᖅ ᑐᑭᓕᐅᓄᑦ. ᑲᑎᕆᓯᑦ 357 ᐊᓈᓇᒌᒃ/ᕿᑐᕐᖓᓖᒃ ᑲᑎᙵᔪᑦ (227 ᐊᓈᓇᒌᒃ/ᕿᑐᕐᖓᓖᑦ ᑲᑎᙵᔪᑦ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᖅᑕᐅᕝᕕᖓᓂ ᐊᒻᒪᓗ 130 ᐊᓈᓇᒌᑦ/ᕿᑐᕐᖓᓖᑦ ᑲᑎᙵᔪᑦ ᐃᑉᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ ᑎᑎᖅᑕᐅᓯᒪᔪᓂ) ᐊᒻᒪᓗ 80 ᐃᓄᑐᐊᑦ ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ (37 ᐃᓄᑐᐊᑦ ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᓂ ᐊᒻ 43 ᐃᓄᑐᐊᑦ ᐃᓐᓇᕈᖅᓯᒪᙱᑦᑐᑦ ᐃᑉᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ ᑎᑎᖅᑕᐅᓯᒪᔪᓂ) ᑎᑎᕋᖅᓯᖃᑦᑕᓚᐅᖅᑐᒍᑦ ᖃᖕᒐᑕᓂᖅ 1-ᒥ ᖃᐅᔨᓴᕐᓂᕐᓂ.

ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᓂ, ᑲᑎᕆᓯᑦ 1,696 ᑑᒑᓕᖕᓂᒃ ᑕᑯᔪᖃᓚᐅᖅᑐᑦ (ᐱᑕᖃᖅᑐᓂ 4,184 ᐃᓛᒃᑰᖅᑐᑎᒃ) ᑎᑎᕋᖅᑕᐅᓚᐅᖅᑐᑦ ᖃᖕᒐᑕᓂᖅ 1-ᒥ, ᑑᒑᓖᑦ ᓇᓅᓐᓂᖏᑦ ᒪᕐᕉᖕᓂ ᐊᔾᔨᒌᖏᑦᑐᓂ; ᐅᐊᖕᓇᖓᓂ ᐃᓗᐊᑕ ᑲᖏᖅᓱᐊᓂ ᐊᒻᒪᓗ ᑲᓇᖕᓇᖓᓂ ᑕᓯᐅᔭᐅᑉ/ᒥᑦᑎᒪᑕᓕᒃ/ᕿᑭᖅᑖᓗᑉ ᐃᑭᖓᓂ. ᑐᕙᖃᕈᐊᕐᓂᖓᓄᑦ ᐱᓇᖕᓇᖓᓂ ᑕᓯᐅᔭᐅᑉ ᐊᕕᒃᑎᑦᑎᓯᒪᑦᑎᐊᓚᐅᖅᑐᖅ ᒪᕐᕉᖕᓂ ᓇᓅᓐᓂᐅᔫᖕᓂ ᐃᒻᒥᖕᓄᑦ. ᑕᓯᐅᔭᒥ/ᒥᑦᑎᒪᑕᓕᒃ/ᕿᑭᖅᑖᓗᑉ ᐃᑭᖓᓂ ᐋᖅᑭᒃᓱᖅᓯᒪᔪᓂ, ᑑᒑᓖᑦ ᐊᒃᑐᐊᔪᑦ ᐊᒥᓲᓂᖏᓐᓄᑦ ᓯᓚ ᒪᓕᑐᐃᓐᓇᓚᐅᖅᑐᑦ ᖁᕙᓯᓐᓇᖅᓗᑎ ᖃᖕᒐᑕᓂ 1-ᒥ ᖃᐅᔨᓴᕐᓂᓗᒃᑖᖏᓐᓂ. ᐃᓗᐊᑕ ᑲᖏᖅᓱᐊᓂ ᐋᖅᑭᒃᓯᒪᓂᐅᔪᓂ, ᑑᒑᓖᑦ ᐊᒃᑐᐊᓂᓖᑦ ᐊᒥᓲᓂᖏᓐᓄᑦ ᓯᓚ ᒪᓕᑐᐃᓐᓇᓚᐅᖅᑐᑦ ᖁᕙᓯᒃᑑᓪᓗᓂ ᓯᕗᓪᓕᖅᐹᓂ ᐱᖓᓱᓂ ᖃᐅᔨᓴᕐᓂᐅᔪᓂ, ᑭᓯᐊᓂᓕ ᐅᖁᕈᓐᓃᖁᓪᓚᓪᓚᕆᓚᐅᖅᑐᑦ ᑭᖑᓪᓕᖅᐹᖓᓂ ᖃᐅᔨᓴᕐᓂᐅᔪᒥ (30 ᔪᓚᐃ), ᖃᐅᔨᓴᕐᓂᕐᒥ ᖃᐅᔨᔭᐅᔪᑦ ᓇᓗᓇᐃᖅᓯᑐᐃᓐᓇᖅᑐᑦ ᑑᒑᓖᑦ ᑕᐅᕙᓂ ᑕᓯᐅᔭᕐᒥ/ᒥᑦᑎᒪᑕᓕᒃ/ᕿᑭᖅᑖᓗᑉ ᐃᑭᖓᓂ ᐋᖅᑭᓯᒪᓂᐅᔪᒥ ᓯᓚ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ ᐱᓕᕆᐊᖑᑎᓪᓗᒍ ᖃᖕᒐᑕᓂᖅ 1 ᖃᐅᔨᓴᕐᓂᕐᒥ, ᑑᒑᓖᑦ ᐃᓗᐊᑕ ᑲᖏᖅᓱᐊᓂ ᐋᖅᑭᒃᓯᒪᓂᕐᒥ ᕿᒪᐃᓯᒪᓕᖅᓱᑎᒃ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ ᖄᖏᖅᓯᒪᓕᖅᑎᓪᓗᒍ 27 ᔪᓚᐃ (ᐃᓯᒪᒋᔭᐅᔪᖅ ᑕᓪᓗᕈᑎᐅᑉ ᐃᒪᖓᒍᑦ). ᑐᕌᓚᐅᖅᑎᓪᓗᒍ ᑕᓯᐅᔭᒥ ᐱᓕᕆᐊᖑᕙᓪᓕᐊᕌᓂᓕᖅᑎᓪᓗᒍ ᖃᖕᒐᑕᓂᖅ 1 (27-28 ᔪᓚᐃ), ᐊᒥᓱᓪᓚᑦ ᑑᒑᓖᑦ ᑕᑯᔭᐅᓯᒪᓂᖏᓐᓂᑦ ᑎᑎᕋᖅᑕᐅᓯᒪᔪᑦ ᐋᔪᕋᓂ ᐱᑕᖃᖅᑐᓂ ᐱᓇᖕᓇᖓᓂ ᑕᓯᐅᔭᐅᑉ. ᑭᓯᐊᓂᓕ, ᑑᒑᓕᖕᓂᒃ

ᑕᑯᓯᐅᔪᖃᓚᐅᙱᑦᑐᖅ ᕿᙳᐊᓂ ᐅᕝᕙᓘᓐᓃᑦ ᑲᖕᒋᖅᓱᐊᕐᔪᐊᖕᒥ ᓇᓕᐊᖕᓂᑐᐃᓐᓇᖅ ᖃᖓᑕᓂᖅ 1 ᖃᐅᔨᓴᕐᓂᕐᒥ, ᐃᓱᒪᒋᔭᐅᓪᓗᓂ ᐃᒪᖓᓂ ᓯᑯᐃᑦ ᖃᓄᐃᓕᖓᓂᖏᑦ ᐊᑐᖅᑕᐅᔪᓐᓇᙱᓐᓂᖏᓐᓄᑦ ᑕᐅᕗᓇ ᐅᕝᕙᓘᓐᓃᑦ ᑑᒐᓖᑦ ᑕᐅᕙᓃᓐᓂᖅᓴᐅᔪᒪᓂᖏᓐᓄᑦ ᓯᑯᖃᑐᐊᕐᓂᖓᓄᑦ.

ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ, ᑲᑎᓪᓗᒋᑦ 578 ᑑᒐᓕᖕᓂ ᑕᑯᓐᓃᑦ (ᐱᓕᕆᖅᑐᑦ 1,152 ᐃᓛᒃᑰᖅᑐᓂᒃ) ᑎᑎᕋᖅᑕᐅᓯᒪᔪᑦ ᖃᖓᑕᓂᖅ 1-ᒥ, ᑕᑯᓯᐅᔪᑦ ᑮᓕᖃᖅᓱᑎᒃ ᐅᐊᖕᓇᖕᖓᓄᑦ ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ. ᑑᒐᓕᖕᓂᒃ ᑕᑯᓯᐅᔪᖃᓚᐅᙱᑦᑐᖅ ᓂᒋᐊᖑᑦ ᑕᐅᕗᓇ ᓯᑯᖃᑐᐊᕐᓂᒃᑯᑦ (9/10-ᒥᑦ 10/10-ᒧᑦ ᓯᑯᖃᑐᐊᕐᓃᑦ) ᐱᓕᕆᓚᐅᖅᑐᑦ ᕿᑎᐊᓂ ᑲᖕᒋᖅᓲᑉ, ᐱᓱᒪᒋᔭᐅᔪᖅ ᐱᔾᔪᑕᐅᓪᓗᑎᒃ ᐃᒪᖓᓂ ᓯᑯᐃᑦ ᖃᓄᐃᓕᖓᓂᖏᑦ ᐅᐸᒃᑕᐅᔪᓐᓇᙱᓐᓂᖓᓄᑦ ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓ ᐅᕝᕙᓘᓐᓃᑦ ᑑᒐᓖᑦ ᑕᐅᕙᓃᑦᑐᒪᓂᖅᓴᐅᓂᖏᓐᓄᑦ ᓯᑯᖃᐅᕐᓂᐅᔪᓂ.

ᓯᑯᖃᙱᑎᓪᓗᒍ (ᖃᖓᑕᓂᖅ 2) ᐊᒥᓲᓂᖏᓐᓄᑦ ᖃᐅᔨᓴᕐᓂᖅ

ᖃᖓᑕᓂᖅ 2 ᖃᖓᑕᓲᒃᑯᑦ ᖃᐅᔨᓴᕐᓂᖅ 2023-ᒥ ᑐᓴᒃᓴᖃᓚᐅᖅᑐᖅ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᑦ ᑑᒐᓖᑦ ᐊᒥᓲᓂᖏᓐᓄᑦ ᑕᓯᔾᔭᐅᒥ ᐊᐅᔭᒃᑯᑦ ᐱᓕᕆᕙᐅᕗᒃᑐᖅ, ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ ᐊᐅᔭᒃᑯᑦ ᐱᓕᕆᕙᐅᕗᒃᑐᖅ, ᐊᒻᒪᓗ ᑲᑎᓪᓗᒋᑦ ᑕᓯᐅᔭᒥ ᐃᒃᐱᐊᕐᔫᓪᓗ ᐃᒪᖓᓂ ᐱᓕᕆᕙᐅᕗᒃᑐᖅ. ᒪᕿᒃ ᖃᓄᐃᑦᑑᓂᖏᑦ ᖃᖓᑕᓲᒃᑯᑦ ᖃᐅᔨᓴᕐᓃᑦ ᖃᖓᑕᔪᐅᓚᐅᖅᑐᑦ: ᑕᑯᔨᐅᓂᒃᑯᑦ-ᑐᙵᕕᖃᖅᓱᑎᒃ ᖃᐅᔨᓴᕐᓃᑦ ᑕᕆᐅᒥ ᐳᐃᔾᔨᑦ ᑕᑯᔨᐅᓂᖏᑦ ᑲᑎᑕᐅᓪᓗᑎᒃ ᑕᐅᕗᓇ ᐋᖅᑭᒃᑕᐅᓯᒪᔪᑎᒍᑦ ᑐᑭᓕᕇᒃᑐᑎᒍᑦ ᐊᑐᖅᓱᑎᒃ ᒪᕐᕈᐃᓕᖅᑲᖓᔪᓂᒃ-ᐋᖅᑭᒃᓯᒪᓂᓛᑦ ᑕᕆᐅᒥ ᐳᐃᔨᓂᒃ ᓇᐅᑦᑎᖅᓱᖅᑏᑦ (MMOs) ᐃᓂᖃᖅᓱᑎ ᓯᕗᓂᐊᓂ ᐃᖅᑯᐊᓂᓗ ᖃᖓᑕᓲᑉ, ᐊᒻᒪᓗ ᐊᔾᔨᙳᐊᓂᒃ-ᑐᙵᕕᖃᖅᓱᑎᒃ ᖃᐅᔨᓴᕐᓃᑦ ᐊᑯᓂᖅᓯᖅᑐᑦ ᐋᖅᑭᒃᓯᒪᓂᖏᑦ ᑖᕋᖃᙱᑦᑐᒃᑯᑦ ᐊᔾᔨᓕᐅᕈᑏᑦ ᐋᖅᑭᒃᑕᐅᓯᒪᓪᓗᑎᒃ ᖃᖓᑕᓲᒥ ᐊᔾᔨᓕᐅᕆᔫᑦ ᐱᐅᓪᓚᕆᒃᑐᓂᒃ ᐊᔾᔨᙳᐊᓂᒃ ᖃᐅᔨᓴᕈᐅᔫᑦ ᐊᑎᑦᑎᐊᖓᓂ ᖃᖓᑕᓲᑉ. ᐊᔾᔨᙳᐊᑎᒍᑦ ᖃᐅᔨᓴᕐᓃᑦ ᖃᖓᑕᔪᐅᔫᑦ ᐃᓂᐅᔪᓂ ᑑᒐᖃᐅᕈᐅᔪᒥ ᑕᒪᖅᓯᒪᙱᑦᑎᐊᖅᓱᑎᒃ ᓈᓴᖅᑕᐅᓂᖏᑦ ᐊᔪᕐᓇᕈᓴᓚᐅᖅᑐᑦ ᐊᑐᕐᓗᑎᒃ ᑕᑯᓂᑐᐃᓐᓇᒃᑯᑦ. ᑲᑎᓪᓗᒋᑦ ᒪᕿᒃ ᖃᐅᔨᓴᕐᓃᑦ ᐱᓕᕆᐊᖑᓚᐅᖅᑐᑦ ᑕᓯᐅᔭᒥ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᑎᑎᖅᑐᖅᑕᐅᓯᒪᔪᓂ ᐊᒻᒪᓗ ᐊᑕᐅᓯᖅ ᐱᓕᕆᐊᖑᓚᐅᖅᓱᓂ ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ ᖃᐅᔨᓴᕐᓂᖅ ᑎᑎᖅᑐᖅᑕᐅᓯᒪᓪᓗᑎᒃ ᖃᖓᑕᑎᓪᓗᒋᑦ 2-ᒥᒃ. ᐱᓯᕋᖅᑕᐅᔪᑦ (ᐱᖃᓯᐅᔾᔭᐅᓇᑎᒃ ᑲᙱᖅᓱᐃᑦ) ᐱᓯᕋᖅᑕᐅᔫᓇᓚᐅᖅᑐᖅ ᓯᕗᓪᓕᕐᒧᑦ ᖃᐅᔨᓴᕐᓂᐅᔪᒧᑦ ᑕᓯᐅᔭᒥ (12-13 ᐋᒡᒋᓯ) ᐊᒻᒪᓗ ᐃᓚᐃᓐᓇᖓᓂ ᐱᔭᐅᓪᓗᑎᒃ ᑭᙳᓪᓕᕐᒥ ᖃᐅᔨᓴᕐᓂᐅᔪᒥ ᑕᓯᐅᔭᒥ (23-25 ᐋᒡᒋᓯ) ᐊᒻᒪᓗ ᐃᓛᒃᑰᖅᑐᖅ ᖃᐅᔨᓴᕐᓂᖅ ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ (19-20 ᐋᒡᒋᓯ).

ᑲᑎᓪᓗᒋᑦ 4,376 ᑭᓛᒥᑕᕐᓂᒃ ᖃᐅᔨᓴᕐᓂᖃᕋᓯᓚᐅᖅᑐᑦ ᐱᓕᕆᐊᖑᓪᓗᑎ ᖃᖓᑕᓂᖅ 2 ᖃᖓᑕᓲᒃᑯᑦ ᖃᐅᔨᓴᕐᓂᕐᒥ (ᐱᖃᓯᐅᑎᓪᓗᒋᑦ ᑕᒪᐃᓐᓂ ᑕᑯᓂᒃᑯᑦ ᐊᒻᒪᓗ ᐊᔾᔨᙳᐊᑎᒍᑦ ᖃᐅᔨᓴᕐᓂᕐᓂ), ᐱᓕᕆᖅᓱᓂ 3,345 ᑭᓛᒥᑕᕐᓂᒃ ᓄᓇᓂ ᐊᕙᑦᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᓂ ᐊᒻᒪᓗ 1,031 ᑭᓛᒥᑕᕐᓂᒃ ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ. ᐱᓕᕆᐊᖃᖅᑎᓪᓗᖕᒋᑦ ᑕᑯᓂᒃᑯᑦ ᖃᐅᔨᓴᕐᓂᕐᓂᑦ, ᑲᑎᓪᓗᒋᑦ ᐊᕙᓂᓕᖕᓂᑦ ᐊᔾᔨᒌᙱᑦᑐᓂ ᑕᕆᐅᒥ ᐳᐃᔨᓂᒃ ᐆᒪᔪᑦ ᐊᔾᔨᒌᙱᐊᕐᔪᒃᑐᓂ ᑎᑎᕋᖅᓯᓚᐅᖅᑐᑦ (ᑑᒐᓕᒃ, ᐊᕐᕕᖅ, ᓇᑦᑎᖅ, ᖃᐃᕈᓕᒃ, ᐅᒡᔪᒃ ᐊᒻᒪᓗ ᓇᓄᖅ) ᓴᖅᐱᓪᓗᑎ ᑲᑎᓪᓗᒋᑦ 271 ᑕᑯᔭᐅᓪᓗᑎᒃ (ᐱᓕᕆᖅᑐᑦ 648-ᓂ ᐃᓛᒃᑰᖅᑐᓂᑦ) ᓄᓇᓂ ᐊᕙᑦᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥ ᐊᒻᒪᓗ 417 ᑕᑯᓯᐅᔪᑦ (ᐱᓕᕆᖅᑐᑦ 893 ᐃᓛᒃᑰᖅᑐᑦ) ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ. ᑑᒐᓖᑦ ᐊᒥᓲᓛᖑᓪᓗᑎ ᐆᒪᔪᓂ ᐊᔾᔨᒌᙱᐊᕐᔫᒃᑐᓂ ᐅᔾᔨᕆᔭᐅᔪᓂ ᖃᖓᑕᓂᖅ 2-ᒥ ᖃᐅᔨᓴᕐᓂᕐᒥ, 140-ᓂᒃ ᑕᑯᓪᓗᑎ (ᐱᓕᕆᖅᑐᑦ 353 ᐃᓛᒃᑰᖅᑐᑦ) ᓄᓇᓂ ᐊᕙᑦᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥ (ᐱᖃᓯᐅᑎᓪᓗᖏᑦ ᖃᐅᔨᓯᐅᓇᓱᒃᑎᓪᓗᒍ ᖃᖓᑕᓃᑦ) ᐊᒻᒪᓗ 348 ᑕᑯᓯᐅᔪᑦ (ᐱᓕᕆᖅᑐᑦ 690-ᓂ ᐃᓛᒃᑰᖅᑐᓂᒃ) ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ. ᐊᔾᔨᖑᐊᑎᒍᑦ ᖃᐅᔨᓴᕐᓂᕐᓄᑦ, ᑲᑎᓪᓗᒋᑦ 9,501 ᑕᑯᓯᐅᔪᑦ(ᐱᓕᕆᖅᓱᑎᒃ 17,675 ᐃᓛᒃᑰᖅᑐᑦ) ᓇᓗᓇᐃᖅᑕᐅᓚᐅᖅᑐᑦ ᐊᔾᔨᙳᐊᑎᒍᑦ ᕿᒥᕐᕈᔭᐅᓪᓗᑎ (ᑲᑎᓗᒃᑖᖅᓱᒋᑦ ᖃᐅᔨᓴᕐᓃᑦ). ᐊᔾᔨᙳᐊᑎᒍᑦ ᖃᐅᔨᓴᕐᓃᑦ ᐱᓕᕆᐊᖑᓚᐅᖅᑐᑦ ᐱᓕᕆᕐᓂᐅᕙᓂᖅᑐᓂ ᕿᙳᐊᓂ, ᑕᓯᐅᔭᒥ ᐊᒻᒪᓗ ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ. ᒪᕿᒃ ᐊᔾᔨᒌᙱᑦᑑᒃ ᐆᒪᔪᐃᑦ ᐊᔾᔨᒌᙱᐊᕐᔫᒃᑐᑦ ᑎᑎᕋᖅᑕᐅᓚᐅᖅᑐᑦ ᐊᔾᔨᙳᐊᑎᒍᑦ ᖃᐅᔨᓴᕐᓂᕐᓂ: ᑑᒐᓖᑦ (9,496 ᑕᑯᓯᐅᔪᑦ ᑲᑎᓪᓗᒋᑦ 17,668 ᐃᓛᒃᑰᖅᑐᑦ) ᐊᒻᒪᓗ ᐊᕐᕕᑦ (ᑕᓪᓕᒪᑦ ᑕᑯᓯᐅᔪᑦ ᑲᑎᓪᓗᒋᑦ 7 ᐃᓛᒃᑰᖅᑐᑦ).

2023-ᒥ ᑕᓯᐅᔭᒥ ᑑᒐᓖᑦ ᐊᔭᒃᑯᑦ ᐱᓕᕆᕝᕕᒋᕙᒃᑕᖏᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᓚᐅᖅᑐᑦ 10,492 ᓂᕐᔪᑏᑦ (ᓈᓴᐅᓯᖅᓯᔾᔪᑦ (CV) = 0.05; ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 9,578-11,494) ᐊᔾᔨᒋᙱᕐᔪᐊᖅᓯᒪᙱᑦᑕᖏᑦ 2013-ᒥ ᐱᒋᐊᕈᑕᐅᔪᓄᑦ ᖃᐅᔨᓴᕈᑏᑦ ᖃᓄᐃᓕᖓᓂᖏᓐᓄᑦ (10,498 ᓂᕐᔪᑏᑦ ; ᓈᓴᐅᓯᖅᓯᔾᔪᑦ (CV) = 0.24; ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 6,342 – 17,347; ᑑᓂᐊᓪ-ᕙᐊᓪᑯᕈᕽ ᐊᓕᖕᒋᖅᓱᑎᒃ 2015ᐃ), 2016-ᒥ ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᑦ (12,039 ᓂᕐᔪᑏᑦ ᓈᓴᐅᓯᖅᓯᔾᔪᑦ (CV) = 0.23; ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI = 7,768-18,660; ᒪᐅᓲ ᐊᓕᖕᒋᖅᓱᑎᒃ 2019) ᐅᕝᕙᓘᓐᓃᑦ 2019-ᒥ ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᑦ (9,931 ᓂᕐᔪᑏᑦ, ᓈᓴᐅᓯᖅᓯᔾᔪᑦ (CV) = 0.05, 95% ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 9,009–10,946; ᒎᑐ 2020ᐃ). 2023-ᒥ ᑕᓯᐅᔭᒥ ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᑦ ᐅᓄᕐᓂᖅᓴᕐᔪᐊᖑᓚᐅᖅᑐᑦ ᐱᖓᓱᓂ ᑭᖑᓕᕇᓂ ᐊᕐᕌᒍᓂ (2020-2022; ᒎᑐ 2021ᐃ, 2022ᐃ, WSP 2023ᐃ). ᐅᓄᖅᓯᒋᐊᕐᓂᖏᑦ 2023-ᒥ ᐅᔾᔨᕆᔭᐅᔪᑦ ᐱᑕᖃᐃᓐᓇᖃᒃᑕᖅᑕᖅᓱᐊᖅᑎᓪᓗᒍ ᑭᖑᓪᓕᐅᓪᓗᓂ ᐅᓄᓛᑦ ᐅᒥᐊᕐᔪᐊᖅᑲᖅᑕᕐᓃᑦ ᖃᓄᐃᓕᖓᓃᑦ ᓄᓇᓂ ᐊᕙᑦᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥ ᑕᐅᒪᙵᓂᑦ ᐅᒥᐊᕐᔪᐊᖅᑲᖅᑕᓯᒋᐊᓚᐅᖅᑎᓪᓗᒋᑦ ᐊᒻᒪᓗ ᐊᑐᖅᑕᐅᓂᓚᐅᖅᑎᓪᓗᒋᑦ ᐊᖏᓂᖅᓴᐃᑦ ᐊᖏᓂᖅᓴᕐᔪᐊᑦ ᐅᒥᐊᕐᔪᐊᑦ ᓴᕕᒃᓴᓂᒃ ᐅᓯᔪᒃᓴᑦ ᐸᕝᕙᓛᓐᓇᑯᑦ ᐅᒥᐊᕐᔪᐊᖅᑲᖅᑕᕐᓂᖏᓐᓄᑦ ᐊᐅᓚᓃᑦ 2023-ᒥ. ᑲᑎᓪᓗᒋᑦ, ᖃᐅᔨᓴᕈᑎᓂ ᖃᐅᔨᓯᐅᔪᓗᒃᑖᑦ ᐅᓪᓗᒥᒧᑦ ᓇᓗᓇᐃᖅᓯᔪᑦ

ᐊᒃᑐᐊᖅᑎᓲᑦᑎᐊᙱᓐᓂᖏᓐᓂᒃ ᑖᒃᑯᓇᓂ ᐊᕐᕌᒍᑕᓚᐅᑦ ᐅᒥᐊᕐᔪᐊᖃᖃᑦᑕᕐᓂᕐᒧᑦ ᖃᓄᐃᓕᖓᓃᑦ ᐊᒻᒪᓗ ᑑᒤᓖᑦ ᐊᒥᓲᓂᖏᑦ ᑕᐅᕙᓂ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ.

2023-ᒥ ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ ᑑᒤᓖᑦ ᐊᐅᔾᒃᑯᑦ ᐱᑕᖃᕐᕕᒋᕚᒃᑕᖏᓐᓂ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᑦ 30,214 ᑑᒤᓖᑦ (ᓈᓴᐅᓯᖅᓯᔾᔪᓰᑦ (CV) = 0.15; ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) 22,559–40,467) ᓈᓴᐅᑎᑎᒍᑦ ᐊᔾᔨᒌᙱᕐᔪᐊᓗᐊᙱᑕᖏᑦ 2013-ᒥ ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᑦ (35,043 ᓂᕐᔪᑏᑦ; ᓈᓴᐅᓯᖅᓯᔾᔪᓰᑦ (CV) = 0.42; ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 14,188–86,553; ᑑᓂᐊᓪ-ᕕᐊᓪᑯᕉᔅ ᐊᑕᖏᖅᓱᑎᒃ 2015ᐃ), 2019-ᒥ ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᑦ (28,746 ᓂᕐᔪᑏᑦ; ᓈᓴᐅᓯᖅᓯᔾᔪᓰᑦ (CV) = 0.15; ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 21,545–38,354; ᒌᑐ 2020ᐃ), 2020-ᒥ ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᑦ (31,026 ᓂᕐᔪᑏ; ᓈᓴᐅᓯᖅᓯᔾᔪᓰᑦ (CV) = 23,406-41,126; ᒌᑐ 2021ᐃ) ᐅᕝᕙᓘᓐᓃᑦ 2022-ᒥ ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᖅᑕᐅᓯᒪᔪᑦ (43,042 ᓂᕐᔪᑏᑦ; ᓈᓴᐅᓯᖅᓯᔾᔪᓰᑦ (CV) = 0.15; ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 32,218–57,502; WSP 2023ᐃ). 2023-ᒥ ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᑦ ᓈᓴᐅᑎᑎᒍᑦ ᐊᒃᐸᓯᖕᓂᖅᓴᐅᔪᑦ 2021-ᓂᓴᕐᓄᑦ ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᑦ 72,582 ᓂᕐᔪᑏᑦ (ᓈᓴᐅᓯᖅᓯᔾᔪᓰᑦ (CV) = 0.09; ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 61,333–85,895; ᒌᑐ 2022ᐃ).

ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᑦ ᑲᑎᑕᐅᓪᓗᑎᒃ ᑕᓯᐅᔭᒥ ᐊᒻᒪᓗ ᐃᒃᐱᐊᕐᔫᑉ ᐃᒪᖓᓂ ᑑᒤᓖᑦ ᐱᑕᖃᕐᓂᖏᓐᓄᑦ 40,706 ᓂᕐᔪᑏᑦ (ᓈᓴᐅᓯᖅᓯᔾᔪᓰᑦ (CV) = 0.11; ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 32,711-50,655), ᓈᓴᐅᑎᑎᒍᑦ ᐊᔾᔨᒌᙱᓗᐊᓚᐅᙱᑕᖏᑦ 2013 ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᓯᒪᔪᓄᑦ (45,532 ᓂᕐᔪᑏᑦ; ᓈᓴᐅᓯᖅᓯᔾᔪᓰᑦ (CV) = 0.33; ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 22,440–92,384; ᑑᓂᐊᓪ-ᕕᐊᓪᑯᕉᔅ 2015ᐃ), ᑖᒃᑯᐊ 2019 ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᔪᑦ (38,677 ᓂᕐᔪᑏᑦ; ᓈᓴᐅᓯᖅᓯᔾᔪᓰᑦ (CV) = 0.11; ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 31,155–48,015; ᒌᑐ 2020ᐃ), ᑖᒃᑯᐊ 2020 ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᔪᑦ (36,044 ᓂᕐᔪᑏᑦ, ᓈᓴᐅᓯᖅᓯᔾᔪᓰᑦ (CV) = 0.12, ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 28,267–45,961; ᒌᑯ 2021ᐃ) ᐅᕝᕙᓘᓐᓃᑦ 2022 ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᔪᑦ (46,408 ᓂᕐᔪᑏᑦ, ᓈᓴᐅᓯᖅᓯᔾᔪᓰᑦ (CV) = 0.13, ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 36,129–59,611; WSP 2023ᐃ). ᑖᒃᑯᐊ 2023 ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᔪᑦ ᓴᖅᑮᔭᖅᑎᑦᑎᓚᐅᖅᑐᑦ ᓈᓴᐅᑎᑎᒍᑦ ᐊᒃᐸᓯᖕᓂᖅᓴᐅᓂᖏᓐᓄᑦ 2021 ᐊᒥᓲᓂᖏᓐᓄᑦ ᒥᒃᓴᐅᓴᒃᑕᐅᔪᑦ (75,177 ᓂᕐᔪᑏᑦ; ᓈᓴᐅᓯᖅᓯᔾᔪᓰᑦ (CV) = 0.08; ᓇᓗᓇᕈᓐᓃᖅᑎᓯᒪᔪᑦ ᐊᑯᓚᐃᓐᓂᖏᑦ ᐃᒪᓐᓇᑎᒋ (CI) = 63,795–88,590; ᒌᑐ 2022ᐃ). ᑕᒪᐃᓐᓅᖓᓪᓗᑎ, ᖃᖓᑕᓲᒃᑯᑦ ᖃᐅᔨᓴᕐᓂᕐᒥ ᖃᐅᔨᔭᐅᔪᑦ ᓇᓗᓇᐃᖅᓯᔪᑦ ᑲᑎᕆᓯᑦ ᐱᑕᖃᕐᓂᖏᑕ ᐊᖏᓂᖏᑦ ᓱᕋᖅᑯᔨᙱᑦᑐᑦ ᐱᒋᐊᓚᐅᖅᑎᓪᓗᒋᑦ ᐹᕙᓖᓐᑯᑦ ᐅᒥᐊᕐᔪᐊᖃᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᐊᐅᓚᓃᑦ ᐊᓚᓗ ᐊᒃᑐᐊᔪᑦ ᐱᒋᐊᕈᑕᐅᔪᓄᑦ ᖃᐅᔨᓴᕈᑏᑦ ᖃᓄᐃᓕᖓᓂᖏᓐᓄᑦ. ᖃᐅᔨᔭᐅᔪᑦ ᓇᓗᓇᐃᖅᓯᒃᑲᓂᖅᑐᑦ ᐃᓚᖏᑦ ᖃᓄᐃᓕᖓᓂᐅᔪᑦ ᓂᕐᔪᑏᑦ ᓅᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᑖᒃᑯᓇᓂ ᒪᕐᕉᖕᓂᒃ ᐱᑕᖃᕐᓂᐅᓇᓱᒋᔭᐅᔪᓂ ᑭᓯᐊᓂᓕ ᑕᒪᓐᓇ ᐊᒃᑐᐊᓂᖃᖅᑯᔨᙱᑦᑐᖅ ᐱᓕᕆᐊᒥ ᐅᒥᐊᕐᔪᐊᖃᖃᑦᑕᕐᓃᑦ ᖃᓄᐃᓕᖓᓂᖏᓐᓄᑦ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᓂ.

ᓯᑯᕚᓕᐊᓕᖅᑎᓪᓗᒍ (ᖃᖓᑕᓂᖅ 3) ᖃᐅᔨᓴᕐᓃᑦ

ᖃᖓᑕᓲᒃᑯᑦ ᓯᒃᑯᔭᐅᔪᖃᙱᒃᑲᓗᐊᕐᒪᖔᑦ ᖃᐅᔨᓴᕐᓂᖅ ᖃᖓᑕᔭᐅᓚᐅᖅᑐᖅ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ ᐃᓯᓕᑎᓪᓗᒍ ᐅᒥᐊᕐᔪᐊᖃᖃᑦᑕᓇᖅ 31 ᐅᑐᐱᕆ 2023-ᒥ ᖃᐅᔨᓴᖅᐸᓪᓕᐊᖏᓇᖅᑕᐅᕐᑯᓪᓗᒋᑦ ᐅᒥᐊᕐᔪᐊᑦ ᐊᖅᑯᑖᓂ ᐊᒻᒪᓗ ᖃᓂᖏᔭᖏᓐᓂ ᑑᒤᓖᑦ ᓯᒃᑯᔭᐅᑐᐃᓐᓇᕆᐊᖃᕐᓂᖏᓐᓄᑦ ᐱᔭᕇᓚᐅᖅᑎᓪᓗᒋᑦ ᐹᕙᓖᓐᑯᑦ 2023-ᒥ ᐅᒥᐊᕐᔪᐊᖏᑕ ᐊᐅᓚᓂᖏᑦ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᓂ. ᑑᒤᓕᖕᓂᒃ ᑕᑯᔪᖃᓚᐅᙱᑦᑐᖅ ᑎᑎᕋᖅᑕᐅᔪᓂ ᖃᐅᔨᓴᖅᑎᓪᓗᒋᑦ. ᖃᐅᔨᔭᐅᔪᑦ ᐱᔭᕇᖅᑎᓪᓗᒋᑦ ᖃᖓᑕᓲᒃᑯᑦ ᓯᒃᑯᔭᐅᔪᖃᙱᒃᑲᓗᐊᕐᒪᖔᑦ ᖃᐅᔨᓴᕐᓃᑦ ᓇᓗᓇᐃᖅᓯᓚᐅᖅᑐᑦ ᓯᒃᑯᔭᐅᔪᖃᙱᓐᓂᖓᓂᒃ 2023-ᒥ ᓴᖅᑭᓱᑎ ᐱᓕᕆᐊᒥ ᓯᑯᓂᒃ ᐊᔭᐅᖅᑐᐃᓂᖏᓐᓄᑦ ᐊᒻᒪᓗ ᐅᒥᐊᕐᔪᐊᖃᖃᑦᑕᕐᓂᕐᒧᑦ ᐱᓕᕆᓂᕐᓄᑦ ᓄᓇᓂ ᐊᕕᒃᑐᖅᓯᒪᔪᓂ ᖃᐅᔨᓴᕐᕕᐅᔪᒥ.

Study Limitations

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Abbreviation and Acronym List

AIC	Akaike's Information Criterion
AIN	Admiralty Inlet North stratum
AIS	Admiralty Inlet South stratum
ASL	Above sea level
Baffinland	Baffinland Iron Mines Corporation
BF	Beaufort Sea State
BB	Baffin Bay stratum
C_a	Availability correction factor
CI	Confidence Interval
CV	Coefficient of Variation
DFO	Fisheries and Oceans Canada
DS	Distance Sampling
ERP	Early Revenue Phase
ESE	Eclipse Sound East stratum
ESW	Eclipse Sound West stratum
FEIS	Final Environmental Impact Statement
ft	Feet
Golder	Golder Associates Ltd.
GPS	Global Positioning System
IQ	Inuit Qaujimajatuqangit
km	Kilometres
km^2	Square kilometres
km/h	Kilometers per hour
kn	Knots
m	Metre
MEWG	Marine Environmental Working Group
MHTO	Mittimatalik Hunters and Trappers Organization

Milne Port	Port at Milne Inlet
MIN	Milne Inlet North stratum
MIS	Milne Inlet South stratum
MMASP	Marine Mammal Aerial Survey Program
MMP	Marine Monitoring Program
Mtpa	Million tonnes per annum
MMOs	Marine Mammal Observers
MR	Mark-recapture
MRDS	Mark-recapture distance sampling
MSV	Multipurpose support/supply vessel
NB	Navy Board Inlet stratum
NEBI	North and East Baffin Region
NIRB	Nunavut Impact Review Board
NWBM	Nunavut Wildlife Management Board
PAM	Passive Acoustic Monitoring
PI	Pond Inlet stratum
Project	Mary River Project
PC	Project Certificate No. 005
QA/QC	Quality Assurance/Quality Control
QIA	Qikiqtani Inuit Association
RSA	Regional Study Area
SBO	Ship-based Observer
Steensby Port	Port at Steensby Inlet
TS	Tremblay Sound stratum

1.0 INTRODUCTION

This report presents the results of the 2023 Marine Mammal Aerial Survey Program (MMASP; hereafter the Program) conducted on North Baffin Island during July, August, and October 2023. Marine mammal aerial surveys were conducted by WSP using distance-based line-transect sampling combined with high-resolution photography. The primary objectives of the surveys were to collect data on the presence/absence and distribution of marine mammals prior to initial shipping operations in the Regional Study Area (RSA), to obtain an annual abundance estimate for the Eclipse Sound and Admiralty Inlet narwhal summer stocks during the open-water season, and to document if narwhal entrapment events occurred in the RSA following completion of Baffinland's 2023 shipping operations along the Northern Shipping Route.

1.1 Project Background

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

To date, Baffinland has been operating in the Early Revenue Phase (ERP) of the Project and is authorized to transport 4.2 million tonnes per annum (Mtpa) of ore by truck to Milne Port for shipping through the Northern Shipping Route using chartered ore carrier vessels. A production increase to ship 6.0 Mtpa from Milne Port was approved for 2018–2025 through Project Certificate amendments (Baffinland 2018, 2020a, 2022, 2023a). During the first year of ERP operations in 2015, Baffinland shipped ~918,000 tonnes of iron ore from Milne Port involving 13 return ore carrier voyages. In 2016, the total volume of ore shipped out of Milne Port reached 2.6 million tonnes involving 37 return ore carrier voyages. In 2017, the total volume of ore shipped out of Milne Port reached 4.1 million tonnes involving 58 return ore carrier voyages. Following approved production increase to 6.0 Mtpa, a total of 5.1 million tonnes of ore were shipped via 71 return voyages in 2018, 5.9 million tonnes of ore were shipped via 81 return voyages in 2019, 5.5 million tonnes were shipped via 72 return voyages in 2020, 5.6 million tonnes were shipped via 73 (one vessel was released unloaded) return voyages in 2021, and 4.7 million tonnes were shipped via 62 return voyages in 2022. In 2023, a total of 6.02 million tonnes of iron ore were shipped via 75 return voyages with the first inbound transit of the season occurring on 9 August and the last outbound transit of the season occurring on 31 October 2023.

LEGEND

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

0 125 250

1:5,000,000 KILOMETRES

REFERENCE(S)

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

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
PROJECT LOCATION

CONSULTANT

wsp

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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1.2 Regulatory Drivers

In accordance with existing Terms and Conditions of Nunavut Impact Review Board (NIRB) Project Certificate (PC) No. 005, Baffinland is responsible for the establishment and implementation of the Marine Monitoring Plan (MMP) which comprises environmental effects monitoring studies that are conducted over a sufficient time to allow for the following objectives:

- To measure the relevant effects of the Project on the marine environment.
- To confirm that the Project is being carried out within the pre-determined terms and conditions relating to the protection of the marine environment.
- To assess the accuracy of the predictions contained in the Final Environmental Impact Statement (FEIS) for the Project.

The MMASP is one of several monitoring programs that collectively make up the MMP for marine mammals. The MMASP was designed to address 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. Specifically, this included the following PC conditions:

- Condition No. 101 - *"The Proponent shall incorporate into the appropriate monitoring plans the following items:*
  - *b. Efforts to involve Inuit in monitoring studies at all levels.*
  - *c. Monitoring protocols that are responsive to Inuit concerns.*
  - *e. Schedule for periodic aerial surveys as recommended by the Marine Environment Working Group (MEWG)."*
- Term and Condition No. 109 - *"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".*
- Term and Condition No. 111 - *"The Proponent shall develop clear thresholds for determining if negative impacts as a result of vessel noise are occurring".*
- Term and Condition No. 126 - *"The Proponent shall design monitoring programs to ensure that local users of the marine area in communities along the shipping route have opportunity to be engaged throughout the life of the Project in assisting with monitoring and evaluating potential project-induced impacts and changes in marine mammal distributions".*

1.3 Adaptive Management Protocol

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

In support of Baffinland's Phase 2 Proposal for the Project, Baffinland developed a draft Adaptive Management Plan (AMP) which provides a framework for how adaptive management is incorporated into Project operations (Baffinland 2020b). As part of this process, a Marine Mammal Trigger Action Response Plan (TARP) was developed for the Project which identifies a number of performance indicators, effect thresholds and pre-defined actions (i.e., responses) that are used to evaluate and respond to potential Project effects on narwhal and other marine mammal species in the Project area (Baffinland 2021b). The TARP uses a broad range of effect indicators that are measured against a series of tiered thresholds (i.e., low, moderate and high-risk thresholds) that are designed to guide short-term and long-term adaptive management strategies. The pre-defined actions identified in the TARP describe the responses that Baffinland would implement should the corresponding threshold levels be exceeded and assuming there is some degree of certainty that the measured change is Project-related. Three levels of action have been identified: low, moderate, and high. These responses range from increased monitoring and data analysis (e.g., trend analysis); identification of possible sources; to risk assessment and/or mitigation. Baffinland released the most current version of the Marine Mammal TARP and Action Toolkits as part of the draft MMP submitted to the NIRB on 15 May 2023 (Baffinland 2023b).

1.3.1 Low Risk Threshold

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

- Confirmed[2] moderate severity behavioural responses (Severity Score 5 and 6)[3] that do not persist for a prolonged period (i.e., for several hours) following the exposure event[4], as described in Section 3.0 of the 2023 Bruce Head Shore-based Monitoring Program report (WSP 2024a).

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

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

[3] Moderate severity behavioural responses are consistent with Level 5 and 6 severity response scores from Southall et al. (2007, 2021) and Finneran et al. (2017). These consist of responses that could become significant (defined for this purpose as responses with potential to impact critical life functions and/or responses consistent with the level of 'harassment' as defined under the U.S. Marine Mammal Protection Act) if sustained over a longer duration (lasting over a period of several hours, or enough time to significantly disrupt a narwhal's daily routine). Also see Section 3.0 of the 2023 Bruce Head Shore-based Monitoring Program report (WSP 2024a) for a detailed description.

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

1.3.2 Moderate Risk Threshold

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

- Confirmed ‘moderate severity’ behavioural responses (Severity Score 5 and 6) that persist for a prolonged period (i.e., for several hours) following the exposure event, as described in Section 3.0 of the 2023 Bruce Head Shore-based Monitoring Report (WSP 2024a).

AND

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

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

1.3.3 High Risk Threshold

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

- Confirmed moderate severity behavioural responses (Severity Score 5 and 6) that persist for a prolonged period (i.e., for several hours) following the exposure event, as described in Section 3.0 of the 2023 Bruce Head report (WSP 2024a).

AND/OR

- Confirmed high severity responses (Severity Score 7 to 10) as described in Section 3.0 of the 2023 Bruce Head report (WSP 2024a).

AND

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

AND/OR

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

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

1.4 Existing Environment

Narwhal

Narwhal are endemic to the Arctic, occurring primarily in Baffin Bay, the eastern Canadian Arctic, and the Greenland Sea (Reeves et al. 2012). Seldom present south of 61º N latitude (COSEWIC 2004a), two populations are recognized in Canadian waters; the Baffin Bay (BB) population and the northern Hudson Bay (NHB) population (Watt et al. 2017). Of these, only the Baffin Bay population occurs seasonally along the Northern Shipping Route for the Project (Koski and Davis 1994; Dietz et al. 2001; Richard et al. 2010). A third recognized population of narwhal occurs in East Greenland and is not thought to enter Canadian waters (COSEWIC 2004a). 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). Recent observations of narwhal in Archer Fjord highlights current knowledge gaps in population ecology in the Eastern Canadian Arctic including an understanding on narwhal seasonal distribution and movements (Carlyle et al. 2021). Carlyle et al. (2021) suggest that the presence of narwhal in Archer Fjord may represent an undocumented annual summer ground for narwhal or may alternatively reflect an ecologically driven range shift.

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

Marine mammal aerial surveys conducted for the Mary River Project were first undertaken during the 2006–2008 open-water seasons. Subsequent aerial surveys were conducted in 2013 and 2014 to establish marine mammal distribution and density estimates along the Northern Shipping Route during the open-water season and prior to ERP operations. In 2015, aerial surveys were undertaken with a modified approach to attempt to examine potential effects of Project shipping on marine mammal distribution and density estimates during the first year of ERP operations. In 2016, photographic aerial marine mammal surveys were conducted by DFO along the Northern Shipping Route and adjacent inlet areas. Aerial photography from these surveys was analyzed by Golder Associates Ltd. (amalgamated under WSP Canada Inc. in January 2023) on behalf of Baffinland in 2016 to calculate narwhal abundance and density estimates for Milne Inlet, Eclipse Sound, Tremblay Sound and Pond Inlet, based on conventional distance sampling methods (Golder 2018b). The analysis was limited to two survey days (15 and 21 August 2016). DFO released the results of their analysis of the 2016 aerial surveys in June 2019 (Marcoux et al. 2019). From 2019 to 2023, WSP conducted annual aerial surveys in the RSA to determine the relative abundance and distribution of marine mammals near the Pond Inlet floe edge prior to and during initial shipping and icebreaking operations, and to obtain abundance estimates of narwhal during the open-water season for the Eclipse Sound and Admiralty Inlet summer stock areas (Golder 2020a, 2021a, 2022c; WSP 2023a).

The Canadian High Arctic Cetacean Survey conducted by DFO in August 2013 represents the most complete simultaneous survey conducted of the six major summer stocks in the Canadian Arctic (Doniol-Valcroze et al. 2015a). The most recent abundance estimate for the Baffin Bay population, corrected for diving and observer bias, is 141,909 individuals (Coefficient of Variation {CV} by stock = 0.2 to 0.65; Doniol-Valcroze et al. 2015a; Doniol-Valcroze et al. 2020). The 2013 abundance estimate for the Eclipse Sound stock was 10,489 narwhal (CV = 0.24; Confidence Interval {CI} = 6,342–17,347; Table 1) while the 2013 abundance estimate for the Admiralty Inlet stock was 35,043 narwhal (CV = 0.42; CI = 14,188–86,553; Table 1). The combined abundance estimate of the Eclipse Sound and Admiralty Inlet summering stock was estimated to be 45,532 in 2013 (CV = 0.33; CI = 22,440–92,384; Table 1).

DFO has historically considered the Eclipse Sound and Admiralty Inlet narwhal summer aggregations as two separate (i.e., geographically isolated) summer stocks. However, interannual variation in abundance estimates between the Eclipse Sound and Admiralty Inlet summer stock areas suggests some degree of exchange between the two summering grounds during the open-water season (Doniol-Valcroze et al. 2015a; DFO 2020; Marcoux and Watt 2021). For example, the Eclipse Sound summer stock was estimated at 20,225 individuals in 2004 (Richard et al. 2010) and 10,489 in 2013 (Doniol-Valcroze et al. 2015a; Doniol-Valcroze et al. 2020). The decrease in narwhal numbers observed in Eclipse Sound between 2004 and 2013 was explained by possible mixing between the Eclipse Sound and Admiralty Inlet summering stocks given the relatively higher number of narwhal recorded in Admiralty Inlet in 2013 (35,043 animals; Doniol-Valcroze et al. 2015a). Telemetry data has also shown evidence of mixing between these summering groups (Watt et al. 2012; Golder 2020b; DFO 2020; Marcoux and Watt 2021). A review of available Inuit Qaujimajatuqangit (IQ) (JPCS 2017; NWMP 2016a, 2016b; QIA 2019; QWB 2022) also supports that the Admiralty Inlet and Eclipse Sound narwhal management units are actually one stock that shift between summering areas depending on many factors such as seasonal ice conditions, food availability, local predator/prey dynamics and vessel traffic.

For the reasons above, WSP has continued to report a combined abundance estimate for the Eclipse Sound and Admiralty Inlet summer stocks as part of its annual monitoring program. Annual abundance estimates calculated for the combined Eclipse/Admiralty stocks for 2019, 2020 and 2022 (Golder 2020a, 2021a; 2022a; WSP 2023a) were not significantly different than the 2013 baseline condition (Table 1). The 2021 abundance estimate for the combined stocks (75,177 animals, CV = 0.08, CI = 63,795 – 88,590) was significantly higher than the 2013 baseline condition and all other survey years (Table 1), when a higher-than-normal number of narwhal were recorded in the Admiralty Inlet survey grid during the open-water season, presumably including narwhal from other adjacent stock areas (Golder 2022a).

For Eclipse Sound stock alone, the narwhal abundance showed a significant decline in 2020 when narwhal abundance was estimated at 5,018 animals (CV = 0.03, 95% CI of 4,736–5,317; Table 1). In 2021, narwhal abundance reached a low of 2,595 animals (CV = 0.33, 95% CI of 1,368–4,919). In 2022, narwhal numbers showed a significant increase from the previous year when narwhal abundance was estimated at 4,592 animals (CV = 0.10, 95% CI of 3,754–5,617; Table 1).

Table 1: Historical abundance estimates for Eclipse Sound, Admiralty Inlet and combined narwhal stocks.

Stock	Year	Survey Dates (Survey #)	No. Replicate Surveys	Abundance	CV	95% CI	Source
Eclipse Sound	2004	August	1	20,225	0.36	9,471–37,096	Richard et al. 2010
Eclipse Sound	2013	18–19 Aug	1	10,489	0.24	6,342–17,347[a]	Doniol-Valcroze et al. 2015a
Eclipse Sound	2016	7–10 Aug	1	12,039	0.23	7,768–18,660	Marcoux et al. 2019

Stock	Year	Survey Dates (Survey #)	No. Replicate Surveys	Abundance	CV	95% CI	Source
Eclipse Sound	2019	21–27 Aug	2	9,931	0.05	9,009–10,946	Golder 2020a
Eclipse Sound	2020	29 Aug	1	5,018	0.03	4,736 – 5,317	Golder 2021a
Eclipse Sound	2021	20–21 Aug	1	2,595	0.33	1,369 – 4,919	Golder 2022a
Eclipse Sound	2022	17–21 Aug	2	4,592	0.10	3,754–5,617	WSP 2023a
Admiralty Inlet	2003	August	1	5,362	0.50	1,920–12,199	Richard et al. 2010
Admiralty Inlet	2010	7–11 Aug	2	18,049	0.23	11,613–28,053	Asselin and Richard 2011
Admiralty Inlet	2013	12–17 Aug	1	35,043	0.42	14,188–86,553[a]	Doniol-Valcroze et al. 2015a
Admiralty Inlet	2019	21–26 Aug	2	28,746	0.15	21,545–38,354	Golder 2020a
Admiralty Inlet	2020	28 Aug	1	31,026	0.14	23,406–41,126	Golder 2021a
Admiralty Inlet	2021	19 Aug	1	*72,582*	*0.09*	61,333–85,895	Golder 2022a
Admiralty Inlet	2022	14–18 Aug	2	43,042	0.15	32,218–57,502	WSP 2023a
Combined	2013	12–19 Aug	1	45,532	0.33	22,440–92,384[a]	Doniol-Valcroze et al. 2015a
Combined	2019	21–27 Aug	2	38,677	0.11	31,155–48,015	Golder 2020a[b]
Combined	2020	28–29 Aug	1	36,044	0.12	28,267–45,961	Golder 2021a
Combined	2021	19-21 Aug	1	75,177	0.08	63,795–88,590	Golder 2022a
Combined	2022	17–18 Aug	1	46,408	0.13	36,129–59,611	WSP 2023a

[a] T. Doniol-Valcroze, Pers. Comm. 2020.

[b] T. Number has been revised from the Golder 2020a report to correct an error.

Bowhead whale

Aerial survey abundance estimates for the Eastern Canada-West Greenland (EC-WG) bowhead whale population in 2002–2004 and 2013 indicated population numbers in the thousands and increasing significantly since commercial whaling protection was provided in the early 20th century (COSEWIC 2009, DFO 2015b). The EC-WG population spends summers in Baffin Bay and adjoining waters of the Canadian High Arctic; with the RSA included as part of their summer aggregation area (COSEWIC 2009).

Milne Inlet, Eclipse Sound and Pond Inlet are not thought to represent important summering areas for bowhead given the low number of bowhead sightings reported in these areas during the summer season. During eight years of shore-based monitoring conducted for Baffinland from 2013 to 2017 and 2019 to 2023, a total of 31 bowhead were recorded near Bruce Head (Thomas et al. 2014; Smith et al. 2015, 2016, 2017; Golder 2018c, 2020b, 2021b, 2022c; WSP 2023c, 2024c). Similarly, a total of 14 bowhead were recorded along the Northern Shipping Route during three consecutive years of aerial surveys conducted between 2013 and 2015 during the open water period (Elliott et al. 2015; Thomas et al. 2015, 2016). Based on the most recent High Arctic Cetacean Survey completed by DFO in the Project area, the predicted number of bowhead in Eclipse Sound during 2013 was 32 (Doniol-Valcroze et al. 2015a). During Leg 1 of 2019, when bowhead were migrating through the RSA, the calculated abundance of bowhead in the RSA was 176 (15 July) and 1,291 whales (21–22 July) (Golder 2020a). Bowhead numbers during Leg 2 of 2019, 2020,2021, 2022, and 2023 were too low to calculate an abundance with only four bowhead recorded in the RSA in 2019 (Golder 2020a), one bowhead recorded in 2020 (Golder 2021a), two bowhead recorded in 2021 (Golder 2022a), and four recorded in 2022 (WSP 2023a). During four years of the Ship-Based Observer (SBO) program conducted for Baffinland from 2013 to 2015 and in 2018, bowhead whale were not observed (SEM 2014, 2016; Golder 2019). In 2019, 23 sightings of 25 individual bowheads were recorded during the SBO program (Golder 2020c).

Observations of bowhead whale in the RSA were consistent with IQ, including observations of bowhead aggregating in the RSA in Aujaq (end of July to September; Hay et al. 2000, JPCS 2017). For example, bowhead were reported to enter the inlets late into July when the ice is breaking up and can occur in large numbers:

> *"Bowhead whales may be at the floe edge at this time. We don't try to catch them because we need permission. August 2010 was our last bowhead hunt. We see porpoises sometimes, but do not harvest them [Group Discussion]."* – Anonymous, 3-4 March 2015, p.158, JPCS 2017.

> *"…bowhead whales started to penetrate deeper into the inlets to start feeding..….late into July when the ice is breaking up. That was also the time that they would be feeding without fear of predators such as killer whales. [Kooneeloosie Nutarak, Sr., PI/ws] BB179"* – Kooneeloosie Nutarak, p.37, 17-18 March 1997, Hay et al. 2000.

According to Hay et al. (2000), "One informant from Pond Inlet reported an annual occurrence of bowheads along the floe edge near Pond Inlet, Navy Board Inlet, and Tallurutiit/Lancaster Sound. Others have reported that bowhead whales occur in large numbers in the Pond Inlet area during summer. One informant reported that his wife counted a minimum of 74 bowheads on migration in Navy Board Inlet during summer 1996" (p.67).

Bowhead whales were also described to migrate through the area with their calves at this time of year. According to the JPCS (2017) IQ report, "bowhead whales will also migrate through the area with their calves in Aujaq but are not actively harvested by Inuit due to strict quotas that are in place" (p.32).

> *"July is the month that we change from using a snowmobile on the ice to a boat on the water. Bowheads will migrate through with calves but we haven't seen them calve in this area. They go in family groups (the bowhead harvest site from 2010 was marked on the map). It took us 3 days to butcher the whale."* – Anonymous, 3-4 March 2015, p.159, JPCS 2017.

Killer whale

Killer whales frequent the high Arctic primarily during the open-water season (Higdon 2007) and have been recorded in the region as early as the mid-1800s (Reeves and Mitchell 1988). Earlier studies reported that this species was uncommon in northern Baffin Bay and Lancaster Sound between August and October (Koski and Davis 1979). By 2001, regular sightings of killer whales were reported in Cumberland Sound, Lancaster Sound, and Pond Inlet (Baird 2001). Regular occurrences of killer whale have been reported in Pond Inlet during spring, summer, and fall, with most of the reported sightings occurring during July–August (Higdon 2007). Killer whales have also been observed in and around Eclipse Sound and Tremblay Sound (Campbell et al. 1988; Marcoux et al. 2009) and in Milne Inlet and Koluktoo Bay on several occasions when they were observed hunting narwhal (Ferguson et al. 2012). During five consecutive years of shore-based monitoring conducted for Baffinland from 2013 to 2017, no killer whale were recorded (Thomas et al. 2014; Smith et al. 2015, 2016, 2017; Golder 2018c).

Although, killer whales were observed in South Milne Inlet by Mr. Panipakoocho as he departed Bruce Head camp in 2015 (Smith et al. 2016). On 18 August 2019, observers stationed at Bruce Head observed one sighting of eight killer whales in south Milne Inlet (Golder 2020b). On 26 and 27 August 2020, 67 and 18 killer whales, respectively, were observed from Bruce Head (Golder 2021b). In 2021, four killer whales were observed from Bruce Head (Golder 2022c). Killer whales were not observed in the RSA during three consecutive years of aerial surveys conducted between 2013 and 2015 during the open water period (Elliott et al. 2015; Thomas et al. 2015, 2016). Killer whales were observed during the 2019 MMASP on 21, 26, and 29 August (Golder 2020a). While it is unclear whether the same killer whales were observed repeatedly in 2019, and where they travelled between surveys, the observations demonstrate that killer whales were likely in the RSA from 17–30 August during Leg 2 of the 2019 MMASP. During the 2020 MMASP, three killer whale sightings were observed on 27 August and one sighting was observed on 29 August (Golder 2021a). It is likely the third sighting of killer whales on 27 August was a resighting of the first sighting. There were two sightings of killer whale in the RSA during Leg 1 of the 2021 MMASP, including one sighting of 11 killer whales near Pond Inlet on 27 July and another sighting of nine killer whale in Navy Board Inlet on 8 August. There were no sightings of killer whale during Leg 2 of the 2021 MMASP (Golder 2022a).

IQ indicates that it is not common for killer whales to be observed at floe edge or leads because their dorsal fins interfere with ice travel. According to IQ from QIA (2018), "beluga are subject to predation by killer whale and polar bear and can become entrapped in ice. When chased by killer whales, they move to shallower waters that cannot be navigated by killer whales. Despite the risk of entrapment, ice is used to avoid killer whales whose dorsal fins interfere with movement in icy waters" (p.45) and "killer whales are generally not noted at floe edge or leads. Their dorsal fins interfere with ice travel…" (p.56).

IQ respondents also reported that killer whales do not normally arrive until Aujaq, i.e., July to September (JPCS 2017, QIA 2018, 2019).

> *"The same harvesting activities as Upirngaaq occur, but in different areas. No polar bears are harvested and walrus would be very rare. We are starting to see porpoises. We have not harvested them. We see killer whales in Eclipse Sound at this time of year. They do not come until summer. Killer whales are "sea wolves". We consider them our hunting partners, we don't hunt them [Group Discussion]."* – Anonymous, 3-4 March 2015, p. 158, JPCS 2017.
>
> *"And one of the other reasons that we see now is that there is a whole lot more killer whales coming to Pond Inlet area, like lots of them; and again, I was talking about earlier that there's different factors involved in narwhals not migrating to Pond Inlet area as they used to, and I believe this is one of them as well. The killer whales two years ago stayed in Milne area all summer and kept the narwhals away from that area; and again, they're killers, they'll just kill. (P13, 06-Feb-19)"* – Anonymous, 6 February 2019, p. 141, QIA 2019.

IQ from QIA (2018) reported that, "… killer whales have been observed leaving before freeze up so that they will not be trapped in ice. As with other whales, harvesters have indicated that killer whales seem to avoid areas with too many boats and that they may be sensitive to noise" (p.56). Killer whales have not been observed during any of the five SBO programs between 2013 to 2019 (SEM 2014, 2016; Golder 2019, 2020c).

In 2009, Argos tracking tags were simultaneously deployed on killer whale and narwhal in Admiralty Inlet to understand how predation risk from killer whale affects narwhal behaviour (Breed et al. 2017). Results from the study showed that the presence of killer whale strongly altered the behaviour and distribution of narwhal. Killer whale presence also caused narwhal to move closer to shore. Dive behaviour was also affected, causing narwhal to perform deeper dives and shorten their dives. Behavioural changes in narwhal were reported to extend beyond active predation events, with altered behaviour and habitat use persisting steadily for the duration (10 days) that killer whales shared the habitat with narwhal.

Beluga whale

Beluga in the RSA are part of the Eastern High Arctic – Baffin Bay population; one of seven populations known to occur in Canadian waters at some point during the year (COSEWIC 2004b). It is assumed these beluga shift from their winter habitat in Baffin Bay and along Western Greenland to the ice-free or pack-ice in Baffin Bay. During the spring migration, beluga travel from Baffin Bay into areas along east and north Baffin Island as the landfast ice breaks up, occupying regions of Lancaster Sound, Barrow Strait, Peel Sound and Baffin Bay during the summer open-water season. The RSA lies within the full extent of beluga summer habitat though is not part of beluga core summer habitat and any beluga observed in the RSA are probably passing through on their way to their summer core habitat.

During five consecutive years of shore-based monitoring conducted for Baffinland from 2013 to 2017, no beluga were recorded (Thomas et al. 2014; Smith et al. 2015, 2016, 2017; Golder 2018c). In 2019, six beluga were recorded, and in 2020 and 2021, one beluga was recorded each year during the shore-based monitoring program (Golder 2020b, 2021b, 2022a). Beluga were not observed in previous Baffinland aerial surveys in the RSA from 2013 to 2015 (Elliott et al. 2015; Thomas et al. 2015, 2016). A total of four beluga were observed in the RSA during the 2019 MMASP (Golder 2020a). Three were sighted during the early shoulder season and one was sighted during the open water season. A total of five beluga were observed in the RSA during the 2020 MMASP (Golder 2021a) with four sighted during the early shoulder season and one during the open water season. During the 2021 MMASP, all seven beluga observed in the RSA were recorded during the early shoulder season (Golder 2022a). Prior to 2022, beluga numbers were consistently low in the RSA. A total of 152 beluga whales were observed in the RSA during 2022 Leg 1 surveys (WSP 2023a). One hundred and fourty-eight of these were observed in Assomption Harbour on 27 July (WSP 2023a). During three consecutive years of ship-based monitoring conducted for Baffinland from 2013 to 2015, beluga were not observed (SEM 2014, 2016). No belugas were observed during the 2018 SBO program (Golder 2019), but one beluga whale was recorded during the 2019 SBO program (Golder 2020c).

Observations of low numbers of beluga in the RSA are consistent with IQ which reports that, “beluga traditionally do not remain near Pond Inlet... Rather, they migrate through Eclipse Sound and Navy Board Inlet moving westward and northward.” (p. 47, QIA 2018). Beluga and narwhal are also reported to travel in tandem and frequently inhabit that same area at similar times and hunting of both species takes place near the floe edge and during open water periods, e.g., May and September (QIA, 2018). However, beluga have also been reported to give birth in the area (QIA 2018) “…during Upirngasaaq, the whales gather at the floe edge waiting for the break-up of ice. Beluga have been known to birth in southern Navy Board Inlet, southern Milne Inlet, and Koluktoo Bay.” (p. 47).

Polar bear

Polar bear are common in the RSA and throughout most of the Canadian Arctic archipelago. Individuals belonging to the Baffin Bay population occupy drifting pack ice and landfast ice between Baffin Island and west Greenland during winter but can be concentrated along the landfast ice edge in Lancaster Sound (Koski 1980; Ferguson et al. 2000; Ferguson et al. 2001). Polar bears were also concentrated along the landfast ice edge near Pond Inlet and Navy Board Inlet during spring. In August, polar bear are forced ashore by the absence of ice (Taylor and Lee 1995; SWG 2016) and spend this period on Bylot Island and Baffin Island (Lunn et al. 2002). Denning activity by pregnant females is concentrated along the North coast of Bylot Island and coastal areas of Baffin Island near Pond Inlet, Admiralty Inlet and Navy Board Inlet (Baffinland 2010). Generally only males and subadults are found in offshore pack-ice areas with only rare sightings of females with young observed in these areas (APP 1982). Polar bears also frequent fast-ice edges in this area (APP 1982). Polar bears from the Lancaster Sound subpopulation tend to occupy the central and eastern part of their range during winter but move westward during spring to summer on multi-year pack ice in eastern Viscount Melville Sound (Schweinsburg et al. 1982).

During eight years of shore-based monitoring conducted for Baffinland from 2013 to 2017 and 2019 to 2021, a total of 11 polar bears were recorded near Bruce Head (Thomas et al. 2014; Smith et al. 2015, 2016, 2017; Golder 2018c, 2020b, 2022a). A total of 14 polar bears were recorded in the RSA during three consecutive years of aerial surveys conducted between 2013 and 2015 (Elliott et al. 2015; Thomas et al. 2015, 2016). In 2019, six polar bears were recorded in the RSA during the shoulder season (July) and 14 polar bears were recorded during the open water season (Golder 2020a). During aerial surveys conducted in 2020, 24 polar bears were recorded in the RSA during the shoulder season and 25 polar bears were recorded over the open water season (Golder 2021a). A total of 38 polar bears were recorded in the RSA during the 2021 MMASP; 16 polar bears during the shoulder season and 22 polar bears during the open water season (Golder 2022a). Over three consecutive years of ship-based monitoring conducted for Baffinland from 2013 to 2015, polar bear were not observed (SEM 2014, 2016). Two polar bears were observed in each of the 2018 and 2019 SBO program (Golder 2019, 2020c).

IQ supports many of these findings (JPCS 2017, QIA 2019) reporting concentrations of polar bear along landfast ice in the area, including Pond Inlet and Navy Board Inlet during the spring.

> *"… pond Inlet floe edge activities continue in Upirngaksaaq, including the hunting of ringed and bearded seal, narwhal, polar bear, and walrus (although this species in not often hunted here)."* (p.26, JPCS 2017).
>
> *"March, April, May is when it is busier for polar bear hunting. [Elijah]"* – response regarding land use in Eclipse Sound and Navy Board Inlet areas, Elijah, 9-10 May 2016, p.228, JPCS 2017.
>
> *"I do a lot of seal hunting around that area [floe edge at Sannirut]. And when I go look for polar bear, that's where I usually go too, because there's always a fresh track. (P09, 05-Feb-19)"* – Anonymous, 5 February 2019, p.39, QIA 2019.

As well, IQ reports female denning activity in coastal areas of Baffin Island near Pond Inlet.

> *"More polar bear dens are found southeast of the floe edge. Young seals can't be found in those areas because the bears eat them [Group Discussion]."* – Anonymous, 3-4 March 2015, p.155, JPCS 2017.
>
> *"We used to use that for overnight site for hunting caribou. Just right beside that cabin, just only about 50 feet away from the cabin there [close to Sannirut] was a little land, a slope like this onto the shore in that area, there was a polar bear denning just about 50 feet away from a cabin here. (P11, 06-Feb-19)"* – Anonymous, 6 February 2019, p.107, QIA 2019.

Ringed seal

Population structures of ringed seal across the Canadian Arctic are poorly understood in general. The ringed seal population in Canada and adjacent waters (West Greenland, Alaska, and Russia) is estimated at 2.3 million seals, with low confidence (COSEWIC 2019). Finley et al. (1983) estimated the Baffin Bay region (Canada and Greenland) to have approximately 787,000 ringed seals. Kingsley (1998) estimated the size of the Baffin Bay ringed seal population using two methods, one based on polar bear energetic models, and another using published density data and estimates of ice areas. The polar bear model yielded a ringed seal population estimate of 1.2 million. The estimate based on sea ice type and availability and estimated ringed seal density was 697,200 hauled out seals, which would yield a similar population estimate as the polar bear predation model (1.2 million seals) (Kingsley 1998).

Aerial surveys of ringed seal in the RSA have been undertaken during the molting period (spring) when ringed seal are largely on the sea ice and easy to count (Yurkowski et al. 2018, Young et al. 2019). Yurkowski et al. (2018) noted several ringed seal hotspots throughout the RSA during the June spring molt, well ahead of the start of yearly shipping operations in July. Their results provided density estimates ranging from 0.57 to 0.79 seals/km^2 for Eclipse Sound, 0.93 to 1.27 seals/km^2 for Milne Inlet, and 0.27 to 0.77 seals/km^2 for Navy Board Inlet. Ringed seal surveys were also undertaken in June 2021 in the RSA. Results from the 2021 survey indicated that ringed seal densities are stable in Eclipse Sound and Navy Board Inlet strata and increased in Milne Inlet stratum compared to surveys flown in 2016 (Golder 2022b). Ringed seal hotspots were identified in similar geographic areas in 2021 as in 2016–2017, with hotspots in western Eclipse Sound, southern Milne Inlet and Tremblay Sound.

IQ from reported in JPCS (2017) indicated that the seal pupping season runs from February to March with seal pupping occurring throughout the RSA. Seal pups occur in the area as late as the middle of April.

> *"…seal hunting also continues in Ukiuq and seal pupping will last into March. Ringed seal pups are preferred by local Inuit and are harvested throughout Eclipse Sound."* (p.32, JPCS 2017).
>
> *"There are seal pups in the area until the middle of April."* – Elijah, 27-29 April 2015, p.165, JCPS 2017.
>
> *"There are no certain areas for seal pups; they are born everywhere. Even along the routes we travel. That is something that needs to be monitored."* - Paniloo, 27-29 April 2015, p. 171, JPCS 2017.

Harp seal

The Northwest Atlantic harp seal population was estimated at 6.8 (95% CI 5.8 – 8.0) million animals in 2017 and was projected to increase to 7.6 (95% CI 6.6 – 8.8) million animals in 2019 (Hammill et. al. 2021). Harp seal are seasonal visitors to the Arctic, arriving along the southwest coast of Greenland in late May and June (APP 1982) and then entering Lancaster Sound in July and August (Johnson et al. 1976; Greendale and Brousseau-Greendale 1976; APP 1982). Harp seal tend to enter Pond Inlet and Navy Board Inlet at the end of July (Miller 1955) with larger groups observed near the southern entrance of Navy Board Inlet and occasionally in Eclipse Sound throughout August and September (Miller 1955; Beckett et al. 2008). The number of adult harp seal entering Lancaster Sound and Eclipse Sound is variable (Tuck 1957; Greendale and Brousseau-Greendale 1976; Johnson et al. 1976; Riewe 1977, APP 1982).

IQ also notes that harp seal occur in the area, are harvested occasionally, and harp seal presence in the area has increased (JPCS 2017).

> *"The hunters and elders had some concerns during the past summer. We only saw harp seals in our area… [Jimmy]"* – Jimmy, 26–27 October, p. 177, JPCS 2017.
>
> *"... I would prefer more people hunt harp seals because we have too many. It's a change we've observed."* – Elijah, 26–27 October, p. 179, JPCS 2017.

Bearded seal

The distribution of bearded seal is largely determined by the presence of shallow water and distribution of ice (Burns 1981; Finley and Evans 1983; Kingsley 1986; Harwood et al. 2005; Kovacs et al. 2011). Bearded seal generally move into inlets and bays <200 m deep to feed during open-water periods and return to areas offshore of the floe edge in the fall once landfast ice has formed (Burns and Frost 1979). They are rarely found in fast-ice areas but are widely dispersed in open-water areas of pack ice where leads and cracks are frequent and where ice pans are sufficient for haul-out sites (McLaren and Davis 1982). No dedicated abundance survey has been completed for bearded seals in the Canadian Arctic. Fuirst et al. (2023) compiled the density and abundance estimates of bearded seals across Canadian waters after review of historic field reports and publications from aerial surveys conducted from 1974 to 2022. The density of bearded seals in Canada were highest (and highly variable) in the Beaufort Sea (0.01–8.68 seals/km^2), then in Baffin Bay-Davis Strait (0.004–8.3 seals/km^2), and lowest and less variable inter-annually in the Hudson Complex (0.02–0.12 seals/km^2; Fuirst et al. 2023). They also determined that bearded seals are more often found in areas of patchy ice cover (50–75%) with shallow water depths ≤500 m.

IQ also reported that bearded seal were associated with the distribution of ice and harvested in the Pond Inlet area.

> *"Seal hunting along the ice cracks occurs in the winter (the perennial ice cracks were indicated on the corresponding map). We hunt mainly ringed seals and occasionally bearded seals along the cracks. Seal hunting at breathing holes occurs anywhere there is ice [Jimmy/Joshua/Elijah]."* – Jimmy/Joshua/Elijah, 3-4 March 2015, p.155, JPCS 2017.
>
> *"The busiest time of the year at the Pond Inlet floe edge is June; but it is used all the time when there is ice. It is always busy. It can be used up to July. May is also very busy. Walrus come through during this season, but not often. Bearded and ringed seals are here at the floe edge too."* – Anonymous, 3-4 March 2015, p.156, JPCS 2017.
>
> *"We go to the south coast of Bylot Island, west of Pond Inlet, to hunt seal. That's where it is busiest. We hunt ringed, bearded, and sometimes hooded seals. We don't hunt harp seals. Ringed seals are the most popular. Hooded seals are rare but we sometimes get them [Paniloo]."* – Paniloo, 3-4 March 2015, p. 154, JPCS 2017.
>
> *"People hunt whatever they can catch. In May, hooded and bearded seals sometimes come into the area. [Joanasie]"* – Joanasie, 9-10 May 2016, p. 228, JPCS 2017.

2.0 LEG 1: EARLY SHOULDER SEASON SURVEYS

2.1 Introduction

2.1.1 Objectives

Leg 1 of the 2023 MMASP targeted a 15-day window during the early shoulder shipping season (late July) when narwhal undergo their spring migration through Eclipse Sound. The objective of the Leg 1 surveys was to collect data on the presence/absence and distribution of marine mammals prior to the start of annual shipping operations in the RSA and relative to ice conditions at this time of year.

2.2 Survey Team and Training

Leg 1 of the 2023 MMASP took place over a 15-day period (19 July to 2 August 2023) using a single survey aircraft based out of the Mary River mine site. The survey team consisted of personnel that flew MMASP surveys in previous years (2019, 2020, 2021 and 2022) including two WSP marine biologists / Marine Mammal Observers (MMOs), one third-party MMO contractor, two Inuit MMOs and two pilots (Figure 2).

Prior to mobilization, the survey team attended a Baffinland orientation held at the Mary River mine site on 20 July 2023. The orientation aimed to familiarize team members with Baffinland's health and safety policies and procedures while working at Mary River. Following the Baffinland orientation, a training session was held with the survey team to review the contents of the training manual and the Program health and safety plan.

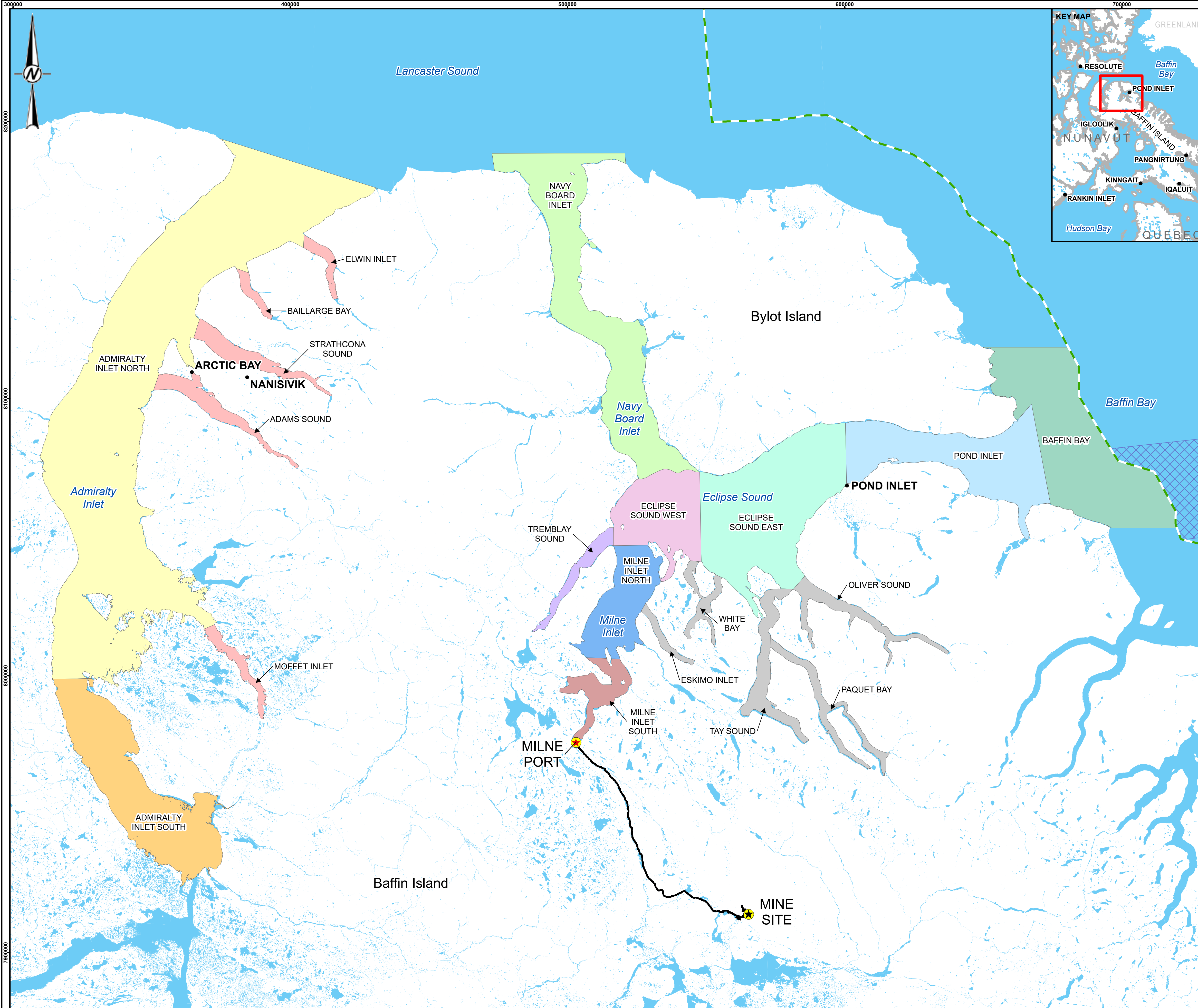
Figure 2: 2023 Marine Mammal Survey Team — Leg 1.

2.3 Study Area and Design

The study area for the Leg 1 surveys was based on the boundaries used in previous surveys from 2013 to 2016 (DFO 2017; Golder 2017), with an additional stratum in Baffin Bay added in 2019 and surveyed from 2019 to 2022 (Figure 3; Golder 2020a, 2021a, 2022c, 2023a). Leg 1 was designed to collect data on the presence/absence and distribution of marine mammals prior to the start of annual shipping operations in the RSA and relative to ice conditions at this time of year (Figure 4). Two surveys were flown in Admiralty Inlet on 29 and 31 July to verify narwhal presence/absence in this area.

Systematic random visual line-transect surveys were flown for all strata when conditions allowed, with the location of the first transect line randomly selected. The survey design consisted of systematically placed and evenly distributed (when possible) line transects across the survey area (Figure 4). Transects were generally straight and uniformly spaced across large waterbodies but were occasionally skewed to follow the shoreline contour. This was necessary in areas where the survey aircraft could not safely perform the turns necessary to cross waterbodies perpendicular to shorelines.

Blue transects shown in Figure 4 followed an east-west parallel line design with an inter-transect spacing of approximately 5 km in Baffin Bay, and a north-south parallel line design with an inter-transect spacing of approximately 2.6 km in Lancaster Sound. Red transects shown in Figure 4 followed a north-south parallel line design with an inter-transect spacing of approximately 8.6 km for the Eclipse Sound East and Pond Inlet strata, and an inter-transect spacing of approximately 4.3 km for the Eclipse Sound West stratum. Transects followed an east-west parallel line design with an inter-transect spacing of approximately 10 km for Navy Board Inlet due to the low occurrence of narwhal in this area based results from previous survey years. Transects followed a northeast-southwest parallel line design with an inter-transect spacing of approximately 4 km for Milne Inlet North (see Figure 4). A single transect was flown down the center of each of the fjords. In the Admiralty Inlet grid, red transects shown in Figure 4 followed an east-west parallel line design with an inter-transect spacing of approximately 8.5 km for both the Admiralty Inlet North and Admiralty South strata.



LEGEND

- COMMUNITY
- MILNE PORT
- MINE SITE
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY

GEOGRAPHIC STRATA

ADMIRALTY INLET GRID

- ADMIRALTY INLET NORTH (AIN)
- ADMIRALTY INLET SOUTH (AIS)
- ADMIRALTY FJORDS

ECLIPSE SOUND GRID

- BAFFIN BAY (BB)
- ECLIPSE SOUND EAST (ESE)
- ECLIPSE SOUND WEST (ESW)
- MILNE INLET NORTH (MIN)
- MILNE INLET SOUTH (MIS)
- NAVY BOARD INLET (NBI)
- POND INLET (PI)
- TREMBLAY SOUND (TS)
- ECLIPSE FJORDS

0 25 50

1:1,400,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. 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 CORPORATIONS

PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
GEOGRAPHIC STRATA FOR 2023 MARINE MAMMAL AERIAL SURVEYS

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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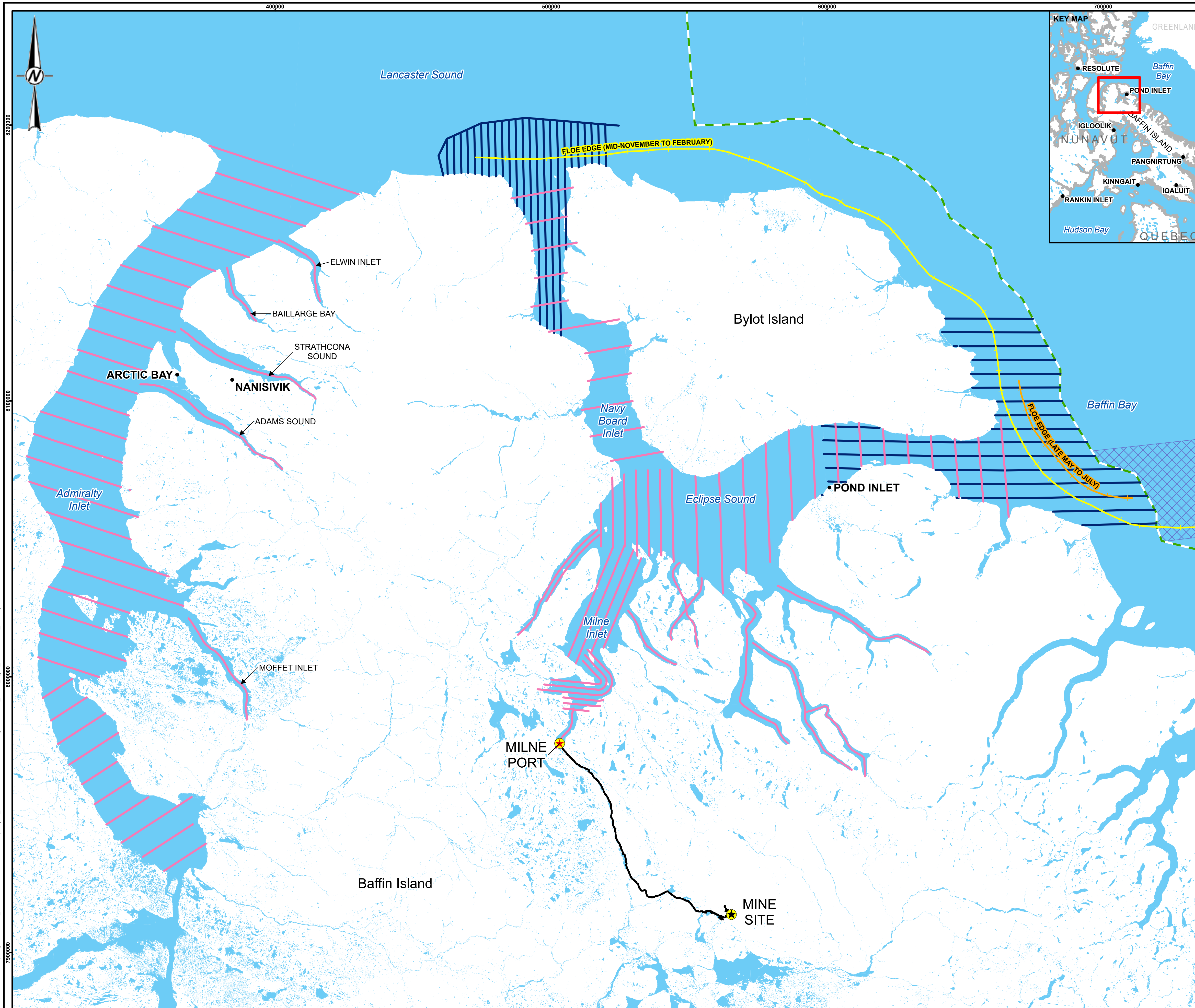

LEGEND

- COMMUNITY
- MILNE PORT
- MINE SITE
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY

FLOE EDGE (APPROXIMATE)

- LATE MAY TO JULY
- MID-NOVEMBER TO FEBRUARY

TRANSECT LINES

- FLOE EDGE ABSENT
- FLOE EDGE PRESENT

0 25 50

1:1,400,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. 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 CORPORATIONS

PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
TRANSECT LINES FOR ECLIPSE SOUND AND ADMIRALTY INLET GRIDS DURING LEG 1 SURVEYS

CONSULTANT

wsp

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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2.4 Material and Methods

2.4.1 Field Methodology

Surveys were flown in a de Havilland Twin Otter (DH-6) equipped with bubble windows and an optical glass covered camera hatch at the rear. Visual line transect surveys were conducted at an altitude of 305 m (1,000 ft) and a ground speed of 185 km/h (100 kn) with four experienced MMOs. MMOs were stationed at the front and rear bubble windows that provided a view of the track line directly below the aircraft. MMOs were instructed to focus their attention on the area closest to the track line and to use their peripheral vision for sightings farther afield. Observers counted all sightings of marine mammals by speaking into a handheld digital recorder. Sightings observed while transiting between transects or to the survey area were recorded as off-effort. Using a geometer, the perpendicular declination angle to the center of each sighting was measured once it was abeam of the observer. MMOs noted the species and number of animals in the sighting. A ‘sighting’ was defined as animals within one or a few body lengths of each other and oriented or moving in a similar direction. A sighting could also consist of one individual if no other animals are in close proximity. When time permitted, observers were instructed to give additional details on the sightings, such as the presence of calves, tusked narwhal, behaviour, and direction of travel. The two MMOs stationed on the same side of the aircraft were separated acoustically to achieve independence of their conditional detections. A fifth member of the survey team was responsible for monitoring the camera system and entering navigational data into the Mysticetus database.

Two MMOs were designated as ‘Primary’ observers and two were designated as ‘Secondary’ observers. In addition to counting animals, all observers were responsible for dictating the following environmental conditions throughout the surveys into the recorders: ice concentrations (in tenths), sea state (Beaufort scale), fog (% of field of view and intensity) and glare (% of field of view and intensity). These environmental conditions were recorded at the start and end of each transect, at regular intervals (every 2 minutes) along the transect or sooner if changes were detected throughout the transect.

Sightings recorded by the MMOs were automatically entered into the Pi Attitude program using manually-operated geometers. Geometers were linked to the Pi Attitude program, allowing observer data (i.e., date, time, location, and declination angles) to be enter electronically into the Pi Attitude program in real time. Environmental conditions recorded on audio recorders were transcribed into the Mysticetus program following completion of each survey flight.

2.4.2 Data Analysis

Animal detection rates were calculated and expressed as number of sightings/km and number of animals/km (used as a proxy for relative abundance). Observational effort was calculated relative to survey distance in linear kilometres using trackline Global Positioning System (GPS) data extracting segments of effort using start and end times recorded during surveys while on transect. Sightings were therefore expressed relative to observational effort consistent with other similar studies and methods (Nichols et al. 2005). Relative narwhal abundance was calculated using the following two methods:

1) Systematic — A pre-established grid of systematic transect lines was surveyed in areas in the RSA with <9/10 ice concentrations. This included open-water areas and areas associated with low to moderate ice cover.

2) Dedicated — Transect lines were surveyed along open-water leads associated with consolidated sea ice (≥9/10 ice concentrations), along the floe edge, along the coastline, and along the ship route.

Animal sighting rates were calculated and expressed as number of sightings/km (no. of sightings relative to survey effort in km). Animal detection rates were calculated and expressed as number of animals/km (used as a proxy for relative abundance)[5].

2.5 Leg 1 Survey Results

The 2023 early shoulder season (Leg 1) surveys were conducted in Eclipse on 23–30 July and in Admiralty Inlet on 29 -31 July, with a total of nine surveys flown during this period.

2.5.1 Ice Cover

Landfast ice was present in the RSA for the full duration of the Leg 1 surveys. During the first week of the surveys (23 to 28 July), the landfast ice extended across Eclipse Sound and north Milne Inlet, with no visible leads present in the ice (Figure 5 and Figure 6). Areas bordering the landfast ice (Pond Inlet and south Navy Board Inlet) were comprised of consolidated / very close pack ice (9/10 to 10/10 concentration). Open-water areas (1/10 to 3/10 concentration) at this time were limited to south Milne Inlet, north Navy Board Inlet and Baffin Bay.

Towards the end of the Leg 1 surveys (28 to 31 July), ice conditions in the RSA began to break-up with landfast now limited to western Eclipse Sound and consolidated / very close pack ice (9/10 to 10/10) extending across eastern Eclipse Sound, north Milne Inlet and south Navy Board Inlet (Figure 7). Open-water areas (0/10 to 3/10) at this time were limited to south Milne Inlet, north Navy Board Inlet and Baffin Bay. In Admiralty Inlet, ice conditions ranged from close pack ice (7/10 to 8/10) in the north to consolidated / very close pack ice (9/10 to 10/10) in the middle reaches of the inlet with some open-water areas in the south (Figure 7).

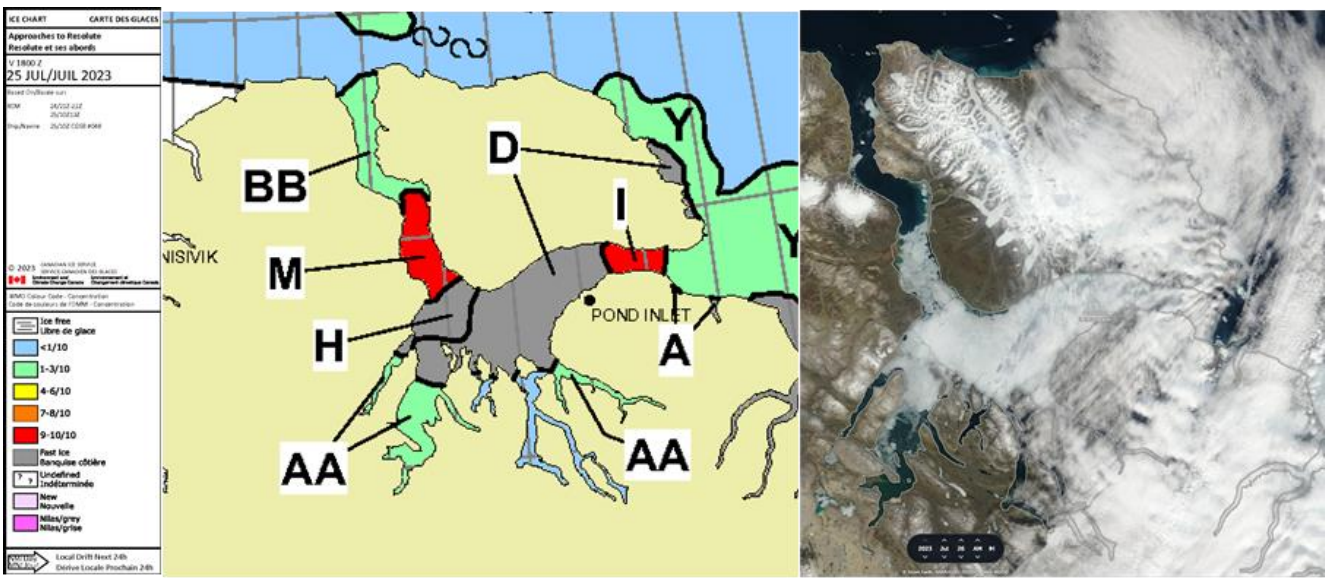


Figure 5: Ice chart for 25 July 2023 (left; Canadian Ice Services) and satellite image (right; Zoom Earth; https://zoom.earth) showing ice conditions in Eclipse Sound area at the start of Leg 1 aerial surveys.

[5] Observational effort was calculated relative to survey distance in linear kilometres using trackline GPS data and extracting segments of effort using start and end times recorded during surveys while on transect.

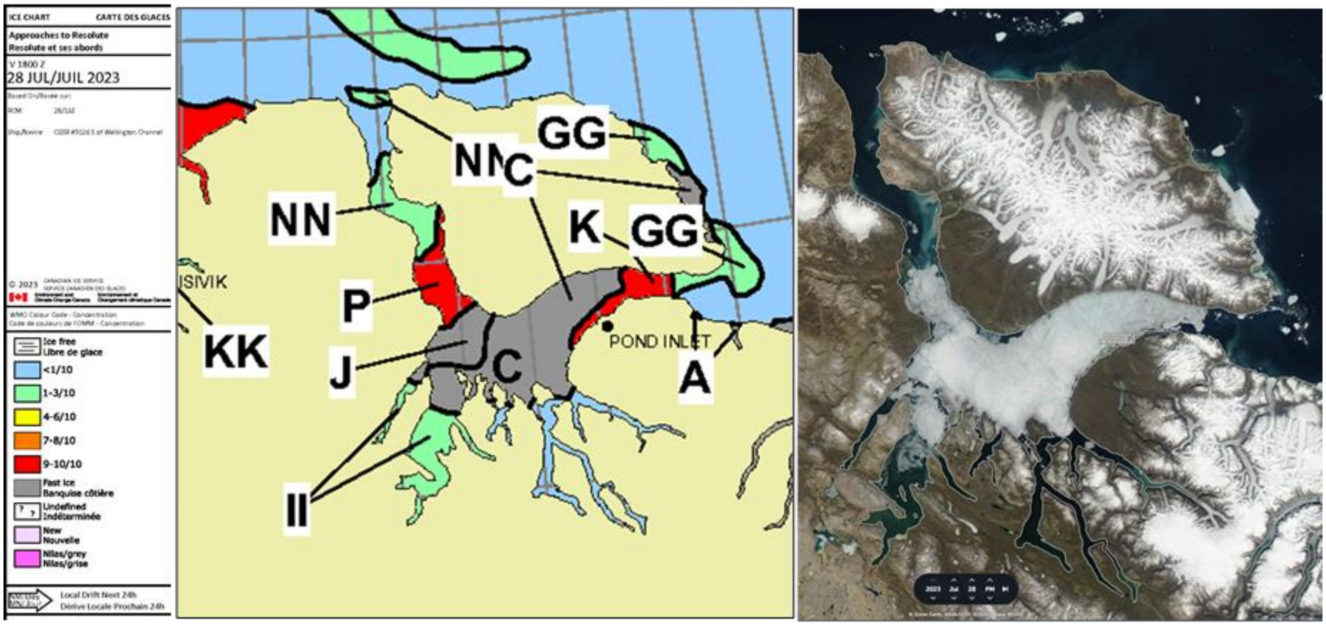


Figure 6: Ice chart for 28 July 2023 (left; Canadian Ice Service) and satellite image (right; Zoom Earth; https://zoom.earth) showing ice concentrations in Eclipse Sound at midpoint of Leg 1 surveys.

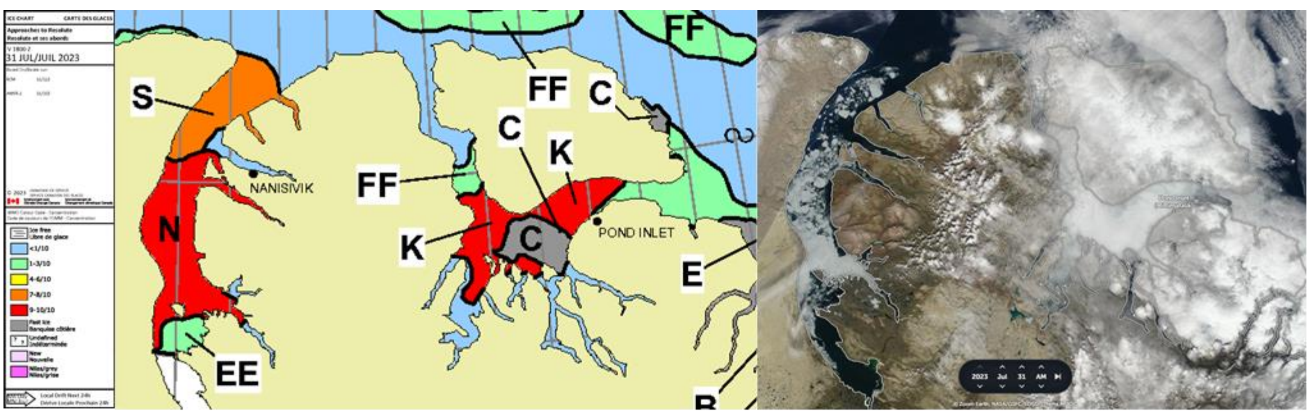


Figure 7: Ice chart for 31 July 2023 (left; Canadian Ice Service) and satellite image (right; Zoom Earth; https://zoom.earth) showing ice conditions in Eclipse Sound and Admiralty Inlet at end of Leg 1 surveys.

2.5.2 Survey Coverage

A total of nine surveys were flown during Leg 1 (see Appendix B; Figures B-1 to B-9) for a total survey effort of 4,957 km. Survey effort included three survey types: 1) systematic line transect surveys (pre-planned transects; see Figure 4) were flown in open-water and areas of mobile ice (i.e., ice floes, drift ice). 2) dedicated transects were flown along ice leads, the floe edge, and the nominal shipping lane, and 3) general reconnaissance flights (Table 2). Total survey effort was 3,688 km for the systematic line transect surveys, 812 km for the dedicated surveys and 458 km for the reconnaissance surveys.

Table 2: Survey effort for 2023 Leg 1 aerial surveys

Survey Stratum	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Survey 6	Survey 7	Survey 8	Survey 9
	23 July	24 July	25 July	26 July	27 July	28 July	29 July	30 July	31 July
Pond Inlet (PI)	S&D	S&D	S&D	—	S&D	S	—	S	—
Eclipse Sound East (ESE)	—	D&R	D	—	D	D	D&R	S	—
Eclipse Sound West (ESW)	—	—	—	—	D	D	D	—	—
Milne Inlet North (MIN)	—	S	R	—	S	D	S	—	—
Milne Inlet South (MIS)	—	S	R	—	—	R	—	—	—
Tremblay Sound (TS)	—	—	—	—	S	—	S	—	—
Navy Board Inlet (NB)	S&D	—	S&D	—	S	—	R	S	—
Baffin Bay (BB)	—	S	—	S	—	—	—	—	—
Lancaster Sound (LS)	—	—	S	—	—	—	R	—	—
Fjords	—	—	S	—	—	—	S	S	
Admiralty Inlet North (AIN)	—	—	—	—	—	—	S	—	S
Admiralty Inlet South (AIS)	—	—	—	—	—	—	—	—	R
Systematic transects (km)	**289.40**	**330.35**	**353.03**	**457.45**	**463.54**	**139.09**	**601.24**	**430.51**	**623.13**
Dedicated transects (km)	**76.57**	**67.83**	**178.95**	—	**103.96**	**195.64**	**188.88**	—	—
Reconnaissance (km)	—	**22.61**	**67.94**	—	—	**32.68**	**219.93**	—	**114.59**
Total Effort (km)	**365.97**	**420.78**	**599.92**	**457.45**	**567.50**	**367.40**	**1,010.05**	**430.51**	**737.72**

Note: S = systematic line transect surveys, D = dedicated transect lines, R = reconnaissance surveys

2.5.3 Sighting Conditions

MMOs onboard the aircraft recorded environmental and sighting conditions at the beginning and end of each transect and when conditions changed along the transect/flight path. Sighting conditions were recorded within the MMO field of view (within 1 km on either side of the transect line; see Appendix A) per relative distance effort**.**

Ice Cover

Ice cover ranged from 0/10 to 10/10 concentrations during Leg 1 of the 2023 MMASP (Figure 8). Ice concentrations in the RSA generally decreased throughout Leg 1 (23 to 31 July) (Figure 5 to 7; Appendix B, Figures B-1 to B-9), although landfast ice was present in some portions of the RSA for the full duration of the Leg 1 surveys. Approximately 54% of total survey effort occurred in areas of <1/10 ice concentrations, while approximately 15% of total survey effort occurred in areas of 9/10 to 10/10 ice concentrations.

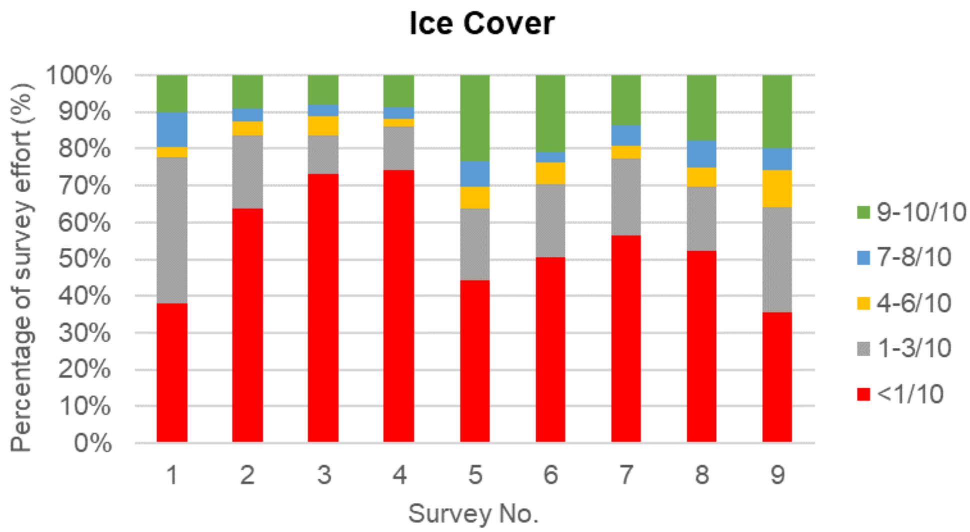


Figure 8: Ice concentrations in RSA during Leg 1 of the 2023 MMASP.

Fog

Sighting conditions included two separate fog categories: fog cover which represents the percent cover of fog (0–100%) obscuring the MMO's plane of view, and fog intensity which represents a measure of fog thickness. Fog intensity included the following four categories: "none" = survey periods with no fog, "light" = survey periods completed in fog where animals were still visible/detectable, "moderate" = survey periods completed in fog where animals when likely missed/undetectable, and "thick" = survey periods completed in fog when animal detections were certainly missed. Areas that were forecasted to be foggy were avoided when scheduling the daily surveys. Fog was present during three (Surveys 1, 5, and 9) of the nine surveys flown in 2023. Approximately 2% of total survey effort during the 2023 Leg 1 surveys was conducted when fog was present (Figure 9), with fog primarily consisting of light to moderate intensity during these periods (Figure 10).

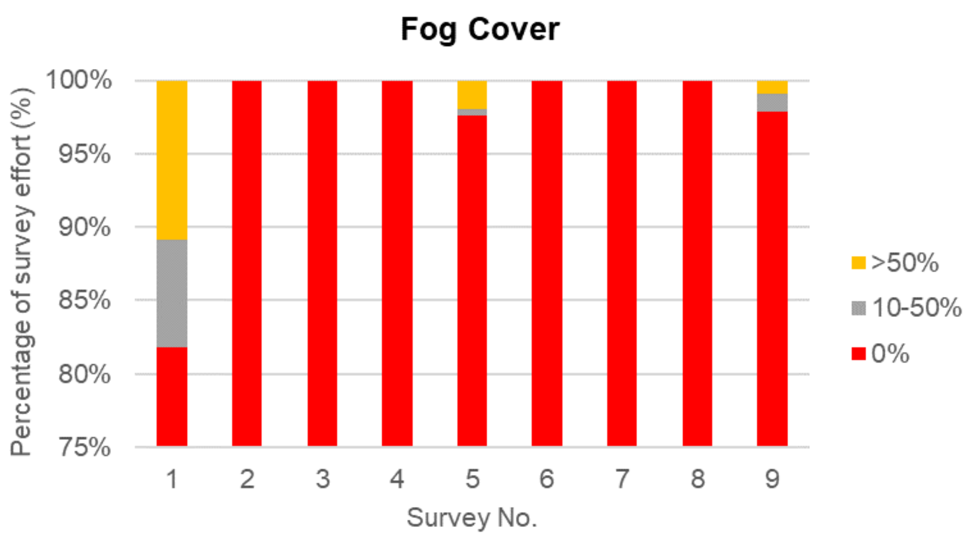


Figure 9: Fog cover during Leg 1 of the 2023 MMASP.

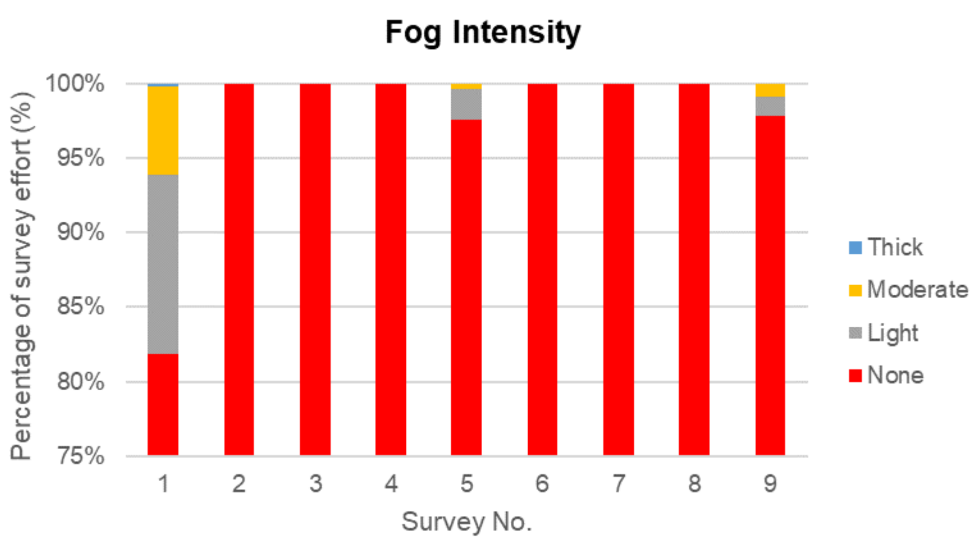


Figure 10: Fog intensity during Leg 1 of the 2023 MMASP.

Beaufort Sea State

Sea state conditions were based on the Beaufort Sea State (BF) scale (0 to 12 - see Appendix A, Table 1). Sea states during the 2023 Leg 1 surveys ranged from BF0 (glassy mirror) to BF6 (large waves) (Figure 11). Approximately 98% of total effort was undertaken in conditions ranging between BF0 and BF4 (small, fairly frequent, whitecaps). Areas forecasted to have high sea states (>BF4) were avoided when scheduling the daily surveys. Survey effort was typically suspended when sea state conditions exceeded BF4, with survey effort resuming when more favorable sea states became available along the planned transects.

High sea states have been shown to result in a negative effect on cetacean counts (DeMaster et al. 2001; Gosselin et al. 2007). DeMaster et al. (2001) found the probability of sighting beluga whales in BF1 was significantly greater than in BF2, BF3 and BF4. Gosselin et al. (2007) demonstrated that animal abundance estimates tended to be lower with increasing sea states. Lower estimates are driven by a reduction in the encounter rate associated with increasing average daily BF condition. Another effect that might be intuitively expected with increasing sea states is a reduction in the effective strip half width, as whales are likely to be less visible (i.e., harder to detect) at greater distances from the plane in poor sea conditions. During DFO narwhal surveys in Eclipse Sound and Admiralty Inlet in 2016, five surveys were prematurely terminated due to high sea states of BF4 and BF5 (DFO 2017).

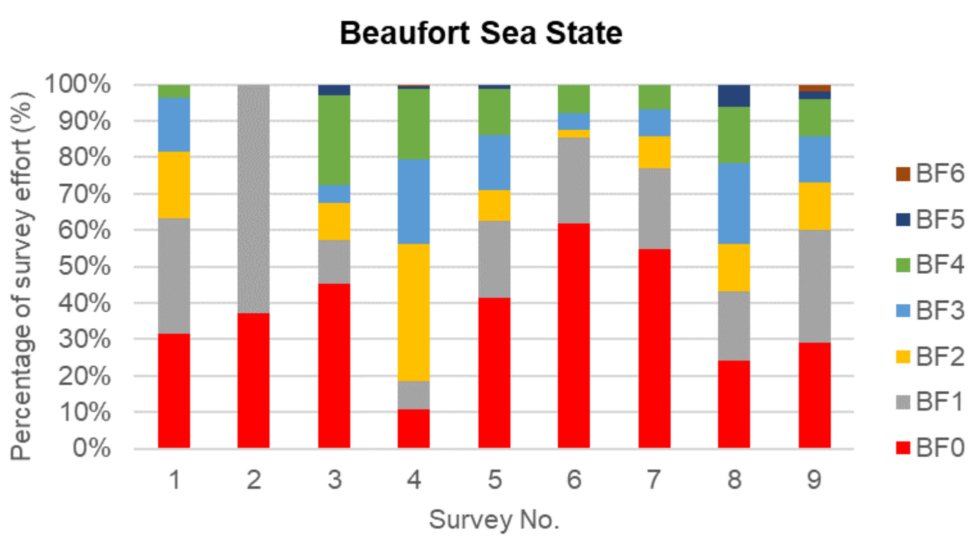


Figure 11: Beaufort Sea State during Leg 1 of the 2023 MMASP.

Glare Cover and Intensity

Sighting conditions included two separate glare categories: glare cover which represents the percent cover of glare (0–100%) obscuring the MMO's plane of view, and glare intensity which represents a measure of glare reflectiveness on the sea surface. Glare intensity included the following four categories: "none" = survey periods with no glare, "low" = survey periods completed in glare conditions where animals were still visible/detectable, "moderate" = survey periods completed in glare conditions where animals when likely missed/undetectable, and "intense" = survey periods completed in glare conditions when animal detections were certainly missed. Approximately 35% of total survey effort was undertaken when some level of glare was present (Figure 12), with periods of 'intense' glare representing approximately 25% of the total survey effort during the 2023 Leg 1 aerial surveys (Figure 13).

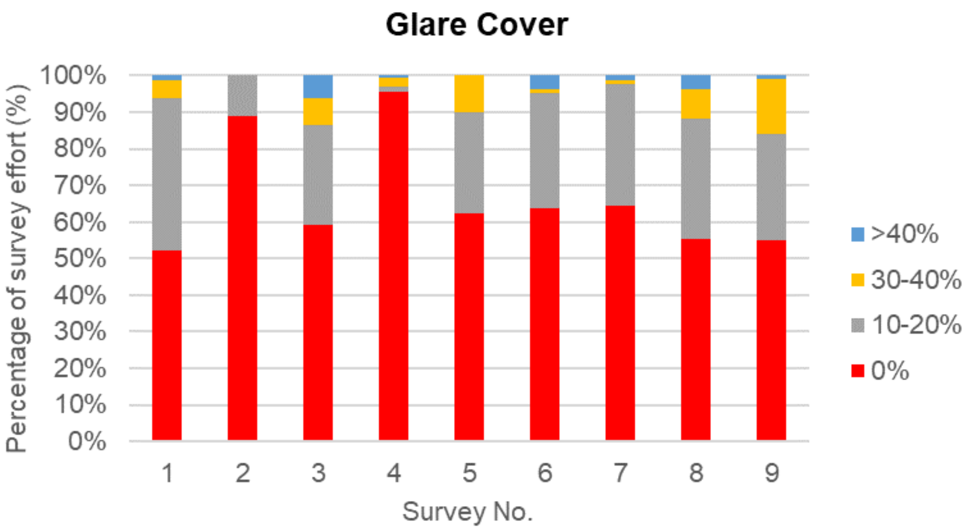


Figure 12: Glare cover during Leg 1 of the 2023 MMASP.

Figure 13: Glare intensity during Leg 1 of the 2023 MMASP.

2.5.4 Survey Sightings

Eight different marine mammal species were recorded during the Leg 1 surveys, including narwhal, bowhead whale, beluga whale, ringed seal, harp seal, bearded seal, hooded seal and polar bear. Several unconfirmed species of seal (i.e., unidentified seals) were also recorded. The total number of marine mammal sightings and number of individuals identified during Leg 1 are presented in Table 3 and Table 4, respectively. A total of 2,886 sightings comprising 8,668 animals were recorded during Leg 1. Two surveys were flown in Admiralty Inlet (29 and 31 July); all other surveys were flown in the RSA (Eclipse Sound survey grid).

Table 3: No. of sightings (including off-effort) recorded during Leg 1 aerial surveys

Survey Date	Survey Area	Narwhal	Bowhead Whale	Beluga Whale	Ringed Seal	Harp Seal	Bearded Seal	Hooded Seal	Unidentified Seal	Polar Bear	Total
23 July	RSA	216	3	—	20	55	4	—	6	2	**306**
24 July	RSA	293	4	—	16	13	2	—	4	—	**332**
25 July	RSA	523	11	—	43	78	2	—	10	1	**668**
26 July	RSA	59	—	—	2	5	—	—	5	1	**72**
27 July	RSA	239	—	—	17	52	5	—	6	3	**322**
28 July	RSA	198	3	—	18	7	—	1	6	—	**233**
29 July	RSA	3	18	—	31	10	—	—	6	1	**69**
29 July	Admiralty	247	1	—	4	2	1	—	8	2	**265**
30 July	RSA	165	5	1	25	49	4	—	8	2	**259**
31 July	Admiralty	331	3	2	10	3	—	—	8	3	**360**
Total		**2,274**	**48**	**3**	**186**	**274**	**18**	**1**	**67**	**15**	**2,886**

Table 4: No. of individuals (including off-effort) recorded during Leg 1 aerial surveys

Survey Date	Survey Area	Narwhal	Bowhead Whale	Beluga Whale	Ringed Seal	Harp Seal	Bearded Seal	Hooded Seal	Unidentified Seal	Polar Bear	Total
23 July	RSA	465	3	—	26	425	4	—	7	2	**932**
24 July	RSA	704	5	—	20	71	2	—	7		**809**
25 July	RSA	1,313	11	—	47	1,500	2	—	12	1	**2,886**
26 July	RSA	122	—	—	2	14	—	—	5	1	**144**
27 July	RSA	748	—	—	17	369	5	—	7	3	**1,149**
28 July	RSA	488	3	—	24	28	—	1	6	—	**550**
29 July	RSA	8	19	—	33	14	—	—	11	1	**86**
29 July	Admiralty	463	1	—	7	10	1	—	8	4	**494**
30 July	RSA	336	5	1	36	443	4	—	8	4	**837**
31 July	Admiralty	689	3	2	10	64	—	—	10	3	**781**
Total		**5,336**	**50**	**3**	**222**	**2,938**	**18**	**1**	**81**	**19**	**8,668**

Narwhal

Narwhal sightings in the RSA were limited to the Navy Board Inlet, Pond Inlet and Baffin Bay strata during the Leg 1 surveys, with the exception of several narwhal sightings recorded in ice leads in western Eclipse Sound near the end of the Leg 1 surveys (Figure 14). No narwhal were observed in Milne Inlet or Tremblay Sound during any of the Leg 1 surveys, presumably due to local ice conditions impeding access to these areas and/or narwhal preference to remain in areas of high ice concentration during this period.

Narwhal sightings were limited to the north end of Admiralty Inlet based on two surveys conducted on 29 and 31 July 2023 (Figure 14). A total of 1,696 sightings (comprising 4,184 individuals) were recorded in the RSA and a total of 578 sightings (comprising 1,152 individuals) were recorded in Admiralty Inlet during Leg 1 (Table 3 and Table 4). Narwhal group sizes ranged from single animals to a group size of 20, with a mean and median group size of 2.3 and 2.0, respectively. A total of 357 mother/calf pairs (227 mother/calf pairs in RSA and 130 mother/calf pairs in Admiralty Inlet grid) and 80 lone calves (37 lone calves in RSA and 43 lone calves in Admiralty Inlet grid) were recorded during the Leg 1 surveys.

Following is a summary of narwhal observations recorded on each survey during Leg 1 of the 2023 MMASP:

- **23 July**: Narwhal were concentrated in two distinct areas in the RSA; this being 1) open-water areas at the top of Navy Board Inlet and 2) consolidated pack ice waters located immediately east of the floe edge in Eclipse Sound and extending into open-water areas northeast of Pond Inlet and the entrance to Baffin Bay (see Appendix B, Figure B-1).

- **24 July**: Narwhal were observed in high numbers along the eastern edge of the floe edge in Eclipse Sound, in areas of consolidated / very close pack ice (9/10 to 10/10 concentration) in the Pond Inlet stratum, and in open-water areas in the Baffin Bay stratum (see Appendix B, Figure B-2).

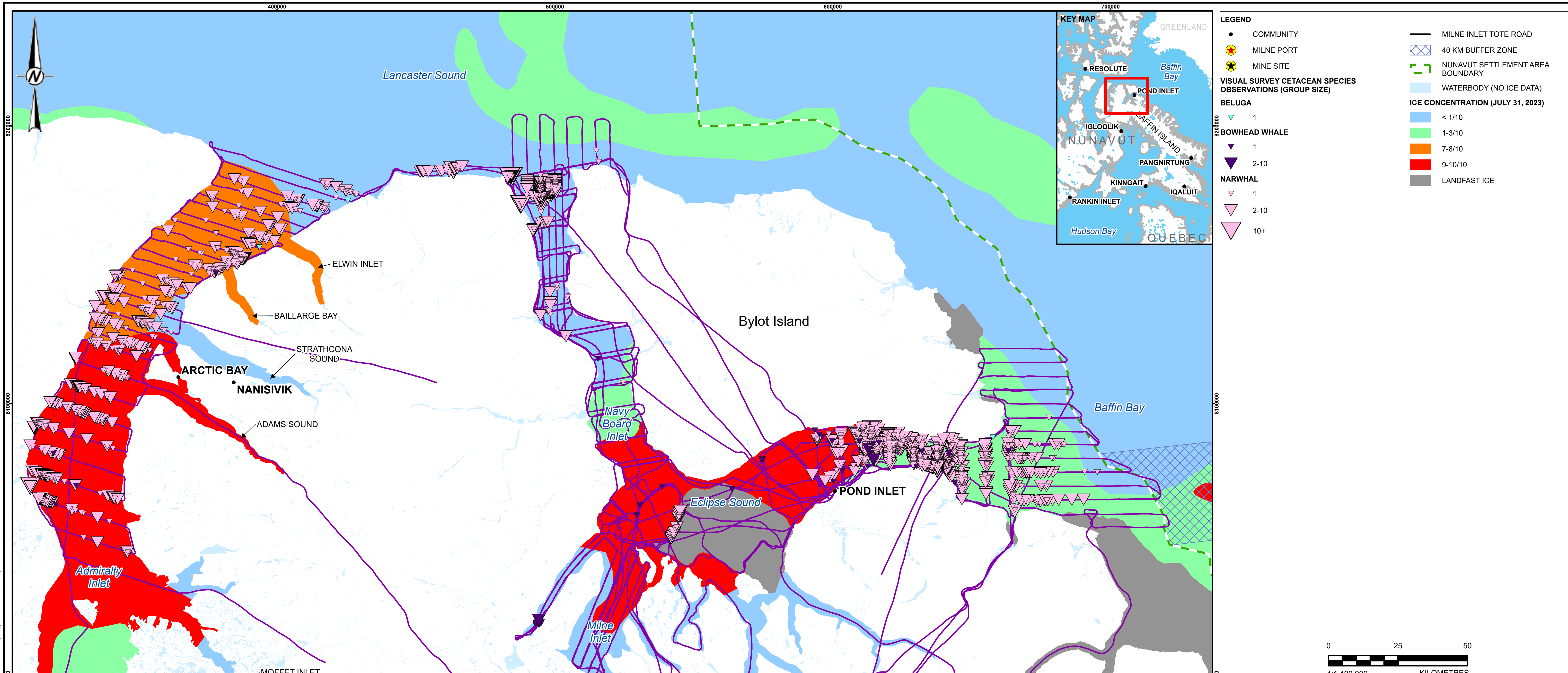
- **25 July**: Narwhal were recorded in similar high concentrations and in the same areas as observed on 23 and 24 July (north Navy Board Inlet and Eclipse Sound/Pond Inlet/Baffin Bay strata) (see Appendix B, Figure B-3).

- **26 July**: A complete survey was flown in Baffin Bay strata in excellent sighting conditions. Narwhal were concentrated in the central western portion of stratum with little to no narwhal sightings observed in north, east, or south portions of stratum (see Appendix B, Figure B-4).

- **27 July**: Narwhal distribution in north Navy Board Inlet changed from that observed during previous surveys (24 and 25 July). Narwhal occurred in similar numbers (and large group sizes) to 25 July survey, but were clumped in tight groups along the western shore of Navy Board Inlet (see Appendix B, Figure B-5). This type of distribution pattern (tight groups remaining close to shore) is commonly associated with narwhal behavioural response to killer whales (Laidre et al. 2006; Breed et al. 2017; Golder 2021a). Although no killer whales were observed on 27 July, it is possible that killer whales were in area prior to the survey. Survey conducted in western Eclipse Sound stratum recorded 27 narwhal sightings (comprising 66 individuals) in ice lead in landfast ice (see Appendix B, Figure B-5).

- **28 July**: Re-surveyed ice lead in western Eclipse Sound but only re-located four of the 66 individual narwhal recorded in the same lead the preceding day (see Appendix B, Figure B-6). No other narwhal were observed in Eclipse Sound following surveys in adjacent ice leads. Missing narwhal were presumed to have entered Navy Board Inlet. Survey conducted in Pond Inlet stratum recorded narwhal in similar numbers and in similar areas as that observed on 23, 24 and 25 July (see Appendix B, Figure B-6).

- **29 July**: Survey conducted in north Admiralty Inlet observed high concentrations of narwhal in open-water, very open drift ice (1-3/10 ice concentration) and close pack ice (7/10 to 8/10 ice concentration) (see Appendix B, Figure B-7). Narwhal were recorded on all survey transects with animals concentrated in open-water areas along eastern shoreline of Admiralty Inlet. A reconnaissance flight was flown in Lancaster Sound resulted in nine sightings of narwhal travelling westward toward Admiralty Inlet and seven sightings of narwhal engaged in resting/milling behaviour. Survey conducted in RSA (transects in Milne Inlet, Tremblay Sound, Eclipse Sound, and Navy Board Inlet) recorded a total of three narwhal sightings in north Navy Board Inlet and eastern Eclipse Sound (see Appendix B, Figure B-7). Previously observed high concentrations of narwhal in north Navy Board (on 27 July) were no longer present (possible animals departed RSA).
- **30 July**: Survey conducted in Pond Inlet stratum recorded narwhal in similar numbers and in similar areas as that observed on 23, 24, 25 and 28 July (see Appendix B, Figure B-8).
- **31 July**: Survey conducted in north Admiralty Inlet recorded high concentrations of narwhal in close pack ice (7/10 to 8/10 ice concentration) and consolidated / very close pack ice (9/10 to 10/10 ice concentration) conditions (see Appendix B, Figure B-9). Narwhal were recorded on all survey transects, with animal distribution progressing southward compared to 29 July survey. A reconnaissance survey flown in the south portion of Admiralty Inlet did not observe any narwhal south of the consolidated ice field.



REFERENCE(S)
MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023. 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 CORPORATIONS

PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
DISTRIBUTION OF CETACEANS DURING LEG 1 – JULY 2023

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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Bowhead whale

A total of 48 bowhead whale sightings (comprising 50 individuals) were recorded during the Leg 1 surveys (Table 3 and Table 4). Bowhead were observed in the Navy Board Inlet, Eclipse Sound, Pond Inlet, Tremblay Sound and Admiralty Inlet North strata (Figure 14). Bowhead whale group sizes ranged from single animals to a pair of animals, with a mean and median group sizes of 1.0. No mother/calf or lone calves were observed during the 2023 Leg 1 surveys.

Beluga whale

A total of three beluga sightings (comprising six individuals) were recorded during the Leg 1 surveys (Figure 14; Table 3 and Table 4). Beluga were observed in the Pond Inlet and Admiralty Inlet North strata (Figure 14). The first sighting (single animal) occured on 30 July in the Pond Inlet stratum (Appendix B, Figure B-8). The second sighting (beluga pair) and third sighting (beluga pair) occurred on 31 July in the northern portion of Admiralty Inlet (Appendix B, Figure B-9). Mean and median group size was 1.7 and 2.0, respectively.

Ringed seal

Ringed seals were regularly observed throughout the RSA and Admiralty Inlet during the Leg 1 surveys (Figure 15). A total of 186 ringed seal sightings (comprising 222 individuals) were recorded during the Leg 1 surveys (Table 3 and Table 4). Of these, 171 sightings consisted of animals in-water and 15 sightings consisted of animals on ice. Most in-water sightings consisted of single animals (158 of 171 sightings). The remaining 13 in-water sightings consisted of groups ranging from two to nine individuals. On-ice sightings consisted of groups ranging from one to six individuals with a mean and median group size of 1.8 and 1.0, respectively.

Harp seal

A total of 274 harp seal sightings (comprising 2,938 individuals) were recorded during the Leg 1 surveys (Table 3 and Table 4). The majority of the sightings occurred in north Navy Board Inlet (Figure 15). All sightings were in-water and involved groups ranging from one to 80 individuals with a mean and median group size of 10.7 and 5.0, respectively.

Bearded seal

A total of 18 bearded seal sightings (all lone individuals) were recorded during the Leg 1 surveys (Figure 15; Table 3 and Table 4). Of these, 14 sightings consisted of animals in-water and four sightings consisted of animals on ice. Bearded seal were observed in the Navy Board Inlet, Eclipse Sound, Pond Inlet, Milne Inlet, Baffin Bay, and Admiralty Inlet North strata (Figure 15).

Hooded seal

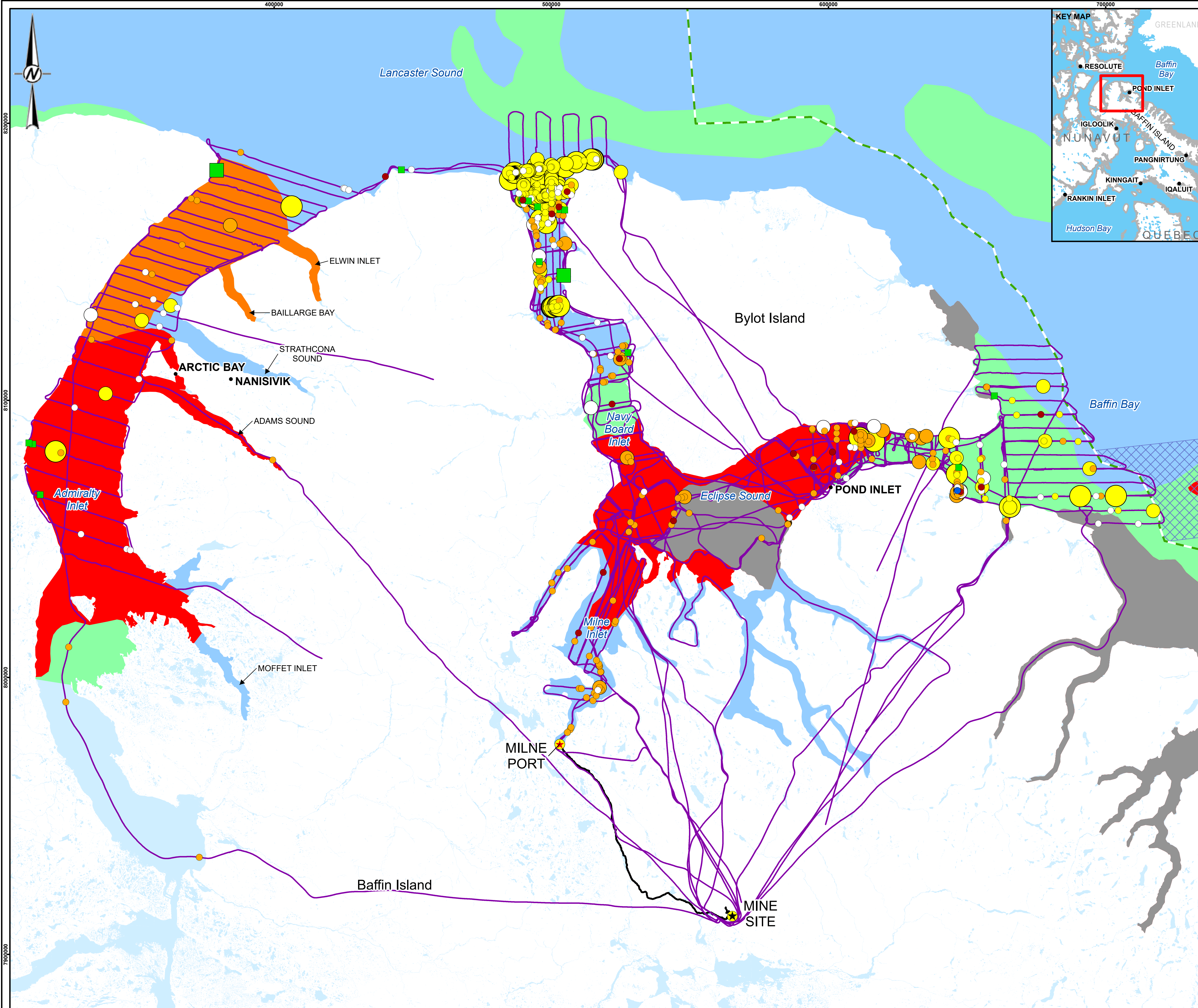
There was one sightings of an individual hooded seal recorded during the Leg 1 surveys (Figure 15; Table 3 and Table 4). The sighting occurred in the Pond Inlet stratum on 28 July (see Appendix B, Figure B-6).

Unidentified seal

Unidentified seal were observed throughout the survey area during Leg 1 surveys (Figure 15). There were 67 sightings totalling 81 seals (Table 3 and Table 4).

Polar bear

Fifteen sightings of polar bears were recorded during Leg 1 surveys (Figure 15; Table 3 and Table 4). Ten of the fifteen sightings were in the RSA (Navy Board Inlet, Pond Inlet, and Baffin Bay strata), and five of the sightings were observed in Admiralty Inlet. Thirteen sightings were of individual bears and two sightings were of a mother with two cubs. Swimming was observed for nine of the sightings, hauled out on an ice floe in one sighting, and on land for the remainder of the sightings.



LEGEND

- COMMUNITY
- MILNE PORT
- MINE SITE

VISUAL SURVEY PINNIPED SPECIES AND POLAR BEAR OBSERVATIONS (GROUP SIZE)

BEARDED SEAL
- 1

HARP SEAL
- 1
- 2-10
- 10+

HOODED SEAL
- 1

POLAR BEAR
- 1
- 2-10

RINGED SEAL
- 1
- 2-10

UNIDENTIFIED SEAL
- 1
- 2-10

- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

ICE CONCENTRATION (JULY 31, 2023)
- < 1/10
- 1-3/10
- 7-8/10
- 9-10/10
- LANDFAST ICE

0 25 50

1:1,400,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023. 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

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2023 MARINE MAMMAL AERIAL SURVEYS

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DISTRIBUTION OF PINNIPEDS AND POLAR BEARS DURING LEG 1 – JULY 2023

CONSULTANT

wsp

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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2.5.5 Relative Abundance of Marine Mammals

In 2023, a total of 4,500 km of effort (3,688 km during systematic transects and 812 km during dedicated transects) were flown over nine surveys during Leg 1 (not including reconnaissance flights). The relative abundance of marine mammals, expressed as the animal detection rate (no. of animals relative to survey effort in km) and sighting rate (no. of sightings relative to survey effort in km) were calculated for marine mammals. Table 5 provides a summary of sighting rates and animal detection rates for each species and according to survey type (systematic vs. dedicated transects). Narwhal, ringed seal and harp seal were the most abundant species during the systematic surveys while narwhal, bowhead and ringed seal were the most abundant species during the dedicated transects (Table 5). Beluga, hooded seal and polar bear were the least common species recorded during Leg 1.

Table 5: Marine mammal sighting and animal detection rates (relative abundance) during Leg 1

Species	No. of Sightings		Sighting Rate (sightings/km)			No. of Animals		Animal Detection Rate (no. animals/km)		
	Sys.[a] Tran.	Ded.[b] Tran.	Sys. Tran.	Ded. Tran.	Combined	Sys. Tran.	Ded. Tran.	Sys. Tran.	Ded. Tran.	Combined
Narwhal	1324	636	0.3590	0.7834	0.4356	2896	1574	0.7853	1.9388	0.9934
Bowhead Whale	10	19	0.0027	0.0234	0.0064	11	20	0.0030	0.0246	0.0069
Beluga Whale	2	0	0.0005	—	0.0004	2	0	0.0005	—	0.0004
Ringed Seal	116	29	0.0315	0.0357	0.0322	126	35	0.0342	0.0431	0.0358
Harp Seal	255	4	0.0691	0.0049	0.0576	2838	56	0.7696	0.0690	0.6432
Bearded Seal	12	5	0.0033	0.0062	0.0038	12	5	0.0033	0.0062	0.0038
Hooded Seal	1	0	0.0003	—	0.0002	1	0	0.0003	—	0.0002
Unknown Seal	44	7	0.0119	0.0086	0.0113	50	8	0.0136	0.0099	0.0129
Polar Bear	5	0	0.0014	—	0.0011	5	0	0.0014	—	0.0011

[a] Systematic Transects
[b] Dedicated Transects

In the RSA, narwhal relative abundance varied among the eight surveys flown ranging from 0 to 2.49 animals/km on the systematic transects and 0 to 6.37animals/km on the dedicated transects (Table 6). Two surveys were flown in Admiralty Inlet with narwhal relative abundance increasing from 0.84 animals/km on 29 July to 0.94 animals/km on 31 July (Table 6).

Table 6: Narwhal detection rates (relative abundance) per survey during Leg 1 program

Date	Survey Area	No. of Animals		Animal Detection Rate (animals/km)	
		Systematic Transects	Dedicated Transects (Leads, Floe Edge and Ship Track)	Systematic Transects	Dedicated Transects (Leads, Floe Edge, and Ship Track)
23 July	RSA	305	147	1.0539	1.2968
24 July	RSA	184	432	0.5570	6.3692
25 July	RSA	445	572	1.2605	3.1965
26 July	RSA	117	—	0.2558	—
27 July	RSA	281	399	0.6062	3.8379
28 July	RSA	346	24	2.4876	0.1227
29 July	RSA	0	0	0	0
29 July	Admiralty	333	—	0.8393	—
30 July	RSA	310	—	0.7201	—
31 July	Admiralty	575	—	0.9228	—
	Total	**2896**	**1574**	**0.7853**	**1.9388**

In the RSA, narwhal were distributed in two distinct areas: north Navy Board Inlet and eastern Eclipse/Pond Inlet/Baffin Bay. The extensive landfast ice in Eclipse Sound effectively isolated the two distribution areas from one another (see Appendix B, Figures B-1 to B-8). Table 7 presents narwhal detection rates (relative abundance expressed as animals/km) in both areas over the duration of the Leg 1 surveys. In the Eclipse Sound/Pond Inlet/Baffin Bay strata, narwhal relative abundance stayed consistently high throughout the Leg 1 surveys. In the Navy Board Inlet stratum, narwhal relative abundance was consistently high for the first three surveys but then dropped to very low numbers (0.03 animals/km) on the last survey (30 July). Survey results generally indicated that narwhal in the Eclipse Sound/Pond Inlet/Baffin Bay stratum remained in the RSA for the duration of the Leg 1 surveys, while narwhal in the Navy Board Inlet strata appeared to have departed the RSA sometime after 27 July (presumably through Lancaster Sound). Once landfast ice in Eclipse Sound began to break-up near the end of Leg 1 (27-28 July), several narwhal sightings were recorded in ice leads present in western Eclipse Sound. However, no narwhal were observed in Milne Inlet or Tremblay Sound during any of the Leg 1 surveys, presumably due to local ice conditions impeding access to these areas or narwhal preference to remain in areas of high ice concentration.

Table 7: Narwhal detection rates (animals/km) recorded in two distinct narwhal distribution areas in RSA during Leg 1 surveys

Date	Survey Area	Eclipse Sound/Pond Inlet/Baffin Bay	Navy Board Inlet
		Sys. Tran.	Sys. Tran.
23 July	RSA	1.5480	1.0185
24 July	RSA	0.7465	—
25 July	RSA	—	1.4761
26 July	RSA	0.2558	—
27 July	RSA	1.1656	1.2695
28 July	RSA	2.4876	—
29 July	RSA	—	—
30 July	RSA	1.7014	0.0312
	Total	**0.9475**	**1.0164**

2.5.6 Comparison with Previous Surveys

Calculation of relative abundance presented in this section is based solely on survey data from the systematic line transects. Sightings data collected from Admiralty Inlet in 2023 were also excluded from this analysis as 2023 was the only year data Admiralty Inlet was surveyed during the early shoulder season. The relative abundance of marine mammals in the RSA during Leg 1 was higher in 2023 (1.84 animals/km) than in 2022 (1.06 animals/km), 2021 (0.84 animals/km), 2020 (0.56 animals/km) and 2019 (0.37 animals/km; Table 8).

Narwhal relative abundance during the Leg 3 surveys increased by 15% in 2023 (0.75 animals/km) compared to 2022 (0.65 animals/km; Table 8). Much of the observed increase was influenced by the high narwhal numbers observed in north Navy Board Inlet. The relative abundance of bowhead increased by 25% in 2023 (0.0030) compared to 2022 (0.0024) but was lower than that recorded in 2019, 2020 and 2021. The relative abundance of ringed seal was lower in 2023 compared to 2021 and 2022, but higher than that recorded in 2019 and 2020. The relative abundance of harp seals in 2023 was higher than all previous survey years (2019-2022). Seal abundance data should be interpreted with caution due to the difficulty of detecting seals and confirming species type at survey altitudes of 305 m (1,000 ft above sea level), particularly in high sea states.

Table 8: Species relative abundance (animals/km) on systematic transects in RSA - Leg 1 (2019-2023)

Species	2019		2020		2021		2022		2023	
	No. of Animals	Relative Abundance (animals/km)	No. of Animals	Relative Abundance (animals/km)	No. of Animals	Relative Abundance (animals/km)	No. of Animals	Relative Abundance (animals/km)	No. of Animals	Relative Abundance (animals/km)
Narwhal	1,187	0.2952	1,431	0.3333	2,091	0.3356	1,925	0.6464	1,988	0.7452
Bowhead Whale	94	0.0234	39	0.0091	118	0.0189	7	0.0024	8	0.0030
Beluga Whale	1	0.0002	4	0.0009	3	0.0005	150	0.0504	0	0.0000
Killer Whale	10	0.0025	0	0.0000	20	0.0032	0	0.0000	0	0.0000
Unknown Whale	4	0.0010	1	0.0002	4	0.0006	1	0.0003	0	0.0000
Ringed Seal	71	0.0199	154	0.0359	568	0.0912	156	0.0524	112	0.0420
Harp Seal	102	0.0286	680	0.1584	2,306	0.3701	895	0.3005	2,764	1.0360
Bearded Seal	2	0.0006	2	0.0005	5	0.0008	3	0.0010	12	0.0045
Walrus	0	0.0000	0	0.0000	1	0.0002	0	0.0000	0	0.0000
Unknown Seal	19	0.0053	107	0.0249	107	0.0172	16	0.0054	33	0.0124
Polar Bear	1	0.0002	2	0.0005	2	0.0003	3	0.0010	3	0.0011
Total	**1,491**	**0.3709**	**2,420**	**0.5637**	**5,225**	**0.8387**	**3,156**	**1.0598**	**4,921**	**1.8446**

Note: Relative abundance = animals/km (corrected for survey effort in km)

2.6 Discussion

2.6.1 Narwhal

The main objective of the Leg 1 aerial surveys in 2023 was to obtain data on the relative abundance and distribution of marine mammals in the RSA during the early shoulder season prior to the start of 2023 shipping activities and relative to ice conditions during this period. When aerial surveys began on 23 July 2023, landfast ice was still present over a large area of the RSA (see Figure 5). Landfast ice still remained in western Eclipse Sound during the last survey conducted on 30 July 2023 (see Figure 7; Appendix B, Figure B-8). The first inbound transit in the RSA by a Project vessel occurred on 9 August.

Throughout Leg 1 surveys, narwhal were distributed in two distinct areas; 1) north Navy Board Inlet, and 2) eastern Eclipse/Pond Inlet/Baffin Bay (Appendix B, Figure B-1). The extensive landfast ice in western Eclipse Sound effectively isolated these two areas from one another. In the Eclipse Sound/Pond Inlet/Baffin Bay strata, narwhal distribution remained static during Leg 1, in that no westward migration by narwhal occurred as observed in previous years. This was likely due to the presence of extensive landfast ice in Eclipse Sound that persisted for the duration of Leg 1, presumably impeding any westward movement of animals through the fast ice in Eclipse Sound and into Milne Inlet and Tremblay Sound. In the Navy Board Inlet stratum, narwhal occurred in large numbers in north Navy Board Inlet during the first three surveys (23, 25 and 27 July), with numbers dropping substantially during the last two surveys (29 and 30 July). Survey results generally indicated that narwhal in the Eclipse Sound/Pond Inlet/Baffin Bay stratum remained in the RSA for the duration of the Leg 1 surveys, while narwhal in the Navy Board Inlet strata appeared to have departed the RSA sometime after 27 July (presumably through Lancaster Sound).

Narwhal distribution during the 2023 Leg 1 surveys differed from previous years (2019-2022) in that the westward migration of narwhal through Eclipse Sound and into Tremblay Sound and Milne Inlet was not observed during the Leg 1 survey period, likely due to the presence of extensive landfast ice in Eclipse Sound. For the duration of Leg 1 in 2023, narwhal distribution in eastern Eclipse Sound and Pond Inlet remained static with little westward movement of animals into western Eclipse Sound. In Navy Board Inlet, narwhal were observed in high concentrations at the top of the Inlet during the initial Leg 1 surveys, with numbers decreasing to just a few individuals by the end of the Leg 1 surveys. A similar pattern was observed in Navy Board Inlet during the three previous survey years (2019, 2020, and 2022).

Narwhal distribution in the RSA during 2021 and 2022 were similar in that, not long after aerial surveys started in both years, narwhal distribution shifted from the Pond Inlet and eastern Eclipse Sound strata to the western Eclipse Sound stratum and eventually into Tremblay Sound and Milne Inlet (Golder 2020a, 2021a, 2022c). By the start of the shipping season in both 2021 (24–26 July) and 2022 (30 July), narwhal had progressed further into the RSA than the two years prior with most narwhal concentrated in Milne Inlet South and Tremblay Sound. In 2019 and 2020, narwhal were distributed throughout Eclipse Sound and Milne Inlet at the start of the shipping season with some differences in dispersal patterns of groups between those years. Ice concentration was likely the main factor driving the differences in distribution and dispersal patterns between years.

In 2019, sea ice remaining in the RSA during the start of the Leg 1 surveys and prior to the start of icebreaking (17 July) was comprised mostly of loose, open drift pack ice allowing narwhal to disperse throughout the Eclipse Sound area and into adjacent fjord waterways (Golder 2020a). In 2020, sea ice remaining in the RSA during the start of Leg 1 surveys and prior to the start of icebreaking (21 July) was largely intact (i.e., large, consolidated ice field) with a few ice leads running through it (Golder 2021a). As a result, narwhal were highly concentrated in several prominent ice leads in Eclipse Sound in 2020, forming a more clumped distribution compared to 2019, 2021, and 2022. No Project-related icebreaking occurred during the early shoulder season in 2021 or 2022 and operational shipping did not begin in these years until ice concentrations were no greater than 3/10 along the entire Northern Shipping Route. In 2021, project vessels entered the RSA on 24–25 July (two tugs) and 26 July (MSV *Botnica* and one ore carrier) (Golder 2022a). In 2022, project vessels entered the RSA on the evening of 30 July and were preceded by non-Baffinland vessels that entered and exited the RSA since as early as 21 July 2022. By the time shipping started in both years (2021 and 2022), narwhal had already traveled through the RSA and were concentrated in the Tremblay Sound and Milne Inlet South strata. In 2023, landfast ice was present in the RSA for the duration of the Leg 1 surveys. As a result, narwhal were highly concentrated east of Pond Inlet and at the top of Navy Board Inlet. Project vessels did not enter the RSA during the Leg 1 surveys.

Nine aerial surveys (systematic and dedicated surveys) were conducted during the 2023 Leg 1 surveys (see Table 2). Relative abundance estimates were calculated for all marine mammals observed during the early shoulder season for both systematic and dedicated transects (Table 5). Narwhal had the highest relative abundance (0.78 animals/km) of all marine mammals observed during systematic transects. The lowest relative abundance of narwhal was observed on 29 July when no narwhal were observed on effort (see Table 6). The highest relative abundance of narwhal on systematic transects was on 28 July with 2.49 animals/km in the Pond Inlet stratum. The highest relative abundance along dedicated transects was on 24 July with 6.37 animals/km again in the 9-10/10 ice concentrations in the Pond Inlet stratum. Narwhal detection rates indicate narwhal in the Eclipse Sound/Pond Inlet/Baffin Bay stratum remained in the RSA for the duration of the Leg 1 surveys, but narwhal in the Navy Board Inlet strata appeared to have left the RSA after the 27 July.

In the RSA, narwhal relative abundance for systematic surveys varied between surveys from 0 to 2.49 animals/km (see Table 6) in 2023. In previous years, narwhal relative abundance ranged from 0.03 to 0.50 animals/km in 2019 (Golder 2020a), 0 to 0.77 animals/km in 2020 (Golder 2021a), 0 to 0.68 animals/km in 2021 (Golder 2022a), and 0.10 to 2.8 animals/km in 2022 (WSP 2023a).

Calculations from systematic surveys were used to compare combined relative abundance between years from 2019 to 2023 (see Table 8). The combined relative abundance estimates from the Leg 1 systematic surveys suggested that narwhal were more abundant in the RSA in 2023 (0.74) compared to 2019, 2020, 2021, and 2022 (0.30, 0.33, 0.34, and 0.65 animals/km respectively) (see Table 8). However, the 2020 relative abundance may be higher or comparable to 2022 when considering the relative abundance estimate derived from the dedicated survey undertaken in exiting ice leads (2.09 animals/km). When combining both systematic and dedicated surveys performed in 2020, the relative abundance of narwhal in in the RSA during Leg 1 would be higher than 0.33 animals/km.

Interannual differences in narwhal relative abundance derived from the Leg 1 surveys should be interpreted with caution due to interannual variability in survey effort, survey coverage, survey timing and survey design (dedicated surveys vs. systematic surveys) primarily associated with varying ice conditions each year. For example, extensive sea ice was present in the RSA in both 2020 and 2023, and therefore the relative abundance estimates in those years were primarily based on dedicated surveys flown in existing ice leads. Survey timing was also inconsistent between years; for example, Leg 1 surveys in 2021, 2022 and 2023 started later (19, 21 and 23 July, respectively) compared to 2019 (12 July) and 2020 (10 July). Prior to the start of shipping in 2021 and 2022, narwhal had already moved through the RSA and had concentrated in Tremblay Sound and Milne Inlet which differed from 2019 and 2020 when narwhal were more evenly distributed across the RSA when shipping first started. In 2023, narwhal remained clumped in the Pond Inlet stratum for the duration of the Leg 1 surveys due to heavy ice conditions in Eclipse Sound during this time. Unlike 2020 and 2023 when Leg 1 surveys were conducted primarily in ice leads, the Leg 1 surveys in 2019, 2021 and 2022 consisted primarily of systematic surveys undertaken in open-water conditions.

For all survey years combined, the relative abundance calculation was not considered to be an accurate estimate of abundance due to uneven aerial coverage effort between surveys. Abundance calculations are considerably influenced if coverage in the survey area is not the same for all surveys. Leg 1 surveys focused on presence/absence and distribution of marine mammals prior to and during initial shipping operations. Complete and equal survey effort coverage of the RSA was not a goal of the Leg 1 surveys. Therefore, relative abundance results from the Leg 1 aerial surveys should be interpreted as a snapshot of abundance in the specific area surveyed at a particular time; it does not represent a true estimate of stock abundance. Additionally, in the spring and early summer, narwhal may migrate through the RSA to Admiralty Inlet or other summering areas, and it is not possible to determine which narwhal stay, and which simply migrate through. When narwhal do stay in the RSA, they tend to concentrate in either Koluktoo Bay or Tremblay Sound. As a result, relative abundance numbers will be higher during surveys that focus on surveying locations where narwhal are concentrated rather than suveying all areas equally.

In summary, one needs to be cautious when comparing narwhal relative abundance across years (2019-2023) as the Leg 1 surveys are subject to potential bias factors including unequal survey effort (spatial and temporal), variability in survey timing, and interannual variability in the observed population (e.g., animals from different stocks, variability in migratory movements and timing). The results of each survey should only be considered representative of that specific location on the specific date surveyed.

2.6.2 Other Marine Mammals

2.6.2.1 Cetaceans

Bowhead Whale

Bowhead were observed in low numbers in the RSA during the Leg 1 surveys in 2023 (50 individuals) and 2022 (16 individuals; WSP 2023a) compared to numbers observed in 2019, 2020, and 2021 which all exceeded 100 individuals (Golder 2020a, 2021a, 2022c). During the 2023 Leg 1 surveys, bowhead were broadly distributed throughout the RSA with observations in Pond Inlet, Eclipse Sound, Tremblay Sound, and Navy Board Inlet (see Figure 14). Bowhead whale distribution occurred more widely across the RSA in 2020-2023 compared to 2019 when bowhead were only observed in Pond Inlet and Eclipse Sound West.

The relative abundance of bowhead in the RSA in 2023 (0.0030 animals/km) was the second lowest recorded since the start of Leg 1 aerial surveys compared to 2019 (0.0230 animals/km), 2020 (0.0091 animals/km), 2021 (0.0189 animals/km) and 2022 (0.0024 animals/km).

Beluga Whale

Beluga numbers have been consistently low in the RSA during all survey years with the exception of 2022. Leg 1 surveys recorded three sightings in 2019, four in 2020, five in 2021 and one in 2023 (Golder 2020a, 2021a, 2022c). In 2022, a total of 15 beluga sightings (comprising 152 individuals) were recorded during Leg 1 (WSP 2023a). Most of these (11 of 15 sightings comprising 148 of 152 individuals) occurred on 27 July when a large aggregation of multiple groups of beluga whales was recorded near Milne Port in Assomption Harbour prior to the start of Baffinland's shipping activities. Outside of this event, all beluga sightings recorded during Leg 1 consisted of solitary animals (Golder 2020a, 2021a, 2022c; WSP 2023a). In 2007 and 2008, beluga were observed in the RSA in small numbers (three individuals in 2007 and 59 animals in 2008; Baffinland 2012). Beluga whales were not observed during Baffinland aerial surveys conducted between 2013 and 2015 (Elliott et al. 2015; Thomas et al. 2015, 2016). The relative abundance of beluga in the RSA was the highest in 2022 (0.0504 animals/km) compared to all previous Leg 1 survey years (0.0002 animals/km in 2019, 0.0009 animals/km in 2020, 0.0005 animals/km in 2021, and 0.0000 animals/km in 2023).

Killer Whale

Killer whale were not observed during the 2023 Leg 1 surveys. This is not surprising considering the amount of landfast ice present in the RSA during the Leg 1 surveys. The relative abundance of killer whales in the RSA was higher in 2019 and 2021 (0.0025 animals/km and 0.0032 animals/km, respectively) compared to 2020, 2022 and 2023 (0 animals/km for all three years). The relative abundance of killer whale sightings in the RSA in recent years (primarily during Leg 2 surveys) suggests that killer whale presence in the RSA may be increasing.

2.6.2.2 Pinnipeds

Pinniped data collected in 2019, 2020, 2021, 2022, and 2023 should be interpreted with caution due to the difficulty in observing seals at survey altitudes of 305 m (1,000 ft) ASL. Apparent differences in sighting data may result from changes in survey conditions and the ability of MMOs to identify species rather than actual changes in pinniped species numbers or distribution.

Ringed Seal

Ringed seals are known to be widely distributed throughout the RSA during the early shoulder season (Leg 1) based on MMASP survey results from 2019-2023 (Golder 2020a, 2021a, 2022c; WSP 2023a) similar to that reported during baseline aerial surveys conducted in the RSA (Elliott et al. 2015; Thomas et al. 2015, 2016). In 2020-2022, ringed seal were more concentrated in the Eclipse Sound West and Milne Inlet strata. In 2019 and 2023, ringed seal were more widely distributed throughout the RSA. The relative abundance of ringed seal was highest in 2021 (0.091 animals/km), followed by 2022 (0.052 animals/km), 2023 (0.042 animals/km), 2020 (0.036 animals/km) and 2019 (0.020 animals/km). Ringed seal sightings data provide important information on relative abundance and distribution, but do not represent reliable estimates of total abundance of ringed seal and do not directly inform on the potential effects of Project shipping on ringed seal. Systematic aerial surveys were previously completed in the RSA as part of the 2021 Ringed Seal Aerial Survey Program which included accurate estimates of ringed seal densities in the RSA. Results of this study indicated that ringed seal densities have remained stable over time, including since the onset of shipping and icebreaking activities in the RSA (Golder 2022b).

Harp Seal

Harp seal were observed throughout the northern Navy Board Inlet, Baffin Bay, and Pond Inlet strata during Leg 1 of the 2023 MMASP. This is similar to numbers observed during previous aerial surveys for the Project (Elliott et al. 2015; Thomas et al. 2015, 2016; Golder 2020a, 2021a, 2022c; WSP 2023a). Harp seal were dispersed throughout the RSA in 2019 and 2020. In 2021, 2022 and 2023, harp seal concentrations were highest in northern Navy Board Inlet. The relative abundance of harp seal in the RSA in 2023 was the highest recorded since the start of Leg 1 aerial surveys at 1.036 animals/km compared to 0.029 animals/km in 2019, 0.158 animals/km in 2020, 0.370 animals/km in 2021, and 0.300 animals/km in 2022. The differences in relative abundance between years may be attributable to the different environmental conditions observed between the years (2019, 2021 and 2022 had less ice in the survey area compared to 2020 and 2023), where the surveys were flown (only one of the five surveys was flown in the very north end of Navy Board Inlet in 2019 where the highest concentrations of harp seal were observed in other years), or it is possible that there was a greater number of harp seals in the RSA in July 2023. Harp seal numbers in the RSA were variable during aerial surveys from 2013 to 2020 (Elliott et al. 2015; Thomas et al. 2015, 2016; Golder 2020a, 2021a, 2022c). The highest count of harp seals recorded on a survey was 80 sightings totalling 1,005 individuals on 16–17 September 2014 (Thomas et al. 2015).

Bearded Seal

Similar to previous years, bearded seal numbers were low during the 2023 MMASP. A total of 17 sightings were recorded in the RSA during the 2023 Leg 1 surveys, compared to two sightings in each of 2019 and 2020, five in 2021, and three in 2022. Relative abundance was highest in 2023 with 0.0045 animals/km compared to 2019, 2020, 2021, and 2022 (0.0006 animals/km, 0.0005 animals/km, 0.0008 animals/km, and 0.0010 animals/km, respectively). Limited IQ was available regarding the overall abundance of bearded seal in the RSA. Some elders form the North Baffin region have reported a decrease in bearded seal abundance since the advent of firearms and motorized transportation (Baffinland 2010). In contrast, one elder noted that bearded seal were rare near Pond Inlet in the past but are now more frequently observed. Five of ten bearded seal observed during the Leg 1 surveys occurred in the Pond Inlet stratum.

Walrus

No walrus were recorded during the 2023 Leg 1 surveys in the RSA. Walrus have rarely been recorded in the RSA during any survey year to date. In 2014, three walrus sightings (comprising four individuals) were recorded during a survey conducted on 3–4 August (Thomas et al. 2015). In 2015, a single walrus was recorded during a survey on 31 August (Thomas et al. 2016). In 2021, a single walrus was observed in the Pond Inlet stratum (Golder 2022a). A review of available IQ indicates that walrus occur at the top of Navy Board Inlet with several established haul-out sites near the entrance to Lancaster Sound (Baffinland 2010). Community feedback indicates that walrus are more prevalent at the Navy Board Inlet floe edge than the Pond Inlet floe edge (JPCS 2017).

2.6.2.3 Polar Bear

A total of 15 polar bear sightings were recorded during the Leg 1 surveys (Figure 15; Table 3 and Table 4). Ten of the 15 sightings occurred in the RSA (Navy Board Inlet, Pond Inlet, and Baffin Bay strata), with the remaining five occurring in Admiralty Inlet. Thirteen of the 15 sightings were of solitary bears and two sightings consisted of a mother with two cubs. The distribution of polar bear in 2023 was similar to what was observed during previous aerial surveys. In the RSA, polar bears were more common in the Navy Board Inlet and Pond Inlet strata; with nine of ten sightings in 2023 occurring in these areas. The tenth sighting in 2023 occurred in the Baffin Bay strata. Because most polar bear sightings consist of on-shore sightings, these are not included in the relative abundance estimates. Relative abundance estimates include only sightings seen in-water while on active transect. Polar bear observations during aerial surveys provide some limited information on relative abundance and distribution but cannot be used to assess effects of Project shipping on polar bear or to provide a reliable estimate of population abundance.

3.0 LEG 2: ABUNDANCE SURVEYS

3.1 Introduction

3.1.1 Objectives

Leg 2 of the 2023 MMASP targeted a -week window during peak summer (August) to obtain an updated annual abundance estimate for the Eclipse Sound and Admiralty Inlet narwhal summer stocks during the open-water season. Survey design and data collection methodology previously developed by DFO (Asselin and Richard 2011; Doniol-Valcroze et al. 2015a; Marcoux et al. 2016; Matthews et al. 2017) and implemented by Golder Associates Ltd. (amalgamated under WSP Canada Inc. in January 2023) in 2019, 2020, 2021, and 2022 (Golder 2020a, 2021a, 2022c; WSP 2023a) enabled for a comparison to previously reported abundance estimates.

3.2 Survey Team and Training

Leg 2 of the 2023 aerial surveys took place from 9 to 30 August using a single survey aircraft based at the Mary River mine site. The survey team consisted of one WSP biologist / MMO, two contracted MMOs, two Inuit researchers with previous MMO experience and two pilots. The two local Inuit researchers were from Pond Inlet and Arctic Bay; both had previous MMO experience on Baffinland's aerial survey program and/or the Bruce Head Shore-based Monitoring Program in previous years.

A one-day data collection and safety training workshop was held at Mary River on 10 August 2023. The training and orientation session was led by a WSP senior marine mammal biologist. The safety component of the workshop aimed to familiarize team members with the Health and Safety Plan that was developed for the program, to review WSP's and Baffinland's health and safety policies and requirements, and to discuss general expectations for the program. The technical component of the workshop including practical (hands-on) training in observational survey procedures, data collection techniques, proper use of equipment, data recording and data entry, and post-processing of the survey data. During the training, all participants were provided with a training manual (see Appendix A) and obtained practical experience using the surveying equipment including recorders, clinometers, and geometer.

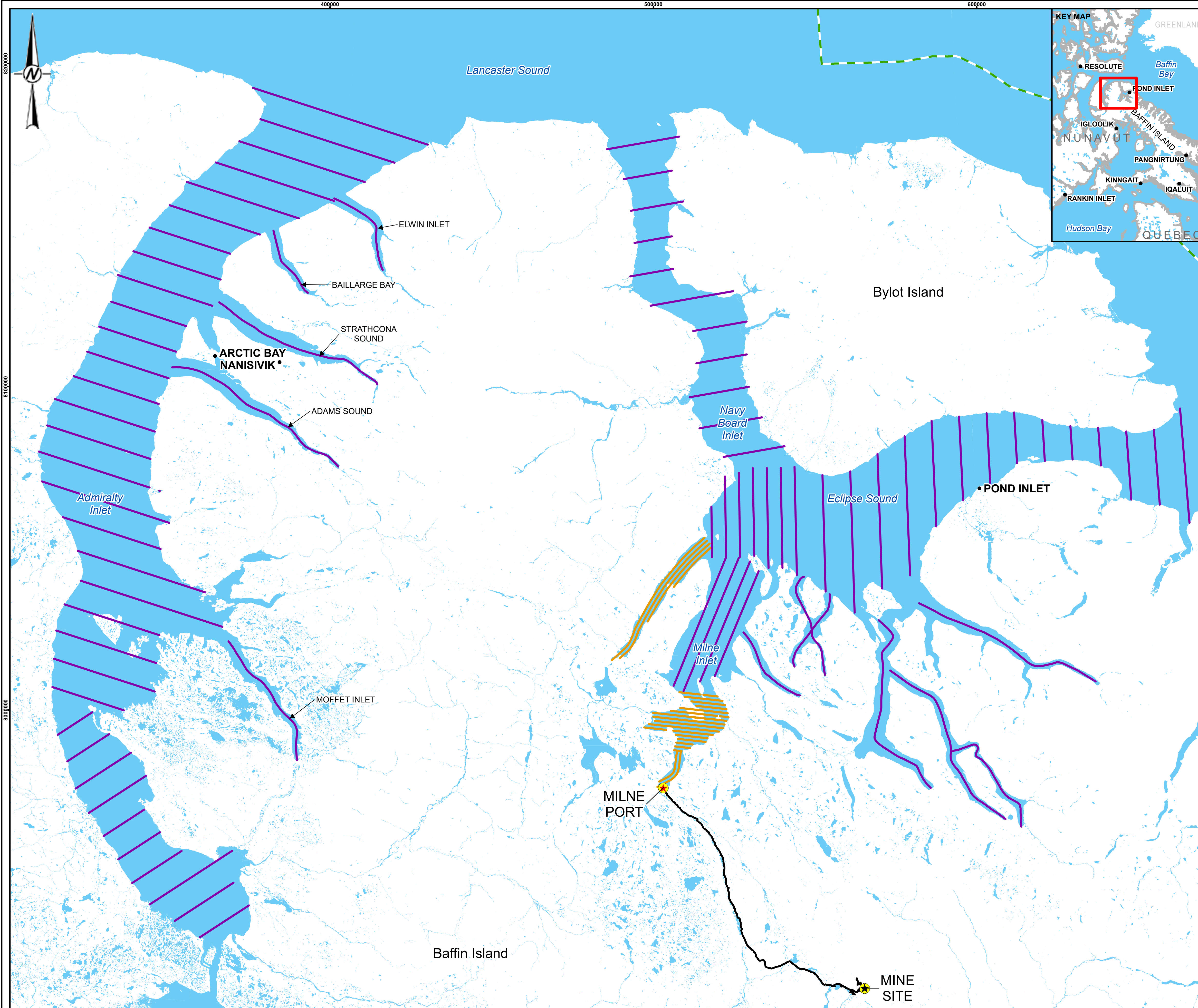
3.3 Study Area and Design

The boundaries for the Eclipse Sound grid during Leg 2 were the same as those for Leg 1 minus the Baffin Bay stratum (see Figure 3). Systematic visual observed-based line transect surveys were flown for all strata with the exception of Tremblay Sound and Milne Inlet South, which were instead surveyed using high-resolution photographic surveys as these represented areas of high narwhal concentration based on available IQ (JPCS 2017) and previous survey results (Doniol-Valcroze et al. 2015a; Elliott et al. 2015; Golder 2020a, 2021a; Marcoux et al. 2019; Thomas et al. 2015; 2016) (Figure 16). Inter-transect spacing in the RSA was similar to that described for Leg 1 (see Section 2.3). Inter-transect spacing of 1,200 m for the photographic survey allowed for lateral overlap of approximately 30% between photos from adjacent transects (see Section 3.4.1.2 for details).

Through consultation with the MEWG prior to the 2019 MMASP (Golder 2020a), the boundaries for Admiralty Inlet were divided into three strata (Admiralty Inlet North, Admiralty Inlet South, and Admiralty Fjords; see Figure 3). Systematic random visual line-transect surveys were flown for the North and South strata with the location of the first line selected at random. The survey design consisted of systematically placed and evenly distributed (when possible) line transects across the survey area (Figure 16). An east-west parallel line design, with an 8.5 km inter-transect spacing, was used to provide uniform coverage probability (Buckland et al. 2001; Figure 16). Transect lines were generally straight and uniformly spaced across the inlet, with occasional skewing to follow the shoreline contour. This was necessary in areas where the aircraft could not safely perform the turns necessary to cross waterbodies perpendicular to shorelines.

To assist with navigation along the survey tracklines and to log the flight path, an iPad was connected to a Bluetooth GPS (Bad Elf GPS Pro+) which directed information to a navigation application (Foreflight™). Foreflight utilizes current and routinely updated digital aeronautical maps. The iPad was used by the navigator/camera operator to coordinate with the flight crew. The flight crew had their own iPad (with Foreflight application) which was synced with the other iPad each time modifications to the planned survey flights were made.

In the preceding four years the Leg 2 surveys were flown (2019-2022), two aircraft were used to obtain complete coverage of the two survey grids (Eclipse Sound and Admiralty Inlet) within a two-to-three-day period. Due to a regional shortage of aircraft in 2023, only a single aircraft was available for the Leg 2 surveys and completion of the two grids within three days was not possible. To increase the odds of obtaining complete coverage of the survey grid, the Eclipse and Admiralty fjords (Figure 3) were considered second priority and were only flown if and when time allowed. In previous years, narwhal were seldom observed in the fjords systems and when they were observed in these areas, they occurred in low numbers.



LEGEND

- COMMUNITY
- MILNE PORT
- MINE SITE
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY

TRANSECT LINES

- PHOTOGRAPHIC SURVEY
- VISUAL SURVEY

0 25 50

1:1,200,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. 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 CORPORATIONS

PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
TRANSECT LINES FOR ECLIPSE SOUND AND ADMIRALTY INLET GRIDS DURING LEG 2 SURVEYS

CONSULTANT

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3.4 Materials and Methods

3.4.1 Field Methodology

3.4.1.1 Visual Survey

The Leg 2 aerial surveys were flown in a de Havilland Twin Otter (DH-6) equipped with bubble windows and an optical glass covered camera hatch at the rear. Visual line transect surveys were conducted at an altitude of 305 m (1,000 ft) and a ground speed of 185 km/h (100 kn) with four experienced MMOs. MMOs were stationed at the front and rear bubble windows that provide a view of the track line directly below the aircraft. MMOs were instructed to focus their attention on the area closest to the track line and to use their peripheral vision for sightings farther afield. Observers counted all sightings of marine mammals by speaking into a handheld digital recorder. Using a geometer (or clinometer), the perpendicular declination angle to the center of each sighting was entered once it was abeam of the observer. MMOs noted the species and number of animals in the sighting. A sighting was defined as animals within one or a few body lengths of each other and oriented or moving in a similar direction. When time permitted, observers were instructed to give additional details on the sightings, such as the presence of calves, tusked narwhal, behaviour and direction of travel. The visual surveys were conducted as a double-platform experiment with independent observation platforms at the front (primary observer) and rear (secondary observer) of the survey plane. The two MMOs stationed on the same side of the aircraft were separated acoustically to achieve independence of their conditional detections. A fifth member of the survey team was responsible for overseeing navigation along the survey grid, monitoring the camera system and entering additional sighting and environmental data obtained from the primary observers into the database.

Two MMOs were designated as ‘Primary’ observers and two were designated as ‘Secondary’ observers. In addition to counting animals, Primary observers were responsible for dictating the following environmental conditions throughout the surveys into the recorders: ice concentrations (in tenths), sea state (Beaufort scale), fog (% of field of view and intensity) and glare (% of field of view and intensity). These environmental conditions were recorded at the start and end of each transect, at regular intervals (every 2 minutes) along the transect or sooner if changes were detected throughout the transect.

The area directly below the aircraft was photographed continuously throughout each visual survey using the camera system described in Section 3.4.1.2. Photographs taken during the visual surveys were used to supplement visual sightings for missed geometer angles and group sizes.

Sightings from the MMOs were automatically entered into the Pi Attitude program by the observers using geometers during the survey. Geometers were linked to the program, allowing observer data (i.e., date, time, location and declination angles) to be enter electronically into the Pi Attitude program in real time. Files from Pi Attitude were opened in excel after the flight and additional sighting data recorded on the recorders were transcribed into the file and saved. Environmental conditions recorded on audio recorders were transcribed into the Mysticetus program after the flight. Effort along transect lengths were calculated in Mysticetus. Strata areas were determined in ArcGIS. Sightings where angles of declinations were not recorded were compared to the photographic records. The perpendicular distance was retrieved from the pixel position of the sighting on the photo if a visual sighting was identified without ambiguity on the corresponding photo. If the sighting was not made within the swath width of the picture, could not be found, or could not be identified from other sightings unambiguously, the sighting was coded as missing distance (these sightings were not used in fitting the detection function, but were added to the total count per transect, as described in Doniol-Valcroze et al. 2015a). Sightings where group size were not recorded, or were coded as ‘uncertain’, were compared to the photographic records, and group size was retrieved if a match could be made based on perpendicular distance. Otherwise, sightings with missing group size were given the average group size in that stratum (posterior to estimation of the expected group size so that it does not affect the estimation of its variance).

During visual line-transect surveys, if large aggregations (e.g., >50 narwhal or when observers indicated that they could not accurately keep up with narwhal counts) were identified during visual transects, the aircraft continued collecting visual line-transect data along transects until narwhal numbers decreased to smaller (e.g., <50) aggregations. The aircraft then ended visual line-transect survey data collection and a photographic survey was flown with complete coverage over the group to allow for accurate counts of animals. Using pre-planned survey grids, the aggregation would be photographed using a systematic grid with complete coverage as seen in Figure 16 (yellow transect lines) for the Milne inlet South and Tremblay Sound strata.

3.4.1.2 Photographic Survey

The aircraft was equipped with two identical camera systems. The systems used FujiFilm GFX 100S medium format mirrorless cameras fitted with 45 mm lens (Fujifilm 45 mm f/2.8 WR). The cameras were connected to intervalometers to control the interval time between photographs. The cameras were installed within the optical glass covered camera hatch on a custom-made mount. Images were saved directly to internal camera cards. Photos were georeferenced (using GPicSync 1.32) at the end of the field season using saved GPS logs from a Bluetooth GPS receiver (Bad Elf GPS Pro+). Cameras and computers were synched with the GPS receiver, and the GPS receiver was calibrated to barometric data provided by the pilots when available.

The cameras were oriented widthwise (long side perpendicular to the track line) and angled obliquely: one to the port side and the other to the starboard side. Each camera provided an oblique image starting at the track line, the viewing angle of each camera (α = 25°) equal to half its field of view (shown as β in Figure 17), calculated using (Covington 1985):

$$\alpha = \beta = arctan\left(\frac{SensorWidth}{FocalLength \times 2}\right)$$

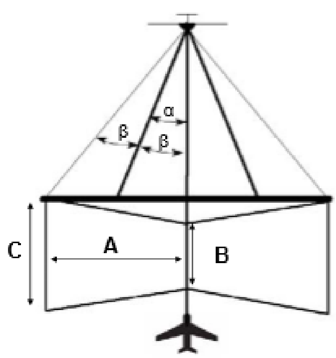


Figure 17: Geometry of oblique aerial photos (modified from Grendzdörffer et al. 2008).

Photographic surveys were conducted at an altitude of 610 m (2,000 ft) and a ground speed of 185 km/h (100 kn). Surveys were flown at an altitude of 305 m (1,000 ft) or 457 m (1,500 ft) if conditions did not allow surveying at higher altitude (610 m). The aircraft maintained appropriate altitude when flying in Simirlik National Park. Using the methods described in Grendzdörffer et al. (2008), the photograph dimensions of the two-camera system (see Figure 17) and the necessary photographic interval were calculated to allow overlap of the photos while flying at 100 knots (Table 9). The photographic interval was set to maintain an overlap (on the inside edge) of approximately 23% between consecutive photos, and with a transect spacing of 600 m (for 1,000 ft surveys) and 1,200 m (for 2,000 ft surveys), the lateral overlap between photos from adjacent transects was approximately 25%.

Table 9: Dimensions of images at three possible altitudes and image interval needed for 23% endlap

	Altitude (m)		
	305	457	610
A (m)	376	564	751
B (m)	200	301	401
C (m)	318	477	636
Interval (sec)	3	4	6

Three sets of grid lines (one for 305 m, a second for 457 m and a third for 610 m altitudes) were prepared prior to field work so a photographic survey could be coordinated within minutes of spotting an aggregation of animals.

All photographs were orthorectified at the end of the field season to create an orthophotograph prior to analysis (Figure 18). An orthophotograph is an aerial photograph that has been geometrically corrected such that the scale is an accurate representation of the earth’s surface, having been adjusted for topographic relief, lens distortion, and camera tilt.

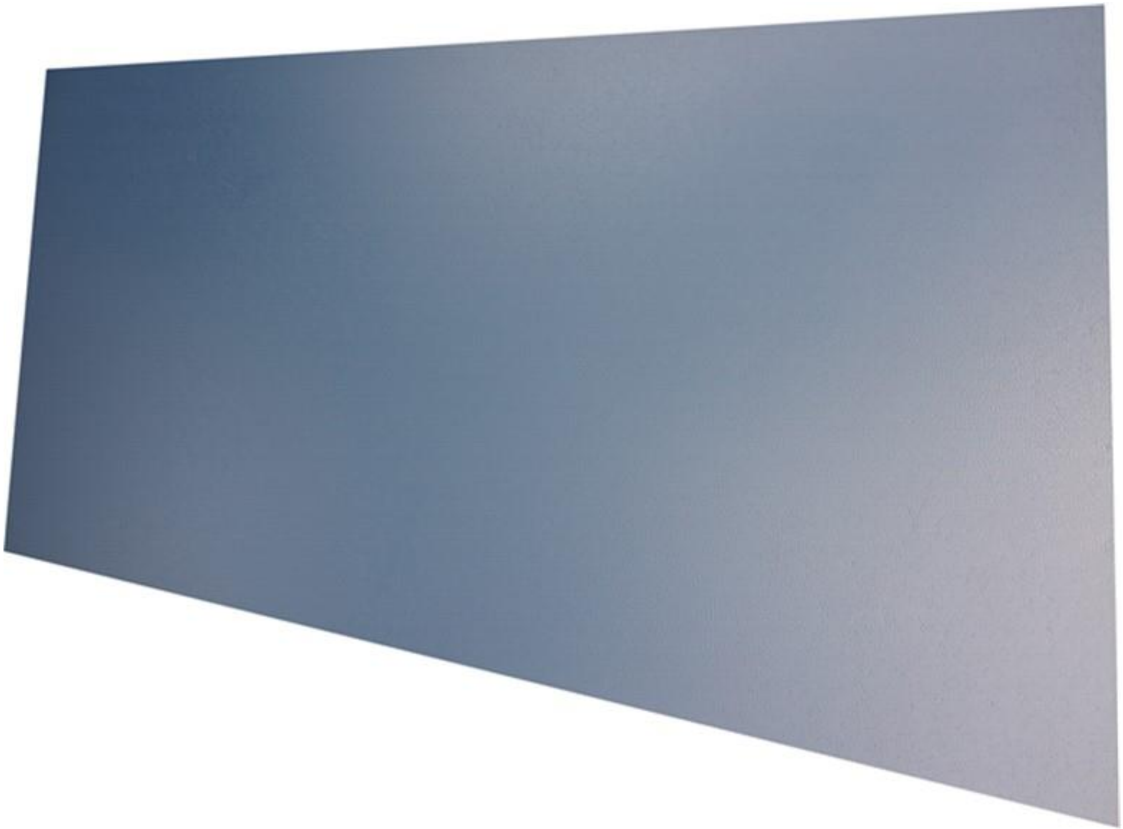


Figure 18: Orthophotograph of an image taken at 610 m (2,000 ft) in Eclipse Sound on 20 August 2020.

3.4.2 Data Analysis

An adaptive sampling plan was used for narwhal abundance estimation that combines visual line-transect sampling of the survey area and aerial photographic surveys of designated strata (Asselin and Richard 2011; Marcoux et al. 2016; Matthews et al. 2017). Animal detection rates were calculated for other marine mammal species recorded during the Leg 2 surveys and are expressed in this report as number of sightings/km and number of animals/km (used as a proxy for relative abundance).

3.4.2.1 Visual Survey

3.4.2.1.1 Distance Analysis

The standard analysis method of this design assumed that on average, over multiple replications of the survey, each point within the survey area had an equal likelihood of being sampled (uniform coverage probability). Given that the locations of the transect lines were considered random with respect to the location of marine mammals, the average density of marine mammals was considered to be the same irrespective of distance from the transect line. Subsequently, observed changes in marine mammal sightings with increasing distance from the transect line was considered a change in the probability of detection, rather than a true change in animal density. The change in detection probability with respect to sighting distance from the track line (flight path) was measured to provide an estimate of the average probability of detection of an animal, which was, in turn, used to estimate the density of marine mammals in the survey area.

Density was calculated by using the line transect estimation method (Buckland et al. 2001). In the standard approach, animal density (D) was estimated using the following equation:

$$\frac{n * f\ (0) * \hat{E}(s)}{2 * L *\ g\ (0)}$$

Where n is the number of observed objects (single or clusters of animals), f (0) is the estimated probability density function at zero distance, $\hat{E}(s)$ is the estimate of expected value of cluster size (estimated group size), L (effort) is the total length of transect lines surveyed and g (0) is the probability of detection on the transect line. Effort was calculated as total length of transect lines surveyed using trackline GPS data. Transits between transects were not included in effort calculations.

An implicit assumption of this method was that the probability of detection depended solely on an animal's perpendicular distance from the transect line. Line transect theory assumes that all animals on the transect line were detected with certainty (g(0)=1). In reality, this is an unrealistic assumption for animals that spend considerable time underwater where observers may fail to detect animals due to availability bias (animal was not detected because it was diving) (Marsh and Sinclair 1989). Correcting for availability bias requires published dive profile data to reliably estimate the proportion of time different marine mammal species spend diving (Laake et al. 1997). The most current time-series dive data collected from tagged narwhal near Arctic Bay and Pond Inlet were used to apply a correction factor for availability bias in photographic data (Watt et al. 2015; Table 10), as was used in the previous DFO narwhal abundance estimates (Doniol-Valcroze et al. 2015a; Marcoux et al. 2019). Mid-August included the period from 13 August (the earliest tagging date) until 24 August and late August included the period from 25–31 August (Watt et al. 2015). For narwhal visual surveys, correction factors (Cα) from Watt et al. (2015) tagging data were used with an additional correction for time in view and animal dive cycle applied from Doniol-Valcroze et al. (2015a) measurements (Table 10).

Table 10: Availability bias correction factors

Species	Survey Type/Date	Correction Factor	CV	Source
Narwhal	Photo / Mid-Aug	3.18	0.03	Watt et al. 2015
	Photo / Late Aug	3.16	0.03	Watt et al. 2015
	Visual / Mid-Aug	2.94	0.03	Watt et al. 2015; Doniol-Valcroze et al. 2015a
	Visual / Late Aug	2.92	0.03	Watt et al. 2015; Doniol-Valcroze et al. 2015a

Encounter rate [$\frac{n}{L}$from the equation above] was calculated as the number of marine mammal sighting per transect kilometre and was specific to each survey area. Although encounter rate was calculated (not estimated), there was a degree of variability in its value since encounter rate may vary among individual transects. Encounter rate variance was estimated using the S2 estimator available within Distance 7.3 (Fewster et al. 2009).

Group size [$\hat{E}(s)$ from equation above] was estimated to correct for observer size-bias whereby larger groups were more likely to be seen at long distances than smaller groups (or individuals). The regression of the natural log of cluster size was tested against the estimated g(x) and considered significant at an alpha level of 0.1; the value of mean group size was used for non-significant results. Distance truncation of the data was performed to remove sightings past a selected distance to remove outliers from the dataset that would otherwise inflate density and abundance estimates, and to eliminate hard-to-fit portions of the dataset.

3.4.2.1.2 Perception Bias

Distance sampling (DS) methods can be used to estimate detection probability away from the track line while assuming that detection on the track line is certain (denoted by g(0)=1). However, aerial survey observers miss some of the narwhal visible at the surface (Richard et al. 2010). This "perception bias" (Marsh and Sinclair 1989) can be corrected for by using mark-recapture (MR) methods on the sighting data from two observers on the same side of the plane (Laake and Borchers 2004). Thus, the combination of MR and DS (MRDS) methods can be used to estimate abundance without assuming that g(0)=1. The two observers in the front of the plane were considered to be the first platform and referred to as "primary observers", and the two observers in the rear were considered to be the second platform ("secondary observers").

To conduct MRDS analysis, duplicate sightings (those seen by both the primary and secondary observer) must be identified. The following criteria, based on previous DFO surveys (Asselin and Richard 2011; Doniol-Valcroze et al. 2015a), were used to identify sightings:

- Timing of sightings within 10 seconds
- Perpendicular declination angle within 10°

As MRDS analysis in Distance requires that duplicate sightings be identical, when this was not the case, the following adjustments to the data were made:

- Used the average perpendicular declination angle as measured by the two observers
- Used the largest group size as measured by the two observers
- Used group differentiation as measured by the primary observer

Although primary and secondary observers were acting independently, detection probabilities of observers can be correlated because of factors such as group size (for example, both observers are more likely to see only large groups at long distances). Buckland et al. (2009) developed a point-independence model, which assumes that detections were independent only on the track line. This model is usually more robust than a model assuming that detections were independent at all perpendicular distances.

Line-transect analyses to estimate density and abundance were performed with the MRDS package in R. A point-independence model involved estimating two functions: a multiple covariate DS detection function for detections pooled across platforms, assuming certain detection on the track line, and a MR detection function to estimate the probability of detection on the track line.

3.4.2.2 Photographic Survey

Whale Seeker, Inc. (Whale Seeker) was contracted to undertake post-survey photographic analyses. The photo analyst contracted from Whale Seeker had previous experience analysing aerial photos from DFO's 2013 aerial surveys in the RSA and Baffinland's 2019-2022 photographic surveys in the RSA. Photographs were orthorectified prior to being analysed. All narwhal within the top 2-m of the water column were included in counts.

Water clarity was subjectively evaluated in each photo and classified as either murky (water in which narwhal could only be observed at the surface) or clear (water in which narwhal could be observed down to 2 m). Each photo survey was re-analyzed by a second experienced photo analyst to evaluate reliability and repeatability. A simple linear regression was run on the comparison of the photo survey readings. Photographic readings from the original photo readers were used in the photo analysis.

Some photographic surveys have reported seeing a decrease in marine mammal detectability with increasing distance from the track line (Golder 2018b). To assess if this was occurring in the present photographic surveys, a survey was selected with no glare or land, to assess if a decrease in detectability with increasing distance from the track line was occurring. Removing re-sightings from subsequent photographs on a track line and measuring the distance from the track line for each sighting allowed assessment of detectability with increasing distance from the track line. The Distance program was used to measure a change in marine mammal sightings with increasing distance from the transect line, referred to as detection probability. The change in detection probability with respect to sighting distance from the track line (flight path) was measured to provide an estimate of the average probability of detection of an animal, which was, in turn, used to estimate the density of narwhal in the photographic survey area.

The area covered by each photograph was calculated in ArcMap (Esri) based on the orthophotograph which accounted for survey altitude, focal length of the camera sensor (45 mm), the length of the camera sensor (43.8 mm), the width of the camera sensor (32.9 mm), angle of the camera (25°), and the tilt of the aircraft. The area of land was subtracted from each photograph. On some photos, a proportion of the photo was masked by sun glare, which made it impossible for the reader to evaluate if narwhal were present. Therefore, the area of the photo covered by sun glare was measured for each photo in ArcMap (Esri) and subtracted from the photograph. When ice was present in concentrations greater than 10%, the proportion of ice was estimated and deducted from the area left after subtracting the land and glare.

Based on the methodology used in past DFO surveys (Asselin and Richard 2011; Marcoux et al. 2016; Matthews et al. 2017), the total area of a photograph A_{total} examined to detect narwhal was calculated by subtracting the area of each photograph A_{photo} from the area on land A_{land}, the area covered in sun glare A_{glare}, and area covered in ice A_{ice}.

$$A_{tot} = A_{photo} - A_{land} - A_{glare} - A_{ice}$$

The area covered by each photographic survey (A_{survey}) was determined by calculating the area of a polygon made of all the photographs merged together and removing the areas that were on land. Due to photograph sidelap and endlap, some narwhal were photographed more than once. To estimate the total number of narwhal at the surface in each survey (N_{tot}) (i.e., exclude the positive bias of double-counts), the within-photo animal density was calculated and multiplied by the total area covered by photos:

$$N_{tot} = A_{survey} * \sum_{i=1}^{I} \frac{N_{surface}}{A_{tot_i}}$$

Where:

$N_{surface}$ is the total number of narwhal detected near or at the surface in a photograph

A_{tot} = area of photo i (excluding land, sun glare and ice cover on water)

A_{survey} = total area covered by merged photos (excluding land)

I is the number of photographs per survey

The total number of narwhal in each survey was corrected for the instantaneous availability bias and detectability bias:

$$N_{cor} = N_{tot} * C_a * C_d$$

Where:

N_{tot} = is the total number of narwhal detected near or at the surface in each survey (excluding the positive bias of double-counts)

C_a = is the availability correction factor taken from Watt et al. (2015)

C_d= is the detection correction factor accounting for decreasing detectability from trackline (i.e., 1/p where p=probability of observing a narwhal in a defined area in Distance analysis)

N_{cor} = number of narwhal in the survey corrected for availability bias

The variance of the surface abundance of narwhal (N_{tot}) was calculated:

$$var(N_{tot}) = \frac{\sum(x_i - \bar{\bar{x}})^2}{N_{photos}}$$

Where x̄ is the average number of narwhal per photo, x_i is the number of narwhal for each photo and N_{photos} is the number of photographs. The coefficient of variation (CV) of the photographic count estimate (N_{tot}) was calculated (Marcoux et al. 2016; Marcoux, Pers. Comm. 2020):

$$CV(N_{tot}) = \frac{\sqrt{var(N_{tot})}}{N_{tot}}$$

The total variance of the estimate from the photographic survey was calculated following the delta method (Buckland et al. 2001):

$$var(N_{cor}) = N_{cor}^2 * \left\{\frac{var(N_{tot})}{(N_{tot})^2} + \frac{var(C_a)}{{C_a}^2} + \frac{var\ (C_d)}{{C_d}^2}\right\}$$

The CV of the estimate from the photographic survey was calculated:

$$CV(N_{cor}) = \frac{\sqrt{var(N_{cor})}}{N_{cor}}$$

3.4.2.3 Abundance Estimates

The total estimate for each Survey (N_i) was calculated by summing the estimate from the visual survey, corrected for availability bias, detectability bias and perception bias (N_{iV}), with the estimate from the photographed area, also corrected for availability bias and detectability bias (for narwhal) (N_{iP}):

$$N_i = N_{iV} + N_{iP}$$

Where N_{iP} is the abundance of whales in the photographic survey previously referred to as N_{tot} for narwhal

With variance calculated (e.g., Asselin and Richard 2011; Matthews et al. 2017):

$$var(N_i) = var(N_{iV}) + var(N_{iP})$$

The CV of the estimate from the total estimate was calculated:

$$CV = \frac{\sqrt{var(N_i)}}{N_i}$$

Confidence intervals (95%) were calculated using the lognormal method of Buckland et al. (2001):

$$(N_i/C, N_i * C)$$

Where: $C = exp\left[z_\alpha * \sqrt{var(log_e N_i}\right]$

and: $var(log_e N^*) = log_e\left[1 + \frac{var(N_i)}{N^{*2}}\right]$

The final averaged abundance estimate ($\widehat{N}_{avg}$) was calculated by combining the estimates from two surveys (Visual and Photo) using a mean weighted by effort (Buckland et al. 2001 eqn. 8.7):

$$\widehat{N}_{avg} = \frac{E_1\,\widehat{N}_1 + E_2\,\widehat{N}_2}{E_1 + E_2}$$

Where E_i is the effort calculated as the area covered by the survey i

The variance of the mean estimate is calculated as follows (Buckland et al. 2001 eqn. 8.8):

$$var(\widehat{N}_{avg}) = \frac{E_1^2\,\widehat{var}(\widehat{N}_1) + E_2^2\,\widehat{var}(\widehat{N}_2)}{(E_1 + E_2)^2}$$

3.4.2.4 Trend Analysis

3.4.2.4.1 Aerial Abundance Estimate Trend Over Time

A resampling simulation method was used to estimate the trend in stock abundance estimates over the past twenty years for three areas: Eclipse Sound, Admiralty Inlet, and the combined Eclipse Sound and Admiralty Inlet summer stock areas. The annual estimates of abundance, provided as mean and 95% confidence intervals, were assumed to have come from a lognormal distribution. This assumption was tested by assessing whether the lower and upper confidence limits provided were estimated using a single standard deviation value and a lognormal distribution. The assumption was found to be accurate for abundance estimates post-2005 (since they were generated using the Distance Sampling software) but did not hold for 2003–2004 estimates provided by DFO. The distribution used to generate these estimates was not detailed in the report (Richard et al. 2010). This may have resulted in reduced resampling variability for 2003–2004 data but is not likely to affect the overall results.

A total of 5,000 iterations were used for the analysis. In each iteration, for each sampling year, a random number was drawn from a lognormal distribution with the mean and standard deviation that were used to generate the annual abundance estimate. This resulted in a single time series of abundances in each of the three areas. These values were used to run a model where the response value was a natural log-transformed abundance and the predictor variable was sampling year, modeled using natural cubic splines to allow for non-linear trends over time. The model was run separately for each area. The significance of the effect of year (alpha = 0.05) and the regression slope at each sampling year were recorded for each iteration. This resulted in an array of 5,000 *P*-values for each area and 5,000 values of slope and its significance for each sampling year in each area. The median and 95% confidence interval around the annual slope values were calculated from the 5,000 iterations for each area, and the proportion of iterations that had a significant slope out of all 5,000 iterations was recorded and was interpreted as the probability of a significant temporal effect for that year.

3.4.3 Quality Management

To confirm data integrity, validity, and reliability, the following Quality assistance/Quality control (QA/QC) measures were undertaken:

- Data was collected and entered into the MMASP database by qualified experienced MMOs following standard field data collection methods (see Appendix A).
- Field data entries were reviewed by a different member of the MMO team for completeness and accuracy.
- Effort and area calculations were reviewed by a WSP biologist to ensure accuracy.
- A final QA/QC of the data results was done by the senior WSP biologist.

3.5 Leg 2 Survey Results

Leg 2 aerial surveys were conducted in the North Baffin area during August 2023. The objectives of the surveys were to obtain abundance estimates of narwhal during the peak open-water season (and within the appropriate time frame recommended by DFO) in both Eclipse Sound and Admiralty Inlet summer stock areas. Aerial surveys (Leg 2) were flown in the Eclipse Sound and Admiralty Inlet survey grids from 10–29 August 2023. Two surveys were flown in the Eclipse Sound survey grid and one survey was flown in the Admiralty Inlet survey grid during Leg 2. Complete coverage (excluding fjords) was obtained on one of the surveys in Eclipse Sound and partial coverage was obtained on the second survey in Eclipse Sound and the single survey in Admiralty Inlet.

3.5.1 Survey Coverage

When the Leg 2 program began on the 10 August, ice was still present in Eclipse Sound and Navy Board Inlet. A reconnaissance flight was flown over the first two days of the Leg 2 program to identify where narwhal were distributed (see Appendix B; Figures B-10). Following the reconnaissance flights, three surveys were attempted over nine days in the Eclipse Sound and Admiralty Inlet survey grids (see Appendix B; Figures B-11 to B-14). Over the course of the reconnaissance flights and the three surveys, a total of 4,376 km of survey effort was conducted which included both visual and photographic surveys (Table 11).

Eclipse Sound Grid: Visual surveys totaled 2,274 km and photographic surveys totaled 1,072 km of survey effort (Table 11). A reconnaissance flight was initially flown to assess narwhal distribution in relation to ice conditions in the RSA as ice was still present in some areas of the RSA at this time (see Appendix B; Figure B-10). Survey 1 achieved complete coverage of the survey grid in all strata except for the fjords (see Appendix B; Figure B-11). Survey 3 achieved complete coverage of the survey grid in all strata except for the fjords and a portion of the Navy Board Inlet stratum (see Appendix B; Figure B-13).

Admiralty Inlet Grid: Visual surveys totaled 843 km and photographic surveys totaled 188 km of survey effort (Table 11). Survey 2 flown in Admiralty Inlet in 2023 did not obtain complete coverage of the survey grid (see Appendix B; Figures B-12). The northern five transects were either partially flown or not flown at all due to dense fog conditions at the time of surveying. Low lying fog also affected visibility on four other transects in the survey area. The photographic survey had to be terminated early due to increasing sea states (>BF4).

Table 11: Visual (V) and photographic (P) survey effort undertaken during Leg 2

Survey Stratum	Recon	Survey 1	Survey 2	Survey 3
	10–11 Aug	12–13 Aug	19–20 Aug	23–25 Aug
Pond Inlet (PI)	—	V	—	V
Eclipse Sound East (ESE)	V	V	—	V
Eclipse Sound West (ESW)	V	V	—	V
Milne Inlet North (MIN)	V	V	—	V&P
Milne Inlet South (MIS)	—	P	—	P
Tremblay Sound (TS)	V&P	P	—	P
Navy Board Inlet (NBI)	—	V&P	—	V
Eclipse Fjords	—	—	—	V
Eclipse Visual Effort (km)	541.32	838.01	—	894.55
Eclipse Photographic Effort (km)	135.26	451.83	—	484.50
Eclipse Total Effort (km)	676.58	1,289.84	—	1,379.05
Admiralty Inlet North (AIN)	—	—	V&P	—
Admiralty Inlet South (AIS)	—	—	V	—
Admiralty Fjords	—	—	V	—
Admiralty Visual Effort (km)	—	—	842.76	—
Admiralty Photographic Effort (km)	—	—	187.84	—
Admiralty Total Effort (km)	—	—	1,030.60	—

3.5.2 Sighting Conditions

MMOs recorded environmental sighting conditions during visual surveys at the beginning and end of each transect and any time conditions changed along the track. All sighting conditions were recorded within the MMO’s field of view (1 km of the transect line). Sightings conditions were evaluated based on survey effort when each condition was observed. For calculating abundance estimates, distance analyses used the sighting conditions as covariates in the model.

Ice Cover

Ice cover ranged from 0/10 to 10/10 ice concentrations during Leg 2 of the 2023 MMASP (Figure 19). The reconnaissance flight flown in the Eclipse Sound grid at the start of the surveys had 40% of the survey effort flown in areas with ice still present in 1/10 to 10/10 ice concentrations. The first survey in the Eclipse Sound grid (1E in figure) had 3% of the survey effort flown in 1/10 to 3/10 ice concentrations, and less than 2% of the survey effort flown in 4/10 to 10/10 ice concentrations. The remaining two surveys flown in Eclipse Sound and Admiralty Inlet (2A and 3E in figure) had no ice present in the survey grids.

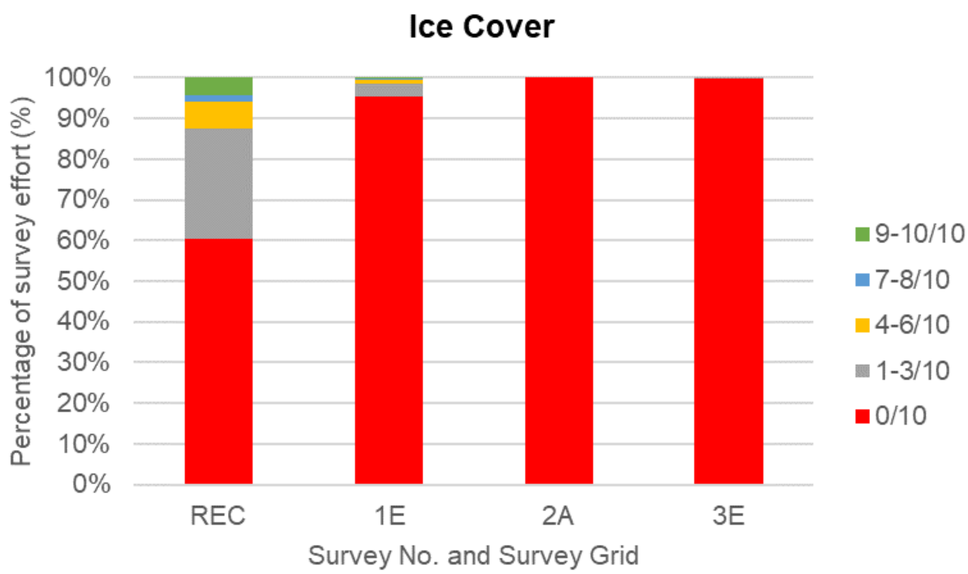


Figure 19: Ice cover during Leg 2 of the 2023 MMASP. Survey grid denoted with 'E' for Eclipse Sound and 'A' for Admiralty Inlet.

Fog

Two measurements of fog were used as sighting conditions. Fog cover was assessed as the percent (0–100%) of fog obscuring the viewing area and fog intensity (four levels: "none" when there was no fog, "light" fog that animals were visible through, "moderate" when animals were likely missed in the fog, and "thick" when animals were certainly missed in the fog). Areas that were forecasted to be foggy were avoided when daily surveys were planned. Fog cover ranged from None to 100% cover during Leg 2 of the 2023 MMASP. Fog was present during all the flights except for the last survey (i.e., Survey 3) during the 2023 Leg 2 surveys (Figure 20). Survey 2 in Admiralty Inlet had the highest percent fog cover with 15% of the survey effort flown fog (Figure 20). Most of the fog that was present on the survey was primarily of light and moderate thickness (Figure 21). Survey 2 in Admiralty Inlet had 2% of the survey effort flown in thick fog (Figure 21). Effort flown in 100% cover of thick fog are excluded from the abundance analyses.

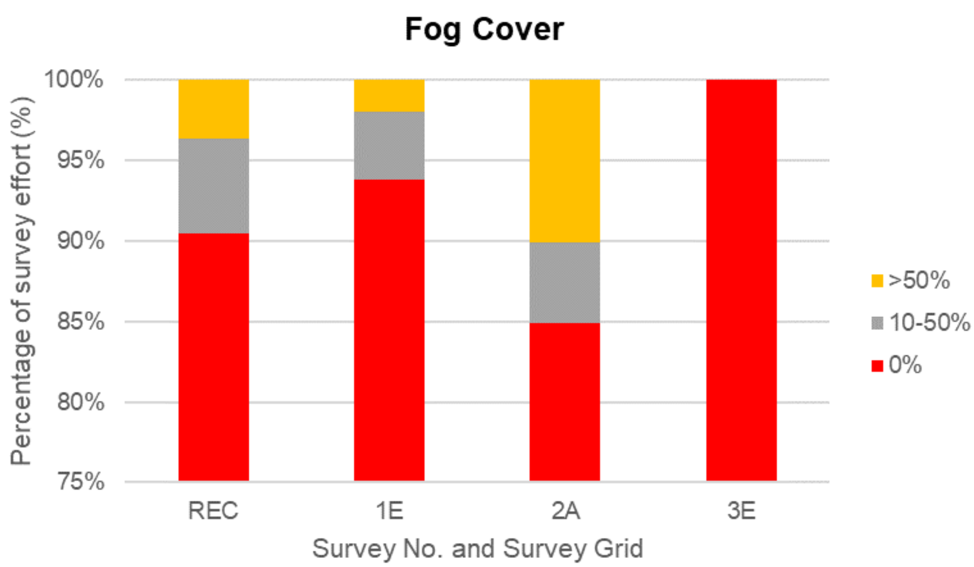


Figure 20: Fog cover during Leg 2 of the 2023 MMASP. Survey grid denoted with 'E' for Eclipse Sound and 'A' for Admiralty Inlet.

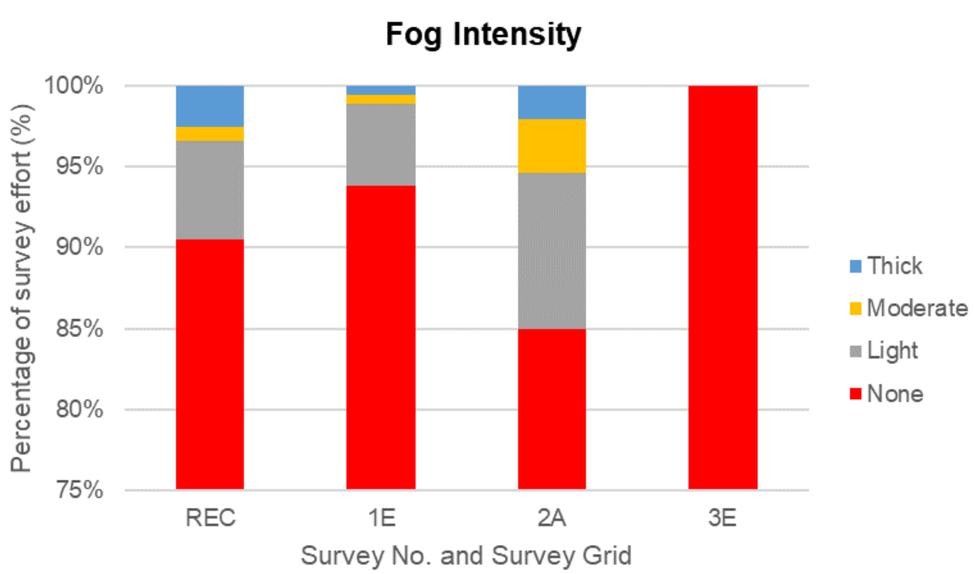


Figure 21: Fog intensity during Leg 2 of the 2023 MMASP. Survey grid denoted with 'E' for Eclipse Sound and 'A' for Admiralty Inlet.

Beaufort Sea State

On a scale of 0 to 12 (see Appendix A, Table 1), the Beaufort Sea State (BF) ranged from BF0 (glassy mirror) to BF6 (large waves) during Leg 2 of the 2023 MMASP (Figure 22). Most sea state conditions were recorded between BF0 (glassy mirror) and BF4 (small fairly frequent whitecaps) for both survey grids. Areas that were forecasted to have high sea states (>BF4) were avoided when daily surveys were planned. If sea state conditions exceeded BF4, the survey area was generally abandoned and the survey was resumed in an area with more favorable environmental sighting conditions.

High sea states have a negative effect on cetacean counts (DeMaster et al. 2001; Gosselin et al. 2007). DeMaster et al. (2001) found the probability of sightings beluga in BF1 was significantly greater than that for sighting beluga in BF2, BF3 and BF4. Gosselin et al. (2007) noted that abundance estimation tends to be lower as BF increases. The lower estimates are driven by a reduction in encounter rate associated with increasing average daily BF condition. Another effect that might intuitively be expected with increasing BF is a reduction in effective strip half width as whales may not be visible as far away from the aircraft in poor sea conditions. During aerial surveys conducted by DFO in Eclipse Sound and Admiralty Inlet in 2016, five surveys were terminated due to high sea states of BF4 and BF5 (DFO 2017). Surveys flown in areas of high sea states have a high probability of negatively biasing the number of animals present and should be excluded from the analysis if a statistically significant difference is found between two abundance estimates.

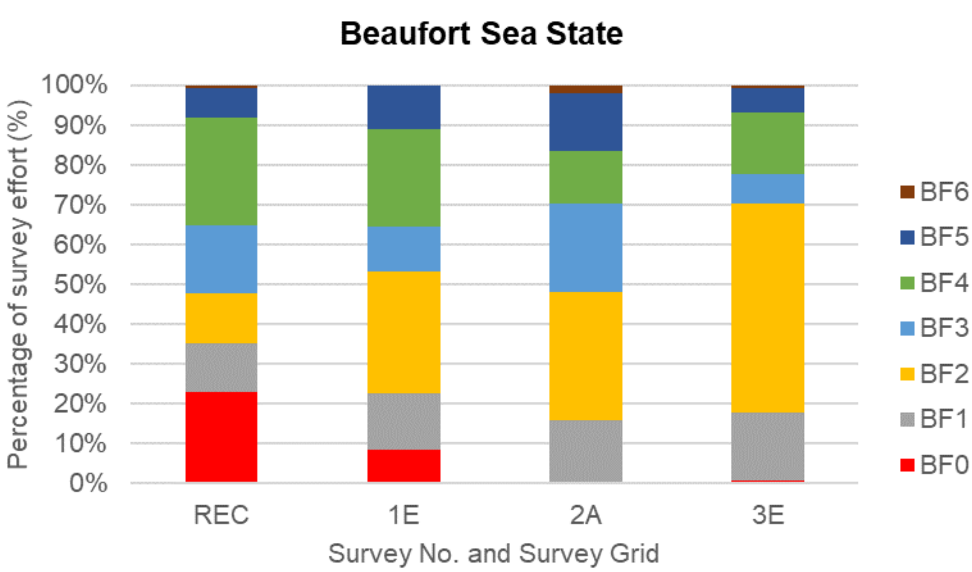


Figure 22: Beaufort Sea State during Leg 2 of the 2023 MMASP. Survey grid denoted with ‘E’ for Eclipse Sound and ‘A’ for Admiralty Inlet.

Glare Cover and Intensity

Two measurements of glare were used as sighting conditions. Glare cover was assessed as the percent (0–100%) of the viewing area affected by sun reflection and glare intensity (four levels: “none” when there was no reflection, “low” when animals were likely detected in center of reflection angle, “moderate” when animals were likely missed in the center of reflection angle, and “intense” when animals were certainly missed in the center of reflection angle). All surveys were flown during partial cloudy conditions with glare recorded as “none” for 37% to 98% of the survey effort in each survey (Figure 23). When glare was present intensity was denoted as intense for 0% to 30% of the survey effort in each survey (Figure 24).

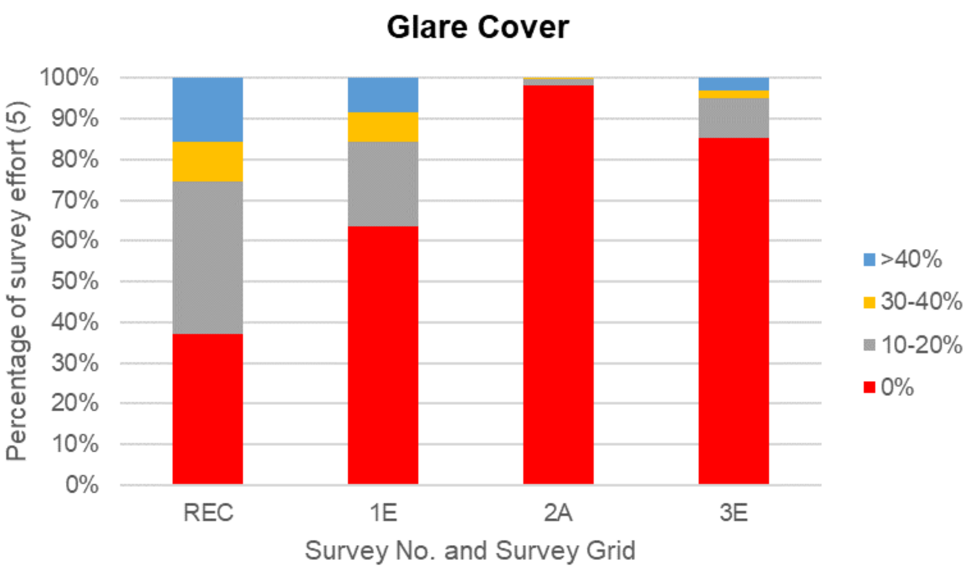


Figure 23: Glare cover during Leg 2 of the 2023 MMASP. Survey grid denoted with ‘E’ for Eclipse Sound and ‘A’ for Admiralty Inlet.

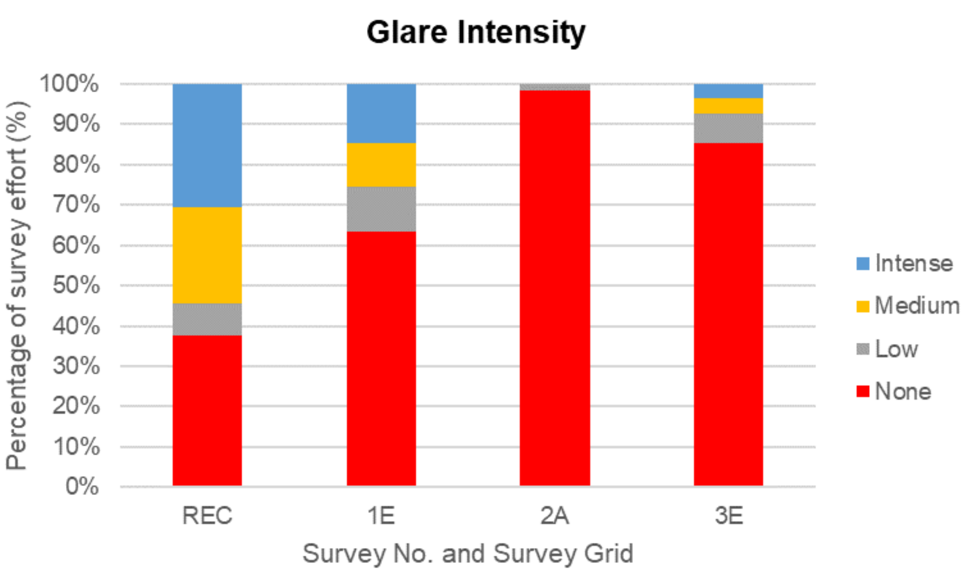


Figure 24: Glare intensity during Leg 2 of the 2023 MMASP. Survey grid denoted with ‘E’ for Eclipse Sound and ‘A’ for Admiralty Inlet.

3.5.3 Visual Survey Sightings

Eclipse Sound Survey Grid: Six different species of marine mammals were recorded in the RSA during the reconnaissance flight and two visual surveys: narwhal, bowhead, ringed seal, harp seal, bearded seal and polar bear. Unidentified seals were also recorded during the visual surveys. Visual sightings that were duplicates (i.e., sighted by both the primary and secondary observer) were only counted once and visual sightings observed in photographic areas are not included in this section to eliminate possible duplicate sightings. Table 12 summarizes the number of sightings and individuals recorded for each species during the Leg 2 aerial surveys. A total of 271 sightings (comprising 648 individuals) were recorded during Leg 2 visual surveys in the RSA. The most commonly sighted species was narwhal (140 sightings totalling 353 animals), followed by ringed seal (86 sightings totalling 92 animals), bowhead (14 sightings totalling 17 animals), harp seal (13 sightings totalling 166 animals), bearded seal (three sightings of single animals) and polar bear (two sightings totalling four animals). There were also 13 unidentified seal sightings (all solitary individuals).

Table 12: Marine mammal sightings (on- and off-effort) in Eclipse Sound and Admiralty Inlet - Leg 2 (2023)

Species	Eclipse Sound Reconnaissance		Eclipse Sound Survey 1		Admiralty Inlet Survey 2		Eclipse Sound Survey 3	
	No. Sightings	No. Animals	No. Sightings	No. Animals	No. Sightings	No. Animals	No. Sightings	No. Animals
Narwhal	97	240	9	25	348	690	34	88
Bowhead Whale	10	11	3	4	6	6	1	2
Ringed Seal	15	17	31	33	17	17	40	42
Harp Seal	0	0	8	160	36	166	5	6
Bearded Seal	0	0	2	2	0	0	1	1
Unidentified Seal	2	2	7	7	6	6	4	4
Polar Bear	1	2	0	0	4	8	1	2
Total	**125**	**272**	**60**	**231**	**417**	**893**	**86**	**145**

Admiralty Inlet Survey Grid: Five different species of marine mammals were recorded in Admiralty Inlet during the single visual survey: narwhal, bowhead whale, ringed seal, harp seal and polar bear. Unidentified seals were also recorded during the surveys. Visual sightings that were duplicates (i.e., sighted by both the primary and secondary observer) were only counted once and visual sightings observed in photographic areas are not included in this section. Table 12 summarizes the number of sightings and individuals recorded for each species during the Leg 2 aerial surveys. A total of 417 sightings (comprising 893 animals) were recorded during Leg 2 visual surveys in the Admiralty Inlet survey grid. The most commonly identified species was narwhal (348 sightings totalling 690 animals), followed by harp seal (36 sightings totalling 166 animals), ringed seal (17 sightings of single animals), bowhead (six sightings of single animals) and polar bear (four sightings totalling eight animals). There were also six unidentified seal sightings (all solitary individuals).

Narwhal

Eclipse Sound Survey Grid: During the reconnaissance survey in the RSA (10-11 August), narwhal were concentrated in Eclipse Sound where sea ice was still present, and in Tremblay Sound which was ice free (see

Appendix B, Figures B-10). During the first visual survey in the RSA (12-13 August), narwhal were no longer present in Eclipse Sound but large numbers of narwhal were recorded in Tremblay Sound and Navy Board Inlet, with several sightings also occurring in Milne Inlet South (Appendix B, Figures B-11). During the second visual survey in the RSA (23-25 August), narwhal were primarily concentrated in Tremblay Sound and Milne Inlet (Appendix B, Figures B-13). A total of 140 narwhal sightings (comprising 353 individuals) were recorded during the Leg 2 visual surveys in the RSA (Table 12). Narwhal group size ranged from single animals to a group size of 12, with a mean and median group size of 2.5 and 2.0, respectively. Forty mother/calf pairs and a pair of calves were recorded during the Leg 2 surveys.

Admiralty Inlet Survey Grid: During the only visual survey in Admiralty Inlet (19-20 August), narwhal were primarily dispersed throughout the central portion of Admiralty Inlet North with several sightings along the western shore of Admiralty Inlet South (Appendix B; Figure B-12). A total of 348 narwhal sightings (comprising 690 individuals) were recorded during the Leg 2 visual survey in Admiralty Inlet (Table 12). Narwhal group size ranged from single animals to a group size of 10, with a mean and median group size of 2.0 and 1.0, respectively. Sixty mother/calf pairs, twenty-four lone calves and three calf pairs were recorded during the surveys.

Bowhead Whale

Eclipse Sound Survey Grid: Bowhead were observed during all Leg 2 visual surveys in the RSA (Appendix B, Figures B-10, B-11, and B-13). A total of 14 bowhead sightings (comprising 17 individuals) were recorded during the Leg 2 visual surveys in the RSA. Bowhead group size ranged from single animals to pairs of animals, with a mean and median group size of 1.2 and 1.0, respectively. No mother/calf pairs were observed on the Leg 2 surveys.

Admiralty Inlet Survey Grid: Bowhead were observed during the only visual survey flown in Admiralty during Leg 2. Bowhead sightings generally occurred in the same areas that narwhal were sighted (Appendix B, Figure B-12). A total of six bowhead sightings (all solitary individuals) were recorded during the Leg 2 visual survey in Admiralty Inlet (Table 12).

Ringed Seal

Eclipse Sound Survey Grid: Ringed seals were observed during all Leg 2 visual surveys in the RSA (Appendix B, Figures B-10, B-11, and B-13). A total of 86 ringed seal sightings (comprising 92 individuals) were recorded during the Leg 2 visual surveys in the RSA (Table 12). Ringed seal sightings were primarily of single animals (81 of 86 sightings). The remaining five sightings consisted of four sightings of ringed seal pairs, and one sighting of three individuals.

Admiralty Inlet Survey Grid: Ringed seals were observed during the only visual survey flown in Admiralty during Leg 2 (Appendix B, Figure B-12). A total of 17 ringed seal sightings (all solitary individuals) were recorded during the Leg 2 visual survey in Admiralty Inlet (Table 12).

Harp Seal

Eclipse Sound Survey Grid: Harp seal were observed during two of the three Leg 2 visual surveys in the RSA, with sightings primarily occurring at the north end of Navy Board Inlet and in the Pond Inlet stratum (Appendix B, Figures B-11 and B-13). A total of 13 harp seal sightings (comprising 166 individuals) were recorded during the Leg 2 visual surveys in the RSA (Table 12). Harp seal group size ranged from one to 100 animals with a mean and median group size of 12.8 and 1.0, respectively.

Admiralty Inlet Survey Grid: Harp seal were observed throughout the survey grid during the only visual survey flown in Admiralty Inlet (Appendix B, Figure B-12). A total of 36 harp seal sightings (comprising 166 individuals) were recorded during the Leg 2 visual survey in Admiralty Inlet (Table 12). Harp seals group size ranged from one to 25 animals with a mean and median group size of 4.7 and 1.0, respectively.

Bearded Seal

Eclipse Sound Survey Grid: Bearded seal were observed during two of the three Leg 2 visual surveys in the RSA (Appendix B, Figures B-10, B-11 and B-13). A total of three bearded seal sightings (all solitary individuals) were recorded during the Leg 2 visual surveys in the RSA.

Admiralty Inlet Survey Grid: No bearded seals were observed in Admiralty Inlet during the Leg 2 visual surveys.

Unidentified Seal

Eclipse Sound Survey Grid: Unidentified seals were observed throughout the survey area during the Leg 2 visual surveys in the RSA (Appendix B, Figures B-10, B-11 and B-13). A total of 13 unidentified seal sightings (all solitary individuals) were recorded during the Leg 2 visual surveys in the RSA (Table 12).

Admiralty Inlet Survey Grid: Unidentified seals were observed throughout the survey area during the only Leg 2 visual survey flown in Admiralty Inlet (Appendix B, Figure B-12). A total of six unidentified seal sightings (all solitary individuals) were recorded during the Leg 2 visual survey in Admiralty Inlet (Table 12).

Polar Bear

Eclipse Sound Survey Grid: A total of two polar bear sightings were recorded during the Leg 2 visual surveys in the RSA (Table 12). One sighting of a mother with a cub occurred in Navy Board Inlet (Appendix B, Figure B-11). The second sighting of a mother with a cub occurred in western Eclipse Sound West (Appendix B, Figure B-13).

Admiralty Inlet Survey Grid: A total of four polar bear sightings (comprising eight individuals) were recorded during the only Leg 2 visual survey flown in Admiralty Inlet (Table 12). One sighting (single adult) occurred in Admiralty Inlet North on 20 August and one sighting occurred in Admiralty Inlet South on 20 August (Appendix B, Figure B-12). The two remaining sightings were of mothers with two cubs in Admiralty Inlet South (Appendix B, Figure B-12).

3.5.4 Photographic Survey Sightings

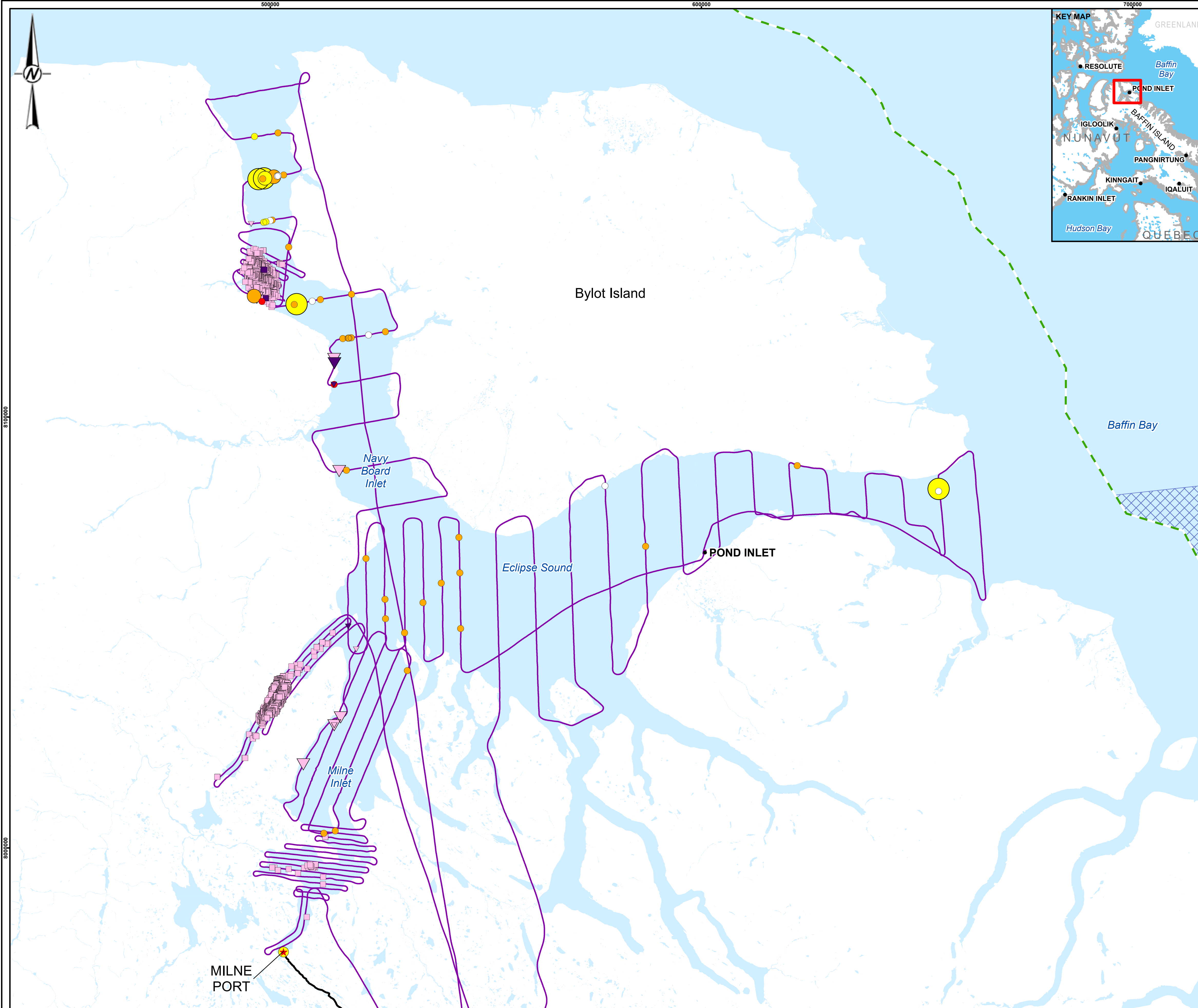
Eclipse Sound Survey Grid: During the open-water season (Leg 2), narwhal were primarily sighted in the Milne Inlet South, Milne Inlet North, Navy Board Inlet and Tremblay Sound strata as evident in the photographic coverage of the areas (Figure 25A–B and Figure 27A–B). A total of 6,437 narwhal sightings (comprising 12,902 individuals) were identified in the photographic survey imagery collected in the RSA (Table 13). Narwhal group size ranged from single animals to a group size of 20, with a mean and median group sizes of 2.0. Three bowhead sightings (one sighting of a solitary individual and two sightings of a pair of animals) were identified in the photographic survey imagery collected in the RSA (Table 13).

Admiralty Inlet Survye Grid: In Admiralty Inlet, the photographic survey was conducted in the northern stratum (Figure 26A–B). A total of 3,059 narwhal sightings (comprising 4,766 individuals) were identified in the photographic survey imagery collected in Admiralty Inlet (Table 13). Narwhal group size ranged from single animals to a group size of 11, with a mean and median group size of 1.6 and 1.0, respectively.

Table 13: Photographic survey sightings in Eclipse Sound and Admiralty Inlet survey grids - Leg 2 (2023)

Grid	Survey #	Stratum	Narwhal		Bowhead[b]	
			No. Sightings	No. Animals	No. Sightings	No. Animals
Eclipse	1	MIS	31	51	0	0
Eclipse	1	TS	1,699	3,910	0	0
Eclipse	1	NB	1,536	2,520	3	4
Admiralty	2	AIN	3,059	4,766	0	0
Eclipse	3	MIS	1,158	3,016	1	2
Eclipse	3	MIN	925	1,482	1	1
Eclipse	3	TS	1,088	1,923	0	0

[a] MIN=Milne Inlet North, MIS=Milne Inlet South, TS=Tremblay Sound, NB=Navy Board Inlet, AIN=Admiralty Inlet North
[b] Not including re-sightings



LEGEND

- COMMUNITY
- MILNE PORT
- MINE SITE
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY

PHOTOGRAPHIC SURVEY MARINE MAMMAL SPECIES OBSERVATIONS

- BOWHEAD WHALE
- NARWHAL

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BEAREDED SEAL
- 1

BOWHEAD WHALE
- 1
- 2-10

HARP SEAL
- 1
- 2-10
- 10+

NARWHAL
- 1
- 2-10

RINGED SEAL
- 1
- 2-10

UNIDENTIFIED SEAL
- 1

0 25 50

1:900,000 KILOMETRES

REFERENCE(S)
MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
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CLIENT
BAFFINLAND IRON MINES CORPORATIONS

PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
DISTRIBUTION OF MARINE MAMMALS RECORDED DURING LEG 2 - SURVEY 1 ON 12-13 AUGUST 2023 IN ECLIPSE SOUND GRID

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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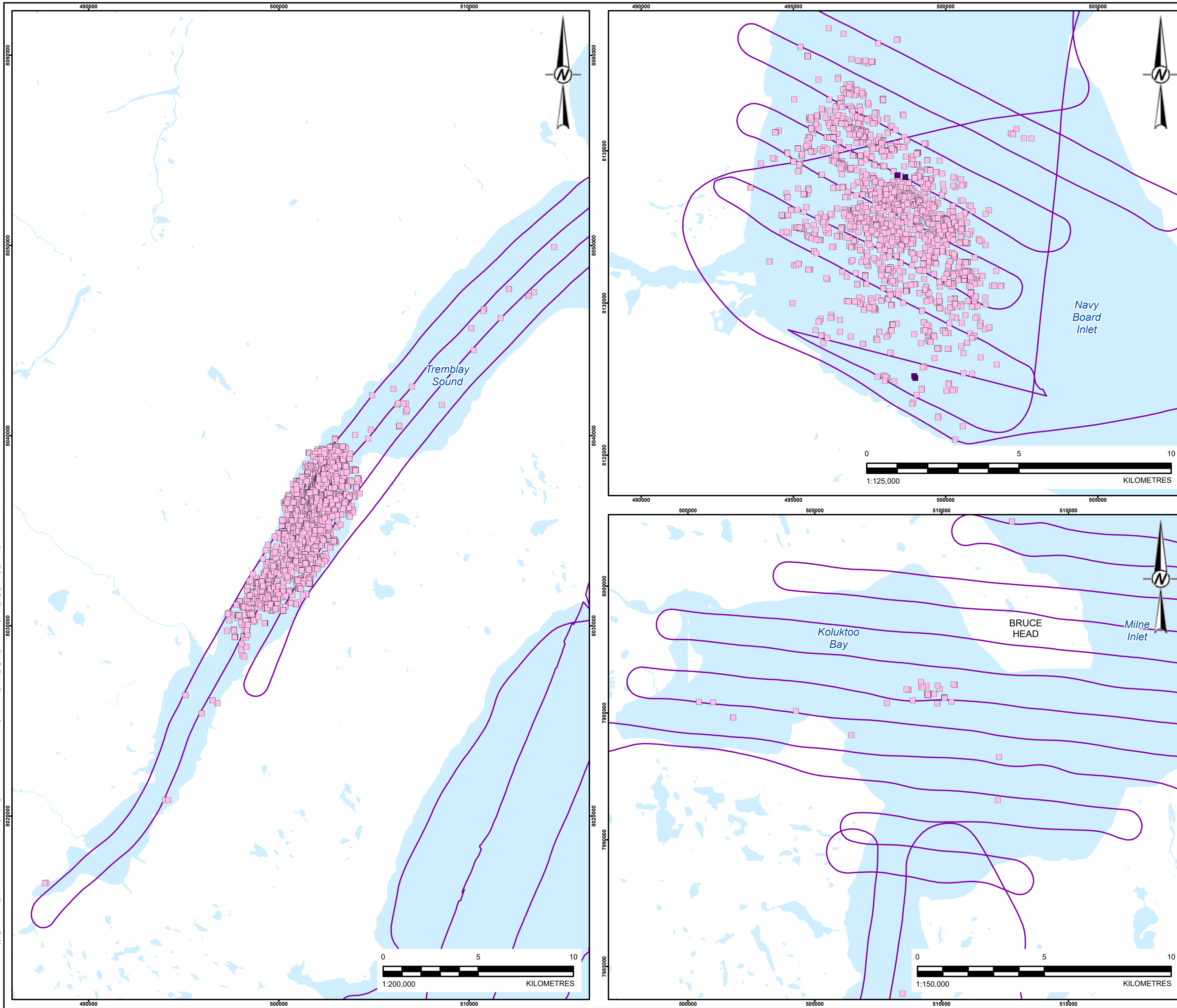


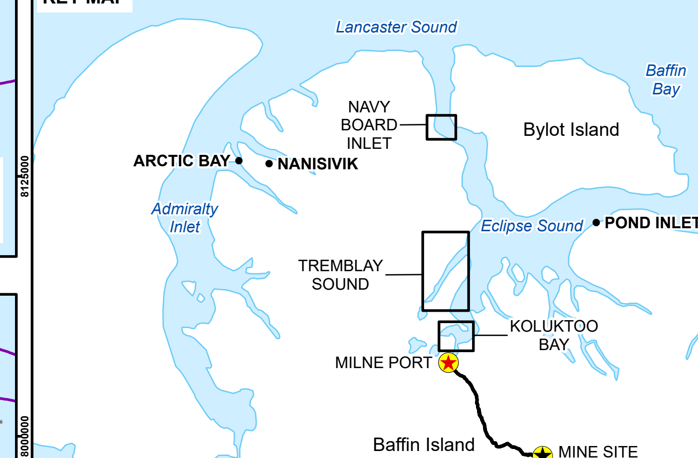
LEGEND

- COMMUNITY
- MILNE PORT
- MINE SITE
- MILNE INLET TOTE ROAD
- WATERBODY

PHOTOGRAPHIC SURVEY MARINE MAMMAL SPECIES OBSERVATIONS

- BOWHEAD WHALE
- NARWHAL

KEY MAP



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MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
PHOTOGRAPHIC SURVEYS DURING LEG 2 - SURVEY 1 ON 12-13 AUGUST 2023 IN ECLIPSE SOUND GRID

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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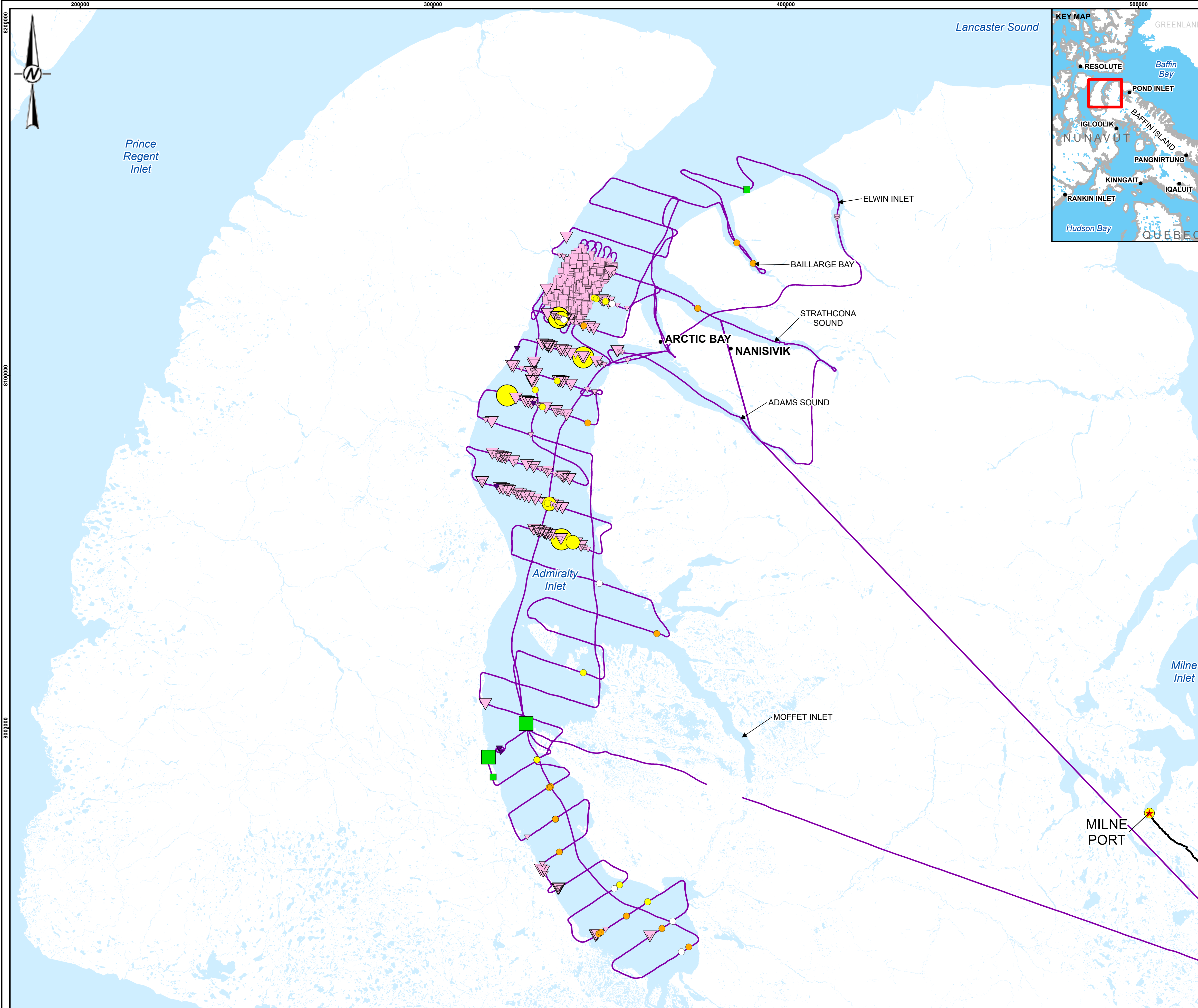

LEGEND

- COMMUNITY
- MILNE PORT
- MINE SITE
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY

PHOTOGRAPHIC SURVEY MARINE MAMMAL SPECIES OBSERVATIONS

- NARWHAL

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BOWHEAD WHALE
- 1

HARP SEAL
- 1
- 2-10
- 10+

NARWHAL
- 1
- 2-10

POLAR BEAR
- 1
- 2-10

RINGED SEAL
- 1

UNIDENTIFIED SEAL
- 1

0 25 50

1:1,100,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
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2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
DISTRIBUTION OF MARINE MAMMALS RECORDED DURING LEG 2 - SURVEY 2 ON 19-20 AUGUST 2023 IN ADMIRALTY INLET GRID

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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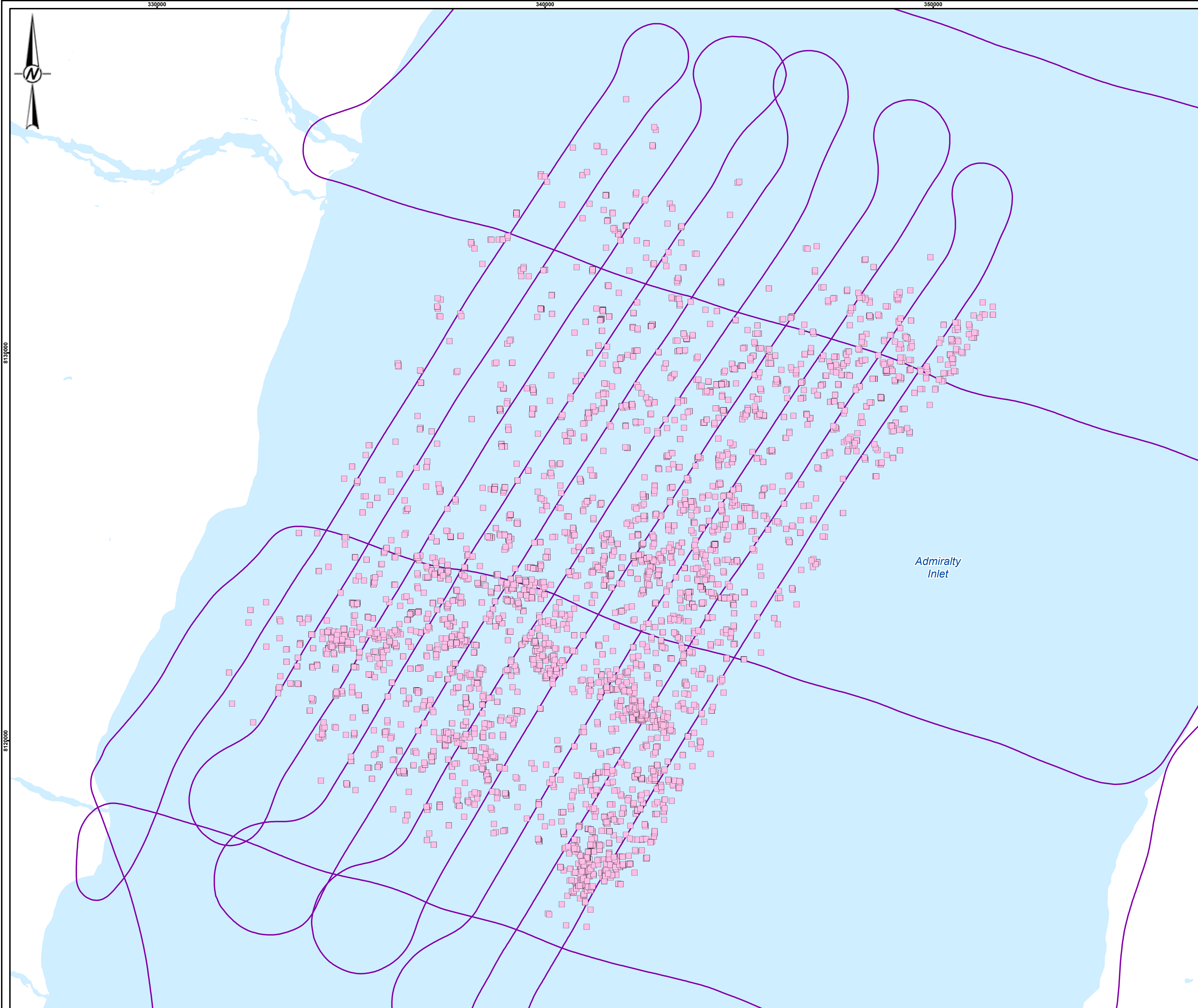


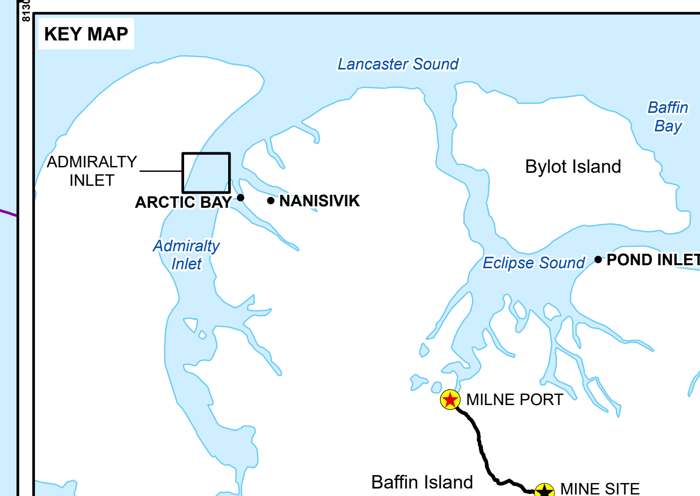
LEGEND

- COMMUNITY
- MILNE PORT
- MINE SITE
- MILNE INLET TOTE ROAD
- WATERBODY

PHOTOGRAPHIC SURVEY MARINE MAMMAL SPECIES OBSERVATIONS

- NARWHAL

KEY MAP



0 2.5 5

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TITLE
PHOTOGRAPHIC SURVEYS DURING LEG 2 - SURVEY 2 ON 19-20 AUGUST 2023 IN ADMIRALTY INLET GRID

CONSULTANT

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PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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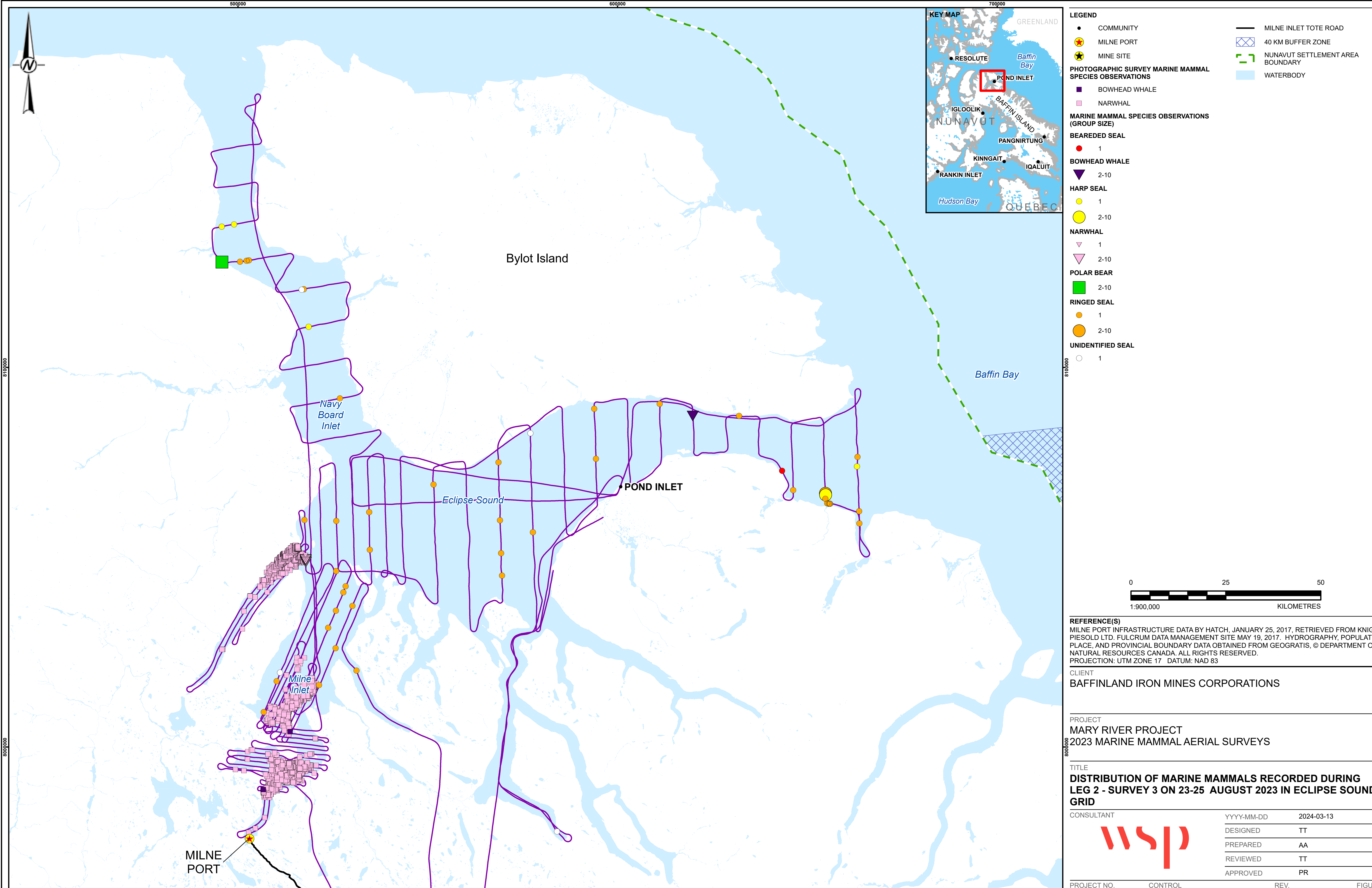

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2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
DISTRIBUTION OF MARINE MAMMALS RECORDED DURING LEG 2 - SURVEY 3 ON 23-25 AUGUST 2023 IN ECLIPSE SOUND GRID

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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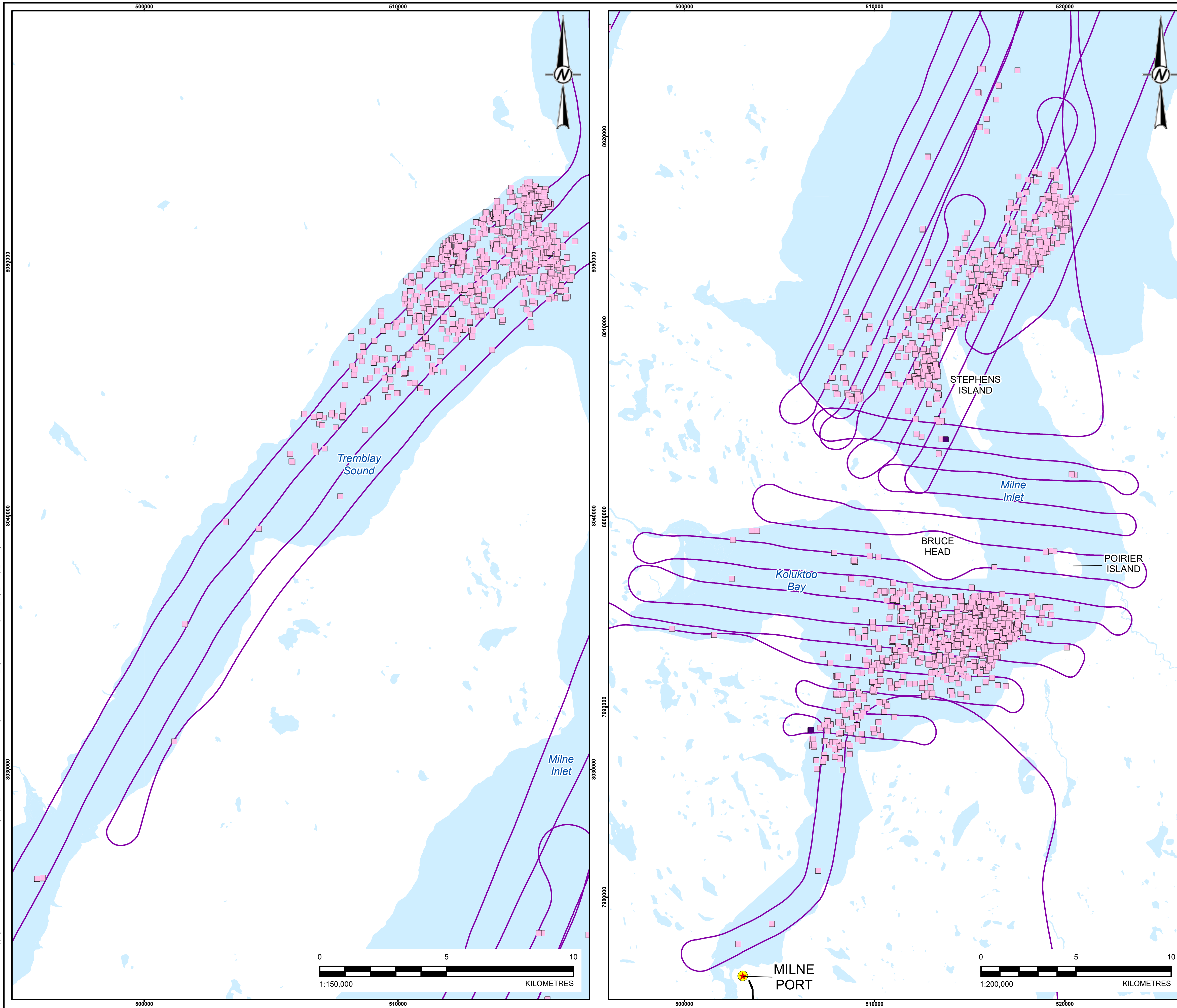


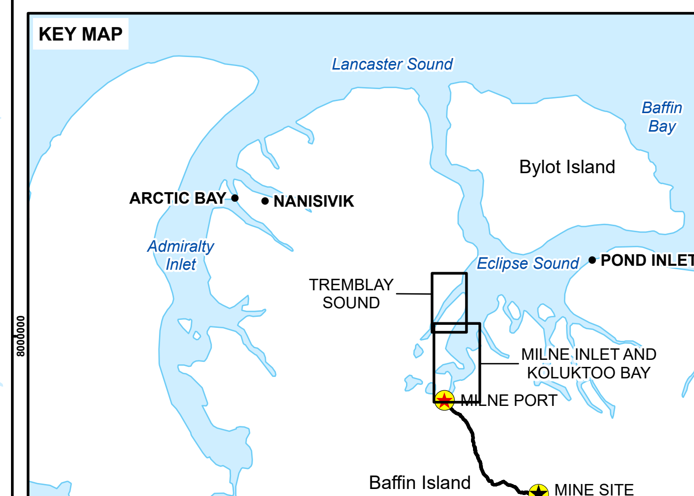
LEGEND

- COMMUNITY
- MILNE PORT
- MINE SITE
- MILNE INLET TOTE ROAD
- WATERBODY

PHOTOGRAPHIC SURVEY MARINE MAMMAL SPECIES OBSERVATIONS

- BOWHEAD WHALE
- NARWHAL

KEY MAP



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2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
PHOTOGRAPHIC SURVEYS DURING LEG 2 - SURVEY 3 ON 23-25 AUGUST 2023 IN ECLIPSE SOUND GRID

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

3.5.5 Narwhal Abundance Estimates

Narwhal abundance estimates were calculated for Surveys #1, 2 and 3;

- Survey #1: flown in Eclipse Sound survey grid on 12-13 August. Survey was completed in two days with 100% survey coverage of the survey grid (excluding fjords) under good sighting conditions.
- Survey #2: flown in the Admiralty Inlet grid on 19-20 August. Survey was flown over two days with partial survey coverage of the survey grid under moderate sighting conditions. Low fog in the survey grid resulted in the top three transects being excluded from the survey (i.e., not flown), and partial transects flown for six other transects in the Admiralty Inlet North stratum. The photographic survey was terminated early due to increasing sea states (>BF4). As a result of the incomplete coverage and moderate sighting conditions, abundance estimates calculated for the Admiralty Inlet survey grid should be considered a minimum number of animals in Admiralty Inlet.
- Survey #3: flown in the Eclipse Sound grid on 23-25 August. Survey was flown over three days with partial survey coverage of the survey grid under good to moderate sighting conditions. Only one flight was flown on 23 August due to deteriorating survey conditions (i.e., high sea states) in the afternoon. On 24 August, high sea states (i.e., BF6) on the top two transects in Navy Board Inlet prevented flying surveys in this area.

3.5.5.1 Visual Survey Data Characteristics

Sightings data from both the Eclipse Sound and Admiralty Inlet survey grids supplemented one another to provide for a more robust model of probability detection function. The same marine mammal observers flew both the Eclipse Sound and Admiralty Inlet grids and were incorporated into the model as a covariate. Re-sightings were not used for the estimation of any variables.

One detection function was created for narwhal for the combined Eclipse Sound and Admiralty Inlet grids. Sightings data was pooled between dates to increase sample size in order to meet the assumptions of the detection probability model, but only if the spatial distribution of species detections (sightings) were similar between those days (i.e., the ability to detect animals at a distance did not change under the available sighting conditions, including altitude). Combining survey data for days with apparent variability in detectability can skew findings and result in either an over- or under-estimation of true animal density for a specific date. Location (i.e., Eclipse Sound vs Admiralty Inlet) was included as a covariate in the detection function model but it did not lower Akaike's Information Criterion (AIC) values and consequently, location specific models were not created.

The number of narwhal sightings during fjord transects was too small (n=6) to appropriately perform abundance estimations using the Density Surface Modelling technique (Doniol-Valcroze et al. 2015b). Individual fjord surveys were instead treated as separate transects within a fjord-based stratum and analyzed the same as transects within the other regional strata.

Analysis of sightings data was performed using the Mark-Recapture Distance Sampling (MRDS) analysis package (Laake et al. 2018) within R version 4.1.2 (R Core Team 2021). The shape of the histogram suggested that some animals were missed close to the track line despite the bubble windows. There was a risk that hazard-rate and half-normal distributions would overestimate the probability of detection and the resulting effective strip width. The gamma key function does not assume a 100% detection on the track line (g(0)=1). A horizontal offset value can be applied to the gamma detection function data since that key function assumes zero detections at zero distance, however this was not required for the current data. Offsetting the data for the gamma key function does bias the results, with larger offsets creating a greater bias. Environmental and observer covariates were included for fitting the detection function and mark-recapture models. Models were selected using the minimum AIC. The gamma key function model had the lowest AIC value of 8569.37 and was selected as the best model (see Appendix C).

The combined narwhal sightings (n=667) for the Eclipse Sound and Admiralty Inlet survey grids from the open-water season survey (Leg 2) were used for estimating the detection function and mark-recapture detection probabilities for narwhal in Eclipse Sound and Admiralty Inlet (Figure 28). This was because the same observers were used for both the Eclipse Sound and Admiralty Inlet grids and location (i.e., Eclipse Sound or Admiralty Inlet) did not affect the model. Examination of the histogram of the perpendicular distances of unique sightings suggested right-truncating the data at 900 m (i.e., discarding sightings beyond 900 m).

Model selection was performed on the three key functions and all the combinations of environmental covariates. A gamma key function model with covariates for ObserverTeam + Beaufort + IceCover + FogIntRank had the lowest AIC for detection function models: (g(x)=0.396 and CV=0.036; see Appendix C).

Selection among mark-recapture models was performed on all combinations of environmental covariates. The lowest AIC was a model with covariates for Observer + Distance + ObserverTeam +Beaufort:Turbidity + GlareCoverSC:RC60s + distance:GlareCoverSc (see Appendix C). It resulted in a p(0) of 0.794 for observers 1 (Figure 29) and 0.396 for observers 2 (Figure 30), and a combined p(0) of 0.858 and (CV=0.038). The combined models resulted in a detection probability of 0.339 (CV=0.056).

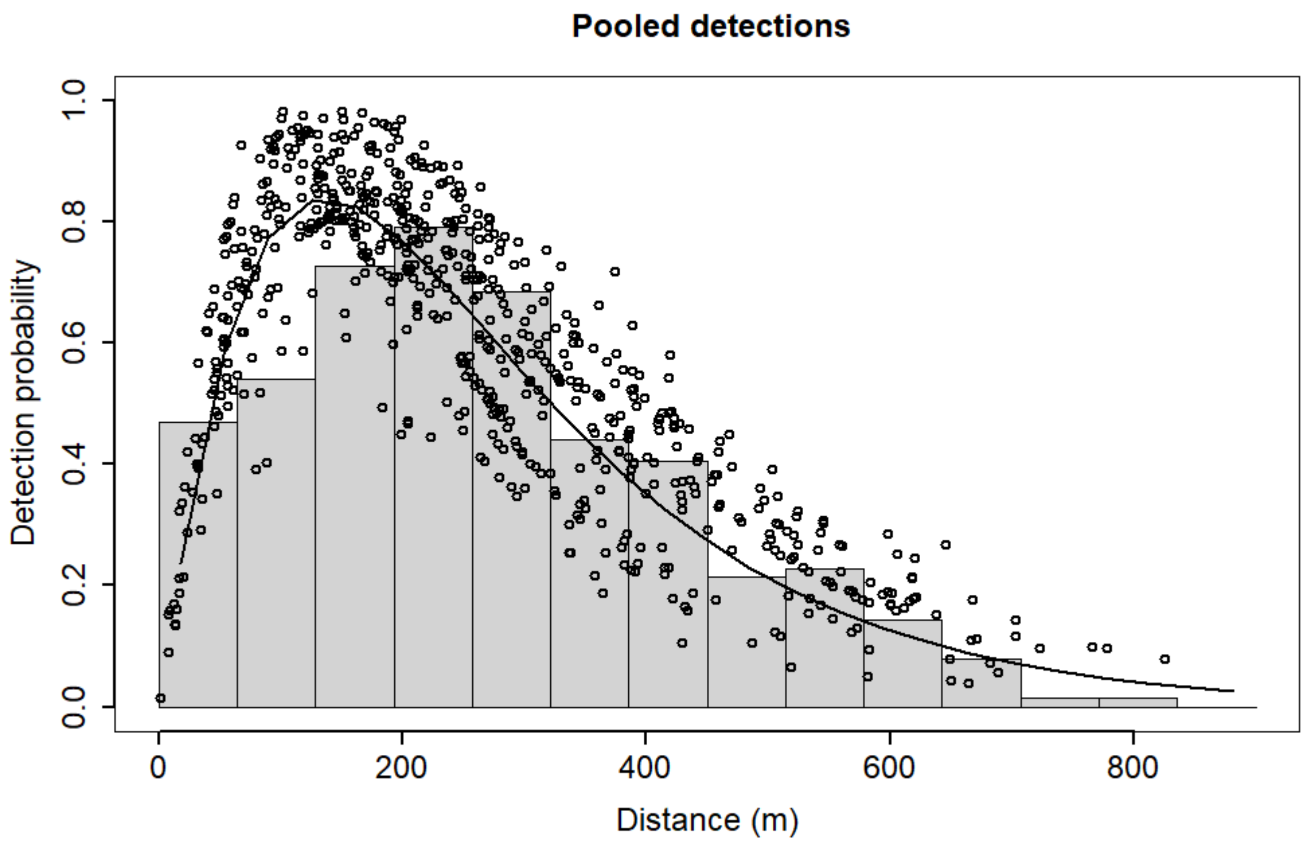

Figure 28: Perpendicular distances of narwhal sightings in Eclipse Sound and Admiralty Inlet survey grids.

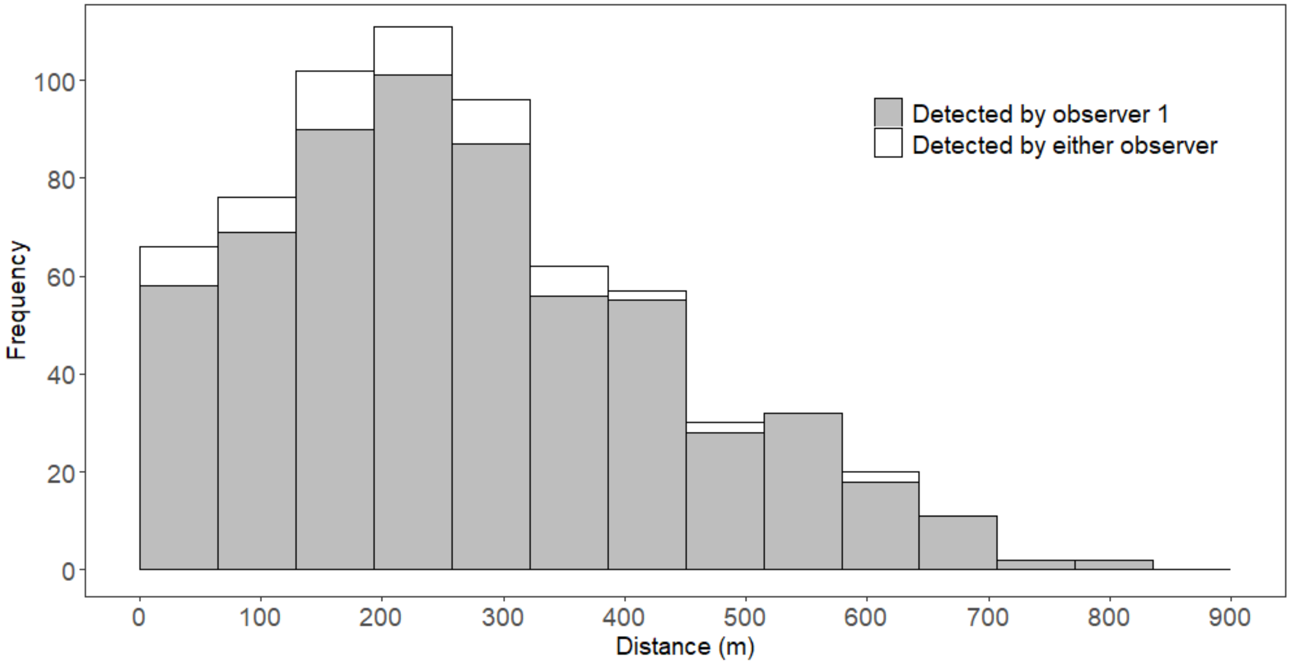

Figure 29: Distribution of narwhal sighting distances for Observer 1 and both observers combined (Observers 1 and 2) in Eclipse Sound and Admiralty Inlet survey grids. Distance is measured in meters.

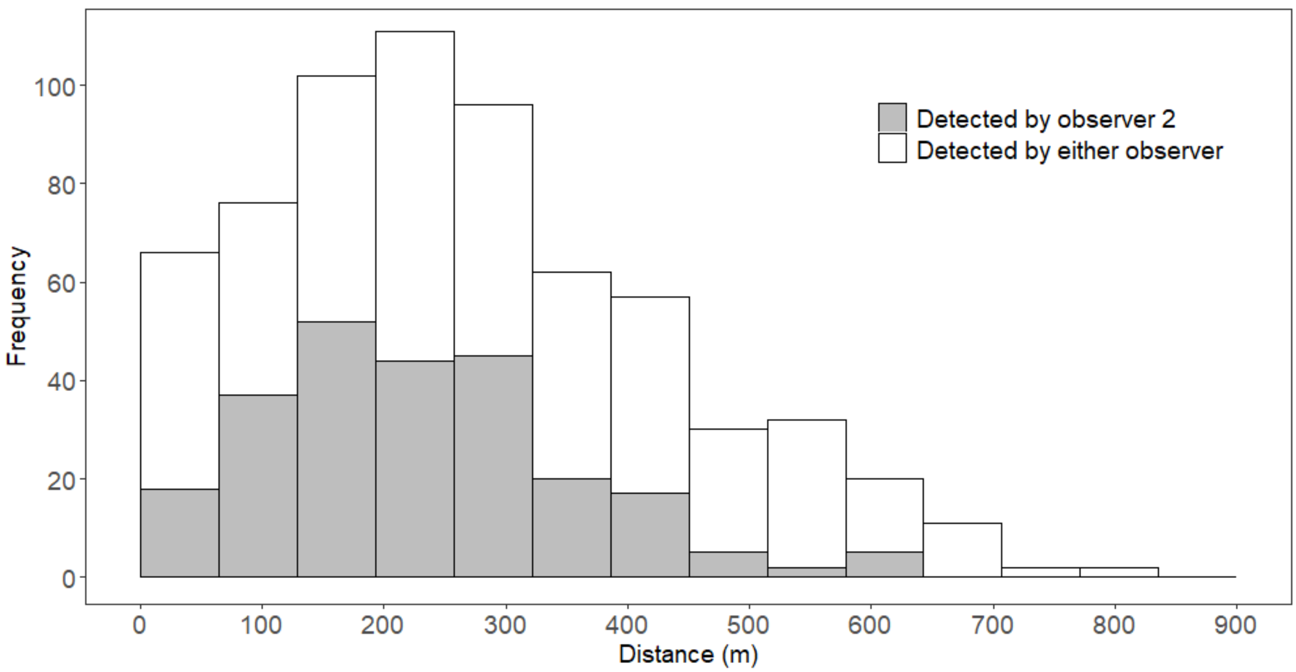

Figure 30: Distribution of narwhal sighting distances for Observer 2 and both observers combined (Observers 1 and 2) in Eclipse Sound and Admiralty Inlet survey grids. Distance is measured in meters.

The availability bias component of g(x), where an animal is diving and is thus out of visual range of the observers, requires species, and area-specific dive profile data to estimate proportion of time spent underwater (e.g., Barlow et al. 1988). A correction factor (2.94, CV=0.03 for mid-August) was applied to the data to account for potential availability bias for this species, adjusted for the specific observation platform. This correction factor is based on previously reported narwhal dive and aerial survey results (Doniol-Valcroze et al. 2015a; Watt et al. 2015).

3.5.5.2 Photographic Survey Data Characteristics

For the assessment of reliability and repeatability of the photographic data, a simple linear regression of the comparison of two experienced photo readers was run. Repeat counts of 276 photos were highly correlated (simple linear regression; $R^2 = 0.978$, $F_{1,274} = 12.133 \times 10^3$, $p < 0.0001$). Counts for the first and repeat reads varied between zero and eight (Table 14). The original counts were kept for the abundance analysis. The same photo analyst has been used since 2019 to analyse the photographs, which further reduces bias with photographic surveys.

Table 14: Count difference between first and repeat reads of photographs

Difference in count between readers	Count	Higher original count	Higher secondary count
Same	191		
One	51	28	23
Two	13	8	5
Three	7	5	2
Four	4	3	1
Five	1	1	0
Six	3	2	1
Seven	4	4	0
Eight	2	2	0

With ideal sightings conditions for photographic data, one would expect a slight decrease in animal detectability with increasing distance from the track line. The data showed a slight decrease in sightings with increased distance from the track line (Figure 31). Possible factors affecting the detectability bias include camera angle, aircraft crab angle (cross wind), imprecise aircraft altitudes, obscurity of subsurface animals, photo observer bias, and animal behaviour. A detection function was created for narwhal in the photographic surveys. Surveys were selected for the analysis that had no land or glare which would skew the results.

A detection model fitted to the photographic data for one survey flown at 610 m (2,000 ft) resulted in a probability of detection of 0.963 (C_d = detectability bias correction factor of 1.04, n=467), CV=0.05 (Figure 31). A hazard rate key function with no adjustments had the lowest AIC of 6187.95 for the detection function model but was rejected because the distribution did not follow a hazard rate function. A half normal key function with no adjustments had the second lowest AIC of 6195.81 for the detection function model and was selected as the best fit.

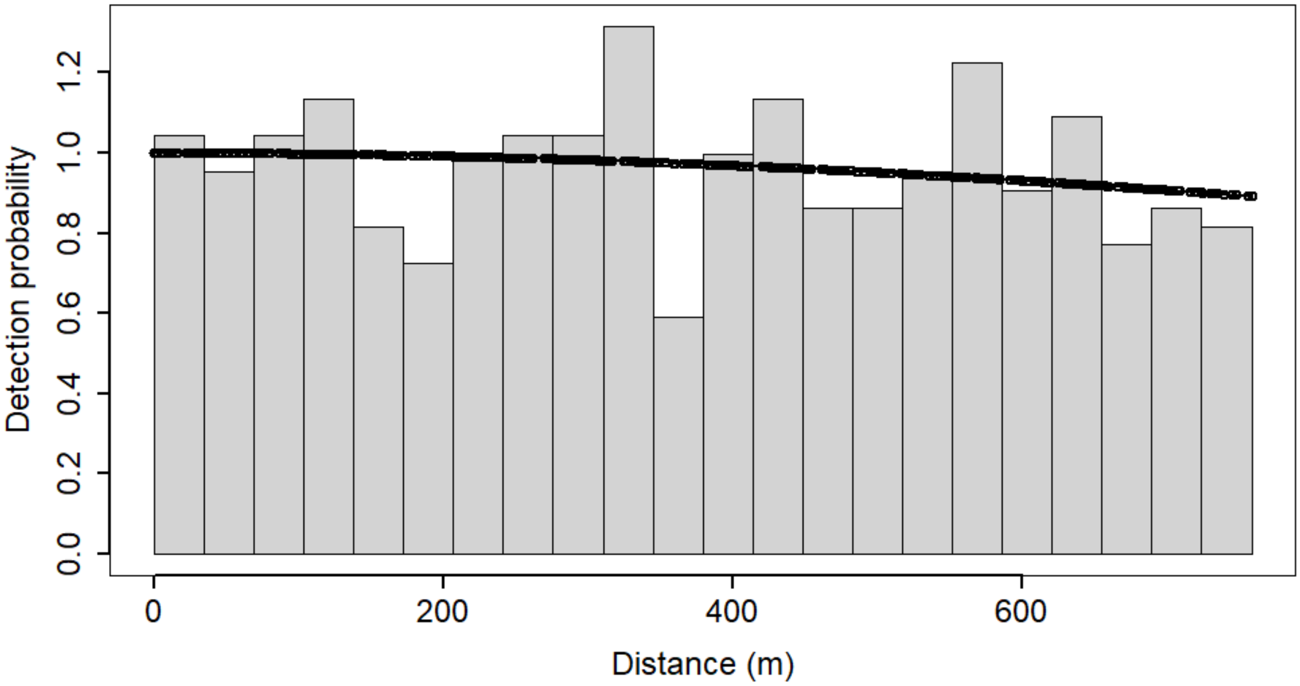

Figure 31: Detection function for photographic survey data at 610 m (2,000 ft).

3.5.5.3 2023 Narwhal Abundance

3.5.5.3.1 Eclipse Sound Stock

Overall, there were 11 narwhal visual sightings during Surveys #1 and #3 (Table 15). Initially, three of the sightings were missing perpendicular distances. After photo-verification of sightings with missing measurements, all three perpendicular distances were recovered from the photographs.

During Survey #1 (12-13 August), a total of 838 km of transects were visually surveyed (Table 15). The total count of narwhal sightings observed on-effort in the visual survey area was four sightings before and after truncation (Table 15). Variation of the abundance estimate was a combination of the variation of encounter rate, cluster size, availability bias, and detection function. The overall variation in abundance estimates came primarily from the encounter rate and cluster size components (Table 15). Narwhal abundance for visual Survey #1 was estimated at 199 narwhal (CV=0.71) (Table 15).

The total length of transect lines visually surveyed during Survey #3 (23-25 August) was 895 km (Table 15). The total count of narwhal sightings observed on-effort in the visual survey area was seven sightings before and after truncation (Table 15). For this survey, the overall variation in abundance estimates came primarily from the encounter rate and cluster size components. Narwhal abundance for visual Survey #3 was estimated at 339 narwhal (CV=0.92) (Table 15).

Table 15: Narwhal abundance estimates from visual surveys in Eclipse Sound grid during Leg 2 (2023)

Survey #	Stratum[a]	Area (km^2)	Effort (km)	No. Sight. Before Trunc.	No. Sight. After Trunc.	Corrected Abundance	CV	% CV contributed by Encounter Rate	% CV contributed by Cluster Size
1	PI	1,381.3	120.8	0	0	—	—	—	—
1	ESE	2,066.5	219.2	0	0	—	—	—	—
1	ESW	841.0	182.9	0	0	—	—	—	—
1	MIN	681.3	161.1	3	3	81	0.893	91.6	7.8
1	NBI	1,891.4	154.0	1	1	118	1.031	99.6	0
1	Fjords	0	0	0	0	—	—	—	—
1	***Total***	**6,861.5**	**838.0**	**4**	**4**	**199**	**0.711**		
3	PI	1,381.3	145.4	0	0	—	—	—	—
3	ESE	2,066.5	227.3	0	0	—	—	—	—
3	ESW	841.0	178.8	7	7	339	0.924	94.1	5.4
3	MIN	521.6	117.3	0	0	—	—	—	—
3	NBI	2,007.8	128.3	0	0	—	—	—	—
3	Fjords	374.9	97.5	0	0	—	—	—	—
3	***Total***	**7,193.1**	**894.6**	**7**	**7**	**339**	**0.924**		

[a] PI=Pond Inlet, ESE= Eclipse Sound East, ESW=Eclipse Sound West, MIN=Milne Inlet North, NBI=Navy Board Inlet.

During Survey #1 (12-13 August), three photographic surveys were undertaken; one in Milne Inlet South (MIS) stratum, one in the Tremblay Sound (TS) stratum, and one in Navy Board Inlet stratum (see Figure 25B). A total of 3,078 photographs were taken to capture the narwhal aggregations in the three areas. The total area photographed was 528.63 km^2 (255.59 km^2 in MIS, 156.58 km^2 in TS, and 116.46 km^2 in NB; Table 16). The total count of narwhal in the photographed areas was 6,481 narwhal (51 in MIS, 3,910 in TS, and 2,520 in NB; see Table 13). The sum of the area of the individual photographs totaled 561.3 km^2 in MIS, 304.8 km^2 in TS, and 270.2 km^2 in NB, resulting in an average density of 0.091 narwhal/km^2 in MIS, 12.826 narwhal/km^2 in TS, and 9.325 narwhal/km^2 in NB. Multiplying the average density by the total area photographed resulted in a surface estimate of 23 narwhal in MIS, 2,008 narwhal in TS, and 1,086 narwhal in NB. The surface estimate was then corrected for availability bias using Cα=3.18 (correction from Watt et al. 2015) and detectability bias of 1.04, resulting in a total narwhal estimate for the photographed areas of 76 narwhal (CV=0.064) in MIS, 6,631 narwhal (CV=0.062) in TS, and 3,586 narwhal (CV=0.062) in NB (Table 16).

During Survey #3 (23-25 August), three photographic surveys were undertaken in the Eclipse Sound study area, one in the MIS stratum, one in the Milne Inlet North (MIN) stratum, and one in the TS stratum (see Figure 27B). A total of 3,361 photographs were taken to capture the narwhal aggregations in the three areas. The total area photographed was 580.64 km^2 (264.38 km^2 in MIS, 159.67 km^2 in MIN, and 156.59 km^2 in TS; Table 16). The total count of narwhal in the photographed areas was 6,421 narwhal (3,016 narwhal in MIS, 1,482 in MIN, and 1,923 narwhal in TS; see Table 13). The sum of the area of the individual photographs totaled 641.1 km^2 in the MIS, 362.6 km^2 in the MIN, and 335.1 km^2 in TS, resulting in an average density of 4.704 narwhal/km^2 in MIS, 4.086 narwhal/km^2 in MIN, and 5.738 narwhal/km^2 in TS. Multiplying the average density by the total area photographed resulted in a surface estimate of 1,244 narwhal in MIS, 653 narwhal in MIN, and 899 narwhal in TS. The surface estimate was then corrected for availability bias using $C\alpha$ = 3.18 (correction from Watt et al. 2015) and detectability bias of 1.04, resulting in a total narwhal estimate for the photographed areas for Survey 3 of 4,108 narwhal (CV=0.062) in MIS, 2,156 narwhal (CV=0.062) in MIN, and 2,969 narwhal (CV=0.062) in TS (Table 16).

Table 16: Narwhal abundance estimates from photographic survey in Eclipse Sound grid - Leg 2 (2023)

Survey #	Stratum[a]	# Photos	# Photos with Murky Water	# Photos with Glare	Photo Area (km^2)	Surface Count	Corrected Abundance	CV
1	MIS	1,554	0	591	255.59	23	76	0.064
1	TS	890	0	388	156.58	2,008	6,631	0.062
1	NB	634	2	108	116.46	1,086	3,586	0.062
3	MIS	1,578	7	0	264.38	1,244	4,108	0.062
3	MIN	884	0	115	159.67	653	2,156	0.062
3	TS	899	11	191	156.59	899	2,969	0.062

[a] MIN=Milne Inlet North, MIS=Milne Inlet South, TS=Tremblay Sound.

For the Eclipse Sound stock, the narwhal abundance estimates calculated for the two survey replicates (Surveys #1 and 3) ranged from 10,492 to 9,572 narwhal (Table 17). Survey #1 flown on 12-13 August was completed in two days whereas Survey #3 flown on 23-25 August required three days to complete due to poor survey conditions. Although Surveys #1 and 3 were not significantly different (t-test = 1.367, p = 0.174), the length of time between the two surveys was too long to recommend an average of the two estimates. Survey #1 was selected as the peak abundance estimate for the Eclipse Sound stock.

Table 17: Narwhal abundance estimates from combined visual and photographic surveys in Eclipse Sound grid during Leg 2

Survey #	Survey Type	Estimate	CV	95% CI
1	Visual	199	0.711	57–697
1	Photographic	10,293	0.045	9,417–11,251
1	**Combined**	**10,492**	**0.046**	**9,578–11,494**
3	Visual	339	0.924	73–1,582
3	Photographic	9,233	0.037	8,588–9,926
3	**Combined**	**9,572**	**0.048**	**8,706–10,524**

3.5.5.3.2 Admiralty Inlet Stock

Overall, there were 211 narwhal sightings while on-effort during Survey #3 (Table 18). All sightings had perpendicular distances recorded during flight.

During Survey #2 (19-20 August), a total of 842.8 km of transects were visually surveyed (Table 18). The total count of narwhal sightings observed on-effort in the visual survey area was 211 sightings before truncation and after truncation (Table 18). Variation of the abundance estimate was a combination of the variation of detection function, encounter rate, cluster size, and availability bias. For Survey #2, the variation in abundance estimates came primarily from the encounter rate and the cluster size components. Narwhal abundance for visual Survey #2 was estimated at 23,372 narwhal (CV=0.19) (Table 18).

Table 18: Narwhal abundance estimates from visual surveys in Admiralty Inlet grid - Leg 2 (2023)

Survey #	Stratum[a]	Area (km^2)	Effort (km)	No. Sight. Before Trunc.	No. Sight. After Trunc.	Corrected Abundance	CV	% CV contributed by Encounter Rate	% CV contributed by Cluster Size
2	AIN	6,597.2	503.5	189	189	21,737	0.205	85.0	4.7
2	AIS	1,651.7	178.8	16	16	1,466	0.504	83.3	15.0
2	Fjords	626.9	160.5	6	6	169	0.565	82.4	16.2
2	**Total**	**8,875.8**	**842.8**	**211**	**211**	**23,372**	**0.193**	—	—

[a] AIN=Admiralty Inlet North, AIS=Admiralty Inlet South.

During Survey #2 (19-20 August), one photographic survey was undertaken in the Admiralty Inlet North (AIN) stratum (see Figure 26B). A total of 1,248 photographs were taken to capture the narwhal aggregations in the area. The total area photographed was 238.28 km^2 (Table 19). The total count of narwhal in the photographed areas was 4,766 narwhal (see Table 13). The sum of the area of the individual photographs totaled 548.14 km^2, resulting in an average density of 8.695 narwhal/km^2. Multiplying the average density by the total area photographed resulted in a surface estimate of 2,072 narwhal. The surface estimate was then corrected for availability bias using Cα=3.18 (correction from Watt et al. 2015), and detectability bias of 1.04, resulting in a total narwhal estimate for the photographed area for Survey 2 of 6,842 narwhal (CV=0.062) in AIN (Table 19).

Table 19: Narwhal abundance estimates from photographic surveys in Admiralty Inlet - Leg 2 (2023)

Survey #	Stratum[a]	# Photos	# Photos Murky Water	# Photos with Glare	Area (km^2)	Surface Count	Corrected Abundance	CV
2	AIN	1,248	4	0	238.28	2,072	6,842	0.062

[a] AIN=Admiralty Inlet North, AIS=Admiralty Inlet South.

For the Admiralty Inlet stock, the narwhal abundance estimates calculated for the survey (Survey 2) was 30,214 narwhal CV = 0.15, 95% CI of 22,559–40,467 (Table 20).

Table 20: Narwhal abundance estimates from combined visual and photographic surveys in Admiralty Inlet grid - Leg 2 (2023)

Survey #	Survey Type	Estimate	CV	95% CI
2	Visual	23,372	0.193	16,068–33,996
2	Photographic	6,842	0.062	6,063–7,721
2	**Combined**	**30,214**	**0.150**	**22,559–40,467**

3.5.5.3.3 Combined Eclipse Sound and Admiralty Inlet Stocks

For the combined Eclipse Sound and Admiralty Inlet stock, Survey #1 was selected as the best abundance estimate from the Eclipse Sound survey grid to be combined with the Admiralty Inlet stock, based on survey quality, survey timing and survey conditions (Survey #1 only required two days to complete compared to three days for Survey #3; Survey #1 had 100% coverage of the survey area, whereas Survey #3 was missing top portion of Navy Board Inlet; Survey #1 was associated with higher accuracy {lower CV}). The abundance estimate for the combined Eclipse Sound and Admiralty Inlet stocks calculated for the two surveys (Survey #1 and 2) was 40,706 narwhal (CV = 0.11, CI = 32,711–50,655) (Table 21).

Table 21: Narwhal abundance estimates for combined Eclipse and Admiralty stocks - Leg 2 (2023)

Survey #	Stock	Estimate	CV	95% CI
1	Eclipse Sound	10,492	0.046	9,578–11,494
2	Admiralty Inlet	30,214	0.150	22,559–40,467
1&2	Combined Stock	40,706	0.112	32,711–50,655

3.5.6 Abundance Comparison with Previous Years

Survey #1 flown in the Eclipse Sound summer stock area resulted in an abundance estimate of 10,492 animals (CV = 0.046, CI = 9,578–11,494). This estimate was selected as the best peak abundance estimate for the Eclipse Sound stock in 2023. Survey #2, the only survey flown in Admiralty Inlet in 2023, resulted in an abundance estimate of 30,214 animals (CV = 0.15, CI = 22,559–40,467). The abundance estimate of the combined Eclipse Sound and Admiralty Inlet summer stocks was 40,706 animals (CV = 0.11, CI = 32,711–50,655) (Table 22).

Table 22: Comparison of narwhal abundance estimates for Eclipse Sound, Admiralty Inlet, and combined stocks

Stock	Year	Survey Dates	No. Replicate Surveys	Abundance	CV	95% CI	Source
Eclipse Sound	2004	August	1	20,225	0.36	9,471–37,096	Richard et al. 2010
Eclipse Sound	2013	18–19 Aug	1	10,489	0.24	6,342–17,347[a]	Doniol-Valcroze et al. 2015a
Eclipse Sound	2016	7–10 Aug	1	12,039	0.23	7,768–18,660	Marcoux et al. 2019
Eclipse Sound	2019	21–27 Aug	2	9,931	0.05	9,009–10,946	Golder 2020a
Eclipse Sound	2020	29 Aug	1	5,018	0.03	4,736 – 5,317	Golder 2021a
Eclipse Sound	2021	20–21 Aug	1	2,595	0.33	1,369 – 4,919	Golder 2022a
Eclipse Sound	2022	17–21 Aug	2	4,592	0.10	3,754–5,617	WSP 2023a
Eclipse Sound	2023	12–13 Aug	1	10,492	0.046	9,578–11,494	Current Report
Admiralty Inlet	2003	August	1	5,362	0.50	1,920–12,199	Richard et al. 2010
Admiralty Inlet	2010	7–11 Aug	2	18,049	0.23	11,613–28,053	Asselin and Richard 2011
Admiralty Inlet	2013	12–17 Aug	1	35,043	0.42	14,188–86,553[a]	Doniol-Valcroze et al. 2015a
Admiralty Inlet	2019	21–26 Aug	2	28,746	0.15	21,545–38,354	Golder 2020a
Admiralty Inlet	2020	28 Aug	1	31,026	0.14	23,406–41,126	Golder 2021a
Admiralty Inlet	2021	19 Aug	1	*72,582*	*0.09*	61,333–85,895	Golder 2022a
Admiralty Inlet	2022	14–18 Aug	2	43,042	0.15	32,218–57,502	WSP 2023a
Admiralty Inlet	2023	19–20 Aug	1	30,214	0.15	22,559–40,467	Current Report
Combined	2013	12–19 Aug	1	45,532	0.33	22,440–92,384[a]	Doniol-Valcroze et al. 2015a
Combined	2019	21–27 Aug	2	38,677	0.11	31,155–48,015	Golder 2020a[b]
Combined	2020	28–29 Aug	1	36,044	0.12	28,267–45,961	Golder 2021a
Combined	2021	19-21 Aug	1	75,177	0.08	63,795–88,590	Golder 2022a
Combined	2022	17–18 Aug	1	46,408	0.13	36,129–59,611	WSP 2023a
Combined	2023	12-13 Aug and 19-20 Aug	1	40,706	0.11	32,711–50,655	Current Report

[a] T. Doniol-Valcroze, Pers. Comm. 2020.

[b] T. Number has been revised from the Golder 2020a report to correct an error.

For the Eclipse Sound summer stock alone, the 2023 narwhal abundance estimate was 10,492 animals (CV = 0.046, CI = 9,578–11,494) based on an aerial survey conducted on 12-13 August (Table 22). The 2023 estimate was not statistically different than the 2013 abundance estimate of 10,489 animals (CV = 0.24, CI = 6,342–17,347; Doniol-Valcroze et al. 2015a), the 2016 estimate of 12,039 animals (CV = 0.23, CI = 7,768–18,660; Marcoux et al. 2019) or the 2019 abundance estimate of 9,931 animals (CV = 0.05, CI = 9,009–10,946; Golder 2020a) (Table 23). The 2023 abundance estimate was statistically higher than the 2022 estimate of 4,592 animals (CV = 0.10, CI = 3,754–5,617, WSP 2023a), the 2021 estimate of 2,595 animals

(CV = 0.33, CI = 1,369–4,919; Golder 2022a) and the 2020 abundance estimate of 5,018 animals (CV = 0.03, CI = 4,736–5,317; Golder 2021a) (Table 23). Power analysis indicated that there was sufficient power (>0.8) to detect a reduction in narwhal abundance at an effect size of -16% (Appendix E).

For the Admiralty Inlet summer stock alone, the 2023 narwhal abundance estimate was 30,214 animals (CV = 0.15, CI = 22,559–40,467; Table 22) based on an aerial survey conducted on 19- 20 August 2023. This estimate was not statistically different than the 2013 abundance estimate (35,043 animals, CV = 0.42, CI = 14,188–86,553; Doniol-Valcroze et al. 2015a), the 2019 abundance estimate of 28,746 animals (CV = 0.15, CI = 21,545–38,354), the 2020 abundance estimate of 31,026 animals (CV = 0.14, 95% CI of 23,406–41,126) or the 2022 abundance estimate of 43,042 animals (CV = 0.15, CI = 32,218–57,502) (Table 23). The 2023 estimate was statistically lower than the 2021 abundance estimate of 72,582 animals (CV = 0.09, CI = 61,333–85,895) (Table 23).

The abundance estimate for the combined Eclipse Sound and Admiralty Inlet stocks was 40,706 animals (CV = 0.11, CI = 32,711–50,655; Table 22) based on aerial surveys conducted on 12–13 and 19-20 August 2023. This estimate was not statistically different than the 2013 abundance estimate (45,532 animals, CV = 0.33, CI = 22,440–92,384; Doniol-Valcroze et al. 2015a), the 2019 abundance estimate of 38,677 animals (CV = 0.11, CI = 31,155–48,015), the 2020 abundance estimate of 36,044 animals (CV = 0.12, CI = 28,267–45,961) or the 2022 abundance estimate of 46,408 animals (CV = 0.13, CI = 36,129–59,611) (Table 23). The 2023 estimate was statistically lower than the 2021 abundance estimate of 75,177 animals (CV = 0.08, CI = 63,795–88,590) (Table 23). For the combined Eclipse Sound and Admiralty Inlet abundance estimate, the power analysis indicated that there was sufficient power (>0.8) to detect a reduction in narwhal abundance at an effect size of -35% (Appendix E).

The sample sizes used to generate the narwhal abundance estimates for DFO's previous surveys (Doniol-Valcroze et al. 2015a; Marcoux et al. 2019) were not reported, thus degrees of freedom for the DFO surveys were assumed to be the same as the corresponding Baffinland estimate for t-test analysis. The use of a Z-statistic was recommended for surveys with unknown sample sizes although this may represent a higher precision than is warranted by the DFO data. Calculations of a Z-statistic for the combined Eclipse Sound and Admiralty Inlet stocks resulted in similar significance value as the t-statistic (2023 vs 2013: Z-test = 0.307, p = 0.759). Calculations of a Z-statistic for the Eclipse Sound stock also resulted in similar significance values as the t-statistic (2023 vs 2013: Z-test = 0.001, p = 0.500, 2023 vs 2016: Z-test = 0.550, p = 0.291). Calculations of a Z-statistic for the Admiralty Inlet stock also resulted in similar significance values as the t-statistic (2023 vs 2013: Z-test = 0.314, p = 0.377).

Table 23: Test statistics for comparison of narwhal abundance estimates between the current and previous years

Region	Year	Abundance	Year	Abundance	T-statistic	P-value (two-tailed)	Statistical Significance
Eclipse Sound	2013	10,489	2023	10,492	0.001	0.999	Not Significant
	2016	12,039			0.550	0.582	Not Significant
	2019	9,931			0.808	0.427	Not Significant
	2020	5,018			10.728	**<0.001**	**Significant**
	2021	2,595			7.916	**<0.001**	**Significant**
	2022	4,592			8.678	**<0.001**	**Significant**

Region	Year	Abundance	Year	Abundance	T-statistic	P-value (two-tailed)	Statistical Significance
Admiralty Inlet	2013	35,043	2023	30,214	0.313	0.756	Not Significant
	2019	28,746			0.236	0.814	Not Significant
	2020	31,026			0.127	0.899	Not Significant
	2021	72,582			5.490	**<0.001**	**Significant**
	2022	43,042			1.637	0.106	Not Significant
Eclipse Sound & Admiralty Inlet	2013	45,532	2023	40,706	0.307	0.761	Not Significant
	2019	38,771			0.297	0.767	Not Significant
	2020	36,044			0.729	0.469	Not Significant
	2021	75,177			4.430	**<0.001**	**Significant**
	2022	46,408			0.761	0.449	Not Significant

The 2023 results indicated there was no exceedance in the ‘change in stock size’ indicator in the marine mammal TARP (Trigger Action Response Plan) (Baffinland 2021b), which identifies a High Risk threshold of >25.0% decrease in stock abundance relative to 2019 stock abundance.

A resampling simulation method was used to estimate the trend in abundance estimates in Eclipse Sound over the past 20 years. A subset of 100 iterations was used to generate a plot showing the individual trends calculated during the resampling process (Figure 32). The orange line shows the fitted trend based on only mean annual abundance estimates, and the red line shows extrapolation for 2024 based on the estimated trends (Figure 32). For Eclipse Sound, 86% of the iterations had an overall significant temporal trend, which suggests evidence of a significant temporal trend in abundance in the area. Following the trend analysis, the slopes at each sampling year were summarized as percent change in narwhal abundance per year (Figure 33). Note that slope estimates may be driven by abundance values in previous or subsequent years, and they do not represent the extent of difference between the estimated abundance values from one survey year to the next one. Rather, they are the estimates of the angle of the spline at the survey year. In Eclipse Sound, estimated slopes in 2004, 2013, and 2016 were small (-12% per year, +2% per year, and +11% per year, respectively). In 2019, 2020, and 2021, estimated slope values were -37% per year, -52% per year, and -18% per year, respectively. This period was followed by positive slopes in both 2022 and 2023, with estimates of +119% per year and +207% per year, respectively. The negative slopes estimated for 2019 and 2020 and the positive slopes estimated for 2022 and 2023 were significant in 93%-98% of the simulations. Note that in 2019, the slope was estimated to be negative due to the low abundance recorded in 2020 as opposed to strictly changes from 2016, the previous sampling year. The remainder of the slopes were significant in <50% of the 5,000 simulations, suggesting little support for changes in abundance in those years.

For Admiralty Inlet, the estimated slopes in 2019 and 2020 were +30% per year and +43% per year, respectively, mirroring the negative slopes in Eclipse Sound during those years. In 2022 and 2023, when Eclipse Sound abundance trended up, the Admiralty Inlet values slopes were estimated to be -29% per year and -39% per year, respectively. For the combined Eclipse Sound and Admiralty Inlet estimates, the negative slope estimated for 2023 (value of -32% per year) was due to the reduction from the high abundance estimated in 2021 (Figure 32) and does not signify an actual large decline in abundance in 2023.

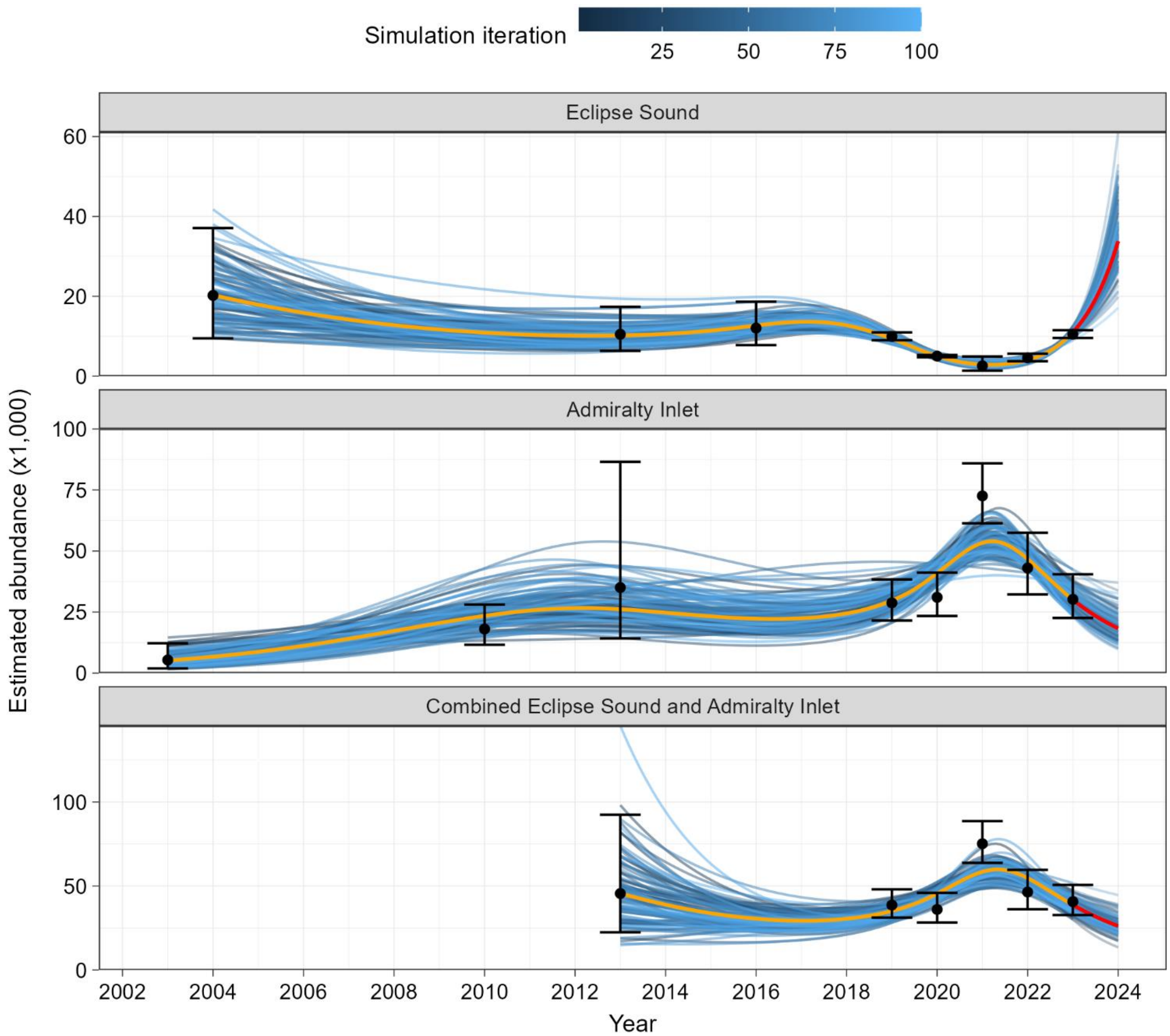

Figure 32: Trend analysis for Eclipse Sound, Admiralty Inlet, and the combined Eclipse Sound and Admiralty Inlet stock estimates using a resampling simulation method.

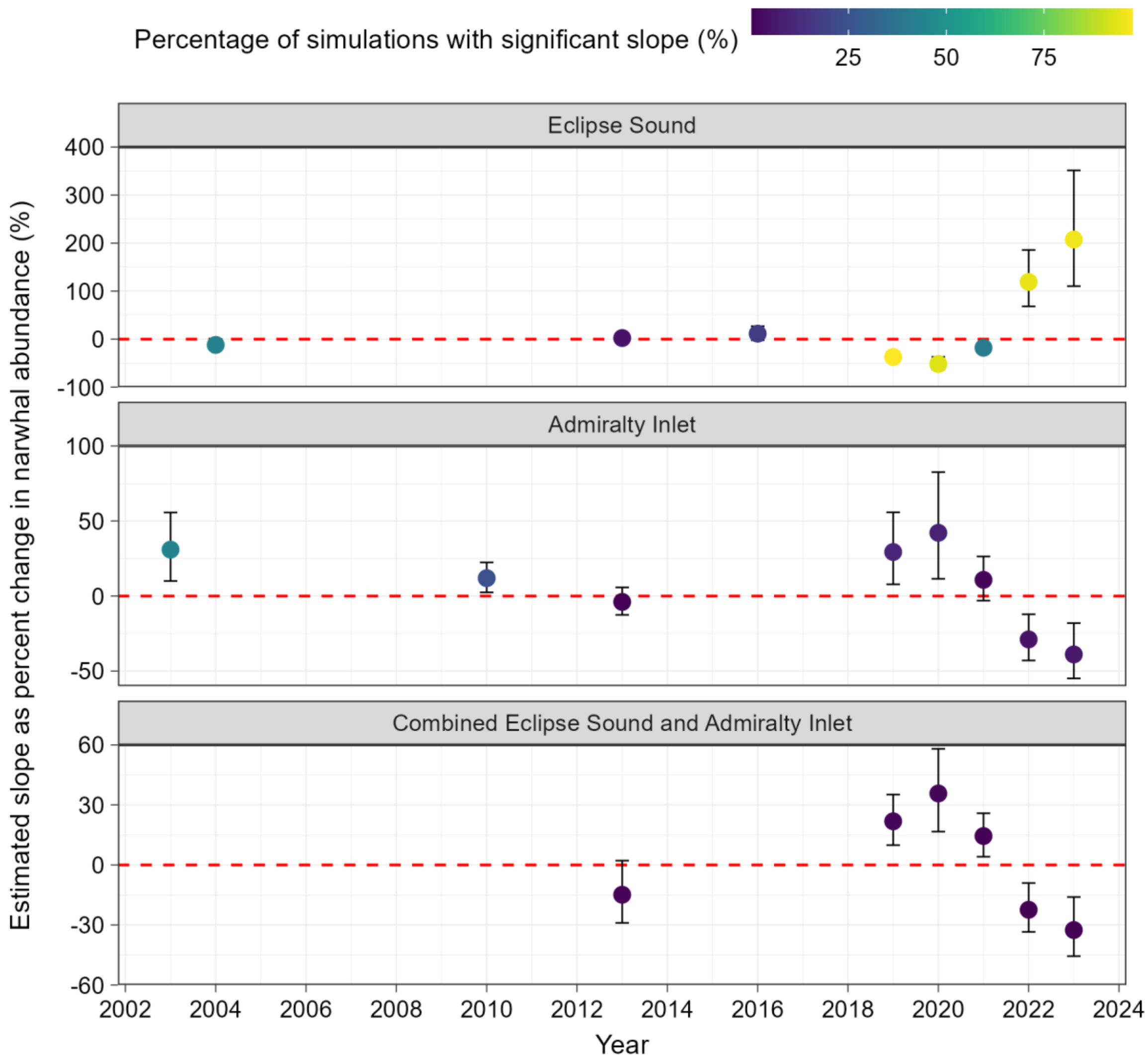

Figure 33: Estimated slopes (as percent change in narwhal abundance) from trend analysis. Error bars are 95% confidence intervals.

3.6 Discussion

3.6.1 Narwhal Abundance and Distribution

The Leg 2 aerial surveys in 2023 provided an updated estimate of narwhal abundance for the Eclipse Sound summer stock, the Admiralty Inlet summer stock, and the combined Eclipse Sound and Admiralty Inlet stocks.

The 2023 Eclipse Sound narwhal summer stock was estimated at 10,492 animals (CV= 0.05; CI = 9,578-11,494) which was not significantly different than the 2013 baseline condition (10,489 animals; CV = 0.24; CI = 6,342 – 17,347; Doniol-Valcroze et al. 2015a), the 2016 abundance estimate (12,039 animals; CV = 0.23; CI = 7,768-18,660; Marcoux et al. 2019) or the 2019 abundance estimate[6] (9,931 animals, CV = 0.05, 95% CI of 9,009–10,946; Golder 2020a). The 2023 Eclipse Sound abundance estimate was significantly higher than the three preceding years (2020-2022; Golder 2021a, 2022a, WSP 2023a). The increase in 2023 was observed despite 2023 having the highest volume of iron ore shipped out of Milne Port since the start of shipping operations and despite the introduction of larger Capesize ore carriers to shipping operations in 2023. Collectively, survey results to date indicate a poor correlation between annual shipping levels and narwhal abundance in the RSA.

The 2023 Admiralty Inlet narwhal summer stock was estimated at 30,214 narwhal (CV = 0.15; CI = 22,559–40,467) which was not statistically different than the 2013 abundance estimate (35,043 animals; CV = 0.42; CI = 14,188–86,553; Doniol-Valcroze et al. 2015a), the 2019 abundance estimate (28,746 animals; CV = 0.15; CI = 21,545–38,354; Golder 2020a), the 2020 abundance estimate (31,026 animals; CV = 0.14; CI = 23,406–41,126; Golder 2021a) or the 2022 abundance estimate (43,042 animals; CV = 0.15; CI = 32,218–57,502; WSP 2023a). The 2023 abundance estimate was shown to be statistically lower than the 2021 abundance estimate of 72,582 animals (CV = 0.09; CI = 61,333–85,895; Golder 2022a). The 2021 abundance estimate for the combined stocks (75,177 animals, CV = 0.08, CI = 63,795 – 88,590) was shown to be significantly higher than all other survey years including the 2013 baseline condition. The higher-than-normal number of narwhal observed in Admiralty Inlet during the 2021 open-water season suggests that animals belonging to other adjacent summer stocks were likely present in Admiralty at this time (Golder 2022a).

The 2023 abundance estimate for the combined Eclipse Sound and Admiralty Inlet narwhal stocks was 40,706 animals (CV = 0.11; CI = 32,711–50,655), which was not statistically different than the 2013 abundance estimate (45,532 animals; CV = 0.33; CI = 22,440–92,384; Doniol-Valcroze et al. 2015a), the 2019 abundance estimate (38,677 animals; CV = 0.11; CI = 31,155–48,015; Golder 2020a), the 2020 abundance estimate (36,044 animals, CV = 0.12, CI = 28,267–45,961; Golder 2021a) or the 2022 abundance estimate (46,408 animals, CV = 0.13, CI = 36,129–59,611; WSP 2023a). The 2023 abundance estimate was shown to be statistically lower than the 2021 abundance estimate (75,177 animals; CV = 0.08; CI = 63,795–88,590; Golder 2022a). Collectively, aerial survey results indicate that the combined stock size appears to be stable since the start of Baffinland shipping operations and relative to baseline levels. Results further indicate that some level of animal exchange occurs between the two putative stock areas but this does not appear to be related to Project shipping levels in the RSA.

During Survey #1 in the RSA (12-13 August), approximately 63% (6,631 of 10,492 individuals) of narwhal recorded in the RSA occurred in the Tremblay Sound stratum and approximately 35% (3,704 of 10,492 individuals) occurred in the Navy Board Inlet stratum. During this survey period, only 76 individuals (~1% of narwhal recorded in the RSA) occurred in the Milne Inlet South stratum. By the time the second survey in the RSA took place (Survey #3; 23-25 Aug), the distribution of narwhal had shifted pronouncedly from Tremblay Sound and

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[6] High-risk threshold in Marine Mammal Trigger Action Response Plan (TARP) = >25.0% decrease in Eclipse Sound narwhal abundance relative to the 2019 aerial survey abundance.

Navy Board Inlet into the Milne Inlet strata. During Survey #3 (23-25 Aug), approximately 43% (4,108 of 9,572 individuals) of narwhal recorded in the RSA occurred in the Milne Inlet South stratum, approximately 22% (2,156 of 9,572 individuals) occurred in the Milne Inlet North stratum, and approximately 31% (2,969 of 9,572 individuals) occurred in the Tremblay Sound stratum.

The 2023 Bruce Head Shore-based Monitoring Program reported a decrease in narwhal relative abundance (i.e., total number of narwhal corrected for survey effort) in the Bruce Head study area during the 2023 study period. Relative abundance in 2023 (2.9 narwhal/h) was significantly lower than in 2016 (178.0 narwhal/h), 2017 (121.8 narwhal/h), and 2019 (127.2 narwhal/h) (WSP 2024a). Prior to 2023, the lowest relative abundance of narwhal recorded at Bruce Head occurred in 2020 (47.5 narwhal/h) followed by 2021 (29.4 narwhal/h) (WSP 2024a). The low narwhal numbers recorded at Bruce Head in 2023 were thought to be potentially linked to the late break-up of landfast ice in the RSA in 2023 and its influence on narwhal distribution during this period. No narwhal were observed in the Bruce Head study area until 05 August 2023, with narwhal numbers slowly increasing towards the end of the Program on 22 August 2023. The low narwhal numbers observed at Bruce Head were shown to spatially and temporally coincide with low narwhal numbers recorded during the 12-13 Aug aerial survey conducted in Milne Inlet South (Survey #1; 76 individuals). It was not until after the Bruce Head program ended on 22 August that narwhal number in the Milne Inlet South stratum increased substantially from 76 animals on 12-13 August (Survey #1) to 4,108 animals on 23-25 August (Survey #3). The 2023 aerial survey results indicate that the low narwhal numbers observed at Bruce Head do not reflect a true decrease in the abundance of the Eclipse Sound summer stock. Instead, the aerial survey results flag issues with the timing of the 2023 Bruce Head Program, as sampling at Bruce Head would have occurred when most animals in the RSA were distributed almost exclusively in the northern strata (i.e., Tremblay Sound and Navy Board Inet), with animals only entering the Bruce Head study area after the Bruce Head Program ended.

Other Considerations:

For the past five consecutive years (2019–2023), Baffinland has undertaken combined surveys of both Admiralty Inlet and Eclipse Sound summering stock areas. The primary impetus for running the combined stock surveys (as opposed to the Eclipse Sound summer stock only) was based on available IQ, which indicated that the geographic and genetic distinction between these two summering stocks may be invalid (NWMB 2016a; 2016b; QWB 2022). DFO has also been investigating the extent to which there may be natural exchange of narwhal between these stock areas during the open-water season (Doniol-Valcroze et al. 2015a, 2020; DFO 2020b; Marcoux and Watt 2021). Natural exchange between the two summering areas was proposed as a possible reason why the 2013 survey results for Admiralty Inlet (~35,000 narwhal) and Eclipse Sound (~10,000 narwhal) differed substantially from previous survey results for the same stocks (18,000 for Admiralty Inlet in 2010 and 20,000 for Eclipse Sound in 2004) (Doniol-Valcroze et al. 2015a).

Given that the combined stock estimate for Admiralty Inlet and Eclipse Sound in 2023 (40,706 animals, CV=0.11, CI = 32,711-50,655) indicates that the regional narwhal population is stable relative to pre-shipping levels in 2013 (45,532 animals; CV = 0.33; CI = 22,440 - 92,384; Doniol-Valcroze et al. 2015a), and in consideration of the available IQ regarding the degree of exchange between narwhal groups on their summering grounds, the observed fluctuations in narwhal abundance in Eclipse Sound in recent years likely reflects a natural exchange between the two putative stock areas that began prior to Baffinland shipping operations, with animals shifting between Eclipse Sound and Admiralty Inlet based on where habitat conditions may be more favorable that season (e.g., ice coverage, prey availability, predation pressure). The trend analysis in Section 3.5.6 also supports the theory of natural exchange between the Eclipse Sound and Admiralty Inlet stocks, where the positive slopes in Admiralty Inlet mirror the negative slopes in Eclipse Sound (and vice versa).

With the recent influence of rapidly warming ocean temperatures and longer open-water seasons due to climate change, more pronounced changes in habitat conditions are to be expected throughout the Arctic along with commensurate changes in animal distributions and migratory movements. For example, it is well documented that sea ice in the Arctic is presently undergoing rapid reduction due to climate warming (Stroeve et al. 2012; IPCC 2013; Overland and Wang 2013) and this has been directly associated with notable shifts in species distributions for both Arctic marine mammals (Laidre et al. 2008, 2015; Frederiksen and Haug 2015; Nøttestad et al. 2015; Víkingsson et al. 2015; Albouy et al. 2020; Chambault et al. 2022;) and their prey (Frainer et al. 2017; Steiner et al. 2019, 2021; Møller and Nielsen 2020). How this might be manifesting on a micro-geographic scale in the North Baffin region is presently unclear, although some insight is offered when considering changes reported in other Arctic environments in close proximity to Eclipse Sound.

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

A recent study by Chambault et al. (2022) predicted the future distribution of Eastern Baffin Bay narwhal under two different climate change scenarios using narwhal satellite tracking data collected over two decades. The long-term predictive models suggest that the current distribution of Baffin Bay narwhal during summer will undergo a +200 km northward shift to cope with climate change, and that summer narwhal habitats in this region are predicted to decline by 31 to 66% (depending on the climate model). These changes may already be underway in the eastern Canadian Arctic and may affect Eclipse Sound and Admiralty Inlet differently. Recent observations of narwhal in Archer Fjord highlights present-day knowledge gaps regarding narwhal population ecology, seasonal distribution and movement patterns, and general life history information (Carlyle et al. 2021). Carlyle et al. (2021) goes on to state that the presence of narwhal in Archer Fjord may be an annual summer occurrence or may represent an ecological range shift.

For the above reasons, the potential for climate-driven shifts in species distributions cannot be ignored as a potential explanation of observed fluctuations in summer narwhal distribution in Eclipse Sound and Admiralty Inlet. To better understand what may be occurring, regional-scale monitoring led by government is needed to better understand how climate change is impacting the Baffin Bay narwhal population as a whole. A Canadian High Arctic Cetacean Survey was conducted by DFO in 2023 to provide an updated abundance estimate for all the Canadian Baffin Bay narwhal stocks. The results of this survey should help to better understand the seasonal distribution and movements of narwhal in the various summering ground areas.

3.6.2 Other Marine Mammals

3.6.2.1 Bowhead Whale

Bowhead sightings were substantially lower in the RSA during the open-water season (Leg 2) compared to the early shoulder season (Leg 1), suggesting that most of the individuals observed during Leg 1 had completed their migration through the RSA prior to the start of the Leg 2 aerial surveys (10 August). A total of 17 bowhead were recorded in the RSA during the Leg 2 surveys (10–25 Aug), with many of these sightings likely representing repeat sightings. The Bruce Head shore-based monitoring team reported a single bowhead whale on five separate occasions, with three of these sightings likely representing the same individual (WSP 2024a). During aerial surveys flown in previous years in the RSA (Golder 2022a), total number of sightings included two bowhead observations in 2021 (Golder 2022a), one in 2020 (Golder 2021a), four in 2019 (Golder 2020a), six in 2014 (Thomas et al. 2015), and no observations in 2013 or 2015 (Elliott et al. 2015; Thomas et al. 2016). The observed reduction in bowhead sightings during mid-summer is consistent with the pattern observed during baseline monitoring and therefore does not suggest potential displacement of animals from the RSA due to shipping. Bowhead whales are known to use Eclipse Sound and Navy Board Inlet as a migration corridor during the early shoulder season, with numbers in the RSA dropping during the open water season. The relative abundance of bowhead in the RSA was higher in 2023 (0.0041 animals/km) compared to the four previous years (0.0006 animals/km in 2021 and 2022, 0.0003 animals/km in 2019 and 2020) (see Appendix D). Aerial survey results are consistent with available IQ which indicates bowhead migration in the RSA occurs in Aujaq (end of July to September) (JPCS 2017).

In Admiralty Inlet, bowhead were dispersed throughout the Admiralty Inlet survey grid. The relative abundance of bowhead in Admiralty Inlet was similar in 2023 and 2022 (0.0039 animals/km and 0.0034 animals/km, respectively) but lower than observed in the previous three years (0.0313 animals/km in 2019, 0.0087 animals/km in 2020, and 0.0510 animals/km in 2021) (see Appendix D). The Canadian High Arctic Cetacean Survey conducted by DFO in August 2013 calculated bowhead abundance in Admiralty Inlet at 82 whales (CV=0.97; DFO 2015b). Bowhead abundance estimates calculated in 2019 were higher than previous estimates in Admiralty Inlet. The highest estimate for the 2019 MMASP was obtained from the 25–27 August survey with an estimate of 834 animals (CV=0.50, 95% CI of 334–2,080). The lowest estimate for the 2019 MMASP was obtained two days later from the 29–30 August survey with an estimate of 472 animals (CV=0.35, CI = 240–926). Bowhead numbers appear to fluctuate considerably from year to year in the Admiralty Inlet survey grid.

3.6.2.2 Killer Whale

In 2023, nine killer whales were observed in the Eclipse Sound grid on 26 August at the entrance to Tremblay Sound. The Bruce Head team did not report any sightings of killer whales in 2023 (WSP 2024a). During previous aerial surveys flown in August in the RSA, no killer whales were observed in 2022 or 2021 (WSP 2023a; Golder 2022a), fourteen killer whales were observed in 2020 (Golder 2021a), 29 killer whales were observed in 2019 (Golder 2020a), and none were observed in 2013, 2014, or 2015 (Elliott et al. 2015; Thomas et al. 2015; Thomas et al. 2016).

In Admiralty Inlet, killer whale were not observed during the 2023 aerial surveys. During previous aerial surveys flown in August in Admiralty Inlet, 26 killer whales were observed in 2021 (Golder 2022a), and none were observed in 2019, 2020 or 2022 (Golder 2020a; Golder 2021a; WSP 2023a).

3.6.2.3 Beluga Whale

In 2023, beluga were not observed in the Eclipse Sound survey grid during Leg 2 aerial surveys. During previous aerial surveys flown in August in the RSA, three beluga were recorded in 2022 (WSP 2023a), one was recorded in 2020 (Golder 2021a), and none were recorded in 2013, 2014, 2015, 2019, and 2021 (Elliott et al. 2015; Thomas et al. 2015; Thomas et al. 2016; Golder 2020a; Golder 2022a).

In Admiralty Inlet, beluga were not observed during the 2023 aerial surveys. Beluga were first observed in Admiralty Inlet in 2022 as part of surveys undertaken for the MMASP.

3.6.2.4 Pinnipeds

Pinniped data collected in 2019, 2020, 2021, 2022, and 2023 should be interpreted with caution due to the relative difficulty in observing seals at survey altitudes of 305 m (1,000 ft) ASL. Apparent differences in sightings may be the result of changes in survey conditions and the ability of MMOs to identify species rather than actual changes in pinniped numbers or distribution.

Ringed Seal: Ringed seals were sporadically distributed throughout the survey area during Leg 2 of the 2023 MMASP, similar to what was observed in previous years (Elliott et al. 2015; Thomas et al. 2015, 2016; Golder 2020a; Golder 2021a; Golder 2022a; WSP 2023a). Ringed seal had the highest sighting count of all pinniped species sighted during the 2023 MMASP, accounting for 84% of all pinniped sightings identified to the species level (386 out of a total of 102). Ringed seal sightings were primarily observed as single animals. During Leg 2, ringed seal relative abundance in the Eclipse Sound grid was also lower in 2023 (0.0352 animals/km) to that observed in the previous three years (0.0726 animals/km in 2022, 0.0702 animals/km in 2021 and 0.0736 animals/km in 2020), although higher to that observed in 2019 (0.0047 animals/km) (see Appendix D). In the Admiralty Inlet grid ringed seal relative abundance was similarly lower in 2023 (0.0202 animals/km) to that observed in the previous three years (0.0615 animals/km in 2022, 0.0920 animals/km in 2021, 0.0830 animals/km in 2020), although higher to that observed in 2019 (0.0122 animals/km) (see Appendix D). Ringed seal observations provide relative abundance and distribution information. However, this information cannot be used to reliably assess the effects of Project shipping or obtain accurate abundance estimates.

A summary of the 2021 ringed seal aerial survey program which indicated that ringed seal densities had remained stable in the RSA with some annual variations since the onset of shipping or icebreaking activities is provided in Golder (2022b).

Harp Seal: Harp seal sightings were primarily observed as groups of multiple animals. The largest group size observed in 2023 was 100 animals. In the Eclipse Sound grid, harp seals were observed primarily at the top of Navy Board Inlet and in the Pond Inlet stratum, similar to what had been observed in previous years (Elliott et al. 2015; Thomas et al. 2015, 2016; Golder 2020a, 2021a, Golder 2022a; WSP 2023a). In the Admiralty Inlet grid, harp seals were observed throughout the survey area, although higher numbers were observed in the Admiralty Inlet North stratum.

During Leg 2, the 2023 harp seal relative abundance in the Eclipse Sound grid (0.0958 animals/km) was higher compared to the previous four years (0.0466 animals/km in 2022, 0.0331 animals/km in 2021 and 0.0448 animals/km in 2020, and 0.0527 animals/km in 2019) (see Appendix D). In the Admiralty Inlet grid, the 2023 harp seal relative abundance (0.1543 animals/km) was lower compared to the previous three years (0.1917 animals/km in 2022, 0.9441 animals/km in 2021 and 0.3685 animals/km in 2020) and higher compared to 2019 (0.1495 animals/km) (see Appendix D). Harp seal observations provide relative abundance and distribution information. However, this information cannot be used to reliably assess the effects of Project shipping or obtain accurate abundance estimates.

Bearded Seal: Similar to previous years, only a few bearded seals were observed during the 2023 MMASP. Three sightings were recorded during Leg 2 surveys. All three sightings were observed in the Eclipse Sound survey grid; one in Eclipse Sound, and two in Navy Board Inlet. Limited IQ has been collected regarding the overall abundance of bearded seal. Some Elders in the Baffin region have observed a decrease in bearded seal abundance since the advent of firearms and motorized transportation (Baffinland 2010). In contrast, one Elder noted that bearded seal were rare near Pond Inlet in the past but are now more frequently observed.

Walrus: Walrus were not observed in the Eclipse Sound or the Admiralty Inlet survey grids during 2023 Leg 2 surveys. This is not unusual as walrus are seldom observed in either area during the summer period.

3.6.2.5 Polar Bear

Polar bear sightings have been regularly recorded during the Baffinland aerial survey programs. The distribution of polar bears in 2023 was similar to that observed during previous aerial surveys. In the Eclipse Sound grid, polar bears were more likely to be recorded in the Navy Board Inlet and Pond Inlet strata. In 2023, polar bear sightings in the RSA were limited to one sighting (mother with cub) in Navy Board Inlet and another sighting (mother and cub) in western Eclipse Sound (Appendix B, Figures B-11 and B-13).

In Admiralty Inlet, polar bear were recorded throughout the study area. Four polar bear sightings (comprising eight individuals) were recorded during the single visual survey undertaken in the Admiralty Inlet survey grid. Two sightings were of single adults, one in the Admiralty Inlet North stratum (20 Aug) and the other in the Admiralty Inlet South stratum (20 Aug) (Appendix B, Figure B-10). The two remaining sightings, each comprised of a mother with two cubs, occurred on 20 August in Admiralty Inlet South (Appendix B, Figure B-12).

4.0 LEG 3: CLEARANCE SURVEY

4.1 Objective

Leg 3 of the 2023 MMASP targeted a two-day window at the end of the shipping season in late October to conduct a visual clearance survey to document whether narwhal entrapment events occurred in the RSA following completion of Baffinland's 2023 shipping operations along the Northern Shipping Route.

4.2 Study Area

An aerial survey (i.e., narwhal clearance survey) was flown in the RSA (Figure 34) at the end of the shipping season on 31 October 2023. The survey was flown along the Northern Shipping Route (i.e., nominal shipping lane) and in adjacent areas in the RSA.

4.3 Materials and Methods

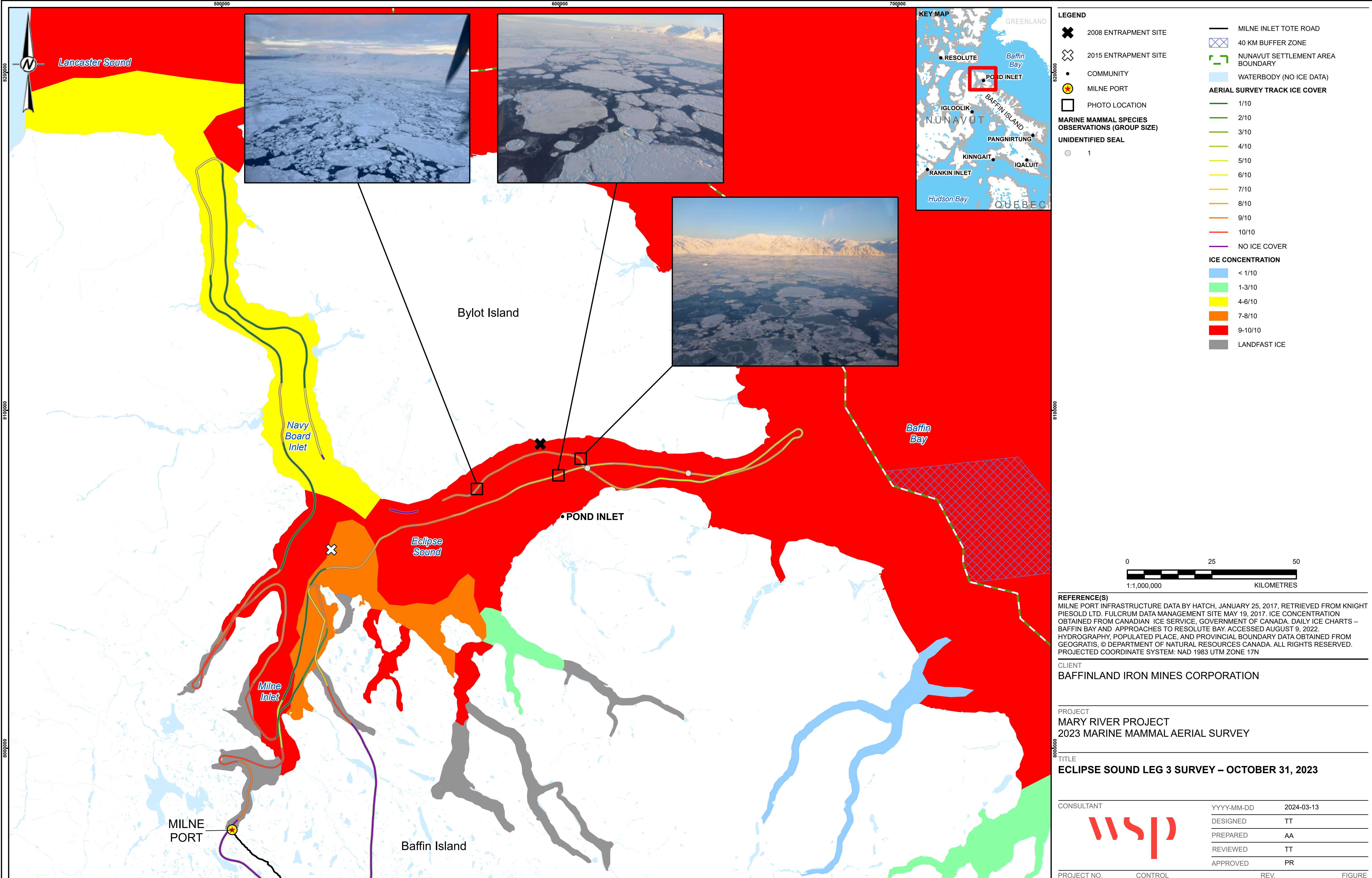
The Leg 3 aerial clearance surveys were flown in a Dornier 228 operated by Summit Air Ltd. based out of the Mary River mine site. Dedicated transects along the shipping lane and throughout Eclipse Sound, Milne Inlet, Navy Board Inlet and Tremblay Sound were flown at an altitude of 457 m (1,500 ft) and a ground speed of 185 km/h (100 kn) with four experienced MMOs. Two experienced Inuit MMOs from Pond Inlet conducted observations from the front of the aircraft. A third member of the survey team was seated on the right side of the plane and was responsible for entering sighting data obtained from the observers into the database and taking representative photos.

MMOs broadly scanned the survey area to identify marine mammal sightings and provide information on weather and ice conditions. For each sighting, information was recorded on species identification and the number of animals included in the sighting. A 'sighting' was defined as animals within one or a few body lengths of each other and oriented or moving in a similar direction. When possible, observers were instructed to give additional details on the sightings, such as the presence of calves, tusked narwhal, behaviour, and direction of travel.

4.4 Leg 3 Survey Results

The clearance survey took place on 31 October when the last Project vessel convoy (two ice breakers, two tugboats and one ore carrier) departed the RSA. During the clearance survey, the vessel convoy was located on the shipping lane near Pond Inlet transiting eastward toward Baffin Bay. Total survey effort on 31 October was 4 h and 47 min, covering a total distance of 934 km (Figure 34)). The clearance survey started at Milne Port with the aircraft proceeding along the shipping lane in Milne Inlet South and Milne Inlet North, but also including a deviation in Koluktoo Bay. The aircraft continued along the shipping lane in Western Eclipse Sound, Eastern Eclipse Sound and Pond Inlet up to the entrance of Baffin Bay. The aircraft then deviated southward and surveyed the shoreline area near Mount Herodier and Beloeil Island where narwhal were observed in previous years (e.g., 2020 clearance survey) and based on local narwhal information shared by the MHTO. The aircraft then crossed back across Eclipse Sound to Bylot Island and flew westward along the south shoreline of Bylot Island including surveying the historical narwhal entrapment site in 2008. The aircraft then flew north up Navy Board Inlet following the Bylot Island shoreline up to the entrance to Lancaster Sound, then crossed Navy Board

Inlet and proceeded southbound following the western shoreline of Navy Board Inlet. The aircraft then continued into Tremblay Sound, conducting a full survey of both shorelines before proceeding back into Milne Inlet North and transiting southbound along the western shoreline of Milne Inlet North before crossing the inlet and heading back up the eastern shoreline of Milne Inlet North. Finally, the survey proceeded into Eskimo Inlet before returning back to the Mary River mine site.



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CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEY

TITLE
ECLIPSE SOUND LEG 3 SURVEY – OCTOBER 31, 2023

CONSULTANT

wsp

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	78000.06	0	34

Based on ice conditions reported by the Canadian Ice Service, fast ice and 9/10 to 10/10 ice concentrations were present in Assomption Harbour, Koluktoo Bay and in the adjacent fjord waterways on 31 October 2023. During the clearance survey, the MMOs reported ice conditions in the RSA that ranged from 0 to 10/10 concentrations (Figure 34). No narwhal were observed in the RSA during the clearance survey. Marine mammal sightings were limited to two sightings of unidentified seal species.

4.5 Discussion

No narwhal were recorded in the RSA during the 2023 Leg 3 survey. The last narwhal sightings in the RSA occurred on 28 October when a total of five narwhal sightings comprising twenty animals were recorded in Eastern Eclipse Sound during the SBO Program (WSP 2024b). Ice conditions at the time ranged from 7/10 to 9/10 concentration, which would not have impeded narwhal movements into and out of the RSA at this time.

5.0 SUMMARY

In 2023, WSP Canada Inc. (WSP), on behalf of Baffinland Iron Mines Corporation (Baffinland), completed a Marine Mammal Aerial Survey Program (MMASP) designed to assess narwhal distribution and abundance in the Regional Study Area (RSA) and Admiralty Inlet. The 2023 MMASP was staged in three separate legs. Leg 1 targeted a 15-day window during the early shoulder shipping season (late July) to collect data on the presence/absence and distribution of marine mammals in the RSA relative to ice conditions at that time of year and prior to the start of shipping operations. Leg 2 targeted a three-week window in peak summer (August) to obtain an annual abundance estimate for the Eclipse Sound and Admiralty Inlet narwhal summer stocks during the open-water season. Leg 3 targeted a two-day window at the end of the shipping season in late October to conduct a visual clearance survey to document if narwhal entrapment events occurred in the RSA following completion of Baffinland's 2023 shipping operations along the Northern Shipping Route. Survey design and data collection methodology previously developed by Fisheries and Oceans Canada (DFO) (Matthews et al. 2017; Marcoux et al. 2016; Doniol-Valcroze et al. 2015a; Asselin and Richard 2011) and implemented by Golder Associates Ltd. (amalgamated in January 2023 under WSP Canada Inc.) in 2019 (Golder 2020a), 2020 (Golder 2021a), 2021 (Golder 2022a) and 2022 (WSP 2023a) was adopted to allow for interannual comparison of the annual abundance estimates.

Early Shoulder Season (Leg 1) Surveys

The 2023 early shoulder season (Leg 1) surveys were conducted in the RSA (i.e., Eclipse Sound survey grid) on 23–30 July and in Admiralty Inlet on 29 and 31 July, with a total of nine surveys flown during this period. Landfast ice was present in the RSA for the full duration of the Leg 1 surveys. During the first week of the surveys (23 to 28 July), landfast ice extended across Eclipse Sound and north Milne Inlet, with no visible leads present in the ice. Areas bordering the landfast ice (Pond Inlet and south Navy Board Inlet) were comprised of consolidated / very close pack ice (9/10 to 10/10 concentration). Open-water areas (1/10 to 3/10 concentration) at this time were limited to south Milne Inlet, north Navy Board Inlet and Baffin Bay.

Towards the end of the Leg 1 surveys (29-31 July), ice conditions in the RSA began to break-up with landfast cover now limited to central Eclipse Sound and consolidated / very close pack ice (9/10 to 10/10) extending across western and eastern Eclipse Sound, north Milne Inlet and south Navy Board Inlet. Open-water areas (0/10 to 3/10) at this time were limited to south Milne Inlet, north Navy Board Inlet and Baffin Bay.

In Admiralty Inlet, ice conditions during the Leg 1 aerial surveys ranged from close pack ice (7/10 to 8/10) in the north to consolidated / very close pack ice (9/10 to 10/10) in the central portion of the inlet with some open-water areas in south Admiralty.

A total of 4,499 km of survey effort (3,688 km of systematic transects and 811 km of dedicated transects) was undertaken for the Leg 1 surveys completed in the RSA and Admiralty Inlet. Eight different marine mammal species were recorded during Leg 1 (narwhal, beluga, bowhead, ringed seal, harp seal, bearded seal, hooded seal and polar bear) resulting in a total of 2,886 sightings (comprising 8,668 individuals). Narwhal were the most abundant species observed during Leg 1, with 0.79 animals/km recorded during the systematic surveys and 1.94 animals/km recorded during the dedicated transects. A total of 357 mother/calf pairs (227 mother/calf pairs in RSA and 130 mother/calf pairs in Admiralty Inlet grid) and 80 lone calves (37 lone calves in RSA and 43 lone calves in Admiralty Inlet grid) were recorded during the Leg 1 surveys.

In the RSA, a total of 1,696 narwhal sightings (comprising 4,184 individuals) were recorded during Leg 1, with narwhal distributed in two distinct areas; north Navy Board Inlet and eastern Eclipse/Pond Inlet/Baffin Bay. The extensive landfast ice in western Eclipse Sound effectively isolated the two distribution areas from one another. In the Eclipse Sound/Pond Inlet/Baffin Bay strata, narwhal relative abundance remained consistently high throughout the Leg 1 surveys. In the Navy Board Inlet stratum, narwhal relative abundance remained consistently high for the first three surveys, but then dropped to very low numbers on the last survey (30 July). Survey results generally indicated that narwhal in the Eclipse Sound/Pond Inlet/Baffin Bay stratum remained in the RSA for the duration of the Leg 1 surveys, while narwhal in the Navy Board Inlet strata appeared to have departed the RSA sometime after 27 July (presumably through Lancaster Sound). Once landfast ice in Eclipse Sound began to break-up near the end of Leg 1 (27-28 July), several narwhal sightings were recorded in ice leads present in western Eclipse Sound. However, no narwhal were observed in Milne Inlet or Tremblay Sound during any of the Leg 1 surveys, presumably due to local ice conditions impeding access to these areas or narwhal preference to remain in areas of high ice concentration.

In Admiralty Inlet, a total of 578 narwhal sightings (comprising 1,152 individuals) were recorded during Leg 1, with sightings limited to north Admiralty. No narwhal sightings were recorded south of the area of consolidated pack ice (9/10 to 10/10 ice concentrations) present in the middle portion of the inlet, presumably due to local ice conditions impeding access to south Admiralty Inlet or narwhal preference to remain in areas of high ice concentration.

Open-water (Leg 2) Abundance Surveys

The Leg 2 aerial surveys in 2023 provided an updated estimate of narwhal abundance for the Eclipse Sound summer stock, the Admiralty Inlet summer stock, and the combined Eclipse Sound and Admiralty Inlet stocks. Two types of aerial surveys were flown: a visual-based survey in which marine mammal sightings were collected along established line transects using a double-platform approach with Marine Mammal Observers (MMOs) stationed at independent observation platforms at the front and rear of the aircraft, and a photographic-based survey in which medium format mirrorless cameras were installed on the aircraft to collect high definition photographic images of the survey area directly below the aircraft. Photographic surveys were flown in areas of high narwhal concentrations where accurate counts would be difficult to obtain using visual means. A total of two surveys were conducted in the Eclipse Sound survey grid and one survey was conducted in the Admiralty Inlet survey grid during Leg 2. Complete coverage (excluding fjords) was achieved for the first survey in Eclipse Sound (12-13 Aug) and partial coverage was obtained for the second survey in Eclipse Sound (23-25 Aug) and the single survey in Admiralty Inlet (19-20 Aug).

A total of 4,376 km of survey effort was undertaken for the Leg 2 aerial surveys (including both visual and photographic surveys), encompassing 3,345 km in the RSA and 1,031 km in Admiralty Inlet. During the visual surveys, a total of six different marine mammal species were recorded (narwhal, bowhead, ringed seal, harp seal, bearded seal and polar bear) resulting in a total of 271 sightings (comprising 648 individuals) in the RSA and 417 sightings (comprising 893 individuals) in Admiralty Inlet. Narwhal were the most abundant species observed during the Leg 2 aerial surveys, with 140 sightings (comprising 353 individuals) in the RSA (including reconnaissance flights) and 348 sighting (comprising 690 individuals) in Admiralty Inlet. For the photographic surveys, a total of 9,501 sightings (comprising 17,675 individuals) were identified during the photographic analysis (all surveys combined). Photographic surveys were conducted in high density areas of Milne Inlet, Tremblay Sound and Admiralty Inlet. Two different species were recorded during the photographic surveys: narwhal (9,496 sightings totalling 17,668 individuals) and bowhead whale (five sightings totalling 7 individuals).

The 2023 Eclipse Sound narwhal summer stock was estimated at 10,492 animals (CV= 0.05; CI = 9,578-11,494) which was not significantly different than the 2013 baseline condition (10,489 animals; CV = 0.24; CI = 6,342 – 17,347; Doniol-Valcroze et al. 2015a), the 2016 abundance estimate (12,039 animals; CV = 0.23; CI = 7,768-18,660; Marcoux et al. 2019) or the 2019 abundance estimate[7] (9,931 animals, CV = 0.05, 95% CI of 9,009–10,946; Golder 2020a). The 2023 Eclipse Sound abundance estimate was significantly higher than the three preceding years (2020-2022; Golder 2021a, 2022a, WSP 2023a). The increase in 2023 was observed despite 2023 having the highest volume of iron ore shipped out of Milne Port since the start of shipping operations and despite the introduction of larger Capesize ore carriers to shipping operations in 2023. Collectively, survey results to date indicate a poor correlation between annual shipping levels and narwhal abundance in the RSA.

The 2023 Admiralty Inlet narwhal summer stock was estimated at 30,214 narwhal (CV = 0.15; CI = 22,559–40,467) which was not statistically different than the 2013 abundance estimate (35,043 animals; CV = 0.42; CI = 14,188–86,553; Doniol-Valcroze et al. 2015a), the 2019 abundance estimate (28,746 animals; CV = 0.15; CI = 21,545–38,354; Golder 2020a), the 2020 abundance estimate (31,026 animals; CV = 0.14; CI = 23,406–41,126; Golder 2021a) or the 2022 abundance estimate (43,042 animals; CV = 0.15; CI = 32,218–57,502; WSP 2023a). The 2023 abundance estimate was shown to be statistically lower than the 2021 abundance estimate of 72,582 animals (CV = 0.09; CI = 61,333–85,895; Golder 2022a).

The 2023 abundance estimate for the combined Eclipse Sound and Admiralty Inlet narwhal stocks was 40,706 animals (CV = 0.11; CI = 32,711–50,655), which was not statistically different than the 2013 abundance estimate (45,532 animals; CV = 0.33; CI = 22,440–92,384; Doniol-Valcroze et al. 2015a), the 2019 abundance estimate (38,677 animals; CV = 0.11; CI = 31,155–48,015; Golder 2020a), the 2020 abundance estimate (36,044 animals, CV = 0.12, CI = 28,267–45,961; Golder 2021a) or the 2022 abundance estimate (46,408 animals, CV = 0.13, CI = 36,129–59,611; WSP 2023a). The 2023 abundance estimate was shown to be statistically lower than the 2021 abundance estimate (75,177 animals; CV = 0.08; CI = 63,795–88,590; Golder 2022a). Collectively, aerial survey results indicate that the combined stock size appears to be stable since the start of Baffinland shipping operations and relative to baseline levels. Results further indicate that some level of animal exchange occurs between the two putative stock areas but this does not appear to be related to Project shipping levels in the RSA.

Late Shoulder Season (Leg 3) Surveys

An aerial clearance survey was flown in the RSA at the end of the shipping season on 31 October 2023 to monitor the shipping corridor and adjacent areas for potential narwhal entrapment events following the completion of Baffinland's 2023 shipping operations in the RSA. No narwhal sightings were recorded during the survey. Results of the end of season aerial clearance survey indicate that no entrapments occurred in 2023 as a result of Project icebreaking and shipping activities in the RSA.

Table 24 presents a summary on how the applicable terms and conditions outlined in Project Certificate No. 005 have been addressed through monitoring undertaken as part of the 2023 MMASP.

[7] High-risk threshold in Marine Mammal Trigger Action Response Plan (TARP) = >25.0% decrease in Eclipse Sound narwhal abundance relative to the 2019 aerial survey abundance.

Table 24: MMASP compliance with applicable terms and conditions of Project Certificate No. 05

Project Certificate Terms and Conditions	Condition / Evidence of Conditions Met
101	Efforts to involve Inuit in monitoring studies at all levels: ■ Inuit researchers participated in Legs 1, 2 and 3 of the 2023 MMASP. Monitoring protocols that are responsive to Inuit concerns: ■ Aerial surveys allow for evaluation of narwhal large-scale displacement effects, abandonment of the RSA, moderate to large changes in stock size. ■ Although not designed to assess ringed seal abundance in the RSA, the MMASP reports on values of relative abundance for ringed seals. Schedule for periodic aerial surveys as recommended by the MEWG: ■ Aerial surveys in support of the Project were conducted in 2006, 2007, 2008, 2012, 2013, 2014, 2015, 2019, 2020, 2021, 2022, and 2023.
109	Conduct a monitoring program to confirm the prediction in the FEIS: ■ Aerial survey can measure effects at the narwhal population and/or stock level including evaluation of large-scale displacement effects or abandonment of the RSA.
111	Develop clear thresholds for determining if negative impacts as a result of vessel noise are occurring: ■ Conducted statistical analyses to compare the values of the current aerial survey to past aerial surveys.
126	Design monitoring program to ensure that local users can assist with monitoring and evaluating potential impacts: ■ Inuit researchers participated in Legs 1, 2 and 3 of the 2023 MMASP.

6.0 RECOMMENDATIONS

With respect to future monitoring initiatives for the Marine Mammal Aerial Survey Program, WSP provides the following recommendations for implementation in 2024:

- Aerial surveys are not proposed for summer 2024 based on the results of the 2023 aerial surveys which show that narwhal abundance in 2023 was not statistically different from baseline conditions in 2013, or from the 2019 abundance estimate (i.e., trigger associated with high risk threshold identified in the TARP), despite 2023 having the second highest shipping levels in the RSA since the start of operations and despite Baffinland introducing larger Capesize ore carriers to shipping operations in 2023. Further, the combined Eclipse/Admiralty stock size appears to be stable since the start of Baffinland shipping operations and relative to baseline levels. Collectively, results to date indicate a poor correlation between annual Project shipping levels and narwhal abundance in the RSA and that some level of animal exchange occurs between the two putative stock areas but this does not appear to be related to shipping levels. As such, annual monitoring of narwhal for the purpose of evaluating Project shipping effects on abundance is not considered warranted at this time. Results from DFO's 2023 aerial surveys of the Baffin Bay narwhal population as a whole (all summer stock areas) will assist in determining future survey requirements for the Eclipse Sound and Admiralty Inlet summer stocks.
- Conduct an end-of-shipping-season visual clearance survey to confirm that no narwhal entrapment events have occurred in the RSA following completion of 2024 shipping operations along the Northern Shipping Route.

7.0 CLOSURE

We trust that this report meets your immediate requirements. If you have any questions regarding the content of this report, please do not hesitate to contact the undersigned.

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APPENDIX A

MMO Training Manual

REPORT

2023 Marine Mammal Aerial Survey Program

Training Manual

Submitted to:

Baffinland Iron Mines Corporation

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1663724-469-R-Rev0-78000

17 July 2023

Distribution List

Baffinland Iron Mines Corporation

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1.0 INTRODUCTION

The Marine Mammal Aerial Survey Program (MMASP) represents one of several programs that were developed to support the Mary River Project (the Project). The MMASP is part of the Marine Monitoring Program (MMP) for marine mammals, in accordance with Project Certificate (PC) terms and conditions issued for the Project. This manual was developed by experienced marine mammal observers to help train other biologists who may or may not have aerial survey experience.

A marine mammal observer (MMO) is a person with training in marine mammal survey techniques. These survey techniques include spotting and identifying marine mammals, determining location of sightings and their movement, and recording environmental variables.

This MMASP training manual will cover the following:

- objectives of the MMASP
- health and safety
- field program overview and procedures
- survey equipment
- data collection, management, and backup

2.0 PROGRAM OBJECTIVES AND OVERVIEW

The 2023 MMASP is proposed to occur during two separate survey legs: Leg 1 (early shoulder season) and Leg 2 (open-water season). The Leg 1 surveys are proposed to occur over a 14-day window in early July, during the staging period when narwhal and other marine mammals await ice break-out prior to their entry into Eclipse Sound and Milne Inlet. The objective of the Leg 1 surveys is to collect data on the presence/absence and distribution of marine mammals prior to and during initial shipping operations in the RSA. These surveys aim to address identified data gaps for narwhal during ice break-up in the early shoulder season. Leg 2 surveys are proposed to occur over a 21-day window in August corresponding with the peak open-water period. The objective of Leg 2 surveys is to obtain an updated (2023) abundance estimate for the Eclipse Sound and Admiralty Inlet narwhal summer stocks, as well as for other marine mammal species in the Regional Study Area (RSA). Survey design and data collection methodology previously developed by Fisheries and Oceans Canada (DFO) (Matthews et al. 2017; Marcoux et al. 2016; Doniol-Valcroze et al. 2015; Asselin and Richard 2011; Golder 2020, 2021) will be used to allow for a comparison to previously reported abundance estimates.

3.0 HEALTH AND SAFETY

3.1 Aircraft

Leg 1&2 surveys will be flown in a de Havilland Canada DHC-6 Twin Otter aircraft operated by Kenn Borek Air Ltd. (Ken Borek;). This short takeoff and landing utility aircraft seats 19 passengers, has a maximum range of approximately 4.5 hours or 1207 km (750 miles) and a cruise speed of 265 km/h (165 mph).

Kenn Borek's safety management system is consistent and aligned with Transport Canada's highest airline standard complete with Emergency Response Plan and Quality Assurance Program. Kenn Borek continuously monitors and develops the following safety objectives:

- Non-punitive Policy
- Proactive Reporting
- Annual Goal Setting
- Management of Change / Risk Management Program
- Corrective Action Planning and Quality Assurance Oversight
- Continuous promotion of a safe and just culture by all Kenn Borek Air management

Figure 1: Aircraft de Havilland Canada DHC-6 Twin Otter operated by Kenn Borek Air Ltd.

3.2 Personnel

MMOs are expected to familiarize themselves with aircraft exit locations and safety equipment on-board the aircraft. This information will be reviewed during the safety briefing prior to each flight. In addition to aircraft safety, all MMOs must read and understand the MMASP program-specific Health, Safety, Security and Environment (HSSE) Plan which will be reviewed prior to the start of MMASP related work. A major component of the HSSE Plan is the identification of potential health and safety hazards associated with the MMASP including environmental conditions and MMO activities and the implementation of the controls necessary to minimize the risk to people. The program specific HSSE Plan is based on the assessment of previous worksites and similar activities and is a dynamic document that can be modified if things change during the MMASP. The HSSE plan will typically cover the following information:

- personnel contact information
- emergency contact information
- Safe Work Practices and Procedures
- toolbox meetings (to be completed at the start of every day)
- incident reporting

4.0 FIELD PROGRAM

4.1 Survey Area

Two survey grids (Eclipse Sound and Admiralty Inlet) encompass the survey area for the 2023 MMASP. Eclipse Sound Grid is divided into nine strata (Baffin Bay, Pond Inlet, Eclipse Sound East, Eclipse Sound West, Navy Board Inlet, Tremblay Sound, Milne Inlet North, Milne Inlet South, and Fjords; Figure 2). Admiralty Inlet Grid is divided into three strata (Admiralty Inlet North, Admiralty Inlet South, and Fjords; Figure 2).

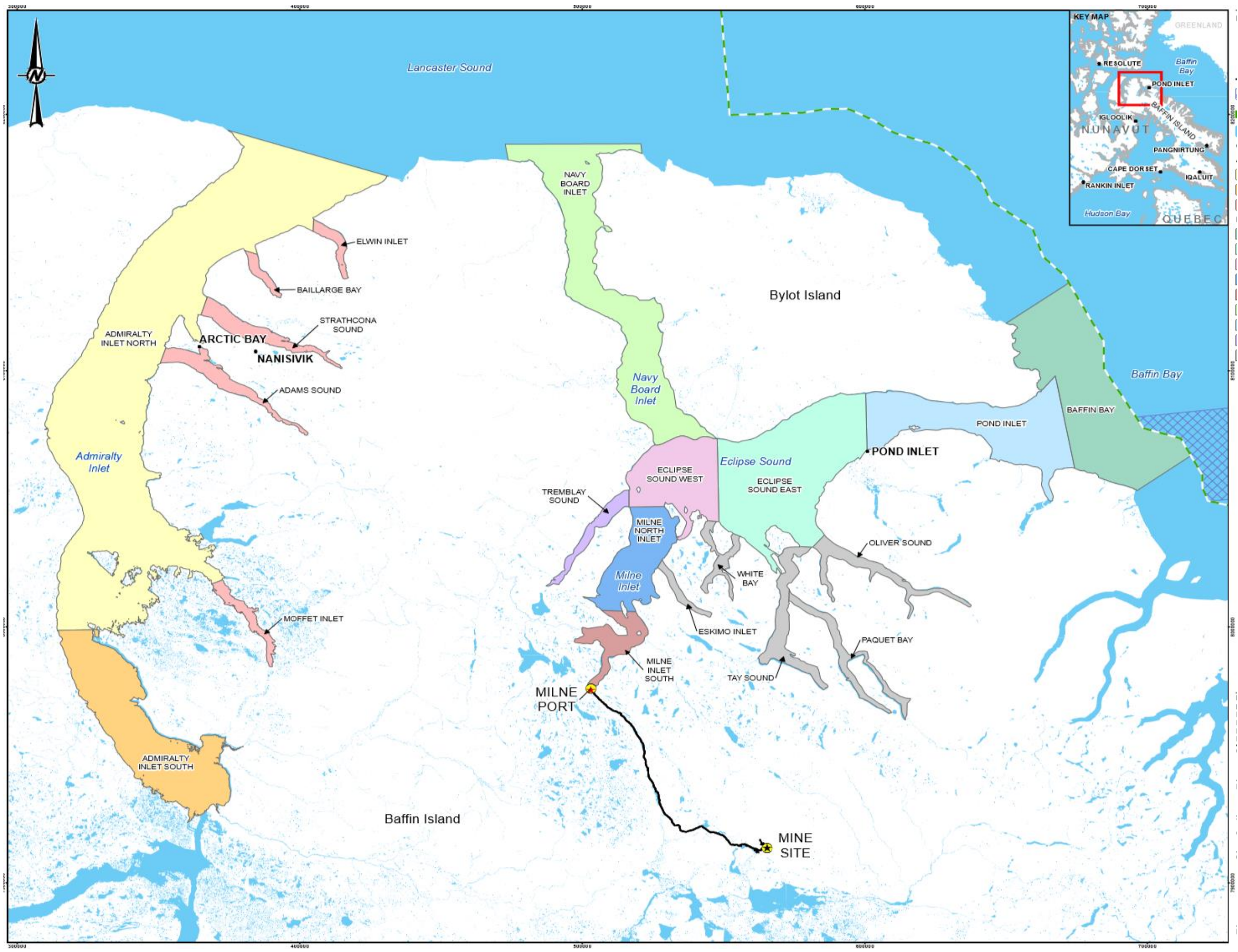


Figure 2: Geographic strata for Eclipse Sound Grid (on the right) and Admiralty Inlet Grid (on the left).

Leg 1 study area encompasses the Eclipse Sound Grid and is based on the boundaries flown in previous surveys from 2013–2016 (DFO 2017; Golder 2017), with the addition of a Baffin Bay stratum (Figure 2). Leg 1 is designed to focus in the open-water area around the floe edge (blue and yellow/orange lines in Figure 3) in the Baffin Bay or eastern Pond Inlet strata where narwhal are known to stage prior to entering Eclipse Sound. Reconnaissance flights will be flown periodically in Tremblay Sound, Eclipse Sound and Milne Inlet to verify narwhal presence/absence. If narwhal are observed in these strata, the entire survey grid will be flown, including all strata (switching from yellow/orange floe edge line and blue transect lines to red transect lines in Figure 3).

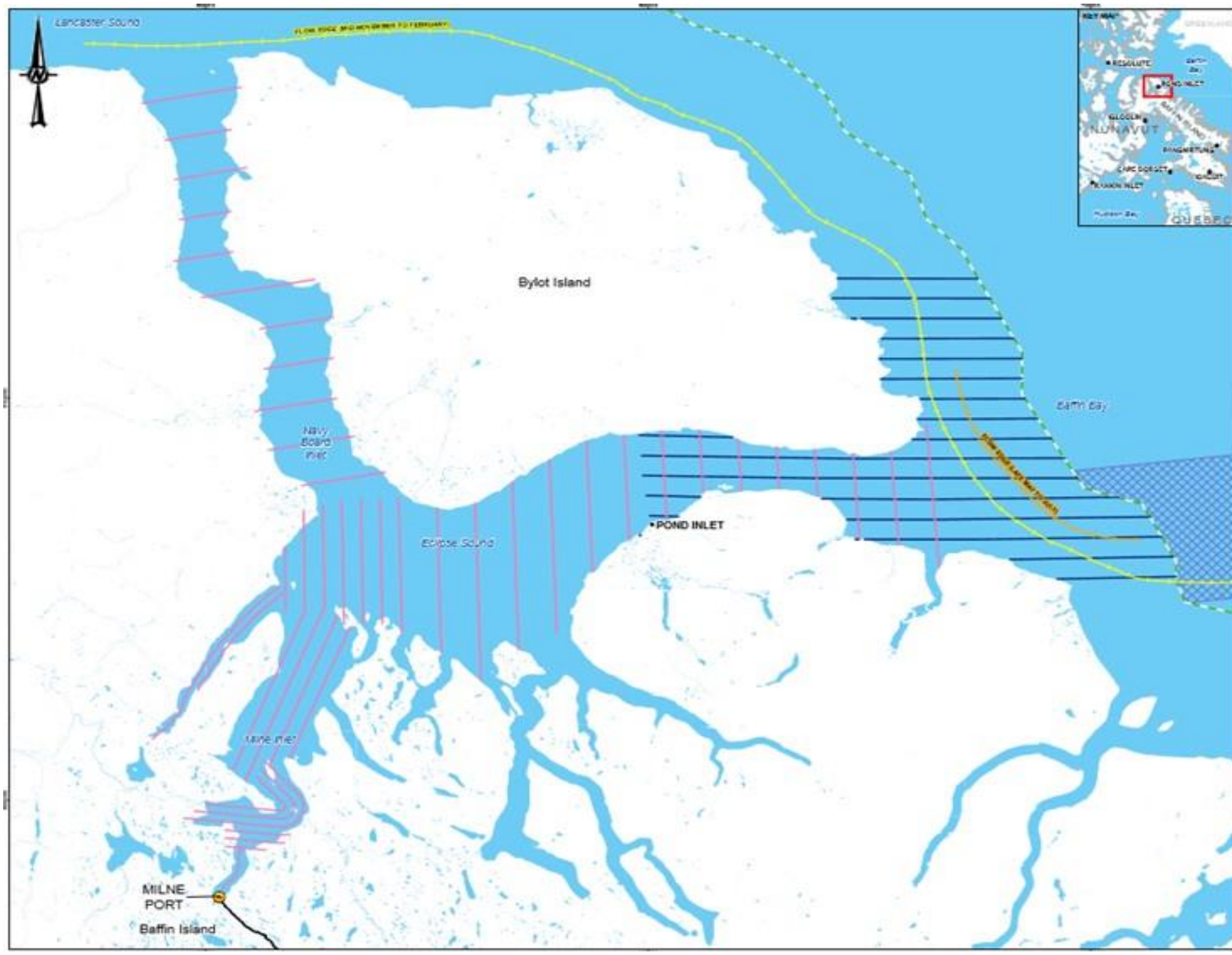


Figure 3: Leg 1 transect lines for the Eclipse Sound study area.

Leg 2 will survey Eclipse Sound Grid and Admiralty Inlet Grid within a two- to three-day period to obtain an estimate of narwhal abundance in the combined areas. The boundaries for the Eclipse Sound Grid are the same as those for Leg 1 with the exclusion of the Baffin Bay stratum (see Figure 2). As during Leg 1, systematic random visual line-transect surveys will be flown for all strata (except Tremblay Sound and Milne Inlet South where photographic surveys will be conducted) with the location of the first line chosen at random (Figure 4). A photographic survey with complete coverage will be flown for the Tremblay Sound and Milne Inlet South strata. Reconnaissance flights in Eclipse Fjords will be flown when time and weather permits.

The boundaries for Admiralty Inlet are divided into three strata (see Figure 4). Systematic random visual line-transect surveys will be flown for the North and South strata with the location of the first line chosen at random (Figure 4). Reconnaissance flights in the fjords will be flown when time and weather permits.

During visual line-transect surveys, if large aggregations (e.g., >50 narwhals or when observers indicated that they cannot accurately keep up with narwhal counts) are identified, a photographic survey will be flown with complete coverage over the group to allow for accurate counts of animals. To identify aggregations observed during visual surveys, all personnel on board the aircraft are instructed to look out for herds of narwhal and alert everyone when one was sighted. When such an aggregation is located, lines will be flown in a cross pattern over the group, to determine its spatial extent. Using pre-planned survey grids, the aggregation will be photographed using a systematic grid with complete coverage as seen in Figure 4 for the Milne Inlet South and Tremblay Sound strata.

Figure 4: Leg 2 transect lines for the Eclipse Sound and Admiralty Inlet study area.

4.2 Flight and Observational Procedures

Each survey will be flown along the transect lines at a target altitude of 305 m (1,000 feet) with a target speed of 185 km/h (100 knots). The survey aircraft for all survey Legs will consist of a de Havilland Twin Otter 300 equipped with four bubble windows on the sides and a large belly window used for cameras. MMOs will be stationed at the front and rear bubble windows that provide a view of the track line directly below the aircraft. Visual surveys will be conducted as a double-platform experiment with independent observation platforms at the front (primary) and rear (secondary) of the survey plane. The two observers stationed on the same side of the aircraft will be separated visually and acoustically to achieve independence of their conditional detections. A fifth member of the survey team will be responsible for overseeing camera operations, data entry, and navigation along the survey grid.

Observers will focus on the area closest to the track line and use their peripheral vision for sightings farther afield. Primary observers will record every marine mammal sighting by speaking into a hand-held audio recorder to supplement the data being collected in real time in Mysticetus. Secondary observers will also record every marine mammal sighting in a hand-held audio recorder, as well as enter partial observation records in Mysticetus. Each sighting record will include information on time, species type, group size, group composition (presence of calves, mother/calf pairs, adults, number of tusks, etc.), direction of travel (heading), speed of travel, sighting cue, behaviour, and activity. A group is defined as animals within one to a few body lengths of each other and oriented or moving in a similar direction. Observers will give priority to estimating group size, especially when densities are high, followed by other variables (direction of movement, presence of young, number of tusks) if time permits. Geometers will automatically assign the perpendicular declination angle of each sighting in the Mysticetus program for the primary and secondary observers. Position and altitude of the plane will be recorded every second using a GPS connected to a laptop running Mysticetus. A dedicated Bluetooth GPS unit and iPad will also be used to track the aircraft location using specialized navigational mapping software (Foreflight pre-programmed with the survey transect grid).

Observational conditions (environmental data) will be recorded onto the audio recorders by the primary observers at the start of each transect and re-stated at any time a change was detected throughout the survey. Conditions will include sea state (Beaufort scale), ice concentration (in tenths), fog (% cover in field of view and intensity), and glare (% of forward field of view and intensity). Environmental data will be entered into Mysticetus after each flight.

4.3 Photographic Data

To supplement visual observations, the aircraft will collect continuous photographic records below the aircraft using dual oblique cameras pointing downwards towards either side of the track line. A three-second interval between photographs will allow for a target overlap of 20% between successive photographs along the direction of the aircraft at the survey altitude of 1,000 ft above sea level. The aircraft will be fitted with a camera belly port hatch to accommodate a custom camera frame and two Fujifilm GFX 100S medium format mirrorless cameras.

Each camera will be connected to CamRanger 2 and controlled remotely (settings, start and stop). Photographs will be stored in high-resolution JPG format. At the end of each survey photos will be transferred to an external hard drive.

4.4 Photographic Surveys

During visual line-transect surveys, if large aggregations (>50 narwhals or when observers indicate that they cannot accurately keep up with narwhal counts) are identified, a photographic survey will be flown with complete coverage over the group to allow for accurate counts of animals. To better quantify large narwhal aggregations observed on the visual surveys, all personnel on board the aircraft will be instructed to look out for herds of narwhal and alert everyone when one was sighted. When such an aggregation is located, two lines will be flown in a cross pattern over the group to determine its spatial extent. Using the pre-planned survey grid, the aggregation will be photographed using a systematic grid with complete coverage. A six-second interval between photographs will allow for a target overlap of ~15% between successive photographs along the direction of the aircraft at the survey altitude of 2,000 ft above sea level. During Leg 2 a dedicated photographic survey will be flown in the Milne Inlet South and Tremblay Sound strata where narwhal are known to concentrate at that time of the year.

5.0 DAILY ROUTINES

Every morning the aerial crew will meet at a designated area to take the bus to the Weather Haven where they will remain for the duration of the day awaiting a weather window for a survey. Upon arriving at the Weather Haven a daily toolbox session will be initiated with the aerial crew and a plan put into motion to either prepare for a survey or to check back in an allotted time if weather conditions are not favorable for a survey. Weather requirements for surveying include a ceiling of greater than 333 m (1,000 ft) and sea states of less than Beaufort level five.

Flight days — If the weather permits a flight, the lead MMO will set up a time for departure. Typical flight days range in length from 10-12 hours depending upon weather. *Punctuality is required*. Delays or missing crew members can force the survey to be canceled. Bring water and food for the flight, keeping in mind that the plane has no toilet. A small bag including toiletries and a coat are also good to bring, as sometimes poor weather may require the use of an alternate landing site. Each MMO will be supplied with a dry suit to wear while working on the aircraft and a headset. After a flight, it is important to enter and validate the data as soon as possible. Depending on the landing time, this could be either that evening or the next morning.

Non-flight days — Typical workdays range in length from 8–10 hours depending upon the number of trained staff members available, the weather, and how much data needs processing from the previous day. When no surveys are flown MMO's will be expected to do data entry and validation.

6.0 EQUIPMENT

Clinometer

Depression angle from the horizon to the sighting is determined using a clinometer when the marine mammal is perpendicular to the aircraft. Use only one clinometer reading for the center of a group (no angle ranges). See Appendix B for instructions of use.

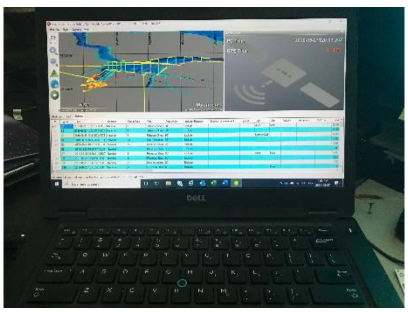
Geometer

When the marine mammal is perpendicular to the aircraft, sight the animal in the center of the scope and press the button on the front of the geometer. This will automatically record sighting time and declination angles of the sighting in the Mysticetus program. This device can be used instead of the clinometer.

Digital Recorder

Digital recorders will be used to record sighting data and environmental data to be transcribed to the Mysticetus database at the end of each flight.

Laptop with Mysticetus program



The Mysticetus program will be used to record GPS tracks and waypoints (transect start and stop, sightings, and environmental data) during each survey. After each survey, additional data will be entered on a laptop computer into the Mysticetus database. The database is programmed with data forms (drop-down menus) and data entry fields that are specific to the type of data being collected.

Bad Elf GPS

A Bad Elf GPS Pro device will be used to track the aircraft during marine mammal surveys at one second intervals.

Each GPS device should be turned on at the start of the flight by pressing the “ON” button located on the left side of the device. It may take a few minutes for the device to acquire satellites.

The MMO should check the GPS device regularly during the flight to ensure that it has not lost signal and is working properly.

Camera Equipment

Each aircraft will be equipped with two identical camera systems, using Fujifilm GFX 100S medium format mirrorless cameras fitted with 45 mm lenses. The cameras will be connected to a laptop computer to control exposure settings and photo interval. The cameras will be installed within the camera hatch on a custom-made mount. Images will be saved directly to the internal camera cards. The cameras will be oriented widthwise (long side perpendicular to the track line) and angled obliquely: one to the port side and the other to the starboard side. See Appendix A for detailed camera setup.

Personal Protective Equipment

Observers will be provided with a dry suit and a headset prior to each flight.

7.0 DATA COLLECTION

Each aerial survey crew consists of five positions: two primary observers (front observers), two secondary observers (rear observers), and the navigator/data manager (Figure 5). The positions are assigned prior to take-off and have different responsibilities, however during long flights positions can be rotated during refuelling to reduce fatigue.

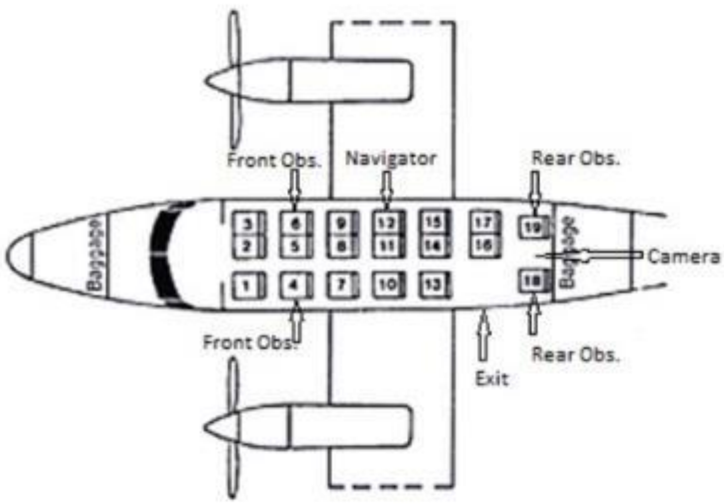


Figure 5: Twin Otter aircraft configuration with aerial crew locations

7.1 Navigator/Data Manager

A specially designed electronic database (Mysticetus) with mapping software will be downloaded with the survey track lines so the observers can be notified by the navigator of the start and stop point of the transects. Geometers will automatically populate Mysticetus with the date, time, location (i.e. GPS coordinates), observer and declination angle of the primary and secondary observer sightings. The data manager will supplement the sighting data for the primary observer sightings in real time with species and group size along with any additional data verbalized by the primary observers. A drop-down menu is available to facilitate recording data collected during the survey, but some data will be transcribed from the audio recorders into the database after the flight. Supplemental sighting data for the secondary observers will be entered after completion of the survey. Primary and secondary observers will be connected to separate computers each running their own version of Mysticetus. A portable GPS unit will be plugged into each computer to record GPS positions and waypoints during each flight with the Mysticetus program. The date, time, and GPS coordinates are automatically recorded with each one-second point on the track line.

The data manager will be responsible for keeping a flight log in the Mysticetus database connected to the primary observers. The flight log should have the date, flight number, start (aircraft starts moving) and stop (aircraft stops moving) times, and the survey number for each time the aircraft is flown.

7.2 Primary and Secondary Observers

At the start of the flight, each observer is issued a geometer, synchronized wristwatch, and digital voice recorder. Primary observers sit in the forward right and left seats and collect environmental and sightings data used for analyses. The two most experienced MMOs on the aircraft should be occupying the primary observer positions. Secondary observers sit in the rear right and left seats and are collecting sightings data to be used in the double-platform experiment. The double-platform experiment requires independent observation platforms at the front (primary) and rear (secondary) of the survey plane. The two observers stationed on the same side of the aircraft will be separated visually and acoustically to achieve independence of their conditional detections.

7.2.1 Environmental Data

Environmental conditions are recorded at the start and end of each transect and whenever conditions change within the viewing area (Table 1). The viewing area is estimated out to approximately 1 km from the aircraft (see Appendix B). Four environmental conditions are recorded:

- **Ice tenths cover**: Tenths of the viewing area covered in ice.
- **Beaufort wind force (Beaufort Sea State)**: Visual conditions of the wave height and froth.
- **Glare**: Percentage of searching area affected by sun reflection and intensity.
- **Fog**: Percentage of the viewing area obscured due to fog and level of intensity.

See Appendix B for examples of the various environmental conditions.

Table 1: Environmental codes.

Environmental Type	Codes	Description
Ice Cover	0/10 – 10/10	Ice cover within viewing area
Beaufort Wind Force	0	Sea like a mirror
	1	Ripples with the appearance of scales are formed, but without foam crests
	2	Small wavelets, short but more pronounced. Crests have glassy appearance and don’t break.
	3	Smooth, large wavelets. Crests begin to break. Scattered whitecaps.
	4	Small waves, becoming longer. Fairly frequent whitecaps.
	5	Moderate waves, taking a pronounced long form. Many whitecaps.
	6	Large waves forming, white foam crests more extensive everywhere. Probably spray.
	7-12	Ranges from a gale to a hurricane.
Percent Glare	0 -100%	Percent glare obscuring viewing area

Environmental Type	Codes	Description
Glare Intensity	Intense	When animals were certainly missed in the center of reflection angle
	Medium	When animals were likely missed in the center of reflection angle
	Low	When animals were likely detected in center of reflection angle
	None	No glare
Fog Cover	0 -100%	Percent fog obscuring viewing area
Fog Intensity	Thick	Dense thick fog that you cannot see through
	Moderate	Thick and light fog interspersed, can see through at times
	Light	Light fog that you can see through
	None	No fog

7.2.2 Sighting Data

Sighting data is recorded every time a marine mammal is sighted (Table 2). Examples with descriptions of each sighting type are provided in Appendix B.

Observers will trigger the geometer when a marine mammal is spotted **perpendicular** to the aircraft so the sighting along with the date, time, location, observer and declination angle is automatically entered in the Mysticetus program. Primary observers will notify the Mysticetus operator (i.e. data manager) of the species and group size.

Both primary and secondary observers will record the following additional information about the sighting on their digital voice recorder in order of importance:

- **Time:** hour, minute and second
- **Species**: name of species observed
- **Group size**: number of individuals in group
- **Included/excluded:** on transect or on transit
- **Direction of movement:** clockface direction of movement in relation to the aircraft.
- **Speed:** relative speed of animal's movement.
- **Age/sex:** apparent age of the animal and if tusk present.
- **Behavior:** movements or biological processes in which animal is engaged.
- **Activity:** a collection of behaviors that indicate the animal is working toward an overall goal (e.g., feeding, migrating).
- **Sighting cue:** What alerted you to the sighting?

Table 2: Sighting data codes

Sighting Type	Code	Description
Species	Species (e.g. narwhal)	Narwhal, bowhead, beluga, ringed seal, harp seal, walrus, etc.
Group Size	#	Number of individuals in group (group is defined as animals that are within one body length of each other and oriented or moving in a similar direction).
Clinometer angle	# degrees	Depression angle from the horizon to the sighting as determined using a clinometer when the marine mammal is perpendicular to the aircraft. Use only one clinometer reading for the center of a group (no angle ranges). If using a geometer, sighting time and depression angle are automatically stored on a laptop with the press of the button. Clinometers will only be used if needed.
Include/Exclude	Include	A sighting seen within the field of view on transect, at the surface or clearly visible just below surface, and at survey altitude.
	Exclude	If the sighting is seen on transit, or outside the field of view (i.e. behind the aircraft or well beyond 1 km), or barely visible below surface, or seen when flying above normal survey altitude (i.e. on transit flights).
Direction of movement	Clockface 1-12	Clockface direction of movement in relation to the aircraft. 12 o'clock means animal is moving in same direction as aircraft.
Speed	Fast	When animal is swimming rapidly through the water, often associated with splashes. Wake left behind.
	Moderate	When animal is swimming moderately through water, often associated with trail behind animal.
	Slow	When animal is swimming slowly through water, but trail barely visible in water.
	Not moving	Animal is stationary, no movement.
Age	# adults	Large whitish animals should be assumed to be adults. Dark animals that are 85% or larger than the length of whitish adults should be assumed to be adults. Code unknown if not sure.
	# juveniles	Dark in color and 15% smaller than adult. May have short tusk present. Code unknown if not sure.
	# calves	Whitish to grey in appearance and slightly less than half of the length of the adult female. Code unknown if not sure.
Sex	# males	If tusk visible code as male. Code unknown if not sure.
	# females # mother	If no tusk visible and not accompanied by a calf. Code as female. Code as mother if seen with a calf. Code unknown if not sure.
Activity	Feeding	Animal seen feeding or evidence of prey observed.
	Traveling	Moving in a distinct direction with a moderate to fast pace.

Sighting Type	Code	Description
	Resting	Animal lying motionless at the surface of the water or on the ice/land.
	Milling	Moving but net movement is near zero, e.g. swimming in circles.
	Socializing	Engaged in social activity (involving more than one animal).
	Unknown	Nothing recorded.
Behaviour	Hauled out	Hauled out on ice or land (pinnipeds). Primary behaviour to record for pinnipeds.
	Diving	Animal descends below the surface.
	Fluking	When a whale raises its fluke as it dives beneath the water.
	Surfacing	When a marine mammal is observed coming to the surface of the water.
	Swimming	Animal is swimming at the surface.
	Surface activity	Splashing, jumping, flipper or tail slapping, implies social interaction.
	Looking	When animal is in an upright position with its head out of the water and is actively looking at something (pinniped or polar bear).
	Blow	When whale releases air from its lungs at the surface of the water, observed as clouds of moist air. Can be visible at far distances.
	Breaching	When a whale leaps with its entire body out of the water.
	Spyhopping	When a whale raises its head vertically out of the water so that its eyes are clear of the surface.
	Walking/Running/Standing	Polar bear walking, running, or standing on ice or land.
	Dead	Observation of a dead marine mammal.
	Logging	When a marine mammal is on the surface and is neither swimming nor moving
	Unknown	Nothing recorded.
Sighting cue	Blow	Whale exhales breath at surface of water seen as a watery mist.
	Body	Body or marine mammal.
	Footprint	Surface of the water looks disturbed and are made when a marine mammal has just been on or near the surface of the water.
	Splash	Splashes may be a sign that a marine mammal is present.
	Birds	Aggregation of birds may be attracted to marine mammal when they are feeding.
	Unknown	Nothing recorded.

8.0 DATA MANAGEMENT

One of the most important parts of the work is to carefully record information on all sightings/observations during the survey onto the audio recorders and transcribe that data into the database after every flight. This information is critical to the success of the MMASP Program. A lot of time and mentorship will be spent on training to properly, efficiently and consistently record information.

8.1 Data Transcription

Once the survey is complete, data from the voice recorders must be transcribed into the Mysticetus database for the primary observers or on data sheets for the secondary observers as soon as possible so that people may be able to accurately fill in any data not recorded during the survey. There will be prompts to enable the MMO to enter data efficiently and out-of-range error checking to ensure that only plausible values can be entered into the database. The Mysticetus database includes three types of data: flight data, environmental/effort data, and marine mammal sightings data.

8.1.1 Flight Data

Flight data is recorded by the data recorder during the flight and is assigned waypoints in the tracking program. Flight data includes the following data:

- Date
- Location (Eclipse Sound or Admiralty Inlet)
- Survey number
- Flight number (can take up to four flights to complete a survey)
- Observers and their locations on the aircraft

8.1.2 Environmental/Effort Data

Environmental/effort data are assigned waypoints in the database by the data recorder during the flight. Primary observers will fill in specific information associated with the waypoints after the flight from their audio recordings. Environmental/effort data include the following data:

- Start and stop transects (assigned a waypoint by data recorder during flight)
- Environmental record (assigned a waypoint by data recorder during flight)
- Ice cover for environmental record (filled in by primary observer audio recordings after flight)
- Beaufort wind force for environmental record (filled in by primary observer audio recordings after flight)
- Glare cover and intensity for environmental record (filled in by primary observer audio recordings after flight)
- Fog cover and intensity for environmental record (filled in by primary observer audio recordings after flight)

8.1.3 Sighting Data

Marine mammal sightings are assigned waypoints in the database by the data recorder during the flight. Primary and secondary observers will fill in specific information associated with the waypoints after the flight from their audio recorders. Sighting data include the following waypoints:

- Marine mammal sighting (assigned a waypoint by geometer during flight)
- Species (filled in by data recorder in real time for primary observer or by primary/secondary observer audio recordings after flight)
- Group size (filled in by data recorder in real time for primary observer or by primary/secondary observer audio recordings after flight)
- Clinometer angle (automatically entered by geometer)
- Observer (automatically entered by geometer)
- Include/exclude (filled in by primary/secondary observer audio recordings after flight)
- Direction of movement (filled in by primary/secondary observer audio recordings after flight)
- Speed (filled in by primary/secondary observer audio recordings after flight)
- Age (filled in by primary/secondary observer audio recordings after flight)
- Sex (filled in by primary/secondary observer audio recordings after flight)
- Activity (filled in by primary/secondary observer audio recordings after flight)
- Behaviour (filled in by primary/secondary observer audio recordings after flight)
- Sighting cue (filled in by primary/secondary observer audio recordings after flight)

Once all data have been entered, all electronic entries should be compared to digital recordings again, by a different observer, to check for errors. Backups of the database should be made regularly and stored on an external hard drive and another computer.

8.2 Data Editing

Check your own work at the end of each survey to ensure accuracy. If you note a mistake, and can remember the details, correct it and initial the changes. If you cannot remember, do not make a guess. Missing data are preferable to incorrect data. All columns should be filled out to the best of your ability; there should be no blank spaces in the spreadsheet. Additionally, if you note a mistake by another MMO, bring it to their attention as soon as possible, so it can be corrected.

8.3 Data Storage and Backup

MMOs are required to do the following measures after each survey is complete to help prevent collected data from being lost:

- Data recorded onto the digital recorders must be backed up onto the field computer.
- Mysticetus data should be backed up regularly in several places: external hard drive, lead MMO's laptop and on the field computer, as coordinated by the lead MMO. Backups should be double-checked to ensure that data were successfully transferred.

The photographic images will be backed up after every flight and a copy made for duplicates.

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APPENDIX A

Camera Setup

Camera Setup

Camera Settings

- Mark each camera left or right (small piece of electrical tape with a "L" or "R" in silver permanent marker), mark media cards left or right
- In playback menu, turn rotate tall and image review off.
- In shooting menu set image quality to RAW size large, 14 bit, image area to FX (36X24) 1.0 x with auto DX crop off, color space to RGB, and turn active D-lighting to off.
- In setup menu format both the SD cards and set camera to write to one card then overflow to the next card. Set camera date and time to the precise GPS date and time, do this at the start of every day, check the date-time at the end of every flight when you're back in the hotel to see if there is any drift. If there is drift record it so that true camera times can be estimated to get an accurate match with GPS time.
- Connect cameras to CanRanger 2 via bluetooth running the camera control software. Using the camera control software, set cameras to shoot in manual settings, shutter priority of at least 1/1600 s, the aperture can be set on automatic if you expect a large variability in the brightness of the photos, particularly when ice in present in the survey area. Try to balance to keep an f stop that is not wide open as there is some clutter introduced to the pixels when shooting at wide open but do not close the aperture too much either. You can increase the ISO to increase shutter speed but there is some noise introduced to the pixels at the highest ISOs. Setting the ISO at 400 to 800 should be acceptable if you need to go that high to get 1/1600 sec shutter speed. We should do some tests in the aircraft when we get the chance to evaluate the tradeoff between ISO and shutter speed.
- Be careful with AF buttons, make sure they are set manual, if need be tape with electrical tape, remove tape after each flight so that glues do not adhere too much.

Inverter

- bring plenty of extension cords, plan layout before flight
- careful with cords draped over seats and along floors, there are pinch points that can cut or damage cables (electrical, antenna, GPS, serial)
- duct tape cords to the walls to keep them from getting in the way or being tripped over
- turned on inverter at start of flight before action starts, may have to ask pilot, they usually turn it off when starting aircraft, best to indicate when they look back to check on passengers before beginning taxiing, or after take-off during level flight

Mounting cameras on the frames

- frame, aircraft floor, camera port opening may have sharp edges, be careful
- setup frame, set camera angles depending on how many cameras you intend on using (eg 2, 3 or 4), 2 is usually one looking left and one looking right. If using a 35 mm lens, adjust angles to 27 degrees from centerline using a digital protractor.
- camera image long axis is usually perpendicular to the flight direction to get the maximum strip width
- fit camera to frame before first flight, make sure that lenses are not touching camera port glass and that frame is setup for least vibration, set camera mount delimiters if they are available so that the camera will not touch parts of the aircraft when they are shooting (airframe vibration transferred to camera, damage to glass, damage to camera). Prevent the edges of the camera port from being included in the photos taken.
- connect electrical
- tape connections if you can, especially between AC/DC power supply and dummy battery lead of camera
- carefully mount camera taking care to avoid stretching cables to prevent connectors from coming loose
- fire test shots to verify the centerline is covered in the images

APPENDIX B

Examples of Environmental and Sighting Data

This appendix contains examples of environmental and sighting data used in the data collection of the MMASP:

Environmental data includes:

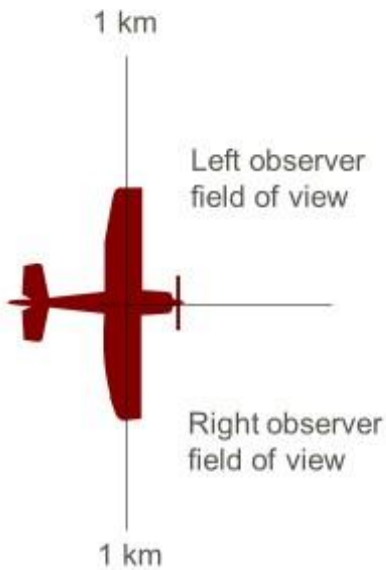
- Ice cover
- Wind force
- Glare
- Fog

Sighitng data contains:

- Species
- Number
- Clinometer
- Include/exclude
- Heading
- Speed
- Age
- Sighting cue
- Behavior
- Activity

Field of View

- Looking forward and to out to the side of the aircraft
- 90 degrees and out to 1 km

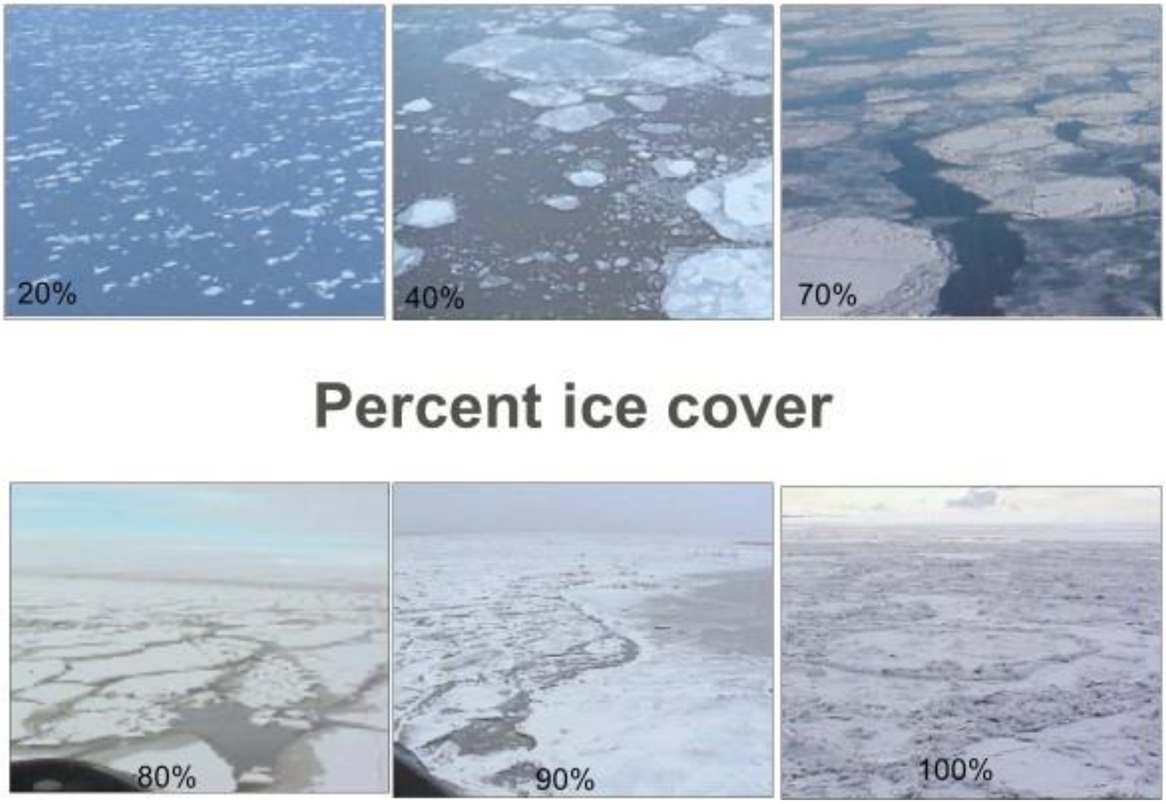


Environmental Data

- **Ice cover**
- Wind force
- Glare
- Fog

Subjective

Based on average of conditions

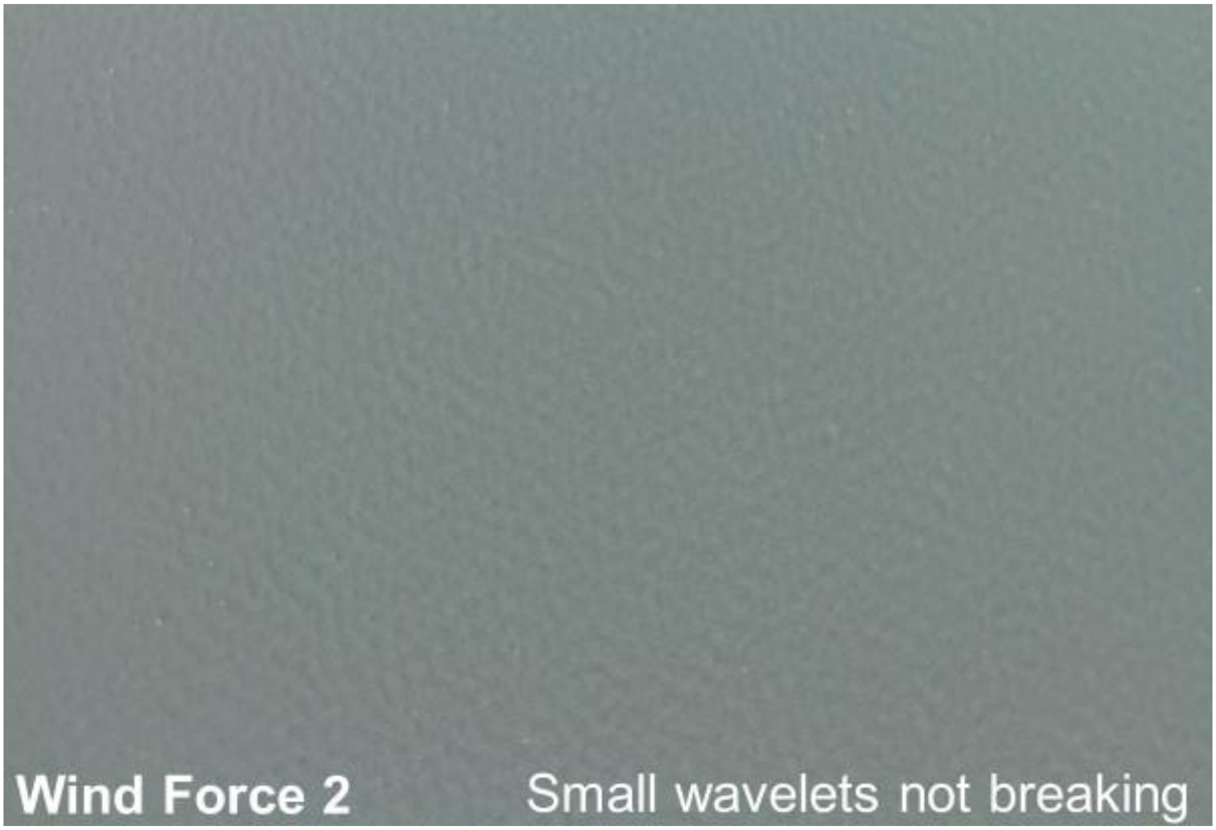


Beaufort Wind Force Chart

Wind Speed		Beaufort Wind Force	World Meteorological Organization Terms	Wave Height (m)	Description
Knots	m/s				
<1	<0.5	0	Calm	0	Glassy like a mirror
1-3	0.5-1.5	1	Light air	<0.1	Ripples with the appearance of scales but no whitecaps or foam crests
4-6	2.1-3.1	2	Light breeze	0-0.1	Small wavelets, crests have a glassy appearance but do not break (no whitecaps)
7-10	3.6-5.1	3	Gentle breeze	0.1-0.5	Smooth large wavelets, crests begin to break, occasional/scattered whitecaps
11-16	5.7-8.2	4	Moderate breeze	0.5-1.2	Slight; small fairly frequent whitecaps
17-21	8.7-10.8	5	Fresh breeze	1.2-2.4	Moderate waves becoming longer, some spray, frequent moderate whitecaps
22-27	11.3-13.9	6	Strong breeze	2.4-4	Rough, larger waves, longer-formed waves, many large whitecaps
28-33	14.4-17.0	7	Near gale	4-6	Very rough, large waves forming, white foam crests everywhere, spray is present
34-40	17.5-20.6	8	Gale		
41-47	21.1-24.2	9	Strong gale		
48-55	24.7-28.3	10	Storm	6-9	High
56-63	28.8-32.4	11	Violent storm	9-14	Very high


Wind Force 0
Glassy


Wind Force 1
Ripples


Wind Force 2
Small wavelets not breaking


Wind Force 3
Scattered white-caps


Wind Force 4
Frequent white-caps


Glare
Two measurements:
• Percent - percent glare obscuring viewing area (0 - 100 %)
• Intensity – intense, medium, low, or none


Medium and 50%


Intense and 25%

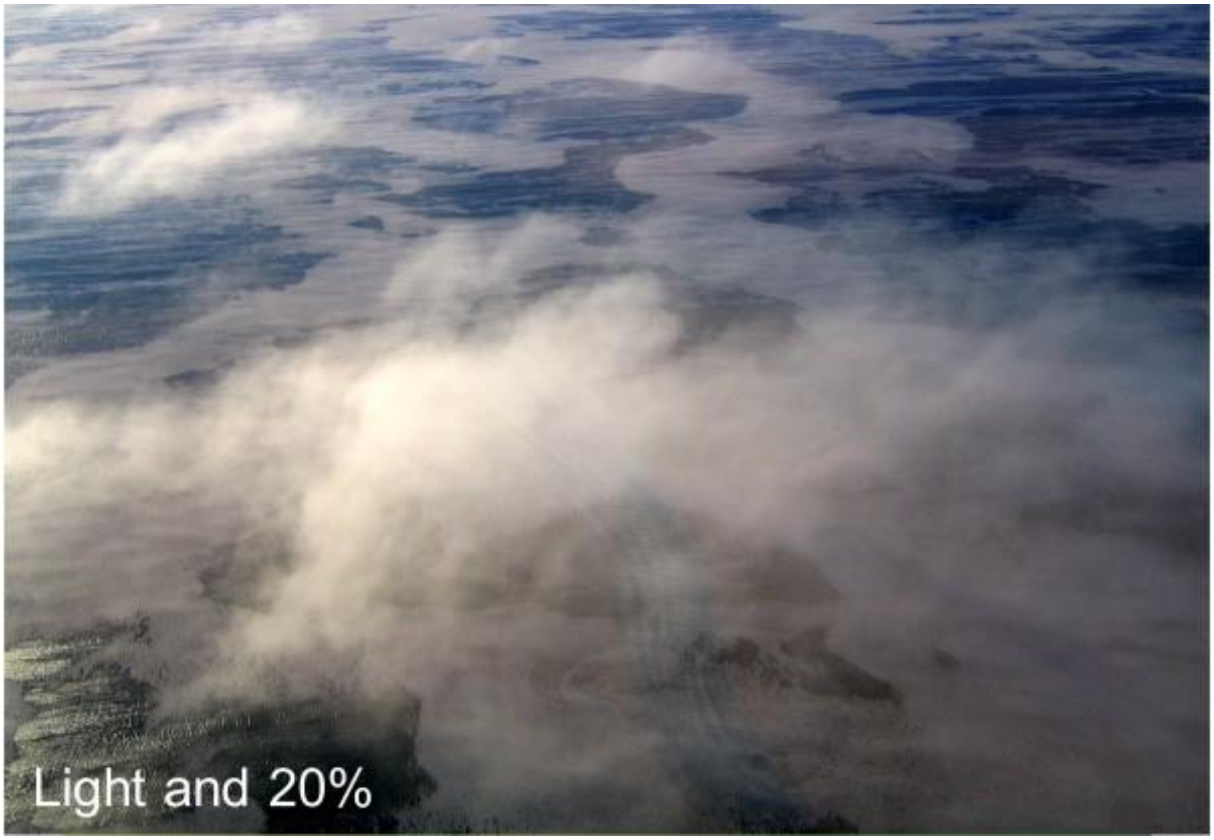
Fog

Two measurements:

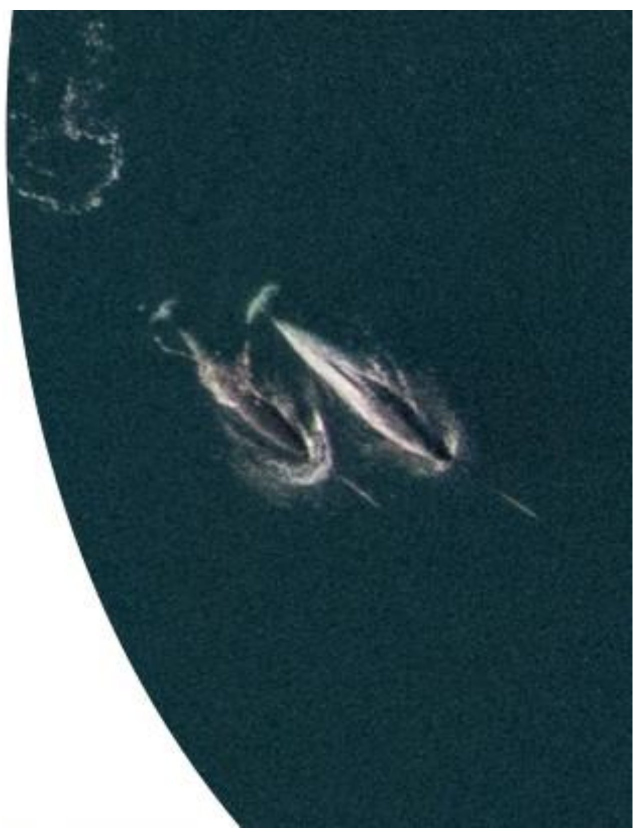
- Percent - percent fog obscuring viewing area (0 - 100 %)
- Intensity – thick, moderate, light, or none


Thick and 100%


Moderate and 100%



Sighting Data



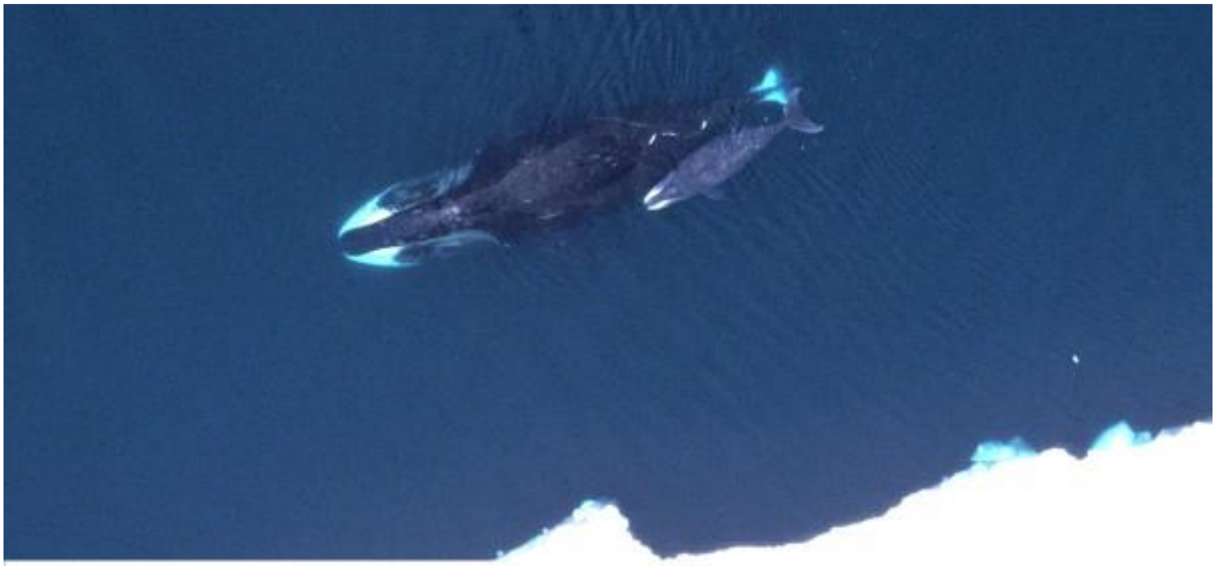
- Collected for each sighting:
  - **Species**
  - Number (group size)
  - Clinometer angle
  - Include/exclude
- Collected if time:
  - Heading
  - Speed
  - Age
  - Sighting Cue
  - Activity/Behavior

Narwhal

- small whale 4.2 to 4.7 m
- low bushy blow
- spotted black and white coloration
- males have a tusk
- tail convex on trailing edge

Beluga

- small whale 4.3 to 4.9 m
- low bushy blow
- adults white and calves are gray



Bowhead

- large whale
- hump near blowhole
- can have white on chin and tail
- blows are v-shaped

Killer Whale

- mid-sized whale 9 m
- dorsal fin
- black with white patches

Sperm Whale

- Large whale 12.5 to 19.2 m
- S-shaped blowhole at front of head and offset to left
- Thick, low dorsal fin followed by series of bumps on dorsal ridge

Seals

- Ringed Seal
- Harp Seal
- Bearded Seal
- Hooded Seal

Ringed Seal

- Small seal 1.1 to 1.6 m
- Short thick neck and fat body
- Color: light gray rings encircle spots on back

Harp Seal

- mid-sized seal 1.8 to 1.9 m
- old animals have harp pattern with black mask
- young animals have dark spots
- can be seen in large groups porpoising

Bearded Seal

- large seal 2.1 to 2.5 m
- color light to dark gray or brown
- small head to body ratio
- densely packed vibrissae (beard)

Hooded Seal

- large seal 2.0 to 2.6 m
- silver white with dark blotches
- face and muzzle very dark
- males with inflatable nasal cavity

Walrus

- large pinniped
- light to dark brown
- white tusks

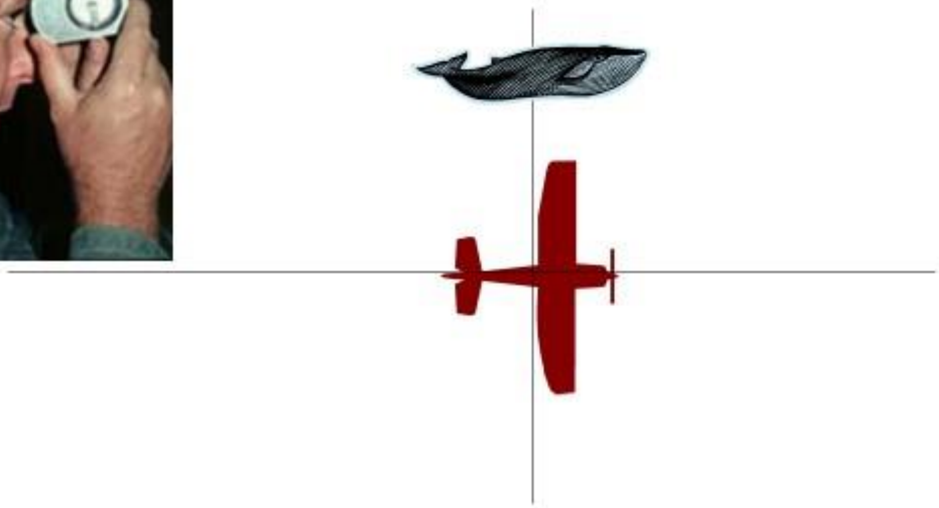
Polar Bear

Group Size

- Number of individuals in group (group is defined as animals that are within one or a few body lengths of each other and oriented or moving in a similar direction)

Using Clinometers

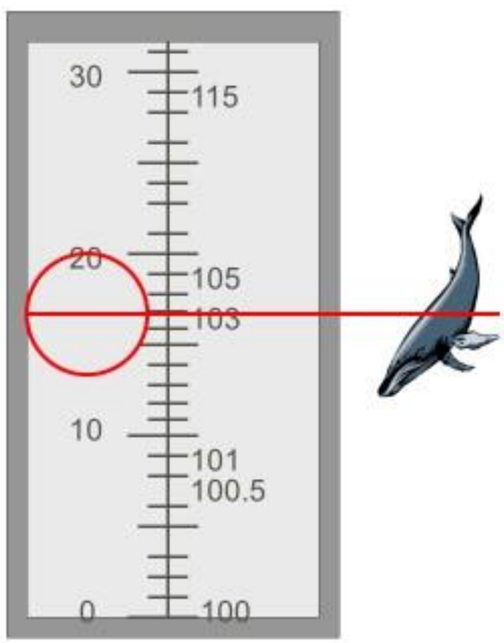
- Wait until the plane is perpendicular to the sighting. Then keep both eyes open and, looking though the inclinometer, line up the horizontal line with the center portion of the animal.
- Record the number on the **left** that the horizontal line passes through.
- If a group of several animals is sighted, measure from the center of the group.



•**Keep both eyes open!**

•Line up mammal with horizontal line (use middle of mammal)

•Use scale on left = **17**



Using Geometers

- Wait until the plane is perpendicular to the sighting.
- Sight the animal in the center of the scope and press the button on the front of the geometer.
- This will electronically record time and declination angles for the sighting in a text file.
- Takes into account the tilt, roll, and yaw of the aircraft.
- If a group of several animals is sighted, measure from the center of the group.

Include / Exclude

Include

- Sighting is on transect, within the field of view, at the surface or clearly visible just below surface, and at survey altitude

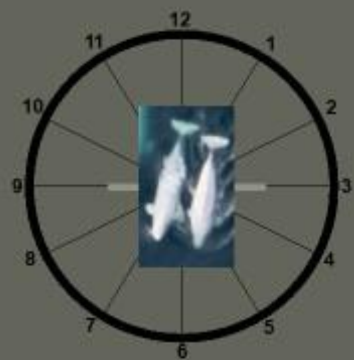
Exclude

- Sighting is on transit or outside of the field of view (i.e. behind the aircraft or well beyond 1 km distance), or barely visible below surface, or seen when flying above normal survey altitude (i.e. on transit flights above 1000 ft).

Heading

- Assume aircraft is always pointing to 12:00
- Record clock face direction of animal (1 to 12)

Belugas heading towards 6:00



Speed

Fast

- White water streaming off bodies, wake left behind

Moderate

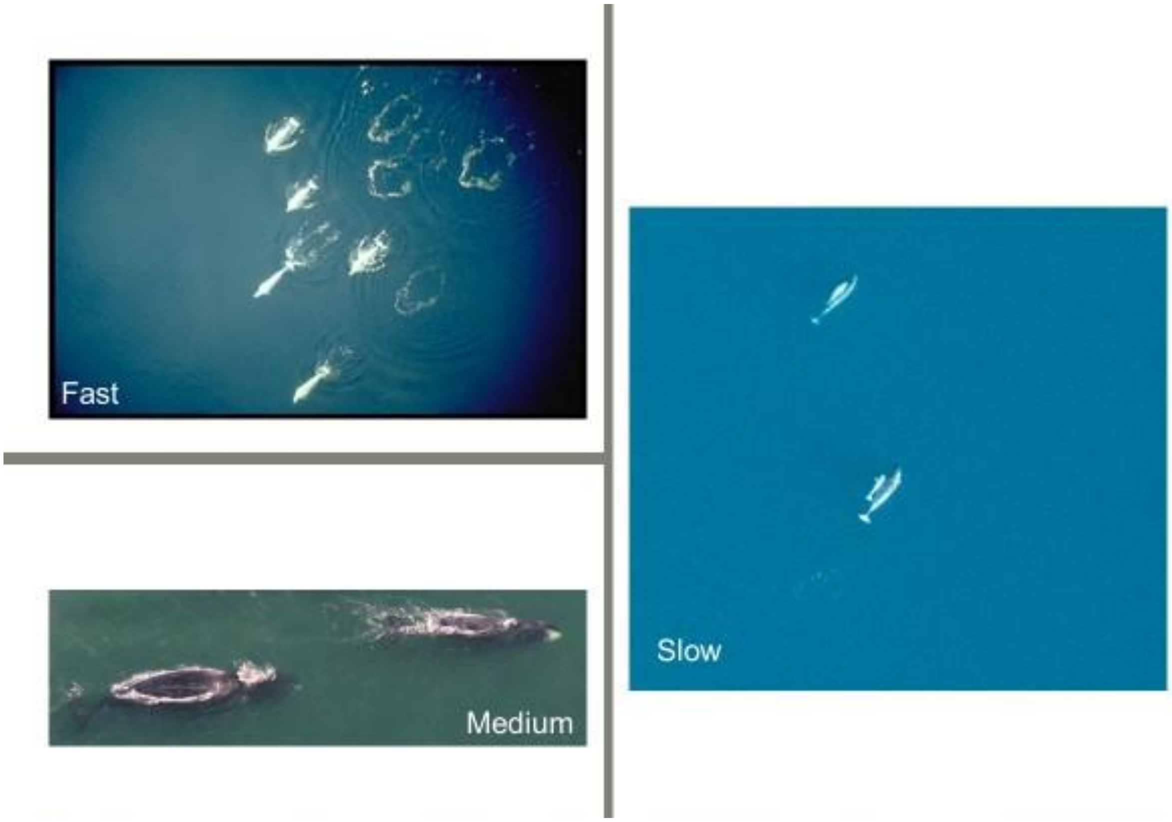
- Definite heading, steady motion, small amount of white water

Slow

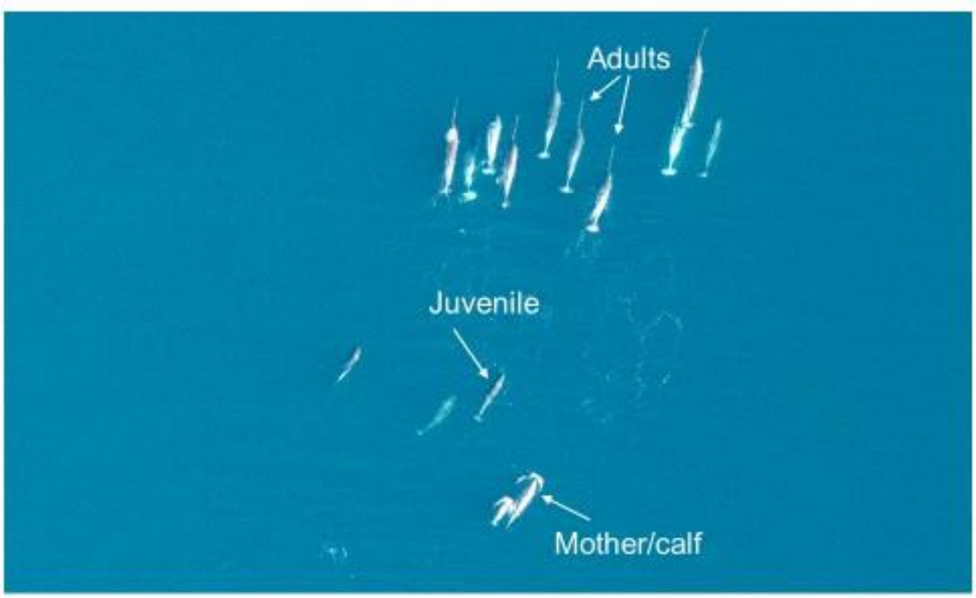
- Definite heading, forward motion observable, no white water visible

Not Moving

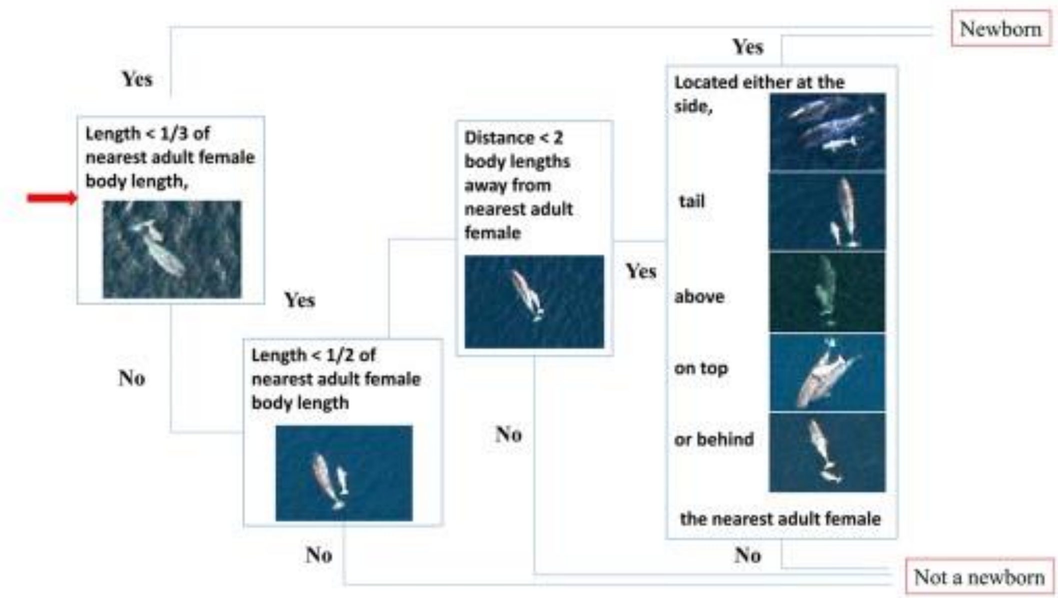
- Marine mammal is stationary, no movement



Narwhal age classes

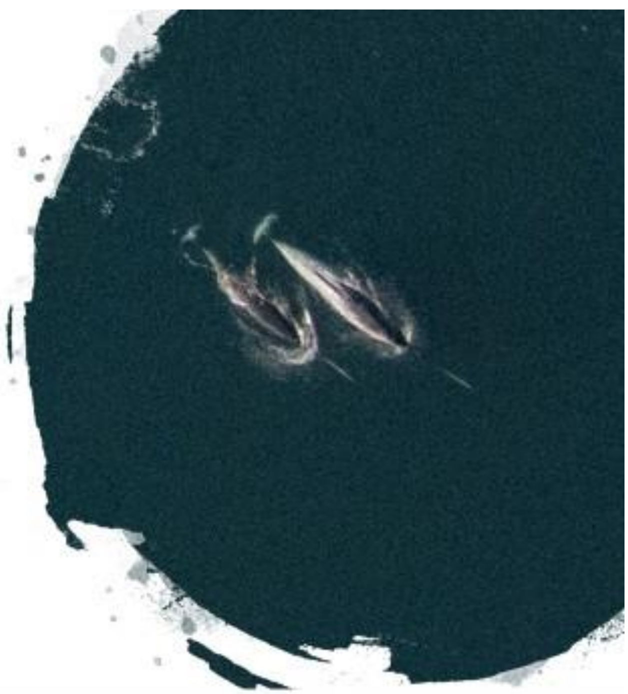


Narwhal Calf Key



Sighting Cue

- Body
- Blow
- Footprint
- Splash
- Birds




Footprint


Splash


Blow


Birds


Behaviour
Hauled Out
Diving
Fluke
Surfacing
Swimming
Surface Activity
Looking
Blow
Breaching
Spyhopping
Walking, Running, Standing (i.e. Polar Bear)
Dead
Logging

Hauled Out

Hauled out on ice or land (pinnipeds)

Diving

Marine mammal descends below the surface.

Fluke

Whale shows its fluke as it dives beneath the water.

Surfacing

Marine mammal observed coming to the surface of the water.

Swimming

Marine mammal swimming at the surface of the water

Surface Activity

Marine mammal splashing, jumping, flipper or tail slapping, implies social interaction

Looking

When animal is in an upright position with its head out of the water and is actively looking at something (pinniped or polar bear)

Blow

Marine mammal releases air from its lungs at the surface of the water, observed as clouds of moist air. Can be visible at far distances.

Breach

When a whale leaps with its entire body out of the water.

Spyhop

Marine mammal raises its head vertically out of the water so that its eyes are clear of the surface.

Walk, Run, Stand

Polar bear walking, running, or standing on ice or land.

Logging

When a marine mammal is on the surface and is neither swimming nor moving.

Dead

When a marine mammal is identified deceased on land or in water

Activity

An activity is composed of several behaviors and cannot always be determined

- Feeding
- Traveling
- Resting
- Milling
- Socializing
- Unknown

Feeding

Marine mammal seen feeding or evidence of prey observed.

Travelling

Moving in a distinct direction with a moderate to fast pace

Resting

Marine mammal lying motionless at the surface of the water or on the ice/land

Milling

Moving but net movement is near zero, eg. swimming in circles.

Socializing

Engaged in social activity (involving more than one animal)

wsp.com

APPENDIX B

Mapbook

LEGEND

- COMMUNITY
- MILNE PORT
- AERIAL SURVEY TRACK
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BEARDED SEAL
- 1

BOWHEAD WHALE
- 1

HARP SEAL
- 1
- 2-10
- 10+

NARWHAL
- 1
- 2-10
- 10+

POLAR BEAR
- 1

RINGED SEAL
- 1
- 2-10

UNIDENTIFIED SEAL
- 1
- 2-10

ICE CONCENTRATION
- < 1/10
- 1-3/10
- 4-6/10
- 7-8/10
- 9-10/10
- LANDFAST ICE

0 25 50
1:1,000,000 KILOMETRES

REFERENCE(S)
MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023. 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
2023 MARINE MAMMAL AERIAL SURVEYS

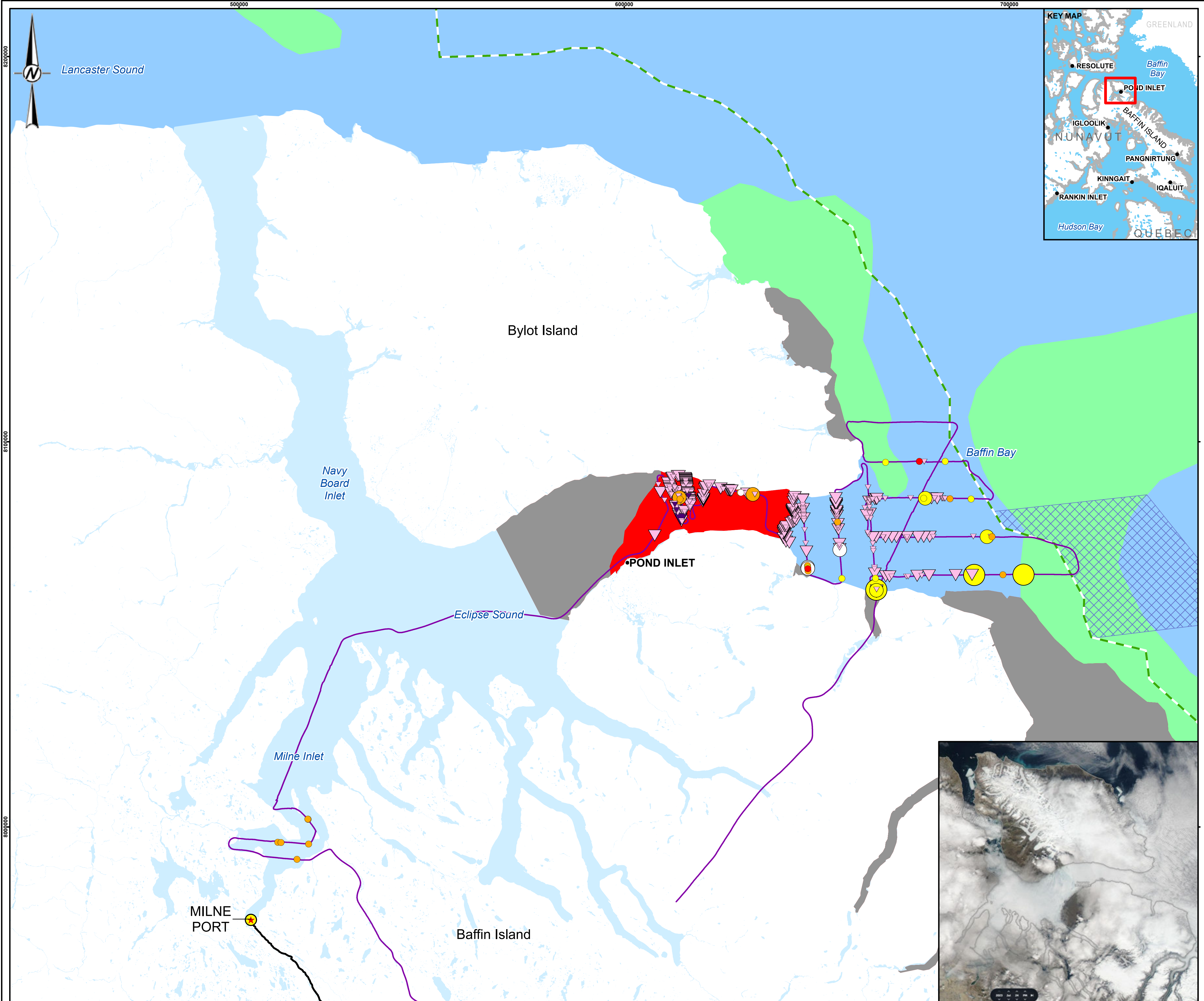
TITLE
ECLIPSE SOUND LEG 1 SURVEY 1 – JULY 23, 2023

CONSULTANT
wsp

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	78000-06	0	B-1

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



LEGEND

- COMMUNITY
- MILNE PORT
- AERIAL SURVEY TRACK
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BEARDED SEAL
- 1

BOWHEAD WHALE
- 1
- 2-10

HARP SEAL
- 1
- 2-10
- 10+

NARWHAL
- 1
- 2-10

RINGED SEAL
- 1
- 2-10

UNIDENTIFIED SEAL
- 1
- 2-10

ICE CONCENTRATION
- < 1/10
- 1-3/10
- 7-8/10
- 9-10/10
- LANDFAST ICE

0 25 50
1:1,000,000 KILOMETRES

REFERENCE(S)
MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
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CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
ECLIPSE SOUND LEG 1 SURVEY 2 – JULY 24, 2023

CONSULTANT
wsp

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	78000-06	0	B-2

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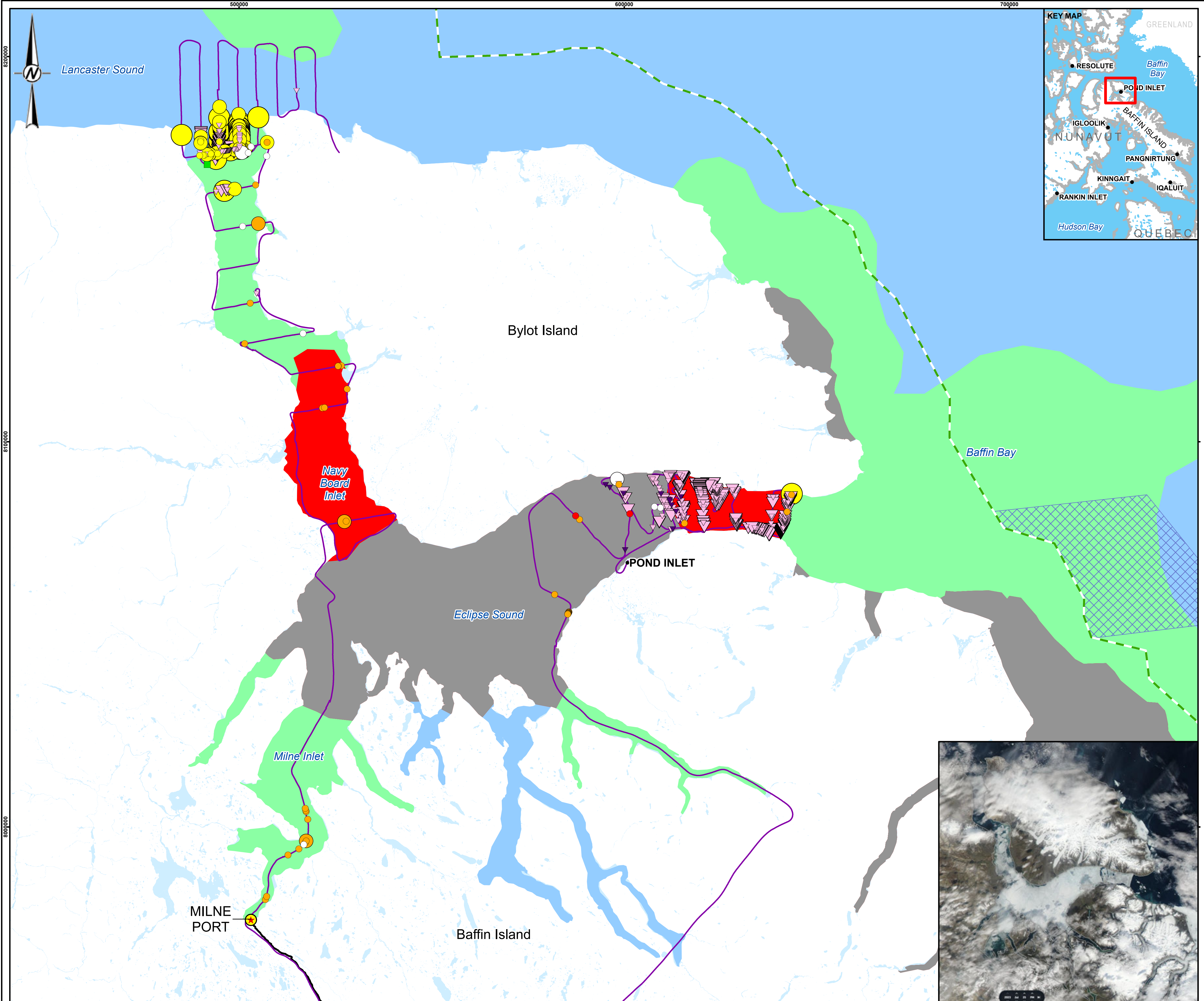

LEGEND

- COMMUNITY
- MILNE PORT

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BEARDED SEAL
- 1

BOWHEAD WHALE
- 1

HARP SEAL
- 1
- 2-10
- 10+

NARWHAL
- 1
- 2-10
- 10+

POLAR BEAR
- 1

RINGED SEAL
- 1
- 2-10

UNIDENTIFIED SEAL
- 1
- 2-10

- AERIAL SURVEY TRACK
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

ICE CONCENTRATION
- < 1/10
- 1-3/10
- 7-8/10
- 9-10/10
- LANDFAST ICE

0 25 50

1:1,000,000 KILOMETRES

REFERENCE(S)

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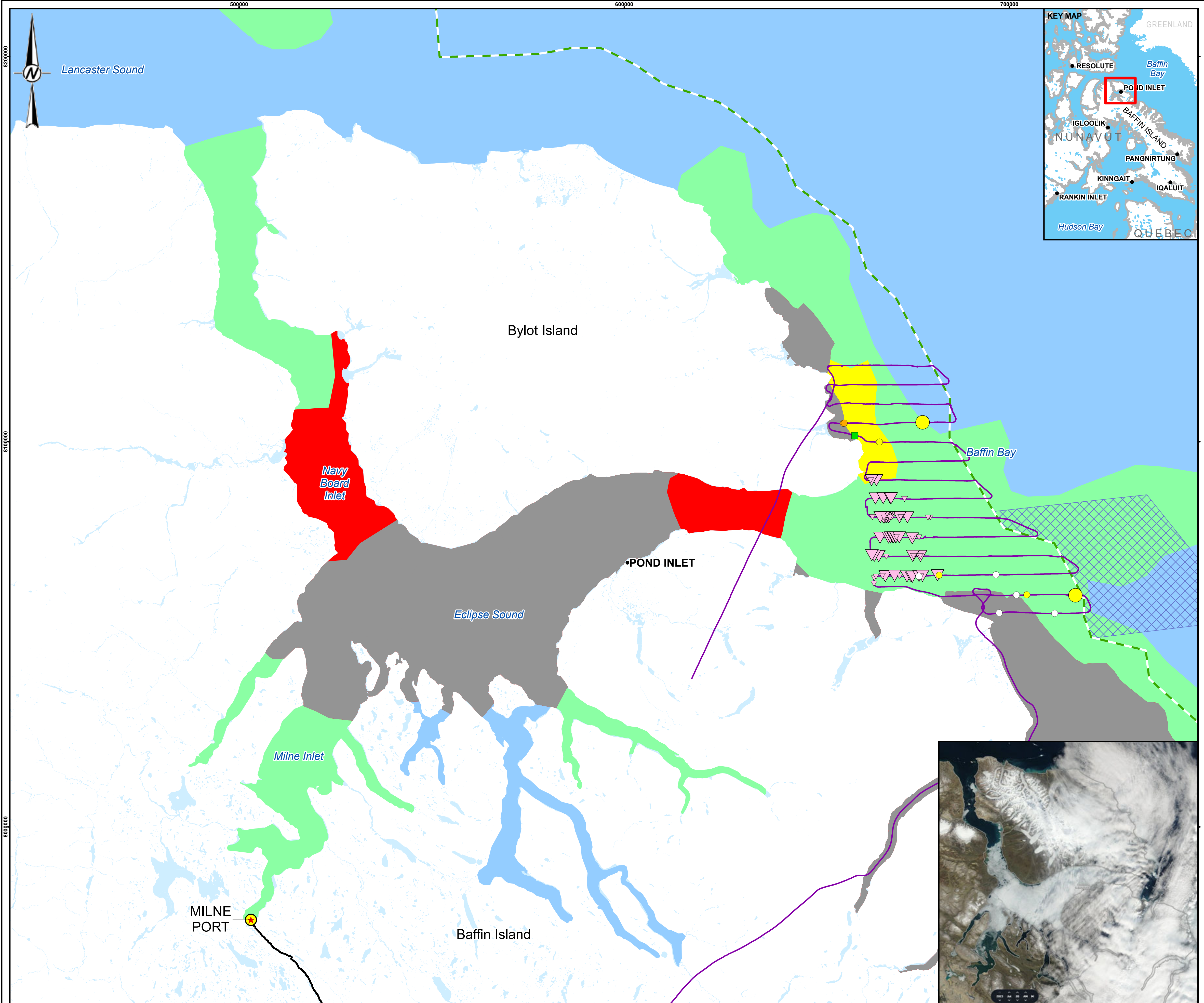
PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
ECLIPSE SOUND LEG 1 SURVEY 3 – JULY 25, 2023

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	78000-06	0	B-3



LEGEND

- COMMUNITY
- MILNE PORT

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

HARP SEAL
- 1
- 2-10

NARWHAL
- 1
- 2-10

POLAR BEAR
- 1

RINGED SEAL
- 1

UNIDENTIFIED SEAL
- 1

- AERIAL SURVEY TRACK
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

ICE CONCENTRATION
- < 1/10
- 1-3/10
- 4-6/10
- 9-10/10
- LANDFAST ICE

0 25 50
1:1,000,000 KILOMETRES

REFERENCE(S)
MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 17 DATUM: NAD 83

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PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
ECLIPSE SOUND LEG 1 SURVEY 4 – JULY 26, 2023

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	78000-06	0	B-4

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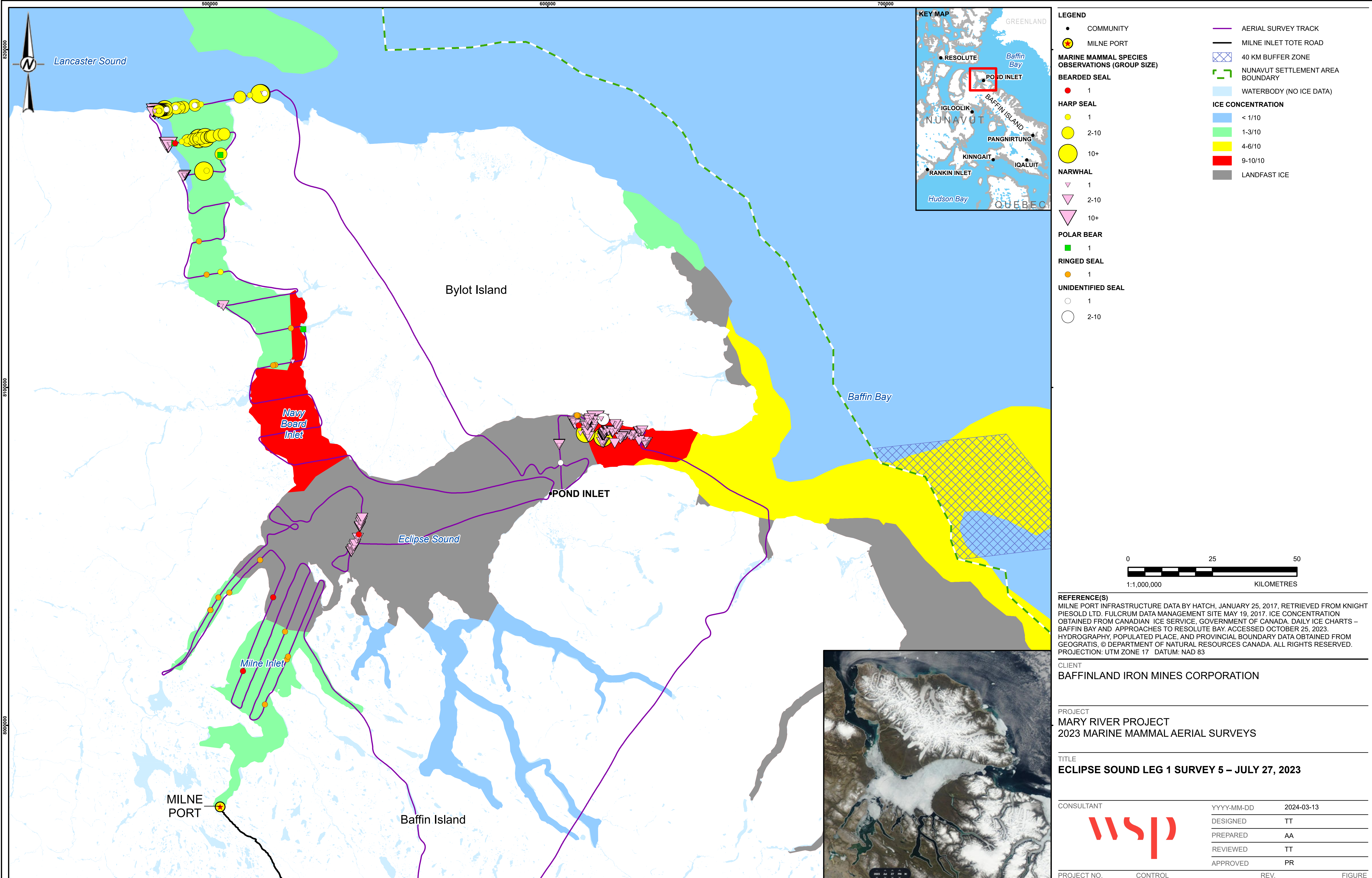

REFERENCE(S)

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BAFFINLAND IRON MINES CORPORATION

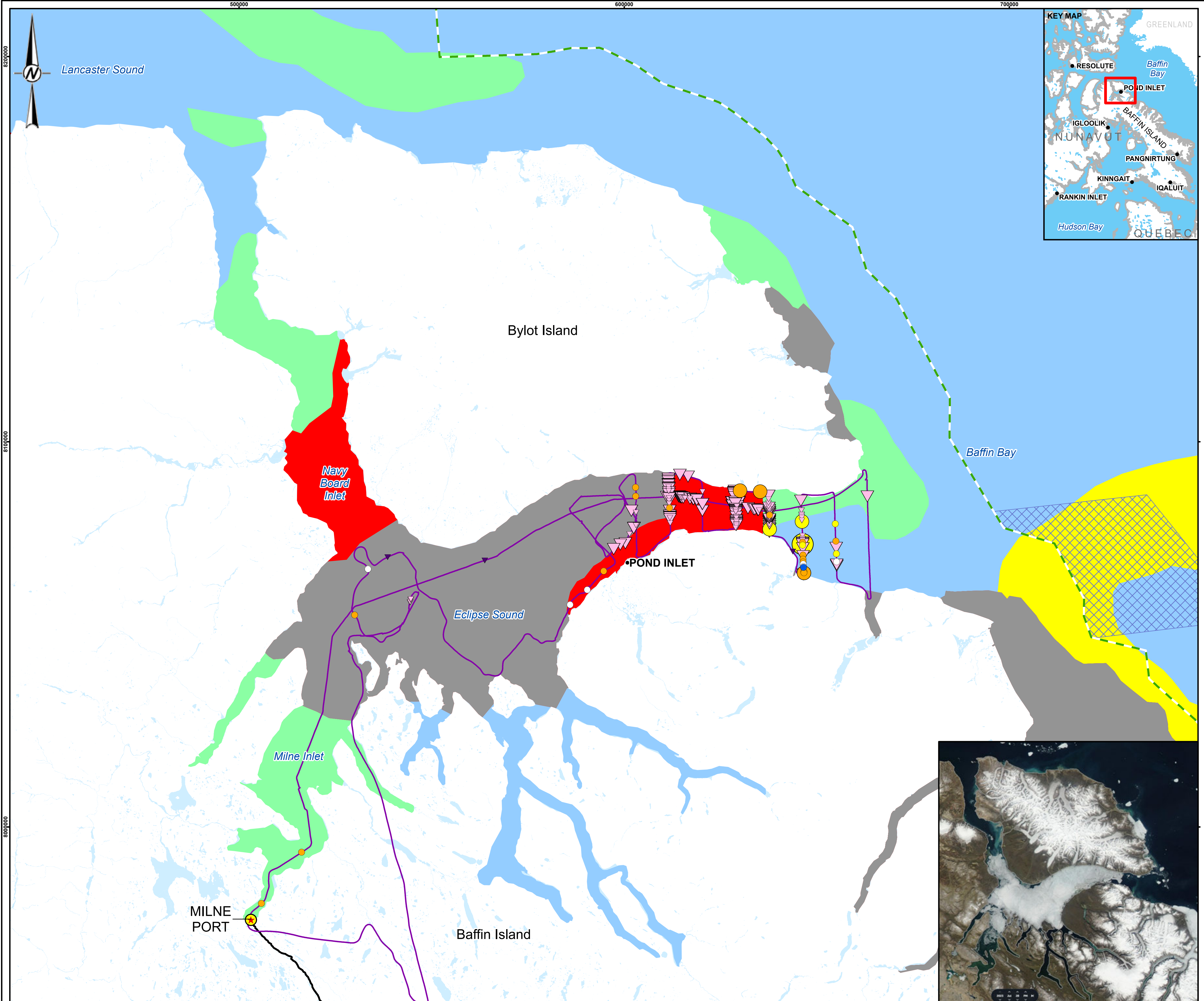
PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
ECLIPSE SOUND LEG 1 SURVEY 5 – JULY 27, 2023

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	78000-06	0	B-5



LEGEND

- COMMUNITY
- MILNE PORT

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BOWHEAD WHALE
- 1

HARP SEAL
- 1
- 2-10
- 10+

HOODED SEAL
- 1

NARWHAL
- 1
- 2-10
- 10+

RINGED SEAL
- 1
- 2-10

UNIDENTIFIED SEAL
- 1

- AERIAL SURVEY TRACK
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

ICE CONCENTRATION

- < 1/10
- 1-3/10
- 4-6/10
- 9-10/10
- LANDFAST ICE

0 25 50

1:1,000,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023. 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
2023 MARINE MAMMAL AERIAL SURVEYS

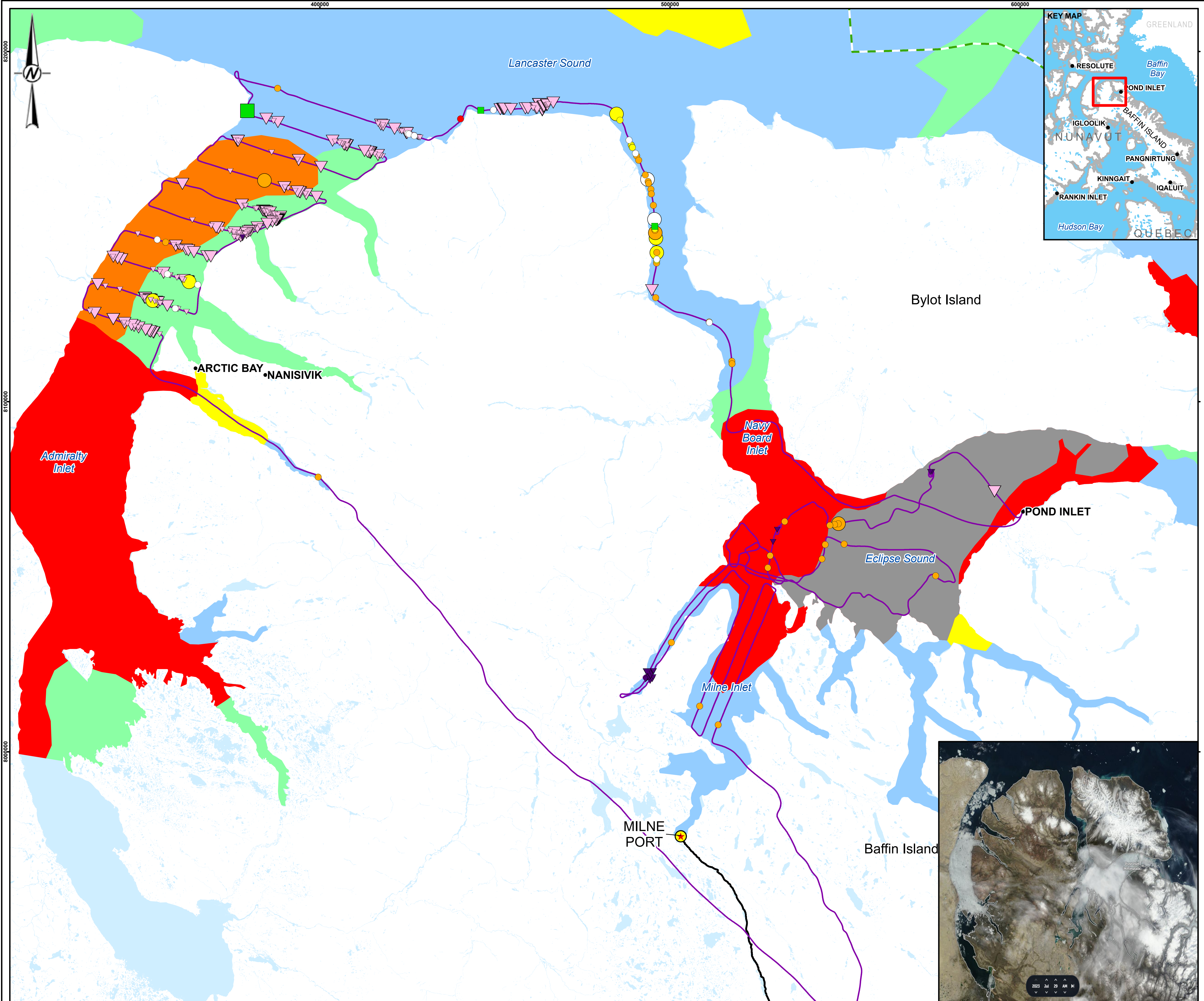
TITLE
ECLIPSE SOUND LEG 1 SURVEY 6 – JULY 28, 2023

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	78000-06	0	B-6

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



LEGEND

- COMMUNITY
- MILNE PORT

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BEARDED SEAL
- 1

BOWHEAD WHALE
- 1
- 2-10

HARP SEAL
- 1
- 2-10

NARWHAL
- 1
- 2-10
- 10+

POLAR BEAR
- 1
- 2-10

RINGED SEAL
- 1
- 2-10

UNIDENTIFIED SEAL
- 1
- 2-10

- AERIAL SURVEY TRACK
- MILNE INLET TOTE ROAD
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

ICE CONCENTRATION
- < 1/10
- 1-3/10
- 4-6/10
- 7-8/10
- 9-10/10
- LANDFAST ICE

0 25 50

1:1,100,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023. 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
2023 MARINE MAMMAL AERIAL SURVEYS

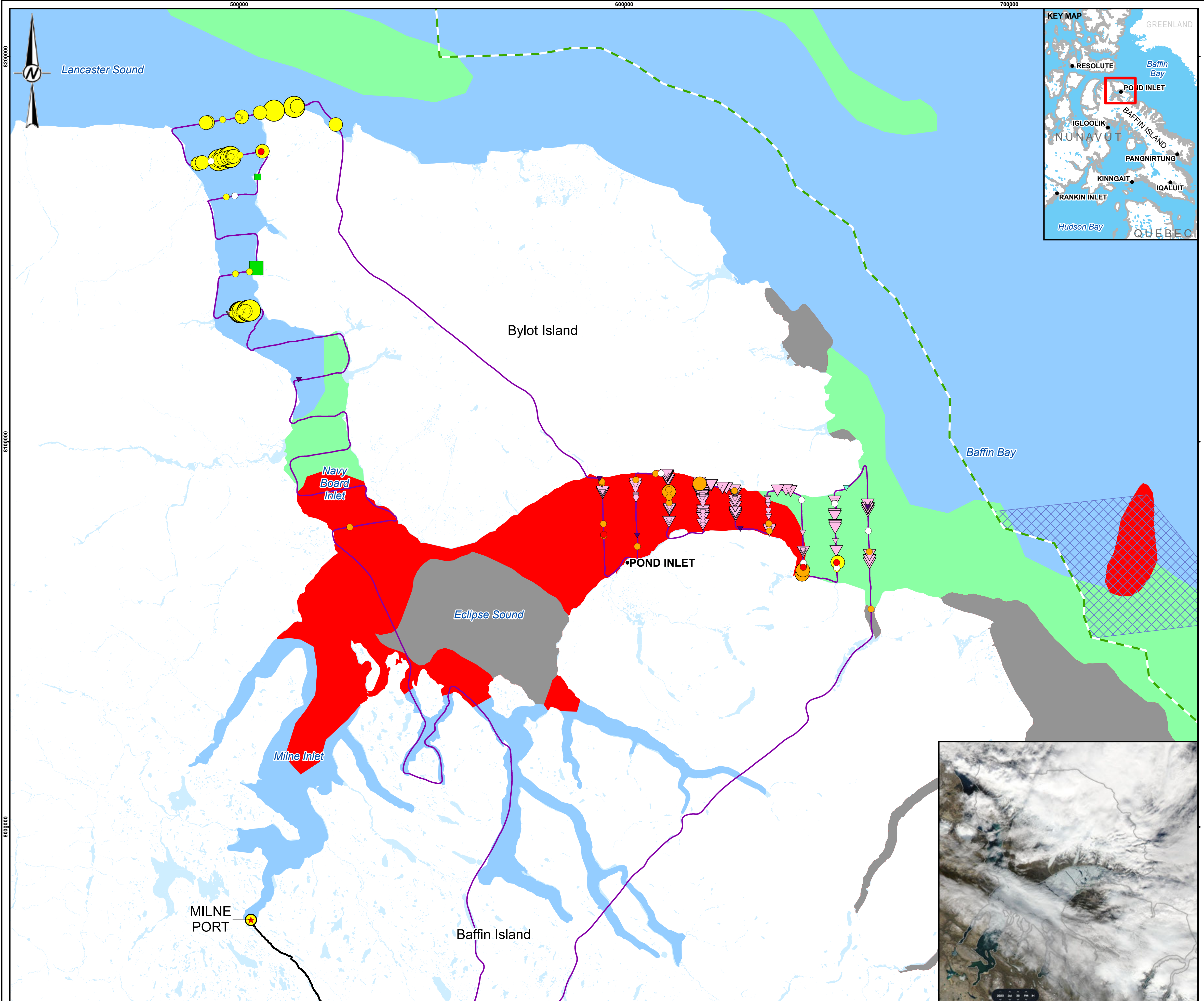
TITLE
ECLIPSE SOUND AND ADMIRALTY INLET LEG 1 SURVEY 7 – JULY 29, 2023

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	78000-06	0	B-7

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



LEGEND

- COMMUNITY
- MILNE PORT

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BEARDED SEAL
- 1

BELUGA
- 1

BOWHEAD WHALE
- 1

HARP SEAL
- 1
- 2-10
- 10+

NARWHAL
- 1
- 2-10
- 10+

POLAR BEAR
- 1
- 2-10

RINGED SEAL
- 1
- 2-10

UNIDENTIFIED SEAL
- 1

- AERIAL SURVEY TRACK
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

ICE CONCENTRATION
- < 1/10
- 1-3/10
- 9-10/10
- LANDFAST ICE

0 25 50

1:1,000,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023. 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
2023 MARINE MAMMAL AERIAL SURVEYS

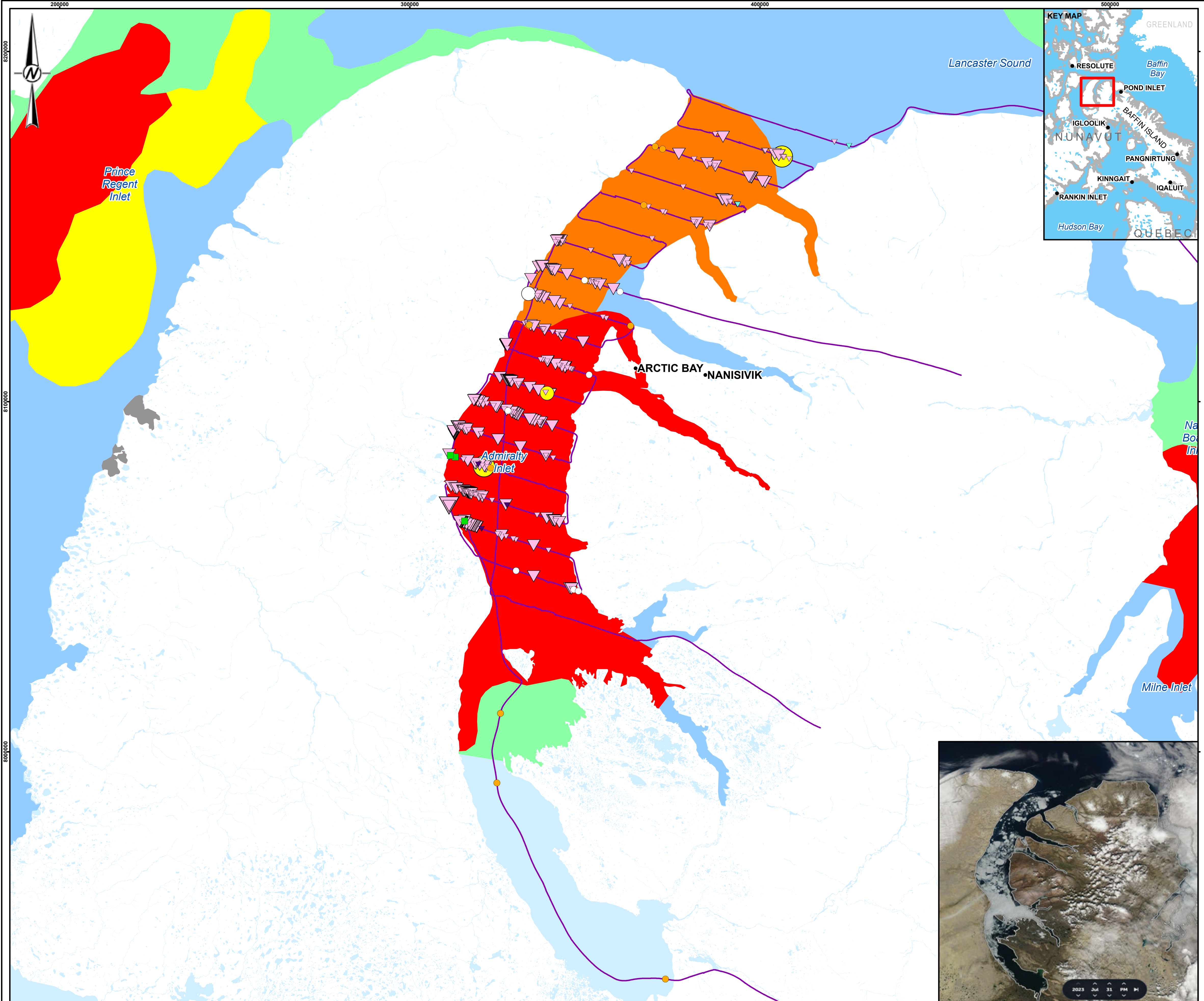
TITLE
ECLIPSE SOUND LEG 1 SURVEY 8 – JULY 30, 2023

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	78000-06	0	B-8

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



LEGEND

- COMMUNITY
- MILNE PORT
- AERIAL SURVEY TRACK
- MILNE INLET TOTE ROAD
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BELUGA
- 1

BOWHEAD WHALE
- 1

HARP SEAL
- 2-10
- 10+

NARWHAL
- 1
- 2-10
- 10+

POLAR BEAR
- 1

RINGED SEAL
- 1

UNIDENTIFIED SEAL
- 1
- 2-10

ICE CONCENTRATION
- < 1/10
- 1-3/10
- 4-6/10
- 7-8/10
- 9-10/10
- LANDFAST ICE

0 25 50

1:1,100,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023. 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

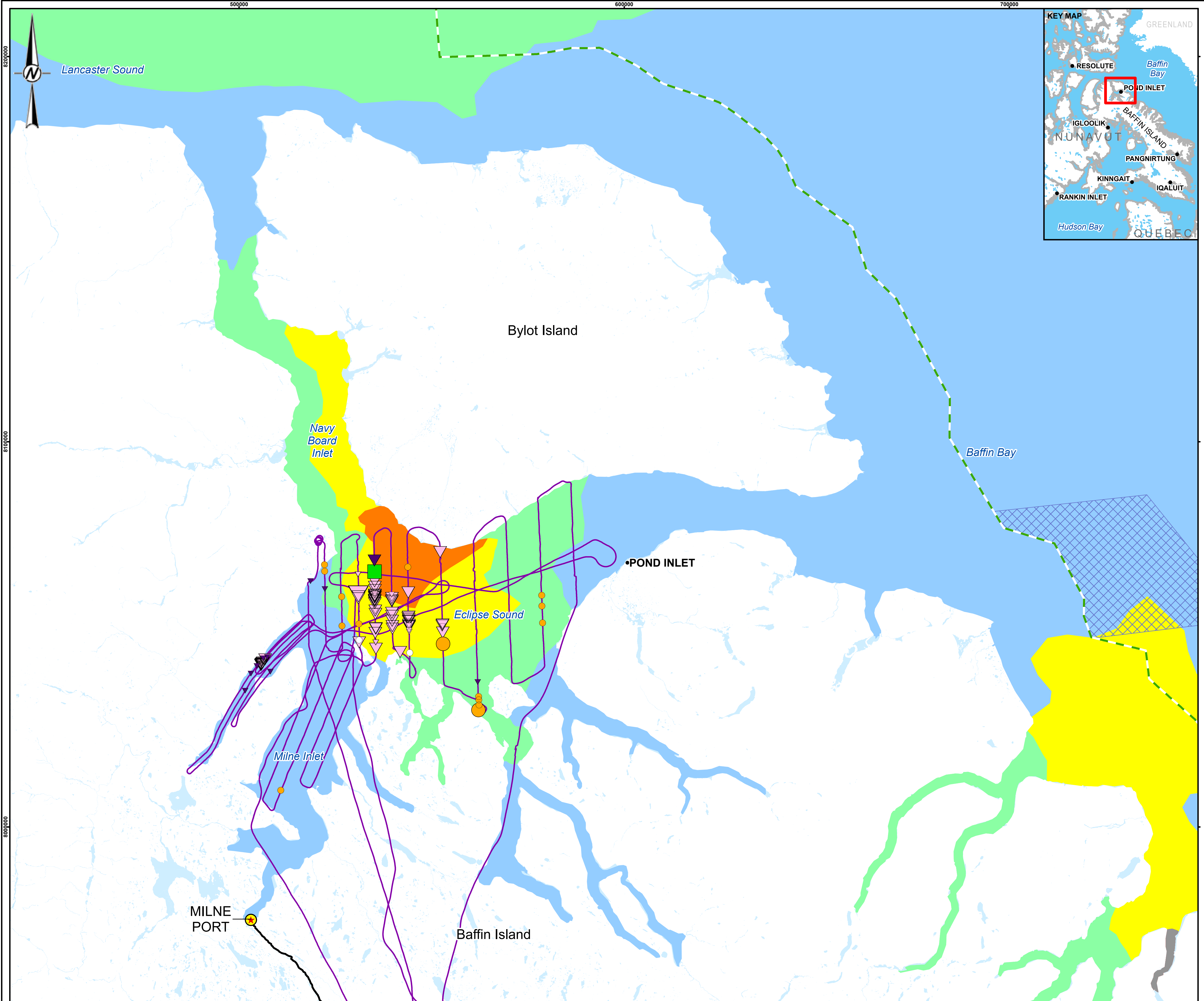
PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
ADMIRALTY INLET LEG 1 SURVEY 9 – JULY 31, 2023

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	78000-06	0	B-9



LEGEND

- COMMUNITY
- MILNE PORT
- AERIAL SURVEY TRACK
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BOWHEAD WHALE
- 1
- 2-10

NARWHAL
- 1
- 2-10
- 10+

POLAR BEAR
- 2-10

RINGED SEAL
- 1
- 2-10

UNIDENTIFIED SEAL
- 1

ICE CONCENTRATION
- < 1/10
- 1-3/10
- 4-6/10
- 7-8/10
- 9-10/10
- LANDFAST ICE

0 25 50

1:1,000,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023. 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
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
ECLIPSE SOUND LEG 2 RECONNAISSANCE SURVEY – AUGUST 10-11, 2023

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

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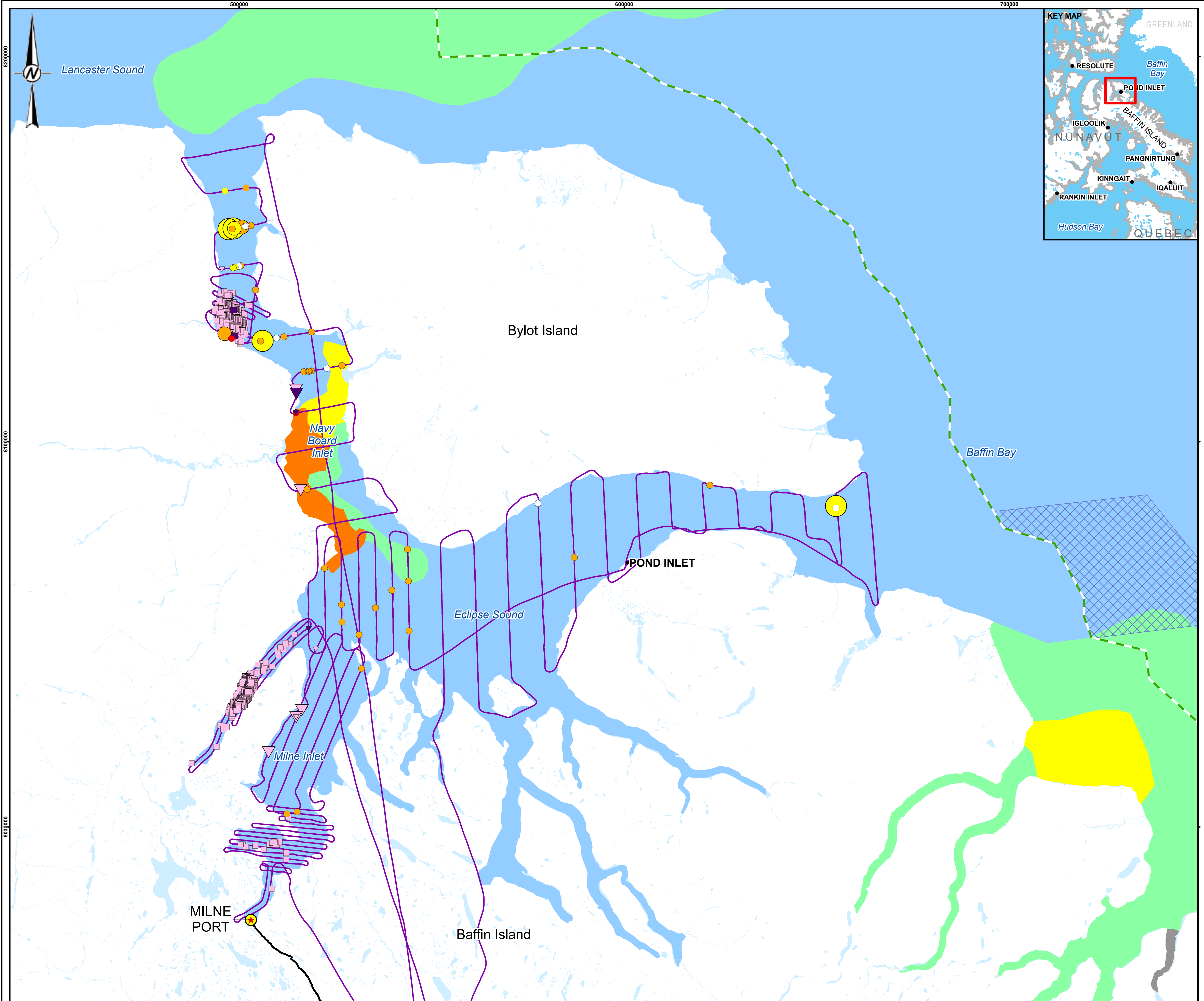

LEGEND

- COMMUNITY
- MILNE PORT

PHOTOGRAPHIC SURVEY MARINE MAMMAL SPECIES OBSERVATIONS

- BOWHEAD WHALE
- NARWHAL

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BEARDED SEAL

- 1

BOWHEAD WHALE

- 1
- 2-10

HARP SEAL

- 1
- 2-10
- 10+

NARWHAL

- 1
- 2-10

RINGED SEAL

- 1
- 2-10

UNIDENTIFIED SEAL

- 1

- AERIAL SURVEY TRACK
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

ICE CONCENTRATION

- < 1/10
- 1-3/10
- 4-6/10
- 7-8/10
- 9-10/10
- LANDFAST ICE

0 25 50

1:1,000,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023. HYDROGRAPHY, POPULATED PLACE, AND PROVINCIAL BOUNDARY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
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CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
ECLIPSE SOUND LEG 2 SURVEY 1 – AUGUST 12-13, 2023

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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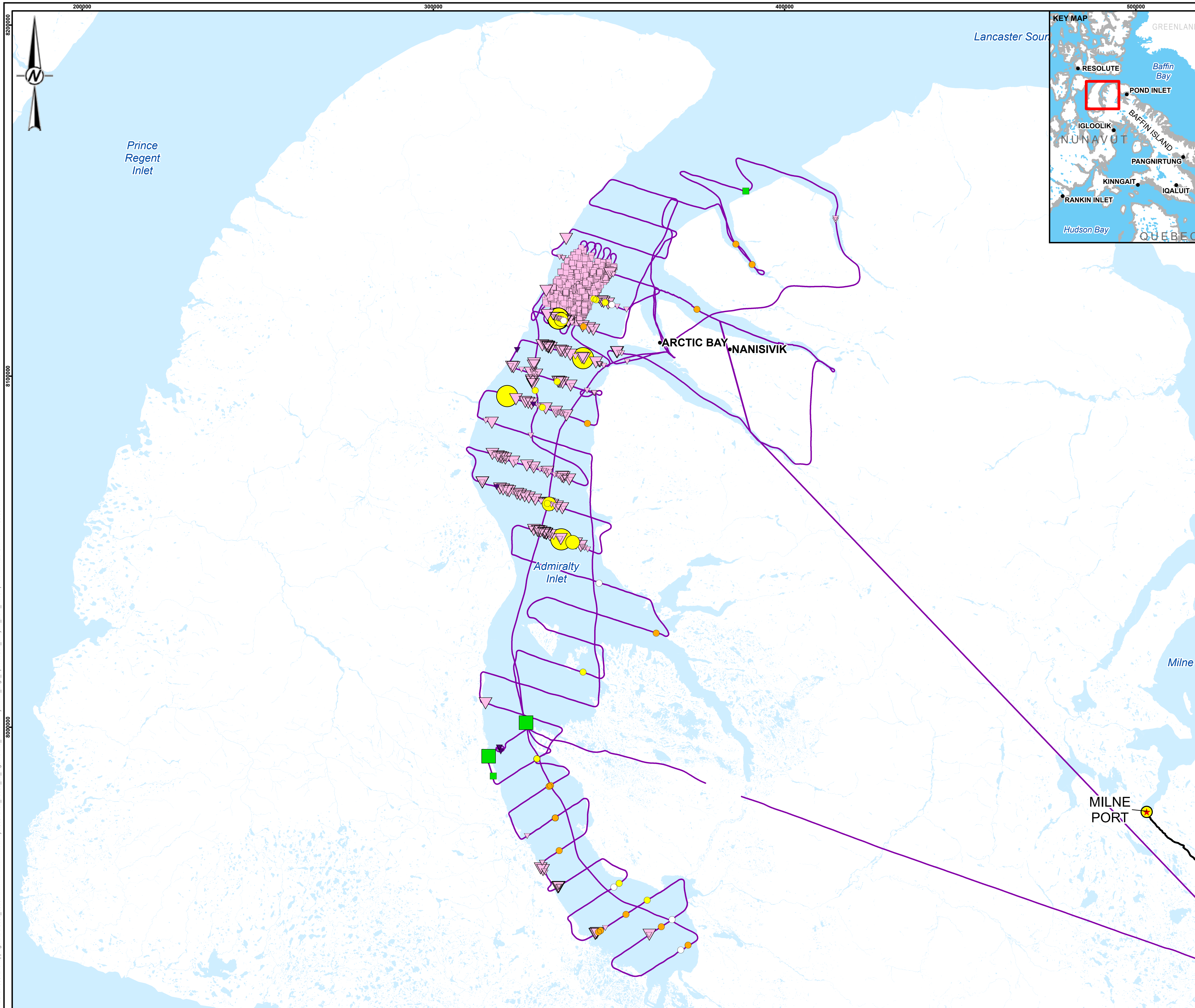

LEGEND

- COMMUNITY
- MILNE PORT

PHOTOGRAPHIC SURVEY MARINE MAMMAL SPECIES OBSERVATIONS

- NARWHAL

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BOWHEAD WHALE

- 1

HARP SEAL

- 1
- 2-10
- 10+

NARWHAL

- 1
- 2-10

POLAR BEAR

- 1
- 2-10

RINGED SEAL

- 1

UNIDENTIFIED SEAL

- 1

- AERIAL SURVEY TRACK
- MILNE INLET TOTE ROAD
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

0 25 50

1:1,100,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023. 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
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
ADMIRALTY INLET LEG 2 SURVEY 2 – AUGUST 19-20, 2023

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
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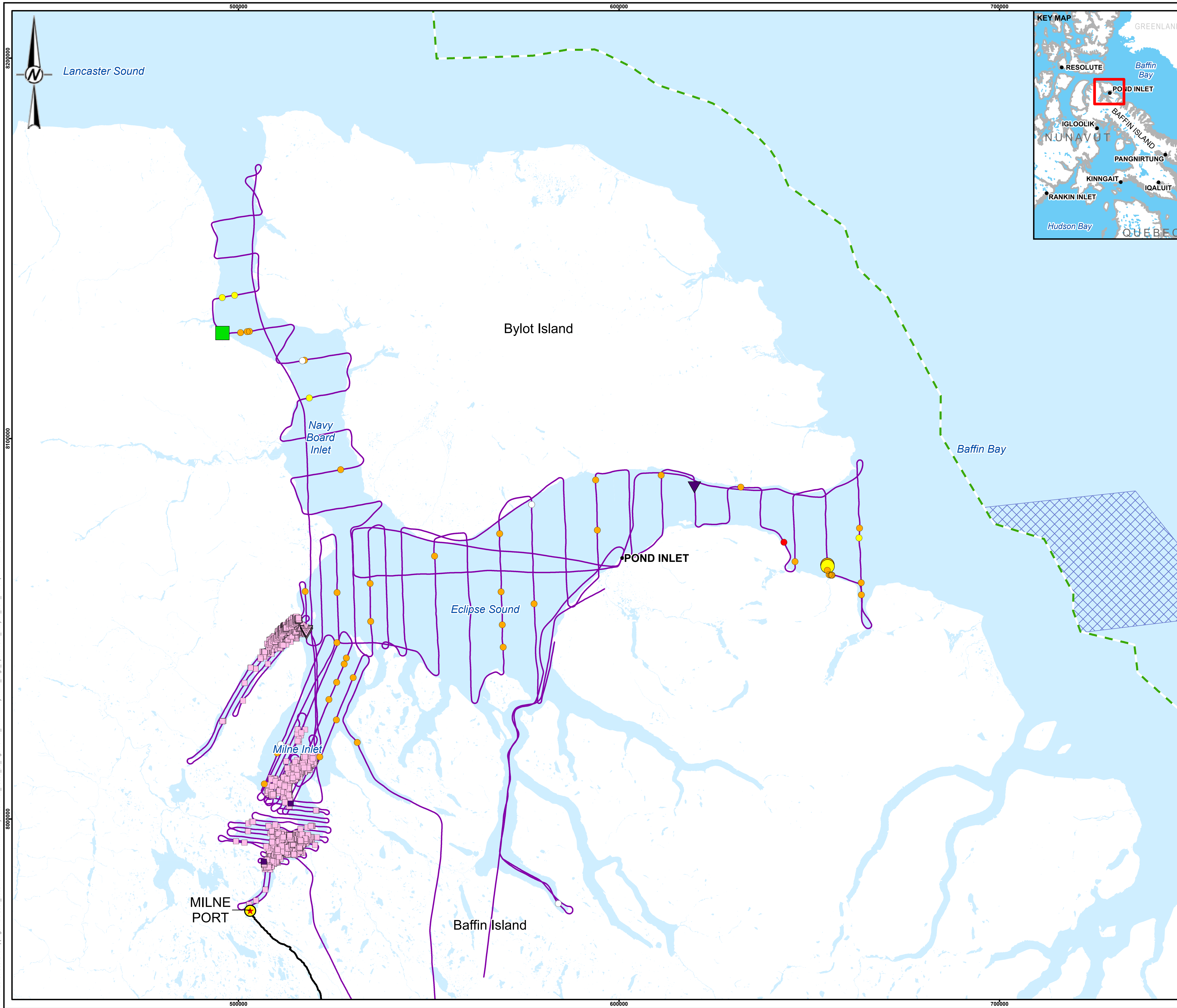

LEGEND

- COMMUNITY
- MILNE PORT

PHOTOGRAPHIC SURVEY MARINE MAMMAL SPECIES OBSERVATIONS

- BOWHEAD WHALE
- NARWHAL

MARINE MAMMAL SPECIES OBSERVATIONS (GROUP SIZE)

BEARDED SEAL

- 1

BOWHEAD WHALE

- 2-10

HARP SEAL

- 1
- 2-10

NARWHAL

- 1
- 2-10

POLAR BEAR

- 2-10

RINGED SEAL

- 1
- 2-10

UNIDENTIFIED SEAL

- 1

- AERIAL SURVEY TRACK
- MILNE INLET TOTE ROAD
- 40 KM BUFFER ZONE
- NUNAVUT SETTLEMENT AREA BOUNDARY
- WATERBODY (NO ICE DATA)

0 25 50

1:1,000,000 KILOMETRES

REFERENCE(S)

MILNE PORT INFRASTRUCTURE DATA BY HATCH, JANUARY 25, 2017, RETRIEVED FROM KNIGHT PIESOLD LTD. FULCRUM DATA MANAGEMENT SITE MAY 19, 2017. ICE CONCENTRATION OBTAINED FROM CANADIAN ICE SERVICE, GOVERNMENT OF CANADA. DAILY ICE CHARTS – BAFFIN BAY AND APPROACHES TO RESOLUTE BAY. ACCESSED OCTOBER 25, 2023.
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PROJECTION: UTM ZONE 17 DATUM: NAD 83

CLIENT
BAFFINLAND IRON MINES CORPORATION

PROJECT
MARY RIVER PROJECT
2023 MARINE MAMMAL AERIAL SURVEYS

TITLE
ECLIPSE SOUND LEG 2 SURVEY 3 – AUGUST 23-25, 2023

CONSULTANT

YYYY-MM-DD	2024-03-13
DESIGNED	TT
PREPARED	AA
REVIEWED	TT
APPROVED	PR

PROJECT NO.	CONTROL	REV.	FIGURE
166372402	78000-06	0	B-13

25mm
0

APPENDIX C

Distance Sampling and Mark-Recapture Models

Table 1: Narwhal Distance Sampling and Mark-Recapture Models

Distance Sampling			Mark-Recapture	
AIC (Gamma key function, no series adjustment)	Model[1]		AIC	Model[1]
8569.377	~ ObsPair + Bft + IceCover + FogIntRank		1079.191	~observer + distance + ObsPair + Bft:Turbidity + GlareAng:RC60 + distance:GlareAng
8570.429	~ ObsPair + Bft + IceCover + FogIntRank + GlareAng		1079.192	~observer + distance + ObsPair + Turbidity + GlareAng:RC60 + distance:GlareAng
8570.636	~ ObsPair + Bft + IceCover + FogIntRank + RC60		1079.192	~observer + distance + ObsPair + Turbidity + GlareAng:RC60 + distance:GlareAng
8570.738	~ ObsPair + Bft + Turbidity + IceCover + FogIntRank		1080.281	~observer + distance + ObsPair + GlareAng:RC60 + FogIntRank:Turbidity + distance:GlareAng
8571.107	~ ObsPair + Bft + Precip + IceCover + FogIntRank		1081.678	~observer + ObsPair + GlareAng:RC60 + distance:Turbidity + distance:GlareAng
8571.2	~ ObsPair + Bft + IceCover + FogIntRank + GlareIntRank		1081.678	~observer + distance + ObsPair + GlareAng:RC60 + distance:Turbidity + distance:GlareAng
8571.255	~ ObsPair + Bft + IceCover + FogIntRank + FogCover		1082.035	~observer + distance + ObsPair + GlareIntRank:Turbidity + GlareAng:RC60 + distance:GlareAng
8571.351	~ ObsPair + Bft + Side + IceCover + FogIntRank		1082.913	~observer + distance + ObsPair + GlareAng:RC60 + distance:GlareAng + RC60
8571.354	~ ObsPair + Bft + IceCover + FogCover		1082.941	~observer + distance + ObsPair + GlareAng:RC60 + GlareIntRank:RC60 + distance:GlareAng
8571.691	~ ObsPair + Bft + IceCover + FogIntRank + GlareAng + RC60		1083.342	~observer + distance + ObsPair + Precip + GlareAng:RC60 + distance:GlareAng
8571.75	~ ObsPair + Bft + Turbidity + IceCover + FogIntRank + GlareAng		1083.752	~observer + distance + ObsPair + GlareAng:RC60 + distance:GlareAng
8571.88	~ ObsPair + Bft + Turbidity + IceCover + FogCover		1084.221	~observer + distance + ObsPair + GlareAng:RC60 + distance:Bft + distance:GlareAng
8572.117	~ ObsPair + Bft + Precip + IceCover + FogIntRank + GlareAng		1084.79	~observer + distance + ObsPair + Bft:GlareIntRank + GlareAng:RC60 + distance:GlareAng
8572.16	~ ObsPair + Bft + Turbidity + IceCover + FogIntRank + RC60		1084.914	~observer + distance + ObsPair + Bft + GlareAng:RC60 + distance:GlareAng

Distance Sampling			Mark-Recapture	
AIC (Gamma key function, no series adjustment)	Model[1]		AIC	Model[1]
8572.174	~ ObsPair + Bft + Precip + IceCover + FogIntRank + RC60		1085.07	~observer + distance + ObsPair + GlareAng:RC60 + GlareIntRank:Precip + distance:GlareAng
8572.227	~ ObsPair + Bft + IceCover + FogCover + GlareAng		1085.253	~observer + distance + ObsPair + GlareAng + GlareAng:RC60 + distance:GlareAng
8572.311	~ ObsPair + Bft + IceCover + FogIntRank + FogCover + GlareAng		1085.309	~observer + distance + ObsPair + FogCover + GlareAng:RC60 + distance:GlareAng
8572.374	~ ObsPair + Bft + IceCover + FogIntRank + GlareIntRank + GlareAng		1085.584	~observer + distance + ObsPair + IceCover + GlareAng:RC60 + distance:GlareAng
8572.432	~ ObsPair + Bft + IceCover + FogCover + RC60		1085.586	~observer + distance + ObsPair + distance:GlareIntRank + GlareAng:RC60 + distance:GlareAng
8572.483	~ObsTeam + Bft + IceCover + FogIntRank + FogCover + RC60		1085.587	~observer + distance + ObsPair + GlareIntRank + GlareAng:RC60 + distance:GlareAng

1) distance = horizontal distance, FogCover = percent coverage of viewing area by fog, FogIntRank = ranking of fog intensity, GlareAng = glare coverage angle, GlareIntRank = glare intensity rank, IceCover = percent ice coverage of viewing area, observer = primary/secondary observer, ObsPair = pairing of individual observers on same side of aircraft, Precip = precipitation intensity, Bft = Beaufort seastate, RCxx = rolling count for the number of observation recorded within the xx seconds prior to an observation and summed for both observers in a pairing, Turbidity = rank of ocean surface turbidity.

APPENDIX D

Leg 2 Relative Abundance of Marine Mammals

Relative Abundance in Eclipse Sound and Admiralty Inlet

Marine mammal relative abundance was calculated and expressed as number of animals/km, as outlined in Section 2.4.2 of the 2023 MMASP Report. In 2023, a total of 3,699 km of effort (2,575 km of visual surveys and 1,124 km of photographic surveys) was flown over two surveys in Eclipse Sound (Survey# 1 and #3) and one survey in Admiralty Inlet (Survey #2). The relative abundance of marine mammals in the Eclipse Sound and Admiralty Inlet survey grids during Leg 2, expressed as the animal detection rate (no. of animals relative to survey effort in km), are presented in Tables 1 and 2.

Eclipse Sound Survey Grid: Narwhal had the highest relative abundance (2.2234 animals/km) of all the marine mammal species identified to the species level, followed by harp seal, ringed seal, bowhead whale, and bearded seal (Table 1). Unidentified seals had the fourth highest relative abundance of 0.0063 animals/km in the Eclipse Sound grid.

Admiralty Inlet Survey Grid: Narwhal had the highest relative abundance (2.3802 animals/km) of all the marine mammal species identified to the species level, followed by harp seal, ringed seal, and then bowhead whale (Table 2). Unidentified seals had the fourth highest relative abundance of 0.0071 animals/km in the Admiralty Inlet grid.

Table 1: Sighting and animal detection rate (relative abundance) of marine mammals in Eclipse Sound survey grid (Survey #1 and 3) during Leg 2 (2023)

Species	Visual Survey		Photographic Survey	Combined Visual and Photographic Survey
	No. of Sightings	No. of Animals	Surface Count	Animal Detection Rate (animals/km)
Narwhal	11	21	5,913	2.2234
Bowhead Whale	3	4	7	0.0041
Ringed Seal	60	63	–	0.0352
Harp Seal	13	166	–	0.0958
Bearded Seal	1	1	–	0.0006
Unidentified Seal	11	11	–	0.0063

Table 2: Sighting and animal detection rate (relative abundance) of marine mammals in Admiralty Inlet survey grid (Survey #2) during Leg 2 (2023)

Species	Visual Survey		Photographic Survey	Combined Visual and Photographic Survey
	No. of Sightings	No. of Animals	Surface Count	Animal Detection Rate (animals/km)
Narwhal	214	381	2,072	2.3802
Bowhead Whale	4	4	0	0.0039
Ringed Seal	17	17	–	0.0202
Harp Seal	19	130	–	0.1543
Unidentified Seal	6	6	–	0.0071

Comparison to 2019-2022 MMASP survey results

The relative abundance values presented in this section were calculated based on data collected during Surveys # 1, 2, and 3 in 2023; Surveys # 2, 3 and 4 in 2022; Survey # 4 in 2021; Surveys # 1 and 3 in 2020; and Surveys #3 and 4 in 2019. These surveys had complete survey coverage in the combined survey grids and were conducted under good sighting conditions.

Eclipse Sound Survey Grid: The relative abundance of marine mammals in the RSA was higher in 2023 (2.3171 animals/km) than all previous survey years (Table 3). Narwhal relative abundance in 2023 (2.2234 animals/km) increased by 241% compared to 2022 (0.6512 animals/km) and by 35% compared to 2019 (1.6396 animals/km), the previously highest recorded value in the Eclipse Sound grid (Table 3). Ringed seal relative abundance in 2023 (0.0352 animals/km) was lower than that observed in the previous three years (2020-2022), but higher compared to 2019 (0.0047 animals/km). Harp seal relative abundance in 2023 (0.0958 animals/km) was higher than that observed in the previous four years (2019- 2022). Relative abundance results for seals should be interpreted with caution due to the difficulty of observing and identifying seals at survey altitudes of 305 m (1,000 ft) above sea level (ASL), especially in high sea states.

Admiralty Inlet Survey Grid: The relative abundance of marine mammals in Admiralty Inlet was lower in 2023 (2.5325 animals/km) to that observed in 2022 (3.1181 animals/km), 2021 (12.6872 animals/km), 2020 (3.3705 animals/km) and 2019 (4.8911 animals/km; Table 3). Narwhal relative abundance in 2023 (2.3802 animals/km) increased by 15% compared to 2020 (2.0704 animals/km), and decreased by 31%, 80% and 16% compared to 2019 (3.4363 animals/km), 2021 (11.6507 animals/km), and 2022 (2.8330 animals/km), respectively. Relative abundance of ringed seal and harp seal was lower in 2023 compared to 2022, 2021, and 2020, but higher relative to 2019 (Table 3). Unidentified seals were observed in lower relative abundance in 2023 compared to the four previous years (2019-2022).

Table 3: Relative abundance of marine mammals in Eclipse Sound and Admiralty Inlet during Leg 2 (2019-2023)

Species	Eclipse Sound Grid					Admiralty Inlet Grid				
	2019 (animals/km)	2020 (animals/km)	2021 (animals/km)	2022 (animals/km)	2023 (animals/km)	2019 (animals/km)	2020 (animals/km)	2021 (animals/km)	2022 (animals/km)	2023 (animals/km)
Narwhal	1.6396	0.7682	0.3270	0.6512	2.2234	3.4363	2.0704	11.6507	2.8330	2.3802
Bowhead Whale	0.0003	0.0003	0.0006	0.0006	0.0041	0.0313	0.0087	0.0510	0.0034	0.0039
Beluga Whale	–	–	–	0.0016	–	–	–	–	0.0285	–
Killer Whale	0.0010	0.0045	–	–	–	–	–	0.0085	–	–
Sperm Whale	–	0.0016	–	–	–	–	–	–	–	–
Unidentified Whale	–	0.0006	–	0.0003	–	–	0.0012	0.0014	0.0004	–
Ringed Seal	0.0047	0.0736	0.0702	0.0726	0.0352	0.0122	0.0830	0.0920	0.0615	0.0202
Harp Seal	0.0527	0.0448	0.0331	0.0466	0.0958	0.1495	0.3685	0.9441	0.1917	0.1543
Bearded Seal	–	–	–	0.0022	0.0006	–	0.0004	–	–	–
Hooded Seal	–	–	–	–	–	–	0.0004	–	–	–
Walrus	–	–	–	–	–	–	–	–	0.0004	–
Unidentified Seal	0.0574	0.1829	0.0289	0.0302	0.0063	1.2938	0.9286	0.1708	0.0318	0.0071
Polar Bear	–	–	0.0006	0.0006	–	–	0.0032	–	0.0004	–
Total	**1.7396**	**1.0490**	**0.4301**	**0.7684**	**2.3171**	**4.8911**	**3.3705**	**12.6872**	**3.1181**	**2.5325**

APPENDIX E

Power Analysis

Introduction

Presented here are the results of a power analysis contrasting the 2013 (Doninol-Valcroze et al. 2015) and 2019 (Golder 2020) aerial surveys as reference years for the Trigger Action Response Plan (TARP) when compared to the 2023 aerial survey abundance estimate. Although 2013 is considered the baseline condition year, the precision of the 2013 abundance estimates are much lower than those from 2019. However, there was no significant difference between the 2013 and 2019 abundance estimates (Golder 2020). The primary reason for the difference in precision is that the 2019 survey included photo-survey areas in addition to the visual transect surveys performed in both years (Golder 2022). This analysis illustrates how the abundance estimate coefficient of variation (CV) changes the ability to detect a decrease in abundance between different survey years.

Power Analysis Methods

In statistics, two types of outcome errors are possible and can mislead conclusions about the presence of detectable effects. A Type I error is concluding there is a significant effect when none exists (i.e., a false positive). Alpha (α) is the probability of committing a Type I error (Zar 1999). A Type II error is the probability of concluding there is no significant effect when there is a real effect of some specified magnitude (i.e., a false negative) (Zar 1999). Beta (β) is the probability of committing a Type II error. Effect sizes are the magnitude of the change or difference in the response variables, which in this report were the estimates of narwhal abundance. The power of a statistical test (1 - β) is the probability of detecting a valid statistical effect. The power of a statistical test depends on the alpha level, the effect size, the sample size, and the variability in the data. In this analysis, the Type I error-rate (α), also referred to as the significance level, was set to 0.05. The desired minimum statistical power was 80%, which corresponds to a Type II error-rate of 0.2.

The starting points for the power analysis were the narwhal abundance estimates from the 2013 and 2019 aerial survey data (hereafter reference). Specifically, the reference estimates used were the estimate for the Eclipse Sound region and the combined Eclipse Sound and Admiralty Inlet regions (Table 1). Separate power analysis were run for the 2019 abundances estimates (Golder 2020) and the 2013 abundance (Doninol-Valcroze et al. 2015) in comparison to the 2023 estimates in this report. Power analyses were completed to evaluate the ability of the aerial survey program to track changes in narwhal abundance for Eclipse Sound and for combined surveys of Eclipse Sound and Admiralty Inlet from baseline values.

The power to detect statistically significant effects was estimated using the formula for comparing two abundance values in R v. 4.3.1 (R 2023), following the approach of Buckland et al. (2001). If two abundance estimates are independent, the difference in abundance by $\hat{N}_1 - \hat{N}_2$ can be estimated with variance:

$$\widehat{var}\left(\hat{N}_1 - N_2\right) = \widehat{var}(N_1) + \widehat{var}(N)$$

Table 1: Narwhal survey abundance estimates used in power analysis

Year	Region(s)	Abundance	% Coefficient of Variation (CV)	Degrees of Freedom
2013	Eclipse Sound	10,489	24.0	30[a]
2019	Eclipse Sound	9,931	4.97	6.45
2023	Eclipse Sound	10,492	4.65	305
2013	Combined Eclipse Sound and Admiralty Inlet	45,532	33.0	30[a]
2019	Combined Eclipse Sound and Admiralty Inlet	38,771	12.01	19.18
2023	Combined Eclipse Sound and Admiralty Inlet	40,706	11.19	30.4

[a] assuming degrees of freedom of 30 as none provided in report (Doniol-Valcroze et al. 2015)

Distance provides the approximate degrees of freedom df_1 for $\widehat{N}_1$ and df_2 for $\widehat{N}_2$, based on Satterthwaite's approximation. The degrees of freedom are used to obtain an approximate *t*-statistic:

$$T = \frac{\left(\widehat{N}_1 - \widehat{N}_2\right) - \left(N_1 - N_2\right)}{\sqrt{\widehat{var}\left(\widehat{N}_1 - \widehat{N}_2\right)}} \sim t_{\mathrm{df}}$$

where

$$df \simeq \frac{\{\widehat{var}(\widehat{N}_1) + \widehat{var}(\widehat{N}_2)\}^2}{\{\widehat{var}(\widehat{N}_1)\}^2/df_1 + \{\widehat{var}(\widehat{N}_2)\}^2/df_2}$$

The null hypothesis H0 : $N1 = N2$ can be tested by substituting $N1 - N2 = 0$ in the t-statistic equation and looking at the resulting value in a t-table. Approximate 100·(1-2α)% confidence limits for ($N1 = N2$) are given by:

$$\left(\widehat{N}_1 - \widehat{N}_2\right) \pm t_{\mathrm{df}}(\alpha) \cdot \sqrt{\widehat{var}\left(\widehat{N}_1 - \widehat{N}_2\right)}$$

Since the interest in the detection of a change in narwhal abundance is a decrease, the analysis was limited to negative effect sizes (one-tailed *t*-statistic).

Effect Size Application and Data Simulation

For each of the potential narwhal abundance reference year estimates in Table 1 (N_1 = 2013 or 2019), a range of negative effect sizes (decreases) were applied to the reference abundance estimates ranging from 1 to 100 %. The calculations comparing the reference year (N_1) and comparison year (N_2 = 2023) included their individual values for CV and degrees of freedom (Table 1).

For each N_1 estimate and effect size test, the resulting $\widehat{N}_1 - \widehat{N}_2$ values were simulated based on the probabilities log-normal distribution. Ten-thousand simulated values were produced for every effect size tested and the proportion of the simulated values with a lower confidence limit that was greater than zero (one-tailed; $P<0.05$), was interpreted as the statistical power of the test (i.e. the ability to detect a decrease in narwhal abundance).

Power Analysis Results

When comparing the 2013 Eclipse Sound estimate to the 2023 estimate, power analysis indicated that there was sufficient power (>0.8) to detect a reduction in narwhal abundance at an effect size of -60.7% and high power (>0.9) was attained at effect size of -67.3% (Figure 1).

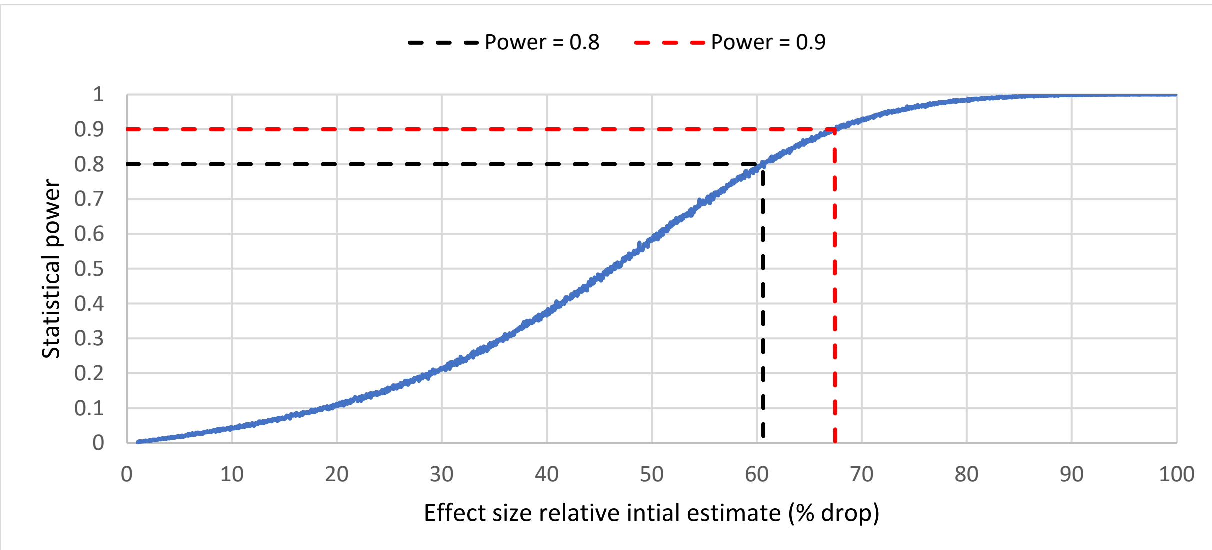

Figure 1: Statistical power to detect an effect size when comparing the 2013 and 2023 Eclipse Sound estimates.

When comparing the 2013 combined Eclipse Sound and Admiralty Inlet estimate to the 2023 estimate, the power analysis indicated that there was sufficient power (>0.8) to detect a reduction in narwhal abundance at effect size of -83.2% and high power (>0.9) was attained at effect size of -92.4% (Figure 2).

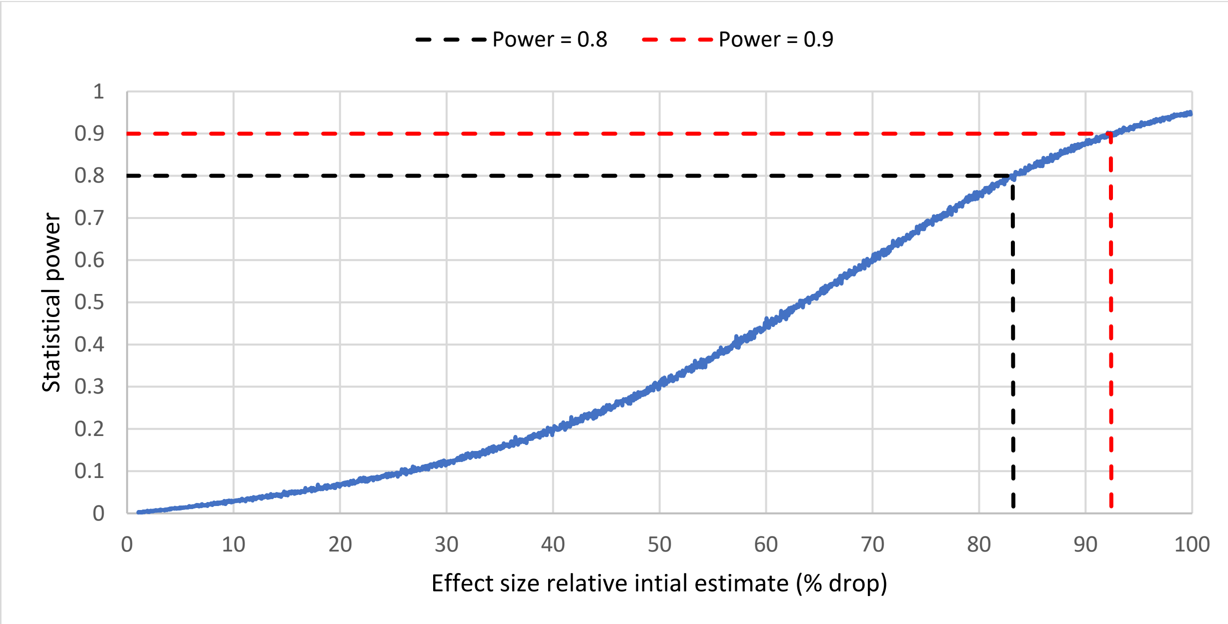

Figure 2: Statistical power to detect an effect size when comparing the 2013 and 2023 combined Eclipse Sound and Admiralty Inlet estimates.

When comparing the 2019 Eclipse Sound estimate to the 2023 estimate, power analysis indicated that there was sufficient power (>0.8) to detect a reduction in narwhal abundance at an effect size of -16.2% and high power (>0.9) was attained at effect size of -17.9% (Figure 1).

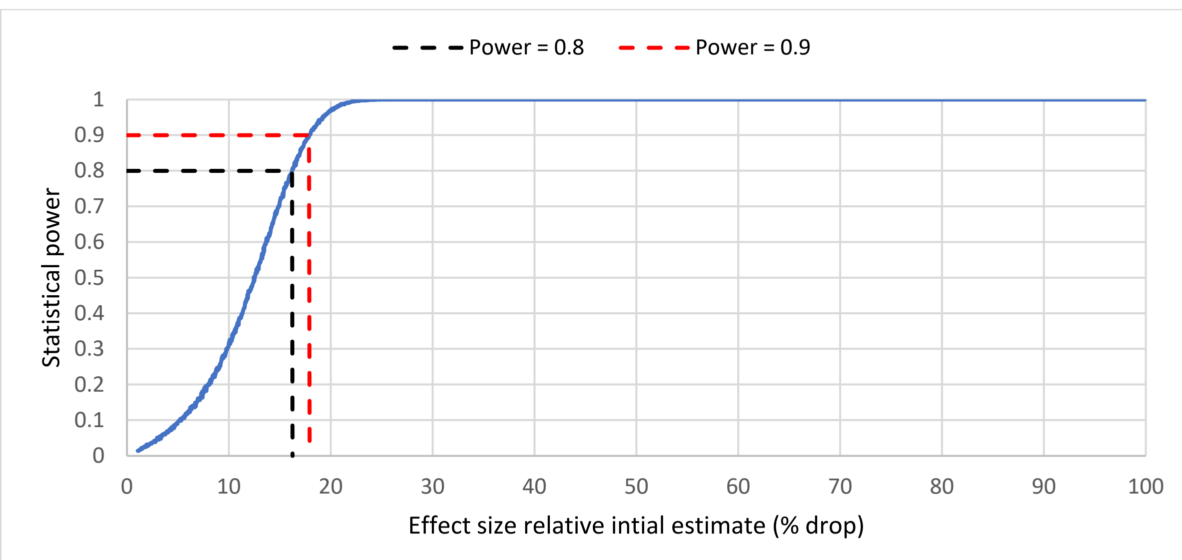

Figure 3: Statistical power to detect an effect size when comparing the 2019 and 2023 Eclipse Sound estimates.

When comparing the 2019 combined Eclipse Sound and Admiralty Inlet estimate to the 2023 estimate, the power analysis indicated that there was sufficient power (>0.8) to detect a reduction in narwhal abundance at effect size of -35.3% and high power (>0.9) was attained at effect size of -38.8% (Figure 1).

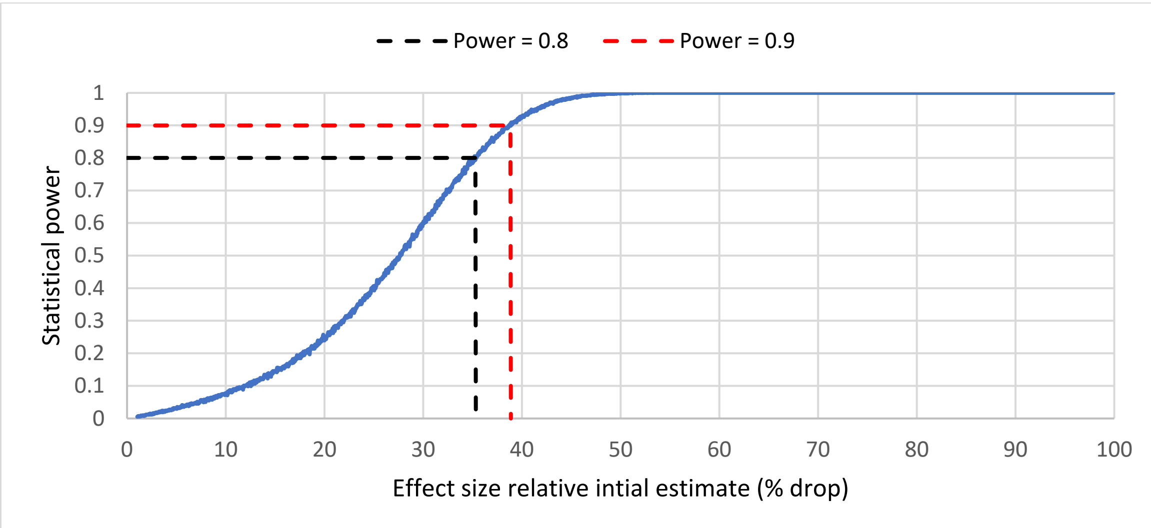

Figure 4: Statistical power to detect an effect size when comparing the 2019 and 2023 combined Eclipse Sound and Admiralty Inlet estimates.

As summarized in Table 2, the results of the power analysis indicate that the effect size (reduction in abundance) required to achieve a power level is larger for the 2013 abundance estimates in comparison to the 2019 estimates. The high effect sizes required for detecting an abundance decline when using the 2013 survey data (-60.7% and -83.2%; power > 0.8) are not appropriate for monitoring narwhal abundance since they represent an unacceptable decline in abundance. The use of the 2019 abundance estimates as a reference year reduces the effect size required for detecting a decline to a more reasonable level (-16.2% and -35.3%; power > 0.8).

Table 2: Results of the statistical power analysis comparing the 2023 survey estimates (N_2) to the two reference year options (N_1)

Reference year (N_1)	Region(s)	Effect size to achieve power >0.8	Effect size to achieve power >0.9
2013	Eclipse Sound	-60.7%	-67.3%
2019	Eclipse Sound	-16.2%	-17.9%
2013	combined Eclipse Sound and Admiralty Inlet	-83.2%	-92.4%
2019	combined Eclipse Sound and Admiralty Inlet	-35.3%	-38.8%

Comparisons for abundance estimates more than one year apart

The statistical power calculated for these comparisons does not have a specific time scale and can be extrapolated to provide comparisons between surveys that occur more than one year apart. Assuming a constant rate of decrease, the reduction (effect size) necessary to achieve a power of 0.8 can be shared over a number of years, to provide an annual rate of decrease that achieves the same total effect size between the first and last years of the comparison. A comparison of the number of years between abundance estimates and the minimum annual rate of change that would be required to achieve a power of 0.8 is presented in Figure 5. Increasing the number of years between surveys reduces the annual effect size required to detect a significant difference but the pattern between potential reference years in the same, with 2019 requiring lower effect levels to detect a significant reduction when compared to 2013.

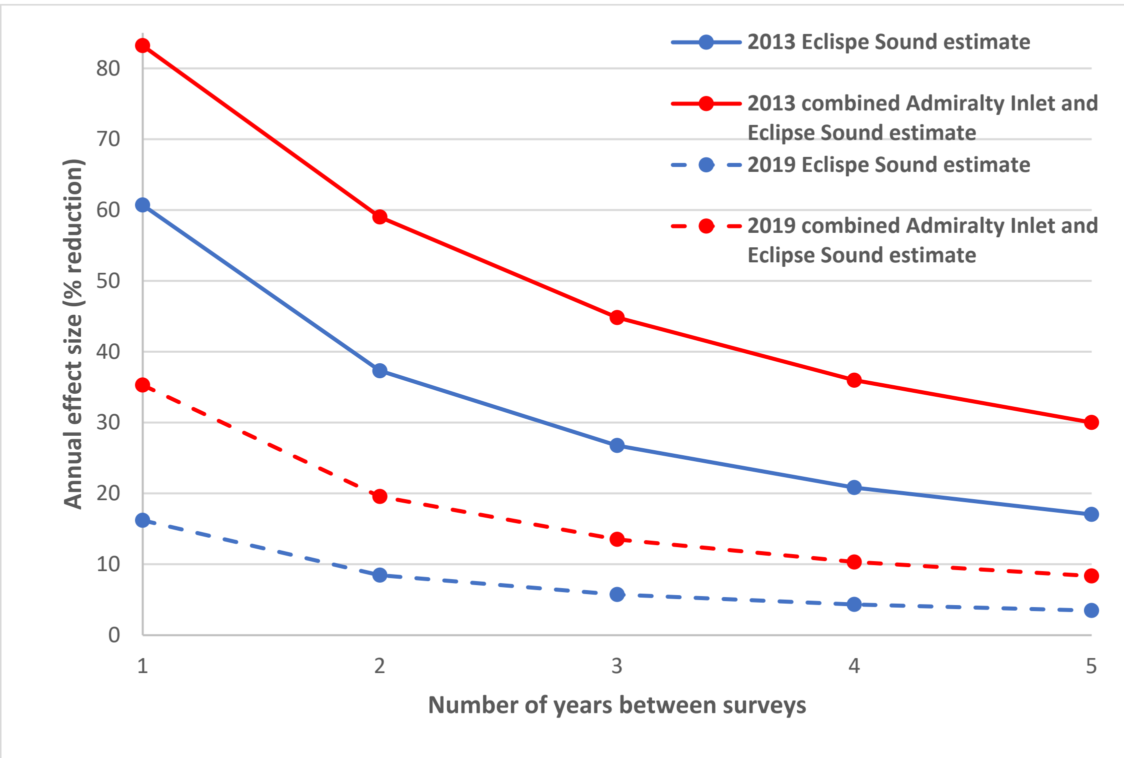

Figure 5: The annual effect size necessary to achieve a power of 0.8 (one tailed; α =0.05) based on increasing the number of years between survey estimates, comparing the 2013 and 2019 survey estimates as reference values.

Power Analysis Using the Log-Linear Regression Framework

Although this document's power analysis focused on the statistical comparison between two estimates, it is also possible to assess the statistical power for 3 or more estimates. When using the log-linear regression framework we can estimate the number of years of data required to achieve a desired power level, given a CV and alpha level. Although this method assumes a continuous time series of data at regular intervals (consecutive years of data in our example), it is still useful to asses the number of years of data required to achieve a power level in comparison to the two-sample test elaborated upon above. As described in Buckland et al. (2004), a model can be used to asses the number of years of data required to detect a log-linear population trend for a range of rates of change and CVs. Assuming the test is one-tailed (i.e. we are only interested in significant declines), the power $(1-\tau)$ of the *t-test* is given by

$$1-\tau \;=\; 1\;-F_t(t_{1-\alpha,\upsilon},\upsilon,\eta)$$

Where $F_t(x,\upsilon,\eta)$ is the cumulative distribution function of the non-central *t*-distribution with υ degrees of freedom and non-centrality parameter η, evaluated at x and $t_{\gamma,\upsilon}$ is the $100\gamma\%$ quantile from a central *t* distribution with υ degrees of freedom. A contour map of the number of years of monitoring required to achieve a power of 0.8 at α = 0.05 at varying CV values, is presented in Figure 6. Based on the observed CVs for Eclipse Sound and combined Eclipse Sound and Admiralty Inlet (Table 1), approximately 5 years of monitoring with a 5% CV would be required for the power to detect a 10% annual decrease in abundance while approximately 7 years of data with a 12% CV would be required for the power to also detect the same decrease in abundance. Likewise, fewer years are required for 0.8 power to detect larger annual rates of decline and more years are required for 0.8 power to detect smaller annual rates of decline. This method is not suited to short temporal time-series datasets since the degrees of freedom for the regression are calculated as the number of samples (years) minus 2 (i.e. this is why 3 years of data will not detect a decline on Figure 6, regardless of the precision of the CV or the annual rate of decrease.

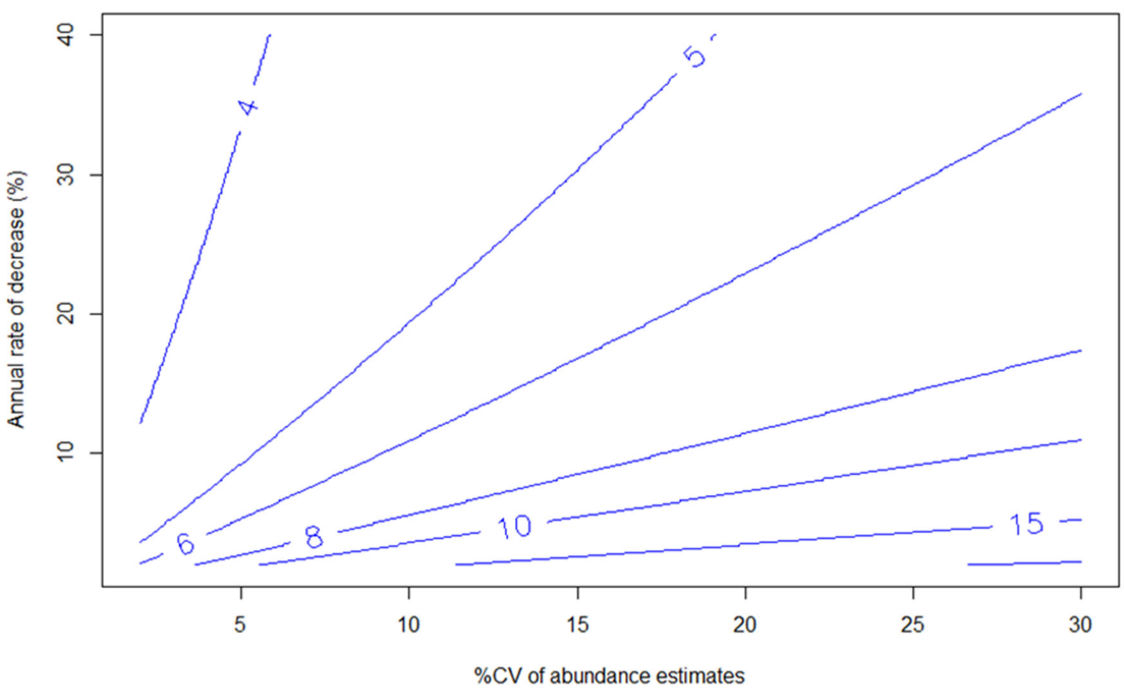

Figure 6: The number of years of monitoring required (blue values) across a variety of log-linear effect sizes and CVs at a power of 0.8 (one-tailed t-test assuming α = 0.05).

Conclusion

The magnitude of effect size required to achieve a power level is dependent on the CV of the refence estimate and the assumption that CV is constant through time. Since the CV of the reference estimates was directly influenced by the percentage of sightings that occurred within the estimate's photographic surveys, the Eclipse Sound estimate had a lower CV and in turn, indicated that smaller effect sizes could be used to achieve the desired power levels when compared to the combined Admiralty and Eclipse estimate. The test statistic used in the power analysis can also be used to compare current and future abundance estimates to identify whether a decrease in abundance is statistically significant.

If future aerial surveys use the same survey methods and capture a similar percentage of narwhal by photographic surveys, then the future surveys will likely achieve a similar precision (CV) of their estimates. Thus, the results of the 2023 power analysis indicate that declines of 16% in the Eclipse Sound regional abundance estimate and 35% in the combined Eclipse Sound and Admiralty Inlet regional abundance estimate relative to the 2019 abundance estimates can be detected. Increasing the number of years between estimates assumes a constant rate of decline that is cumulatively equal to these effect sizes and detectable at the same power level.

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