



NUNAVUT WILDLIFE MANAGEMENT BOARD

Agenda: Regular Meeting 003-2024

October 30, 2024

Arviat, Nunavut



	No:	Item:	Tab:	Presenter:	Maximum Time
9:00 - 9:02 AM	1	Open Meeting		Chairperson	2 Minutes
9:02 - 9:04 AM	2	Declaration of Conflict of Interest		Chairperson	2 Minutes
9:04 - 9:05 AM	3	Agenda: Review and Approval of RM003-2024	1	Chairperson	1 Minute
9:05 - 10:00 AM	4	Results of the 2021 survey results and community consultations of the Western Hudson Bay Polar Bear Subpopulation (Information)	2	Government of Nunavut - Department of Environment	
10:00 - 10:15 AM		BREAK			15 Minutes
10:15 - 12:00 PM	4	Results of the 2021 survey results and community consultations of the Western Hudson Bay Polar Bear Subpopulation (Information)	2	Government of Nunavut - Department of Environment	
		LUNCH			
1:15 - 3:00 PM	5	Results of the 2021 survey results and community consultations of the Southern Hudson Bay Polar Bear Subpopulation (Information)	3	Government of Nunavut - Department of Environment	
		BREAK			15 Minutes

3:15 - 5:00 PM	6	The Qamanirjuaq Caribou herd population status and management (Information)	4	Government of Nunavut - Department of Environment	
	7	Adjournment of RM003-2024			



NUNAVUT WILDLIFE MANAGEMENT BOARD

Agenda: Regular Meeting 003-2024

October 31, 2024

Arviat, Nunavut



	No:	Item:	Tab:	Presenter:	Maximum Time
9:00 - 9:02 AM	1	Open Meeting		Chairperson	2 Minutes
9:02 - 9:04 AM	2	Declaration of Conflict of Interest		Chairperson	2 Minutes
9:04 - 9:05 AM	3	Agenda: Review and Approval of RM003-2024	1	Chairperson	1 Minute
9:05 - 10:00 AM	4	Total Allowable Catch Levels for Greenland Halibut in Subarea 0 for the 2025 and 2026 Fishing Seasons (Decision)	5		
10:00 - 10:15 AM		BREAK			15 Minutes
10:15 - 11:00 AM	5	Update on the Co-Development of the Nunavut Fishery Regulations (Information)	6		
11:00 - 12:00 PM	6	Fisheries and Oceans Canada Update - Marine Conservation Areas (Information)	7		
		LUNCH			
1:15 - 2:00 PM	7	Update on the interim plan for the Tallurutiup Imanga National Conservation Area (Information)	8		
	8	Adjournment of RM003-2024			



SUBMISSION TO THE

NUNAVUT WILDLIFE MANAGEMENT BOARD

FOR

Information: X

Decision:

Issue: Results of the 2021 survey results and community consultations of the Western Hudson Bay (WH) Polar Bear Subpopulation.

Background:

- The Western Hudson Bay (WH) polar bear subpopulation is shared between Manitoba and Nunavut (Figure 1). The last inventory studies to estimate abundance were conducted in 2011 and 2016, resulting in estimates of 949 and 842 bears, respectively. The WH polar bear subpopulation was considered to be in decline at that time.
- Communities from Arviat, Whale Cove, and Rankin Inlet harvest from WH. The current Total Allowable Harvest (TAH) for WH is 38 bears per year. This TAH was set under the Flexible Quota System (FQS) at a 2:1 harvest sex ratio and was maintained under the 1:1 harvest sex ratio when the new Harvest Administration and Calculation system (HACCS) came into effect in 2022. The average harvest between 2012/2013 and 2022/2023 was 28 bears per year (Figure 2). The average harvest in WH over the last 10 years (2012/2013 to 2022/2023) was about 26% below the available TAH.
- WH and Southern Hudson Bay (SH) have been following a 5-year monitoring regimen, with the most recent surveys completed in 2021. Following community consultations via phone in 2021 (in-person consultations were not possible due to COVID-19 related travel restrictions), the survey began in August 2021 and finished in September 2021. A minimally invasive aerial abundance survey method was used for this study. SH was surveyed at the same time by the Government of Ontario and Government of Québec.
- Environment and Climate Change Canada (ECCC) has been conducting scientific studies in WH since the 1980s. Ongoing research includes a biopsy darting genetic analysis project which has been conducted since 2017 along the Manitoba and Ontario coast. This research examined movement between WH/SH and ice dynamics in Hudson Bay. The results from this report were very informative and help to explain the lower estimate from the 2021 GN aerial survey.

Current Status:

- The final report and results for the 2021 WH study were distributed to all relevant co-management partners in November 2022. The new abundance estimate of 618 bears is less than the estimate from the last studies in 2011 and 2016.
- The WH and SH estimates for 2011, 2016, and 2021 were combined in the WH report. This resulted in combined estimates of 1892, 1622, and 1621 bears, respectively. When both subpopulations are combined, this shows a stable population (WH and SH) between the 2016 and 2021 surveys.
- Given the limitations of an aerial abundance survey, it was unclear to what degree the decline in WH in 2021 was due to movement of bears into SH, which the ECCC and Ontario genetic mark and recapture studies confirmed.
- The ECCC biopsy darting report determined that the decline in WH in 2021 was largely due to movement of bears into SH, likely due to remnant ice in SH near the time of the aerial survey.
- The ECCC biopsy darting report also examined harvested bear locations. It reaffirms that the WH management boundary is valid because bears harvested in WH were initially biopsied in WH, whereas bears harvested in SH were initially biopsied in SH.

Consultations:

In-person community consultations with WH Hunters and Trappers Organizations (HTOs) were held between March 26-27 and May 9-10, 2024. Consultations focused on the results of the GN aerial abundance survey and ECCC biopsy darting study. HTO members raised concerns with the accuracy of the aerial abundance survey and were interested in the results of the biopsy darting study. HTOs expressed interest in increasing the TAH due to public safety concerns and cultural preservation. Staff from Nunavut Tunngavik Inc. and Nunavut Wildlife Management Board attended several meetings (see details in WH Consultation Summary Report by GN ENV).

Recommendations:

1. ENV recommends **no change to the current TAH of 38 for the WH subpopulation**. When considering the SH and WH estimates collectively between 2016 and 2021, the subpopulations have been stable under current environmental conditions and harvest levels.

2. In keeping with current national and international polar bear management initiatives, ENV requests that the NWMB establish a management objective for the Western Hudson Bay polar bear subpopulation. ENV suggests that the management objective is to **maintain current abundance**.

Appendix 1

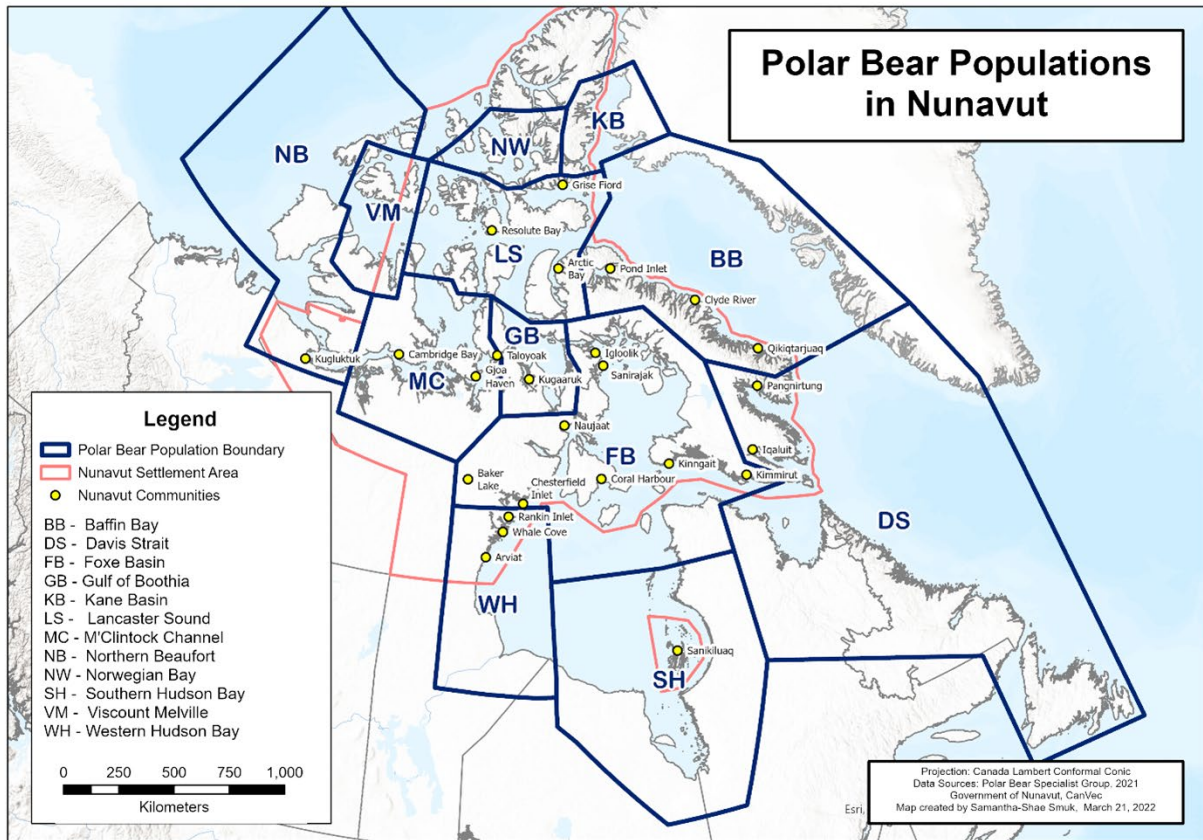


Figure 1. Overview of Nunavut polar bear subpopulations (WH = Western Hudson Bay, SH = Southern Hudson Bay).

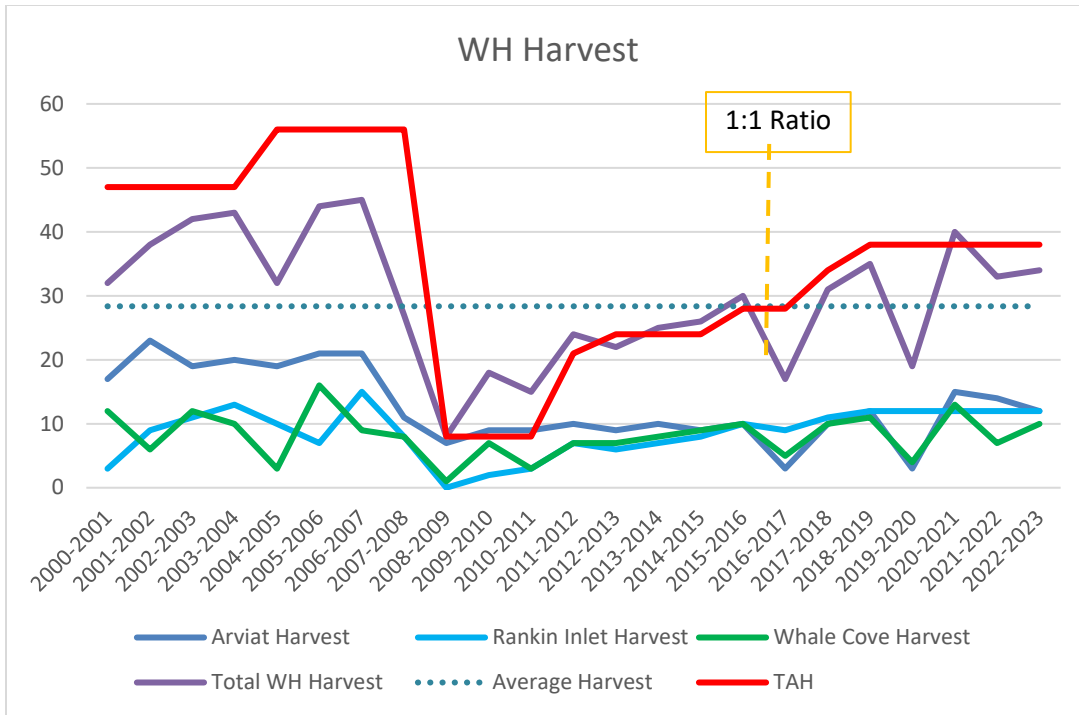


Figure 2. Overview of the Western Hudson Bay polar bear Total Allowable Harvest (TAH), actual and average harvest since 2000.

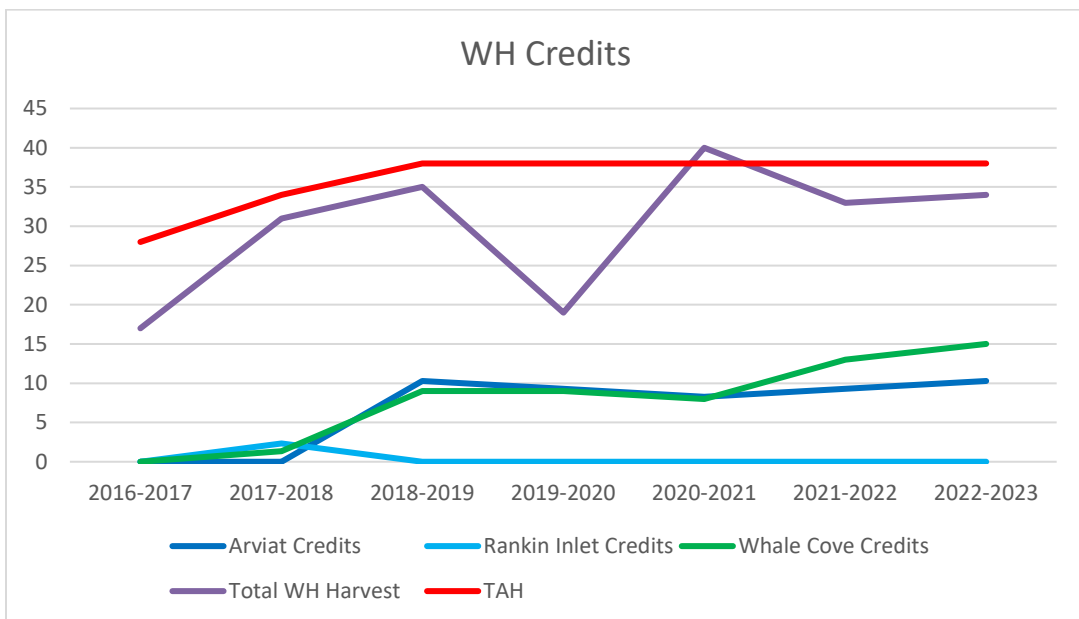


Figure 3. Overview of the Western Hudson Bay polar bear credits since 2016.

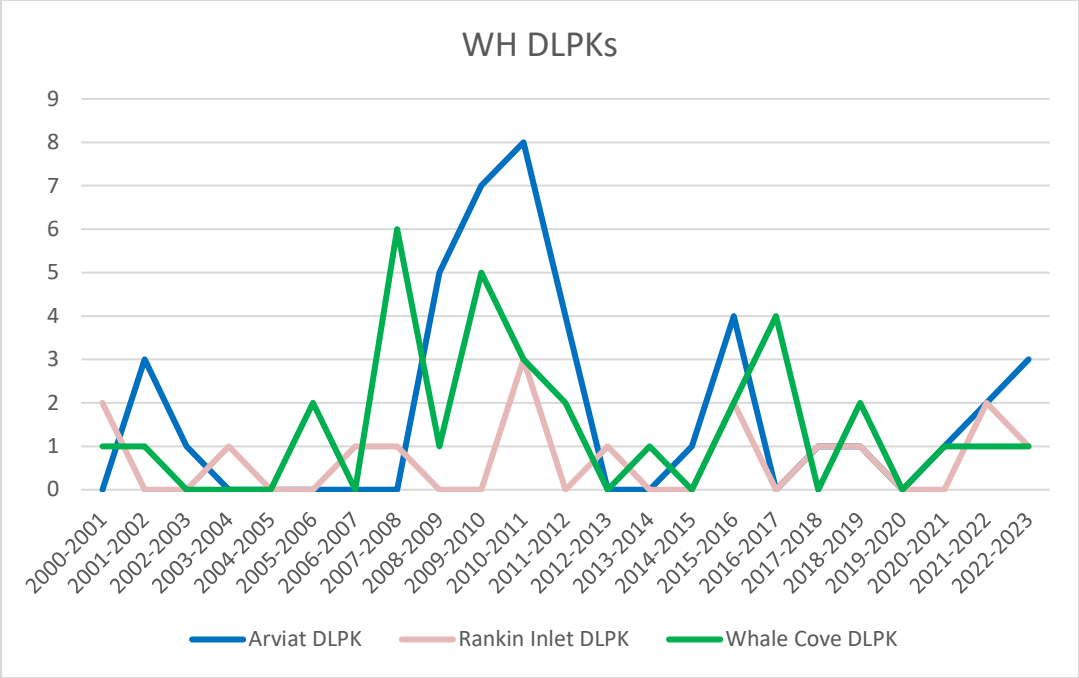
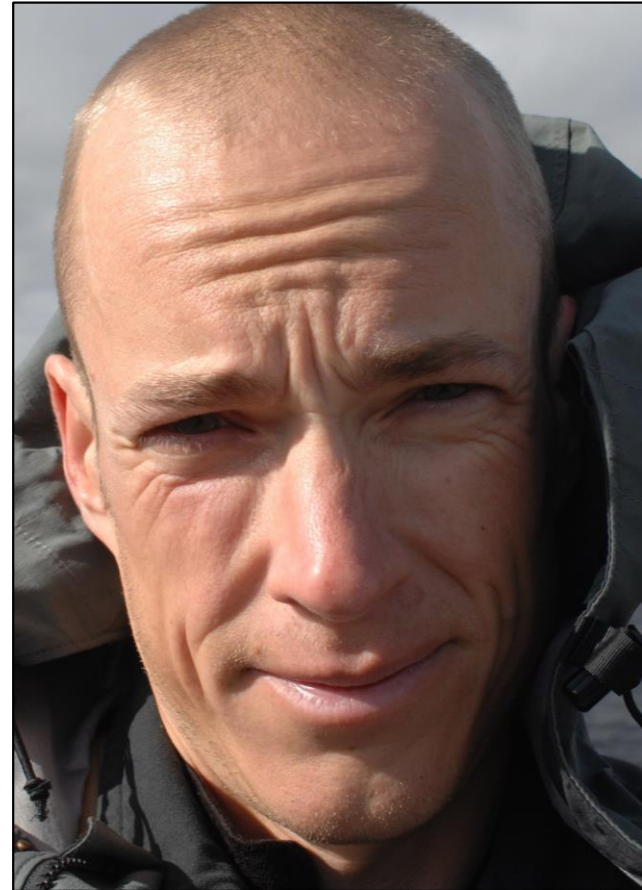


Figure 4. Number of Defence of Life and Property polar bear kills (DLPKs) in Western Hudson Bay since 2000.

Introductions



Alyssa (“Uh-Liss-Uh”) Bohart
Polar Bear Biologist
Department of Environment
Government of Nunavut



Evan Richardson
Polar Bear Biologist
Environment and Climate Change
Canada

- Since 2021 there has been a transition at the Department of Environment in the Government of Nunavut
 - Tragic loss of our Polar Bear Biologist Markus Dyck in an accident
 - Two Polar Bear Biologists resigned last year
 - There are two new biologists continuing the program



Outline

- Survey Process
- 2021 GN Aerial survey
- ECCC Biopsy darting study
- ECCC Collaring Research
- Ongoing GN Research/Public Safety
- TAH discussion

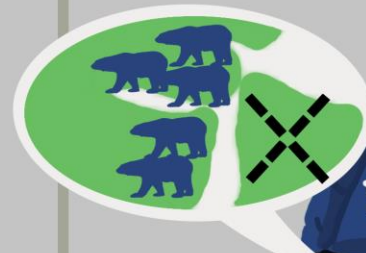
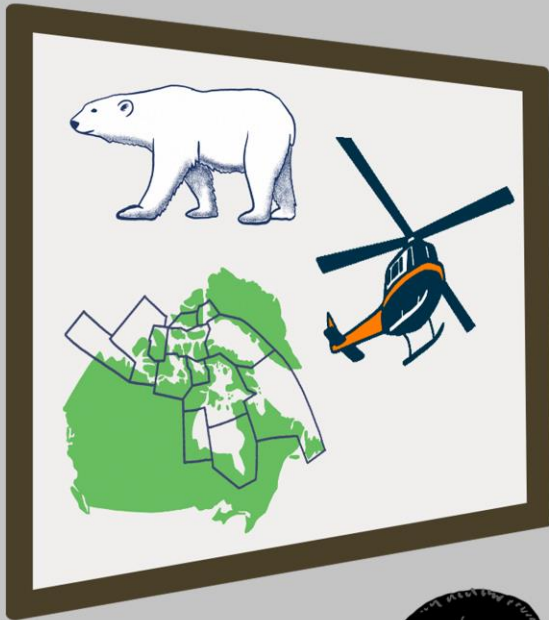


Survey Process



1. Create a study design

Survey Process



2. Consult on study design and get feedback

1.

Survey Process



1.



3. Incorporate feedback into study design

Survey Process

1.



4. Fly the survey

Survey Process



$$8x + 5 = 5^2$$



1.

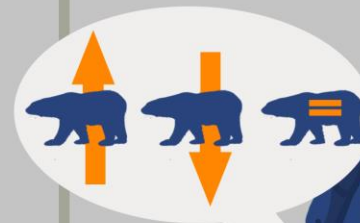
4.



5. Analysis & Writing Final Report



Survey Process



6. Consulting on Final Report

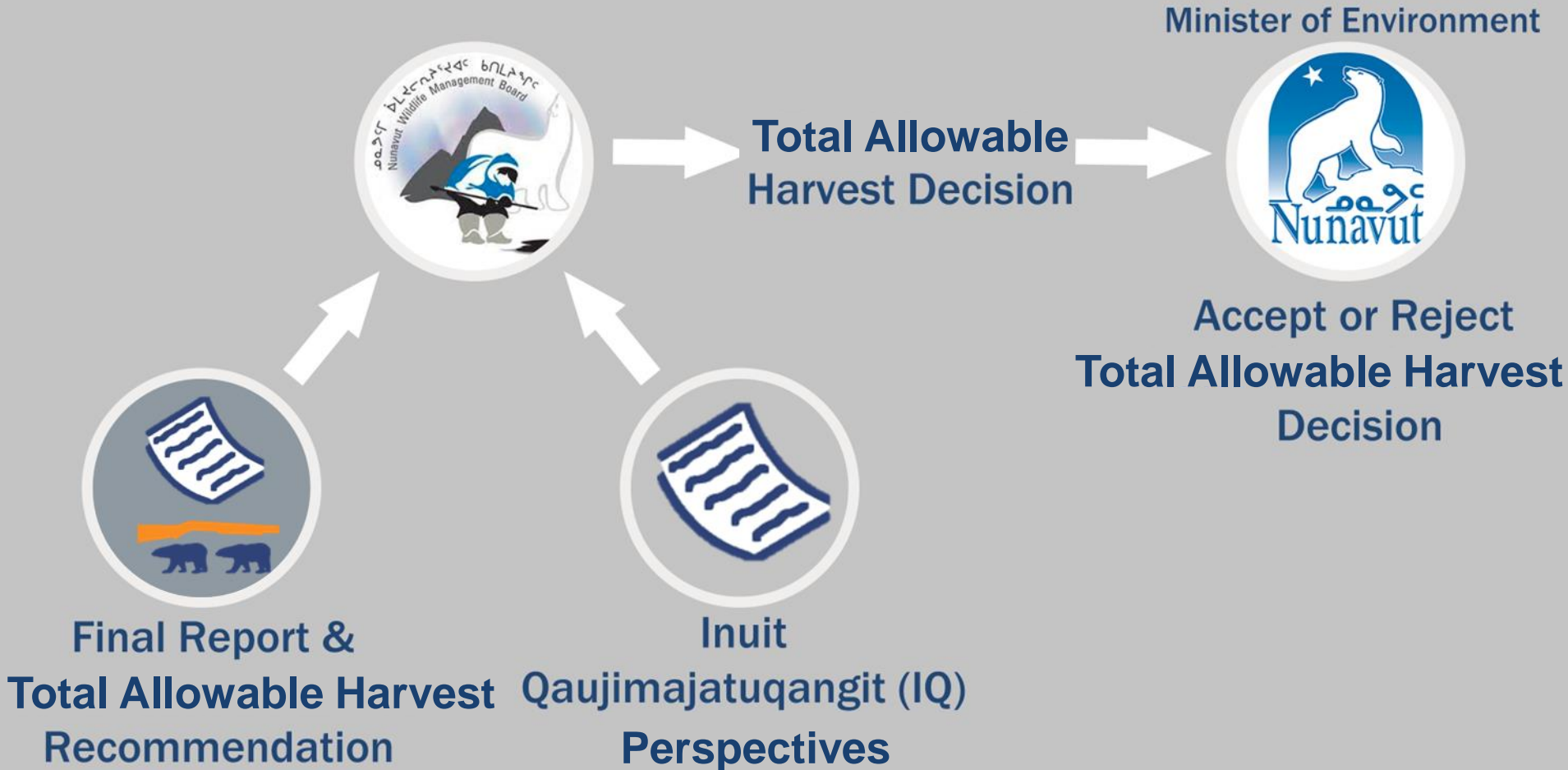
1.

4.





Survey Process



7. Total Allowable Harvest Decision-Making



Survey Process

Minister of Environment



Accepts



Regional Wildlife Boards



Accept or Reject
Total Allowable Harvest
Decision

Decide how many
tags each community gets



Send tags to
communities

7. Total Allowable Harvest Decision-Making



Survey Process



Minister of Environment

Regional Wildlife Boards

7.



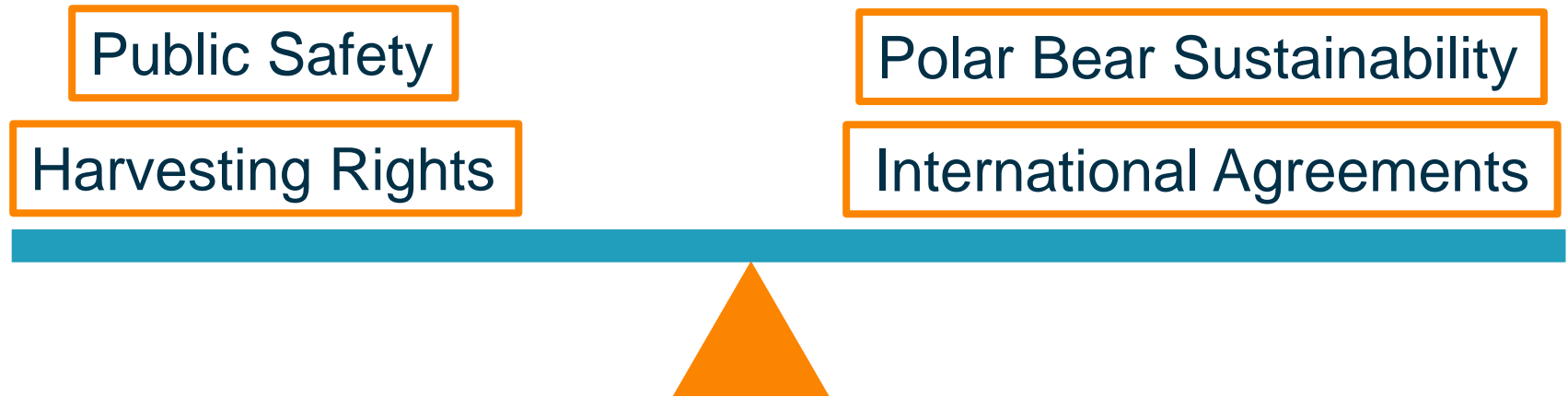
Accepts





Job of the Department of Environment

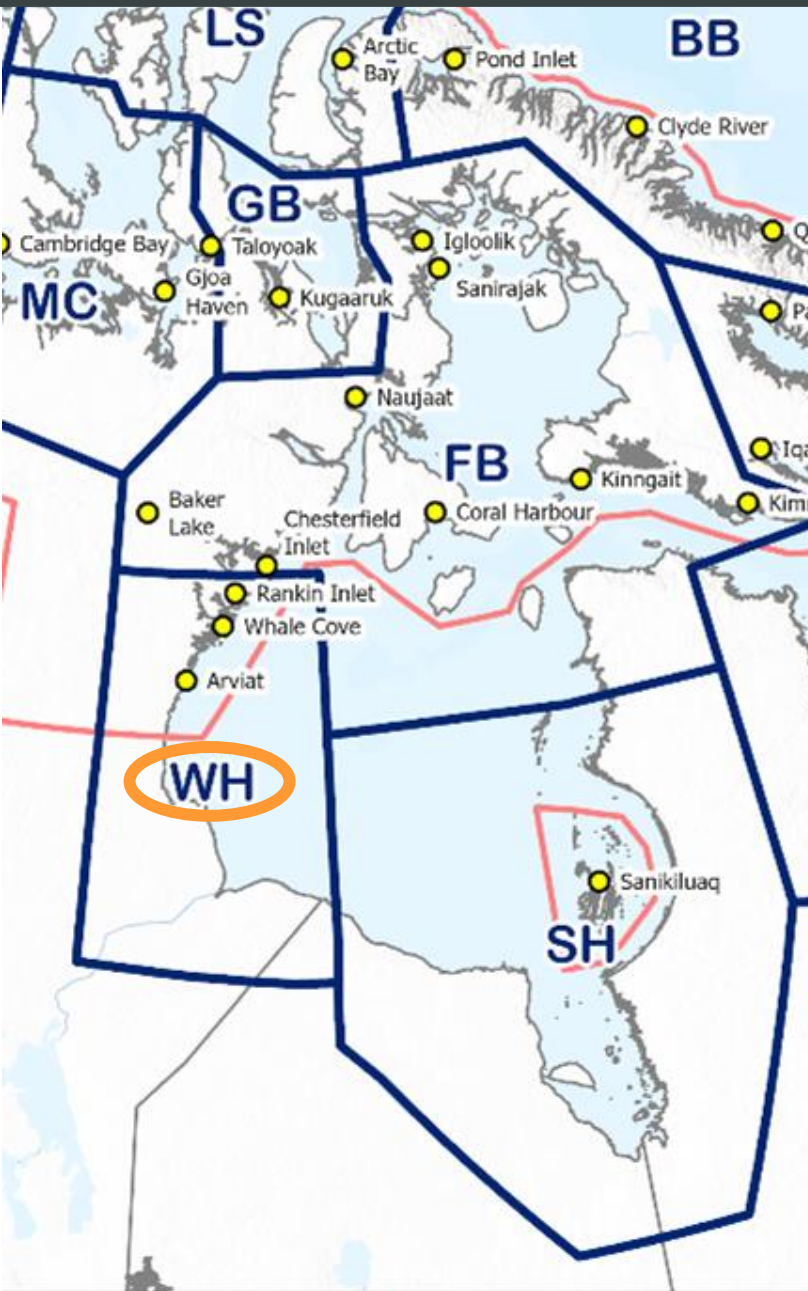
- Balancing act



Total Allowable Harvest (TAH)

- The current TAH for Western Hudson Bay is 38 bears per year.
- Department of Environment at this time is **recommending a TAH of 38.**

Western Hudson Bay Subpopulation



- Previously surveyed by the Government of Nunavut in 2011 and 2016



- Ongoing studies being done by Environment and Climate Change Canada since the 1980s
 - Work done in Manitoba
- Agreement that the **number of human-bear conflicts has increased over time**
- Frequent studies needed to **detect sudden changes** in bear population when using aerial surveys



Aerial Survey Report

WH Polar Bear Aerial Survey 2021

2021 AERIAL SURVEY OF THE WESTERN HUDSON BAY POLAR BEAR SUBPOPULATION



FINAL REPORT

November 16, 2022

Stephen N. Atkinson¹, John Boulanger², Mitch Campbell³, Vicki Trim⁴, Jasmine Ware⁵
and Amélie Roberto-Charron⁶

Submitted to meet requirements of:
Wildlife Research Permit WL 2021-0061, Wapusk National Park Research and
Collection Permit Number WAP-2021-3990

Status Report 2022, Nunavut Department of Environment, Wildlife Research Section,
Igloolik, NU

Thank You



This work would not have been possible without the participation and support of the HTOs and the following observers:

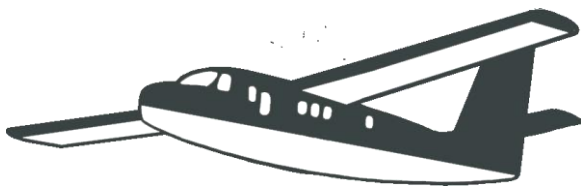
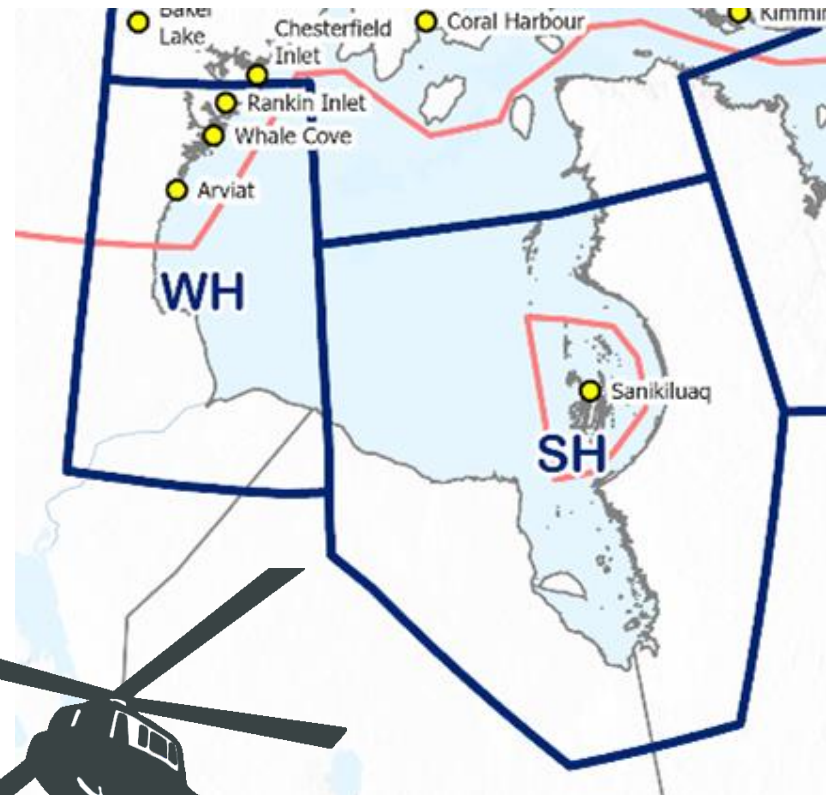
- Gerard Maktars
- Timothy Kookeyuk
- Timothy Pissuk
- Kevin Subgut
- Conor Camphaug
- Clayton Tartuk
- Jack Backstone





Aerial Abundance Surveys

- Surveys were done in 2011, 2016, and 2021
- Surveys done in late August-early September
- Bears on land
- Western (WH) and Southern Hudson (SH) Bay done at same time





What is an Aerial Abundance Survey?

- Collect data to **estimate the abundance** of a species
- **Distance sampling** and **double observer** method
- Strata and transects based on **past survey data, harvest data, and community feedback**







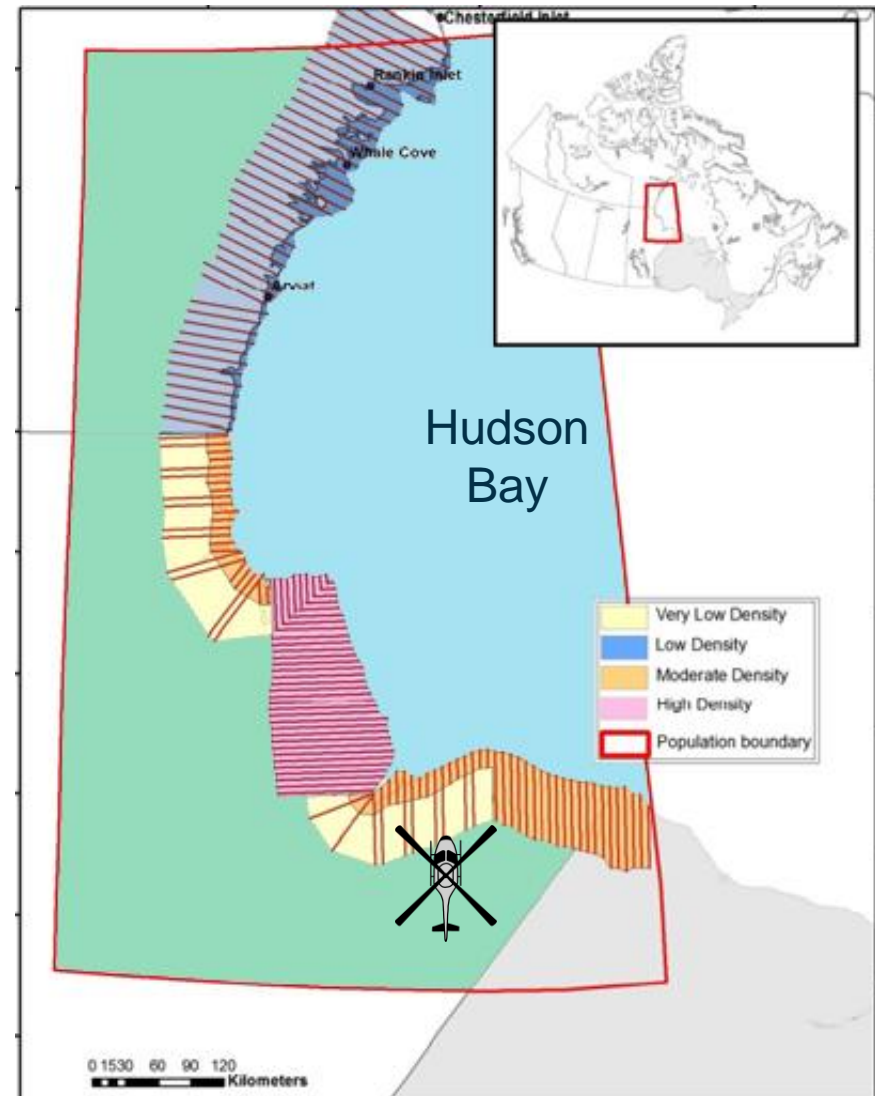


Aerial Abundance Surveys

- Used same transects as 2016 study
- Transects in 2016 determined using:
 - 2011 survey and results
 - Inuit Qaujimagatuqangit (IQ)
 - Telemetry data (University of Alberta & Environment and Climate Change Canada)

- Transects divided into 4 densities:

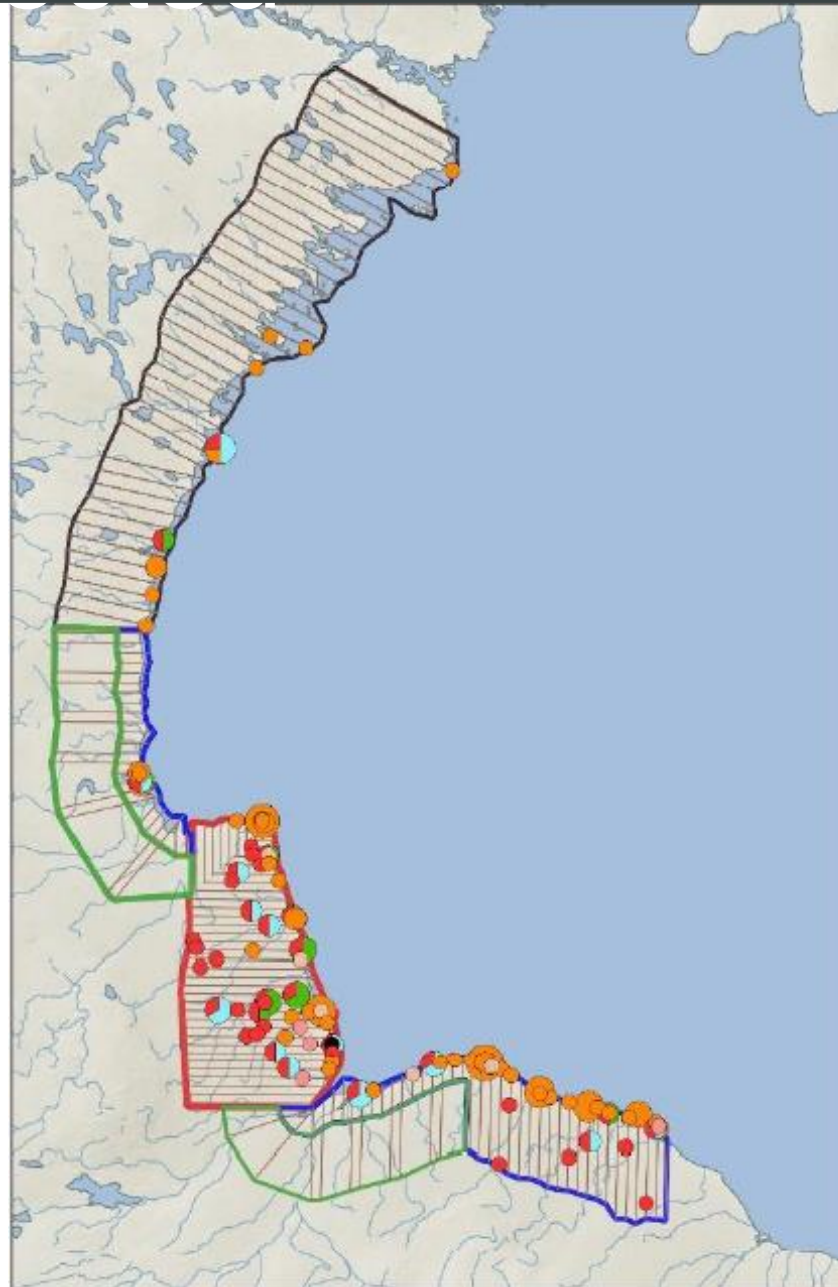
-  • **Very low:** inland outside of Wapusk Park
-  • **Low:** northern Western Hudson Bay
-  • **Moderate:** north and west of Churchill River
-  • **High:** Wapusk Park, coast between Churchill and Nelson River





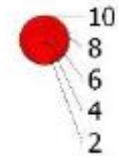
Aerial Abundance Survey Results

- 17,000 km flown
- Observed 194 bears, in 125 groups observed
- Estimate: 618 bears
- 8% of bears in Nunavut
- Males mostly along coast
- Females mostly inland



Legend

- Age and sex group (size)
- Female adult
- Male adult
- Yearling
- Male subadult
- Female subadult
- Cub
- Unknown adult
- Unknown subadult



Strata

- High
- Low
- Moderate N
- Moderate S
- Very Low N
- Very Low S

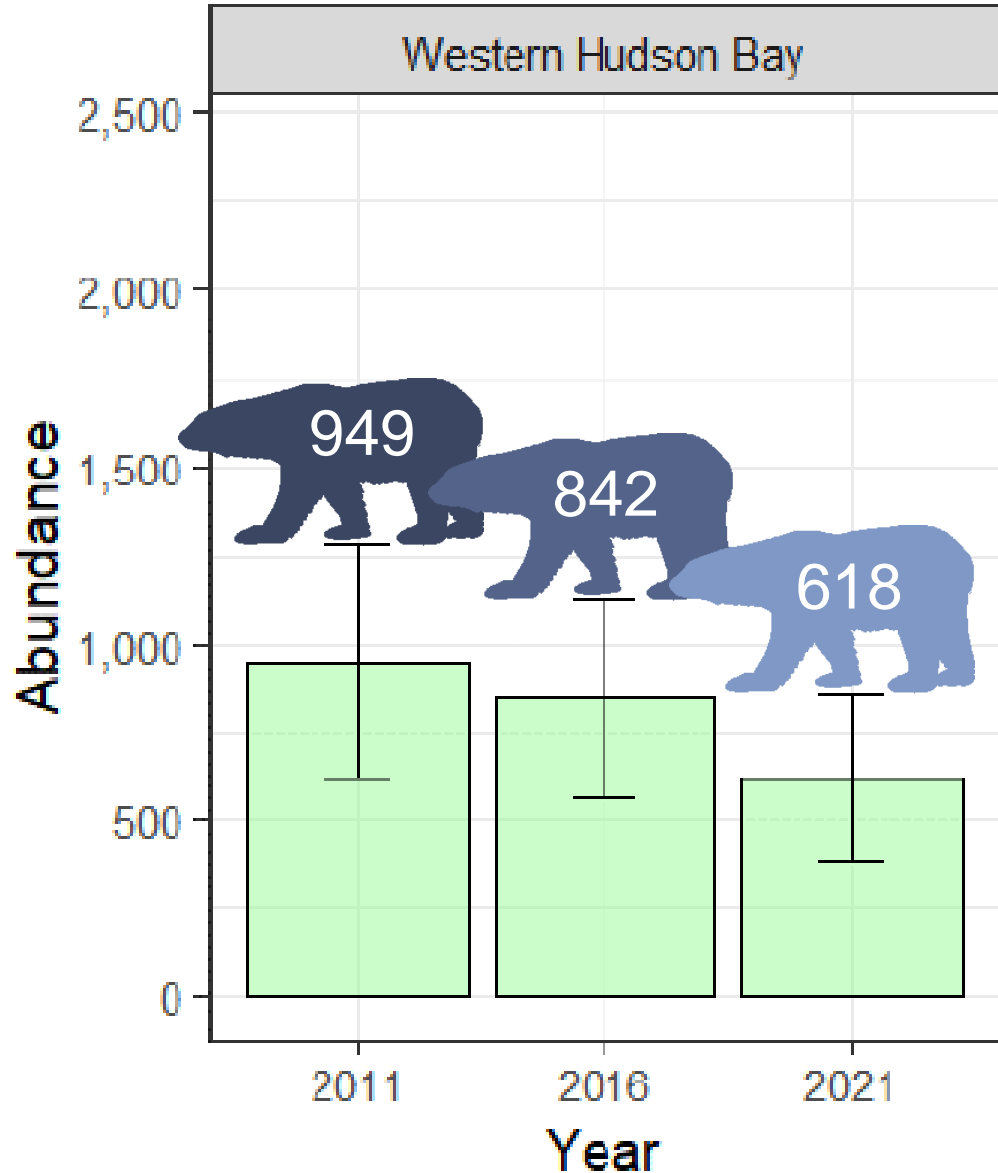
50 0 50 100 150 200 km





Aerial Abundance Survey Results

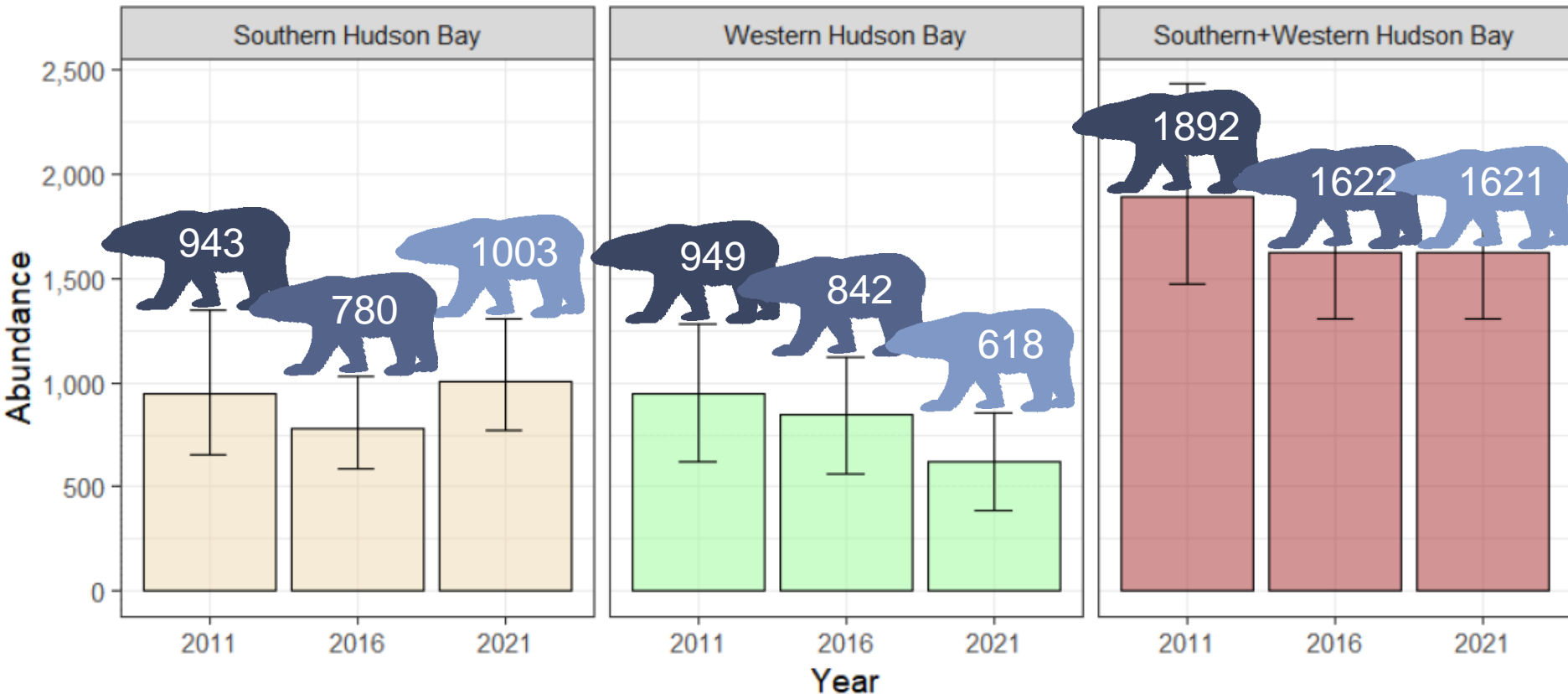
- 17,000 km flown
- Observed 194 bears, in 125 groups observed
- Estimate: 618 bears
- 8% of bears in Nunavut
- Males mostly along coast
- Females mostly inland





Aerial Abundance Survey Results

- Reasons for decrease?
 - Annual shifts into Southern Hudson Bay?



Biopsy Darting Report



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada

Distributional shifts of polar bears (*Ursus maritimus*) in Hudson Bay in relation to sea ice dynamics, 2017-2022 Final Report

D. McGeachy^{1,4}, N. J. Lunn¹, J. M. Northrup², V. Trim³, C. Davis⁴, A. E Derocher⁴

¹ Environment and Climate Change Canada, CW-405 Biological Sciences Building, University of Alberta, Edmonton, AB T6G 2E9

² Ontario Ministry of Natural Resources and Forestry, DNA Building B217, Trent University, 2140 East Bank Drive, Peterborough, ON K9L 1Z8

³ Manitoba Department of Natural Resources and Northern Development, Water Stewardship and Biodiversity Division, Wildlife and Fisheries Branch, Box 28, 59 Elizabeth Drive, Thompson, MB R8N 1X4

⁴ Department of Biological Sciences, University of Alberta, Edmonton, AB T6G 2E9



David McGeachy
Polar Bear Technician
Environment and Climate Change
Canada

Biopsy Darting



Biopsy Darting



Genetics/DNA



- Biopsy sampling – bears **not physically handled** or **sedated**



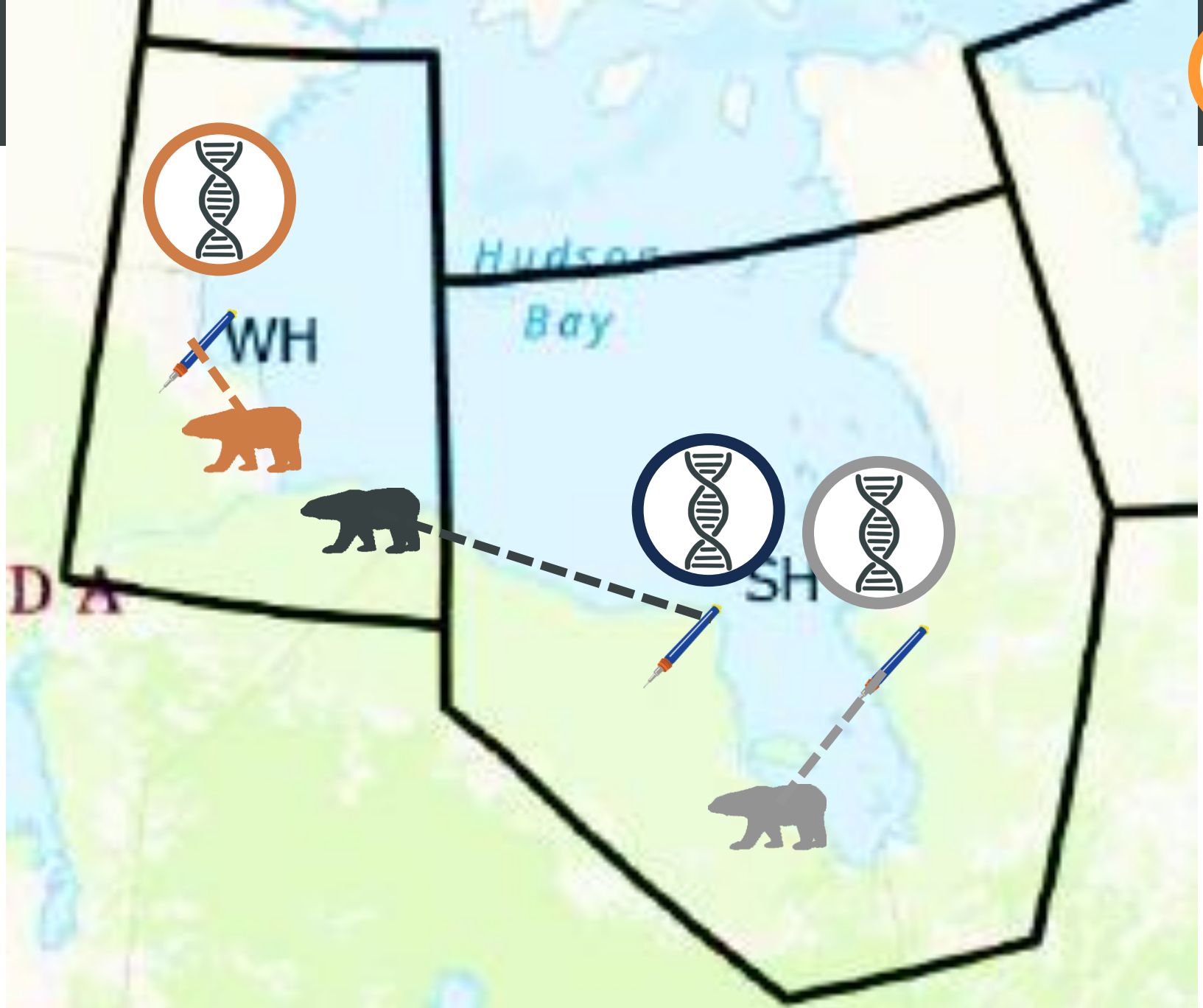




WH



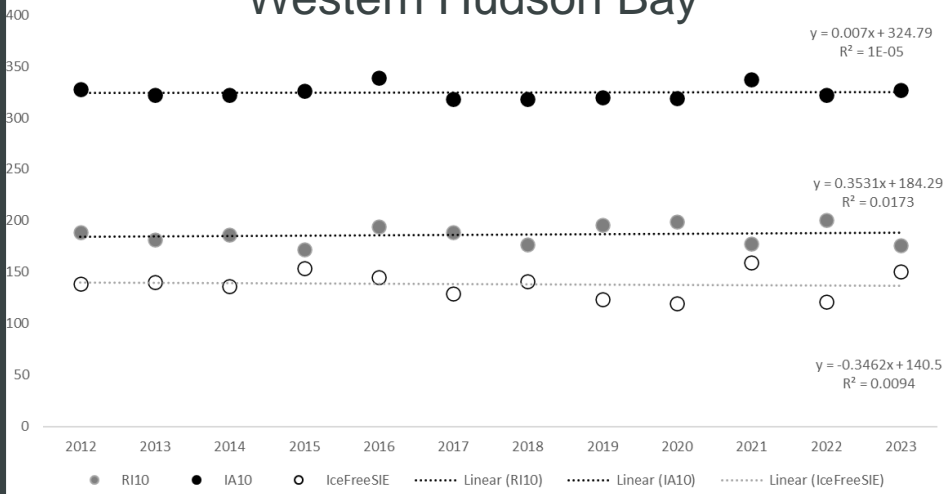
SH



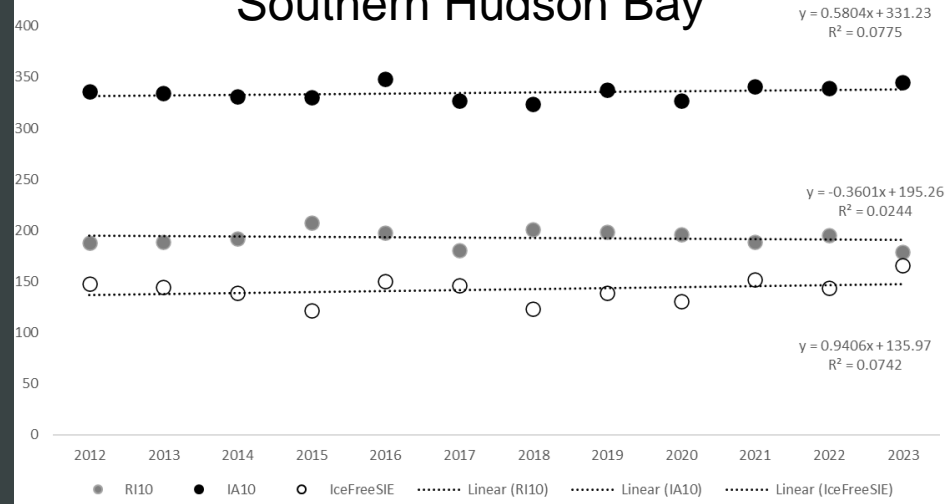
Results – Sea Ice



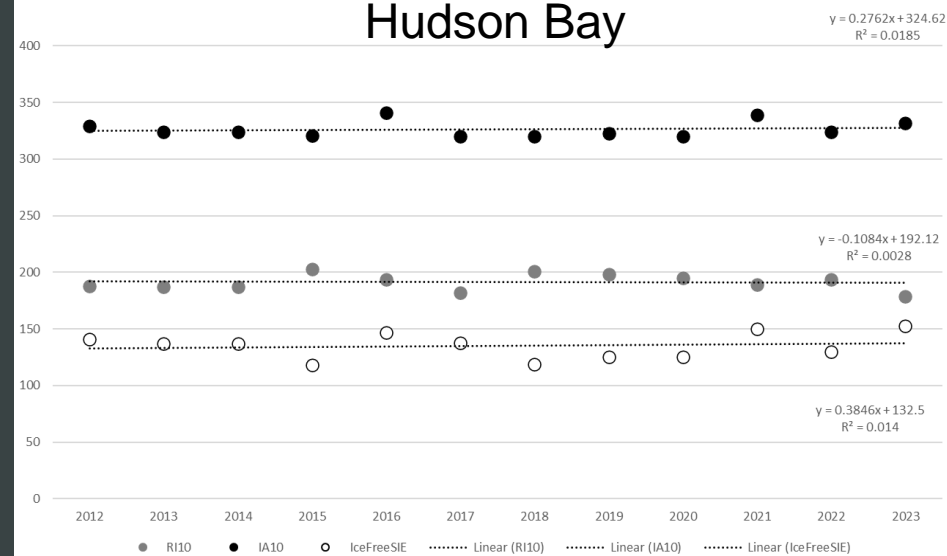
Western Hudson Bay



Southern Hudson Bay



Hudson Bay

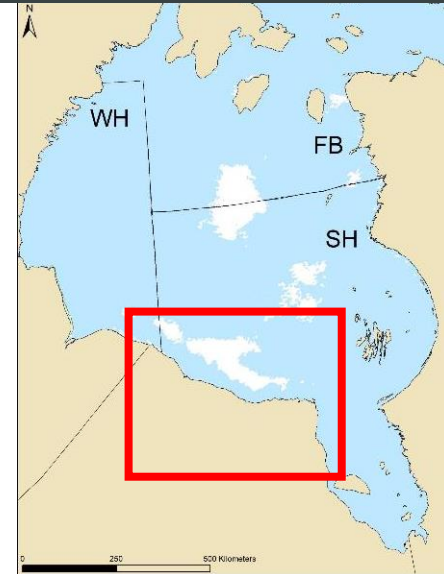
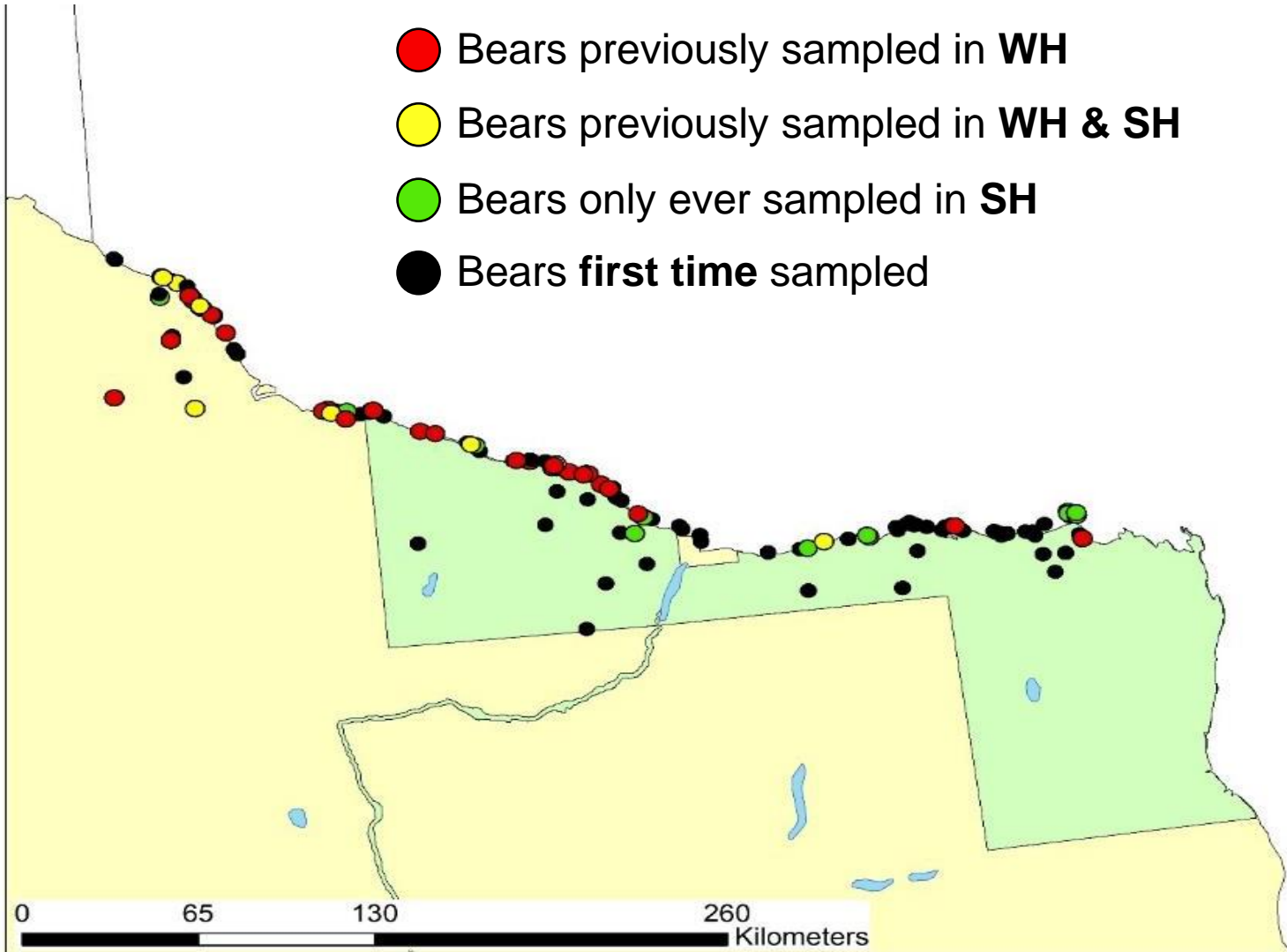


Results – 2021 SH Recaptured Bears

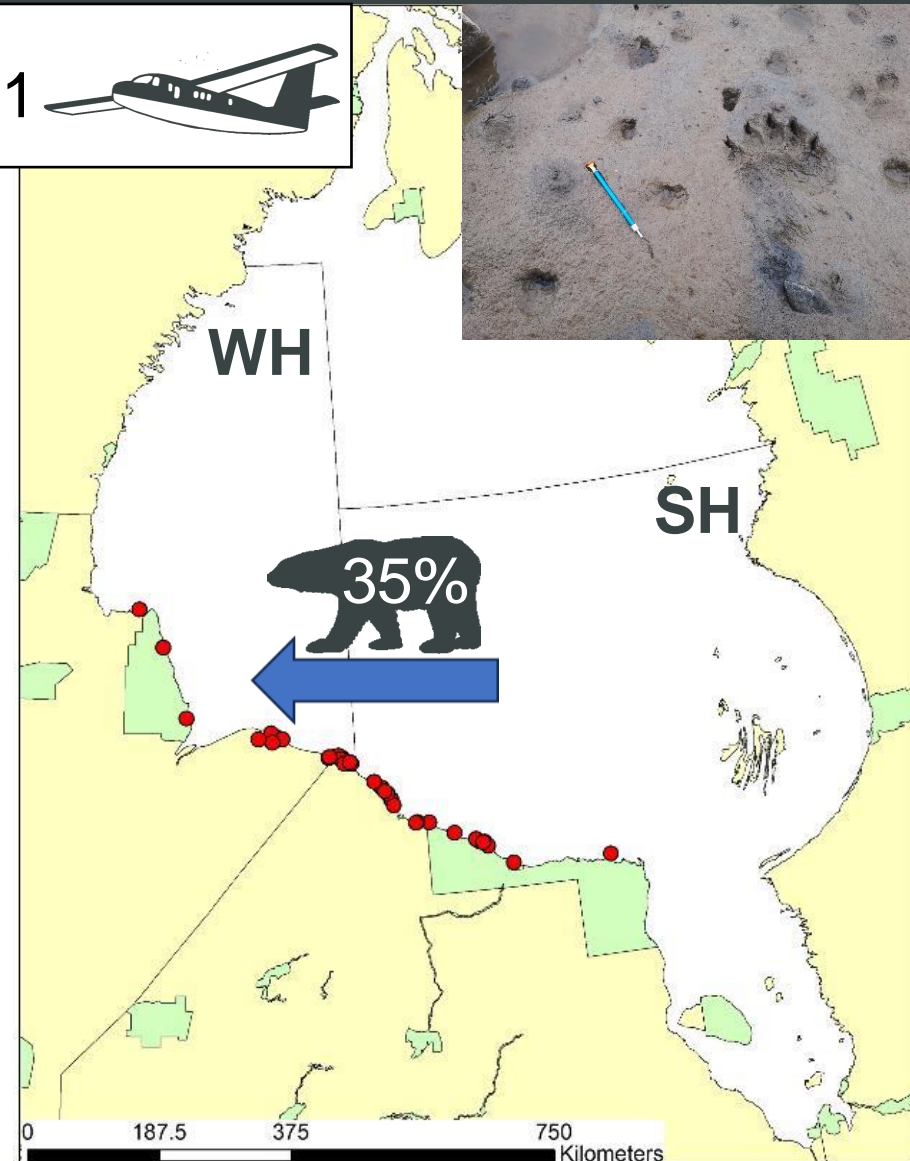
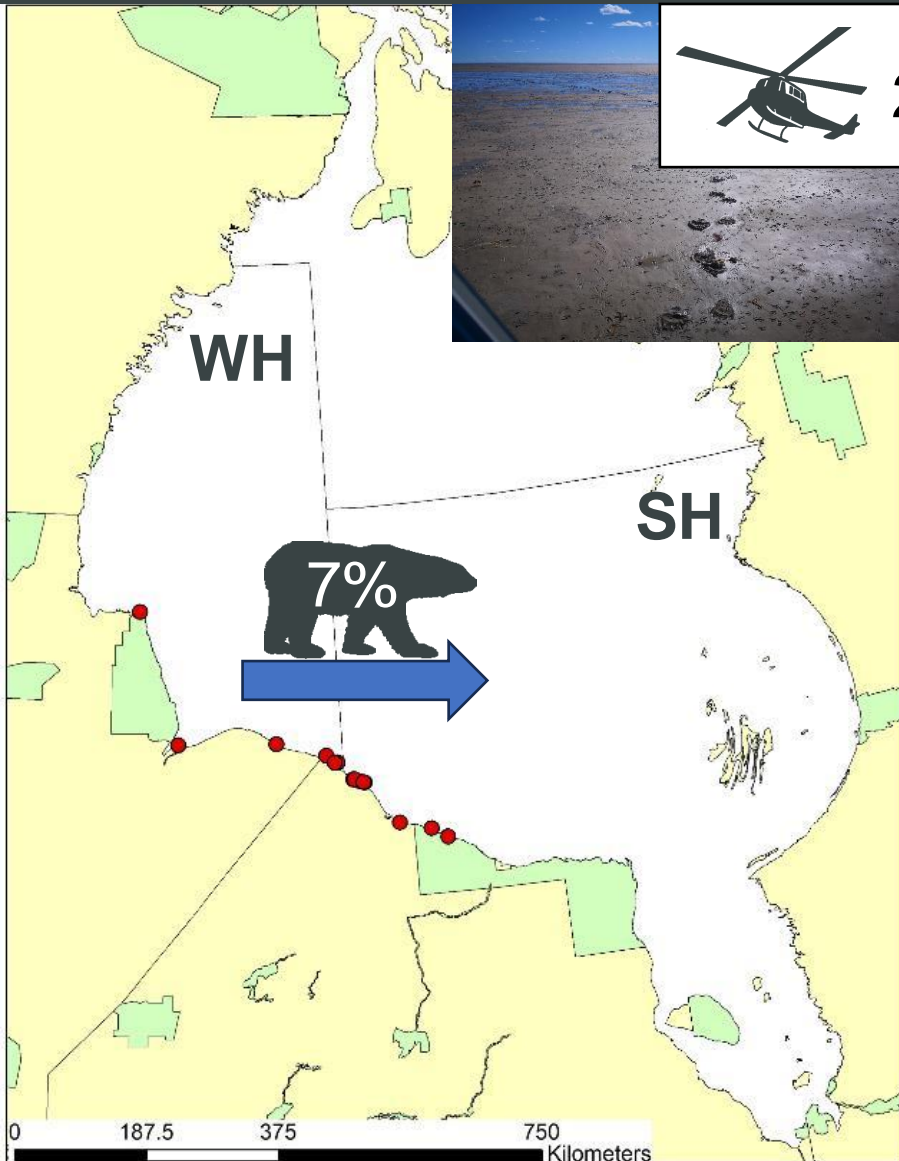


Sampling locations for bears biopsied in 2021 in SH

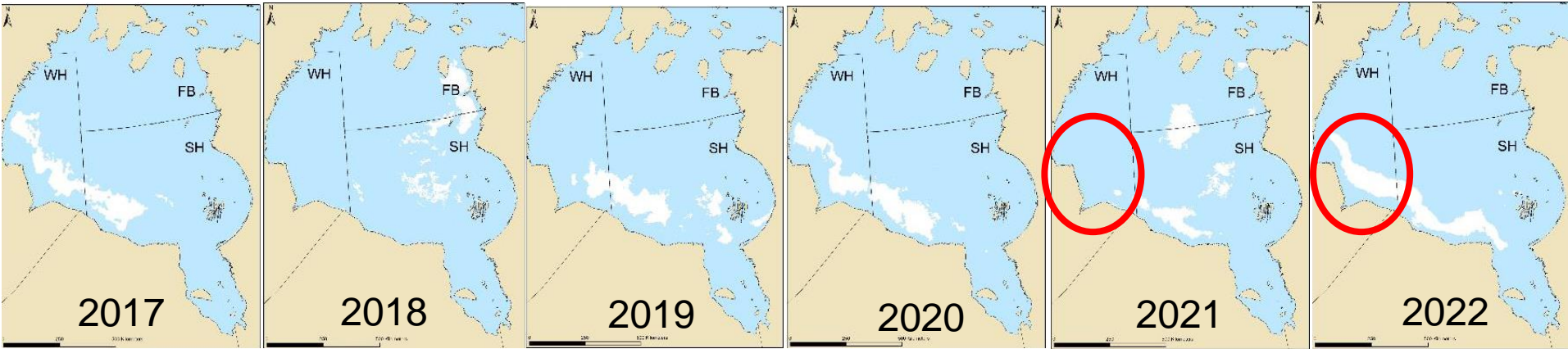
- Bears previously sampled in **WH**
- Bears previously sampled in **WH & SH**
- Bears only ever sampled in **SH**
- Bears **first time** sampled



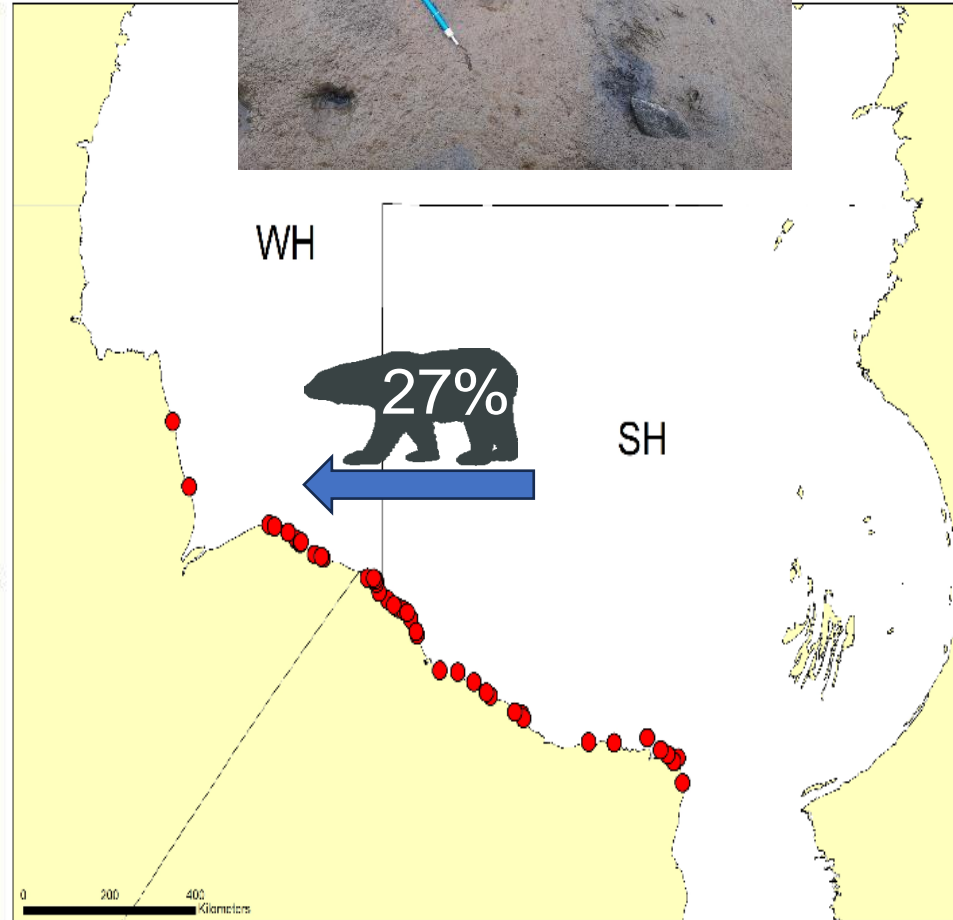
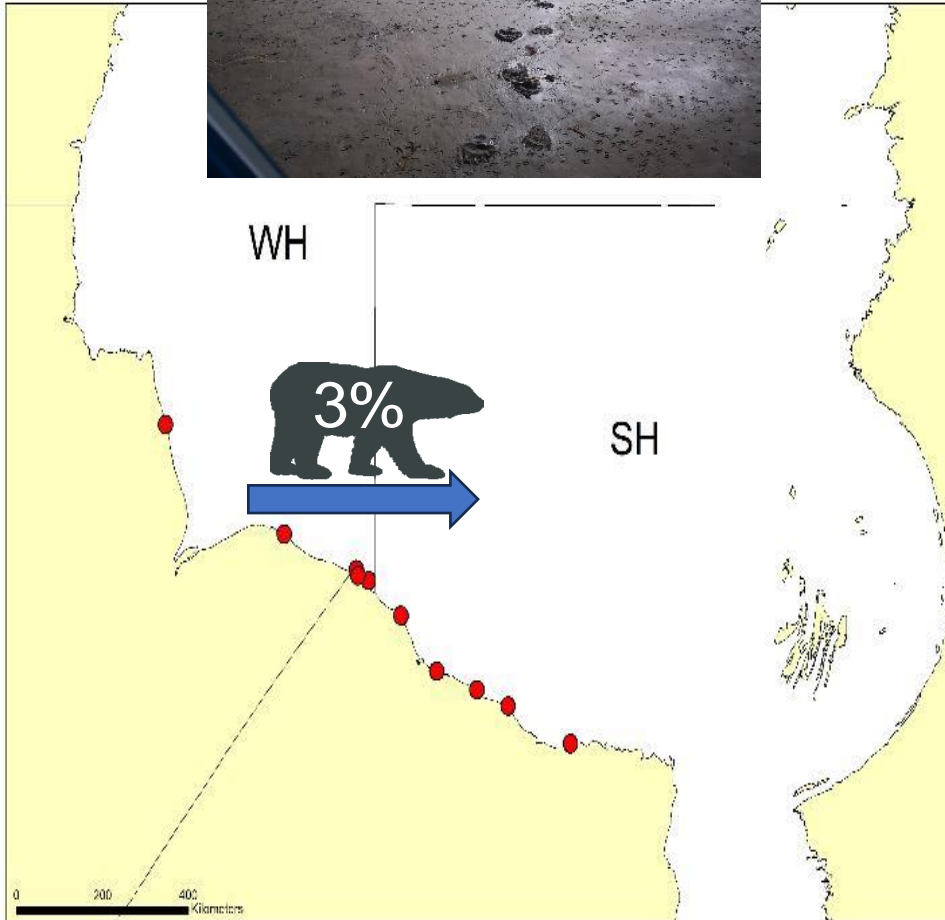
Results – WH to SH and SH to WH 2021/2022



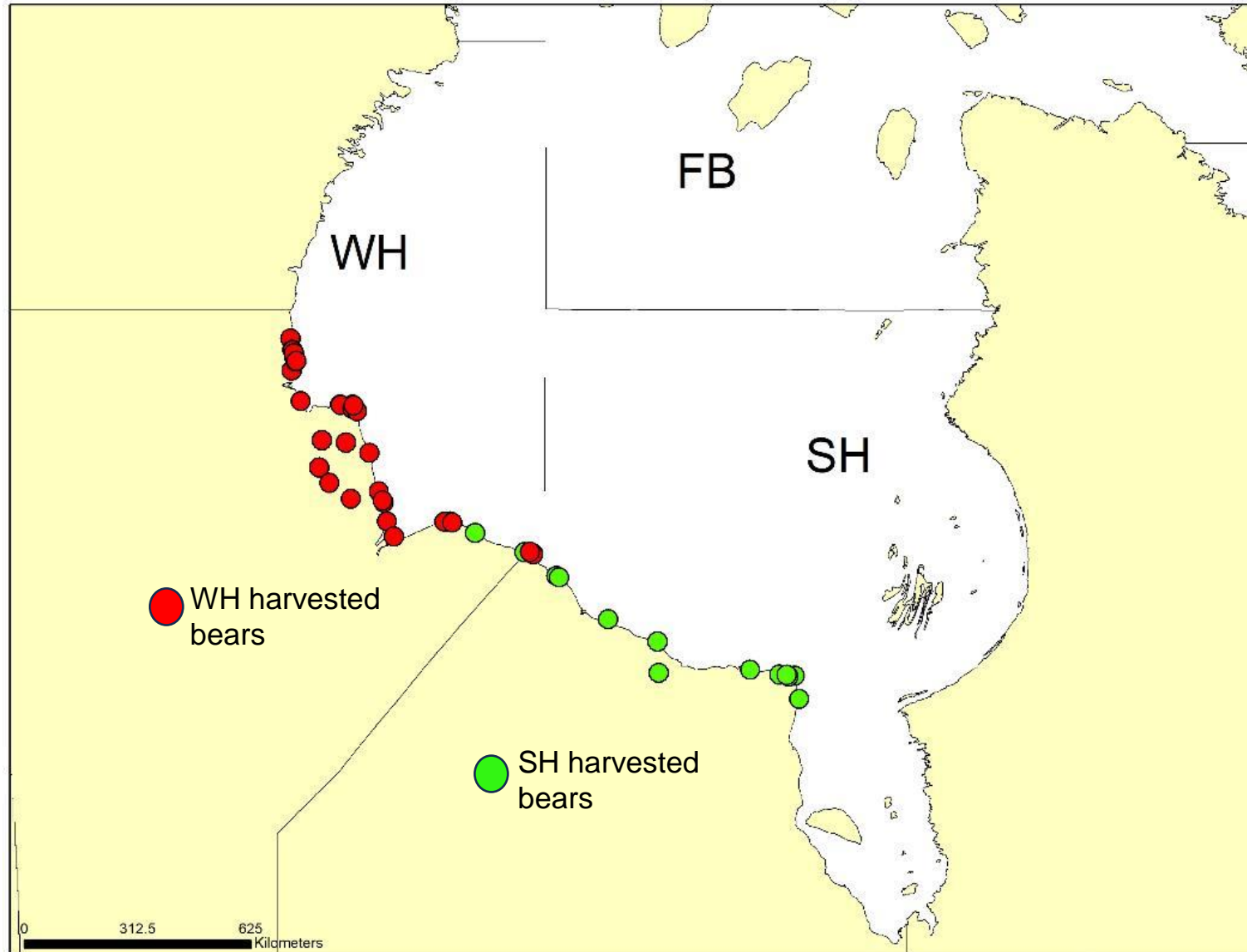
Results – Last area of consolidated ice before summer

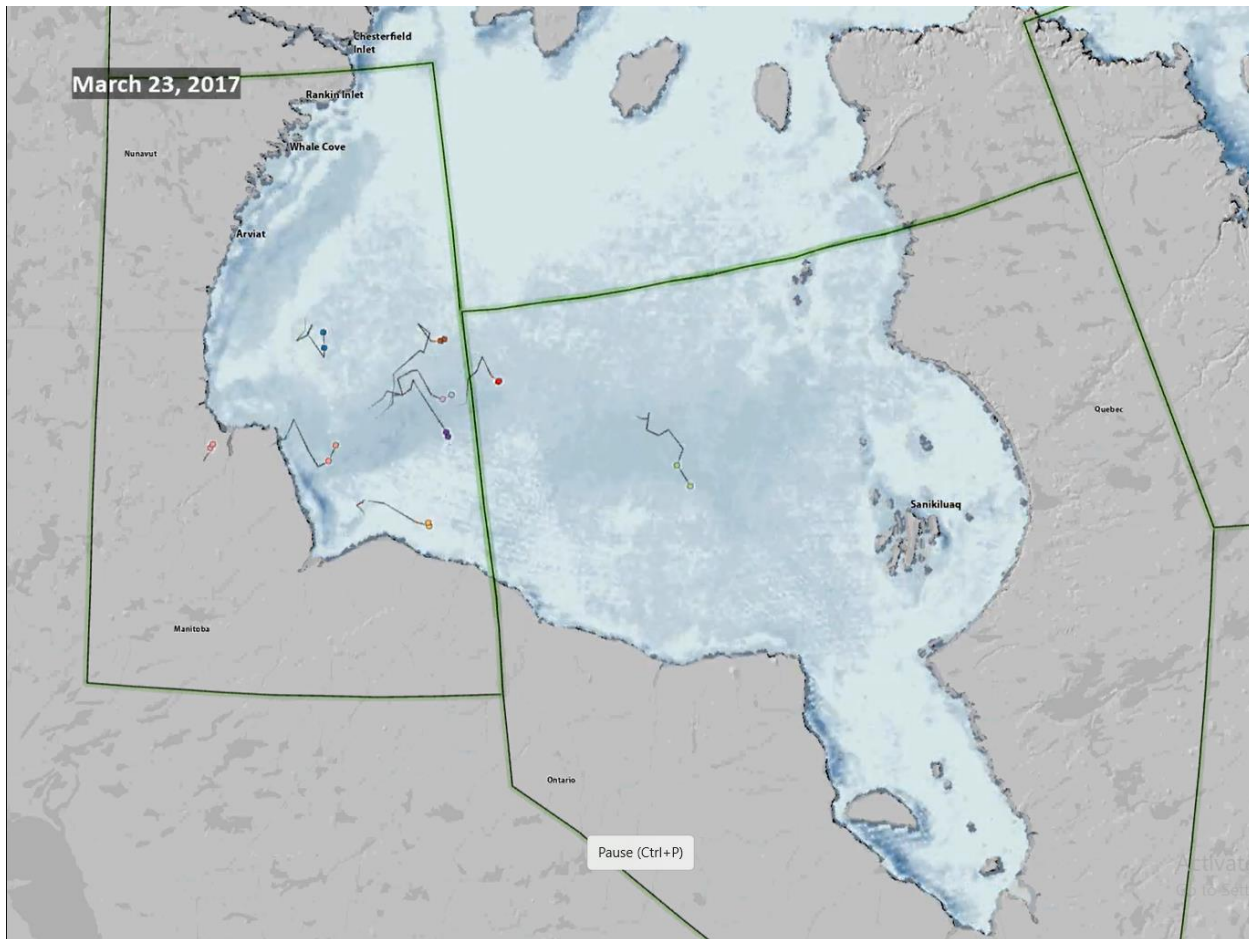


Results – WH to SH and SH to WH 2022/2023



Results – WH to SH and SH live sampling of harvested bears 2017-2023





Method Differences



- Aerial Surveys
 - “Snap shot” in time
 - Unable to determine bear movements



- Biopsy Darting
 - Can identify individual bears
 - Determine some level of bear movements



- Collars
 - Can identify individual bears
 - Determine precise movements for 1-2 years



Arviat

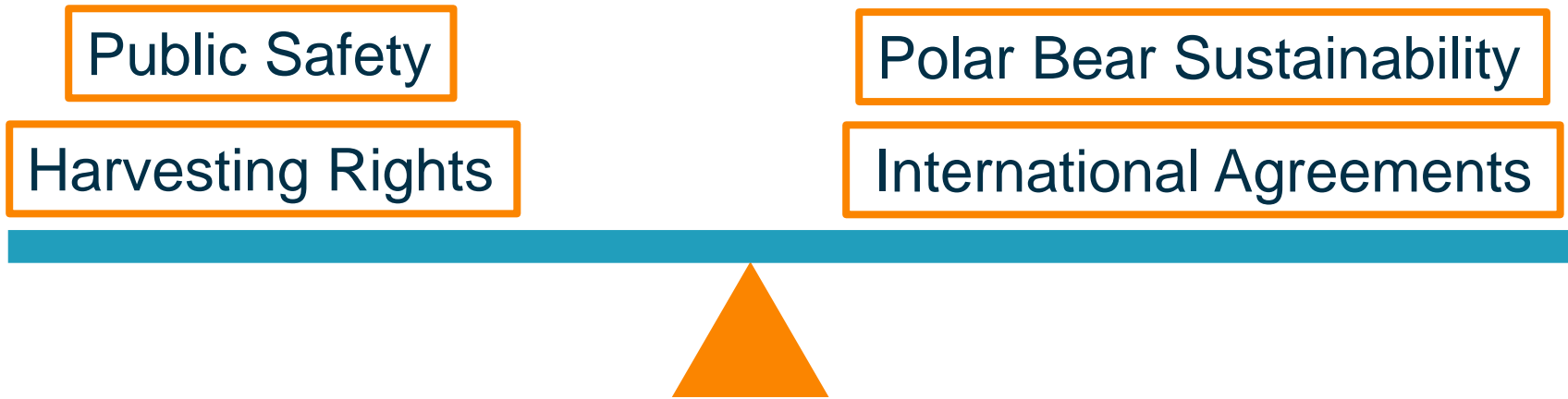
- Joe Savikataaq Jr. – Conservation Officer
- Running bear deterrence/public safety program
- Biopsy darting
 - How many conflict bears are the same bear returning?
 - How many conflict bears are conflict bears from Churchill?
- What deterrence tools are most effective?
 - Frozen seal lure stations
 - Trapping and relocation
 - Flares, bangers, etc.





Job of the Department of Environment

- Balancing act



Total Allowable Harvest (TAH)

- The current TAH for Western Hudson Bay is 38 bears per year.
- Department of Environment at this time is **recommending a TAH of 38.**
 - This is because of the ECCC biopsy darting results **showing movement between WH and SH**



- Do you agree that the number of polar bears **stayed relatively the same** over time?
- Are there **enough** bears to harvest? Are there **too few**? **Too many**?
- What did you observe in the bears' **body condition** over time?
- Is there anything **special** that you observed and wanted to share with us?
- Where do you **agree/disagree** with our findings?

Thank you!



Contact Info:

Alyssa Bohart



abohart@gov.nu.ca

Evan Richardson



evan.richardson@ec.gc.ca

Questions?

Consultation with Kangiqliniq, Arviat, and Issatik Hunters and Trappers Organizations on the 2021 Aerial Survey of the Western Hudson Bay Polar Bear Subpopulation Report

March 26, 2024

March 27, 2024

May 9, 2024

May 10, 2024

Department of Environment
Government of Nunavut
Iqaluit, Nunavut



Executive Summary

Government of Nunavut (GN), Department of Environment (ENV) representatives conducted in-person consultations with Kangiqliniq Hunters and Trappers Organization (HTO) on March 27 the Arviat HTO March 27, and the Issatik HTO on May 9 and May 10, 2024.

The intent of this consultation was to ensure the GN and HTOs could discuss the results of the 2021 Aerial Survey of the Western Hudson Bay Polar Bear Subpopulation (WH) Report, led by the GN. The survey collected data in 2021. The previous abundance data for WH was collected in 2011 and 2016. The 2021 survey results suggested a decline in the polar bear subpopulation from 2016 to 2021, but when results were pooled with the 2021 Aerial Survey of Southern Hudson (SH) Bay Polar Bear Subpopulation results, there was a difference of 1 bear between 2016 and 2021. Due to the limitations of aerial survey methodology, it could not be determined how much of the decline was due to movement between subpopulations. Environment and Climate Change Canada (ECCC) have been conducting research on WH since the 1980s, including a biopsy darting project from 2017 to present. Results from this work suggested that the decline was partially due to movement near the boundary between WH and SH in 2021, as opposed to declines in survival. The goals of the consultations and presentations were to provide co-management partners with an overview of the results of the GN report and ECCC's research, collect feedback on the results presented, collect additional *Inuit Qaujimaqatuqangit* (IQ), and to discuss the ENV Total Allowable Harvest (TAH) recommendation.

Polar bear biologists met with each community's respective HTO that hunts from the WH subpopulation.

Support for ENV's harvest recommendation were not expressed by HTOs at the time of consultation. The HTOs indicated they would like to see an increase in the TAH. At the end of the consultation, HTOs were left with questions to discuss and send their feedback to ENV or the Nunavut Wildlife Management Board (NWMB), whichever was preferred by the HTOs.

The feedback and IQ collected during these consultations will be summarized when submitting TAH recommendations for the WH subpopulation to the NWMB for decision.

This report attempts to summarize the comments made by participants during the consultations.

Preface

This report represents the Department of Environment's best efforts to accurately capture all of the information that was shared during consultation meetings with the Hunters and Trappers Organizations of Rankin Inlet on March 26 Arviat on 27, and Whale Cove on May 9 and May 10, 2024.

The views expressed herein do not necessarily reflect those of the Department of Environment, or the Government of Nunavut.

Table of Contents

Table of Contents

Executive Summary	ii
Preface	iii
1.0 Report Purpose and Structure	1
2.0 Purpose of Consultation	1
2.1 Format of Meetings	1
3.0 Summary of Consultations	2
Appendix A	3
2021 Western Hudson Bay Polar Bear Subpopulation Aerial Survey Report Consultation Meeting Notes Rankin Inlet.....	3
Participants.....	3
Goal of meeting:	3
Next Steps and Action Items:	3
Short term Action Items (within 4-6 weeks):	3
Longer term Action Items (next 2-3 months):.....	3
Meeting Notes:.....	3
2021 Western Hudson Bay Polar Bear Subpopulation Aerial Survey Report Consultation Meeting Notes Arviat	14
Participants.....	14
Goal of meeting:	14
Next Steps and Action Items:	15
Short term Action Items (within 4-6 weeks):	15
Longer term Action Items (next 2-3 months):.....	15
Meeting Notes:.....	15
2021 Western Hudson Bay Polar Bear Subpopulation Aerial Survey Report Consultation Meeting Notes Whale Cove.....	21
Participants.....	21
Goal of meeting:	21
Next Steps and Action Items:	22
Short term Action Items (within 4-6 weeks):	22
Longer term Action Items (next 2-3 months):.....	22

Meeting Notes:.....	22
2021 Western Hudson Bay Polar Bear Subpopulation Aerial Survey Report Consultation	
Meeting Notes Whale Cove	25
Participants.....	25
Goal of meeting:	25
Next Steps and Action Items:	25
Short term Action Items (within 4-6 weeks):	25
Longer term Action Items (next 2-3 months):.....	26
Meeting Notes:.....	26

1.0 Report Purpose and Structure

This report is intended to collate and summarize comments, questions, concerns and suggestions provided by the Kangiqliniq HTO, Arviat HTO, and Issatik HTO regarding the results of the 2021 Aerial Survey of the Western Hudson Bay (WH) Polar Bear Subpopulation Report.

Representatives from the Department of Environment (ENV) attended the consultation along with other co-management partners and interested parties.

2.0 Purpose of Consultation

The purpose of the consultation was to discuss the newest scientific information regarding the WH polar bear subpopulation as reported in the 2021 Aerial Abundance Survey report and scientific work done by Environment and Climate Change Canada (ECCC). In addition, the Government of Nunavut (GN) also put forward a Total Allowable Harvest (TAH) recommendation during this consultation, but also discussed that management objectives can be formulated depending on the communities' needs and objectives for this subpopulation.

3.0 Format of Meetings

The meetings were held in the evenings and one morning, and ran for approximately 2 - 3 hours. Government of Nunavut Polar Bear Biologist, Alyssa Bohart, and Environment and Climate Change Canada Polar Bear Biologist, Evan Richardson facilitated and led the meetings. Each presentation started with opening remarks from A. Bohart and E. Richardson on who they are and what organization they are representing as well as the purpose of the consultation. This was followed by a PowerPoint presentation with an overview of the scientific survey and co-management process, historic management background, a detailed overview of the results from the 2021 polar bear aerial abundance survey, and the results from scientific work conducted by ECCC in Hudson Bay. Work by ECCC aided in the explanation of the aerial abundance survey results. The participants were invited to ask questions, raise concerns, or provide recommendations throughout the meetings. At the end of the meeting, the GN recommendation on the TAH for WH was presented. After the presentations, questions/discussion continued until no further questions were raised, or until the HTOs adjourned the meeting. HTOs were left with discussion questions regarding the studies and WH management objectives from ENV to internally discuss and send responses to ENV or directly to the Nunavut Wildlife Management Board (NWMB).

4.0 Summary of Consultations

This summary combines the general themes and ideas generated from the three HTOs. For a summary of key commentary and participants in each consultation, please see Appendix A.

Comments and questions:

- HTOs indicated that they would like to see an increase in TAH. Discussions around determining a management objective for WH at the NWMB meeting.
- HTOs raised public safety concerns:
 - Not able to camp in tents anymore, can't egg pick along the shore, need to carry rifles now, bears getting fish in nets, processing seal/beluga kills differently to prevent bears from coming, and bears at cabins/property damage.
 - The number of public safety incidents and deaths need to be considered in the TAH decision.
- HTOs expressed frustrations with the co-management system and feelings that their voices are not heard and consultation meetings seem pointless. Inuit Qaujimajatuqangit needs to be incorporated into the management system more. Dedicated studies are needed to collect Inuit Qaujimajatuqangit for decision making. Frustrations with people from the south making decisions affecting Inuit lives.
- HTO indicated how the TAH system conflicts with Inuit culture:
 - Creates competition with other communities, which is not Inuit culture.
 - Harvesting a polar bear has become rare for men, due to the TAH being too low. Polar bear hunting is an important part of Inuit culture and becoming a man.
 - Feelings of “disrespecting our elders and their traditions”.
- HTOs expressed concerns about limitations/accuracy of the aerial survey method (missing bears in the water, sightability issues). Distrust in science.
- Concerns were raised regarding polar bear tourism in Churchill and the public safety threats it creates for Nunavummiut, including habituation, hearing damage from bear bangers, tissue damage from imbedded rubber bullets, and relocating bears closer to Arviat.
- HTOs asked questions about genetics/relatedness and movement between WH, SH, and Foxe Basin. HTOs asked questions about collaring and biopsy darting methods and safety of the bears.

Appendix A

2021 Western Hudson Bay Polar Bear Subpopulation Aerial Survey Report Consultation Meeting Notes Rankin Inlet

Location: Rankin Inlet, NU, Kangiqliniq HTO office

Date/Time: March 26, 2024

Start time: 19:17

End time: 21:31

Participants

Donna Adams (HTO manager)

Harry Ittinuar (HTO Chairperson)

Levi Curley (HTO Secretary-Treasurer)

Chris Connelly (HTO Member)

Savikataaq Kowmuk (HTO Member)

Sam Alagalak (HTO Member)

Alyssa Bohart, Polar Bear Biologist, GN ENV

Evan Richardson, Polar Bear Biologist, ECCC

Ezra Greene, Acting Senior Advisor - Land Use Planning and Regulatory Review, Nunavut Tunngavik Inc.

Raymond Mercer, Resource Management Coordinator, Nunavut Tunngavik Inc.

Clayton Tartak, Meeting Attendee

Johanne Coutu-Autut, ENV Conservation Officer Rankin Inlet

Daniel Kaludjak, ENV Conservation Officer Rankin Inlet

Goal of meeting:

Provide an overview of the newest scientific information regarding the WH polar bear subpopulation as reported in the 2021 Aerial Abundance Survey report and scientific work done by ECCC. Discuss the GN TAH recommendation. Discuss any questions HTO has for both studies. Collect feedback and IQ on WH management.

Next Steps and Action Items:

Short term Action Items (within 4-6 weeks of meeting):

- Email HTO the questions
- Email to confirm correct spelling of aerial survey participants names
- Email HTO with how far offshore was surveyed
- Email HTO the % of harvest of polar bears for the last 10 years

Longer term Action Items (within 2-3 months of meeting):

- Provide HTO the animation of collared bears
- Ask for occurrence reports involving polar bears from Operations

Meeting Notes:

Question to Group after Introductions:

The meeting began with introduction of participants. Alyssa Bohart presented slide show with background on the transition at the GN polar bear research group due to the loss of biologist

Markus Dyck. She then presented an overview of the polar bear study process including the planning stages up to when a TAH management decision is accepted by the minister and harvest tags are distributed to communities. She then noted that the purpose of this meeting was to provide a summary of the results from the aerial abundance survey and ECCC's work to hear HTO feedback.

Aerial abundance survey background slides

- **Sam:** Have you looked at the diets of bears around Arviat area?
- **Evan:** There has been work done in Manitoba. Lots of berries, I've seen bears kill seals, and bears on caribou carcasses.
- **Sam:** How much of your studies incorporate IQ studies?
- **Evan:** I've only done western science, but I'm learning how to incorporate IQ studies.

Aerial abundance survey methodology/field work

- **Clayton** identified that several of the observer participant's names were spelled wrong in the report. Alyssa apologized and indicated that she would look into getting those fixed.
- **Chris:** How far offshore do you guys survey?
- **Alyssa:** I will double-check and get back to you.
- **Chris:** Some bears stay in the ocean almost all summer too.
- **Alyssa:** Yeah, this is feedback we've heard before. The tricky part about surveying water is it's not safe to do so in helicopters, so something that we're looking at for future surveys is Mitch Campbell is doing a pilot project using drones to survey. We're hopeful that if drones seem to be an effective way to survey, we can send drones out onto the water to survey water.
- **Clayton:** Is there any genetic variation between Foxe Basin, Western and Southern Hudson Bay bears?
- **Evan:** There's a little bit of variation, but not full distinction between the two. We do see these mother, daughter, offspring relationships. Females quite often go back to where their moms had them in their dens - they tend to go back to the same areas, whereas males tend to roam more. It's a continuum of relatedness across the landscape. There's no hard divides based on genetics or movements.
- **Sam:** The methodologies used, is leaving a lot of loopholes. You're not going far offshore. They've been known to be 200 miles offshore. If you start missing 5 or 10% of bears, that's a potential increase to our quota. It seems that the authorities that be, have become quite comfortable in never increasing any quota, whether its muskox or polar bears, yet they act so quick when it comes time to decreasing allowable harvest. So it's very important that the time of year these studies are being done, you're able to identify population growth by the man made border system. There's really no way to prove it, but it's easy to assume because of what we're seeing, especially in Arviat, more polar bears. Maybe the Southern Hudson Bay population is in decline and they're kind of borrowing some Western Hudson Bay population. That's where Inuit Qaujimagatuqangit becomes very important right from step one of this whole process, not just at the NWMB level. Maybe that should be your first study, what are you seeing the differences between 1990 and 2023, the polar bear population. Every single Arviammuit is going to say there's more bears. Your studies are showing there's not more bears.
- **Harry:** Having been with the board, early 2000s. I used to listen to my dad and other elders talk about polar bears being surveyed, even back in the 80s and 90s, they've always said

that this method being used for doing surveys is not accurate at all (estimates). It's obvious nowadays we're seeing more and more bears around our communities in the summer. We never used to have that problem. Today, a lot of people will not stay in tents because of the increase in polar bears. Even for our community, we never ever had problems like that. So today we have more incidents. Because of climate change? I don't know. Probably mostly because of that. A lot of bears are not making it back to where they usually summer. So a lot more bears are starting to be seen in these areas.

- The survey is not sufficient. I wouldn't call it accurate. Not even close. I've been hearing for years. They've always known they've been way offshore. Not a small number, but a lot of bigger bears. Animals have no boundaries. People's boundaries are not accurate at all.
- **Donna:** It's a form of being able to manage with those boundaries.
- You start off with the memory of your coworker's tragic death. We've had tragic deaths. That triggers. Deaths, mauled to death. And near-death experiences. I know you noted down public safety, but you have to include deaths, I think. One life is one too many.

- **Sam:** With the goal of government, you have climate change now, stooping into wildlife. What would you like to achieve? What would the government like to achieve?
- **Evan:** It's a question we frequently get asked and I've thought about it a lot over my career. The one fundamental thing I think probably everybody in the room could maybe agree on is we all want to see polar bears in the future. We all want there to be polar bears, 10, 15, 20, 60, 80, a hundred years from now for future generations.
- **Sam:** I'm sure you've had your discussions with your peers, caribou biologists, fisheries, climate change. Can you name one species that Inuit have hunted to extinction?
- **Evan:** No.
- **Sam:** Then what are we doing here at this table? Let us do what we do. Let us live how we live. That's where problems arise. Really, what's the point of these meetings? Let us live.
- **Evan:** We're all wrapped up in this system right?
- **Sam:** Your system, it's not my system.
- **Evan:** Well, the Land Claims Agreement.
- **Sam:** Even that is your system. It's nothing personal.
- **Donna:** They're in place, but there's always broken systems, no matter what level, that need serious addressing.
- **Sam:** I was sworn in last night and I was thinking why am I going to go spend 2 hours? What do I want to see? What do Inuit want to see? So what are we going to achieve?
- **Evan:** I'm hoping we can share some information and have some comments.
- **Sam/Donna:** We've been sharing information for 30 years, 40 years, 50 years and we've yet to see it in one of these (presentation/report).
- **Evan:** Maybe that's an important thing that comes out of the meeting is that you guys are frustrated that IQ is not being considered more and that it should be incorporated more into the management system and dedicated studies should be done to collect and curate IQ of polar bears and Western Hudson Bay. That should be a recommendation for the future.
- **Sam:** It's the same song we've been singing.
- **Donna:** It hasn't done us any earthly good. In any way shape or form. It's actually brought despair.
- **Evan:** The whole management process?
- **Donna:** Yeah, counting, we don't count our animals. Harry was sharing, his dad was a really good leader, Savik's dad. They're gone now, and we're left here to share what they

knew. Especially like you said, it's a picture. If I took a picture of you today and 10 years from now, I expected that you look exactly the same? That's not how our animals and climate and environment thrives. We adapt to all the changes, we always have. It's not going to change if they're counted. If they go extinct, let us be there to enjoy until the last day. It's our majestic animal.

- **Johanne:** What percentage are polar bears harvested at in all of Nunavut?
- **Alyssa:** I don't know the number off the top of my head. The TAH has traditionally been set at 4.5% of what the estimate for that population. The last decision that was made for Western Hudson, when it was increased to 38, NWMB changed it to 38 because 38 was 4.5% of that estimate.
- **Johanne:** Are you sure? Because I've been hearing 3%.
- **Sam:** There was a time where it was 3%. I think it was even 2%, it was very low and we were forced to agree with it. When the polar bear population reached a target, that percentage ratio would increase. The total allowable harvest should have increased, but didn't because the government keeps moving the healthy population figure. Sometimes its 2000, 3000, 5000, whatever it might be. That's a moving target.

- **Johanne** expressed concerns over people's safety on the land.
- **Sam:** We used to be able to camp in tents. You didn't need a dog. We'd pick eggs miles from home along the shore as kids. You can't do that anymore.
- **Chris:** Even now, when we go out, we sleep on the boat because when we were staying in a tent, a couple times you'd wake up and there's two or three bears around the tent, so we stopped using it.
- **Clayton:** The Kivalliq Wildlife Board previously recommended that they wanted to look at options for reducing the population. Has that been considered in this TAH recommendation?
- **Alyssa:** No it hasn't, but this is part of the discussion right? If the HTO wants to decide that's the management goal, then we can record that in the notes and it can be incorporated. For example, this was done in the Davis Strait subpopulation. Before my time, the decision those communities indicated, that their management objective was to decrease the subpopulation and so that was incorporated into the TAH. The newest decision by NWMB was to increase the TAH by 4. I wanted to highlight the fact that NWMB does increase the TAH sometimes. It has been done in Gulf of Boothia, M'Clintock Channel, and Davis Strait.
- **Clayton:** Is that an explicit purpose of the consultation to determine management objectives?
- **Alyssa:** Well, it can be, I think. I think this is the time to capture that, if there is management objectives.
- **Ezra:** I've been looking at management objectives and thinking about who determines them, and I've been looking because of issues in other places. In the Polar Bear Management Plan that NWMB recommended for approval and GN accepted, the way management objectives are described is that when there's a new TAH that's going to be determined, the NWMB is also supposed to make a decision on the management objective. From what I've read, that has actually not been done in any case. So even though the GN says there's a management objective, it's not coming from an NWMB decision. The way the management plan is written is that it should come from that decision. In the Polar Bear Management Plan, there's management recommendations, not objectives, so the wording I think matters. The only one where there's explicitly a management objective named is M'Clintock Channel, which it says the management

objective of M'Clintock Channel is to keep a stable population. That's one thing that I've been arguing related to PBTC and PBAC, Polar Bear Technical Committee and Administrative Committee. In my opinion, even though there's statements like, the goal is to, the objective is to lower the population or to keep it stable. The process that's supposed to be followed, according to the management plan, hasn't been followed. My point here is that if there's going to be a total allowable harvest hearing, part of that discussion should be what the management objective is.

- Even when it was 38, I helped a lot with the Kivalliq Wildlife Board at that time. At that time, I talked to the board because KWB suggested 45 (estimate was 842, that's where the 4.5% of 842 is 38), we had recommended 45 and we said that based on Inuit Qaujimagatuqangit, we assume that the population could easily be higher than 842 and that it would still be within the confidence interval of the science. The NWMB decided to recommend the 38, which is 4.5% of the 842. At that time, I had asked the board, because I helped prepare the written documents, whether we wanted to explicitly argue, to decrease the population and the board said that they thought that that request would be within keeping the population stable, but then later there was more discussions. I felt like at one point it was about keeping it stable. And then at one point, people were talking about decreasing or having the goal be to decrease the population. So that's just some historical context from my background. I would say that if a hearing comes up, definitely a conversation on the objective for this subpopulation would be important to include in that discussion.
- **Johanne** commented how harvesting too many bears and getting an NDF wouldn't be detrimental because there's no longer a market for bear hides.
- **Evan:** I 100% agree with all the safety issues and the things that people have been dealing with and the sensitivities around that. The importance of having discussions in regard to, cultural carrying capacity for polar bears on the landscape, what's the goal there. On the CITES piece, hide prices are down right now. China was buying a lot and not so much anymore. You guys all know fur prices go up and down, there's lulls and they come back. The one thing is if polar bears get moved to CITES appendix one (up listed), the chance that they'll ever come back is low, so once you cross that threshold, even if hide prices do come back, once you get to that CITES appendix one, the likelihood of species being delisted after that is pretty low historically. Not saying it couldn't happen, but just maybe a cautionary note. I understand your comments and the current value of hides, and the international stuff obviously is a thorn in the side for you guys.
- **Johanne** commented how not being able to sell hides could provide cultural opportunities for youth and selling within the territory.
- **Harry:** Have you seen an increase in defence kills?
- **Johanne:** There's a very big difference with bears handled here compared to other areas of Nunavut because of the tourism in Manitoba. They're encouraging them to be close to people on the buggy. You'll see bears look in people's windows in Arviat. You don't see that in Arctic Bay, the bears there have a healthy fear of people. The tourism is why the bears here are so scary.
- **Harry:** I find it hard to accept the numbers being given, reported by using this survey method. I find it really hard to accept with what we're being given as total allowable harvest, but we have no choice. We're given what we're given by the GN. For 20-30 years now, our elders were talking about this, the method being used that's not accurate. We're being given certain numbers that are not accurate. That's why we keep repeating this.

- **Clayton:** Could we start with the results of the aerial survey and talk about sightability? On 2 days of the survey, I know that we missed bears. Also, I fly a plane a lot and the attitudes we were flying for the survey were too low to get good sightability. If you could fly a bit higher, you'd be more likely to see bears. I've flown my plane down into Manitoba and I've observed bears that just run into the bush before you have a chance to see them. If that's how they react when you survey, there's a good possibility that you're missing bears.
- **Alyssa:** Thanks for bringing those points up. I can understand the issues of sightability for the fact that if we're always putting 4.5% on the estimate. I know when the aerial abundance surveys were first suggested, it was more so to get a trend.
- **Raymond:** You said this is good grounds and notes being taken for what's wanted from HTOs and locals. Marcus took the same notes. Mitch Taylor took the same notes. But yet it's still being repeated today. I know you guys are both new and just starting. So the outcome from this meeting/consultation hopefully will be used. Nick Lunn didn't listen, he was told by the board to do community consultations. He never did. I appreciate you doing this, Evan. It's a good sign. For years and years, Inuit have been lobbying for no contact, no darting, no tags, no collars. Biopsy is a really big step forward for Inuit that you guys are listening. So we appreciate that. There's no demand for bear hides.
- It used to be called bear encounters. Now its always how many bear problems are we going to have? For safety of all Nunavummiut. In the NWT days, bears used to be numbered out of Churchill, now you don't see it, which is a plus. It's moving forward really slowly. Requests to lower the population has been brought up a number of times before your guys' time, before Markus' time and this HACCS system, that's got to go. It doesn't work anywhere else. It's not used anywhere else in the world. Why is it used in Nunavut, with polar bears?
- You'll hear about a lot of safety for people and property. You'll hear a lot, no matter where you go.
- **Clayton:** For the CITES listing, who determines designatable units for the CITES process? Is that something done by Environment Canada?
- **Evan:** Designatable units are typically done through COSEWIC for polar bears. Right now, Canada is considered one single designatable unit. All 13 subpopulations are one designatable unit.
- **Clayton:** So a change in TAH in WH will not have an impact on CITES?
- **Evan:** It may stir things up in terms of people viewing it as sustainable or not. It gets back to cultural sustainability of how many bears you want on the landscape and human polar bear conflicts and climate change, changes in sea ice. You never know what somebody way down south is going to do right and it's not me. I'm not petitioning for them to be uplisted, I'm not in favor of that. I think the harvest management system works and I believe in cultural use of the resource. I completely understand the perspective of not wanting more bears on the landscape. I've worked on polar bears. I've had close encounters and I know how scary it can be. People have lost their lives and that's tragic. When it comes to CITES, you have people in South Africa saying we should uplist polar bears because of climate change, so you just never know who's going to come out of the woodwork and put one of these petitions out, so that's a tough one.
- **Harry:** Last summer, HTO looked into getting funding from WWF for bear guards, but it was our very first time to discuss this and we felt there's a real need for bear watch. For a

couple guys being hired every summer for bear watch alone or community, outlying rivers, and camp sites and popular fishing areas, and we still, I think myself, that it's needed. Very much needed now because of increase of bears in our area every spring, summer, right through the summer and into fall.

- **Johanne** commented how there's a misconception of bears starving in the summertime – they're able to scavenge on harvester-killed whale carcasses. Most defence kills they get are fat bears.
- **Harry**: Every day I see something posted by activists and this is from today, but every day they post something about polar bears, it's ridiculous.
- **Donna**: Just to share again the different principles our elders always followed. They were always disturbed and not just frustrated, but fed up with people coming up here, doing these surveys or just visiting for a time, for a season and then they go back down. If we challenged everyone who's having a say in decision making, let's say, over our polar bears, what if we challenge you to go camp out there and then you'll see. If you don't live up here, you don't have the value. You have to live up here, get to know. Even if you live up here 20 years, you still won't know it all. We can't. We can't even know it all. Elders would never say we know it all, we have the answers. They just speak from their experience. Even if they're not saying they're the experts themselves. No one dare even try, especially if you don't live up here. That was a huge issue they had all the time. They didn't like people coming up here making decisions affecting our lives impacting us and then go back south.
- **Alyssa**: Thank you, Donna, for sharing that. I think that's the goal of the co-management system, to make sure that the communities and the people that it affects, your perspectives are incorporated into that decision making process. I'm at least hopeful with the conversation that's captured in these minutes and that will be forwarded to the Nunavut Wildlife Management Board, everything that you're sharing with us today, that will be captured in the report. I'm hopeful at least the Nunavut Wildlife Management Board will do the due diligence of incorporating all the community feedback. It's hard though, I know. But you know, I'm hopeful, at least from the past few decisions they have made, to me, it seems like they are incorporating perspectives more.
- **Donna**: Something has to break, there's too much damage here with our lives.
- **Sam**: Would you want your family to experience and go through the close encounters you've been through? Your children, your grandchildren, your brothers, your sisters and your elders? Nobody wants that. We wouldn't wish it upon you, and we don't wish it upon anybody.
- You know your methods have evolved over the years. They're done at different seasons now. If you're doing it by using different methods, how accurate? You know your 2011, 2021 numbers, that's a pretty big jump, so what's happening?

Aerial abundance survey results

- **Savik**: The surveys are done in August and September. A lot of bears are not being spotted due to thick willow.
 - **Alyssa**: We try to account for that in the models. When observations are made, they'll also record the different types of obstructions and sightability issues that could happen in the habitat. Ideally that's incorporated into the model, but obviously there's always a level of some error. We know that this method is not perfect. The history of going to an aerial survey was because at the time, that was the method that seemed to be the least invasive
-

way to get an estimate. The traditional methods used to be collaring and so as communities indicated they didn't support collaring, there's a lot of concerns around immobilization and drugging bears. That's why at that time an aerial survey was chosen as the method, but we also can recognize it is a snapshot, it does have limitations to it as a method.

- **Sam:** If you look at the WH numbers, it shows that the population is declining. You're going to get somebody out there that's going to see this, they're going to ignore what you just said and what you show on the next slide (SH results), because of your method, right? I could argue and say, hey, look, we need to decrease our total allowable harvest and just show the Western Hudson Bay population, that's so easy. It almost seems like that's what the government wants, but of course you will say no.
- **Alyssa:** What I can tell you, is I've had other researchers that I've worked with when this survey came out. Alarm bells. You know, people are saying, oh, my goodness, the population's crashing. I've seen the media and I respond to them with you're not seeing the other side of the picture because the Southern Hudson Bay report isn't getting the media attention. I agree completely with you.
- **Sam:** I'm suggesting you get rid of these two populations. Just show just the one. You're begging for us to get trampled on like there's no tomorrow. You get somebody in South Africa to see that with social media now. You're begging for it whether you like it or not, you're going to get that.
- **Alyssa:** For me, I want to make sure that the truth is being told in the media. I can't control the media unfortunately, but I'm just as appalled as you when those stories go out, because I know it's not accurate.
- **Clayton:** Andrew Derocher has already used that number (the 2021 WH estimate) in the media and it was immediately before Christmas, as soon as the report went out. That is an issue because I don't believe the government had released the report prior to that. It's an issue that needs to be addressed within the government already.

- **Donna:** When you submit the report, do they (NWMB) react or notice when there had been a death? The number of interactions with bears approaching people, like the danger? Do they see that? You provide a report, then what? Besides never changing the quota or decreasing. But do they have a human part of them that realizes, hey, we should really do something?
- **Alyssa:** What we did with the Davis Straight submission, we submitted the data of how many DLP (defense) kills have happened. We could also include, I would have to get it from Operations, the occurrence reports of the amount of conflict. I think it's a really good point that it's an important thing for us to include.
- The last Nunavut Wildlife Management Board meeting, from what I have heard, there was community members at that meeting expressing the issue of public safety and that heavily weighed into the decision to increase the TAH at that time.
- **Ezra:** Yeah, that one happened in January of 2018 - the last time there was a hearing. So that was before the maulings had happened - that was later that summer. I helped write the submission and present the submission for the Kivalliq Wildlife Board. We emphasized public safety a lot. Joe Savikataaq Jr. had the numbers of how many incident reports they had, from just what they're doing. That's not everything, that's not everybody who's had a bear come to their cabin or whatever. So we had all those numbers in the report and then, I think, the HTO Chairpersons and stuff came and they all emphasized it as well. It definitely was a strong point and I think the NWMB made an emphasis on the importance of public safety in their decision or they commented on public safety. So yeah, I would say get those numbers. Even if at the HTO, if you know there's been a run in with a polar bear,

try to maybe keep a spreadsheet or something that you're telling them - let people know how many things you know about.

- **Harry:** This fall we had to open up a tag for a problem bear. Cabin owners kept spotting going right up to their cabins. Ongoing problem every year, at the same spot. Bears are being spotted on these islands, every summer month close by, 5 kilometers or even closer.
- **Donna:** We get punished for defence kills. That's one of your tags.
- **Raymond:** WH border is where you stop the survey, you don't go to Foxe Basin or into SH?
- **Alyssa:** When we do the aerial abundance survey, we do WH and SH at the same time. But you're right that we don't do Foxe Basin and I think the main challenge with Foxe Basin is it's just so large and so logistically and financially challenging. We just don't have the resources to do all three together, but I'm assuming the point you're making is that movement could be happening between them and yeah, for sure. I think that's one of the limitations of the aerial abundance survey. But as I've mentioned we'll go over what types of different research methods Evan's research group does, and how those do capture movements and the question of movement between the borders.
- **Donna:** Since we're sharing about boundaries, you can see here (shows map on the wall) that's from Inuit heritage. They're doing all the place names. That's just one little area and that's how many names and big families in the past used to have their own land. It was family land lots and that's how many names for every inch of Nunavut we have. We have to adjust to Southern Hudson Bay, like in the boundaries, I don't see what Inuit calls them, and it's not really with boundaries or limitations, but they can tell you, and I have yet to ever see that, those regions where you've labeled them Western civilization, Inuit have it labeled or the place names as well. Those need to be included and taken seriously. They weren't just collected overnight. They're streams, lakes, hills - everything they all have, they can identify. Again, it's so personal because if I came and told you how to brush your hair, how to wear your hair, that's how personal it is. When it comes to having outsiders labeling them and doing their studies and making us listen to it and adapt to, OK, how they say it, this is how they say it. This is their system, this is how they manage it. It's our backyard. We have names for it. And we know what animals go which way.
- **Chris:** This aerial abundance survey map, do you have one for SH?
- **Alyssa:** I don't have one for SH. The GN didn't lead that survey. It was led by the Government of Ontario and in their report they don't produce them.
- **Chris:** Some of these bears are going to travel way past the border. So it's inaccurate.
- **Alyssa:** We don't have data for the Foxe Basin north area because we're actually doing that survey this summer. We'll have data from this summer, but we will produce a map similar to that one for the Foxe Basin stuff.

ECCC research

- **Sam:** How many bears have you sampled?
- **Evan:** For the biopsy work, I think we're over 900 samples for individuals. That's between WH and SH.
- **Sam:** You sampled them once or every year?
- **Evan:** Multiple times. Sometimes some individuals have only been seen once. Some individuals seen two or three times. So it is variable. But as you build up your list of known bears, you get more information every time you go out.

- **Clayton:** 2021 was a really windy summer. I woke up one morning to Harry knocking on my door saying my plane was knocked over.
- **Ezra:** There's been way more biopsy work over time in Western Hudson than Southern Hudson. So even though a lot of bears were previously sampled in Western Hudson, because there's less work that's been done in Southern Hudson, these bears could be moving back and forth, or there could be patterns that aren't captured and just because of when the research happened.
- **Evan:** Yeah, 100%. There's obviously a longer history of research in WH than SH, but we've been making dedicated efforts on both sides of the border for three years now, so we think the picture's coming together, we're getting decent sample sizes.
- **Harry:** Do you know they migrate? Do you know where they go when you say move around?
- **Evan:** My understanding is from science data and collar movements, but sometimes bears like living in a smaller area. Other bears have larger areas and other bears just go and walk right around the north end of Canada and end up in Greenland. They do lots of different things.
- **Harry:** OK, it happens every fall, where we expect bears migrating this way, they migrate north where there's more ice and more seals. Every year it's always the same. They migrate along this coast. They don't just move back and forth like you're saying. Do you know a lot about where they start moving?
- **Evan:** They move through Churchill and move toward Arviat in the fall. We have collar data we're going to share on movements.

20:53-20:59 Break

- **Clayton:** When will this be submitted to NWMB?
- **Alyssa:** The next one is in June, but I don't think realistically, given the amount of work that goes into a submission, we'll be able to submit for that meeting. So it'll likely be the fall meeting.
- **Johanne:** July 1 is the new year, so we're not going to get a TAH change this year. It'll come the following year.
- **Sam:** Governments come here to defend their decision that's already made. If we stay at 4.5%, why don't you give us 10%? How is that going to change your recommendation? We have the meetings every year and our two hours have no impact because officials come in defending the decision that they made. The timing, HTOs, typically tags are open October 1 and it's right at the last hour and we have decisions to make. How many are we going to allow? In our civil obedience, we ensure there's a little buffer there so we don't overharvest. And then we also allocate some to sport hunters. What are we doing here? You've already made a decision. You come here to tell us why you made that decision. We provide feedback. What kind of an impact is this meeting going to have? We've had these meetings for over 50 years. The government already has an agenda and they're not shy about it - international agreements.
- **Clayton:** Have any of these WH/SH bears been harvested in Foxe Basin?
- **Alyssa:** As part of the Foxe Basin survey that we're planning, we're hoping that we can submit samples, harvester samples to the same database that these (WH/SH samples) are kept in, and try and see if there are any matches between the two.

- **Sam:** Almost none of the bears (collar data) go to Rankin. Are you sure we're not hunting Foxe Basin bears here?
- **Ezra:** These are only female bears (collar data)?
- **Evan:** Yes.
- **Chris:** How many bears do you have collared in WH?
- **Evan:** Wearing a GPS collar at any given point in time, typically 10 collars go out a year, and they last for a couple of years. So anywhere from like 10 to 20 individuals in total.
- **Johanne:** Are you putting ear tags at all on male bears?
- **Evan:** We're not doing any ear tagging of males. I think they are putting some ear tags on problem bears that are released.
- **Alyssa:** It's only collars, not ear tags in this video. The ear tag data I believe started in 2017, so we could see if we could add that data into the animation, to see the difference between males and females.
- **Harry:** Where are these bears being collared?
- **Evan:** Primarily in Wapusk National Park.
- **Harry:** No bears were collared along the Nunavut coast?
- **Alyssa:** No.
- **Harry:** And that's what's being used for the TAH?
- **Alyssa:** The collar data? No.
- **Harry:** So why is it being shown to us? Why bother? If it's not going to be of any use for us?
- **Alyssa:** We had gotten feedback before from HTOs that they wanted to see the collar data, what is that data being used for. Based on that feedback, I took the initiative to have this animation created so we could show the HTOs.

Public safety initiatives in WH

- **Harry:** That blue dye that stays on after biopsy darting, does that wear off? After how long?
- **Evan:** Like a good swim in the water and it's gone. Yeah, it's pretty water soluble. So it comes off in, like, a week.
- **Harry:** So what you said earlier doesn't really apply, you said you're not going to get the same bear twice, but as soon as it cools down in the water...
- **Evan:** We work our way up the coast, so we'll do 100 kilometers of coast, just kind of keep going. So we don't typically get that many repeat samples.
- **Alyssa:** In the case of using dye for bears in town, the dye might not be as reliable, as you say Harry.
- **Daniel:** Every year we send our harvester samples. What's happening with those? Are they used with biopsy samples?
- **Alyssa:** Yeah, that's what Evan was presenting on, those harvested bears, that was Nunavut data. That was compared to the biopsy samples. The GN itself, we have all the samples and we don't typically have the time to take on the projects to analyze a lot of the data. A lot of the data gets requested by collaborators who then run the genetic analysis. As I mentioned before with the Foxe Basin survey that we're planning to do this August, we're hoping to have a component of biopsy darting in that survey. So we'll collect some

samples from the Foxe Basin subpopulation. Part of that is we'd also like to submit some harvester samples within Foxe Basin to try and piece together. I think the useful feedback that we've gotten here is that it's of interest and there's this potential that Rankin Inlet is harvesting Foxe Basin bears. I think it'll be really valuable for the Foxe Basin survey to submit samples to then be compared to the WH/SH, because then we'll have a better understanding of all of the Hudson Bay Complex, of the genetics and the movements.

- **Johanne:** The spring hunt bears, there's a good chance they're coming from Foxe Basin.
- **Group** identified that seal pupping happens at that time.

TAH Discussion

- **Sam:** For what it's worth, we would like to see the TAH increased for this upcoming harvest season.
- **Alyssa** discussed the timeline of the submission and the potential delays, not making a June submission realistic.

Participants were thanked for attending, and their feedback.

21:31 Meeting End

2021 Western Hudson Bay Polar Bear Subpopulation Aerial Survey Report Consultation Meeting Notes Arviat

Location: Arviat HTO office
Date/Time: March 27, 2024
Start time: 19:00
End time: 20:49

Participants

Nicole Issakiark (HTO Manager)
Alex Ishalook (Chairperson) via phone
Kevin Kalluak (Vice Chairperson)
Laurent Angalik (Secretary Treasurer) via phone
Peter Shamee (Director)
Alyssa Bohart, Polar Bear Biologist, GN ENV
Evan Richardson, Polar Bear Biologist, ECCC
Mitch Campbell, Kivalliq Regional Biologist, GN ENV

Goal of meeting:

Provide an overview of the newest scientific information regarding the WH polar bear subpopulation as reported in the 2021 Aerial Abundance Survey report and scientific work done by ECCC. Discuss the GN TAH recommendation. Discuss any questions HTO has for both studies. Collect feedback and IQ on WH management.

Next Steps and Action Items:

Short term Action Items (within 4-6 weeks of meeting):

- Email HTO the questions
- Email to confirm correct spelling of aerial survey participants names
- Email HTO how many polar bear tags were allocated each year after 2007 between the communities of Arviat, Whale Cove, Rankin Inlet, Chesterfield Inlet, and Baker Lake.

Longer term Action Items (within 2-3 months of meeting):

- Provide HTO the animation of collared bears
- Email the HTO if the dead bears found during the survey were reported to any authorities.

Meeting Notes:

Question to Group after Introductions:

The meeting began with introduction of participants. Alyssa Bohart presented slide show with background on the transition at the GN polar bear research group due to the loss of biologist Markus Dyck. She then presented an overview of the polar bear study process including the planning stages up to when a TAH management decision is accepted by the minister and harvest tags are distributed to communities. She then noted that the purpose of this meeting was to provide a summary of the results from the aerial abundance survey and ECCC's work to hear HTO feedback.

Aerial abundance survey background slides

- No comments received.

Aerial abundance survey methodology/field work

- **Kevin:** When you cover the Hudson Bay Ocean, how far offshore do you go?
- **Alyssa:** We'll fly along the coastline and observers from aircraft can look from the coastline into the ocean, but as you can imagine, we can't see too far into the ocean. The main reason that we don't survey the water is due to safety concerns with the passengers in the aircraft. Something that's promising, is the testing of drones. We're hoping once the technology gets a little bit more advanced, we can use drones to survey the ocean, and I think Mitch has a project coming up with drones.
- **Mitch:** In Nunavut, we did fly out onto the water to cover the islands that are in that area, so we would just keep going. So there was quite a bit of water coverage and it was a twin Otter, so we could fly over water, just north of Whale Cove where there were islands. In 2016, we had a twin engine helicopter so were able to go further out into the water in 2016 as well.
- There's these new drones that have come out. They can have up to, especially in the summertime up to 20 hours, so they can be autonomous and fly up to 20 hours. We're looking to test them this summer.
- **Kevin:** When I take boat trips along the coast to Churchill, I'll see 3 or 4 bears in just one trip. Those are usually the bigger ones. You may be limited to only seeing a little speck of white if you're in the helicopter. If your drone system is successful, they'll be able to spot what we encounter during our long-distance trips.
- **Mitch:** It's high-resolution imagery, so you'd be able to detect a polar bear for sure.

Aerial abundance survey results

- **Alex:** I have 2 questions. How many polar bear tags were allocated each year after 2007 between the communities of Arviat, Whale Cove, Rankin Inlet, Chesterfield Inlet, and Baker Lake?
- Since the 1950s, 1960s, 1970s, we the communities in this region have been following the polar bear GN recommendation of a 3:1 ratio, which means all those years we've been harvesting mostly male polar bears. We followed the regulation enforced by the GN for those 35 years. Over that time, the GN suggested that the population had declined and maybe that is a result of harvesting too many males. Since 2015, the ratio is now changed to 1:1. Now that being said, I don't think we, the beneficiaries, made the polar bear population decline, but the GN at the time for those 30+ years, was saying the polar bear population has declined.
- More of a comment, when we're presented with the 38 TAH between the communities of Arviat, Whale Cove, and Rankin Inlet, we are now facing since 2007, we are fighting for those 38 tags, which is not our Inuit culture to fight each other. With Arviat being the big community, we encounter lots and lots of polar bears each year since 2007. We get the same equal amount with Rankin Inlet and Whale Cove. I think Arviat should have more of the TAH allocated.
- **Alyssa:** In regards to your first question, I'll look into our files and I can pull those numbers for you and I can e-mail them to Nicole to share it to you.
- There can be detrimental effects if too many males are harvested, so thank you for sharing that, Alex. I'll remind folks that the up to 1 to one ratio is where you can harvest one male for every female. But if you do choose to harvest more males than females, that's also allowed in the one-to-one system. So if you wanted to harvest out of that 12, 8 males and the rest females, you could do that or you could do 6 males, 6 females. It's up to the HTO.

- **Kevin:** Listening and watching your slide show, it looks like you fly and sit at a computer, then do statistics to decide how much TAH we receive, is that right?
- How is Inuit Qaujimajatuqangit helped in getting your number?
- There's 8 Inuit Qaujimajatuqangit principles. One of them is respect for their culture and surroundings. A saying from our elders, no matter which community, region or northern country you go to (Alaska, Greenland), they have always said, don't let predator numbers be so high. It seems like there's a worry of having to keep polar bear numbers high. I'm not saying kill them all or reduce them to a tiny little bit, but please respect the Inuit Qaujimajatuqangit and show how Inuit Qaujimajatuqangit has been involved in your study.
- **Alyssa:** Our study is Western science, but we do incorporate Inuit Qaujimajatuqangit to inform the areas that we cover and the knowledge of where the bears will be. We have community participants on the survey as well. We've been trying to have Inuit Qaujimajatuqangit studies with our polar bear projects, when we're able to. Other organizations will conduct an IQ study in the communities and gather knowledge. We did this in Davis Straight, which gave us a much better understanding of the polar bear population because we had both science and Inuit Qaujimajatuqangit. Science is limited to the short amount of time on the land each year and it only started in the 1980s, whereas harvesters are out on the land much of the year, making observations. Inuit Qaujimajatuqangit spans generations and decades. Having both Inuit Qaujimajatuqangit and science gives us a more full understanding.
- The statistics will give us an estimate and so based on that estimate number, then we'll consider all those types of factors I covered like public safety, conservation, and we typically try and look for the trend, not necessarily the number of bears. When we look at WH and SH combined estimates between 2016 and 2021, it looks like the population

hasn't changed, then that would influence our recommendation to say the TAH should stay the same.

- The history of 38 TAH in Western Hudson came from the number 4.5%, which was a number that was scientifically calculated, before my time, to be a sustainable harvest percent of the population estimate. And so 38 is 4.5% of 842.
- One of the goals of this consultation is discuss the draft TAH of 38 and capture in the meeting minutes, the HTOs thoughts around this number. It's also important for us to share information with each other, so thank you for sharing one of the principles about too many predators.
- **Kevin** clarified that he was not necessarily suggesting there should be a decrease, he was sharing Inuit Qaujimajatuqangit.

- **Lorne:** Clayton from NIWS told us that there was an interview on Inuit Qaujimajatuqangit that was held in Arviat that they asked questions about the polar bear population. Was this given to you guys? This was 2015, 2014, I can't remember the year.
- I remember that Alex mentioned that 2021 was a bad year for our area, we had a lot of east winds and bad weather and all that - and while they were doing the survey or counting the polar bears in our area. Looking at the WH and SH numbers, it looks like they switched, and the combined numbers, there's a difference of 1 bear, would this be a decrease?
- **Alyssa:** I had heard that an Inuit Qaujimajatuqangit study was planned, but he hasn't shared that data with us. It would be important that the information be shared with the Nunavut Wildlife Management Board.
- I'm glad you brought that up, because we have heard from other communities that 2021 seemed to be a weird weather year and Evan's going to go into a bit about how the ice was unique in that year.
- In regards to the combined WH and SH estimates between 2016 and 2021, we wouldn't consider the difference of 1 bear a decrease in the population, we'd consider the population stable.

- **Peter:** Do you see any sick bears when you do the surveys? Would you report it to NTI? Do they decrease the numbers that can be harvested by the communities?
- **Alyssa:** On this particular survey in the report, they had four dead bears that they found and unfortunately no samples were collected, so we don't know the cause of death of those bears. It could be something like disease or starvation or old age. I think it was noted one of the bears was a 21 year old male. So that's older for bear, so not super out of the ordinary. I'm not sure what the process was, if that was ever reported to anybody, I can ask.
- When a dead bear that died of natural causes is found, it's not taken off the quota.
- **Mitch:** We flew the Nunavut side and all the bears looked healthy, Stephen flew the Manitoba side where the dead bears were found.

ECCC research

- Alyssa offered to share the collar animation video with the HTO and when the SH collars are incorporated into the video.
- **Alex:** The GN did an aerial survey in 2006 and 2007, at the time I was on the Board. We saw the reports that the GN put out. The biologist at the time requested a 14-day aerial survey, which had poor weather at the time, and they flew only two days. That was the time when the Western Hudson Bay polar bear tags were cut right down to 0. We had no tags/quota for the WH zone until 2010. At least now we're at 38. I'm trying to go back in

time so that it's in the record. In 2018, we had strong winds from the east, and all the polar bears were drifted to northern Quebec area. Our neighbours down there, reported over the radio that there's lots and lots of polar bears around Sanikiluaq and northern Quebec.

- **Alyssa:** Thank you, Alex, for sharing that with us.
- **Evan:** I can certainly appreciate that we need to be cognizant of how the environment influences not only the distribution of bears, but also the success of the surveys. If it's really foggy, it's not a good year to fly surveys. All those things need to be taken into consideration when considering results.

- **Kevin:** From the 2016, 2021, 2022 population, what percentage of that was tested with biopsy?
- **Evan:** I think the database, and this includes previous samples that were collected from bears and in Churchill as part of Polar Bear Alert and Environment Canada's work there, I think the biopsies were around 900 individuals, but we have DNA fingerprints for close to around 3000 bears in total, but that's from like 1980 all the way till now. So that's 40 years of data, so a lot of those bears aren't living anymore. But the biopsy program was around 900 samples taken I think.
- **Kevin:** So you can recognize Western Hudson Bay or Southern Hudson Bay or Foxe Basin bear by the biopsy you collect?
- **Evan:** Yeah, the one issue is that you have to have caught it somewhere before because you just catch it for the first time, you don't know if it just walked down from Foxe Basin and came. It's most informative if you get multiple samples from the same individual. We saw this bear north of Churchill, then we saw it in Nelson River and then back north of Churchill again. That's a Western Hudson Bay bear because we always see it in Western Hudson Bay, but some of them jump back and forth. So you have to build up this knowledge of where you've seen bears before and where they like to hang out, and then you can put the picture together.

Public safety initiatives in WH

- **Alex:** I'm glad to hear that there's some different methods to deter polar bears, which you guys have presented. Watching the polar bear town in Churchill, MB, I've seen lots of times where people use bear bangers too much. When the bear is running away, they're still using bear bangers and shooting at the bear. Polar bears are really sensitive in hearing. That's their hunting style, they hear seals under the ice. They can smell 50 miles away. If they're being shot at too much, they're going to go deaf. When they come to Arviat, they can't hear properly. The conservation officers are overdoing it, and should be properly trained. Maybe your department can make some recommendations.
- **Alyssa:** I really appreciate you sharing because we can ensure at least, in Nunavut, we can make sure that we aren't using bear bangers too much. Unfortunately, the Manitoba conservation officers are out of either mine or Evan's jurisdiction. We can certainly share what you've shared with us today with folks in Manitoba.
- **Evan:** Thanks, Alex. One other point I would make is that there is a group called the Polar Bear Technical Committee that's comprised of territorial and provincial biologists that are involved in polar bear research and management. There is a woman on that committee that represents Manitoba. She's a biologist from Thompson. Her name is Vicky Trim and she's kind of in charge of running that Polar Bear Alert program. So we can certainly share your message with her on the overuse of bear bangers and concerns that community members have about polar bear hearing and problem bear behavior in towns.

- **Peter:** In Churchill, MB, when the conservation officers move the bears by helicopter, they move them north into our boundary area. Here in our hometown, the people don't like it. Why don't they bring down the polar bear from where they got it?
- **Evan:** It's a frequent issue that's brought up. When you talk to the province of Manitoba, because the bears naturally migrate north, they start walking north, to come to the sea ice in the fall time, that's their reasoning. I'm not saying it's right, but their reasoning for not flying the bears south is that they'll just walk back and be a problem bear in Churchill again. So they take them across the river, but then obviously as you guys know, they walk up the coast, and can end up in Arviat as a problem.
- I think it would be good to get everybody in a room together, like the province of Manitoba, all the HTO's, and maybe the Wildlife Board and discuss jurisdictional obstacles.
- **Alex:** I have friends in Coral Harbour that have seen polar bears with green markers on their back, which were painted in Churchill, MB. They can go way up to Coral Harbor area, just wanted to share that with you all.
- **Kevin:** In Arviat, in September, mostly October and some November we go, we see a lot of bears at the local dump. Sometimes we'll see a big skinny bear that can hardly step on their hind leg. These bears are very bony and very dangerous. If the biopsy is being taken from the rump, is there a possibility it can become infected?
- **Evan:** The needles we use are sterile when they come in the package. There's always a possibility, when we take them out of the package. We've done hundreds of biopsies, so if it was a frequent thing, we'd see this a lot, so we don't think it would lead to infection.
- **Kevin:** Because we've just recently started to see the very scary way too skinny bears. They were not very common during the fall migration previously.
- **Alyssa:** Thank you. I'm just trying to think of what else it could be. I know sometimes there can be injuries associated with too many rubber bullets or something like that too. I've seen that in black bears before and so I'm just trying to think of other reasons. It's a good observation. I think it it's something for us to keep in mind.
- **Alex:** I've seen myself, here in Arviat, times where we have to put down bears because they're too skinny. We have spotted rubber bullets inside the tissue when they were put down.
- **Alyssa:** It'd be really important if you find that happens again, if you would be able to take pictures and send it to us at the polar bear lab or even to Joe Jr. We want to keep track of it, to make sure that it's not becoming a problem and it's not causing more problem bears.
- **Alex:** Joe would be aware because he was there to see it.
- **Alyssa:** Thanks Alex, I'll follow up with him.

TAH Discussion

- **Alex:** This topic can become very sensitive and we talk for days and not come up with any kind of recommendation. However, TAH, between the communities, we lobby, we fight, we compete, which is not normal to us between Arviat, Whale Cove, and Rankin Inlet. We fight each other to get the biggest part of the TAH. Only because polar bear hunting is our Inuit culture in becoming a hunter. If you've seen the movie Big Game, where the men become a man when they harvest their first kill, that is our Inuit tradition, how a young boy becomes a man, a hunter. I recommend you watch that.
- I have 3 boys. The oldest one is turning 30. He hasn't even found a bear his whole life. The second oldest is 20 and he hasn't shot a polar bear. Third oldest, 16 now, hasn't had a chance to shoot a polar bear because our TAH is too low. Myself, I was drawn once in

my whole life. I just wanted to share with you all how important it is to give the community TAH, because of our tradition.

- **Evan:** Thanks for sharing that, Alex. It's important to hear those sorts of things to help frame the context of these discussions and the importance of the cultural value of bears and considerations of that and the broader context of conservation and management that all these things need to be considered.
- **Lorne:** I just wanted to share a story that happened last year, I just want to see some smiles so we don't forget this. There were some people who just moved to Arviat and these polar bear patrol guys thought they saw a wolf somewhere in the town. And they were skinning it and it was a dog, but they thought it was a wolf. They didn't know it was a dog, a musher that owns it. Thank you for this night to share about polar bears and I hope the TAH will be higher this year or higher in coming years.
- **Peter:** Do you do this work every year? How often do you guys come here and report like this one?
- **Alyssa:** As the GN, we try to do a survey about every five years, if we can and that's just to get an abundance estimate, but I'll let Evan speak to his work and how much work they do.
- **Evan:** We've been to visit the communities in the past and I recently took over as the leader for the research programs around Churchill. Our goal moving forward is to come back to the communities more often and visit with you guys and talk to you and listen to what you're seeing and what's going on. Share our results on a more regular basis and also do a better job of just sending out some short reports, documents that are translated and trying to be better at exchanging knowledge with each other, so we have common understandings, and we can work together to make sure there's polar bears for everybody in the future.
- **Kevin:** I just wanted to share what I have experienced in my life in Arviat. As a child in the summertime, my late dad had a canoe, and every opportunity we get, we would go out to Sentry Island, because that's the only island we have out on the Hudson Bay - it has a nice sandy beach on the west side and there's a watch tower where people could scope for marine mammals. Lots of Arctic tern and eider duck eggs. As soon as the boat(s) would land, us kids would jump out of the boat and race to the top of the hill and be the first to collect eggs or try and be the first to reach the top of that homemade tower, without worries. Our mothers or fathers didn't even care if we disappeared somewhere on the island. That's how life was. When the mothers and fathers or the family was collecting eggs, we did not even have to carry our rifle with us. That's how worry free life was.
- Today you go there, you don't want to even step on land because there will be at least 5, 6, 7, 8 bears on the island already. When you have your nets, they'll be waiting on the shore for any movement. Once a fish gets in your net, they'll go right in and because of the strength, they won't even get tangled in the net, they will just bite off the fish. You catch a seal or beluga, which are one of our main staples, we don't want to work on it on that island. We want to either try and bring it home or try and do it maybe on the open water because once we land, we know who's coming and how many are coming to us.
- For decades, as Alex said, for 30-40 years we've been asking to back what was about 20 tags, that were suddenly stopped in 2007 for so long. How long will we wait? When will the scale balance out? How much should we repeat the same message? When will it not fall on deaf ears? What next event must we witness before we finally get the quota or even more than what was 20? We've waited long enough. What else should we say? Should

we say anything at all? It is worth voicing our concern? What use is this meeting or other types of these similar meetings? How long must we disrespect our elders and their traditions? Do we even know them anymore? Are we getting numb?

- **Evan:** Thanks for those comments, Kevin. We heard similar things in Rankin Inlet yesterday in regards to people's frustrations with the management system, more polar bears being on the landscape, human polar bear conflicts, people not being able to go out and go to the places they used to hunt and enjoying in the summer time because there's too many bears now and they don't want their kids out and it's more dangerous. It's a common thread amongst a lot of the discussions we've been a part of and hopefully since this is being recorded, that theme will continue through Whale Cove and it'll potentially resonate with NWMB and the decision makers on quotas and be part of the broader discussion when those decisions are made.
- **Alex:** To close my comments, we have over 1500 hunters interested in hunting a polar bear. Only 10-12 are given a tag, which is a lottery. Those lucky people hunt 2 days in 48 hours and it's a big event for our community. Hopefully we get an increase in TAH, only because the past survey failures (that resulted in a TAH of 0). Now science and IQ is not balanced. Science is saying polar bears are declining. In the summer, we are encountering more and more polar bears. All along the coast of Arviat. It is hard to believe science.

Participants were thanked for attending, and their feedback.

20:49 Meeting End

2021 Western Hudson Bay Polar Bear Subpopulation Aerial Survey Report Consultation Meeting Notes Whale Cove

Location: Whale Cove Hamlet Chambers

Date/Time: May 9, 2024

Start time: 19:20

End time: 20:31

Participants

Robert Enuapik (HTO Chairperson)

Alyssa Bohart, Polar Bear Biologist, GN ENV

Evan Richardson, Polar Bear Biologist, ECCC

Jonathan Pynn, Senior Wildlife Advisor, GN ENV

Kyle Ritchie, Senior Wildlife and Policy Advisor, Wildlife Management Biologist, NWMB

Oliver Shipton-Ouellet, ENV Conservation Officer Whale Cove

Regrets: Gabriel Nirlungayak, Director, Nunavut Tunngavik Inc. and Raymond Mercer, Resource Management Coordinator, Nunavut Tunngavik Inc.

Goal of meeting:

Provide an overview of the newest scientific information regarding the WH polar bear subpopulation as reported in the 2021 Aerial Abundance Survey report and scientific work done

by ECCC. Discuss the GN TAH recommendation. Discuss any questions HTO has for both studies. Collect feedback and IQ on WH management.

Next Steps and Action Items:

Short term Action Items (within 4-6 weeks of meeting):

- Email HTO the questions
- Email to confirm correct spelling of aerial survey participants names
- Email HTO and KWB regarding credit use process

Longer term Action Items (within 2-3 months of meeting):

- Provide HTO the animation of collared bears

Meeting Notes:

Question to Group after Introductions:

The meeting began with introduction of participants. Alyssa Bohart offered to postpone the consultation either remotely or to the next day to allow for more board members to attend the meeting. Robert Enuapik indicated that he would reach out to board members to see if they would be available to meet the next day, but to continue with the meeting today since they have trouble meeting quorum. Alyssa Bohart presented slide show with background on the transition at the GN polar bear research group due to the loss of biologist Markus Dyck. She then presented an overview of the polar bear study process including the planning stages up to when a TAH management decision is accepted by the minister and harvest tags are distributed to communities. She then noted that the purpose of this meeting was to provide a summary of the results from the aerial abundance survey and ECCC's work to hear HTO feedback.

Aerial abundance survey background slides

- No comments received.

Aerial abundance survey methodology/field work

- **Robert:** When you do your survey, that includes the Churchill area?
- **Alyssa:** Yes, that's right. When we do Western Hudson aerial survey, we also do Southern Hudson aerial survey at the same time. We recognize that these boundaries are more like management units, since the bears don't see them as boundaries and movement can happen.
- **Robert:** Do you survey the land?
- **Alyssa:** Yes. When we consulted (remote at the time due to COVID), we surveyed the land as well under recommendation from the HTOs. We do our best to incorporate Inuit Qaujimaqatuqangit into our studies.

Aerial abundance survey results

- **Robert:** When we had the meeting in Rankin with KWB, there was a presentation about the survey. The presentation was that we lost 500 bears and Southern Hudson gained 500. They move a lot.
- **Alyssa:** Yes, so it probably wasn't surprising for you to see these results hey? (Robert nodded in agreement).

- **Oliver:** Its kind of nice that you looked at them both together and that they seem to move together.

ECCC research

- **Evan:** If the community is interested, we could work with you Oliver on analyzing biopsy samples that you collect. Could tie into identifying patterns particularly about problem bear dynamics. Who they are, where they go, where they come from.
- **Oliver:** Yes, let's discuss that further.
- **Robert:** When you talk about dying them/tagging, what do you mean?
- **Evan:** There's a couple of parts to our program, so there's some tagging that goes on as well and that's how the collars get put out. We're monitoring for things like disease, like Avian Influenza, stuff like that, you know things people are concerned about. We collect other samples for health assessments and contaminants. Understanding what contaminants are in the marine environment and wildlife is consuming, and what people are consuming and what levels they are in wildlife and in different species. Environment Canada is kind of responsible for understanding chemicals in the environment and how they influence human and wildlife health. A little bit of demographic work too. Just understanding population growth and impacts and changing sea ice.
- **Oliver:** What are studies on when bears are paint tagged? Are they more visible to prey?
- **Evan:** Not aware of any research on this. Dyes are water soluble and don't last too long.
- **Oliver:** If the studies keep showing mixing, will this be a combined subpopulation and result in an increased TAH?
- **Alyssa:** We aren't considering managing them as one unit or changing boundaries, but do consider our TAH recommendation of WH and SH at the same time, looking at the results of both. If you look strictly at the data separately, we would suggest a lower TAH in WH and a higher in SH because of the "decline" and "increase". But based on both surveys, we recommend the TAH stays the same for both.
- **Oliver:** How many surveys will it take to change the boundaries? You've got 3 surveys now, but say in 15 years and if that information stays the same to show one group, would you look at changing the boundaries?
- **Alyssa:** I can't really answer that as it is a broad scale discussion. The boundaries were set out based on the information at the time and made at a higher level than the GN.
- There was further discussion on this and how remaking the boundary lines would be a decision at the national or international level.
- Alyssa explained how aerial surveys were chosen as a less invasive method to surveying bears. This decision was in respect to HTO wishes. Other methods can be discussed with HTOs for future surveys.
- **Oliver:** It'd be really interesting to do biopsy darting in other places like Coral Harbour. I'm curious if their population ever mingles with WH.
- **Alyssa:** We are actually planning to do Foxe Basin this year and will get more information from that. Hoping to add a biopsy darting component to this to look at movement between boundaries.
- **Oliver:** Are you considering doing hair snagging like they do for grizzly?
- **Alyssa:** Yes this is something we plan to start this year too in Foxe Basin.

- Alyssa showed an animation of ECCC and University of Alberta polar bear collar data.
- **Oliver:** Does the size of a bear indicate where it goes?
- **Evan:** Its all really nutritionally based. Bears that are born in a good ice year with a lot of food tend to get bigger.
- **Oliver:** Do you collar males?
- **Evan:** No. The necks on males are too big for collars to stay on. So these are all female bears in the animation. There are “burrs” on the fur, but they don’t work as well, bears are pretty hard on them. There are some new ear tags with antennas, but the antennas are weak points that break. They’ve been put on males and subadults. Technology is coming a long way and as it gets better then we may be able to explore other GPS options.
- **Oliver:** Can you share this animation with the HTO?
- **Alyssa:** Yes. I’ll make sure to send a copy.
- **Evan:** A lot of bears tend to congregate into the centre of Hudson Bay once the ice comes. Is this something you’ve seen or has anyone travelled there? I haven’t been there so don’t know what is drawing them there.
- **Robert:** Not sure.
- **Evan:** It’s amazing their ability to navigate, they cover such huge areas. Since they’re collared, we see the same bears navigate to the same areas and small islands year after year.

Public safety initiatives in WH

- Some discussions on bear deterrence and projects on how to collect additional information via biopsies and the existing genetic database for WH bears.
- Discussion on pilot research in Arviat testing deterrence types.
- **Oliver:** Rubber bullets don’t do much for me. Screamers work sometimes. The big ones don’t care too much, so I usually just monitor it until it leaves. It depends on their age, body condition. Small ones are curious and follow people up to their house, but when you scare them, it works well. Skinny ones don’t care any more. There’s so many variables to all of this.

TAH Discussion

- **Robert:** We’ve been trying to get more tags for a while.
- **Oliver:** On credits. How does that work?
- **Alyssa** went over Credit Process from HACCS. Went into detail on how the credits accumulate and reiterated that we are here to give advice.
- **Oliver:** What is WWF’s role? Are they helping you guys at all or with any data because they’re collecting data here, we have a joint program. HTO has a partnership with WWF for bear monitors. They do their own Occurrence Reports and share it with me.
- **Evan:** We’ve never asked for it.
- **Oliver:** get in contact with Jason Harasimo if you want that information. Great program, especially if other communities get it. Their Bear Deterrence project helps me sleep at night.
- **Robert:** The bear that was shot with the collar, do you have that?
- **Evan:** That bear was collared in September 2022 and was spotted just south of Churchill in September of this year, and had a 1 year old cub. The cub wasn’t around when she was

harvested. She was 24 years old (showed image of collar location on screen). She walked all the way over to Coats Island and then back.

- Oliver asked that the map be sent to the hunter. 1st bear for the hunter. Relayed additional details about the harvest. Thinks it would be great to share the tag/harvest information with the hunter.
- **Robert:** No other questions but I'll try to get the other members for tomorrow and if not we'll get the information back to you.

20:31 Meeting End

2021 Western Hudson Bay Polar Bear Subpopulation Aerial Survey Report Consultation Meeting Notes Whale Cove

Location: Whale Cove Hamlet Chambers

Date/Time: May 10, 2024

Start time: 10:40

End time: 11:45

Participants

Mona Okalik (HTO Manager)

Robert Enuapik (HTO Chairperson)

Shiela Ebing

Manu Nattar

Alyssa Bohart, Polar Bear Biologist, GN ENV

Jonathan Pynn, Senior Wildlife Advisor, GN ENV

Kyle Ritchie, Senior Wildlife and Policy Advisor, Wildlife Management Biologist, Nunavut Wildlife Management Board

Oliver Shipton-Ouellet, ENV Conservation Officer Whale Cove

Regrets: Gabriel Nirlungayak, Director, Nunavut Tunngavik Inc. and Raymond Mercer, Resource Management Coordinator, Nunavut Tunngavik Inc.

Goal of meeting:

Provide an overview of the newest scientific information regarding the WH polar bear subpopulation as reported in the 2021 Aerial Abundance Survey report and scientific work done by ECCC. Discuss the GN TAH recommendation. Discuss any questions HTO has for both studies. Collect feedback and IQ on WH management.

Next Steps and Action Items:

Short term Action Items (within 4-6 weeks of meeting):

- Email HTO the questions
- Email to confirm correct spelling of aerial survey participants names
- Email HTO and KWB regarding credit use process

Longer term Action Items (within 2-3 months of meeting):

- Provide HTO the animation of collared bears

Meeting Notes:

Question to Group after Introductions:

This meeting was held again to allow for higher attendance of board members. The meeting began with introduction of participants. Alyssa Bohart presented slide show with background on the transition at the GN polar bear research group due to the loss of biologist Markus Dyck. She then presented an overview of the polar bear study process including the planning stages up to when a TAH management decision is accepted by the minister and harvest tags are distributed to communities. She then noted that the purpose of this meeting was to provide a summary of the results from the aerial abundance survey and ECCC's work to hear HTO feedback.

Aerial abundance survey background slides

- No comments received.

Aerial abundance survey methodology/field work

- No comments received.

Aerial abundance survey results

- **Robert:** When you get the survey numbers, is the whole total you have there from Western and Southern Hudson together? Does that number go to manage the TAH?
- **Alyssa:** The way we are looking at it now is to manage it as one/taking each into account, but there are two separate TAHs. If we look at the numbers, there isn't a change from the last survey. To us it seems that the population hasn't changed and it would be reasonable to keep it the same. If WH draft TAH is to stay the same, then SH TAH would be to stay the same.
- **Robert:** In looking at the numbers it looks like the numbers went down.
- **Alyssa:** Agreed. 2021 looked like a windy year and aerial surveys have limitations.
- Highlights the reason to survey both subpopulations at the same time.
- **Oliver:** At the end of the day, the populations are stable.
- **Alyssa:** Yes, and I think Evan's research really highlights that.

ECCC research

- During showing animation, Alyssa reminded everyone that the collar information only shows female bears.
- **Robert:** When is mating season? March/April?
- **Evan:** April/May

Public safety initiatives in WH

- No comments received.

TAH Discussion

- Alyssa reiterated the GN recommendation is to not change the TAH
- **Robert:** We usually try to ask for more for WH. For SH, what is the TAH?

- **Alyssa:** 25 for Sanikiluaq. SH is shared with Ontario and Quebec. There is little harvesting from Ontario but there is a TAT of 23 for Quebec. So that would be 48 take from SH total.
- **Robert:** When we have KWB, Chesterfield Inlet, there is always tags given to Chesterfield. How come Chesterfield who is in Foxe Basin, why do they get WH tags?
- **Alyssa:** KWB only decides who receives tags. A few years ago I noticed that Baker Lake and Chesterfield Inlet only get FB tags now and we haven't heard from KWB on other allocations. We're only meeting with the communities that currently have a WH allocation.
- Showed information about the collared bear that was recently harvested by resident of Whale Cove.
- **Shiela:** How long was the collar on?
- **Evan:** Two years.
- **Shiela:** Do you check up on bears when they are collared?
- **Evan:** Collar was scheduled to drop off in September. It has a release mechanism with a timer for it to fall off. I wasn't involved when it was collared, but whoever fitted the collar made it too tight, we will be following up to make sure it doesn't happen again. We don't want to see pictures or hear that collars are impacting the bears and thanks for sharing this information.
- **Evan** showed a picture of typical collar wear on the fur.
- **Shiela:** When you have a date for the collar to come off, do you go to the bear to make sure its off?
- **Evan:** Depending on where the bears are, if we are working in the area we do go check. The collars have beacons on them and we listen to and go check on them if they are in the area. Even if a collar was programmed to come off, we will listen for it in the following years to try and make sure its off. We can't come up to Nunavut as we don't have a permit to work up here but we do our best.
- **Shiela:** What do you do with the collars?
- **Evan:** We send them back to get refurbished. We also download the data on the collar. They are satellite based, but not all the information gets transmitted (technology limitation). The data gets stored on a memory card on the collar that we can download on a laptop.
- **Robert:** Its always nice when you show the movement of the collared bear. But when we see pictures that bears are affected like that, we don't like it. Even with caribou we sometimes get people shooting collared caribou. We don't really accept any more collaring. Even elders say it isn't good to put collars on animals - it is pretty hard to make decisions about putting collars on. Most times we'll say we don't like that, but we know it's just going to happen anyways. Not much say about that, I think. If the GN wants to do that, we don't have much say about it.
- **Evan:** There are some jurisdictional issues. This collaring happens in Manitoba, there's Manitoba research permits. I know there's work to get more Inuit representation on boards in Manitoba. We are now putting out less collars (typically maximum of 10) and doing the bare minimum to get the information needed for research. Just enough to balance needs between community concerns, management and science needs. We try to strike a balance. We do our best.
- **Robert:** How many years do you guys do collaring?
- **Evan:** Every year we do 10 collars. They fall off and we replace them. Its part of an ongoing monitoring program.
- **Alyssa:** Thank you to the Board Members for showing up and meeting with us today. We'll be sending copies of the presentation and the video to the HTO. And we have these questions that we'd like to have input on.

- **Robert:** That was a good one. We got the survey numbers. That was good information for us.
- **Manu:** this was good information for us too. Thank you.

- Some discussion on HTO hunting season.
- **Alyssa:** Do you do sport hunts?
- **Robert:** A few years back the quotas would go pretty quick in the fall. When it used to ice up late, the quotas would go quick. Now when the ice forms its quick and the bears go. Its like beluga, we used to get them the third week of August when they migrated. Now its September. I guess its climate change. Even our caribou are migrating sooner than last year.

11:45 Meeting End

2021 AERIAL SURVEY OF THE WESTERN HUDSON BAY POLAR BEAR SUBPOPULATION



FINAL REPORT

November 16, 2022

Stephen N. Atkinson¹, John Boulanger², Mitch Campbell³, Vicki Trim⁴, Jasmine Ware⁵
and Amélie Roberto-Charron⁶

Submitted to meet requirements of:
Wildlife Research Permit WL 2021-0061, Wapusk National Park Research and
Collection Permit Number WAP-2021-3990

Status Report 2022, Nunavut Department of Environment, Wildlife Research Section,
Igloolik, NU

¹ 26104 Melrose Rd, Cooks Creek, MB R5M 0B9

² Integrated Ecological Research, Nelson, BC, V1L 5T2³ Department of Environment, Box 120, Arviat, NU, X0C 0E0

³ Department of Environment, Box 120, Arviat, NU, X0C 0E0

⁴ Manitoba Department of Agriculture and Resource Development, Thompson, MB, R8N 1X45

⁵ Nunavut Department of Environment, Wildlife Research Section, Igloolik, NU, X0A 0L0

⁶ Nunavut Department of Environment, Wildlife Research Section, P.O. Box 377, Kugluktuk, NU, X0B 0E0

Please cite as: Stephen N. Atkinson, John Boulanger, Mitch Campbell, Vicki Trim, Jasmine Ware and Amélie Roberto-Charron. (2022). Aerial survey of the Western Hudson Bay polar bear subpopulation 2021. Final Report. Government of Nunavut, Department of Environment, Wildlife Research Section, Status Report 2022-xx, Igloolik, NU. XX pp + x Supplements.

Disclaimer

The opinions in this report reflect those of the authors and not necessarily those of the Government of Nunavut, Department of Environment.

We dedicate this report to Markus Dyck; a dear friend and colleague who will be missed but of whom we have many fond memories. Your dedication to the future of polar bears and their place in the world will forever be remembered. We will do our best to make your contributions known to others. This is for you Markus. See you later mate.



(Photo credit: J. Ware, 2020)

SUMMARY

Relative to most polar bear subpopulations, the Western Hudson Bay (WH) subpopulation has been the subject of significant, long-term research, monitoring and management efforts. Concerns about the observed effects of long-term changes in sea-ice habitat, harvest pressure and increasing levels of human-bear conflict have made this subpopulation the focus of attention in discussions about the status of polar bears globally. Recently, part of the monitoring regimen for WH has involved a plan to conduct aerial surveys at 5-year intervals in-order to closely track abundance and distribution. Here, we report the third in this sequence of surveys.

Using double observer (sight-resight) and distance sampling methods from helicopter and fixed wing platforms, an aerial survey of the WH polar bear subpopulation was conducted in late August and early September 2021. Survey design, including study area stratification and transect spacing, was based on previous surveys in 2011 and 2016. Transects were oriented perpendicular to the coastline to align with bear density gradients.

We recorded a total of 194 bears in 125 groups. Like previous surveys, bears were concentrated along the coast and offshore islands, although both lone individuals and family groups were also regularly sighted inland, particularly within the Wapusk National Park region. The estimated abundance of WH in 2021 was 618 bears (SE=119.3, CI=425-899, CV=0.19). Comparison to aerial surveys estimates from 2011 and 2016 suggests that WH may be decreasing in abundance. Post-stratifying the results by sex and age classes revealed significant declines in the abundance of adult female and subadult bears between 2011 and 2021.

We were unable to definitively conclude whether the finding of declining abundance in WH over the last decade, specifically that of adult females and subadults, was the result of reduced survival and recruitment, movement of bears into neighbouring subpopulations (emigration), or harvest pressure. Based upon the multiple lines of evidence reviewed in

this report, it is plausible that all these factors have contributed to some degree. Of particular concern, however, is our finding that the observed declines are consistent with long-standing predictions regarding the demographic effects of climate change on polar bears. If these apparent trends continue, the progression of a reduced subadult cohort into the adult age class, combined with an already reduced adult female class, reproductive senescence, and mortality amongst older bears, may result in cascading effects on WH abundance and reproductive performance over the next decade. We therefore provide several recommendations for timely follow-up to these findings.

Table of Contents

SUMMARY	v
1. INTRODUCTION.....	1
1.1. Status of Polar Bears.....	1
1.2. Western Hudson Bay Subpopulation	2
2. OBJECTIVES.....	5
3. METHODS.....	6
3.1. Study Area.....	6
3.2. Survey Design and Field Methods.....	7
3.2.1. Survey Timing.....	8
3.2.2. Stratification.....	8
3.2.3. Aircraft.....	9
3.2.4. Double Observers	9
3.2.5. Fixed-Wing	10
3.2.6. Rotary-Wing	10
3.2.7. Distance Sampling	11
3.2.8. Observations.....	12
3.2.9. Coastal Contour Transects	13
3.3. Data Analyses.....	14
3.3.1. Data Screening and Truncation	14
3.3.2. Distance Sampling Double Observer Analysis	14
3.3.3. Trend Analyses.....	16
4. RESULTS	17
4.1. Survey Timing and Effort.....	17
4.2. Summary of Observations	18
4.3. Abundance Estimation.....	19
4.3.1. Truncation of Observations.....	19
4.3.2. Covariates	19
4.3.3. Summary of Double Observer Data	20
4.3.4. Model Selection	20
4.4. Abundance Trend Analyses	22
4.5. Polar Bear Mortalities	22

5. DISCUSSION.....	23
5.1. Distribution.....	23
5.2. Abundance	25
5.3. Assumptions and Potential Biases	26
5.4. Trends in Abundance.....	29
5.5. Reproductive Performance	34
5.6. Mortalities	35
6. CONCLUSIONS	36
7. ACKNOWLEDGEMENTS	38
8. LITERATURE CITED.....	38
Appendix 1 - Sensitivity Analyses to Truncation and Observer Issues.....	85
Appendix 2 – Further estimation of trend for age-sex post stratified estimates	88

1. INTRODUCTION

1.1. Status of Polar Bears

Across the Arctic, warming temperatures and changes in circulation patterns have led to profound changes in sea-ice, including declines in its extent and thickness, earlier spring melt ('break-up'), later fall advance ('freeze-up') and longer seasonal ice-free periods (Stroeve et al. 2012; Overland and Wang 2013; Stern and Laidre 2016; Stroeve and Notz 2018). These climate-induced changes have been identified as the ultimate threat to the status of polar bears (*Ursus maritimus*); a species whose life history is reliant upon sea-ice as a primary habitat for foraging, movement, and reproduction (Wiig et al. 2015; Regehr et al. 2016). The sensitivity of polar bears to changes in sea-ice habitat quality is evident from the numerous field studies that have demonstrated associations between sea-ice habitat metrics and polar bear survival, body condition, growth, energy expenditure, movement patterns, distribution, reproductive performance and abundance (e.g. Stirling et al. 1999; Regehr et al. 2007; Rode et al. 2010; Cherry et al. 2013, 2016; Lunn et al. 2016; Obbard et al. 2016; Johnson et al. 2020; Laidre et al. 2020a and b; Pagano et al. 2021). Although most of these studies have documented negative consequences for polar bears from long-term changes in Arctic sea-ice, some have documented positive responses, in terms of body condition and abundance (Rode et al. 2014; 2018; Laidre et al. 2020b; Dyck et al. 2020a and b; Regehr et al. 2018; SWG 2016).

Observed variation in the responses of polar bears to a warming Arctic has largely been consistent with predictions (Stirling and Derocher 1993; Derocher et al. 2004; Stirling and Parkinson 2006; Stirling and Derocher 2012; Regehr et al. 2016). Subpopulations in southern portions of the species' range, where the annual sea-ice melts completely during summer and autumn (e.g. polar bears in the seasonal sea-ice ecoregion *sensu* Amstrup et al. 2008) have been the first to experience negative effects (e.g. Stirling et al. 1999; Rode et al. 2010; Obbard et al 2016; Lunn et al. 2016; Johnson et al. 2020). In contrast, some subpopulations in northern portions of the range are currently showing positive effects as these regions shift from multi-year sea-ice to thinner, annual sea-ice and a

longer period of open water (Rode et al. 2014, 2018, 2021; Laidre et al. 2020b; Dyck et al. 2020a and b; Regehr et al. 2018). Thinner, annual ice provides better habitat for both polar bears and their ice-breeding seal prey. Combined with rising ocean temperatures, longer periods of open water, and greater penetration of sunlight into the water column, marine ecosystem productivity in these northerly areas appears to have increased thereby increasing the carrying capacity to support higher densities of bears (Stirling and Derocher 2012; Rode et al. 2014, 2018, 2021; Laidre et al. 2020; Dyck et al. 2020a ; Dyck et al. 2020b ; Häder et al. 2014, Frey et al. 2018). However, these benefits are predicted to be temporary and ultimately replaced by negative effects on polar bears if sea-ice conditions continue to deteriorate in the future. Overall, therefore, the predicted long-term consequence of continued sea-ice loss is that global polar bear abundance is likely to decline by greater than 30% over the next 4 decades (Regehr et al. 2016).

The polar bear is listed as a “Vulnerable” species by the International Union for the Conservation of Nature (IUCN) (Wiig et al. 2015) and a “Species of Special Concern” within Canada (ECCC 2020). Across its circumpolar range, the species is comprised of 19 subpopulations. Current assessments regarding the state of knowledge and demographic status of these subpopulations presents a varied picture reflecting the expected variation in subpopulation responses to climate change, as well as the immense financial and logistical challenges of monitoring this species in its remote, inhospitable range. As of 2021, ten subpopulations were assessed as ‘Data Deficient’, two as ‘Likely Increased’, four as ‘Likely Stable’ and three as ‘Likely Decreased’ by the IUCN’s Polar Bear Specialist Group (PBSG 2021).

1.2 Western Hudson Bay Subpopulation

The Western Hudson Bay (WH) subpopulation is one of three currently assessed as ‘Likely Decreased’ by the PBSG. This subpopulation ranks as one of the most intensively studied large mammal populations worldwide, with a history of scientific research and monitoring dating back five decades (e.g. Jonkel et al., 1972; Stirling et al., 1977;

Derocher and Stirling, 1995a; Regehr et al., 2007; Stapleton et al. 2014; Lunn et al. 2016; Dyck et al. 2016). Implemented predominately through mark-recapture sampling, findings from these studies suggest that WH abundance increased during the 1970s, remained somewhat stable, and then declined by an estimated 22% between 1987 and 2004 (Derocher and Stirling 1995; Lunn et al. 1997; Regehr et al. 2007). A more recent analysis suggests the population remained stable between 2001 and 2011 concurrent with a period of stability in sea-ice conditions (Lunn et al. 2016). In addition to these trends in abundance, linkages have been established between sea-ice conditions in WH and polar bear body condition, reproduction, movement patterns, distribution and survival (e.g. Stirling et al. 1999; Regehr et al. 2007; Cherry et al. 2013, 2016; Lunn et al. 2016; Johnson et al. 2020).

Long-term concern for WH polar bears, centers on the impact of a progressively earlier spring sea-ice break-up and delayed fall freeze-up that has, and will, result in bears spending longer periods on land where they have limited access to food (Stirling et al. 1999; Regehr et al. 2016; Stern and Laidre et al. 2016; Johnson et al. 2020). Satellite-derived sea-ice data for the period 1979 to 2014, indicate that the length of the annual ice-free period in WH is increasing by approximately 9 days per decade (Stern and Laidre 2016). If this trend continues, further reductions in body condition, reproduction, survival and ultimately the abundance of polar bears are expected to occur (Molnar et al. 2010; Lunn et al. 2016). Harvest of WH bears is an additional concern that has the potential to exacerbate subpopulation decline if not managed appropriately.

Within Canada, the assessment of WH status based on scientific knowledge contrasts with that based on Indigenous Knowledge (IK); as summarized by several authors (McDonald et al. 1997; Dowsley and Taylor 2006; Tyrrell 2006; Nunavut Tunngavik Incorporated 2007; Committee on the Status of Endangered Wildlife in Canada 2008; Dowsley and Wenzel 2008; Canadian Wildlife Service 2009; York et al 2016; PBTC 2021). Canada's Federal-Provincial-Territorial Polar Bear Technical Committee (PBTC) assesses WH as "likely declined" based on scientific information and as "increased" based on IK (PBTC 2021). There is consensus between science and IK that polar bear

abundance in WH has increased since the 1970's (Tyrell 2006). There is also agreement that polar bear distribution has changed, that more bears are being sighted around communities, that sea-ice breakup is occurring earlier, and that climate change is negatively influencing seal populations (NWMB 2007). However, in contrast to scientific evidence, Inuit perceptions of WH do not support the notion that abundance has declined since the mid-1980's (Tyrell 2006). Reports of more bears summering on land in the Nunavut portion of Hudson Bay (i.e., the Kivalliq region) and increased incidences of problem bears around camps and communities have been attributed to factors such as higher abundance, habituation of bears to human activities such as ecotourism, changes in behavior due to capture and handling for scientific research, and increasing use of unmanaged garbage dumps in communities along the Hudson Bay coastline (Stirling and Parkinson 2006; Dyck et al. 2007; NWMB 2007; Stirling et al. 2008a; Smith et al. 2022).

With the large body of scientific knowledge about observed and predicted declines in status and the disparities between science- and IK- based assessments, monitoring of WH has become a priority amongst governments, co-management agencies and stakeholders. Accurate and timely information is essential for detecting sudden changes in the subpopulation's status, if and when they occur (Von Graven et al. 2012; Derocher 2013); assessing population viability (e.g. Lunn et al. 2016); supporting adaptive or 'state-dependent' management measures, such as adjustments in harvest levels (Regehr et al. 2017a, b); and resolving apparently diverging views.

In 2011, the GN adopted the use of aerial surveys for monitoring WH (Stapleton et al 2014). Aerial surveys have been used for decades as a tool in monitoring wildlife species worldwide. Although their use for studying polar bears is a recent development, they have proven to be an effective means of monitoring subpopulation abundance, distribution and reproductive performance (Aars et al. 2009, 2017; Stapleton et al. 2014, 2016; Obbard et al. 2015, 2018; Dyck et al. 2017; Conn et al. 2021; Wiig et al. 2021). Aerial surveys are relatively inexpensive and quick compared to the mark and recapture methods that have typically been used to study polar bears. As such, they are an ideal tool for providing the frequent information updates needed to support near-real time adjustments in the

management and conservation of a subpopulation undergoing unprecedented change. For communities in Nunavut that have expressed concern about the handling of bears or potential sampling biases in mark-recapture studies, aerial surveys have also offered an acceptable alternative. Unlike mark-recapture studies, however, aerial surveys do not provide estimates of demographic parameters such as survival rates, needed for population modelling and trend projection, nor do they allow sampling of individual bears to support studies in other areas of priority such as body condition, growth, diet, disease status, movements, habitat use and contaminant burdens (Von Graven et al. 2012). In the context of WH, therefore, aerial surveys and mark-recapture are both considered key components of the monitoring scheme.

A subpopulation wide aerial survey of WH was designed and implemented in 2011 (Stapleton et al. 2014). Based on the results and subsequent simulations, it was determined this survey should be repeated at 5-year intervals in-order to provide sufficient power to detect changes in subpopulation abundance (GN unpublished data). The survey was repeated in 2016 using similar methods (Dyck et al. 2017). Results from both surveys were used to facilitate status assessment by the IUCN and PBTC, as well as inform local harvest management decisions (PBSG 2021; PBTC 2021). Here we report the results of the third scheduled aerial survey of the WH subpopulation, conducted in 2021.

2. OBJECTIVES

The study's objectives were to:

- a) Generate an accurate and precise estimate of polar bear abundance in WH via aerial survey.
- b) Evaluate the distribution of polar bears in WH during the 2021 ice-free season.

- c) Compare results from the 2021 survey with those of surveys conducted in 2011 and 2016 to examine trends in subpopulation abundance, composition and distribution.

3. METHODS

3.1. Study Area

The annual range of the Western Hudson Bay (WH) subpopulation, located at the southern extent of the global polar bear distribution, stretches across roughly 435,000 km² of Hudson Bay and the adjacent coastline including portions of Nunavut, Manitoba, and Ontario (Figure 1). WH is part of the Hudson Bay complex that includes the neighboring Foxe Basin (FB) and southern Hudson Bay (SH) subpopulations (Obbard et al. 2010; Thiemann et al. 2008, Peacock et al. 2010). Although there is marked spatial overlap of polar bear movements from these three subpopulations while on the sea-ice (e.g., Stirling et al. 1999; Obbard and Middell 2012; Sahanatien et al. 2015), past capture-mark-recapture studies (Stirling et al. 1977; Derocher and Stirling 1990; Ramsay and Stirling 1990; Kolenosky et al. 1992; Taylor and Lee 1995; Derocher et al. 1997; Lunn et al. 1997, 2016), genetic studies (Paetkau et al. 1995, 1999; Crompton et al. 2008; Malenfant et al. 2016; Viengkone et al. 2020), and analyses of satellite telemetry data (Stirling et al. 1999; Obbard and Middell 2012; Sahanatien et al. 2015; Viengkone et al. 2020) generally support the currently accepted WH subpopulation boundary (Obbard et al. 2010).

Our study area has been well-described by Brook (2001), Dredge and Nixon (1992), Ritchie (1962), Clark and Stirling (1998), Peacock et al. (2010) and Richardson et al. (2005) and includes the areas described by Stapleton et al. (2014) and Lunn et al. (2016). The terrestrial portion of the study area stretches for approximately 1,500 km from about 35 km southeast of the Manitoba-Ontario border and northwards into Nunavut (approximately 20 km south of Chesterfield) (Figure 1). In addition to Rankin Inlet, the communities of Whale Cove and Arviat (Nunavut) and Churchill (Manitoba) are located

within the boundaries of WH. In general, the southern portion of the study area displays the characteristics of the Hudson Plains ecozone and the Coastal Hudson Bay and Hudson Bay Lowlands. As described by Dyck et al. (2017), the northern portion exhibits Taiga and the Southern Arctic ecozone (Ecological Framework of Canada 2016). Where trees (black spruce [*Picea mariana*], white spruce [*P. glauca*], and tamarack [*Larix laricina*]) are quite common in the southern extents, dwarf birch (*Betula nana*), willows (*Salix spp.*), and ericaceous shrubs (*Ericaceae spp.*) are the norm to the north. The near-coastal southern areas exhibit elevated beach ridges, marshes and extensive tidal flats. There is very little relief (<200 m) with underlying continuous and semi-continuous permafrost. Sea-ice is absent in this region generally from July to November (Stirling et al. 1999; Scott and Marshall 2010; Stern and Laidre, 2016), and biting insects are plentiful during the summer (Twinn 1950).

Spatial separation of WH polar bears from individuals in neighboring subpopulations of the Hudson Bay complex is most complete during the late summer and early fall ice-free season when bears are on land (Peacock et al. 2010). Polar bears of WH come ashore when sea-ice levels diminish to $\leq 50\%$ (Stirling et al. 1999; Cherry et al. 2013, 2016), which generally occurs during July (Stern and Laidre, 2016). Once on land, the bears segregate by sex, age class, and reproductive status within the study area where they exhibit fidelity to their terrestrial summer retreat areas (Stirling et al. 1977; Derocher and Stirling 1990). In general, adult males are found along the coastline, pregnant females and females accompanied by offspring are found in the interior denning area, which is mostly included within Wapusk National Park, and subadults are distributed throughout the study area (Stirling et al. 1977; Derocher and Stirling, 1990; Ramsay and Stirling 1990; Clark and Stirling 1998; Clark et al. 1997; Richardson et al. 2005; Stapleton et al. 2014). When sea-ice reforms during November, all bears except pregnant females return to the ice. Pregnant females give birth in terrestrial dens during December and early January, and these family groups generally depart their dens in March and April to return to the sea-ice (Jonkel et al. 1972; Stirling et al. 1977; Ramsay and Stirling 1988).

3.2. Survey Design and Field Methods

3.2.1. Survey Timing

The polar bear aerial survey was conducted in late August to early September 2021. This survey window during the ice-free period was selected because (a) all polar bears of the WH population are forced to be on land during this time; (b) range overlap between subpopulations within the Hudson Bay complex reaches a minimum, since polar bears exhibit a high degree of fidelity to terrestrial habitats during this period (Derocher and Stirling 1990; Lunn et al. 1997; Stirling et al. 2004; Parks et al. 2006); (c) the absence of ice and snow means that polar bears are readily observable against the landscape; (d) pregnant females are less likely to have begun denning yet and can be detected while moving towards their inland denning area (Stapleton et al. 2014); (e) non-denning bears have not yet begun to make directional northerly movements as they are known to do in the late fall, prior to freeze-up (e.g., Stirling et al. 1977; Derocher & Stirling 1990; Stirling et al. 2004); and (f) the two previous surveys in 2011 and 2016 occurred during a similar window.

3.2.2. Stratification

Like the 2011 and 2016 surveys (Stapleton et al. 2014; Dyck et al. 2017), we implemented a systematic, stratified study design to allocate sampling effort and improve estimate precision. For consistency, we used the same strata and sampling transects as the 2016 survey; themselves a modification of those used in the 2011 survey (Figure 2). The survey strata included the following derived polar bear density distributions: 1) very low, 2) low, 3) moderate, and 4) high. Descriptions of these strata, as provided by Dyck et al. (2017) are presented in Table 1. Polar bears tend to congregate along or near the shoreline during the ice-free season (Derocher and Stirling 1990; Towns et al. 2010), so overland transects were oriented roughly perpendicular to the coast (i.e., against the coastal density gradient; hereafter denoted as perpendicular transects) to improve precision and minimize potential biases (Figure 2; Buckland et al. 2001).

3.2.3. Aircraft

One de Havilland Twin Otter fixed-wing aircraft with radar altimeter and an Airbus AS 350B2 twin engine rotary-wing aircraft with radar altimeter were used to complete the survey. All aircraft throughout the survey maintained, as close as possible, an altitude of 400 feet above ground level (AGL) and an air speed of between 70 and 90 knots for the fixed-wing, and 70 to 80 knots for the rotary-wing aircraft while flying on transect. The Twin Otter fixed-wing aircraft was used to complete the low-density stratum within Nunavut and the very low and moderate density strata west and north of the high-density stratum bounded by the Churchill River, Manitoba, in the south. The twin engine fixed-wing and its ability to fly on one engine was chosen to increase safety while flying over extensive open water transects characteristic of the northern half of the survey study area within Nunavut.

3.2.4. Double Observers

The double observer pair (sight/resight) method is a variation of physical mark-recapture (Pollok and Kendall 1987). The aircraft's front and rear observers comprise two independent survey teams, visually 'marking' (i.e., front observers' sighting) and 'recapturing' (i.e., rear observers' resighting) polar bears. Observer teams must be independent to estimate detection probabilities. This resultant information provides an independent estimate of the number of bears present in the survey strip that were not observed by either team (Laake et al. 2008; Buckland et al. 2010).

The double observer pair method requires two pairs of observers on each of the left- and right-hand sides of the aircraft (Figure 3) (Buckland et al. 2001; Pollock and Kendall 1987). One "primary" observer sits in the front seat of the aircraft and a "secondary observer" is located behind the primary observer on the same side of the aircraft. To ensure visual isolation, a barrier was installed between same side observers to remove any visual cues that could modify an observer's ability to sight the animal. Observers waited until bear groups passed before calling out the observation to ensure independence of

observations. The data recorder/recorders categorized and recorded counts of each bear (group) into “primary only”, “secondary only”, and “both”.

3.2.5. Fixed-Wing

Within the fixed-wing aircraft, we utilized an 8-person platform; 4 dedicated observers, 2 data recorders (for each of the left and right primary and secondary observer pairs) and a pilot and co-pilot. Observers within the fixed-wing survey crew included members of Hunters and Trappers Organizations in the Kivalliq region of Nunavut. The observers were further divided into primary and secondary teams, each isolated from the other using visual barriers between the seats as well audio barriers using two independent intercom systems monitored by each of a primary data recorder/navigator and a secondary data recorder/navigator. The pilot’s responsibilities were to monitor air speed and altitude while following transects pre-programmed on a Garmin 650T Geographic positioning system (GPS). The data recorder/navigators were responsible for monitoring a second and third identically programmed GPS unit for the purposes of double-checking the position as well as to record the geographic position, body condition, composition and numbers of observed polar bear groups on data sheets.

The positioning of the four observers within the aircraft differed during and between survey days and was adjusted to account for any possible variability in sightability or the detection of polar bears associated with seat position. The front and rear observer exchanged spots mid-day, and the left and right sets of observers changed periodically. The data recorders and pilots did not vary their position within the aircraft and remained consistent during the survey.

3.2.6. Rotary-Wing

The AS 350B2 only allowed for a four-person configuration due to weight and balance issues while carrying full fuel as well as seating configuration. Using this configuration only the secondary observers were dedicated observers while the left primary observer

seat was occupied by a data recorder/observer and the right primary position by a pilot/observer. Additionally, observers could not exchange primary and secondary positions using this configuration to determine sightability differences between seating positions. While the methods used during this study generally followed those used by Stapleton et al. (2014), it is important to note that no pooling of front and rear observers was made. All observations made during this study were independent.

3.2.7. Distance Sampling

In addition to the deployment of the double observer pair method within all aircraft, we also collected observations using distance sampling. The distance sampling method followed Buckland et al. (1993, 2004, 2010) and used the *mrds* (Laake et al. 2012) R package (R Development Core Team 2009) to model stratified line transect observation data and estimate density and abundance for polar bears. Using the conventional distance sampling approach (CDS), we modeled the probability of detecting a group of polar bears and their densities within five delineated strata as a function of distance where the detection function represents the probability of detecting a group of polar bears, given a known distance from the transect (Buckland et al. 2001). Recognizing that other variables may affect the detection probability, density estimates were also derived using multiple covariate distance sampling (MCDS), which allowed us to model probability of detection as a function of both distance and one or more additional covariates (Buckland et al. 2004). This approach was explored in-order to increase the reliability of density estimates made on subsets of the data based on terrain, vegetation, and environmental conditions, and to increase precision of the density estimates within each unique density-derived stratum (Marques et al. 2007).

For the fixed-wing portion of the survey only, and in addition to flying to the observed bears for position and data collection, we also used distance bins marked out with streamers and tape on the wing struts after Norton-Griffiths (1978) (Figure 4). In total, 6 distance bins were used including the following: 0-200 meters, 200-400 meters, 400-600 meters, 600-1,000 meters, 1,000-1,500 meters, and 1,500-2,000 meters. Though binned

observations were not used during analysis, they did inform on the precision of binning for distance sampling platforms when compared to the actual observation waypoint recorded.

3.2.8. Observations

Polar bears observed while flying along a transect line were considered on-transect while those observed while ferrying to, from, or between transects, or to bear and/or wildlife sightings, were considered off-transect. Because polar bears are often found in groups, each observation (whether an individual or group) represented a group of polar bears. In this work a group of polar bears was defined as one or more individuals within a visually estimated 100-meter radius of one another. All observations were investigated by moving off the transect line to the center of the group as they were initially observed, to record the location, group size, sex/age classes, body condition.

We determined sex and body condition, to the extent possible, from approximately 30 meters altitude. Sex of bears was determined based on body size, the presence of morphometric characteristics (e.g., such as scars, large head, thick neck, long fur on front legs, vulva patch and urine stains) and behavior when encountered (SWG 2016). Age-class assessment from the air can be accomplished reliably for adult males, pregnant females, and members of family groups (Government of Nunavut, unpublished data; SWG 2016). Based on these methods, polar bears were classified as male or female, and as adult males (6+ years), adult females (5+ years), subadult males (2 to 5 years), subadult females (2 to 4 years), yearlings (>1 and < 2 years), and cubs-of-the-year (<1 year).

A general, relatively robust though subjective fat index has been successfully used in past studies to assess body condition of polar bears (Stirling et al. 2008; SWG 2016; Laidre et al. 2020a, b; Dyck et al. 2020a, b; Dyck et al. 2022). Standardized body condition indices [i.e., poor (1), fair (2), good (3), excellent (4) and obese (5)] were scored for each individual bear (Stirling et al. 2008). Each aircraft had at least one experienced biologist

on board who could identify age classes and body conditions of observed bears with confidence.

Additional covariates that could affect detection probabilities were recorded for each group including activity when first sighted, height and density of surrounding vegetation, habitat class, visibility, cloud cover, glare and general habitat description (Table 2). Observation times were kept to a minimum to reduce disturbance and stress. All distances to the observations were measured perpendicularly from the transect line to the center of the observation and recorded along with the observation's date and time of day. It was assumed that the bear location at initial observation was determined accurately with no effect of movement after detection on estimated distance from the transect line. The distance from line was then estimated using shapefiles of transect lines with GIS methods. All aircraft deployed the distance sampling methods and collection of covariate data consistently across the study.

3.2.9. Coastal Contour Transects

Like the 2011 WH survey (Stapleton et al. 2014), we additionally surveyed along comprehensive coastal contour transects covering the entire coastline of WH, independent of the transect flown perpendicular to the coast. Contour transects were flown at or slightly below the high-water line (HWL) with one side of the aircraft dedicated to monitoring tidal flats and near-shore waters (i.e. swimming bears). We surveyed along coastal contours as close to high tide as possible to minimize tidal flat exposure and reduce the need to double-back to ensure that the coastal zone was comprehensively covered. Observers looked for bears as far as they could reasonably see, not within a pre-defined strip width. Because perpendicular transects were extended to the shoreline and over tidal flats (where applicable), some bears along the shoreline could be sighted from both perpendicular and coastal transects. Bears sighted on tidal flats or in nearshore waters were considered within the coastal zone (i.e., on land, where area could be estimated with GIS) in order to calculate density. Although collected, coastal contour data

are not analyzed and present in this report since such data were not collected during the 2016 survey thus preventing comparison of the three surveys.

3.3. Data Analyses

3.3.1. Data Screening and Truncation

Data was initially screened for outlier observations that occurred at far distances therefore creating a tail on the detection function that can be difficult to fit. A right truncation distance that eliminated the upper 5% of observations was considered to minimize the influence of these observations (Buckland et al. 1993, Stapleton et al. 2014). The blind spot under each aircraft was estimated using geometric formulas. From this, left truncation distances were estimated for the twin otter as 98.9 m and approximately 70 m for the AS350B helicopter. Adjusted distance from the transect line was then estimated as the distance from the transect line minus the left truncation distance for each aircraft.

Like the survey in 2016 (Dyck et al. 2017), but unlike that in 2011 (Stapleton et al. 2014), we left truncated both the front (pilot and data recorder) observations from the helicopter rather than only left truncating the rear observations. The rationale for this was that we wanted to keep the data sets as similar as possible for the double observer analysis. There were 3 observations of 7 bears that were only observed in the rear observer blind spot by the front observers in the helicopter. Therefore, the degree of reduction due to left truncation of the helicopter data was not large.

3.3.2. Distance Sampling Double Observer Analysis

Analysis methods

Mark-recapture distance sampling methods were applied to the survey data (Buckland et al. 2004, Laake et al. 2008a, Laake et al. 2008b, Buckland et al. 2010, Laake et al. 2012). A mark-recapture / distance sampling model assuming point independence was used which allows estimation of the detection probabilities at the transect line (or left truncation

distance) using independent double observer methods with distance sampling methods used to model the decline in sighting probabilities as a function of distance from the survey line.

Covariates that affected bear sightability were considered that included environmental, observer and survey factors (Table 3). These covariates included group size, aircraft type, observer, and visibility. Like the 2016 survey, a remote sensing-based covariate (*RSveg*) based on LANDSAT 8 vegetation classification was also considered (Figure 5). The rationale behind this covariate was that it would systematically index dominant vegetation types in the proximity of observations therefore providing the best comparison of habitat and potential obstruction of observations across all observations. The main categories in Figure 5 that were present in the study area were gravel, shrub, trees, low vegetation, and water.

The twin otter fixed-wing aircraft had 2 dedicated observers per side of the aircraft. The A-star helicopter had 2 dedicated surveyors in the back seat of the helicopter and the pilot and data recorder/navigator as observers in the front. The pilot and data/recorder did not have the same view as the observers and were distracted by piloting the helicopter and navigating/data recording. Therefore, special covariates were formulated for the pilot and data recorder/observers in this aircraft.

Distance model fitting

A sequential process was used for model building. First, parsimonious distance sampling models were formulated using a mark recapture model with constant detection probabilities. Once the most supported distance model was determined, parsimonious mark-recapture models were formulated using the most supported distance model as a base model in the mark-recapture model analysis. As a final step, optimal distance and mark-recapture models were combined and assessed for goodness of fit and overall parsimony. Information theoretic methods (Burnham and Anderson 1992) methods were used to assess relative model fit. More exactly Akaike Information Criterion (AIC) were used as an index of model parsimony with lower scores indicating a model that explained

the most variation in the data set with the least number of parameters. The difference between the most supported model and given model was evaluated (ΔAIC) to indicate relative support with models with ΔAIC values of less than 2 being of interest. Akaike weights were used to estimate proportional support of models. Models were averaged based on $AICc$ weights using the *AICcmodavg* (Mazerolle 2016) package in program R (R Development Core Team 2009). The AIC score indexes relative fit but does not provide a test of overall goodness of fit. Goodness of fit tests incorporated the *mrds* package as well as graphical methods were used to further evaluate fit of the most supported models.

Abundance estimates were derived for the most supported models with variances being estimated assuming sequential systematic sampling (the S2 estimator in *mrds*). This estimator accounted for sequential lines sampling in the survey (Innes et al. 2002, Fewster 2011).

3.3.3. Trend Analyses

Given the previously observed declines in WH abundance and predictions regarding future decline, we examined estimates from the current series of 3 aerial surveys that have been conducted at 5-year intervals for evidence of decline. Data from the previous 2 projects were re-analyzed using the same methods (Dyck et al 2017). Trends in polar bear abundance estimates from the 2011, 2016 and 2021 WH distance sampling surveys were initially compared graphically. Estimates of trend were then derived using ratios of estimates. A simulation approach that assumed log-normal distributions of estimates was used to test for significance between successive estimates as well as confidence limits on overall (gross) change and yearly change in estimates. Log-normal distributions were assumed since they best describe the distribution of estimates from distance sampling and are also assumed when estimating confidence limits of estimates (Buckland et al. 2004). One thousand simulations of estimates were generated from a log-normal distribution for each year. The proportion of simulations where gross change (the ratio of successive estimates i.e. $N_1:N_2$) was greater than 1 was tallied. If this proportion was

less than 0.05 then a significant decline was suggested. We note this test is equivalent to a one tailed test between two abundance estimates testing for evidence of decline (null hypothesis $H_0: N_2 \geq N_1$ and alternative hypothesis $H_a: N_2 < N_1$). Confidence limits were then derived based on the 2.5th and 97.5th percentile of the resulting distributions of gross (GC) and annual change (with $\lambda = GC^{(1/\text{survey interval})}$). The 1-tailed hypothesis provides a more powerful test for decline than a 2-tailed test (which tests if the 2 estimates are equal). A 1-tailed test was justified given previously observed and predicted declines in the subpopulation; a question of key management interest.

To explore whether change was occurring within specific segments of the subpopulation, abundance estimates from 2011, 2016, and 2021 were post-stratified to derive estimates for adult males, adult females, and subadults. Trends within these segments were examined. Finally, there was interest in assessing whether change was occurring evenly across the study area or whether there were geographic patterns in change. To explore this, the 2011, 2016, and 2021 study areas were divided into Nunavut (Area 3), the area from Nunavut to the Nelson River (Area 2), and from the Nelson River to eastern boundary of WH in Ontario (Area 1). To do this required dividing the moderate strata used in 2011 and 2016 into a moderate north and south strata as was used in 2021. Estimates were derived based on strata in these areas for overall estimates as well as estimates of age/sex groups. The 2011 strata were redrawn and the areas of the 2 new strata double checked to make sure they were similar to the original single stratum.

Distance sampling analyses were conducted using the *mrds* (Laake et al. 2012) R package (R Development Core Team 2009). Data was explored graphically using the *ggplot* (Wickham 2009) R package with GIS analyses conducted using the simple features (*sf*) (Pebesma 2018) R package and QGIS program (QGIS Foundation 2020).

4. RESULTS

4.1. Survey Timing and Effort

Extensive forest fires across Canada in the summer of 2021 limited the availability of suitable aircraft and delayed the planned start of 2021 WH polar bear survey by approximately 1 week. The survey was flown between August 21st and September 6th. This compares to survey windows of August 13th to 29th and August 12th to 21st in 2011 and 2016, respectively. Using 50% sea-ice cover in WH as an index of ice break-up (e.g. Laidre and Stern 2016), the 2011, 2016 and 2021 surveys were conducted at 67 to 83, 55 to 64 and 65 to 81 days post-break-up, respectively.

Including weather-related delays, 2021 survey strata between Chesterfield Inlet and Churchill, flown using the Twin Otter, took 6 days to complete (August 21-27). The remainder of the study area, flown by helicopter, took 13 days (August 24-September 6). Approximately, 41 and 72 hours were flown with the Twin Otter and helicopter, respectively, for an estimated total distance of approximately 17,000 km, including ferry time. Weather during the survey was good and allowed for completion of all transects and coastal contour surveys.

4.2. Summary of Observations

Overall, 194 bears in 125 groups were observed during distance sampling with 176 observed on transect and 18 observed off transect (Table 4). Group sizes ranged from single individuals up to groups of 6. Eighteen cubs-of-the-year (COY) and 17 yearlings were observed. Mean litter sizes were 1.46 (SD: 0.50; n = 13) and 1.39 (SD: 0.63; n = 13) for COYs and yearlings, respectively¹.

Polar bear sightings were not uniformly distributed across WH (Figure 6; Table 4). Similar to surveys in 2011 and 2016, the highest concentrations of bears were documented in the high-density stratum, encompassing the historical Environment Canada study area, including Wapusk National Park and along the coast of southeastern WH. Eight percent

¹ Includes off transect observations

of observations were in Nunavut. In general, observations were concentrated along or near the coast throughout the subpopulation (Figure 6). However, inland bears >10 km from the coastline were often recorded in the high-density stratum and less frequently observed in the southeastern portion of WH (the southern moderate density strata). Adult males were concentrated along the coast. In contrast, lone adult females or adult females with offspring, either COY or yearlings, were most often observed inland.

4.3. Abundance Estimation

4.3.1. Truncation of Observations

Observation data were left and right truncated (based on 97th percentile of distance from line after adjustment for left truncation) (Table 5 and Figure 7) yielding a dataset of 154 bears for analyses. Left truncation was based on measured blind spots for each aircraft and eliminated data not available to both observers. Using the right truncation distance (2100 m) eliminated excess observations at the tail end of the detection histogram that would exert influence on fitting of detection functions. A sensitivity analysis was conducted to validate the right truncation distance (Appendix 1).

4.3.2. Covariates

Habitat classes (as classified by observers) did not have sufficient sample sizes to allow modelling of detection functions for each class. These were pooled into similar categories (Figure 8). Overall, the detection histograms for each category were relatively similar (when considering differences in sample sizes). The remote sensing vegetation classification (RSveg) was also pooled into 3 categories (Figure 9). The detection histograms for each category were also relatively similar (when considering differences in sample sizes). When plotted on a map, both of these pooled vegetation classifications corresponded to shoreline and inland habitats (Figure 10). Other descriptors of vegetation, recorded for each bear observation, were vegetation height and density. Low density vegetation generally corresponded with vegetation of low height (Figure 11).

Vegetation density also corresponded to general habitat class with the shore/tidal areas mainly having low vegetation class ratings (Figure 12).

Group size can influence detectability. However, the relative range of group sizes was small with most observations being of single bears and few large groups over 3 bears (Figure 13). A bear's activity when first observed was also considered. Observations were pooled into 4 main categories of activity (Figure 14). Visibility was recorded, with the majority of observations 101 of 102 being in clear to broken conditions and only one observation in fog. Glare, based on sun angle, was also recorded with 91 of 102 observations having no glare. Sun angle was overhead for most observations.

4.3.3. Summary of Double Observer Data

Sample sizes for observers were much higher for the helicopter that flew the higher density strata. Detection probabilities ranged from 0.6 to 1 (Table 6). Detection histograms amongst individuals were relatively similar for the helicopter-based observers (Figure 15). Low sample sizes precluded assessment of individual histograms for the Twin Otter-based observers.

A related issue occurred with the helicopter where the pilot and a potentially weaker observer were on the right side of the aircraft for the majority of the survey (Figure 16). This potentially resulted in a reduced number of observations on this side of the aircraft. To assess this issue, models were fit to exactly test the difference in detection function and double observer probabilities of sighting on the line for the right side of the helicopter. A HeliSide covariate was used which modelled detection functions (distance sampling) or detection probabilities at the line (MR analysis) for the right and left side of the helicopter and fixed-wing (sides pooled given limited sample sizes). Results of this analysis, presented in appendix 1, found little evidence of differences in detection function between the left and right side of the helicopter.

4.3.4. Model Selection

The first phase of model selection was assessment of covariates (Table 3) that describe the shape of the distance sampling detection function (Table 7). None of the covariates had substantial support with a constant hazard rate model being most supported. A variety of models had some support as indicated by ΔAICc scores of less than 2. The next step was assessment of variation in sightability near the aircraft from double observer models. The most supported distance model (hazard rate constant) was used for this analysis. Of covariates considered, vegetation density (VegDensity) had the highest support (Table 8).

The most supported distance and double observer models were combined (Table 9). Minimal variation was detected in the detection function based on covariates. A constant distance sampling model showed the highest support with double observer detection varying with vegetation density. Other models with helicopter navigator/data recorder and habitat class as covariates were supported, however, the sensitivity of abundance estimates (N) to model variation was low.

Goodness of fit of model 1 (Table 9) to the distance sampling ($\chi^2=4.7$, d.f.=4, $p=0.31$), mark-recapture ($\chi^2=15.3$, d.f.=12, $p=0.23$) components was adequate with adequate overall fit of ($\chi^2=20.1$, df=12, $p=0.23$). A Von-Mises test also suggested adequate fit (Test statistic=0.028, $p=0.98$). Plots of fit to the model 1 suggest reasonable fit of predictions to front (observer=1) and rear (observer 2) observations as well as duplicate observations (seen by both observer) (Figure 17). Also suggested is minimal dependence between observer detections (as suggested by no directional trends in histograms by distance which indicate conditional probabilities). The mean single observer probability at the line for model 1 was 0.69 (SE=0.04, CV=0.07) with a combined (both observers) probability of 0.89 (SE=0.04, CV=0.46). Figure 18 shows predictions from model (DS (HR(.), MR(VegDensity) with predictions further delineated by VegDensity category and also group size observed, as represented by data point size

Estimates of abundance from the most supported model (Table 9, model 1) by strata are given in Table 10. A model averaged estimate of abundance using the models in Table 9 is 618 bears (SE=119.3, CI=425-899, CV=0.19). Of additional interest was a breakdown of estimates by adult males, adult females and subadults. Post-stratified estimates for these groups are presented in Table 11.

4.4. Abundance Trend Analyses

Data sets from WH aerial surveys conducted in 2011 and 2016 were analyzed and the results compared with those of the 2021 survey. A visual comparison of distance sampling total abundance estimates suggests a decrease in abundance from 2011 to 2021 (Figure 19). Additionally, post-stratified estimates suggest a decrease in the adult female and subadult classes with no apparent trend in adult males (Figure 19).

Gross and annual changes were estimated using the ratio of survey estimates with confidence limits calculated assuming a log-normal distribution of estimates for adult males, adult females, subadults, and all bears (Table 12). The annual rate of growth changed from 0.90 for subadults to 1.00 for adult males for the period 2011-21. The estimate of gross change was significantly lower than 1 for the 2011-21 interval for females, subadults, and all bears (at $\alpha=0.1$) suggesting declining abundance. This estimate was based on the proportion of log normal simulations where the estimate from 2021 was greater than the estimate of 2011. Similar results were derived from standard t-test comparisons of estimates (Appendix 2).

Of further interest was geographic trends in each sex and age class. Downward trends in adult females and subadults were suggested in Area 2 with less distinctive trends in other areas (Figure 20). Trends were significant for adult females and subadults between 2011 and 2021 for Area 2 but were not significant in other areas (Table 13).

4.5. Polar Bear Mortalities

Three polar bear carcasses were found while conducting the 2021 WH survey (Figure 21). Based on body size and dentition, one appeared to be an adult female and another a subadult. The third was identified as a 21-year-old adult male of known age, based on previous capture and tagging records. All three carcasses were in advanced stages of necrosis making cause of death difficult to determine. However, the adult male was noted to be in poor body condition making starvation a potential contributing factor in this case. A fourth polar bear carcass, that of an 18-year-old adult female, was found in WH in August 2021 during polar bear research unrelated to the aerial survey (S. Atkinson pers. obs). In 2 of the 4 cases, polar bears were observed feeding on the carcasses of their conspecifics.

5. DISCUSSION

5.1. Distribution

With some exceptions, discussed later in this report, the summertime distribution of polar bears within WH in 2021 (Figure 6) was broadly similar to previous surveys in 2011 and 2016 (Stapleton et al. 2014; Dyck et al. 2017). The northern part of WH extending north from the Manitoba-Nunavut boundary, referred to as the low-density strata or Area 3 in this study, contained relatively few bears. Eight percent of bear observations recorded during the survey were found in this region, along the coast and offshore islands, compared to 6% and 5% in 2011 and 2016, respectively (Stapleton et al. 2014; Dyck et al. 2017). In the area extending Northwards from the Nelson River up to the Nunavut border, referred to as Area 2 in this study, the highest densities of bears occurred along the coastline. However, we also encountered a significant number of individuals far inland (>10 km), mostly within the bounds of Wapusk National Park. In contrast, virtually all polar bears in the region from the Nelson River eastward into Ontario (denoted as Area 1) were highly concentrated in a relatively narrow strip along the coast. In both areas, adult males were most often found on the coast while adult females tended to occupy areas further

inland. These patterns of distribution and segregation have been well-documented in previous studies and attributed to several factors, including variation in the availability of suitable inland habitats for denning, the avoidance of conspecifics, thermoregulation, and insect avoidance (Stirling et al. 1977; Derocher and Stirling 1990; Lunn et al. 1997; Clark and Stirling 1998; Richardson et al. 2005).

Looking at estimates of abundance for the 3 areas of WH (Figure 20), we also found little evidence that the distribution of bears within WH has changed significantly over the last 10 years. Although, the estimated abundance of adult female and subadult bears in Area 2 decreased significantly between the 2011 and 2021 surveys, concurrent increases of these types of bears in Areas 1 (Cape Tatnum) or 3 (Nunavut) of WH were not found (Table 13). This suggests that the observed declines are not the result of more bears occupying regions to the north or southeast of what has historically been considered the core summer range of the WH subpopulation. Emigration, reduced survival and/or reduced reproductive performance could account for the observed declines. However, the finding that bear numbers (in absolute terms) were unchanged in areas bordering the northern (Area 3) and southeastern (Area 1) boundaries of the subpopulation between 2011 and 2021, makes emigration a somewhat less plausible explanation for the observed declines. Increased emigration from WH, if driven by changes in habitat availability, quality or phenology, such as sea-ice break-up patterns, would likely be concurrent with, or preceded by, apparent reductions in the abundance of bears in these 'boundary' areas. This is especially the case in Area 3, bordering the Southern Hudson Bay subpopulation, where there are high densities of bears and the distribution of remnant summertime sea-ice is known to affect the location bears come ashore (Stirling et al. 2004; Cherry et al. 2013).

Given our findings regarding distribution and the low number of bears observed and estimated in the Nunavut (Area 3) portion of the subpopulation, on-going mark-recapture studies in WH that focus sampling effort in a core study area centered around Churchill and Wapusk National Park (Area 2) are unlikely to contain significant bias in estimates of abundance or vital rates due to unsampled bears in Nunavut. However, relative to

historical mark-recapture sampling (e.g. Regehr et al. 2007; Lunn et al. 2016), increased sampling effort is recommended in the area east of the Nelson River (Area 1), along the coast towards Ontario. As documented by the 2011, 2016, 2021 aerial surveys, and coastal surveys conducted by the Government of Manitoba, this area is typically occupied by several hundred bears during the on-land period. In generating estimates of WH abundance for conservation and management planning, it has been assumed by this and past aerial survey studies (Stapleton et al. 2014; Dyck et al. 2017) that these bears are part of the WH demographic unit. Studies are currently in progress to test this assumption (D. McGeachy per comm.).

5.2. Abundance

The estimated total abundance of WH polar bears in 2021 was 618 bears (SE=119.3, CI=385-852) based on model averaging. Overall, there was minimal change in estimates with different models suggesting that this estimate is robust to model selection uncertainty. The relative simplicity of the most supported distance sampling (constant) and double observer (vegetation density) models was surprising, given the range of covariates included in the analyses. However, inspection of histograms from the observed data does not indicate a large degree of variation in detection functions beyond differences in sample sizes. The covariate explaining variation in detectability in the vicinity of the aircraft was vegetation density. Vegetation density was also associated with vegetation height whereby low-density vegetation tended to be of low height (Figure 8). Support for this covariate suggests differences in detection between the inland versus coastal areas of WH. Bears occupying inland shrub or treed habitats tended to be harder to detect than those in open coastal areas.

Similar to the WH 2021 survey, previous aerial survey-based estimates of abundance in both WH and the neighbouring Southern Hudson Bay (SH) subpopulation (in 2011 and 2016) have all relied on relatively simple models with vegetation density, or a similar covariate reflecting vegetation density and height, included in top models (Stapleton et al. 2014; Dyck et al. 2017; Obbard et al. 2015, 2018). These earlier surveys have also

included a covariate describing visibility, based on weather conditions, in some top models. This covariate was not among top models in the 2021 analysis potentially due to good survey conditions (i.e. clear, sunny skies) as well as the reduced sample sizes relative to 2011 and 2016 surveys. Overall, despite some differences in aircraft types and observers, the similarity of models amongst the 2011, 2016 and 2021 surveys suggests the sampling methods, maintained across these surveys, are robust and yield comparable datasets suitable for long-term trend monitoring.

The precision of the 2021 estimate was comparable to that of previous WH aerial surveys with a coefficient of variation (CV) of 19% compared to 17% for both the 2011 and 2016 surveys. Aerial surveys of polar bears conducted during the on-land or minimal sea-ice seasons have proven to be a cost-effective monitoring tool in subpopulations where flat terrain and high densities of bears that show interannual fidelity to on-shore regions facilitate detections (Stapleton et al. 2014, 2016; Dyck et al. 2017; Obbard et al. 2015, 2018). These types of surveys have yielded abundance estimates with CVs ranging from 11-19%. In contrast, surveys over sea-ice during the spring tend to be more expensive and have resulted in CVs ranging from 13-39% (Macdonald et al. 1999; Wiig and Derocher 1999; Evans et al. 2003; Aars et al. 2009, 2017; Conn et al. 2016; Wiig et al. 2021). The relatively poor precision of some 'on-ice' surveys is due to low bear densities and reduced detection probabilities on ice. On-ice surveying of WH is not recommended for several reasons including potential cost, expected poor precision and the extensive range overlap amongst individuals of the WH, Foxe Basin and Southern Hudson Bay subpopulations that is known to occur on the sea-ice (Peacock et al. 2010; Viengkone et al. 2018). Continued monitoring of the WH subpopulation via summertime aerial surveys is recommended.

5.3. Assumptions and Potential Biases

Generating unbiased (accurate) abundance estimates via the distance sampling method used in the survey is dependent on several assumptions (Buckland et al. 2001). To satisfy the assumption that bears were randomly distributed with respect to distance from the

transect line, we surveyed with systematically spaced transects oriented perpendicular to the coastal density gradient; the same or similar transects flown in previous surveys (Stapleton et al. 2014; Dyck et al. 2017). A second assumption is that all bears present on the transect line or at the point of left truncation (i.e. distance zero) when the aircraft flies over are detected (Buckland et al. 2001). This assumption was evaluated in our analysis by estimating the combined double observer detection probability. Combined detection at the point of left truncation was 0.89 in 2021 compared to 0.97 and 0.90 for the 2011 and 2016 surveys respectively. This suggests that most, but not all, bears ‘on the line’ were detected. However, this bias was corrected by estimated detection probabilities on the line using the mark-recapture distance sampling approach.

A third assumption is that bears are not disturbed/displaced from their initial location, by the approaching survey aircraft, before being observed. This potential source of bias was minimized by maintaining rapid flight speeds of up to 150 km/hr thus reducing opportunities for bears to move great distances before detection. Ninety-three percent of bears were either sitting, laying, standing, walking or swimming and 7% were running when first observed during the survey. This suggests that most bears did not move or did not move significantly in response to aircraft. Accurate measurement of the distance between a bear sighting and the transect line is also essential (Buckland et al., 2001). We used GPS and GIS to measure distance from the line in accordance with accepted methods (Marques et al. 2006) that have been used extensively for polar bear aerial surveys (e.g. Aars et al. 2009, 2017; Obbard et al. 2016, 2018; Stapleton et al., 2014, 2016; Wiig et al. 2021). Assuming bears were recorded at their initial location, as discussed above, this method should have provided accurate distance data.

Another potential source of bias was the difference in number bear observations between the left and right sides of the helicopter either due to chance or weaker observers on the right side that were not accounted for by the mark-recapture distance sampling models. Although relatively small samples may have limited power, additional analyses to explore this issue did not provide evidence of bias in abundance estimate (Appendix 1). Additionally, any potential bias, while affecting the overall abundance estimate would not

explain differences in abundance trends amongst adult males, adult females and subadults that we observed between 2011 and 2021.

Polar bears that were entirely hidden from both front and back observers during the survey would not have been incorporated into the abundance estimate. Two sources of this 'availability bias' were possible in our survey. Some WH polar bears, typically pregnant females, use earthen dens during the ice-free season, entering them as early as August (Jonkel et al. 1972; Stirling et al. 1977; Clark et al. 1997; Clark and Stirling 1998; Lunn et al. 2004; Richardson et al. 2005). Although we cannot correct for bears that were underground and entirely unavailable for observation during the survey, the number of such individuals was likely low. During the survey we observed numerous dens, including some that were freshly excavated. When observed, these dens were inspected from the air but none were found to be occupied. Bear occupying dense vegetation may also be harder to observe from the air than those in more open habitats. This reduced probability of observation was accounted for in the abundance estimate by incorporating a vegetation density covariate in models. Nevertheless, some individuals sheltering under dense vegetation, such as willows or trees, may be completely unavailable for observation. In particular, inland areas parts of WH, are tree covered creating the potential for bears to be unobservable from the air. However, densities of bears in these areas tend to be low since these treed areas are not preferred habitat for most bears. Thus, while we are unable to quantify this potential source of availability bias, our impression was that although trees and brush impeded detection and reduced sighting probabilities, it is likely that very few bears on or near the transect line were completely concealed by vegetation.

Directional, or migratory, movements of bears in, out or within the study area during a survey could lead to under and over counting of bears or observations of the same individuals more than once. Polar bears in WH make several directional movements during the on-land period. The first of these involves their migration from sea-ice onto land in the summer, the timing of which is known to be determined by sea-ice concentration (Cherry et al. 2013; Cherry et al. 2016; Pilfold et al. 2017). To minimize this

potential bias, the survey was timed to occur after bears had migrated to land. Using 50% sea-ice cover as an index of break-up (Laidre and Stern 2016), the 2021 survey occurred 65 to 81 days post-break-up. Although the survey start was delayed due to availability of aircraft, the survey window was almost identical to that of the 2011 survey (67 to 83 days post-break-up) but approximately 2 weeks later than the 2016 survey. All three surveys occurred well after the 50% sea-ice threshold and when Canadian Ice Service maps indicate that WH was essentially ice-free. Thus, all WH bears should have been on-land at the start of these surveys. WH bears are also known to make directional movements northwards later in the fall (Stirling et al. 1977, Derocher and Stirling 1990; Bohart et al. 2020). Again, the survey was timed to avoid this period thus eliminating potential for this source of bias. Finally, field work was completed within a narrow temporal window and the aircraft were able to cover large expanses of land within a single day. Therefore, distributional shifts within WH during the study period did not impact our results.

In summary, because this study met analytical assumptions and potential sources of bias were minimized, we believe the aerial survey-based estimate of 618 bears (SE=119.3, CI=385-852) accurately reflects the number of polar bears within the bounds of WH during August 2021. Any biases in the aerial survey would likely result in an underestimate of the true polar bear abundance in WH. However, we note that such bias, if present, would not affect the ability to detect trends in abundance since the same methods (hence the same biases) were utilized in the 2011, 2016 and 2021 surveys.

5.4. Trends in Abundance

Estimates derived for the WH subpopulation indicated a possible decline in total bear abundance between 2011 and 2021. The 2011 survey produced an estimate of 949 bears (95%CI: 618–1280), the 2016 survey an estimate of 842 bears (95% CI: 562–1121) and this survey derived an estimate of 618 (SE=119.3, CI=385-852) for 2021. Although differences amongst these estimates were not statistically significant, total abundance has declined consistently between successive surveys. Significant reductions in the

number of subadult bears and adult females appear to account for this observed change. Interestingly, the abundance of adult males remained unchanged during this period. These changes may be the result of internal demographic processes within WH (i.e. rates of birth and death) and/or changes in distribution leading to increased emigration of bears out of WH and into neighbouring subpopulations on a temporary or permanent basis. As discussed below, a review of multiple lines of evidence provides support for both hypotheses.

Several lines of evidence suggest that internal demographics have played a role in the observed decline in WH subpopulation abundance. The finding that abundance of subadult bears and adult females has declined whilst that of adult males has remained stable is particularly striking given its consistency with both long-standing hypotheses and field studies. Reduced recruitment and survival of subadults, hence reduced abundance, are typically among the first demographics effects to occur within large mammal populations experiencing density-dependent regulation (Fowler 1987). For polar bears, it was first predicted almost 30 years ago that negative impacts from things such as climate change would first appear amongst subadult and adult female bears (e.g. Stirling and Derocher 1993; Stirling et al. 1999; Derocher et al. 2004; Robbins et al. 2012; Klappenstein et al. 2020). These two classes of bears have nutritional ecologies that are likely to make them more vulnerable to deteriorating environmental conditions than other polar bears. Subadult bears must sustain the energetic costs of growth whilst also gaining experience in hunting. Adult females have the added costs of repeatedly raising litters of offspring over periods of up to 2 years, which is predicted to reduce their tolerance of fasting relative to that of adult males (Robbins et al. 2012; Stirling and Derocher 2012).

A series of field studies have validated the hypothesis that subadult and adult female polar bears are more sensitive environmental conditions than other classes of polar bears such as adult males. In some subpopulations, experiencing long-term declines in sea-ice, reductions in body condition (itself a precursor to reduced survival) have been greater and/or more readily detected amongst the adult female and subadult classes (Obbard et al. 2006, Rode et al. 2010; Laidre et al. 2020). In WH, Johnson et al. (2020) found that

body condition and energy metrics have declined over time in relation to earlier sea-ice breakup with the most significant effects seen amongst solitary adult females and subadult males. Studies, including several in WH, have also demonstrated that links between sea-ice conditions and survival are stronger amongst subadults and adult females relative to other age and sex classes (Regehr et al. 2007; Bromaghin et al. 2015; Lunn et al. 2016). For subadults in WH, declining abundance between 2011 and 2021 may also be the result of reduced recruitment. Aerial surveys in 2011 and 2016, found low numbers of the yearlings compared to other subpopulations suggesting that recruitment into the subadult age class was poor in these years (Stapleton et al. 2014; Dyck et al. 2017). Additionally, mark-recapture sampling during this period also suggests recruitment has been low in multiple cohorts with the number of yearlings, expressed as a proportion of total captures, being less than 0.06 in 6 of the 10 years (ECCC unpublished data). A series of years with poor recruitment from the yearling age class, combined with potentially lowered survival amongst subadult cohorts, may thus have contributed to the observed decline in subadult abundance.

Changes in distribution leading to increased emigration of bears from WH into neighbouring subpopulations, such as SH, could also account for some of the variation in abundance observed across the 3 aerial surveys. Prevet and Kolenosky (1982) found significant interannual variation in aerial counts of bears along the southern coast of Hudson Bay in Manitoba and Ontario, around the WH and SH boundary, during the ice-free period. They attributed this to ice-dependent variation in on-shore arrival locations suggesting that in years when bear counts on the Manitoba (or WH) side of the boundary were high counts on the Ontario (or SH) side tended to be low and vice-versa. A series of subsequent studies utilizing mark-recapture, telemetry and coastal survey data did not find evidence to support this hypothesis instead finding that WH bears exhibited a high degree of fidelity to on-shore areas during the ice-free period (Derocher and Stirling, 1990; Kolenosky et al., 1992; Lunn et al., 1997; Stirling et al., 1999; Stirling et al. 2004). More recently, however, analyses of telemetry data for adult females in WH have found that the timing of bears' movements to shore and the locations where they arrive on-shore are primarily influenced by environmental variables including wind direction, ice

concentration and ice distribution during break-up (Cherry et al. 2013, 2016; Pilfold et al. 2017; Bohart et al. 2020). In particular, Cherry et al. (2013) found that on average approximately 12% of WH adult females came ashore outside the boundaries of WH, typically further south and east, and within the boundaries of the SH subpopulation. Additionally, WH bears were more likely to come ashore outside WH in years when there was more remnant summer-time ice in SH relative to WH (Cherry et al. 2013). Based on these findings, a degree of year-to-year variation in aerial survey-based estimates of WH should be expected as a result of ice-dependent variation in the locations bear come ashore. In years when ice remains longer in SH relative to WH, a higher proportion of WH bears may come ashore within the bounds of SH where they would be included in a SH rather than WH estimate.

Several lines of evidence support the hypothesis that the observed decline in WH abundance between 2011 and 2021 was to some degree the result of interannual variation in the distribution of bears between WH and SH. Aerial surveys of the SH subpopulation have been conducted concurrently with the surveys in WH in 2011, 2016 and 2021. Pooling estimates from the WH and SH surveys show a decline in total 'Hudson Bay' abundance from 2011 to 2016 but no change from 2016 to 2021 (Figure 22). Notably, between 2016 and 2021, the estimated abundance of SH increased by 223 bears while that of WH decreased by 224 (Northrup et al. 2022). Changes in both subpopulations, at least between 2016 and 2021, could therefore be accounted for by movement of WH bears into SH. Preliminary results from genetic mark-recapture work conducted along the coast of WH and SH provide additional evidence to support this hypothesis. In 2021, biopsy darting conducted as part of a genetic mark-recapture program found that 22% of bears sampled in SH had been previously sampled in WH only (McGeachy et al. 2022). In contrast, sampling within WH did not detect any recaptures of bears previously sampled in SH only.

Although they provide evidence of a potential distribution shift, comparison of abundance estimates for WH and SH, as well as preliminary findings of the genetic mark-recapture program should be interpreted with caution for several reasons. First, recent physical

and genetic mark-recapture sampling effort has been markedly greater in WH relative to SH. For example, for genetic mark-recapture alone, more than 350 bears were marked within WH between 2017 and 2020, while none were marked in SH. This disparity in marking effort would have increased the likelihood of recapturing bears, originally marked in WH, within SH in 2021 and reduced the likelihood of SH marks being recaptured in WH. Second, the vast majority of bears marked in WH and recaptured in SH in 2021 were adult males yet the observed decline in WH appears to be due to declining numbers of subadults and females rather than adult males. Third, adult male bears are likely to exhibit greater flexibility in where they come ashore to spend the summer. Unlike adult females they do not require access to suitable denning habitat or in-land areas in which to avoid infanticide of dependent off-spring by conspecifics (Derocher and Stirling 1990; Stirling et al. 2004). Consequently, trends in abundance resulting from sea-ice related shifts in summer range are more likely to be observed in WH adult males. Our findings that adult female and subadult abundance has declined while adult male abundance has remained unchanged are thus inconsistent with a range-shift hypothesis. Fourth, as noted above, WH bears exhibit a greater likelihood of coming ashore in SH in years when there is more remnant summer-time ice in SH relative to WH (Cherry et al. 2013). If an ice-dependent shift in summertime range were responsible for the observed decline in WH, sea-ice data for 2011, 2016 and 2021 should show that greater amounts of late break-up sea-ice were present in SH, relative to WH, in 2021 versus 2011 or 2016. However, the data suggest sea-ice that remnant sea-ice conditions in July, for example, were very similar in 2021 and 2011 (Figure 23). Finally, if trends in WH abundance were due to a distributional shift with bears moving out of WH, this shift would likely also be apparent within the boundaries of the subpopulation itself. We examined trends in abundance within 3 zones of WH and found declining abundance within the central or core zone of the WH summer range (zone 2). However, similar trends were not apparent in the areas of WH bordering the neighbouring SH and FB subpopulations. Again, these findings do not support a distribution shift hypothesis to explain the changes in WH abundance.

Harvest mortality has also likely contributed to the observed changes in WH abundance. Dependent on sea-ice conditions, the most recent demographic assessment of WH projected a long-term population growth rate ranging from 0.97 to 1.02 from 2011 onwards. Between 2011-2021, annual harvest in WH increased in accordance with the regulated Total Allowable Harvest (GN unpublished data; Figure 24) from a rate of approximately 2.5% of estimated abundance in 2011/12 up to 6.6% in 2021². Since the rate of harvest has exceeded projected population growth, a decline in total abundance between 2011 and 2021 would be expected due to harvest pressure. However, the apparent decline in adult females and subadults but lack of trend in adult males is harder to rectify with a harvest-induced effect. Harvest in WH has been sex-selective with an annual average of 66% males between 2011 and 2021. Subadults have compromised approximately 26% of annual harvest ³, a level comparable with other subpopulations (GN unpublished data). Lunn et al. (2016) found that probability of harvest (H) was highest amongst young adult males (5-9 yrs) and lowest amongst adult females at 0.73 and 0.05, respectively. For subadults, H was 0.44 and 0.28 for males and females, respectively. Given the higher harvest pressure on adult males compared to other classes, a harvest-induced change in subpopulation composition would be expected to appear first amongst adult males rather than subadults and adult females, a pattern not consistent with our results.

5.5. Reproductive Performance

As discussed earlier in this report, aerial surveys in 2011 and 2016 suggested that reproductive performance in WH was poor. Relative to neighbouring subpopulations in the seasonal ice ecoregion, the number of yearlings, expressed as a proportion of all individuals observed, was low suggesting poor recruitment into the subadult age classes (Table 14). Similarly, mark-recapture sampling yielded relatively low numbers of yearlings in 6 of 10 years from 2011 to 2020 (ECCC unpublished data). These findings

² Based on 2011 and 2021 aerial survey abundance estimates.

³ Data available for the period 2010-2019 only.

suggest that over the previous decade WH has experienced a series of years with low recruitment into the subadult age class.

Results from the 2021 survey indicate that yearling numbers were higher and more comparable with levels seen in other subpopulations (Table 14). A similar improvement in yearling numbers was also seen in SH in 2021, suggesting conditions in Hudson Bay over the last few years have been generally favorable for raising offspring (Northrup et al. 2022). Whether this improvement in reproductive performance will continue is unknown. Regehr et al. (2015) estimated conditions necessary for polar bear population persistence which included recruitment levels of 0.1-0.3 yearling per adult female and adult female survival rates between 0.93-0.96. Raw aerial survey observation data indicate that recruitment was approximately 0.14, 0.15 and 0.31 in 2011, 2016 and 2021, respectively suggesting that reproductive performance although variable has likely been sufficient. Of concern with respect to future reproductive capacity in WH, is the apparent decline in subadult abundance. A reduced subadult cohort will eventually result in cascading negative effects on reproduction as these individuals enter the adult age classes and current adult bears begin to either enter reproductive senescence or die (Regehr et al. 2021).

5.6. Mortalities

What appears to be an unusually high number of polar bear carcasses were found in WH during 2021. Three were located during the aerial survey and 1 during other polar bear research activities. Based on flying times for both projects, this equates to approximately 3 carcasses per 100 hours of search effort. By comparison, while flying more than 1200 hours conducting aerial sampling of polar bears during the ice-free period in 4 other subpopulations in the seasonal ice ecoregion, over the last decade, 3 polar bear carcasses (0.25 per 100 hours) were found (S. Atkinson pers. obs.).

Cause and timing of mortality was unknown in all cases, although starvation was likely involved in one case. Interestingly, three of the 4 were adults which is somewhat

unexpected since adult survival rates are higher than other age classes. The observation of other bears feeding on the carcasses is consistent with previous reports of cannibalism amongst polar bears (Lunn and Stenhouse 1985; Taylor et al. 1985; Amstrup et al. 2006; Dyck and Daley 2002; Derocher and Wiig 1999; Stone and Derocher 2007). Amongst bear species, polar bears display the highest reported levels of cannibalism (Allen et al. 2022). Amstrup et al. (2006) suggested incidences of predation and cannibalism amongst polar bears may reflect increased nutritional stress within a subpopulation. However, for the cannibalism observed in WH in 2021, it is unknown whether the mortalities were the result of conspecific predation or opportunistic scavenging on available carcasses.

Given the high number of carcasses found in 2021 and the fact that at least 3 were adults, careful documentation of future carcass observations is recommended to assess whether deeper investigation is warranted.

6. CONCLUSIONS

Ultimately, it is important to stress that we are unable to definitively conclude whether the finding of declining abundance in WH over the last decade, specifically that of adult females and subadults, is the result of reduced survival and recruitment, movement of bears into neighbouring subpopulations (emigration), or harvest pressure. Based upon the multiple lines of evidence reviewed in this report, it is plausible that all these factors have contributed to some degree. Of particular concern, however, is our finding that the observed declines in subadults and adult females are consistent with long-standing predictions regarding the order in which negative demographic effects will emerge amongst the different sex and age classes of polar bears due to climate related environmental change. If these apparent trends continue, the progression of a reduced subadult cohort into the adult age class, combined with an already reduced adult female class, reproductive senescence, and mortality amongst older bears, may result in cascading effects on WH abundance and reproductive performance over the next decade. We therefore recommend follow-up on these findings in several forms as follows:

1. Analyses of on-going physical and genetic mark-recapture programs are best suited to address the uncertainties arising from our aerial survey findings and are a strongly recommended next step in the assessment of WH. An analysis of physical and genetic mark-recapture data for 2011 to 2021 is needed to determine whether demographic effects such as reduced recruitment and survival of subadults have occurred in WH.
2. Management agencies should consider increasing monitoring efforts in WH by changing the frequency of future aerial surveys from every 5 years to every 3 years, in the near term. The purpose of this increased frequency would be to determine whether the subpopulation is entering a period rapid change in abundance requiring more frequent adjustments in harvest management strategy than at present.
3. Questions remain about the interannual movements of bears between WH and SH and the effect these movements have on aerial survey abundance estimates. It is also unclear whether the significant number of bears, mostly adult males, that occupy the southeastern coast of WH during the ice-free season are available for harvest by WH communities or whether these bears function as either an unharvested segment of the subpopulation or are in fact harvested in SH. Results from current genetic sampling and telemetry studies in this region are expected to address these questions and inform WH management. Priority should be placed on completing these studies.
4. A harvest risk assessment should be conducted to determine the impact of recent and future harvest under current conditions.
5. The high number of polar bear carcasses found during the WH survey is concerning. We recommend closer monitoring and reporting of polar bear carcasses found in WH during future aerial surveys and on-going mark-recapture studies.

7. ACKNOWLEDGEMENTS

Financial support for the survey was provided by the Government of Nunavut (Department of Environment), Government of Manitoba (Department of Agriculture and Resource Development), and Environment and Climate Change Canada. In-kind support was received from Parks Canada and the Ontario Ministry of Natural Resources.

The authors wish to thank Gerard Maktars, Timothy Kookeyuk, Timothy Pissuk, Kevin Subgut, Conor Camphaug, Clayton Tartuk, Jack Batstone (Government of Manitoba) for their work as observers and data collectors during the survey. Input on survey design was provided by members of the Arviat, Rankin Inlet, Whale Cove Hunting and Trapping Organizations during meetings and workshops held between 2010 and 2021.

The survey was carried out under research permits from Parks Canada (Wapusk National Park Research and Collection Permit #WAP-2021-48823), Government of Nunavut (Wildlife Research Permit # 2021-061).

8. LITERATURE CITED

- Aars J, Marques TA, Buckland ST, Andersen M, Belikov S, Boltunov A, Wiig Ø. (2009). Estimating the Barents Sea polar bear subpopulation size. *Mar Mamm Sci* 25: 35-52.
- Aars J, Marques T, Lone K, Andersen M, Wiig Ø, Fløystad IMB, Hagen SB, Buckland S. (2017). The number and distribution of polar bears in the western Barents Sea area. *Polar Research* 36:1, 1374125, DOI:10.1080/17518369.2017.1374125.
- Allen ML, Krofel M, Yamazaki K, Alexander EP, and Koike S. (2022). Cannibalism in bears. *Ursus* 2, 1-9, (12 July 2022). <https://doi.org/10.2192/URSUS-D-20-00031.2>.

- Amstrup SC, Stirling, I, Smith, TS, Perham C, and Thiemann, GW. (2006). Recent observations of intraspecific predation and cannibalism among polar bears in the southern Beaufort Sea. *Polar Biology* 29:997–1002.
- Amstrup SC, Marcot, BG and Douglas DC. (2008). A Bayesian network modeling approach to forecasting the 21st century worldwide status of polar bears. Pages 213–268 in E.T. DeWeaver, C.M. Bitz, AND L.B. Tremblay, editors. *Arctic sea ice decline: Observations, projections, mechanisms, and implications*. Geophysical Monograph 180. American Geophysical Union, Washington, DC, USA.
- Bohart A, Lunn N, Derocher AE and McGeachy D. (2021). Migration dynamics of polar bears (*Ursus maritimus*) in western Hudson Bay. *Behavioral Ecology*. 32. 10.1093/beheco/araa140.
- Bromaghin JF, McDonald TL, Stirling I, Derocher AE, Richardson ES, Regehr EV, et al. Polar bear population dynamics in the southern Beaufort Sea during a period of sea ice decline. *Ecol Appl*. 2015; 25 (3):634–651. <https://doi.org/10.1890/14-1129.1> PMID: 26214910.
- Brook RK. (2001). Structure and dynamics of the vegetation in Wapusk National Park and the Cape Churchill Wildlife Management Area of Manitoba: community and landscape scales. MNRM thesis, University of Manitoba, Winnipeg, MB.
- Buckland ST, Anderson DR, Burnham KP, Laake JL. (1993). Distance sampling. Estimating abundance of biological populations. Chapman & Hall, London, UK.
- Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L. (2001). Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford, UK.
- Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L. (2004). Advanced Distance Sampling - estimating abundance of biological populations. Oxford University Press, Oxford, UK.
- Buckland ST, Laake J, Borchers DL. (2010). Double-observer line transect methods: Levels of independence. *Biometrics* 66:69-177.
- Cherry SG, Derocher AE, Thiemann GW, Lunn NJ. (2013). Migration phenology and seasonal fidelity of an Arctic marine predator in relation to sea ice dynamics. *J Anim Ecol* DOI:10.1111/1365-2656.

- Cherry SG, Derocher AE, Lunn NJ. (2016). Habitat-mediated timing of migration in polar bears: an individual perspective. *Ecol. Evol.* 6:5032-5042.
- Clark DA, and Stirling I (1998) Habitat preferences of polar bears in the Hudson Bay Lowlands during late summer and fall. *Ursus* 10:243-250.
- Clark DA, Stirling I, Calvert W. (1997). Distribution, characteristics, and use of earth dens and related excavations by polar bears on the Western Hudson Bay lowlands. *Arctic* 50:158-166.
- Conn PB, Chernook VI, Moreland EE, Trukhanova IS, Regehr EV, Vasiliev AN, et al. (2021) Aerial survey estimates of polar bears and their tracks in the Chukchi Sea. *PLoS ONE* 16(5): e0251130. <https://doi.org/10.1371/journal.pone.0251130>
- COSEWIC. 2008. COSEWIC assessment and update status report on the polar bear (*Ursus maritimus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. Vi +29pp.
- Crompton AE, Obbard ME, Petersen SD, Wilson PJ. (2008). Population genetic structure in polar bears (*Ursus maritimus*) from Hudson Bay, Canada: implications for future climate change. *Biol. Conserv.* 141:2528-2539.
- Derocher AE, Stirling I. (1990). Distribution of polar bears (*Ursus maritimus*) during the ice-free period in western Hudson Bay. *Can J Zool* 68:1395-1403.
- Derocher AE and Wiig Ø. (1999). Infanticide and cannibalism of juvenile polar bears (*Ursus maritimus*) in Svalbard. *Arctic* 52:307–310.
- Derocher AE, Stirling I. (1995a). Estimation of polar bear population size and survival in western Hudson Bay. *J Wildl. Manage* 59:215-221.
- Derocher, A.E. and I. Stirling. (1995b). Temporal variation in reproduction and body mass of polar bears in western Hudson Bay. *Human Dimensions of Wildlife* 73:1657-1665.
- Derocher AE, Lunn NJ, Stirling I. (2004). Polar bears in a warming climate. *Integr Comp Biol* 44:163-176.
- Derocher AE, Aars J, Amstrup SC, Cutting A, Lunn NJ, Molnar PK, Obbard ME, Stirling I, Thiemann GW, Vongraven D, Wiig Ø, York G. (2013). Rapid ecosystems change and polar bear conservation. *Cons Lett* 6:368–375.

- Dowsley, M., and M.K. Taylor. (2006). Management consultations for the Western Hudson Bay (WH) polar bear population (01-02 December 2005). Government of Nunavut, Department of Environment, Final Wildlife Report 3, Iqaluit, NU. 55 pp.
- Dowsley M, Wenzel G. (2008). "The time of the most polar bears": a co-management conflict in Nunavut. *Arctic* 61:177-189.
- Dredge LA, Nixon FM. (1992). Glacial and environmental geology of northeastern Manitoba. *Geol Surv Can Mem* 432.
- Dyck MG, and Daley KJ. (2002). Cannibalism of a Yearling Polar Bear (*Ursus maritimus*) at Churchill, Canada. *Arctic* 55: 190-192.
- Dyck, MG, Soon W, Baydack RK, Legates DR, Baliunas S, Ball TF, and Hancock LO. (2007). Polar bears of western Hudson Bay and climate change: Are warming spring air temperatures the "ultimate" survival control factor? *Ecological Complexity* 4:73-84.
- Dyck M, Campbell M, Lee DS, Boulanger J, Hedman D (2017) Aerial survey of the western Hudson Bay polar bear sub-population 2016. 2017 Final Report. Government of Nunavut, Department of Environment, Wildlife Research Section, Status Report 2017-xx, Igloolik, NU. 82 pp
- Dyck M, Lukacs P, Ware JV. (2020a). Re-estimating the abundance of a recovering polar bear subpopulation by genetic mark-recapture in M'Clintock Channel, Nunavut, Canada. Final Report, Government of Nunavut, Department of Environment, Iglulik, NU. 79 pp
- Dyck M, Regehr EV, Ware JV. (2020b). Assessment of abundance for the Gulf of Boothia polar bear subpopulation using genetic mark-recapture. Final Report, Government of Nunavut, Department of Environment, Iglulik, NU. 73 pp.
- Dyck M, Dunham KD, Ware JV, Koons DN, Regehr EV, Hosmer DW, Derocher AE, Dale A, Pisapio J, and Szor G. (2021). Re-estimating the abundance of the Davis Strait polar bear subpopulation by genetic mark-recapture. Final Report, Government of Nunavut, Department of Environment, Iglulik.
- Dyck M, Regehr E, and Ware J (2022). Demographic assessment using physical and genetic sampling finds stable polar bear subpopulation in Gulf of Boothia, Canada. *Marine Mammal Science*. 10.1111/mms.12968.

- Ecological Framework of Canada. (2016). <http://ecozones.ca/english> (accessed 15 November 2016).
- Environment and Climate Change Canada. (2020). Conservation of polar bears in Canada. www.canada.ca/en/services/environment/wildlife-plants-species/wildlife-habitat-conservation/conservation-polar-bears.html
- Evans TJ, Fischbach A, Schliebe S, Manly B, Kalxdorff S, York G. (2003). Polar bear aerial survey in the Eastern Chukchi Sea: a pilot study. *Arctic* 56:359–366.
- Fewster RM, Buckland ST, Burnham KP, Borchers DL, Jupp PE, Laake J, Thomas L. (2009). Estimating the encounter rate variance in distance sampling. *Biometrics* 65:225-236.
- Fowler, C. W. (1987). A review of density dependence in populations of large mammals. *Current Mammalogy* 1:401–441.
- Frey, K.E., Comiso, J.C., Cooper, L.W., Grebmeier, J.M., and Stock, L.V. (2018). Arctic Ocean Primary Productivity: The response of marine algae to climate warming and sea ice decline. NOAA Arctic Report Card 2018.
- Häder, D.-P., Villafañe, V.E., and Helbling, E.W. (2014). Productivity of aquatic primary producers under global climate change. *Photochemical and Photobiological Sciences* 13:1370-1392.
- Hostetter NJ, Lunn NJ, Richardson ES, Regehr EV, Converse SJ. (2021). Age-structured Jolly-Seber model expands inference and improves parameter estimation from capture-recapture data. *PLoS ONE* 16(6): e0252748. <https://doi.org/10.1371/journal.pone.0252748>.
- Innes S, Heide-Jørgensen MP, Laake JL, Laidre KL, Cleator HJ, Richard P, and Stewart REA. (2002). Surveys of belugas and narwals in the Canadian High Arctic in 1996. *NAMMCO Scientific Publications* 4:169-190.
- Jonkel CJ, Kolenosky GB, Robertson RJ, Russell RH. (1972). Further notes on polar bear denning habits. *Int Conf Bear Res Manage* 2:142-158.
- Johnson AC, Reimer JR, Lunn NJ, Stirling I, McGeachy D, Derocher AE. (2020). Influence of sea ice dynamics on population energetics of Western Hudson Bay polar bears. *Conserv Physiol* 8(1): coaa132; doi:10.1093/conphys/coaa132.

- Klappstein NJ, Togunov RR, Reimer JR, Lunn NJ, & Derocher AE. (2020). Patterns of sea ice drift and polar bear (*Ursus maritimus*) movement in Hudson Bay. *Marine Ecology Progress Series*, 641, 227–240. <https://doi.org/10.3354/meps13293>.
- Kolenosky GB, Abraham KF, Greenwood CJ. (1992). Polar bears of southern Hudson Bay. Polar Bear Project, 1984–88. Final Report, Ontario Ministry of Natural Resources, Maple, ON.
- Laake J, Dawson MJ, Hone J. (2008a). Visibility bias in aerial survey: mark-recapture, line-transect or both? *Wildl Res* 35:299-309.
- Laake J, Guenzel RJ, Bengtson JL, Boveng P, Cameron M, Hanson MB. (2008b). Coping with variation in aerial survey protocol for line-transect sampling. *Wildl Res* 35:289-298.
- Laake J, Borchers DL, Thomas L, Miller D, Bishop J. (2012). Mark-recapture distance sampling (MRDS) 2.1.0. R statistical package program.
- Laidre KL, Atkinson S, Regehr EV, Stern HL, Born EW, Wiig Ø, Lunn NJ, Dyck M. (2020a). Interrelated ecological impacts of climate change on an apex predator. *Ecol Appl* 30(4):e02071. <https://doi.org/10.1002/eap.2071>.
- Laidre KL, Atkinson SN, Regehr EV, Stern HL, Born EW, Wiig Ø, Lunn NJ, Dyck M, Heagerty P, Cohen BR (2020b) Transient benefits of climate change for a high-Arctic polar bear (*Ursus maritimus*) subpopulation. *Global Change Biol* 26:6251-6265. <https://doi.org/10.1111/gcb.15286>.
- Lunn NJ, and Stenhouse GB. (1985). An observation of possible cannibalism by polar bears (*Ursus maritimus*). *Canadian Journal of Zoology* 63:1516–1517.
- Lunn NJ, Stirling I, Andriashek D, Kolenosky GB. (1997). Re-estimating the size of the polar bear population in western Hudson Bay. *Arctic* 50:234-240.
- Lunn NJ, Stirling I, Andriashek D, Richardson E. (2004). Selection of maternity dens by female polar bears in western Hudson Bay. *Polar Biol* 7:350-356.
- Lunn NJ, Servanty S, Regehr EV, Converse SJ, Richardson E, Stirling I. (2016). Demography of an apex predator at the edge of its range: impacts of changing sea ice on polar bears in Hudson Bay. *Ecol Appl* 26:1302-1320.
- McDonald LL, Garner GW, Robertson DG. (1999). Comparison of aerial survey procedures for estimating polar bear density: Results of pilot studies in northern

- Alaska in Marine mammal survey and assessment methods. In: Garner GW, Amstrup SC, Laake JL, Manly BFJ, McDonald LL, Robertson DG (eds). *Marine Mammal Survey and Assessment Methods*. A.A. Balkema Publishers, Rotterdam, Netherlands. pp 37–51.
- McDonald TL. (2012). Aerial surveys for polar bears in offshore areas of the Northern Beaufort Sea. Report prepared for Aboriginal Affairs and Northern Development Canada, Gatineau, QC, Canada, 6 pp.
- Malenfant RM, Davis CS, Cullingham CI, Coltman DW. (2016). Circumpolar genetic structure and recent gene flow of polar bears: a reanalysis. *PLOS ONE* 11: e0148967.
- Marques T, Andersen M, Christensen-Dalsgaard S, Belikov S, Boltunov A, Wiig Ø, Buckland S, Aars J. (2006). The use of global positioning systems to record distances in a helicopter line-transect survey. *Wildl Soc Bull* 34:759-763.
- Mazerolle MJ. (2016). AICcmodavg: Model selection and multimodel inference based on (Q)AIC(c). . R package version 2.1-0.: <https://cran.r-project.org/package=AICcmodavg>.
- Molnár PK, Bitz CM, Holland MM, Kay, JE, Penk SR and Amstrup SC. (2020). Fasting season length sets temporal limits for global polar bear persistence. *Nat. Clim. Chang.* 10, 732-738. doi:10.1038/s41558-020-0818-9
- Northrup JM, Howe E, Lunn N, Middel K, Obbard ME, Ross T, Szor G, Walton L, Ware J. (2021) Southern Hudson Bay polar bear subpopulation aerial survey report. Ontario Ministry of Natural Resources, pp xx.
- Norton-Griffiths M. (1978). Counting animals. In: Grimsdell JJR (ed) *African Wildlife Foundation technical handbook No. 1*. African Wildlife Foundation, Nairobi, Kenya.
- Nunavut Wildlife Management Board. (2007). West Hudson Bay polar bear population total allowable harvest. *Record of Decision*. 37pp.
- Obbard ME, Cattet MRL, Moody T, Walton LR, Potter D, Inglis J, and Chenier C. (2006). Temporal trends in the body condition of Southern Hudson Bay polar bears. *Climate Change Research Information Note, No. 3*. Applied Research

and Development Branch, Ontario Ministry of Natural Resources, Sault Ste. Marie, ON.

- Obbard ME, Thiemann GW, Peacock E, DeBruyn TD (eds) (2010) Polar bears: proceedings of the 15th working meeting of the IUCN/SSC Polar Bear Specialist Group, Gland, Switzerland and Cambridge, UK.
- Obbard ME, and Middel KR. (2012). Bounding the Southern Hudson Bay polar bear subpopulation. *Ursus* 23:134-144.
- Obbard ME, Stapleton S, Middel KR, Thibault I, Brodeur V, Jutras C. (2015). Estimating abundance of the Southern Hudson Bay polar bear subpopulation using aerial surveys, 2011 and 2012. *Polar Biol* 38:1713-1725.
- Obbard ME, Cattet MRL, Howe EJ, Middel KR, Newton EJ, Kolenosky GB, Abraham KF, Greenwood CJ. (2016). Trends in body condition in polar bears (*Ursus maritimus*) from the Southern Hudson Bay subpopulation in relation to changes in sea ice. *Arctic Sci* 2:15-32.
- Obbard ME, Stapleton S, Szor G, Middel KR, Jutras C, and Dyck M. (2018). Re-assessing abundance of Southern Hudson Bay polar bears by aerial survey: effects of climate change at the southern edge of the range. *Arctic Science*.
- Overland JE, Wang M. (2013). When will the summer Arctic be nearly sea ice free? *Geophys Res Lett* 40:2097-2101.
- Pagano AM, Durner GM, Atwood TC, and Douglas DC. (2021). Effects of sea ice decline and summerland use on polar bear home range size in the Beaufort Sea. *Ecosphere* 12(10):e03768. 10.1002/ecs2.3768.
- Parks EK, Derocher AE, and Lunn NJ. (2006). Seasonal and annual movement patterns of polar bears on the sea ice of Hudson Bay. *Canadian Journal of Zoology- Revue Canadienne de Zoologie* 84: 1281-1294.
- Peacock E, Derocher AE, Lunn NJ, Obbard ME. (2010). Polar bear ecology and management in Hudson Bay in the face of climate change. In: Ferguson SH, Loseto LL, Mallory ML (eds) *A little less Arctic: top predators in the world's largest northern inland sea, Hudson Bay*. Springer Science, New York, NY, p 93-115.

- Peacock E, Taylor MK. (2007). Polar bears of western Hudson Bay: survey extension investigation. Unpublished Report, Government of Nunavut, Igloolik, NU.
- Pebesma E. (2018). Simple Features for R: Standardized Support for Spatial Vector Data. *The R Journal* 10:439-446.
- Pilfold NW, McCall A, Derocher AE, Lunn NJ, Richardson E. (2017). Migratory response of polar bears to sea ice loss: to swim or not to swim. *Ecography* 40: 189–199.
- Polar Bear Technical Committee (PBTC). (2021). Canadian polar bear subpopulation status table. www.polarbearsCanada.ca/sites/default/files/public/PBTC-2021_StatusTableRemovalsNarratives_Final-20210621.pdf.
- Pollock K, Kendall W. (1987). Visibility bias in aerial surveys: a review of estimation procedures. *J Wildl Manage* 51:502-510.
- QGIS Foundation. (2020). QGIS: A free and open geographic information system (www.qgis.org).
- R Development Core Team. (2009). R Foundation for Statistical Computing, Vienna, Austria.
- Ramsay MA, Stirling I. (1988). Reproductive biology and ecology of female polar bears (*Ursus maritimus*). *J Zool (Lond)* 214:601-634.
- Ramsay MA, Stirling I. (1990). Fidelity of polar bears to winter den sites. *J Mammal* 71:233-236.
- Regehr EV, Lunn NJ, Amstrup SC, Stirling I. (2007). Effects of earlier sea ice breakup on survival and population size of polar bears in western Hudson Bay. *J Wildl Manage* 71:2673-2683.
- Regehr, E.V., Wilson, R.R., Rode, K.D., and Runge, M.C. (2015). Resilience and risk—A demographic model to inform conservation planning for polar bears: U.S. Geological Survey Open-File Report 2015-1029, 56 p., <http://dx.doi.org/10.3133/ofr20151029>.
- Regehr EV, Laidre KL, Akçakaya HR, Amstrup SC, Atwood TC, Lunn NJ, Obbard M, Stern H, Thiemann GW, Wiig Ø. (2016). Conservation status of polar bears (*Ursus maritimus*) in relation to projected sea-ice declines. *Biol Lett* 12: 20160556.

- Regehr EV, Wilson RR, Rode KD, Runge MC, Stern H. (2017). Harvesting wildlife affected by climate change: a modeling and management approach for polar bears. *J App Ecol* 54:1534–1543.
- Regehr EV, Atkinson S, Born EW, Laidre KL, Lunn NJ, Wiig Ø. (2017). Harvest Assessment for the Baffin Bay and Kane Basin Polar Bear Subpopulations: Final Report to the Canada-Greenland Joint Commission on Polar Bear, 31 July 2017: iii + 107 pp. Available from the Greenland Institute of Natural Resources, Nuuk, DK3900.
- Regehr EV, Hostetter NJ, Wilson RR, Rode KD, St. Martin M, Converse NJ. (2018). Integrated Population Modeling Provides the First Empirical Estimates of Vital Rates and Abundance for Polar Bears in the Chukchi Sea. *Nature Sci Rep* 8:16780.
- Regehr, E. V., M. C. Runge, A. Von Duyke, R. R. Wilson, L. Polasek, K. D. Rode, N. J. Hostetter, and S. J. Converse. (2021). Demographic risk assessment for a harvested species threatened by climate change: polar bears in the Chukchi Sea. *Ecological Applications* 31(8):e02461. 10.1002/eap.2461.
- Richardson E, Stirling I, Hik DS. (2005). Polar bear (*Ursus maritimus*) maternity denning habitat in western Hudson Bay: a bottom-up approach to resource selection functions. *Can J Zool* 83:860-870.
- Ritchie JC. (1962). A geobotanical survey of northern Manitoba. Technical Paper of the Arctic Institute of North America 9.
- Robbins CT, Lopez-Alfaro C, Rode KD, Tøien Ø, Nelson OL. (2012). Hibernation and seasonal fasting in bears: the energetic costs and consequences for polar bears. *JMammal* 93: 1493–1503.
- Rode KD, Amstrup SC, Regehr EV (2010) Reduced body size and cub recruitment in polar bears associated with sea ice decline. *Ecol Appl* 20:768–782.
- Rode KD, Peacock E, Taylor M, Stirling I, Born EW, Laidre KL, Wiig Ø (2012) A tale of two polar bear populations: ice habitat, harvest and body condition. *Pop Ecol* 54:3–18.
- Rode KD, Regehr EV, Douglas DC, Durner G, Derocher AE, Thiemann GW, et al. (2014). Variation in the response of an Arctic top predator experiencing habitat

- loss: feeding and reproductive ecology of two polar bear populations. *Global Change Biol.* 20(1):76–88. <https://doi.org/10.1111/gcb.12339> PMID: 23913506.
- Rode KD, Regehr EV, Bromaghin JF, Wilson RR, St. Martin M, Crawford JA, Quakenbush LT. (2021). Seal body condition and atmospheric circulation patterns influence polar bear body condition, recruitment, and feeding ecology in the Chukchi Sea. *Glob Change Biol.* 27:2684–2701.
- Sahanatien V, Peacock E, Derocher AE. (2015). Population substructure and space use of Foxe Basin polar bears. *Ecol Evol* DOI:10.1002/ece3.1571.
- Satterthwaite, F. E. 1946. An Approximate Distribution of Estimates of Variance Components. *Biometrics Bulletin* 2:110–114.
- Scott JBT, Marshall GJ. (2010). A step-change in the date of sea-ice breakup in western Hudson Bay. *Arctic* 63:155-164.
- Smith TS, Derocher, AE, Mazur R, York G., OWEN MA, Obbard ME, Richardson ES., and Amstrup SC. (2022) Anthropogenic food: an emerging threat to polar bears. *Oryx* doi:10.1017/S0030605322000278.
- Stapleton S, Atkinson S, Hedman D, Garshelis D. (2014). Revisiting Western Hudson Bay: using aerial surveys to update polar bear abundance in a sentinel population. *Biol Cons* 170:38-47.
- Stapleton S, Peacock E, Garshelis D. (2015). Aerial surveys suggest long-term stability in the seasonally ice-free Foxe Basin (Nunavut) polar bear population. *Mar Mamm Sci* 32:181-201.
- Stern HL, Laidre KL. (2016). Sea-ice indicators of polar bear habitat. *The Cryosphere* 10:1-15.
- Stirling I., Derocher AE. (1993). Possible impacts of climatic warming on polar bears. *Arctic* 46:240–245.
- Stirling I, Lunn NJ, Iacozza J, Elliott C, Obbard M. (2004). Polar bear distribution and abundance on the southwestern Hudson Bay coast during open water season, in relation to population trends and annual ice patterns. *Arctic* 57:15-26.
- Stirling I, Derocher AE. (2012). Effects of climate warming on polar bears - a review of the evidence. *Glob Change Biol* 18:2694-2706.

- Stirling, I. and Parkinson CL. (2006). Possible effects of climate warming on selected populations of polar bears (*Ursus maritimus*) in the Canadian Arctic. 59 ed. pp. 261-275.
- Stirling I, Lunn NJ, Iacozza J. (1999). Long-term trends in the population ecology of polar bears in western Hudson Bay in relation to climatic change. *Arctic* 52:294-306.
- Stirling I, Thiemann GW, Richardson E. (2008). Quantitative support for a subjective fatness index for immobilized polar bears. *J Wildl Manage* 72:568-574.
- Stirling I, Jonkel C, Smith P, Robertson R, Cross D. (1977). The ecology of the polar bear (*Ursus maritimus*) along the western coast of Hudson Bay. *Can Wildl Serv Occas Pap* 33, Ottawa.
- Stone IR, and Derocher AE. (2007). An incident of polar bear infanticide and cannibalism on Phippsøya, Svalbard. *Polar Record* 43:171–173.
- Stroeve JC, Kattsov V, Barrett A, Serreze M, Pavlova T, Holland M, Meier WN. (2012). Trends in Arctic Sea ice extent from CMIP5, CMIP3 and observations. *Geophys Res Lett* 39 DOI:10.1029/2012GL052676.
- Stroeve J, Notz D. (2018). Changing state of Arctic Sea ice across all seasons. *Environ Res Lett* 13: 103001.
- SWG [Scientific Working Group to the Canada-Greenland Joint Commission on Polar Bear]. (2016). Re-Assessment of the Baffin Bay and Kane Basin Polar Bear Subpopulations: Final report to the Canada-Greenland Joint Commission on Polar Bear.
- Taylor MK, LARSEN T, and Schweinsburg R. (1985). Observations of intraspecific aggression and cannibalism in polar bears (*Ursus maritimus*). *Arctic* 38: 303–309.
- Taylor MK, Lee LJ. (1995). Distribution and abundance of Canadian polar bear populations: A management perspective. *Arctic* 48:147-154
- Thiemann GW, Derocher AE, Stirling I. (2008). Polar bear *Ursus maritimus* conservation in Canada: an ecological basis for identifying designatable units. *Oryx* 42:504-515.

- Thomas DC, Buckland ST, Rexstad EA, Laake J, Strindberg S, Hedley SL, Bishop, Marques TA, Burnham KP. (2009). Distance software: Design and analysis of distance sampling surveys for estimating population size. *J Appl Ecol* 47:5-14.
- Towns L, Derocher AE, Stirling I, Lunn NJ. (2010). Changes in land distribution of polar bears in Western Hudson Bay. *Arctic* 63:206-212.
- Twinn CR. (1950). Studies of the biology and control of biting flies in northern Canada. *Arctic* 3:14-26.
- Tyrrell M. (2006). More bears, less bears: Inuit and scientific perceptions of polar bear populations on the west coast of Hudson Bay. *Etud Inuit* 30:191-208.
- Tyrrell M. (2009). West Hudson Bay polar bears: the Inuit perspective. In: Freeman MMR, Foote L (eds) *Inuit, polar bears and sustainable use: local, national and international perspectives*. CCI Press, University of Alberta, AB, p 95-110.
- Viengkone, M, Derocher AE, Richardson ES, Obbard ME, Dyck MG, Lunn, NJ, Sahanatien V, Robinson BG, and Davis CS. (2018). Assessing spatial discreteness of Hudson Bay polar bear populations using telemetry and genetics. *Ecosphere* 9(7):e02364. 10.1002/ecs2.2364.
- Vongraven V, Aars J, Amstrup S, Atkinson SN, Belikov SE, Born EW, DeBruyn TD, Derocher AE, Durner G, Gill M, Lunn N, Obbard ME, Omelak J, Ovsyanikov N, Peacock E, Richardson E, Sahanatien V, Stirling I, Wiig Ø. (2012). A circumpolar monitoring framework for polar bears. *Ursus Mon Ser* 5:1–66.
- Wickham H. (2009). *ggplot2: Elegant graphics for data analysis*. Springer, New York, NY.
- Wiig Ø and Derocher AE. (1999). Application of aerial survey methods to polar bears in the Barents Sea. Pages 27–36 in G.W. Garner, S.C. Amstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald, AND D.G. Robertsen, editors. *Marine mammal survey and assessment methods*. Balkema, Rotterdam.
- Wiig Ø, Amstrup S, Atwood T, Laidre K, Lunn N, Obbard M, Regehr E, Thiemann G (2015) *Ursus maritimus*. IUCN Red List Assessment of Threatened Species 2015: e.T22823A14871490.
- Wiig Ø, Atkinson SN, Born EW, Stapleton S, Arnold T, Dyck M, Laidre KL, Lunn NJ, Regehr EV. (2021). An on-ice aerial survey of the Kane Basin polar bear (*Ursus*

maritimus) subpopulation Polar Biology <https://doi.org/10.1007/s00300-021-02974-6>.

York, J., Dowsley, M., Cornwell, A., Kuc, M. & Taylor, M. Demographic and traditional knowledge perspectives on the current status of Canadian polar bear subpopulations. (2016). *Ecol. Evol.* 6, 2897–2924.

Zar, J. H. 1996. *Biostatistical analysis*. Third edition. Prentice-Hall, London.

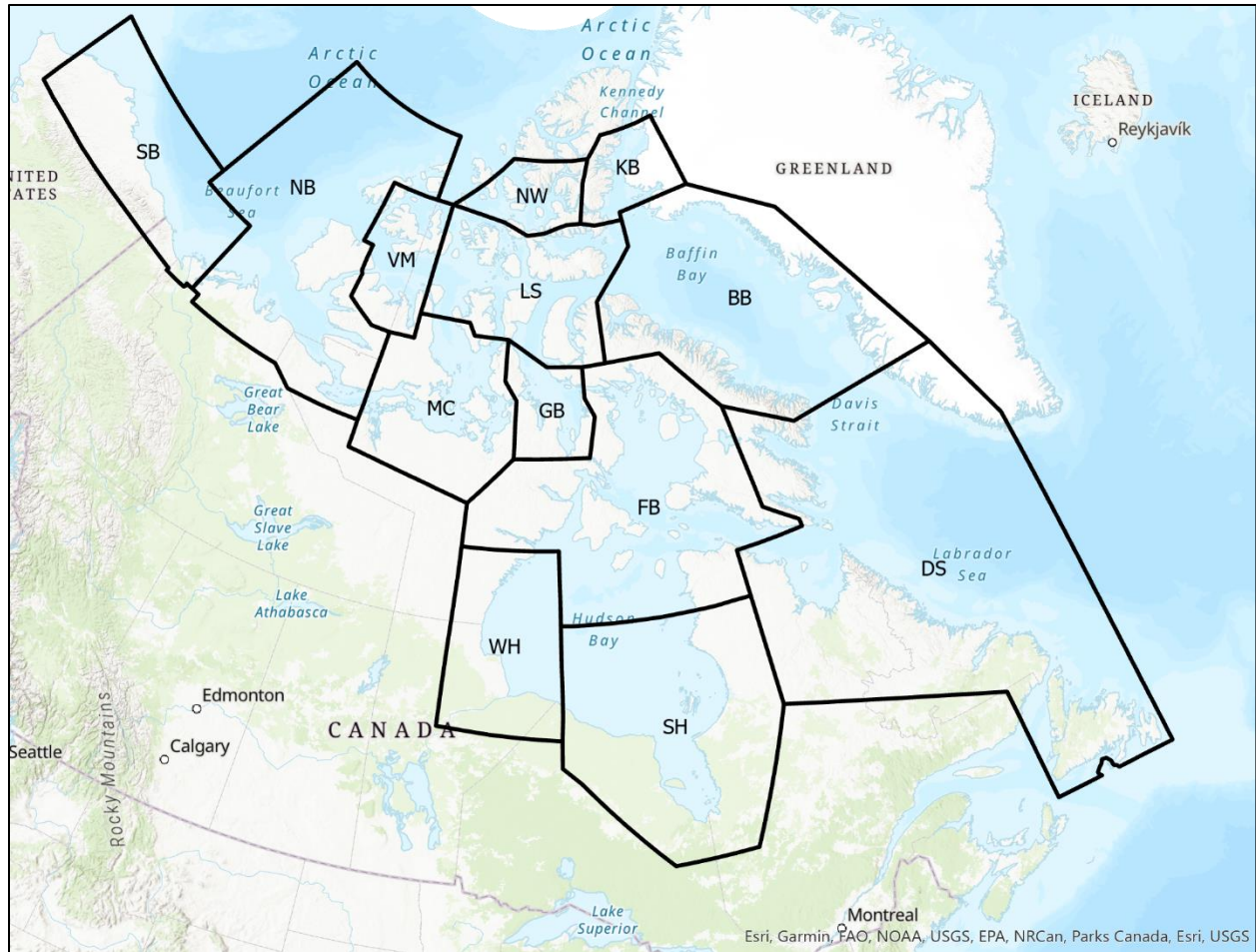


Figure 1. Boundaries of polar bear subpopulations that are partially or totally under management from Canadian jurisdictions. These include Southern Beaufort Sea (SB), Northern Beaufort Sea (NB), Viscount Melville Sound (VM), McClintock Channel (MC), Lancaster Sound (LS), Norwegian Bay (NW), Kane Basin (KB), Baffin Bay (BB), Gulf of Boothia (GB), Foxe Basin (FB), Davis Strait (DS), Western Hudson Bay (WH) and Southern Hudson Bay (SH).

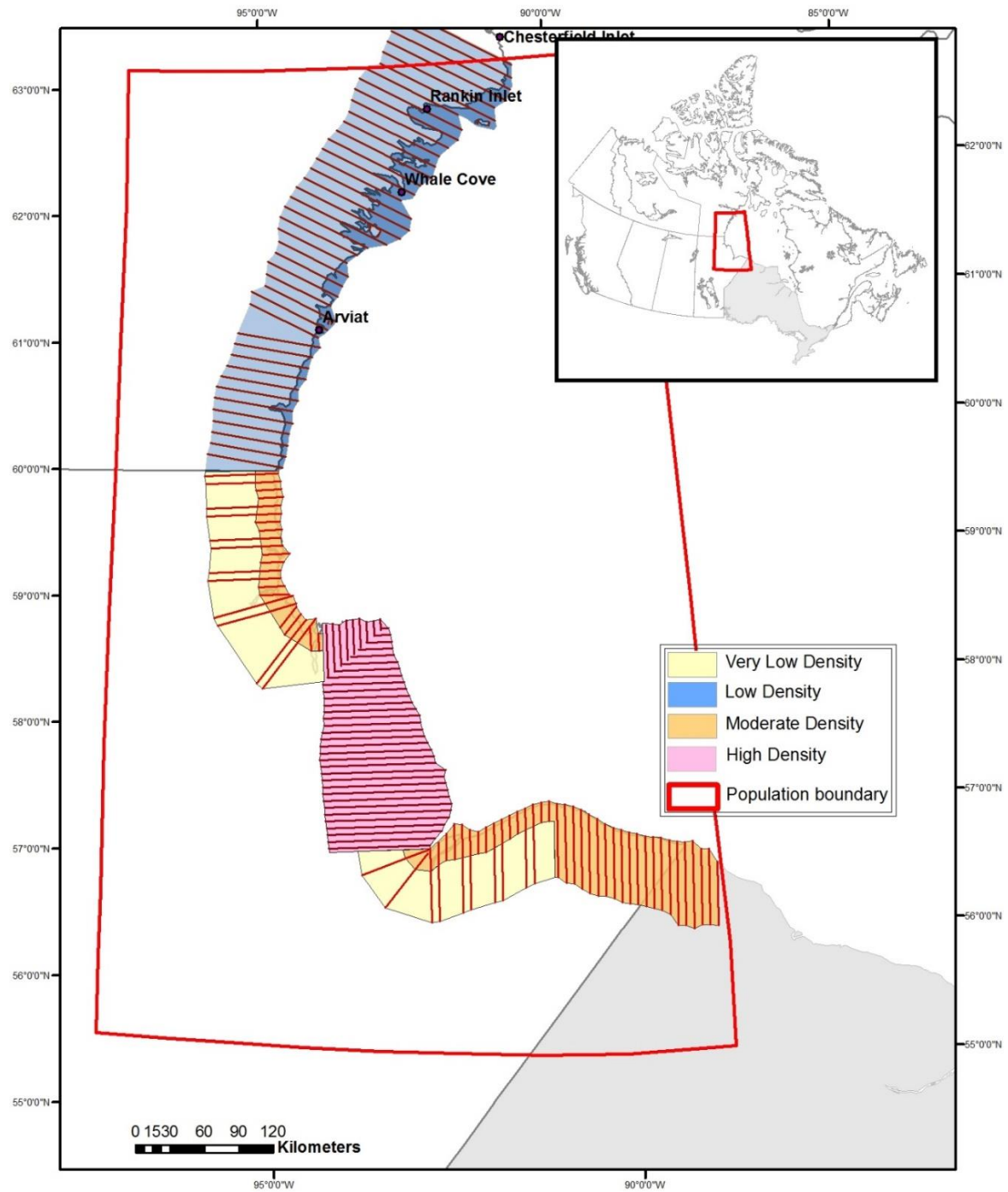


Figure 2. Survey strata and transects for the 2021 aerial survey of the Western Hudson Bay polar bear subpopulation.

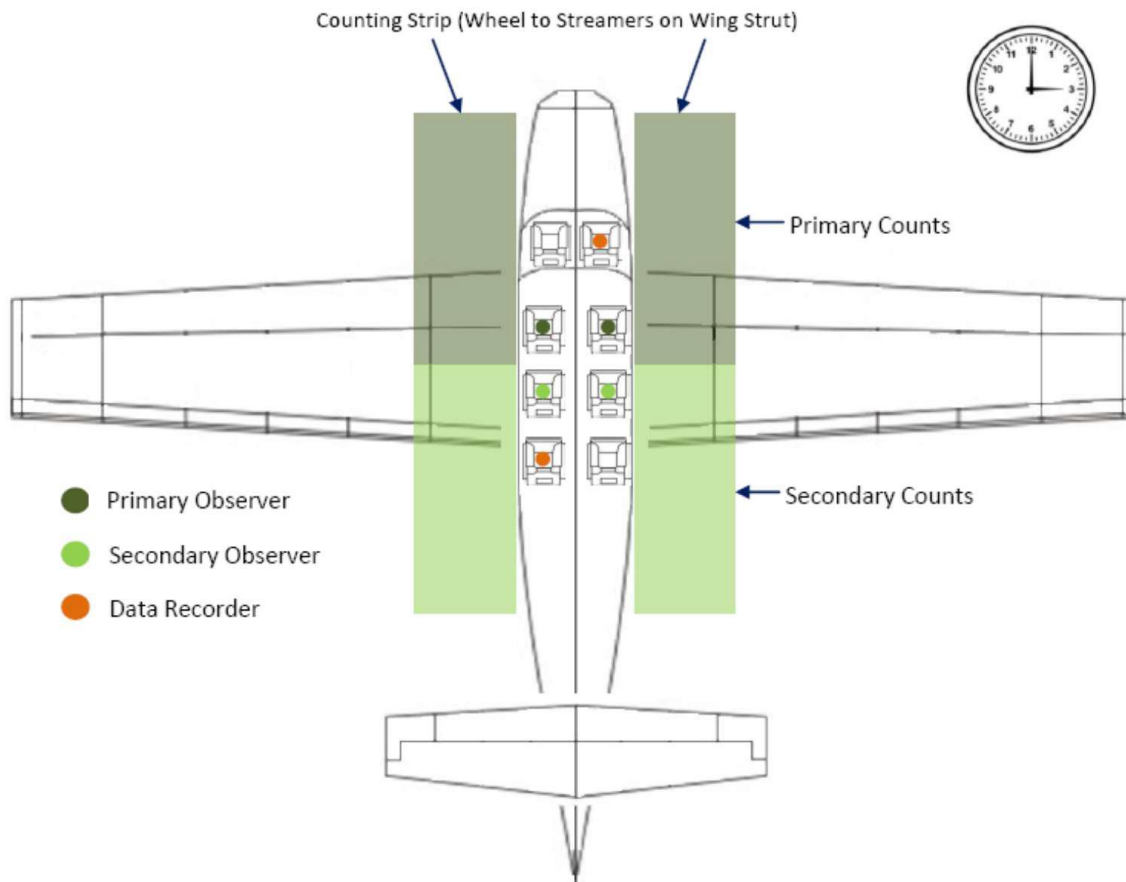


Figure 3. Observer position for the double observer method employed on this survey. The secondary observer calls polar bears not seen by the primary observer after the polar bear/bears have passed the main field of vision of the primary observer at a point halfway between same side primary and secondary observers. The small hand on a clock is used to reference relative locations of polar bear groups (e.g. “Polar bear group at 3 o’clock” would suggest a polar bear group 90o to the right of the aircrafts longitudinal axis).

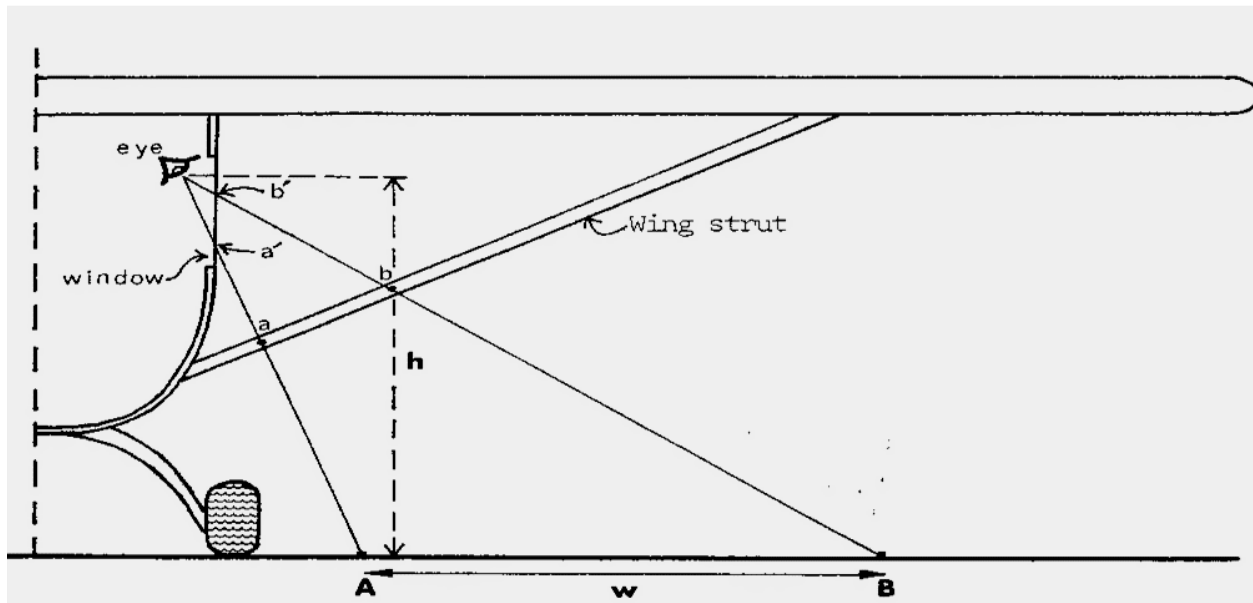


Figure 4. Schematic diagram of aircraft configuration for strip width sampling (Norton-Griffiths, 1978). w is marked out on the tarmac, and the two lines of sight $a' - a - A$ and $b' - b - B$ established. The streamers are attached to the struts at a and b , whereas a' and b' are the window marks. (After Jolly 1969)

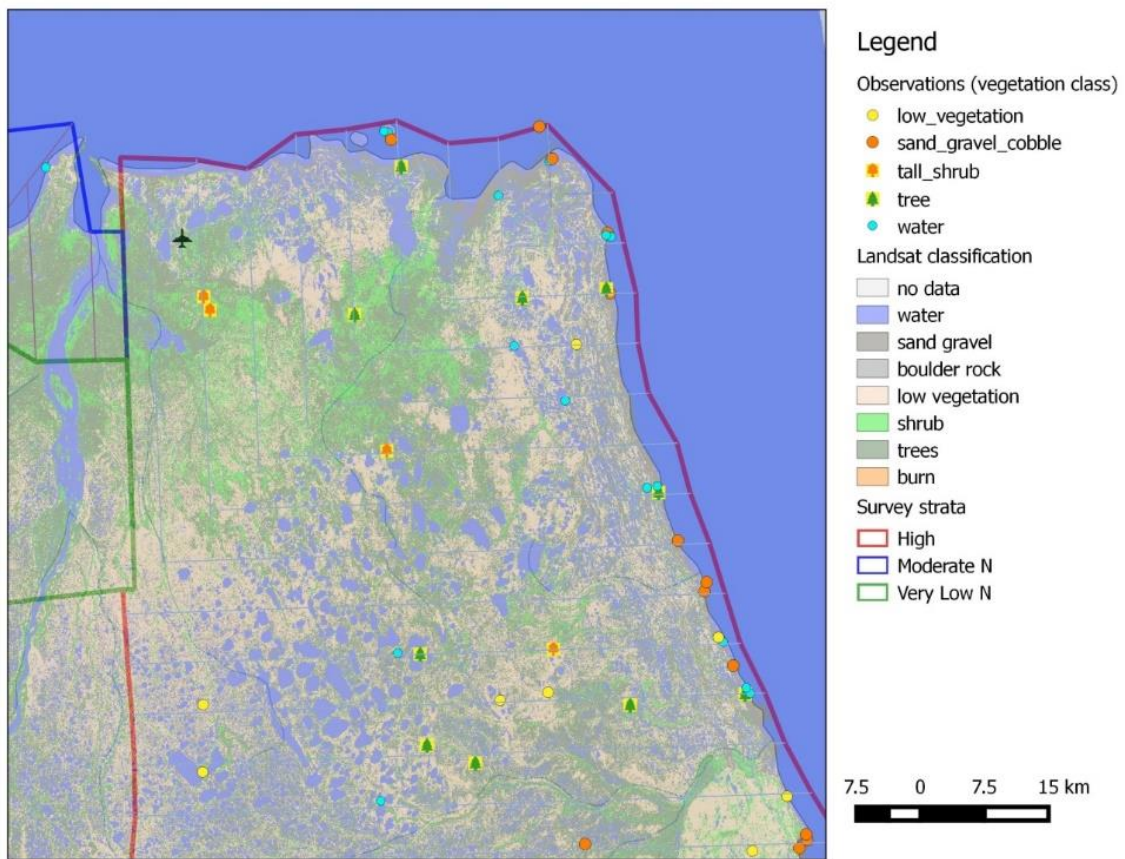


Figure 5. Landsat habitat classification and observations for a section of the 2016 high stratum (Dyck et al. 2017)

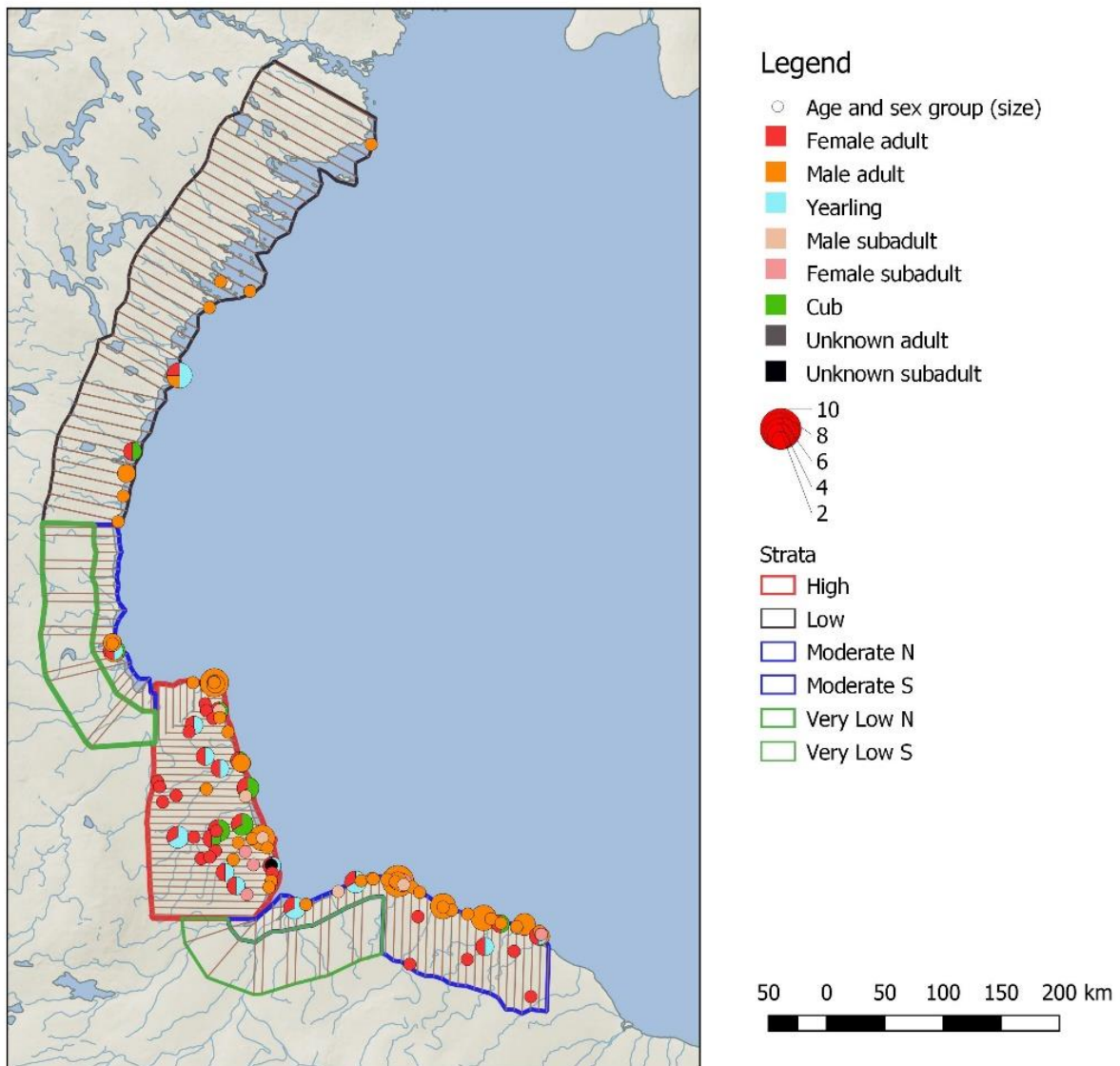


Figure 6: Distributions of bears observed on transect during the 2021 WH aerial survey; with group composition and size noted.

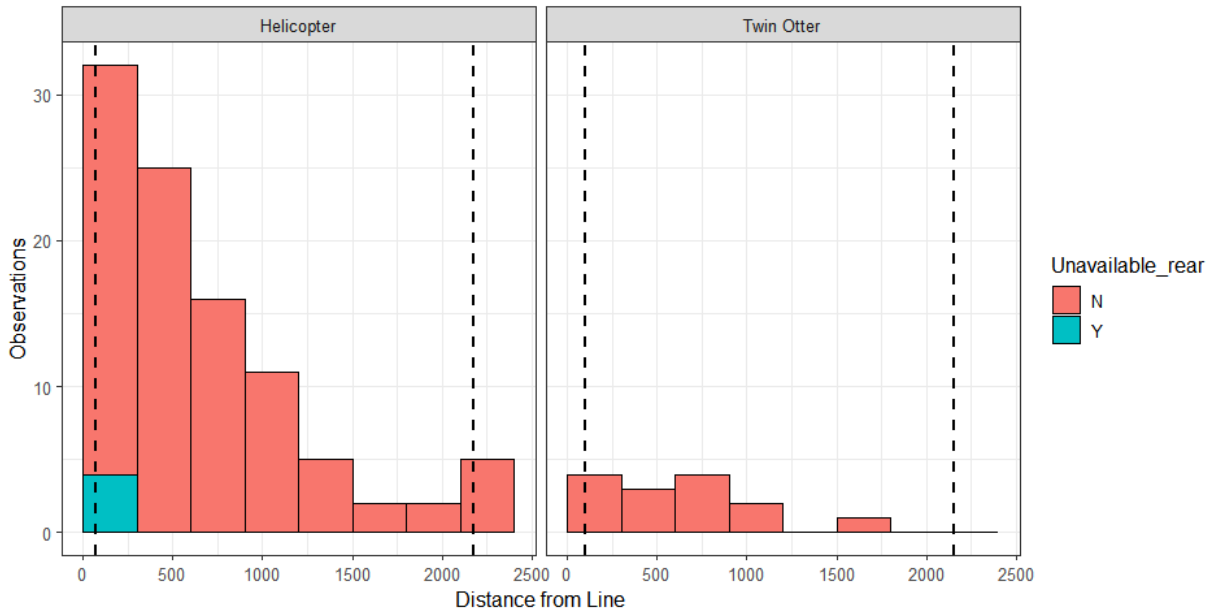


Figure 7: Detection histogram of full data set before right and left truncation by aircraft type. Left and right truncation distances are shown as hashed vertical line

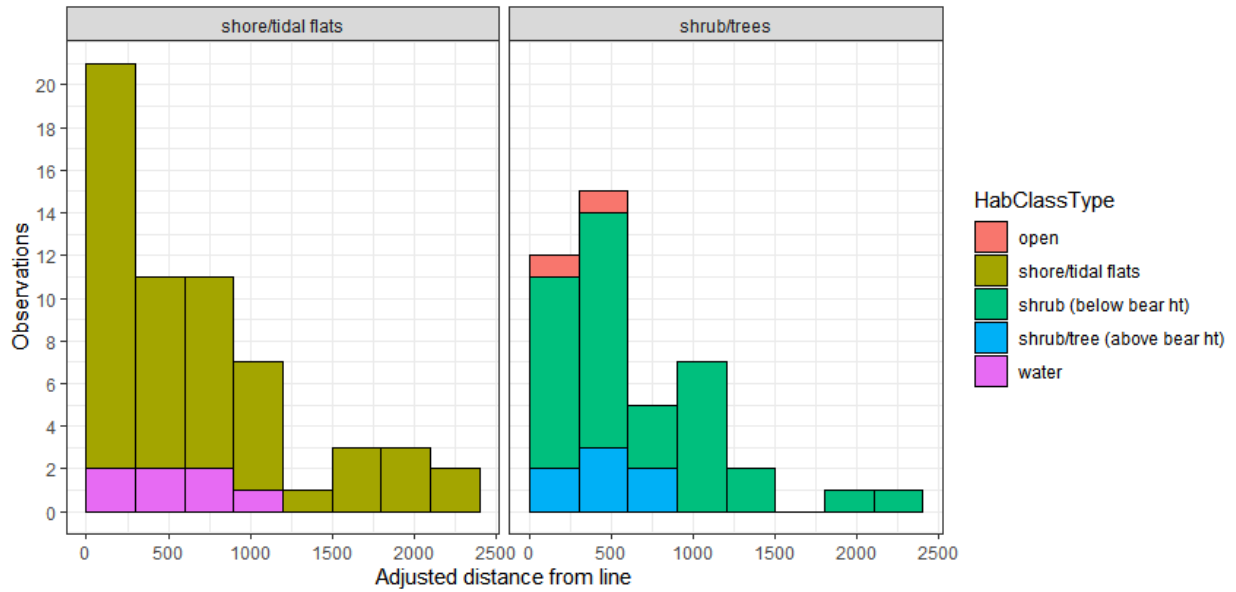


Figure 8: Detection histograms for pooled habitat class (HabClassP) categories with original categories shown as sub-bars. Adjusted distance from line (left truncation distance subtracted) is displayed on the x-axis.

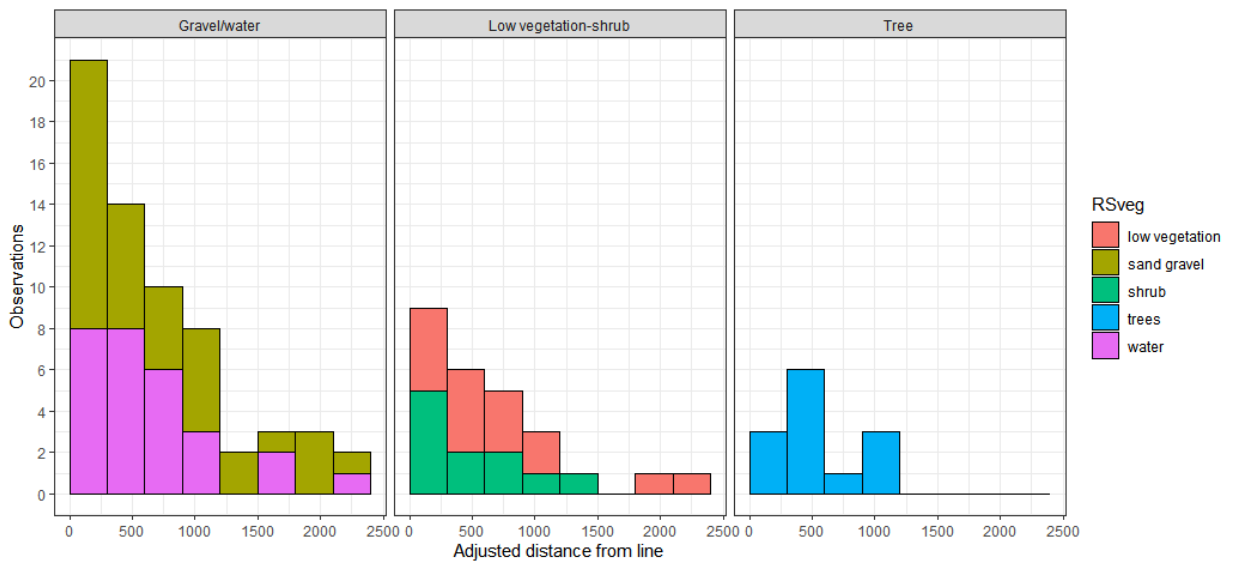


Figure 9: Detection histograms for pooled RSveg habitat categories with original categories shown as sub-bars. Adjusted distance from line (left truncation distance subtracted) is displayed on the x-axis.

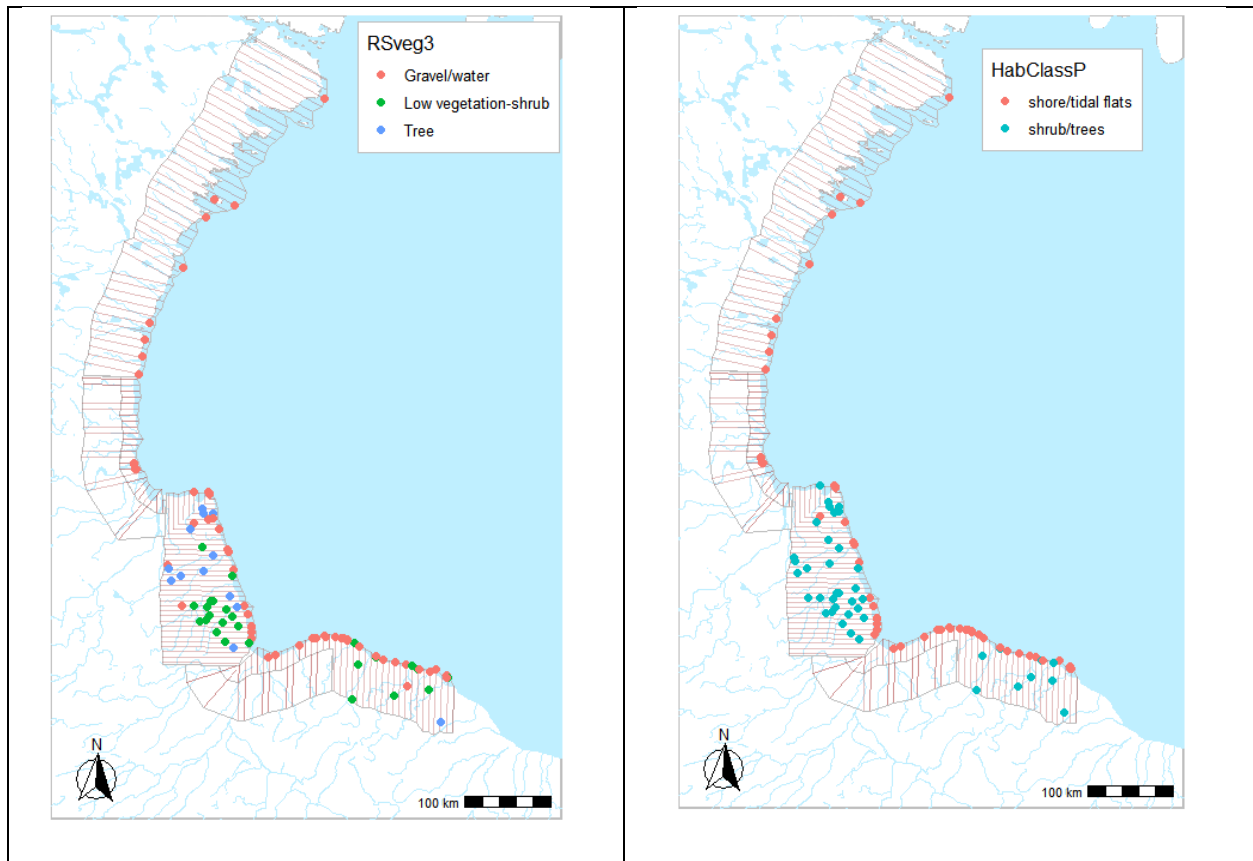


Figure 10: Distribution of observations by RSveg and HabClass classifications.

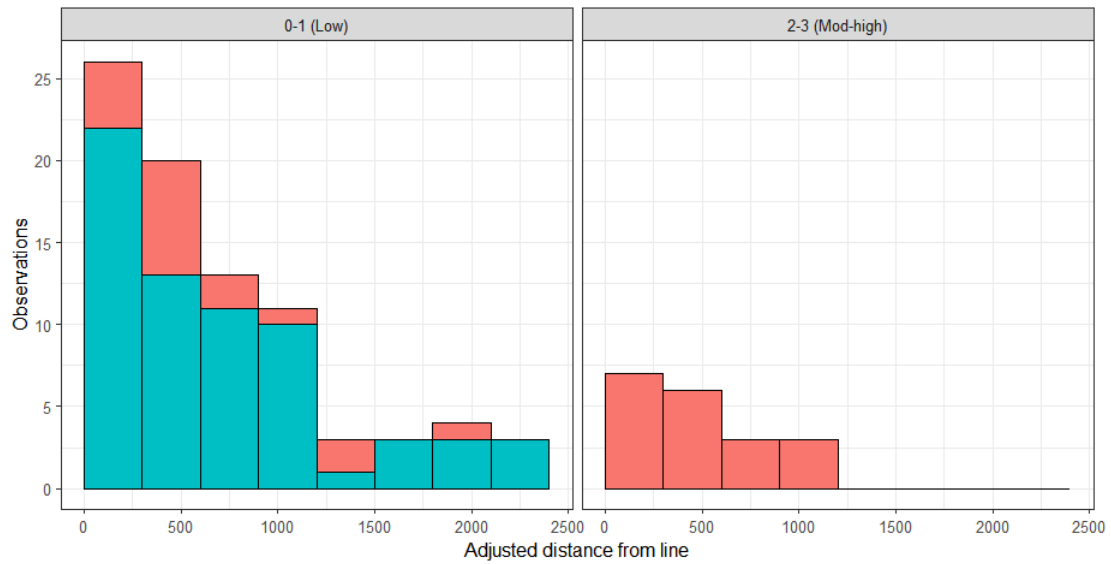


Figure 11: Detection of vegetation height and density (sub-bars).

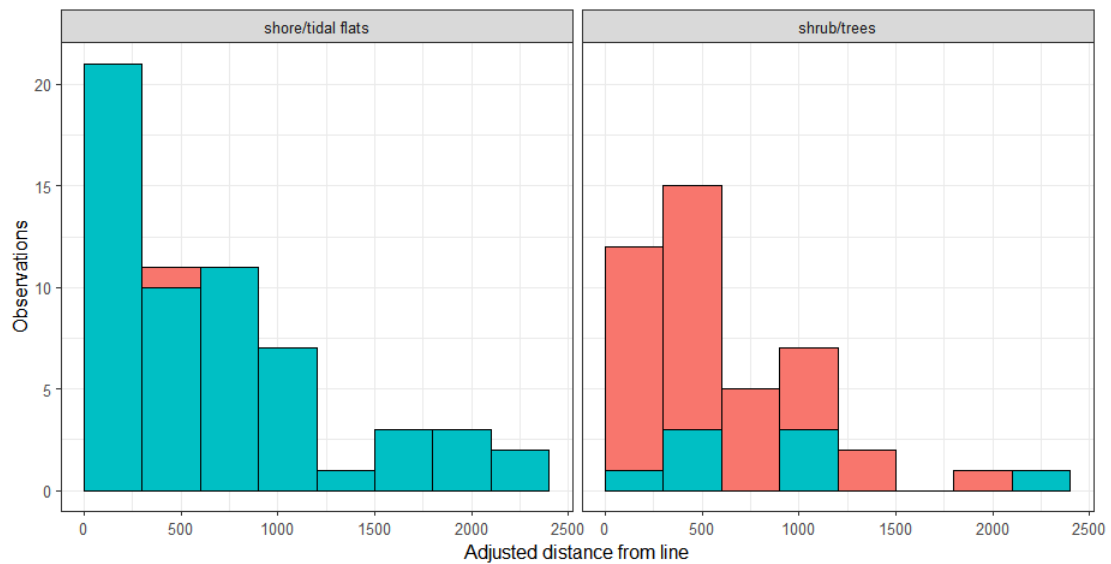


Figure 12: Detection of vegetation height and density (sub-bars).

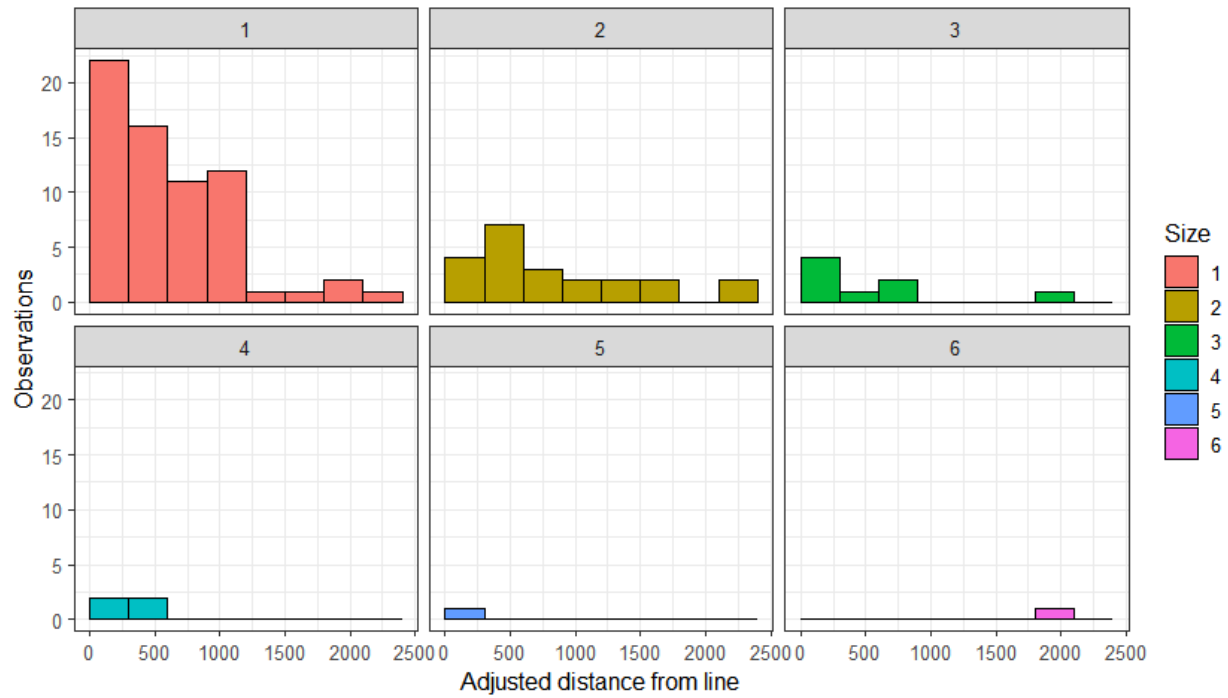


Figure 13: Detection histograms as a function of group size observed.

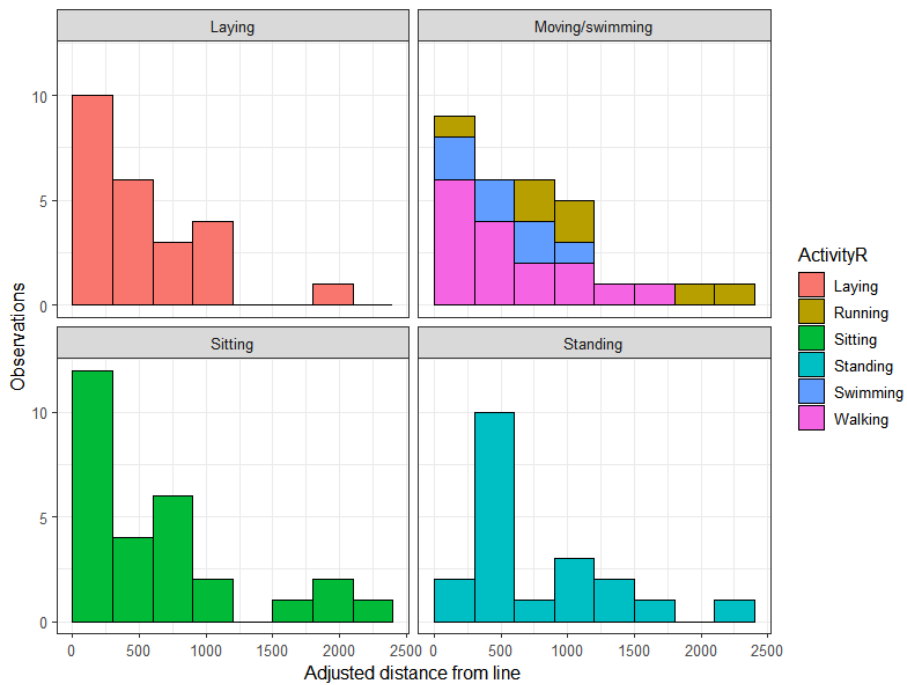


Figure 14: Detection histograms by activity type.

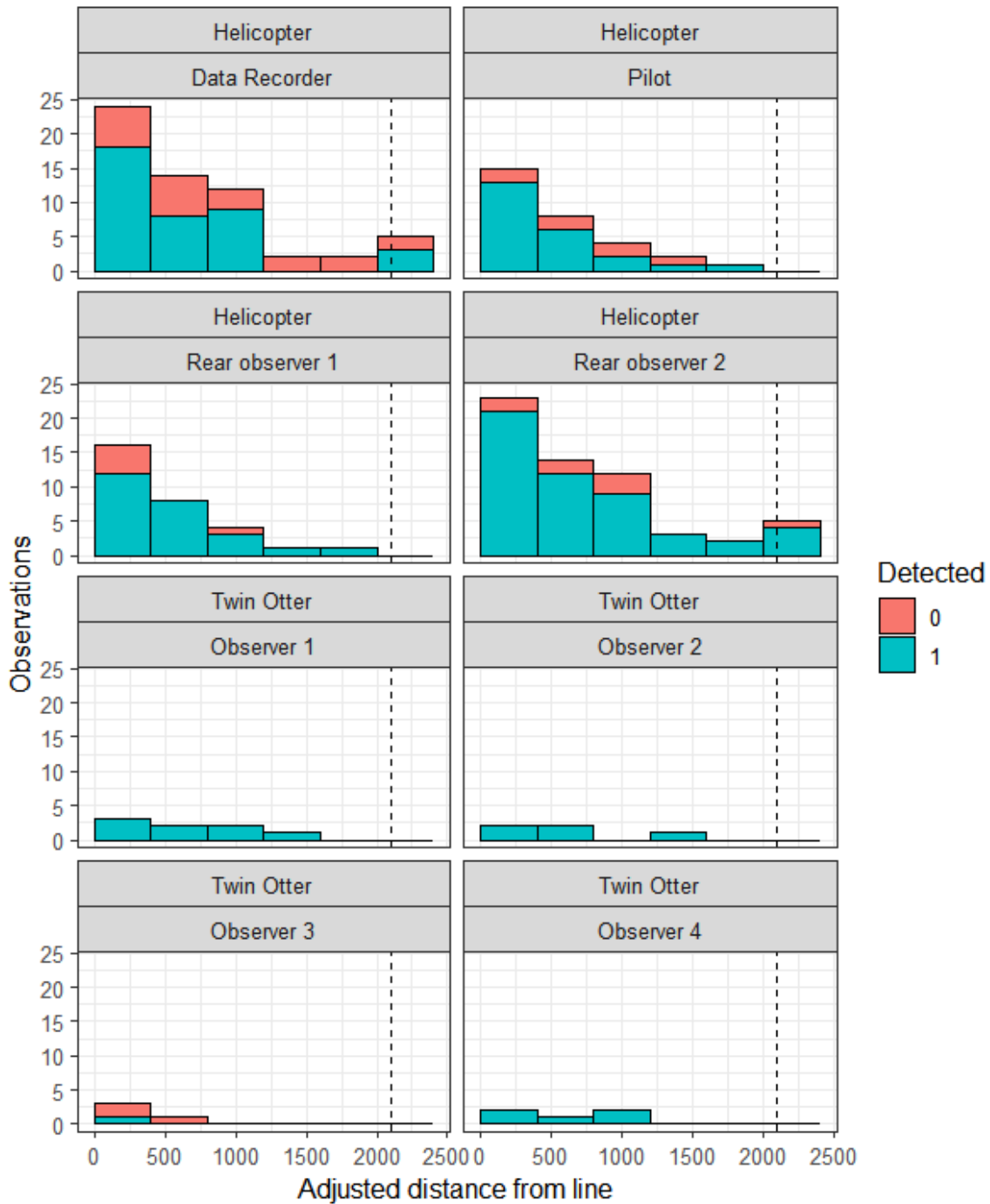


Figure 15: Observer detection histograms for the observers with detections noted (0-not detected, 1-detected)



Figure 16: Observations by side of aircraft with detection type noted.

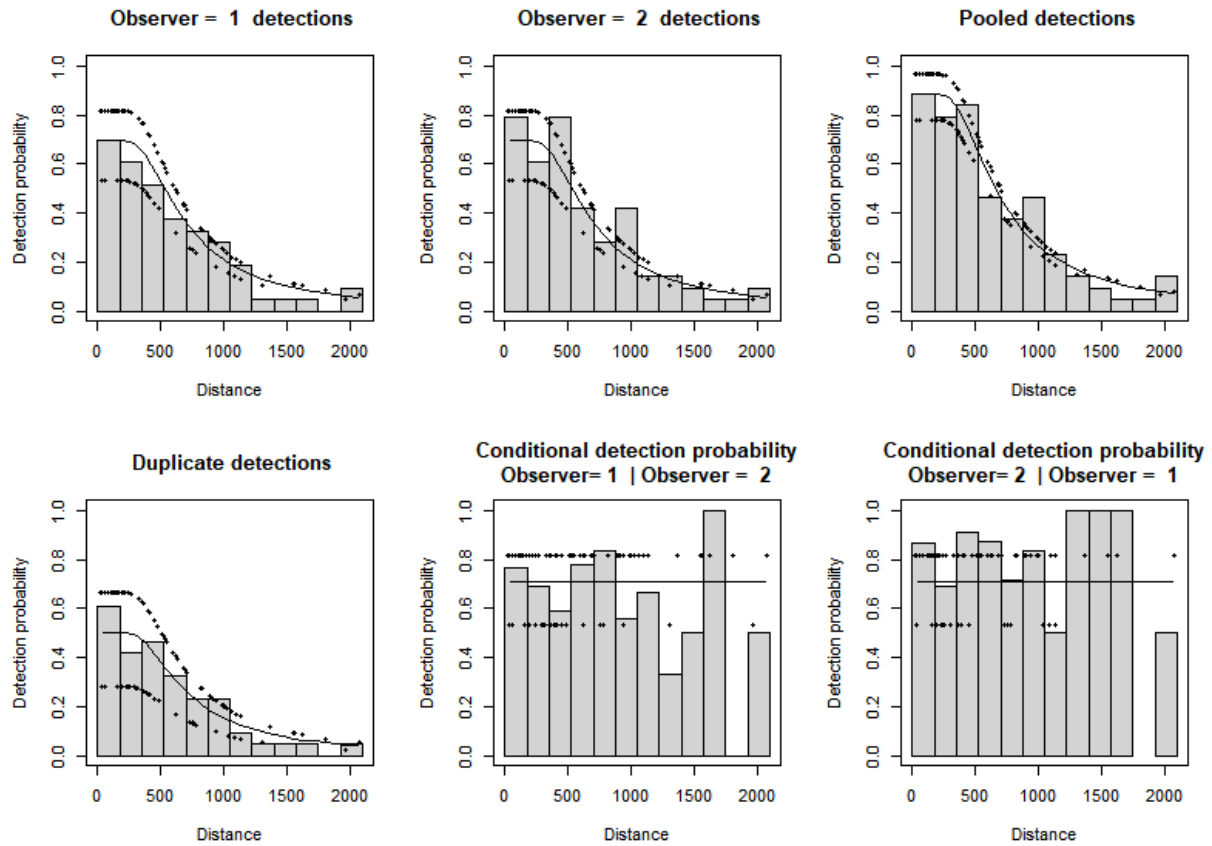


Figure 17: Fit of the most supported distance sampling/double observer model (DS HR(.), MR(VegDensity)) by observers (front and rear). Predictions are given as points for 2 levels of VegDensity.

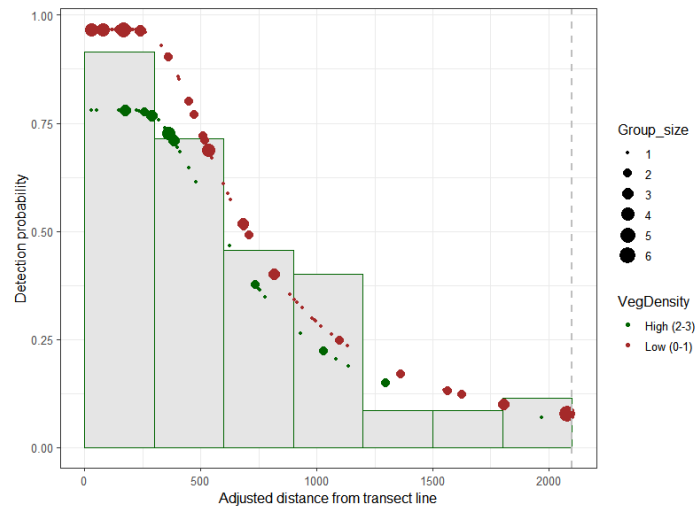


Figure 182: Fit of the most supported distance sampling/double observer model (DS HR(.), MR(VegDensity)) with group sizes and Veg Density delineated.

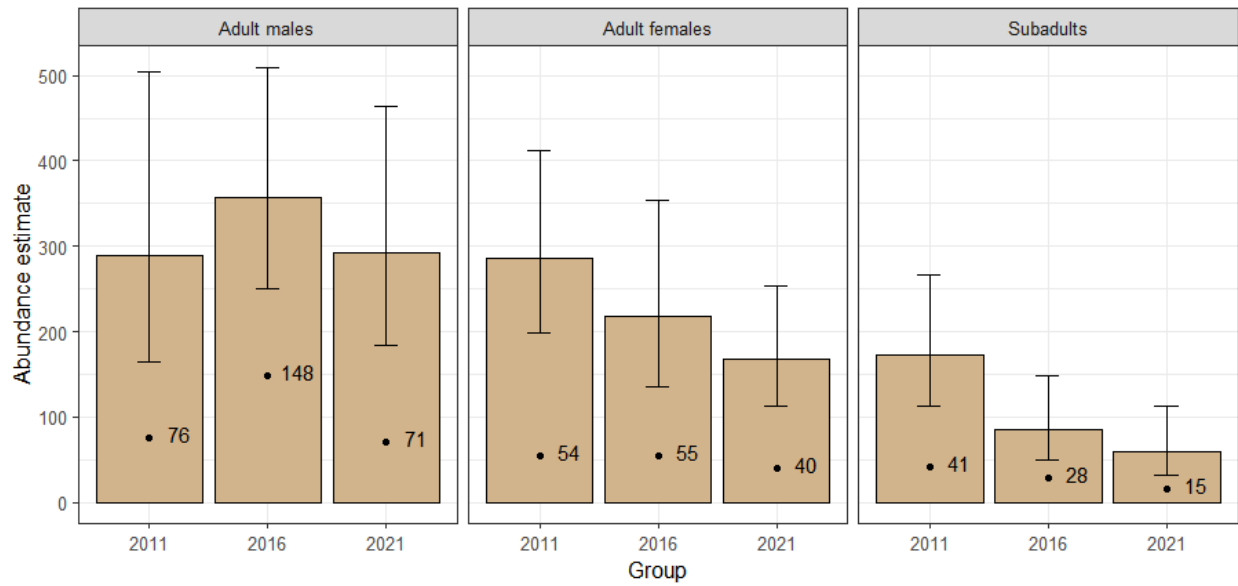


Figure 3: Post-stratified estimates of each age and sex group for 2011, 2016 and 2021. The number of bears observed on transect is also given as a data point.

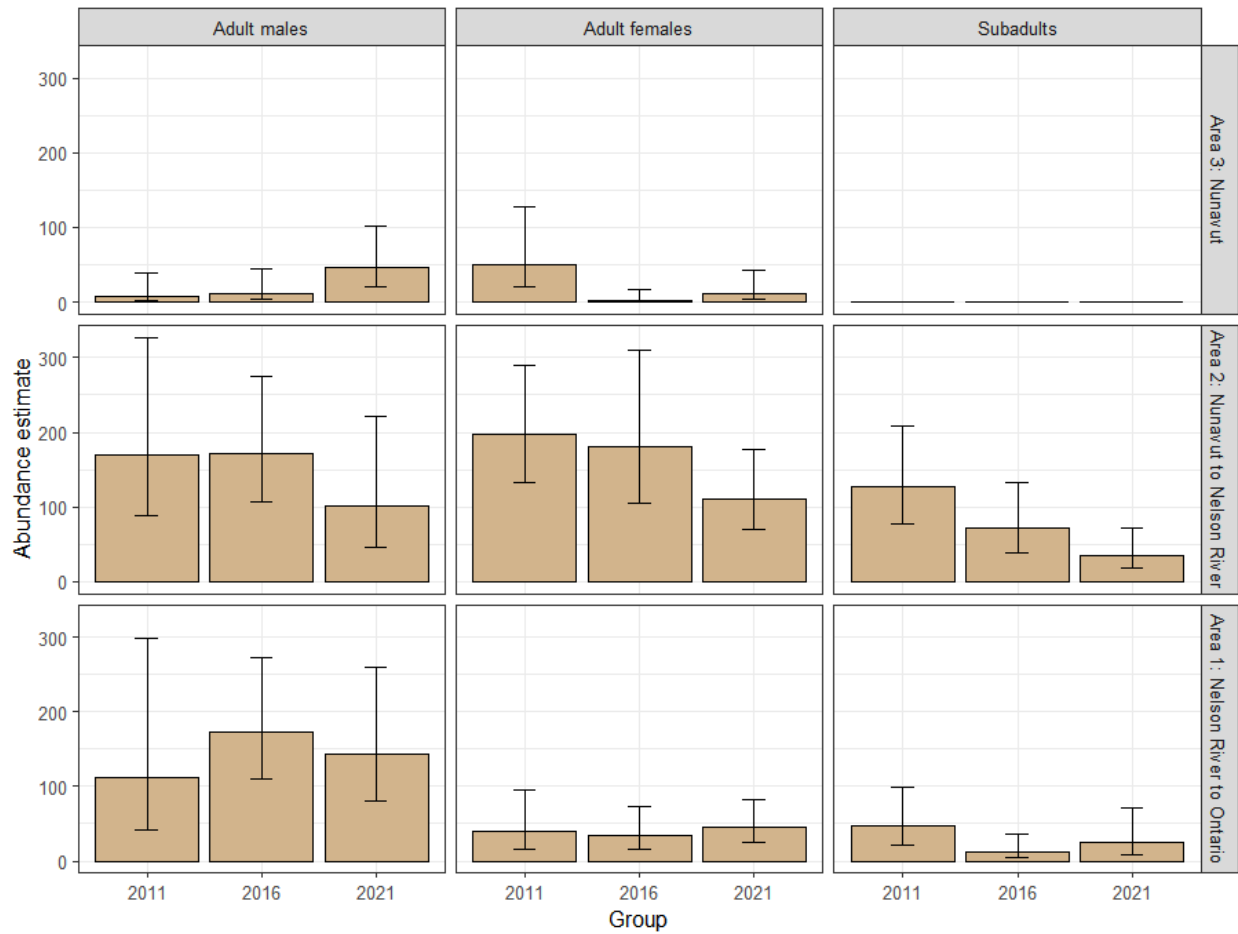


Figure 4: Estimate of abundance by geographic region for adult males, adult female, and subadults.



Figure 21. Two of three polar bear carcasses encountered during the 2021 WH survey.
(Photo credit: S. Atkinson)

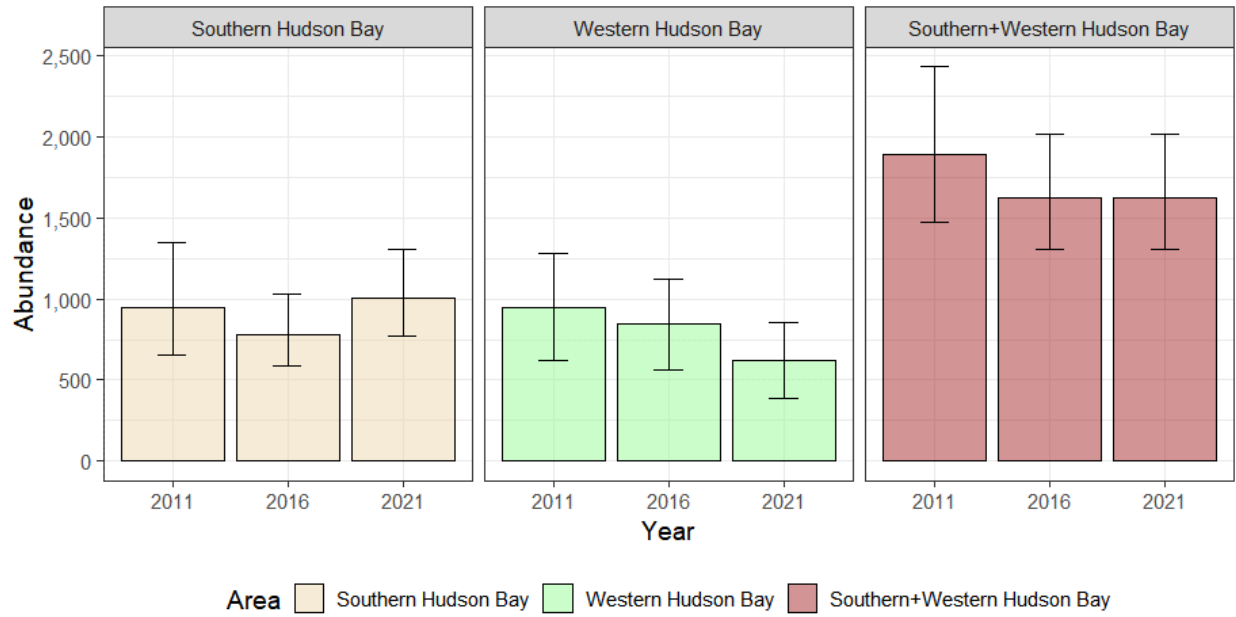
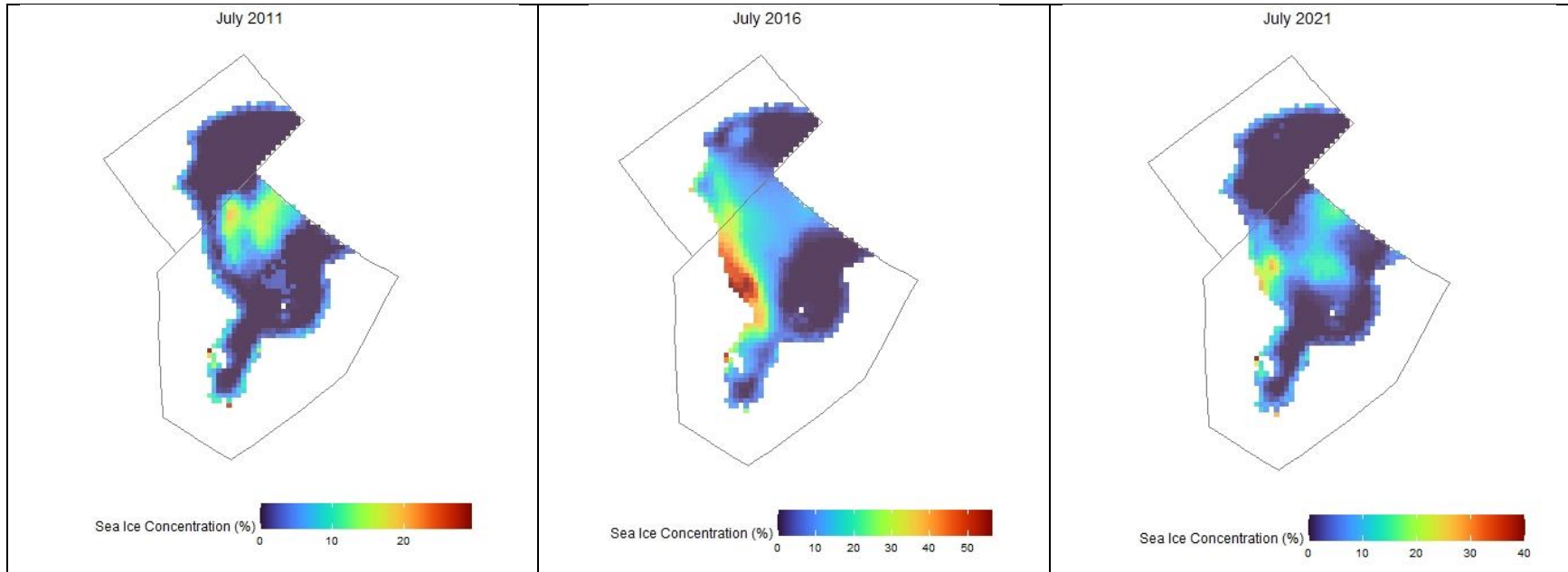


Figure 22. Individual and pooled aerial survey abundance estimates for the Western Hudson Bay (WH) and Southern Hudson Bay (SH), polar bear subpopulations.

1
2



3
4

5 Figure 23. Mean daily sea ice concentration in WH and SH for the month of July from 2011-2021. We used sea ice
6 concentration data from the Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave data set available from the
7 National Snow and Ice Data Center (NSIDC). The monthly average was calculated for each 25 x 25 km grid cell over the
8 eleven-year period.

9
10
11
12

1 Table 1. Description of survey strata used in the 2016 and 2021 WH polar bear aerial surveys. (Source: Dyck et al. 2017).

2

Strata Name	Description
Very Low Density	These strata and transects represented the inland portions of the survey area outside of the Wapusk National Park high density stratum boundaries (Figure 2). These strata were divided further into two main areas, one north and west of the Churchill River up to the Nunavut/Manitoba boundary in the north, and the second south and east of the Nelson River bounded to the east by Cape Tatnam. The very low-density strata covered only inland transects generally ending within 20 to 30 km of the Hudson Bay coastline. Transect spacing was irregular but averaged 17 km across the strata.
Low Density	The stratum and transects occupied the northern extents of the WH polar bear population boundary (approximately 20 km south of Chesterfield Inlet) to the Nunavut/Manitoba border (Figure 2). Modifications from Stapleton et al. (2014) included IQ-based transect extensions both over water and inland within the northern extent of this stratum. Overwater extensions within the remaining extents including 2 transects bi-sectioning Sentry Island were derived solely from Inuit Qaujimagatuqangit (IQ) reports and recommendations. Transect lines in this stratum were spaced 10 km apart, and extended up to 90 km inland, and up to 30 km into Hudson Bay beyond the coast to incorporate the many offshore islands characterizing this coastline. The development of this stratum was largely based on local knowledge which strongly recommended the extension of coastal transects inland and across open water and coastal islands.
Moderate Density	These strata and transects were divided into two areas, one north and west of the Churchill River up to the Nunavut/Manitoba boundary in the north, and the second south and east of the Nelson River, approximately 60 km east into Ontario to the eastern extent of the WH polar bear population boundary. These strata primarily covered a Hudson Bay coastal strip that was approximately 20 to 30 km wide. Transect spacing within this stratum was 7 km with transects extended beyond the tidal flats into open water. Recent information collected by the Manitoba Department of Sustainable Development on summer and spring polar bear habitat including denning sites, spring emergence habitat, and coastal summer retreat, led this survey effort to modify Stapleton et al. (2014) survey design to define a moderate-density stratum from Cape Tatnam east toward East Penn Island with transects extending beyond the coastal strip up to 70 km inland into known denning habitat (Figure 2).
High Density	The stratum and transects followed those described by Stapleton et al. (2014). The stratum boundary ran between the Churchill River in the west to the coast of Hudson Bay in the east with Churchill forming the northern boundary and the Nelson River approximating the southern boundary. The core of the high-density stratum included Wapusk National Park which is known to be a high density summering area, and further inland, a heavily used denning area (Lunn et al. 2016). Transects in this stratum extended up to 100 km inland and were spaced 6 km apart. As with all other survey strata, all transects were extended 5-30 km beyond the coast into Hudson Bay which enabled the survey design to include bears either in water or on the extensive tidal flats known to be occupied by bears during summer and fall periods (Dyck, 2001; Clark and Stirling 1997).

3

1

2 Table 2. Covariates collected for each polar bear observation.

3

Covariate	Description
Activity when sighted	Sitting, lying, running, walking, swimming, other
Vegetation Height	1 = <1m, 2 = 1-3m, 3 = >3m
Vegetation Density	1 = sparse/tundra, 2 = moderate, 3 = dense
Habitat Class	1 = open, 2 = water, 3 =shore/tidal flats, 4 = shrub (below bear head height), 5 = shrub (above bear head height) or trees
Habitat Description	Specify general habitat type (e.g. Coastal plain, tundra, beach, rocky coast, island)
Visibility	1= poor, 2 = fair, 3 = excellent
Cloud Cover	Clear, broken, overcast
Glare	Effect on observer ability to see bears. 1 = no effect, 2 = moderate, 3 = strong.

4

5

1 Table 3: Covariates considered in the mark-recapture/distance sampling analysis. The
 2 primary use of the covariate for distance sampling analysis (DS) and mark-recapture
 3 analysis (MR) is denoted.

4

Covariate	Type	DS	MR	description
size	continuous	x	x	group size
aircraft	binary	x	x	helicopter or airplane
helip	binary	x	x	Pilot of helicopter
helir	binary	x	x	Recorder/Navigator of helicopter.
hab	categorical	x	x	habitat within 30m of observation as classified by observers (Open, Water, Shore, low shrub, tall shrub, and Tree)
RSveg	categorical	x	x	Landsat habitat (Gravel, Low vegetation, Shrub, Tree, and water) at pixel (625 m ²) scale
Veg_height	continuous	x	x	Relative height of vegetation (0-3)
Veg_density	continuous	x	x	Relative density of vegetation (0-3)
vis	binary	x	x	Visibility based on weather
observer	categorical		x	Observers (12)
side	categorical	x	x	Side of plane
Heliside	Categorical	x	x	Fixed-wing, heli right and heli left categories
glare	continuous	x	x	Sun altitude; only in equation if sun was facing observer
Activity	categorical	x	x	Activity of bear when first observed

5

6

1 Table 4. Summary of bears counted on and off transect during distance sampling for
 2 the Western Hudson Bay survey 2021.

3

Strata	On/off transect	Bears observed	Groups observed	Mean group size	SD group size	min	max
High	On	92	60	1.53	0.87	1	5
Low	On	14	9	1.56	1.01	1	4
Moderate N	On	9	5	1.80	0.84	1	3
Moderate S	On	61	38	1.61	1.14	1	6
Very Low S	On	1	1	1.00	0.00	1	1
total		176	112	1.57	0.97	1	6
High	Off	10	6	1.67	1.63	1	5
Low	Off	3	3	1.00	0.00	1	1
Moderate N	Off	2	2	1.00	0.00	1	1
Moderate S	Off	3	2	1.50	0.71	1	2
Total		18	13	1.38	1.12	1	5
Total (on+off)		194	125	1.55	0.98	1	6

4

5

1 Table 5: Summary of bears included and excluded from the distance analysis based on
 2 left truncation (measured blind spot for twin otter=99 m, ASTAR-73.5m on each side of
 3 aircraft), right truncated (2100 meters after left truncation subtracted). Also, 2 bears
 4 were only observed by data recorders and were not included in the analysis.

Strata	Left Truncated	Included in analysis	Only observed by data recorder	Right truncated
High	13	76	0	3
Low	0	13	1	0
Moderate N	1	7	1	0
Moderate S	1	58	0	2
Total	15	154	2	5

7

8

9 Table 6: Summary of observer detection frequencies and naïve detection probabilities
 10 based on frequencies of detections. Note that sample sizes pertain to an event (bears
 11 seen on a side of the aircraft) and therefore will be double the actual number of
 12 observations (given that 2 observers were involved in each observation).

13

Aircraft	Observer	Observed	missed	total	naïve p
Heli	pilot	23	7	30	0.77
Heli	Navigator/Data Recorder	38	21	59	0.64
Heli	1	25	5	30	0.83
Heli	2	51	8	59	0.86
Otter	1	7	1	8	0.88
Otter	2	5	1	6	0.83
Otter	3	5	1	6	0.83
Otter	4	1	4	5	0.20
Otter	5	1	0	1	Constant

14

15

16

1 Table 7: Model selection results for distance sampling analysis. The mark-recapture
 2 component of the MRDS model was set at constant for this analysis step. Covariates
 3 are listed in Table 1. The detection function (hr=hazard rate, hn=half normal) is shown
 4 along with covariates. Constant models are shaded. Akaike information criterion (AIC),
 5 the differences between AIC of the given model and most supported model ΔAIC ,
 6 Akaike weight (w_i), and Log-likelihood of each model is also shown.

7

No	DF	Detection function model	AICc	$\Delta AICc$	w_i	K	LogL
1	hr	constant	1621.73	0.00	0.13	3	-807.7
2	hr	VegDensity	1622.14	0.41	0.10	4	-806.9
4	hr	Helirecorder	1622.72	0.98	0.08	4	-807.1
5	hr	HabClassP	1622.91	1.17	0.07	4	-807.2
6	hr	Side	1623.11	1.38	0.06	4	-807.3
7	hr	VegDensity + Helirecorder	1623.15	1.41	0.06	5	-806.3
8	hn	constant	1623.19	1.45	0.06	2	-809.5
10	hn	size	1623.60	1.86	0.05	3	-808.7
11	hr	VegDensity + Side	1623.68	1.95	0.05	5	-806.5
12	hr	Glare	1623.70	1.96	0.05	4	-807.6
13	hr	size	1623.71	1.97	0.05	4	-807.6
14	hr	Aircraft	1623.90	2.17	0.04	4	-807.7
15	hr	VegDensity + VegHeight	1624.06	2.32	0.04	5	-806.7
16	hr	VegDensity + HabClassP	1624.36	2.63	0.03	5	-806.9
17	hr	HeliSide	1624.60	2.87	0.03	5	-807.0
18	hr	RSveg3	1625.02	3.29	0.02	5	-807.2
19	hr	VegDensity + HabClassP + Helir	1625.38	3.65	0.02	6	-806.2
20	hr	Strata	1626.05	4.32	0.01	6	-806.6
	hr	ObName	1626.51	4.77	0.01	8	-804.5
21	hr	ActivityP	1627.04	5.31	0.01	6	-807.1
	hr	HabClassType	1628.01	6.28	0.01	7	-806.4

8

1 Table 8: Model selection results for double observer analysis. The most supported
 2 distance sampling model (HR constant) was used for the distance sampling component.
 3 Covariates are listed in Table 1. The detection function (hr=hazard rate, hn=half
 4 normal) is shown along with covariates. Constant models are shaded. Akaike
 5 information criterion (AIC), the differences between AIC of the given model and most
 6 supported model ΔAIC , Akaike weight (w_i), and Log-likelihood of each model is also
 7 shown.

8

No	Double observer model	AICc	$\Delta AICc$	w_i	K	LogL
1	VegDensity	1613.95	0.00	0.30	4	-802.8
2	VegDensity + HeliSide	1615.05	1.10	0.17	6	-801.1
3	VegHeight + VegDensity	1615.81	1.86	0.12	5	-802.6
4	HabClassP	1615.89	1.95	0.11	4	-803.7
5	RSveg3	1616.84	2.89	0.07	5	-803.1
6	VegHeight	1617.82	3.88	0.04	4	-804.7
7	Heli recorder	1617.99	4.04	0.04	4	-804.8
8	Heli pilot	1618.41	4.47	0.03	4	-805.0
9	Position	1619.15	5.20	0.02	4	-805.4
10	Activity	1619.27	5.33	0.02	6	-803.2
11	Helip + Helir	1619.56	5.62	0.02	5	-804.5
12	Side	1620.71	6.76	0.01	4	-806.1
13	ObName	1621.09	7.14	0.01	11	-798.0
14	size	1621.22	7.27	0.01	4	-806.4
15	Constant	1621.73	7.79	0.01	3	-807.7
16	Glare	1621.98	8.03	0.01	4	-806.8
17	HeliRight+HeliLeft+Fixedwing	1622.04	8.09	0.01	5	-805.7
18	HeliRight (only)	1622.27	8.33	0.00	6	-804.7
19	AirPosition	1622.55	8.60	0.00	4	-807.1
20	Aircraft	1623.85	9.91	0.00	7	-804.3
21	Helip + Helir +jb +vt	1624.06	10.11	0.00	6	-805.6
22	Strata	1624.35	10.40	0.00	6	-805.7

9

10

1 Table 9: Model selection results for composite distance sampling and double observer analysis. The most supported
 2 distance sampling model (HR constant) was used for the distance sampling component. Covariates are listed in Table 1.
 3 The detection function (hr=hazard rate, hn=half normal) is shown along with covariates. Constant models are shaded.
 4 Akaike information criterion (AIC), the differences between AIC of the given model and most supported model ΔAIC ,
 5 Akaike weight (w_i), and Log-likelihood of each model is also shown. Abundance estimates across all strata are given for
 6 reference.

7

Model selection									Abundance	
No	DSDF	DS model	Double ob model	AICc	$\Delta AICc$	w_i	K	LogL	N	CV
1	hr	constant	VegDensity	1613.94	0.00	0.13	4	-802.8	639	19.2%
2	hr	VegDensity	VegDensity	1614.39	0.45	0.10	5	-801.9	608	18.6%
3	hr	Hellir	VegDensity	1614.96	1.02	0.08	5	-802.2	619	19.2%
4	hr	constant	VegDensity + HeliSide	1615.03	1.09	0.07	6	-801.1	648	19.2%
5	hr	HabClassP	VegDensity	1615.15	1.21	0.07	5	-802.3	605	18.5%
6	hn	constant	VegDensity	1615.35	1.41	0.06	3	-804.6	578	15.7%
7	hr	VegDensity + Bellr	VegDensity	1615.44	1.50	0.06	6	-801.3	604	18.8%
8	hr	VegDensity	VegDensity + HeliSide	1615.57	1.64	0.06	7	-800.2	619	18.8%
9	hr	constant	VegDensity + Ob_jb	1615.63	1.69	0.05	5	-802.5	638	19.1%
10	hr	constant	Veg_Height+ VegDensity	1615.79	1.85	0.05	5	-802.6	639	19.1%
11	hr	HeliRight	VegDensity + HeliSide	1615.87	1.93	0.05	7	-800.3	598	18.7%
12	hr	size	VegDensity	1615.95	2.01	0.05	5	-802.7	671	21.8%
13	hr	VegDensity + Side	VegDensity	1615.97	2.03	0.05	6	-801.5	603	18.8%
14	hr	HeliSide	VegDensity + HeliRight	1616.27	2.33	0.04	7	-800.5	599	18.8%
15	hr	VegDensity	HabClass	1616.34	2.40	0.04	5	-802.9	596	18.3%
16	hr	Veg_HeightP+ VegDensity	VegDensity	1616.34	2.41	0.04	6	-801.7	607	18.5%
17	hr	VegDensity+ HeliSide	VegDensity	1617.69	3.75	0.02	7	-801.2	599	18.7%
18	hr	constant	constant	1621.73	7.79	0.00	3	-807.7	622	19.1%
19	hr	VegDensity + HeliSide	HeliSide	1625.92	11.98	0.00	8	-804.2	578	18.1%

1 Table 10: Strata estimates from the most supported DS/MR model (Table 9, model 1)

2

Strata	individuals	N	SE	Conf. Limit	CV
High	76	290	75.01	175 482	0.26
Low	13	76	32.77	33 174	0.43
Moderate N	7	28	21.39	7 113	0.76
Moderate S	58	244	57.08	154 387	0.23

3

4

1 Table 11. Post-stratified estimates of sex and age groups from model 1 (Table 9).
 2

Group	Strata	Individuals	N	SE	CIL	CIU	CV
Males	High	25	89.3	39.7	38	210	0.44
Males	Low	8	46.5	18.9	21	102	0.41
Males	Moderate N	3	12.1	8.9	3	47	0.74
Males	Moderate S	35	144.0	43.1	80	259	0.30
Males	Very Low S	0	0.0	0.0	0	0	0.00
Males	Total	71	292.0	69.2	184	463	0.24
Females	High	26	102.7	24.5	64	164	0.24
Females	Low	2	11.6	8.5	3	43	0.73
Females	Moderate N	2	8.0	8.0	1	45	1.00
Females	Moderate S	10	46.1	13.9	26	83	0.30
Females	Very Low S	0	0.0	0.0	0	0	0.00
Females	Total	40	168.5	35.2	112	253	0.21
Cubs	High	9	35.9	15.3	16	82	0.43
Cubs	Low	1	5.8	5.9	1	31	1.01
Cubs	Moderate N	1	4.0	4.0	1	22	1.00
Cubs	Moderate S	1	4.9	4.9	1	27	1.01
Cubs	Very Low S	0	0.0	0.0	0	0	0.00
Cubs	Total	12	50.6	18.2	25	101	0.36
Yearlings	High	7	27.4	11.6	12	62	0.42
Yearlings	Low	2	11.6	12.0	2	64	1.03
Yearlings	Moderate N	1	4.0	4.0	1	22	1.00
Yearlings	Moderate S	6	24.7	13.2	9	68	0.53
Yearlings	Very Low S	0	0.0	0.0	0	0	0.00
Yearlings	Total	16	67.7	22.8	35	129	0.34
Subadults	High	9	35.1	12.7	17	71	0.36
Subadults	Low	0	0.0	0.0	0	0	0.00
Subadults	Moderate N	0	0.0	0.0	0	0	0.00
Subadults	Moderate S	6	24.7	13.7	9	70	0.56
Subadults	Very Low S	0	0.0	0.0	0	0	0.00
Subadults	Total	15	59.8	19.5	32	112	0.33

3
 4

1 Table12. Estimates of gross change (GC), probability that gross change is greater than
 2 1 p(GC<1), and annual rate of change (λ) at different survey intervals for distance
 3 sampling estimates.
 4

Interval Group	GC	SE	Conf. Limit	p(GC>1)	λ	SE	Conf. limit		
<u>2011 to 2016</u>									
Males	1.24	0.46	0.66	2.43	0.759	1.04	0.07	0.92	1.19
Females	0.76	0.25	0.41	1.37	0.177	0.95	0.06	0.84	1.06
Subadults	0.49	0.19	0.24	0.97	0.021	0.87	0.06	0.75	0.99
All	0.87	0.22	0.54	1.39	0.282	0.97	0.05	0.89	1.07
<u>2016 to 2021</u>									
Males	0.82	0.26	0.45	1.44	0.237	0.96	0.06	0.85	1.08
Females	0.77	0.27	0.42	1.45	0.214	0.95	0.06	0.84	1.08
Subadults	0.70	0.34	0.30	1.59	0.193	0.93	0.08	0.79	1.10
All	0.77	0.20	0.47	1.25	0.144	0.95	0.05	0.86	1.05
<u>2011 to 2021</u>									
Males	1.01	0.41	0.50	2.10	0.525	1.00	0.04	0.93	1.08
Females	0.59	0.17	0.34	1.01	0.027	0.95	0.03	0.90	1.00
Subadults	0.35	0.15	0.16	0.72	0.002	0.90	0.03	0.83	0.97
All	0.67	0.18	0.40	1.10	0.056	0.96	0.02	0.91	1.01

5
 6
 7

1 Table 13. Estimates of gross change (GC), probability that gross change is greater than
 2 1 and annual rate of change (λ) from 2011 to 2021 for distance sampling estimates for
 3 age/sex groups by geographic region. Estimates are given for adult females, adult
 4 males and subadults.

5

Area Group	GC	SE	Conf. Limit	p(GC>1)	λ	SE	Conf. Limit		
<u>Area 3: Nunavut</u>									
Males	6.60	16.34	1.40	55.55	0.990	1.21	0.12	1.03	1.49
Females	0.23	0.27	0.04	1.00	0.025	0.86	0.07	0.73	1.00
Subadults	None observed								
<u>Area 2 Nunavut to Nelson River</u>									
Males	0.60	0.36	0.22	1.58	0.145	0.95	0.05	0.86	1.05
Females	0.56	0.18	0.31	1.02	0.028	0.94	0.03	0.89	1.00
Subadults	0.28	0.13	0.12	0.63	0.001	0.88	0.04	0.81	0.95
<u>Area 1: Nelson River to Ontario</u>									
Males	1.29	1.00	0.46	4.21	0.720	1.03	0.06	0.93	1.15
Females	1.18	0.81	0.44	3.49	0.661	1.02	0.05	0.92	1.13
Subadults	0.53	0.44	0.14	1.76	0.140	0.94	0.06	0.82	1.06

6
 7
 8

Table 14. Polar bear litter sizes and number of dependent offspring observed (as proportion of total observations) during recent ice-free season studies in central and eastern Canada. Data are presented as mean (standard error).

Subpopulation	Litter Size		Proportion of Total Observations		Source
	Cubs-of-the-year	Yearlings	Cubs-of-the-year	Yearlings	
Western Hudson Bay (2011)	1.43 (0.08)	1.22 (0.10)	0.07	0.03	Stapleton et al. (2014)
Western Hudson Bay (2016)	1.63 (0.10)	1.25 (0.16)	0.11	0.03	Dyck et al. (2017)
Western Hudson Bay (2021)	1.46 (0.13)	1.39 (0.18)	0.09	0.09	This report
Southern Hudson Bay (2011)	1.56 (0.06)	1.54 (0.08)	0.16	0.12	Obbard et al. (2015)
Southern Hudson Bay (2016)	1.46 (0.06)	1.32 (0.10)	0.19	0.05	Obbard et al. (2018)
Southern Hudson Bay (2021)	1.57	1.47	0.18	0.18	Northrup et al. (2022)
Baffin Bay (2011-13)	1.57 (0.06)	1.51 (0.09)	0.19	0.10	SWG (2016)
Foxe Basin (2009-2010)	1.54 (0.04)	1.48 (0.05)	0.13	0.10	Stapleton et al. (2015)
Davis Strait (2017-2018)	1.42 (0.15)	1.54 (na)	0.12	0.09	Dyck et al. (2022)

Appendix 1 - Sensitivity Analyses to Truncation and Observer Issues

a) Right Truncation

Model 1 was also run with distances up to the maximum distance (2210 included) to test sensitivity of model fit and estimates to right truncation. Model fit was reduced (overall $\chi^2=24.1$, $df=16$, $p=0.0088$) with an overall estimate of 650 bears (SE=128.1, CI=442-966, CV=19.7%). The reduction of model fit suggested that right truncation was justified with minimal overall change in estimates.

b) Left Truncation

Data was left truncated at intervals further from the predefined distances up to 100 meters with minimal change in estimates (Figure A2-1).

c) Sensitivity to Lower Number of Observations on the Right Side of the Helicopter

The right side of the helicopter had the pilot as the front observer and the same individual as second observer for most of the survey. The number of observations from this side was reduced with 30 groups observed compared to 59 to the left side of the helicopter. The difference in detections was modelled using the HeliSide term that allowed for distinct detection function or detection probabilities for the fixed wing (sides pooled), right side and left side of the helicopter. A model that allowed distinct detection probabilities for each side of the helicopter (Table 7, model 4) showed moderate support from the data ($\Delta AICc=1.1$) with an estimate that was 10 bears higher than the most supported model. The main challenge with this analysis is that the actual detection probabilities for the pilot and right observer as indicated by double observer data suggests reasonable detection probabilities (Table 4) with the pilot and right observer showing naïve detection probabilities of 0.77 and 0.83. Therefore, missing of observations is not evident from these probabilities, which could be due to low sample sizes. Detection plots for each observer (Figure 12) also show observations at the full range of distances and therefore there is little evidence of differences in detection functions.

One approach to assess potential bias is to post-stratify the data by side of aircraft. For this the full data set is used to model detection, and then the right and left side observations are used for estimates. Estimates from the 2 sides then add up to the total estimate (Table A2-1). If this is done approximately 40% of the estimate comes from the right side of aircraft and 60% from the left side. Obviously, it would not be expected for the 2 estimates to be equal, however, this gives a sense of the difference in estimates by side of aircraft.

The main potential bias with the right side of the helicopter would be unmodelled heterogeneity of detection probabilities which are exacerbated when detection probabilities become lower. Having 2 weaker observers paired together makes it harder to assess if this is occurring. The amount of data available to model this potential effect is limiting.

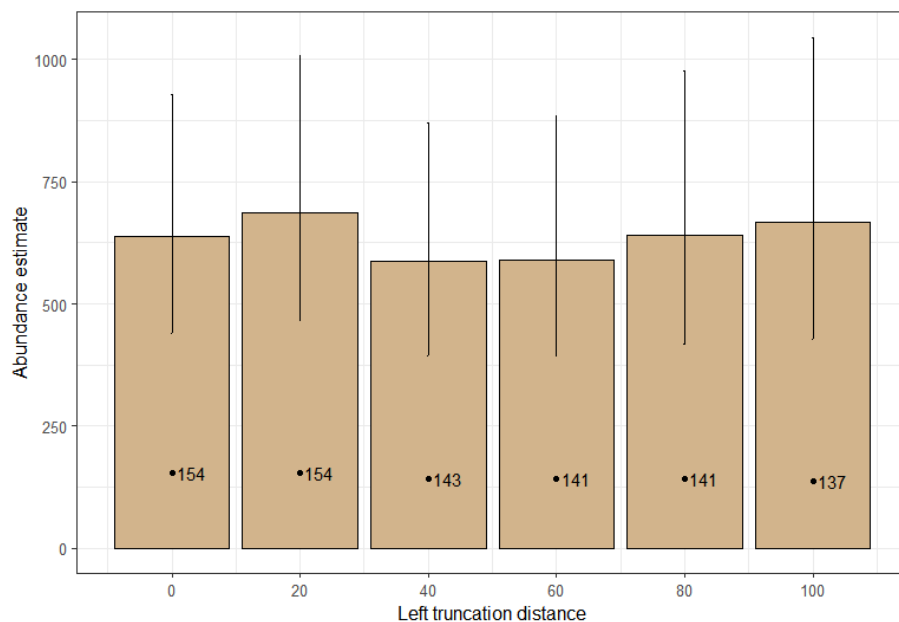


Figure A2-1. Model 1 sensitivity to additional left truncation distances. Points are the sample size of bears used in the analysis.

Table A2-1: Post-stratified estimates by side of aircraft.

Strata	Individuals	N	SE	CIL	CIU	CV
<u>right side</u>						
High	31	115	49.9	50	265	43.4%
Low	9	52	30.2	18	154	57.7%
Moderate N	2	8	8.1	1	45	100.6%
Moderate S	18	79	29.0	38	161	36.9%
Very Low S	0	0	0.0	0	0	0.0%
Total	60	254	71.1	148	437	28.0%
<u>left side</u>						
High	45	175	41.5	110	279	23.7%
Low	4	23	11.8	9	61	50.5%
Moderate N	5	20	20.1	4	112	100.0%
Moderate S	40	166	40.3	103	267	24.3%
Very Low S	0	0	0.0	0	0	0.0%
Total	94	385	73.9	264	560	19.2%
Combined Total (left +right)	154.00	638.56				

Appendix 2 – Further estimation of trend for age-sex post stratified estimates

We used a simulation methodology to estimate confidence limits on gross and annual change in post-stratified estimates of males, adult females (excluding cubs and yearlings), subadults, and all bears. This simulation test is equivalent to a one-sided hypothesis test for decline where the null hypothesis is that the estimate in the previous year is equal or greater than the current year $H_0: N_2 \geq N_1$ and the alternative hypothesis is that the current year estimate is lower ($H_a: N_2 < N_1$). We cross-validated these results using a standard t-test (Satterthwaite 1946, Zar 1996). Comparison of p-values and pGC reveals that these two test methods yielded very similar results.

We note that the 1-tailed hypothesis provides a more powerful test for decline than a 2-tailed test (which tests if the 2 estimates are equal). We felt the 1 tailed test was justified given that the question of management interest was whether a decline was occurring as opposed to whether the two estimates were equal. We also note that overlap of confidence intervals (Figure 20) is not a valid test for statistical significance especially if the hypothesis being tested is one tailed.

Table 1: Results of t-tests for decline in yearly estimates of age/sex groups for WHB (null hypothesis $H_0: N_2 \geq N_1$ and alternative hypothesis $H_a: N_2 < N_1$). Degrees of freedom (df) for each survey and combined degrees of freedom are also given.

Year	Estimates						t-test	p-value	simulation	
group	N_1	SE_ N_1	df_ N_2	N_2	SE_ N_2	df_ N_2	t-test	(N_1 & N_2)	(1-tailed)	p(GC<1)
<u>2011-6</u>										
Males	289	82.9	91.4	357	65.0	224.6	0.65	206.4	0.741	0.759
Females	286	53.1	204.5	219	54.0	154.3	-0.89	350.1	0.186	0.177
Subadults	173	38.3	124.0	85	24.2	75.3	-1.94	192.4	0.027	0.021
All	956	166.3	244.9	831	138.6	217.5	-0.58	455.7	0.282	0.281
<u>2016-21</u>										
Males	357	65.0	224.6	292	69.2	170.0	-0.68	378.9	0.248	0.236
Females	219	54.0	154.3	168	35.2	192.8	-0.78	273.9	0.219	0.216
Subadults	85	24.2	75.3	60	19.5	108.9	-0.82	158.7	0.207	0.194
All	831	138.6	217.5	639	122.3	198.9	-1.04	413.7	0.149	0.144

<u>2011-21</u>										
Males	289	82.9	91.4	292	69.2	170.0	0.03	208.7	0.512	0.525
Females	286	53.1	204.5	168	35.2	192.8	-1.85	351.6	0.033	0.027
Subadults	173	38.3	124.0	60	19.5	108.9	-2.63	182.8	0.005	0.002
All	956	166.3	244.9	639	122.3	198.9	-1.54	427.5	0.062	0.056

EXECUTIVE SUMMARY

- We used biopsy mark recapture data to assess the movement of bears between Western Hudson Bay (WH) and Southern Hudson Bay (SH) polar bear subpopulations
- 727 DNA samples were obtained over 6 years, from which 458 unique individuals were identified
- In 2021 and 2022, 25-36% of sampled bears were found to move between the two subpopulations demonstrating extensive movements across the WH and SH subpopulation boundaries.
- Interannual variation in the spatial distribution of sea ice influenced bear distribution
- Bear movement between the adjacent subpopulations were higher than previously reported but primarily occurred at the southern boundary of WH (Cape Tatnam) and the SH subpopulation. Analysis of bear movement and harvest vulnerabilities across Hudson Bay may be necessary to ensure harvest management objectives can be achieved.

TECHNICAL SUMMARY

Harvest summary

The following is a summary of the harvest locations for individual bears that were sampled as part of the ECCC biopsy report (McGeachy et al. 2023)

Three areas in Hudson Bay were defined, Area 1 Nelson River to the NU/MB border, Area 2 from the Nelson River to the WH/SH subpopulation boundary and Area 3 from the WH/SH boundary to James Bay (Figure 1). Bears were sampled in Area 1 from 2017-2022, in Area 2 from 2017-2022 and Area 3 in 2021/2022. No sampling occurred in 2020. In total 613 (32%) samples were collected in Area 1, 724 (38%) in Area 2 and 571 (30%) in Area 3.

Harvest samples (N=377, WH = 187, SH = 190) were collected from Nunavut and Quebec from 2017/2018 through 2022/2023 harvest season. Of these samples, 39 (10%) matched bears previously sampled between 2017-2022 (Figure 2). Area 1 represented 54% of the recoveries, Area 3 represented 28% and Area 2 represented 18%.

Bears sampled in Area 1 were only harvested in WH and comprised 81% of the WH harvest recoveries. Bears sampled in Area 2 were harvested in both WH and SH. Bears sampled in Area 2 comprised 11% of the recoveries from WH while bears that were sampled in both Area 1 and Area 2 comprised 8% of the harvest recoveries. Thus, in total, only 19% of the harvest recoveries in WH included bears sampled in Area 2.

In SH, 85% of the harvest recoveries were from bears previously sampled in Area 3 while bears sampled in Area 2 represented 15%.

The data suggests that bears from Area 2 in Hudson Bay are harvested less frequently. When they are harvested, they are harvested in both WH and SH. Thus, the assumption that all bears in Area 2 are available for harvest in WH appears to be invalid. A cautionary approach should be taken when considering a harvest quota for WH that includes abundance estimates from Area 2.

The report from ECCC (McGeachy et al. 2023) showed movement between adjacent subpopulations is likely a contributing factor that influenced abundance estimates derived from aerial surveys in 2021 for WH and SH. Movement between adjacent subpopulations was primarily the result of exchange between Area 2 and Area 3 in relation to sea ice dynamics. When considered in conjunction with this summary, the movement of bears between WH and SH appear to be individuals that have a lower vulnerability to harvest within WH and SH.

References

McGeachy, D., Lunn, N.J., Northrup, J.M., Trim, V., Davis, C., and Derocher, A.E. (2023). Distributional shifts of polar bears (*Ursus maritimus*) in Hudson Bay in relation to sea ice dynamics, 2017-2022 Final Report. Environment and Climate Change Canada, 32 pp.



Figure 1. Study area showing 3 distinct geographic regions in Hudson Bay (Area 1, Area 2 and Area 3). Area 1 and Area 2 were sampled from 2017-2021 and Area 3 was sampled 2021-2023. No sampling occurred in 2020.

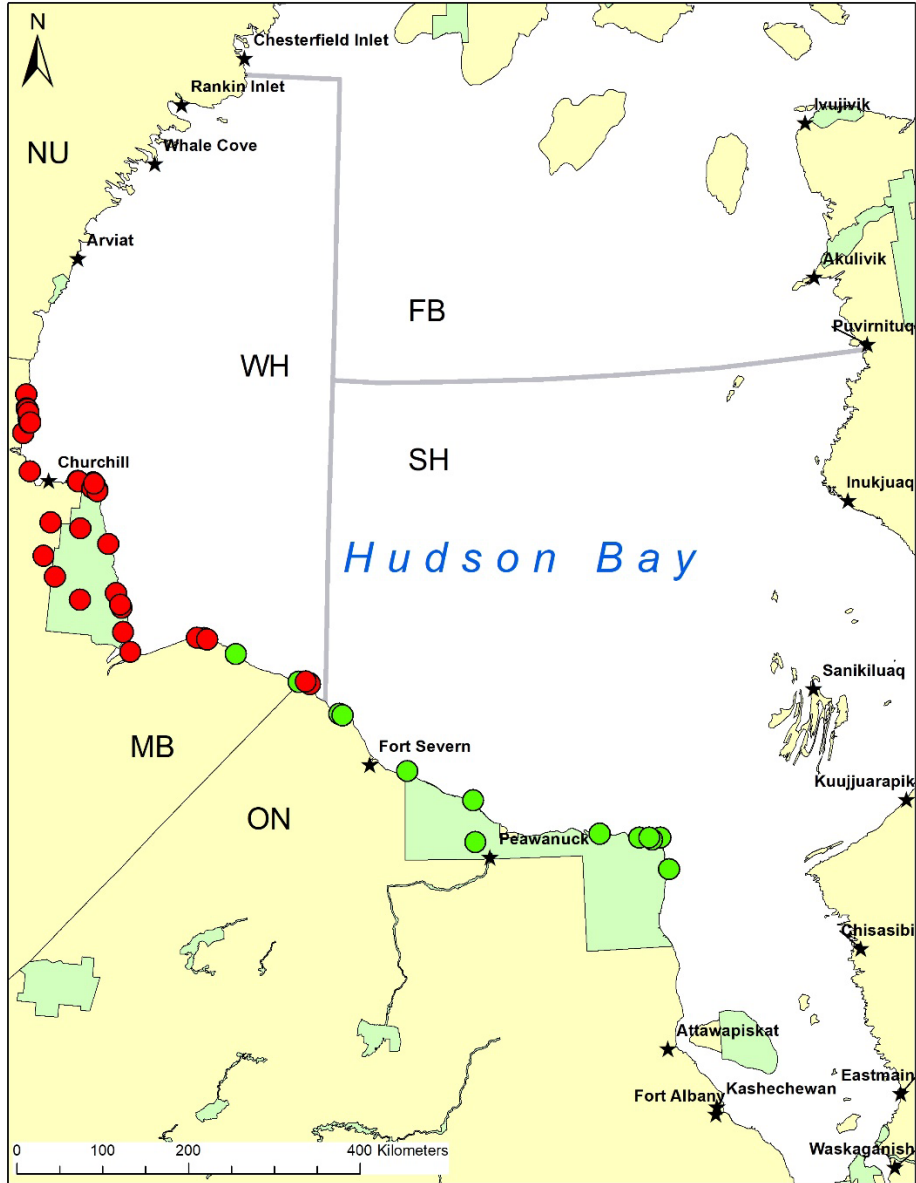


Figure 2. Locations where bears were sampled from 2017-2022 that were later harvested in WH (red circles) or SH (green circles) between 2017/18 and 20122/23 harvest seasons.



Distributional shifts of polar bears (*Ursus maritimus*) in Hudson Bay in relation to sea ice dynamics, 2017-2022 Final Report

D. McGeachy^{1,4}, N. J. Lunn¹, J. M. Northrup², V. Trim³, C. Davis⁴, A. E Derocher⁴

¹ Environment and Climate Change Canada, CW-405 Biological Sciences Building, University of Alberta, Edmonton, AB T6G 2E9

² Ontario Ministry of Natural Resources and Forestry, DNA Building B217, Trent University, 2140 East Bank Drive, Peterborough, ON K9L 1Z8

³ Manitoba Department of Natural Resources and Northern Development, Water Stewardship and Biodiversity Division, Wildlife and Fisheries Branch, Box 28, 59 Elizabeth Drive, Thompson, MB R8N 1X4

⁴ Department of Biological Sciences, University of Alberta, Edmonton, AB T6G 2E9



Please cite as: McGeachy, D., Lunn, N.J., Northrup, J.M., Trim, V., Davis, C., and Derocher, A.E. (2023).
Distributional shifts of polar bears (*Ursus maritimus*) in Hudson Bay in relation to sea ice dynamics,
2017-2022 Final Report. Environment and Climate Change Canada, 32 pp.

Executive Summary

We investigated distributional shifts and likely subpopulation of origin of polar bears sampled genetically while onshore near the Western Hudson Bay (WH) and Southern Hudson Bay (SH) subpopulation boundary between 2017 and 2022. We used logistic regression to assess the influence of spatial location of remnant ice in Hudson Bay on bear distribution and one-way ANOVAs to assess annual displacement from repeated sampling events for adult males, adult females, subadult females and subadult males.

At the outset of the study, most bears near the subpopulation boundary had not previously been handled and tagged by researchers (57-71% between 2017 and 2019), previously tagged bears were a mixture of WH (72%) and SH (28%) animals. In 2021, when comprehensive aerial surveys of SH and WH were flown, remnant ice occurred within the boundaries of SH, off the coast of Peawanuck, ON. We sampled 183 independent bears in SH of which 25% were classified as WH bears, 10% as SH and the remaining 65% were first occurrences. In 2022 remnant ice occurred along much of the Manitoba and Ontario coastline with more ice present in WH compared to 2021. We sampled 73 bears in SH in 2021 that were sampled again in 2022; 64% of these resampling's occurred in SH and 36% in WH. In comparison, we sampled 120 bears in WH in 2021 that were sampled again in 2022; 93% of the resampling's were in WH and 7% in SH. This represents a possible increase in the number of bears in WH by 29% and an equivalent decrease in SH from 2021 to 2022 based on movement from our data.

Sea ice influenced bear movement with bears 5x more likely to move westward in years when remnant ice occurred in the western part of the Bay. Adult male displacement differed between years ($F_{2, 222} = 4.175$, $P = 0.02$) with longer movements associated with larger interannual variation in the spatial dynamics of remnant ice. Subadult females had higher displacement compared to adult females or adult males ($F_{3, 185} = 3.57$, $P = 0.02$) but not compared to subadult males. The coefficient of variation for displacement was high 87%, 66%, 77% and 77% for adult males, adult females, subadult males, and subadult females, respectively.

We documented higher exchange between neighbouring subpopulations than previously reported associated with higher displacement of all age and sex classes and linked to variation in sea ice dynamics. Our findings suggest temporary distributional shifts of bears, especially near the SH/WH subpopulation boundary increase the uncertainty in abundance estimates and the trends in those estimates from aerial surveys of each subpopulation in isolation. Such uncertainty has important implications for the management of polar bears in Hudson Bay.

Introduction

Polar bears are distributed throughout the ice-covered waters of the circumpolar Arctic in 19 relatively discrete subpopulations and rely on sea ice as a platform from which to hunt seals, their primary prey (Stirling and Øritsland 1995, Laidre et al. 2008, Thiemann et al. 2008, Galicia et al. 2015). Although polar bears still occupy much of their historic range, the Arctic has been warming more rapidly than the global mean and the loss of Arctic sea ice is accelerating (Stroeve et al. 2012, Rantanen et al. 2022). The loss of sea ice, caused by anthropogenic forcing of the climate system, has raised long-term conservation concerns for Arctic marine mammals, including polar bears (Stirling and Derocher 1993, Derocher et al. 2004, Laidre et al. 2015).

The Western Hudson Bay (WH) and Southern Hudson Bay (SH) polar bear subpopulations occur near the southern limit of the species' range. Increasing spring temperatures in the region have resulted in earlier sea-ice breakup and later freeze-up trends (Gagnon and Gough 2005, Stirling and Parkinson 2006, Hochheim et al. 2010). These changes have reduced the amount of time that polar bears can hunt seals from the ice, especially during the critical spring period, and forced WH polar bears to spend progressively longer periods on land, where they enter a negative energy balance (Cherry et al. 2013, Lunn et al. 2016, Johnson et al. 2020). Longer ice-free periods have been linked to lower body condition and reproductive rates of WH polar bears (Derocher and Stirling 1995b, Stirling et al. 1999, Sciuillo et al. 2016). More recently, declines in abundance were related to declines in survival and sea ice chronology (Regehr et al. 2007, Lunn et al. 2016). SH has had less consistent monitoring of polar bears over the last 4 decades, but has seen similar patterns, with a generally longer ice-free season (Stern and Laidre, 2016), and declines in both body condition and survival between the 1980s and early 2000s (Obbard et al. 2007, 2016).

The distribution, abundance, and delineation of boundaries of the WH subpopulation (Figure 1) were largely based on harvest recoveries and recapture of tagged individuals (Stirling et al. 1977, Derocher and Stirling 1990, Derocher and Stirling 1995a, Taylor and Lee 1995). Although the neighbouring Foxe Basin and SH subpopulations have high levels of mixing with WH and each other on the sea ice during the

mating season (Viengkone et al. 2016), throughout the ice-free period, the majority of bears show high fidelity to terrestrial summering areas and little exchange with neighbouring subpopulations is thought to occur (Stirling et al. 1977, Derocher and Stirling 1990, Peacock et al. 2010, Obbard and Middel 2012, Lunn et al. 2016). While fidelity to terrestrial summering areas is generally high, inter-annual variation in sea-ice dynamics has been shown to influence bear distribution during the ice-free season in Hudson Bay (Stirling et al. 1999, Cherry et al. 2013). Prevet and Kolenosky (1982) used aerial counts of the coastal area and documented higher numbers of bears in Ontario (SH) when low numbers were observed in Manitoba (WH) and vice versa, suggesting higher rates of exchange occurred than previously suggested (Stirling et al. 1977). Subsequent research showed that sea ice influenced bear distribution within each subpopulation but not between them (Stirling et al. 2004). Using radio telemetry, both Stirling et al. (1999) and Cherry et al. (2013) found that when remnant ice remained in the eastern part of Hudson Bay some bears shifted their onshore arrival distribution to the southeast. Thus, there is variation in the on-land distribution of bears in the region and how this might change with ongoing reductions in sea ice is unknown, but it is an important consideration for the management of polar bears because harvest levels are based on abundance estimates derived from studies designed to survey within current subpopulation boundaries. This is particularly important for subpopulations managed using aerial surveys where abundance is estimated from a single year.

In 2011/2012, 2016, and 2021, aerial surveys were flown to estimate the abundance of the WH (Stapleton et al. 2014, Dyck et al. 2016, Atkinson et al. 2022) and SH subpopulations (Obbard et al. 2015, Obbard et al. 2018, Northrup et al. 2022). In WH, the 2011 estimate was 1030 (CI = 754-1406), declining by 18% to 842 (CI = 562-1121) in 2016 and a further 27% decline to 618 (CI = 425-899) in 2021. In SH, the 2011/12 estimate was 943 (CI = 658-1350), declining 17% to 780 (CI = 590-1029) in 2016 and increasing by 43% to 1119 (CI = 860-1454) in 2021. During the surveys, a larger number of bears were found east of the Nelson River to the WH/SH boundary compared to previous coastal counts from 1970 to 2011 (Figure 1, referred to as Area 2) (Stirling et al. 2004, Stapleton et al. 2014, Dyck et al. 2017, Atkinson et al.

2022). However, because these bears were not physically handled, it was unknown whether the increase in numbers of bears represented a short- or long-term shift in distribution of either subpopulation or overlap of animals from both the WH and SH subpopulations. Resolving this uncertainty is important from a management perspective because both subpopulations are harvested, and annual target harvest levels are established from abundance estimates based on current subpopulation boundaries and the assumption that bears within these boundaries are from the subpopulation in which they are observed. Understanding whether changes in abundance are due to temporary or permanent distributional shifts or the result of changes in population demography is critical for their conservation and management.

Our objectives for this study were to 1) examine the likely subpopulation of origin of bears near the SH/WH subpopulation boundary and 2) assess inter-annual differences in polar bear distribution in relation to sea ice.

Methods

We used remote biopsy darts to collect genetic samples from free-ranging polar bears onshore from the Nunavut-Manitoba border to James Bay, Ontario (Figure 1). We sampled three main areas of the WH and SH subpopulations: Area 1, Nunavut-Manitoba border to the Nelson River; Area 2, Nelson River east to the WH/SH subpopulation boundary; and, Area 3, WH/SH boundary to James Bay (Figure 1). A 27.5 km strip along the Manitoba coast was not flown to minimize potential research impact on polar bear viewing tourism. Area 2 was searched primarily along the coast in all years. In 2017, an inland search was made of known denning areas. Geographical coverage expanded over time; in 2017 we only sampled in Manitoba, in 2018 and 2019 we sampled to just inside the WH/SH boundary, 2021 we sampled to 30km west of Cape Henrietta Maria and 2022 we sampled the entire Hudson Bay coastline of Ontario including the western part of the James Bay coast, Akismiski and the Twins Islands. No sampling occurred in 2020 due to the COVID pandemic.

Subpopulation of Origin

We collected genetic samples from bears captured as part of a long-term research program (Stirling et al. 1999, Lunn et al. 2016) or remotely using either 5cc marine biopsy or 6cc marking biopsy darts (Pneu Dart Williamsport, PA, USA) fired from a helicopter (Pagano et al. 2014). At the time of sampling, we assigned sex and estimated age class based on size and morphological characteristics. We classified bears as cubs-of-the-year, dependent yearlings, subadults (1-4 years old), and adults (≥ 5 years old).

DNA was extracted from each biopsy sample using DNEASY blood and tissue kit (Qiagen, Hilden, Germany). Each sample was genotyped at 24 microsatellite loci at the Molecular Biology Service Unit (University of Alberta, Edmonton, AB). Microsatellites genotyped included; CXX20 and CXX110 (Ostrander et al. 1993) G1A, G10B, G1D, G10L (Paetkau and Strobeck 1994) G10C, G10M, G10P, G10X (Paetkau et al. 1995), UarMU05, UarMU10, UarMU23, UarMU26, UarMU50, UarMu51, UarMU59 (Taberlet et al. 1997), G10H, G10J, G10U (Paetkau et al. 1998), MSUT-1, MSUT-2, MSUT-6, MSUT-8 (Kitahara et al. 2000). Microsatellite loci were amplified in 4 multiplexed reactions and resolved in 3 co-loaded sets on an ABI 3730 DNA Analyzer (Applied Biosystems, Waltham, Massachusetts, USA). Sizes of microsatellite products were determined relative to Genescan 500 size standard and genotypes were called in Genemapper 3.0 (Applied Biosystems). The genotypes generated from the biopsy samples were compared to the genotypes of previously typed individuals from ongoing long-term research in WH (3938) and intermittent studies in SH (864). Matching genotype analysis was performed using the Microsatellite Toolkit (Park 2001) or GenAIEx 6.5 (Peakall and Smouse 2012) allowing for up to 4 mismatching alleles. Matches were visually investigated and rejected as matching if they differed at more than 4 alleles at a maximum of 2 loci. We defined a bear's subpopulation of origin to be the one in which it was first sampled. We acknowledge this assignment may be arbitrary, especially when close to a subpopulation boundary but felt it provided an objective classification for comparison over time.

Inter-annual variation in distribution and sea ice dynamics

We used AMSR2 passive microwave satellite imagery with a spatial resolution of 3.5 x 3.5 km (University of Bremen, [Index of /amsr2/asi_daygrid_swath/n3125 \(uni-bremen.de\)](https://amsr2.asi.daygrid.swath/n3125.uni-bremen.de)) to examine inter-annual variation in the spatial dynamics of remnant ice. We defined remnant as sea ice extent equalling 10% of the winter maximum for all of Hudson Bay excluding James Bay. Ice was defined as pixels with sea-ice concentrations $\geq 30\%$. Hudson Bay was divided in half using the midway point from the widest point of the Bay and remnant ice was classified, as a binary variable, with persistence in the east (0) or west (1) based on which contained the larger area of sea ice on the ordinal date of remnant ice. An east/west division of remnant ice was defined because previous research has shown that when remnant ice occurred in the east of the Bay adult females came ashore further east compared to years when remnant ice occurred in the west (Stirling et al. 1999, Cherry et al. 2013).

To examine interannual variation in bear distribution, we measured displacement which was defined as the distance between individual bear locations in consecutive years using the great-circle distance. Due to low sample sizes in 2017-2019, we were only able to assess displacement for adult males. However, large sample sizes in 2021 and 2022, allowed us to examine displacement in all age- and sex- classes. Displacement was transformed using square root transformation to obtain a normal distribution. Differences were assessed using a one-way ANOVA. Differences in displacement between groups were determined using a post-hoc Tukey's HSD test. To examine the influence of sea ice on the direction of movement we used a logistic regression to represent eastward displacements (0) or westward displacements (1) as the dependent variable and the location of remnant ice as the predictor variable. To evaluate model significance, we used a likelihood-ratio test compared to a null model. Unless stated otherwise, all statistical tests were considered significant at $P \leq 0.05$.

Results

We obtained 727 DNA samples from 458 unique individuals from Area 2 (Figure 2) during 2017-2022 and 570 DNA samples from 514 individuals in SH (Area 3) during 2018-2022. The annual percentage of previously tagged bears in Area 2 ranged from 30% to 43%. In all years, most bears in Area

2 were assigned to WH (range 19-28%), while the percentage of SH bears ranged from 11 to 15% of the bears sampled (Table 1). In Area 2, we obtained 360 biopsies from 268 individuals >1 year old between 2017 and 2019 (Figure 3). Of these, 168 (63%) did not match previously tagged individuals, 72 (27%) matched WH bears, and 28 (10%) matched SH bears (i.e., 72% and 28% of previously tagged bears were WH and SH bears respectively). The distribution of previous capture locations (n=221) for these 100 bears occurred across all areas, however, 76% were in Area 1, 17% in Area 3 and 7% in Area 2 (Figure 4). Physical mark/recapture efforts were conducted on an annual basis in Area 1 since 1980, however, 2009 was the last year a physical mark/recapture program occurred in the Hudson Bay portion of SH (marking occurred between 2012 and 2015 along the James Bay coast and on Akimiski Island). Sub-setting the 2017-2019 data to include only captures before 2010 resulted in 71 (26%) individuals matching previously tagged bears in the genetic database. Of these, 43 (16%) were classified as WH bears, and 28 (10%) were classified as SH bears (i.e., 61% of tagged bears were WH and 39% were SH bears).

In 2021, we sampled 140 individuals in Area 2 >1 year old. Of these, 96 (69%) matched bears in the genetic database (including biopsies from 2017-2019; Figure 5). Eighty-seven (62%) were WH bears and 9 (6%) were SH bears all with a previous capture history in WH (Table 1, Figure 6). In 2021, we also collected 183 samples (102 (55%) adult males, 12 (7%) subadult males, 55 (30%) adult females and 14 (8%) subadult females) from independent bears >1 year old in SH of which 64 (35%) matched existing genotypes (Figure 7) with 34 (53%) matched to tagged bears and 30 (47%) matched to untagged bears previously biopsied (Figure 8). Of the 64 matches, 45 (25%) were classified as WH bears and 19 (10%) as SH bears. Of the WH bears in SH (78%) were adult males, 16% were adult females, and 6% were subadults. Of the WH bears sampled in SH, 90% of the previous captures were from Area 2.

In 2022 we assessed two-way movement of bears across subpopulations by looking at previous sampling in 2021. In 2021 we collected samples from 254 bears in WH of which 120 were resampled in 2022; 111 (93%) of the resampled bears occurred in WH and 9 (7%) in SH (Figure 9). We sampled 209 (includes yearlings) bears in SH in 2021 of which 72 were resampled in 2022 with 46 (64%) resampled in

SH and 26 (36%) resampled in WH (Figure 10). Of the bears sampled in SH in 2021 that were resampled in WH in 2022, 62% were adult males, 12% were adult females, 12% were subadult males and 15% were subadult females. Collectively, these numbers indicate that there were possibly 29% more bears in WH in 2022 compared to 2021. Adult males were the dominant age and sex class of bears in Area 2 in all years comprising 77%, 69%, 67%, 57%, and 62% of samples in 2017-2019, 2021, and 2022, respectively.

Inter-annual variation in distribution and sea ice dynamics

There was inter-annual variation in sea ice dynamics. In 2017, 2019, 2020, and 2022 the remnant ice was in the west, whereas in 2018 and 2021 it was in the east (Figure 11). The coefficient of variation for adult male displacement was 82% in 2017/2018, 84% in 2018/2019 and 87% in 2021/2022. In 2017/2018 the mean displacement was the greatest (\bar{x} =120 km, range 0.04 – 387 km, n=32), followed by 2021/22 (\bar{x} =104 km, range 0.07 – 411 km, n=113) with 2018/19 having the lowest (\bar{x} =71 km, range 0.2 - 260 km, n=80) (Figure 12). There was a significant difference in displacement distance for adult males (One-way ANOVA, $F_{2, 222} = 4.175$, $P=0.02$). Significant difference in displacement was found for 2017/2018 compared to 2018/2019 (post-hoc Tukey's HSD test $P=0.03$) and displacement between 2018/2019 and 2021/2022 approached significance ($P=0.06$).

There was a significant difference in displacement between age classes ($F_{3, 185} = 3.57$, $P=0.02$). The coefficient of variation for displacement for each age class in 2021/22 was 87% for adult males, 66% for adult females and 77% for both subadult females and males. The mean displacement was highest for subadult females (\bar{x} =184km, range 15-438 km, n=20), followed by adult males (reported above) followed by subadult males (\bar{x} =100 km, range 0.27-332 km, n=29) and adult females (\bar{x} =80km, range 2.7 -195 km, n=27) (Figure 12). Post-hoc Turkey's HSD test revealed the displacement for subadult females was significantly higher than adult females ($P=0.02$) and adult males ($P=0.01$) but not when compared to subadult males ($P=0.07$).

The logistic regression model that included remnant ice as a predictor for movement direction was significantly better than a null model (likelihood-ratio test, $X^2 = 20.80$, $df = 1$, $P < 0.001$). The

predicted logit for direction displacement = $-1.0033 + (1.65115) \cdot \text{Remnant Ice}$. Interpreted as an odds ratio, the probability that a bear's distribution moved to the west following remnant ice occurring in the western part of the bay was 5.01x greater (95%CI 2.46 to 10.92) compared to a move to the east.

Discussion

Understanding how variation in sea ice affects the distribution and abundance of Arctic species is vital for conservation and management as climate change continues to bring environmental change at unprecedented rates (Macias-Fauria and Post 2018, Rantanen et al. 2022). Further, understanding shifts in distribution and abundance has important implications for communities that rely on arctic species for subsistence harvest. In this study, we identified the subpopulation of origin of polar bears onshore near the WH/SH subpopulation boundary, linked distributional shifts across this boundary to sea ice dynamics, and identified differences in displacement between age classes.

Most of the polar bears in Area 2 in 2017-2022 had not been previously handled as part of research and monitoring programs. Those that had been previously handled had capture histories from both the WH and SH subpopulations. In 2017-2019, 28% of the tagged bears we sampled in Area 2 were SH bears (39% if the data was restricted to 2009 or earlier, which represents the last years bears were tagged in Area 3) compared to only 11% in the mid-1990s (Lunn et al. 1997). The greater number of SH bears in Area 2, combined with the large number of untagged bears there, may be the result of increased subpopulation growth rate, increased temporary and/or permanent immigration from the SH subpopulation, or a combination of both. This potential is supported by higher coastal counts in Area 2 (Stapleton et al. 2014) and movement associated with a higher abundance estimate for SH (Northrup et al. 2022).

The low number of previously tagged bears in Area 2 may also be due to a 10-year absence of research in this area combined with relatively high fidelity to this region. In 2017, the proportion of SH bears in Area 2 was the greatest over our study, although our sample size of SH bears was low. Lunn et al.

(1997) sampled a similar area (i.e., only the Manitoba portion of Area 2) and the proportion of SH bears was higher in 2017 than in their work. Coincidentally, during 2017, the remnant ice primarily occurred in the western part of Hudson Bay. While the assignment of bears to the WH subpopulation was likely influenced by the long-term research program which marked bears annually throughout the last 4 decades, Area 2 had a higher proportion of SH bears than in previous years despite the absence of tagging since 2009.

In 2021 and 2022, we more comprehensively sampled both WH and SH. In these years, 25-36% of the bears sampled in one subpopulation were resampled the following year in the neighbouring subpopulation, indicating a high degree of subpopulation overlap/exchange occurs near the WH/SH boundary. While our results and those of others, suggest that this higher exchange was likely related to interannual variation in the spatial distribution of remnant ice (Scott and Marshall 2010, Towns et al. 2010, Cherry et al. 2013, this study), it could also be related to changing demographics (Lunn et al. 2016, Atkinson et al. 2022, Northrup et al. 2022). Despite our results suggesting interannual movement between SH and Area 2 of WH, the number of first time captures in Area 2 declined to 23% by the end of the study, suggesting a degree of fidelity to Area 2. Considering that most of the bears were untagged in Area 2, the number of bears has been increasing in this area in conjunction with an increase in SH, suggesting the greater number of bears in this area is likely more related to immigration from SH than from Area 1 (Stapleton et al. 2014, Northrup et al. 2022). Further supporting this assertion, we collected samples from a higher number of bears in Area 2 annually from 2018 to 2021 than were observed in aerial counts of along the coast from York Factory to Fort Severn (which is a larger area) from 1972 to 1996 (Stirling et al. 2004) further suggesting an increase in the number of bears over time. The above evidence suggests that the number of bears in Area 2 has increased over the long-term, however the mechanism that would allow for a higher growth rate compared to Area 1 is unclear. These findings have important implications for harvest management because if Area 2 and SH are increasing in numbers with large variation in distribution, then a greater number of bears is potentially shifting between subpopulations annually.

Further, because abundance estimates for both WH and SH are currently being derived from aerial surveys that assume that all bears counted belong to the subpopulation in which they were observed, temporary distributional shifts across subpopulation boundaries could inflate or deflate these estimates and the harvest levels derived from them.

Over the duration of the study, there was variation in the inter-annual patterns of sea ice. We found that bears shifted their onshore distribution in alignment with whether the remnant ice occurred in the western or eastern half of the Bay. While previous research supports subpopulation boundaries in Hudson Bay (Stirling et al. 1977, Derocher and Stirling 1990, Peacock et al. 2010, Obbard and Middel 2012), our results indicate that the influence of sea ice dynamics on polar bear distribution may, in some years, be sufficient to shift abundance estimates up or down based solely on movements. For example, in 2021, SH and WH aerial surveys were flown when the remnant ice was in the east and we documented a shift of bears from WH into SH. The shift was mainly within 200km of the WH/SH boundary and few bears identified from WH were further east. The vast majority of the WH bears found in SH were previously sampled in Area 2. In 2022 the remnant ice occurred in the west and we documented 36% of the bears in SH in 2021 that were resampled in 2022 were in WH. Surprisingly we did not find that adult males had greater displacement than other age- and sex-classes between 2021 and 2022 despite adult males representing the majority of WH bears identified in SH. Subadult females had significantly greater displacement distances compared to adult males and adult females but not when compared to subadult males. Derocher and Stirling (1990) found subadult females had higher daily movements rates than bears of other sex and age class (other than solitary females) and also had the highest frequency of displacement distances more than 150 km amongst all age and sex classes.

Our findings of a higher proportion of SH bears within WH in some years with the reverse in others may indicate that greater temporary immigration/emigration is occurring than in previous decades (Lunn et al. 1997). The reasons for this are unknown but may be related to the scale of concurrent sampling, spatial dynamics of sea ice, altered space use, differing demographics and distributional shifts of polar bears during the ice-free period (Towns et al. 2010; McCall et al. 2015, Northrup et al. 2022).

Alternatively, breakup phenology could also influence polar bear distribution. For example, years with later breakups may affect bear distribution if they have recently come ashore and not yet arrived at their preferred summering area (Stirling et al. 2004). Derocher et al. (2004) suggested that the mixing of subpopulations would increase possibly related to changes in sea ice distribution. Our findings support this prediction. Breakup in Hudson Bay is occurring earlier (Stern and Laidre 2016), and bears have been coming ashore in poorer condition (Stirling et al. 1999). Thus, bears may be faced with a trade-off of coming ashore with less fat reserves but in familiar areas or remaining on the ice longer to increase their fat reserves but coming ashore elsewhere.

The 2021 aerial survey of WH documented a 27% decline from the 2016 estimate that was attributed to lower abundance of adult females and subadults (Atkinson et al. 2022). We found evidence of temporary emigration out of WH in 2021 because a shift of bears back into WH occurred in 2022. Accounting for temporary immigration/emigration in WH in 2022, our study suggests that WH could have increased up to 29% from movement alone which almost equates exactly to the change in abundance documented in WH (27%). Additionally, when the combined estimates of WH and SH in 2016 are compared to 2021, there was no change in total abundance (Atkinson et al. 2022). While the WH bears documented in SH in 2021 were primarily adult males, our study design was such that we were more likely to detect adult males as we focused efforts primarily along the coastline of SH. Our study did not detect higher displacement for adult males compared to other age classes and surprisingly found the highest displacement for subadult females. Given that Area 2 consists primarily of adult males, we had more adult males marked since 2017 and thus were more likely to detect this age and sex class. Nevertheless, 16% of the WH bears identified in SH in 2021 were adult females despite sampling primarily along the coastline, which is typically dominated by adult males. Different demographics were documented between WH and SH and the decline in abundance was documented primarily in Area 1 suggesting a declining population in WH and increasing population in SH in combination with temporary immigration/emigration likely contributed to the lower estimate in WH and increased estimate in SH (Atkinson et al. 2022, Northrup et al. 2022).

Distributional shifts occurred across subpopulation boundaries so that all bears counted on a single aerial survey of one subpopulation may not necessarily belong to it. Both WH and SH polar bears are harvested, and sustainable harvest levels are determined from updated abundance estimates based on aerial surveys within the boundaries of the subpopulations that provide a snapshot of distribution when the surveys are flown. Our study demonstrates the potential for inflated or deflated estimates of abundance from which harvest levels are derived that are due to temporary distributional shifts of bears. Abundance estimates could result in harvest levels that are too high or too low for intended management objectives. Since most bears in Area 2 were untagged, matching the genetic ids from the biopsy samples to untagged harvest samples will be informative to evaluate the vulnerability to harvest of these bears compared to the adjacent areas. Nevertheless, this study should complement the information provided by aerial surveys in the interpretation of the status and trend of polar bears across Hudson Bay.

Acknowledgements

For logistical, financial, and in-kind support, we thank Churchill Northern Studies Centre, Environment and Climate Change Canada, Kaska Goose Lodge, Isdell Family Foundation, Manitoba Department of Agriculture and Resource Development, Natural Sciences and Engineering Research Council of Canada, Ontario Ministry of Natural Resources and Forestry, Parks Canada Agency, Polar Bears International, Prairie Helicopters, Takla Foundation, University of Alberta, WCS Canada, Weston Foundation, Wildlife Media, Inc., and World Wildlife Fund Canada (Arctic Species Conservation Fund). We thank Greg Thiemann, Lyle Walton, and Tyler Ross for assistance in the field. We thank pilots Doug Holtby (OMNRF), and Jamie Boles and Justin Seniuk (Prairie Helicopters). We thank Evan Richardson and Lynne Burns for reviewing a previous version of this report. We acknowledge and thank Fox Lake Cree Nation, Wasaho Cree Nation, Weenusk First Nation and York Factory First Nation.

Literature Cited

- Atkinson, S. N., J. Boulanger, M. Campbell, V. Trim, J. Ware, and A. Roberto-Charron. 2022. Aerial Survey of the Western Hudson Bay polar bear subpopulation 2021. Final Report. Department of Environment Government of Nunavut, Wildlife Research Section.
- Cherry, S. G., A. E. Derocher, G. W. Thiemann, and N. J. Lunn. 2013. Migration phenology and seasonal fidelity of an Arctic marine predator in relation to sea ice dynamics. *Journal of Animal Ecology* **82**:912-921.
- Derocher, A. E., N. J. Lunn, and I. Stirling. 2004. Polar bears in a warming climate. *Integrated and Comparative Biology* **44**:163-176.
- Derocher, A. E., and I. Stirling. 1990. Distribution of polar bears (*Ursus maritimus*) during the ice-free period in western Hudson Bay. *Canadian Journal of Zoology* **68**:1395-1403.
- Derocher, A. E., and I. Stirling. 1995a. Estimation of polar bear population size and survival in western Hudson Bay. *The Journal of Wildlife Management* **59**:215-221.
- Derocher, A. E., and I. Stirling. 1995b. Temporal variation in reproduction and body mass of polar bears in western Hudson Bay. *Canadian Journal of Zoology* **73**:1657-1665.
- Dyck, M., M. Campbell, D. Lee, J. Boulanger, and D. Hedman. 2016. aerial survey of the Western Hudson Bay polar bear subpopulation, final report. Government of Nunavut, Department of Environment. Wildlife Research Section, Igloolik.
- Gagnon, A. S., and W. A. Gough. 2005. Trends in the dates of ice freeze-up and breakup over Hudson bay, Canada. *Arctic* **58**:370-382.
- Galicia, M. P., G. W. Thiemann, M. G. Dyck, and S. H. Ferguson. 2015. Characterization of polar bear (*Ursus maritimus*) diets in the Canadian High Arctic. *Polar Biology* **38**:1983-1992.
- Hochheim, K., D. Barber, and J. Lukovich. 2010. Changing sea ice conditions in Hudson Bay, 1980–2005. in *A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay* (eds SH Ferguson, LL Loseto, ML Mallory), pp. 39-52. Springer, London, New York.
- Johnson, A. C., J. R. Reimer, N. J. Lunn, I. Stirling, D. McGeachy, and A. E. Derocher. 2020. Influence of sea ice dynamics on population energetics of Western Hudson Bay polar bears. *Conservation Physiology* **8**:coaa132.
- Kitahara, E., Y. Isagi, Y. Ishibashi, and T. Saitoh. 2000. Polymorphic microsatellite DNA markers in the Asiatic black bear *Ursus thibetanus*. *Molecular ecology* **9**:1661-1662.
- Laidre, K. L., H. Stern, K. M. Kovacs, L. Lowry, S. E. Moore, E. V. Regehr, S. H. Ferguson, Ø. Wiig, P. Boveng, R. P. Angliss, E. W. Born, D. Litovka, L. Quakenbush, C. Lydersen, D. Vongraven, and F. Ugarte. 2015. Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century. *Conservation Biology* **29**:724-737.
- Laidre, K. L., I. Stirling, L. F. Lowry, Ø. Wiig, M. P. Heide-Jørgensen, and S. H. Ferguson. 2008. Quantifying the sensitivity of Arctic marine mammals to climate-induced habitat change *Ecological Applications* **18**:S97-S125.
- Lunn, N. J., S. Servanty, E. V. Regehr, S. J. Converse, E. Richardson, and I. Stirling. 2016. Demography of an apex predator at the edge of its range: impacts of changing sea ice on polar bears in Hudson Bay. *Ecological Applications* **26**:1302-1320.
- Lunn, N. J., I. Stirling, D. Andriashok, and G. B. Kolenosky. 1997. Re-estimating the size of the polar bear population in western Hudson Bay. *Arctic* **50**:234-240.
- Macias-Fauria, M., and E. Post. 2018. Effects of sea ice on Arctic biota: an emerging crisis discipline. *Biology Letters* **14**:20170702.
- Northrup, J. M., E. Howe, N. J. Lunn, K. Middel, M. E. Obbard, T. R. Ross, S. Guillaume, L. Walton, and J. Ware. 2022. 2021 Southern Hudson Bay polar bear subpopulation aerial survey. Ontario Ministry of Natural Resources and Forestry. Wildlife Research and Monitoring Section.

- Obbard, M. E., T. L. McDonald, E. J. Howe, E. V. Regehr, and E. S. Richardson. 2007. Polar bear population status in southern Hudson Bay, Canada. US Geological Survey Administrative Report. US Department of the Interior, Reston, VA.
- Obbard, M. E., and K. R. Middel. 2012. Bounding the Southern Hudson Bay polar bear subpopulation. *Ursus* **23**:134-144, 111.
- Obbard, M. E., S. Stapleton, K. R. Middel, I. Thibault, V. Brodeur, and C. Jutras. 2015. Estimating the abundance of the Southern Hudson Bay polar bear subpopulation with aerial surveys. *Polar Biology* **38**:1713-1725.
- Obbard, M. E., M. R. Cattet, E. J. Howe, K. R. Middel, E. J. Newton, G. B. Kolenosky, K. F. Abraham, and C. J. Greenwood. 2016. Trends in body condition in polar bears (*Ursus maritimus*) from the Southern Hudson Bay subpopulation in relation to changes in sea ice. *Arctic Science* **2**:15-32.
- Obbard, M. E., S. Stapleton, G. Szor, K. R. Middel, C. Jutras, and M. Dyck. 2018. Re-assessing abundance of Southern Hudson Bay polar bears by aerial survey: effects of climate change at the southern edge of the range. *Arctic Science* **4**:634-655.
- Ostrander, E. A., G. F. Sprague Jr, and J. Rine. 1993. Identification and characterization of dinucleotide repeat (CA)_n markers for genetic mapping in dog. *Genomics* **16**:207-213.
- Paetkau, D., W. Calvert, I. Stirling, and C. Strobeck. 1995. Microsatellite analysis of population structure in Canadian polar bears. *Molecular ecology* **4**:347-354.
- Paetkau, D., G. F. Shields, and C. Strobeck. 1998. Gene flow between insular, coastal and interior populations of brown bears in Alaska. *Molecular ecology* **7**:1283-1292.
- Paetkau, D., and C. Strobeck. 1994. Microsatellite analysis of genetic variation in black bear populations. *Molecular ecology* **3**:489-495.
- Pagano, A. M., E. Peacock, and M. A. McKinney. 2014. Remote biopsy darting and marking of polar bears. *Marine Mammal Science* **30**:169-183.
- Park, S. D. E. 2001. Trypanotolerance in West African cattle and the population genetic effect of selection. Trinity College, Dublin, Ireland.
- Peacock, E., A. Derocher, N. Lunn, and M. Obbard. 2010. Polar bear ecology and management in Hudson Bay in the face of climate change. A little less Arctic: top predators in the world's largest northern inland sea, Hudson Bay:93-116.
- Peakall, R., and P. E. Smouse. 2012. GenAlEx 6.5: genetic analysis in Excel. Population genetic software for teaching and research—an update. *Bioinformatics* **28**:2537-2539.
- Prevelt, J., and G. Kolenosky. 1982. The status of polar bears in Ontario. *Naturaliste Canadien* **109**:933-939.
- Rantanen, M., A. Y. Karpechko, A. Lipponen, K. Nordling, O. Hyvärinen, K. Ruosteenoja, T. Vihma, and A. Laaksonen. 2022. The Arctic has warmed nearly four times faster than the globe since 1979. *Communications Earth & Environment* **3**:168.
- Regehr, E. V., N. J. Lunn, S. C. Amstrup, and I. A. N. Stirling. 2007. Effects of earlier sea ice breakup on survival and population size of polar bears in western Hudson Bay. *Journal of Wildlife Management* **71**:2673-2683.
- Sciullo, L., G. W. Thiemann, and N. J. Lunn. 2016. Comparative assessment of metrics for monitoring the body condition of polar bears in western Hudson Bay. *Journal of Zoology* **300**:45-58.
- Scott, J., and G. Marshall. 2010. A step-change in the date of sea-ice breakup in western Hudson Bay. *Arctic* **63**:155-164.
- Stapleton, S., S. Atkinson, D. Hedman, and D. Garshelis. 2014. Revisiting Western Hudson Bay: Using aerial surveys to update polar bear abundance in a sentinel population. *Biological Conservation* **170**:38-47.
- Stern, H. L., and K. L. Laidre. 2016. Sea-ice indicators of polar bear habitat. *The Cryosphere* **10**:2027-2041.
- Stirling, I., and A. E. Derocher. 1993. Possible impacts of climatic warming on polar bears. *Arctic*:240-245.

- Stirling, I., Jonkel, Smith, Robertson, and D. Cross. 1977. The ecology of the polar bear (*Ursus maritimus*) along the western coast of Hudson Bay. . Canadian Wildlife Service Occasional Paper. No. 33: 1-64, illust. **33**:62.
- Stirling, I., N. Lunn, J. Iacozza, C. Elliott, and M. Obbard. 2004. Polar bear distribution and abundance on the southwestern Hudson Bay coast during open water season, in relation to population trends and annual ice patterns. *Arctic*:15-26.
- Stirling, I., N. J. Lunn, and J. Iacozza. 1999. Long-term trends in the population ecology of polar bears in western Hudson Bay in relation to climatic change. *Arctic* **52**:294-306.
- Stirling, I., and N. A. Øritsland. 1995. Relationships between estimates of ringed seal (*Phoca hispida*) and polar bear (*Ursus maritimus*) populations in the Canadian Arctic. *Canadian Journal of Fisheries and Aquatic Sciences* **52**:2594-2612.
- Stirling, I., and C. L. Parkinson. 2006. Possible effects of climate warming on selected populations of polar bears (*Ursus maritimus*) in the Canadian Arctic. *Arctic*:261-275.
- Stroeve, J. C., M. C. Serreze, M. M. Holland, J. E. Kay, J. Malanik, and A. P. Barrett. 2012. The Arctic's rapidly shrinking sea ice cover: a research synthesis. *Climatic Change* **110**:1005-1027.
- Taberlet, P., J. J. Camarra, S. Griffin, E. Uhres, O. Hanotte, L. Waits, C. Dubois-Paganon, T. Burke, and J. Bouvet. 1997. Noninvasive genetic tracking of the endangered Pyrenean brown bear population. *Molecular ecology* **6**:869-876.
- Taylor, M. K., and J. Lee. 1995. Distribution and abundance of Canadian polar bear populations: A management perspective. *Arctic* **48**:147-154.
- Thiemann, G. W., S. J. Iverson, and I. Stirling. 2008. Polar bear diets and arctic marine food webs: insights from fatty acid analysis. *Ecological Monographs* **78**:591-613.
- Towns, L., A. E. Derocher, I. Stirling, and N. J. Lunn. 2010. Changes in land distribution of polar bears in western Hudson Bay. *Arctic* **63**:206-212.
- Viengkone, M., A. E. Derocher, E. S. Richardson, R. M. Malenfant, J. M. Miller, M. E. Obbard, M. G. Dyck, N. J. Lunn, V. Sahanatien, and C. S. Davis. 2016. Assessing polar bear (*Ursus maritimus*) population structure in the Hudson Bay region using SNPs. *Ecology and Evolution* **6**:8474-8484.

Table 1. The number of biopsies collected from bears > 1 year old in Area 2 that did not match previously tagged bears (M-CAP) or matched previously tagged bears from Western Hudson Bay (WH) or Southern Hudson Bay (SH). Previously tagged bears were assumed to belong to the subpopulation in which they were first encountered. Area 3 samples were collected just inside the WH/SH boundary in 2018/2019 and across most of the Ontario coastline of Hudson Bay in 2021 and complete coverage in 2022.

Sample		N	M-CAP	WH bears	SH bears
Location	Year				
Area 2	2017†	60	34 (57%)	17 (28%)	9 (15%)
	2018	140	88 (63%)	32 (23%)	20 (14%)
	2019	160	113 (71%)	30 (19%)	17 (11%)
	2021*	140	44 (31%)	87 (62%)	9 (6%)
	2022*	146	33 (23%)	98 (67%)	15 (10%)
Area 3	2017	n/a	n/a	n/a	n/a
	2018	8	6 (75%)	1 (12.5%)	1 (12.5%)
	2019	12	7 (58%)	1 (8%)	4 (34%)
	2021*	183	119 (65%)	45 (25%)	19 (10%)
	2022*	259	182 (70%)	18 (7%)	59 (23%)

†No sampling occurred in the Ontario portion of Area 2 in 2017.

*In 2021 and 2022 all previously sampled bears were used to find genetic matches including bears only previously biopsied while 2017-2019 only matches to tagged bears are reported.



Figure 1. Hudson Bay showing the management boundaries (dashed lines) between the Western Hudson Bay (WH), Southern Hudson Bay (SH), and Foxe Basin (FB) polar bear subpopulations and geographic sampling areas 1, 2 and 3.

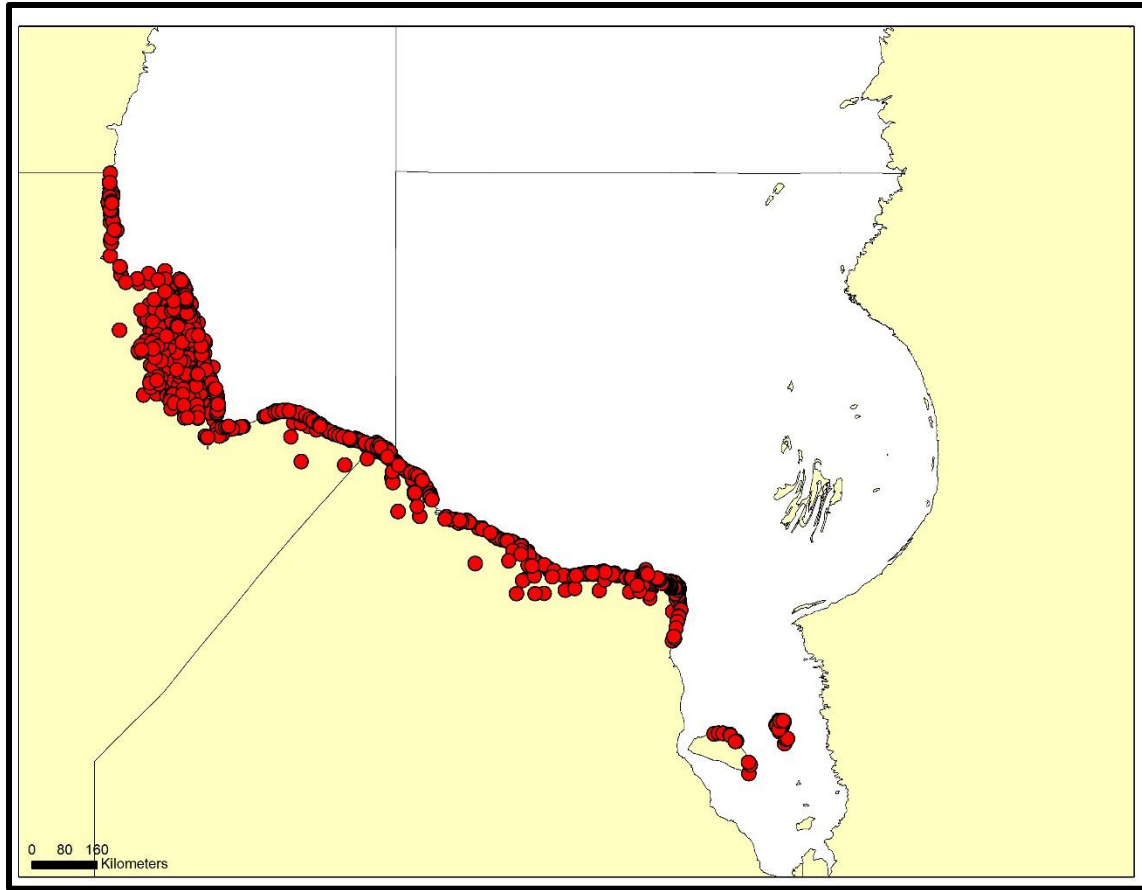


Figure 2. The spatial distribution of polar bear tissue samples collected via biopsy or physical capture between 2017 and 2022.

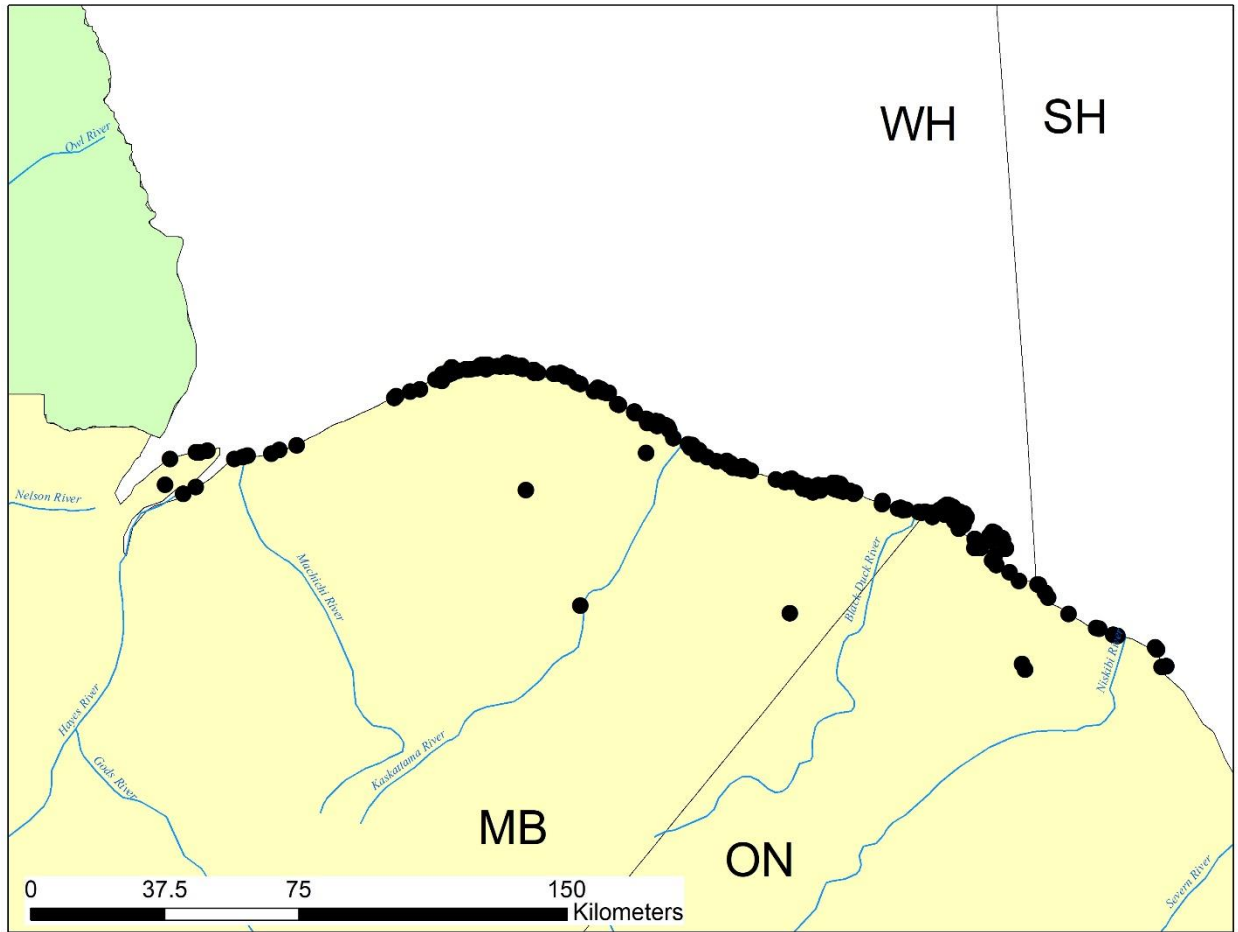


Figure 3. Locations where polar bear samples were collected, 2017-2019 in Area 2 and Area 3.

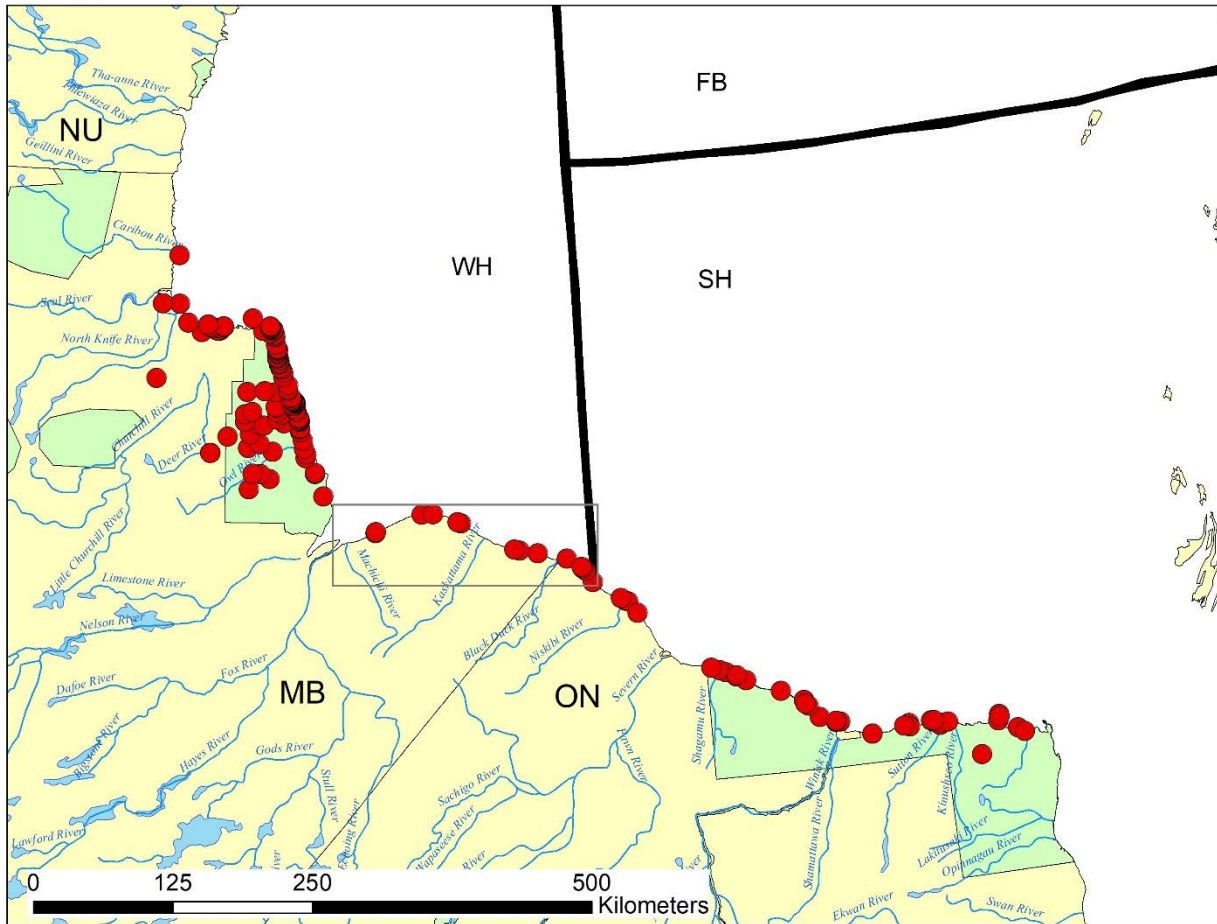


Figure 4. Previous capture locations of 100 bears sampled in Area 2 (grey rectangle) from 2017 to 2019 (Figure 3) that matched individuals tagged before 2017 and were identified in the WH and SH genetic database. No bears have been physically captured and tagged along the Ontario coastline since 2009 or in Area 2 since 2005.

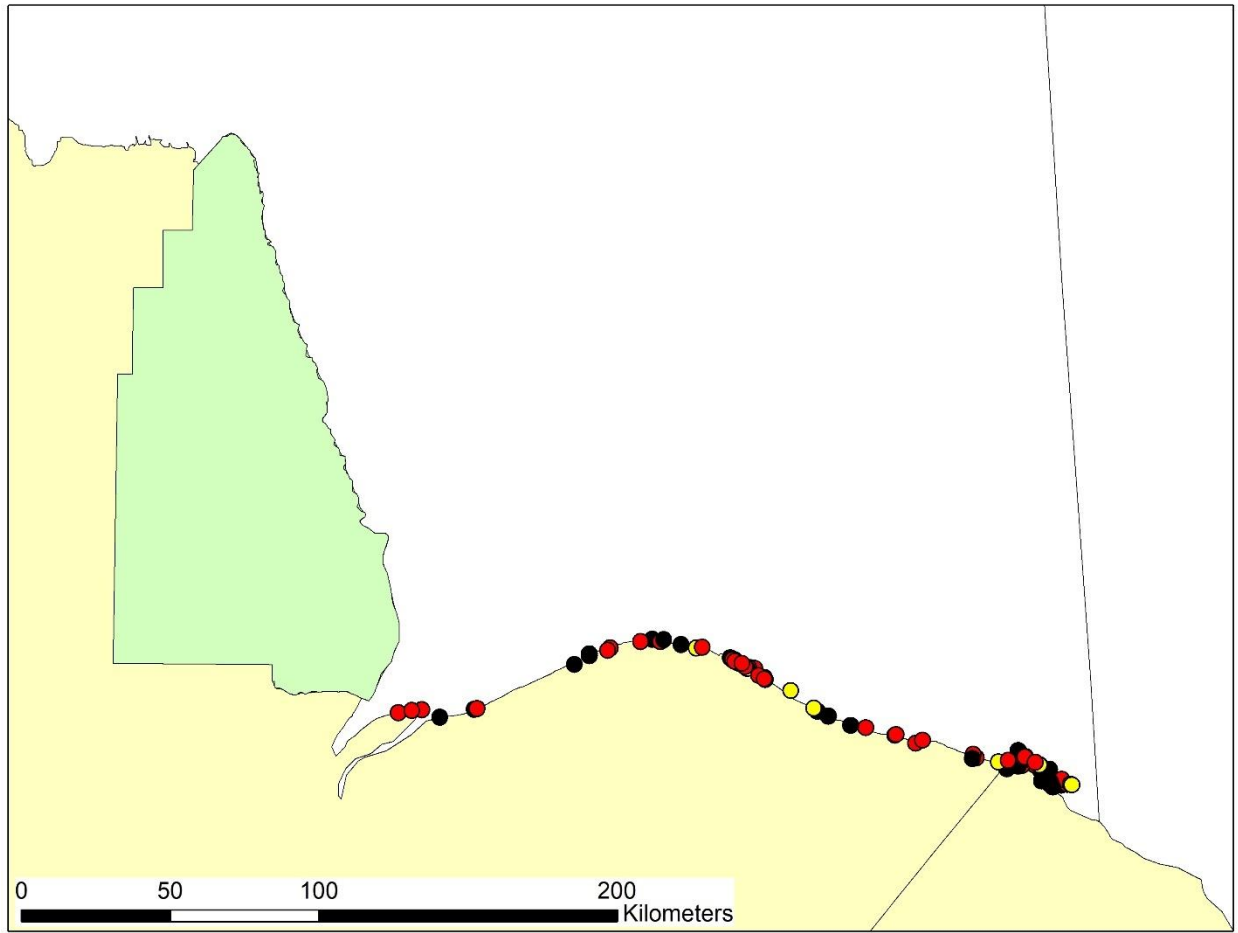


Figure 5. Locations of polar bears biopsied in 2021 in Area 2 that matched individuals previously sampled in WH (red circles) both SH and WH (yellow circles) and first-time captures (black circles).

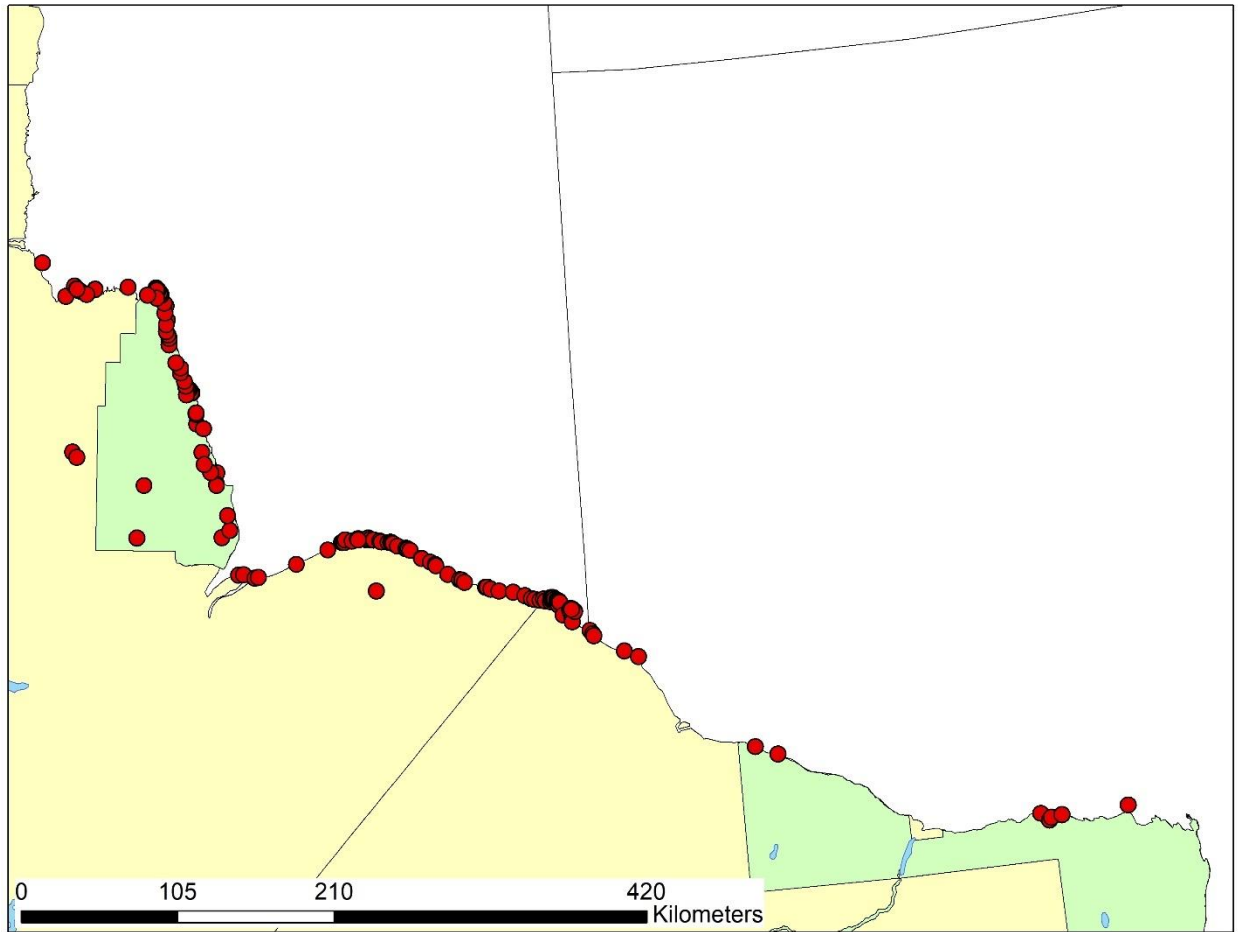


Figure 6. Previous sampling locations for 96 bears (capture or biopsy from Figure 5) that were biopsied in Area 2 in 2021.

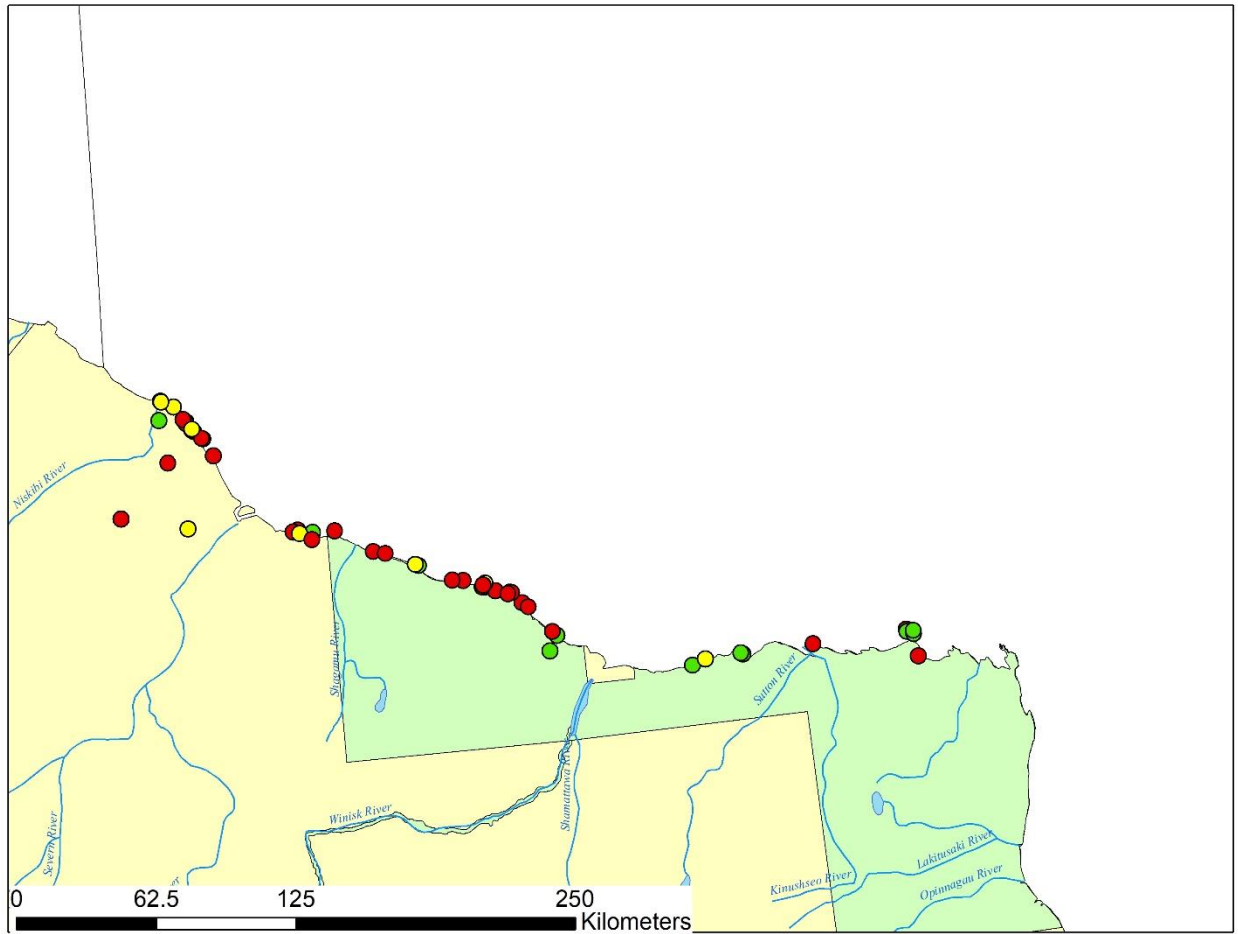


Figure 7. Sampling locations of 65 bears biopsied in SH in 2021 that were previously sampled in WH (red circles), both WH and SH (yellow circles), and only SH (green circles).

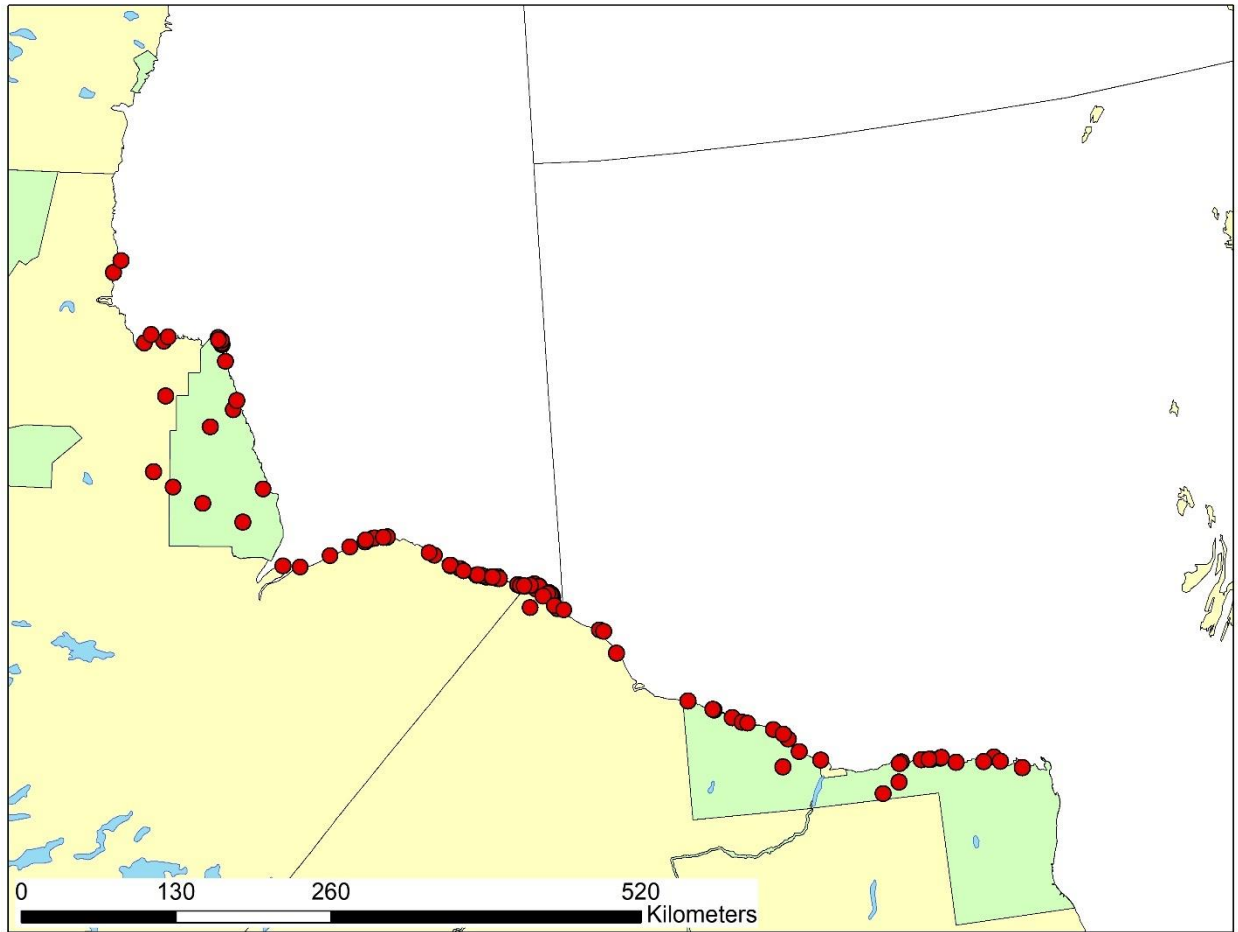


Figure 8. Previous sampling locations for 65 bears (Figure 7) that were biopsied in 2021 in SH.

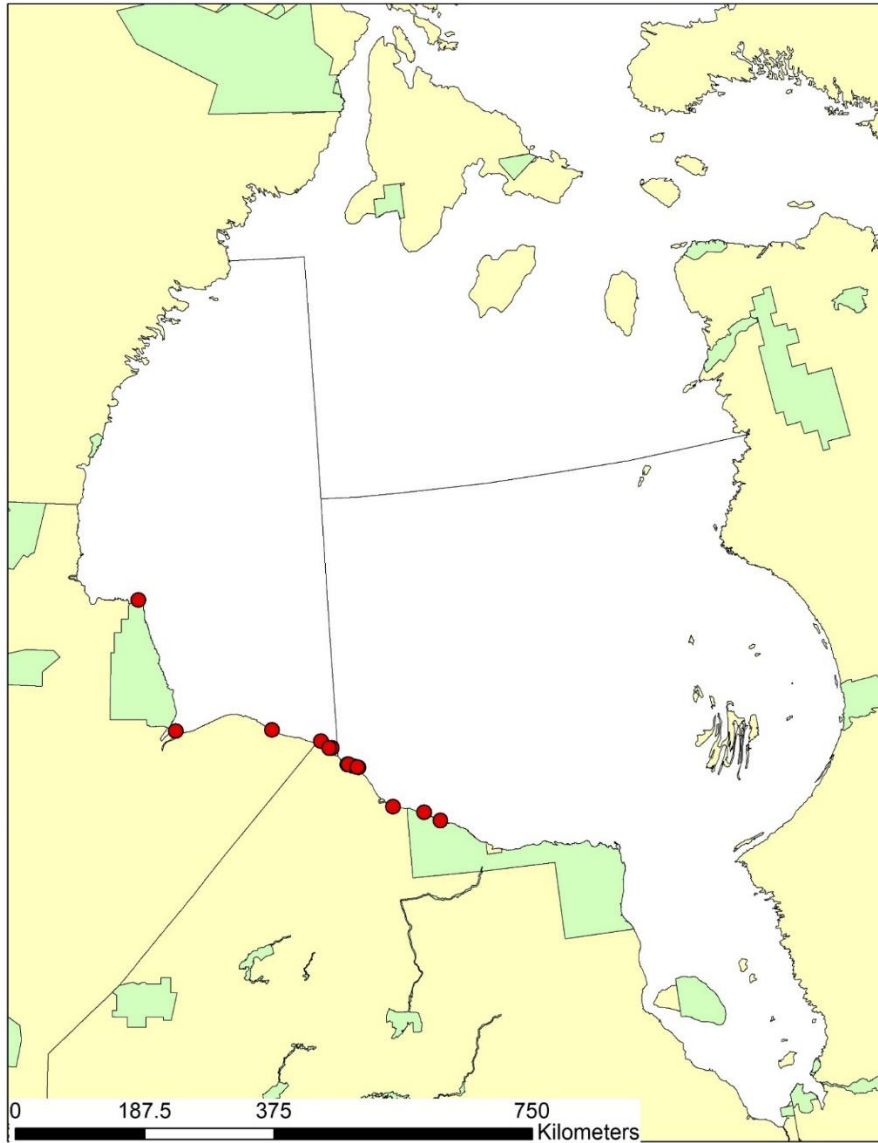


Figure 9. Distribution of bears in WH in 2021 that were resampled in SH in 2022 (i.e WH locations represent 2021 while SH locations represent 2022 for the same bears).

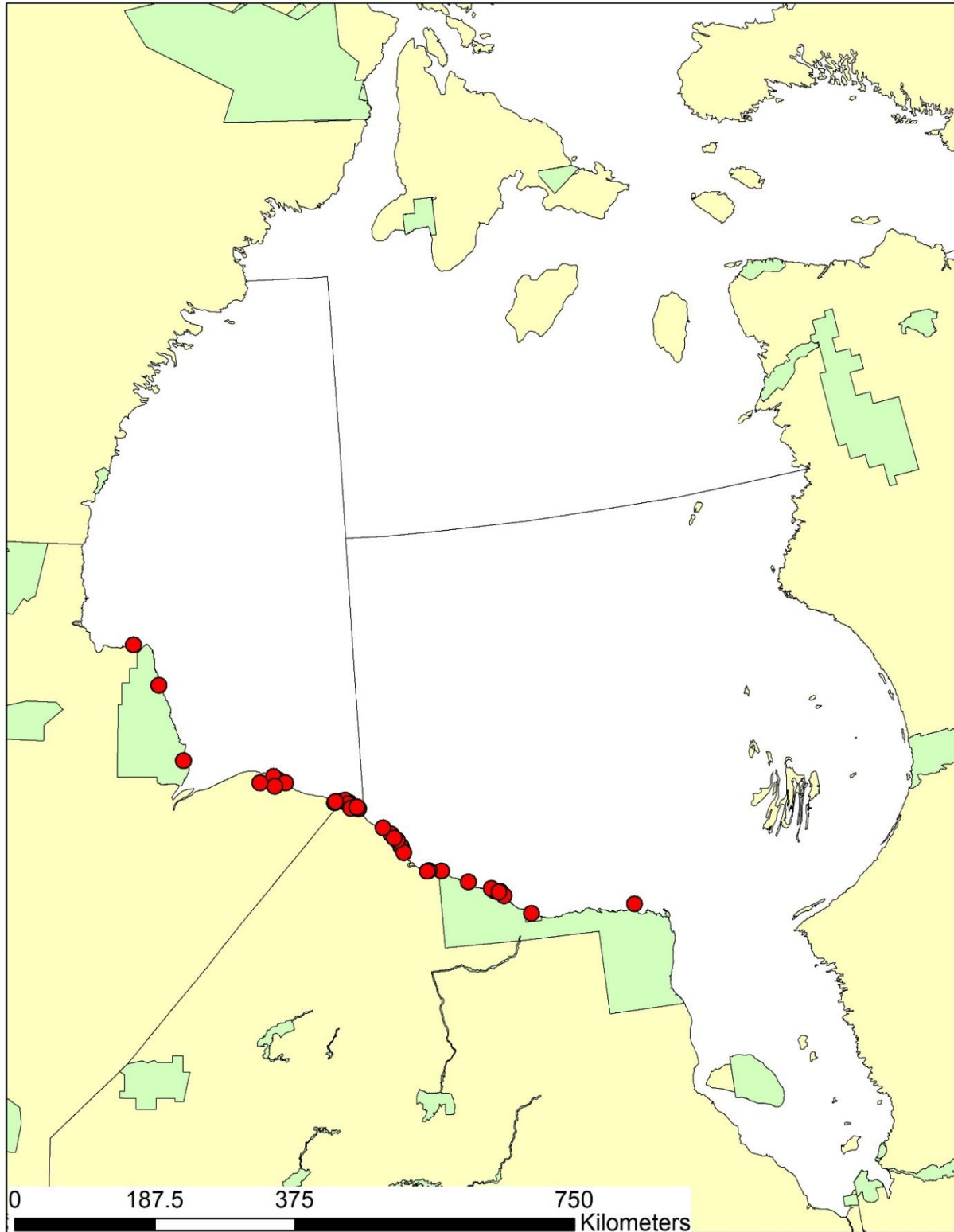


Figure 10. Distribution of bears in SH in 2021 that were resampled in WH in 2022 (i.e SH locations represent 2021 while WH locations represent 2022 for the same bears).

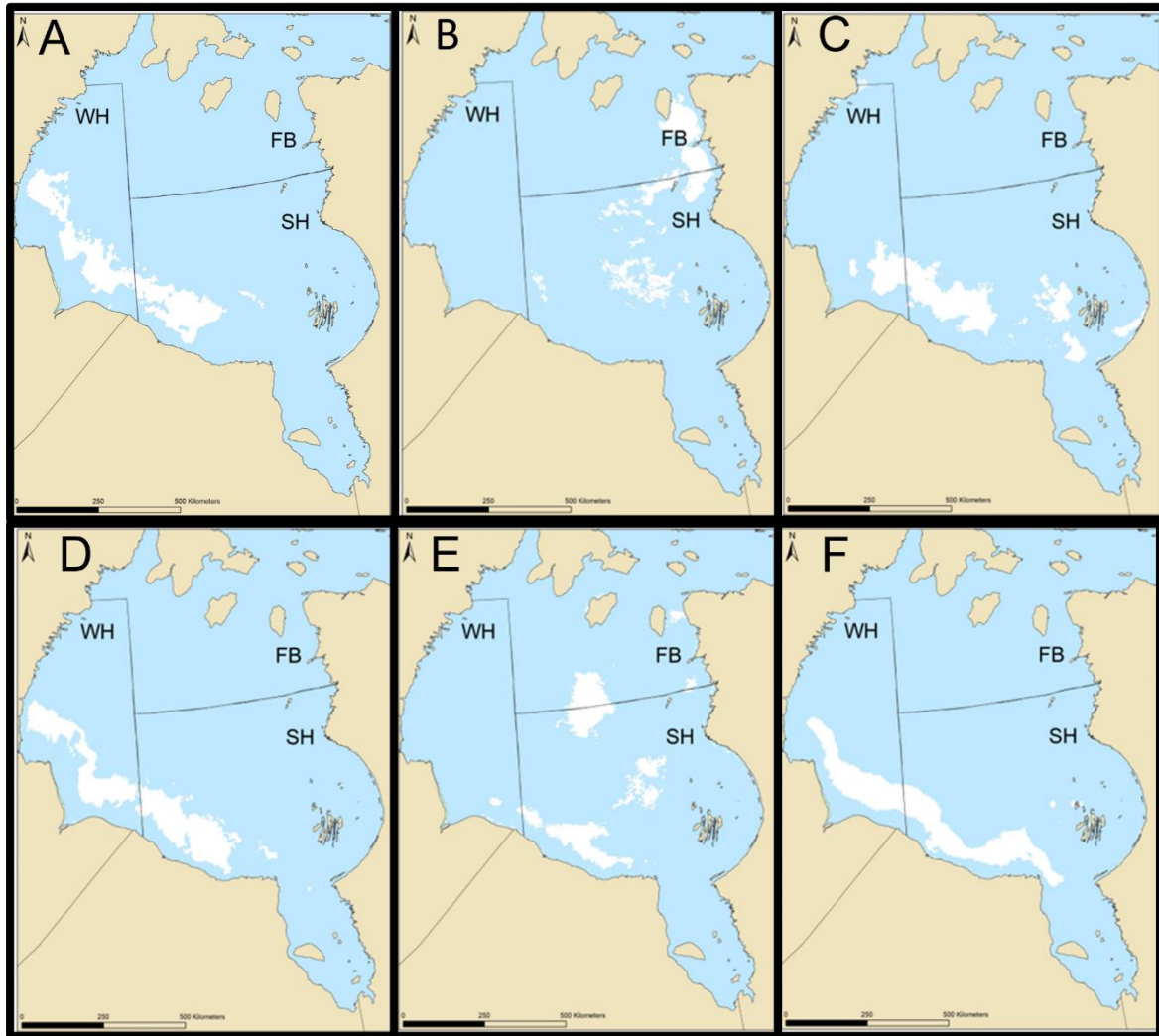


Figure 11. Remnant ice (sea ice cover $\geq 30\%$ when sea ice extent was 10% of winter maximum) in Hudson Bay (excluding James Bay) in 2017 (A), 2018 (B), 2019 (C), 2020 (D), 2021 (E) and 2022 (F).

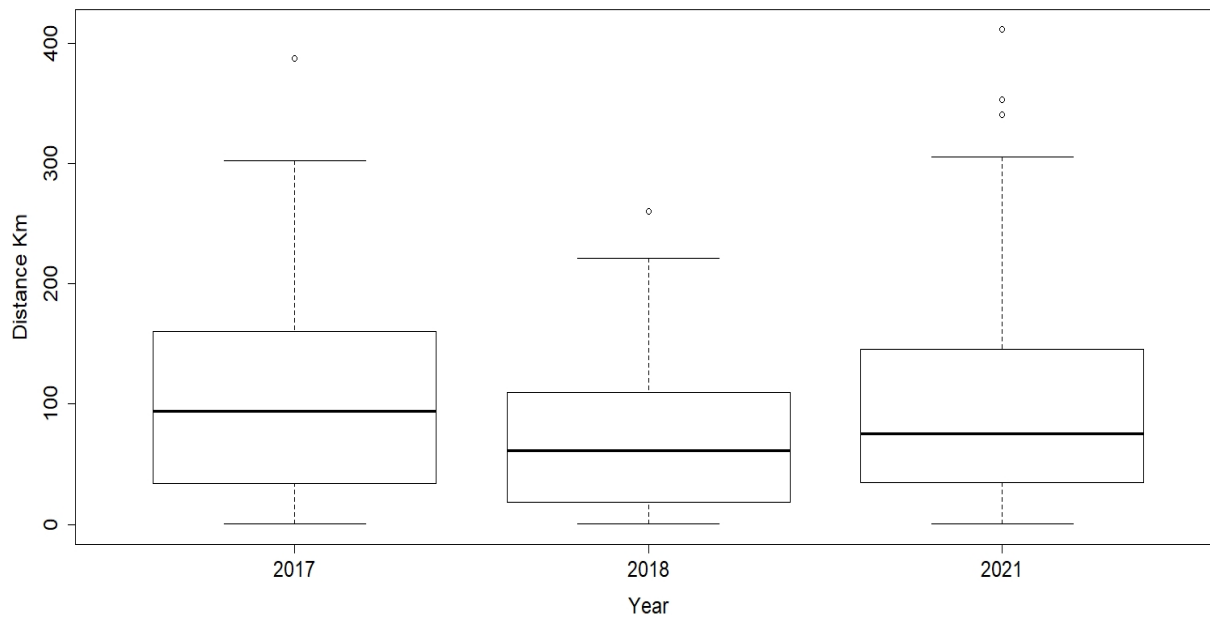


Figure 12. Boxplot of displacement distance (Km) for adult males sampled in consecutive years 2017 (2017/2018, n=32), 2018 (2018/2019, n=80) and 2021 (2021/2022, n=113) in Hudson Bay. Inter quartile range represents 25th and 75th percentile, solid line represents the median and whiskers indicate range with dots representing outliers.

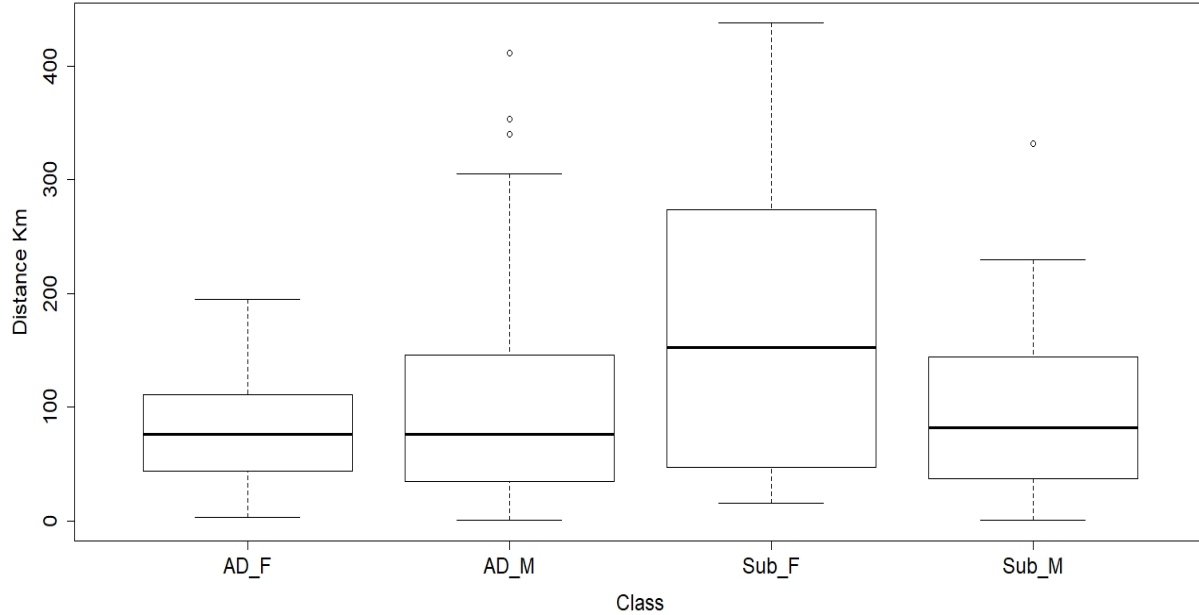


Figure 13. Boxplot of displacement distance (Km) for adult females (AD_F, n = 27), adult males (AD_M, n=113), subadult females (Sub_F, n=20), subadult males (Sub_M, n=29) sampled in late August/September in 2021 and 2022 in Hudson Bay. Inter quartile range represents 25th and 75th percentile solid line represents the median and whiskers indicate range with dots representing outliers.



SUBMISSION TO THE

NUNAVUT WILDLIFE MANAGEMENT BOARD

FOR

Information: X

Decision:

Issue: Results of the 2021 survey results and community consultations of the Southern Hudson Bay (SH) Polar Bear Subpopulation.

Background:

- The Southern Hudson Bay (SH) polar bear subpopulation is shared between Ontario, Québec, and Nunavut (Figure 1). The last inventory studies to estimate abundance were conducted in 2011 and 2016, which resulted in estimates of 943 and 780 bears, respectively. The SH polar bear subpopulation was considered declining at that time.
- Sanikiluaq hunters harvest from SH. The current Total Allowable Harvest (TAH) for SH is 25 bears per year. This TAH was set under the Flexible Quota System (FQS) at a 2:1 harvest sex ratio and was maintained under the 1:1 harvest sex ratio when the new Harvest Administration and Credit Calculation System (HACCS) came into effect in 2022. The average harvest between the 2011/2012 and 2022/2023 harvest seasons was 28 bears per year (Figure 2).
- SH and Western Hudson Bay (WH) have been following a 5-year monitoring regimen, with the most recent surveys completed in 2021. Following community consultations via phone in 2021 (in-person consultations were not possible due to COVID-19 related travel restrictions), the survey began in August 2021 and finished in September 2021. A minimally invasive aerial abundance survey method was used for this study. WH was surveyed at the same time by the GN.
- Environment and Climate Change Canada (ECCC) has been conducting scientific studies in WH since the 1980s. Ongoing research includes a biopsy darting genetic analysis project which has been conducted since 2017 along the Manitoba and Ontario coast. This research examined movement between WH/SH and ice dynamics in Hudson Bay. The results from this report were very informative and help to explain the higher estimate from the 2021 aerial survey.

Current Status:

- The final report and results for the 2021 SH study were distributed to all relevant co-management partners in November 2022. The new abundance estimate of 1003 bears is more than the estimates from 2011 and 2016.
- The WH and SH estimates for 2011, 2016, and 2021 were combined in the WH report. This resulted in combined estimates of 1892, 1622, and 1621 bears, respectively. When both subpopulations are combined, this shows a stable population (WH and SH) between the 2016 and 2021 surveys.
- Given the limitations of an aerial abundance survey, it was unclear to what degree the increase in SH in 2021 was due to movement of bears into SH from WH, which the ECCC and Ontario genetic mark and recapture studies confirmed.
- The ECCC biopsy darting report determined that the increase in SH in 2021 was largely due to movement of bears into SH, likely due to remnant ice in SH near the time of the aerial survey.
- The ECCC biopsy darting report also examined harvested bear locations. It reaffirms that the SH management boundary is valid because bears harvested in SH were initially biopsied in SH, whereas bears harvested in WH were initially biopsied in WH.

Consultations:

In-person community consultations with the Sanikiluaq Hunters and Trappers Association (HTA) was held on May 13, 2024. Consultations focused on the results of the aerial abundance survey and ECCC biopsy darting study. HTA members had many questions about research methods and welfare of bears with more invasive research methods (collaring and biopsy darting). HTA members expressed interest in submitting their own letter to NWMB with their ideas on the TAH recommendation. Staff from Nunavut Wildlife Management Board attended the meeting. See details in SH Consultation Summary Report by GN ENV.

Recommendations:

1. ENV recommends **no change to the current TAH of 25 for the SH subpopulation**. When considering the SH and WH estimates collectively between 2016 and 2021, the subpopulations remain stable under current environmental conditions and harvest levels.

2. In keeping with current national and international polar bear management initiatives, ENV requests that the NWMB establish a management objective for the Southern Hudson Bay polar bear subpopulation. ENV suggests that the management objective is to **maintain current abundance**.

Appendix 1

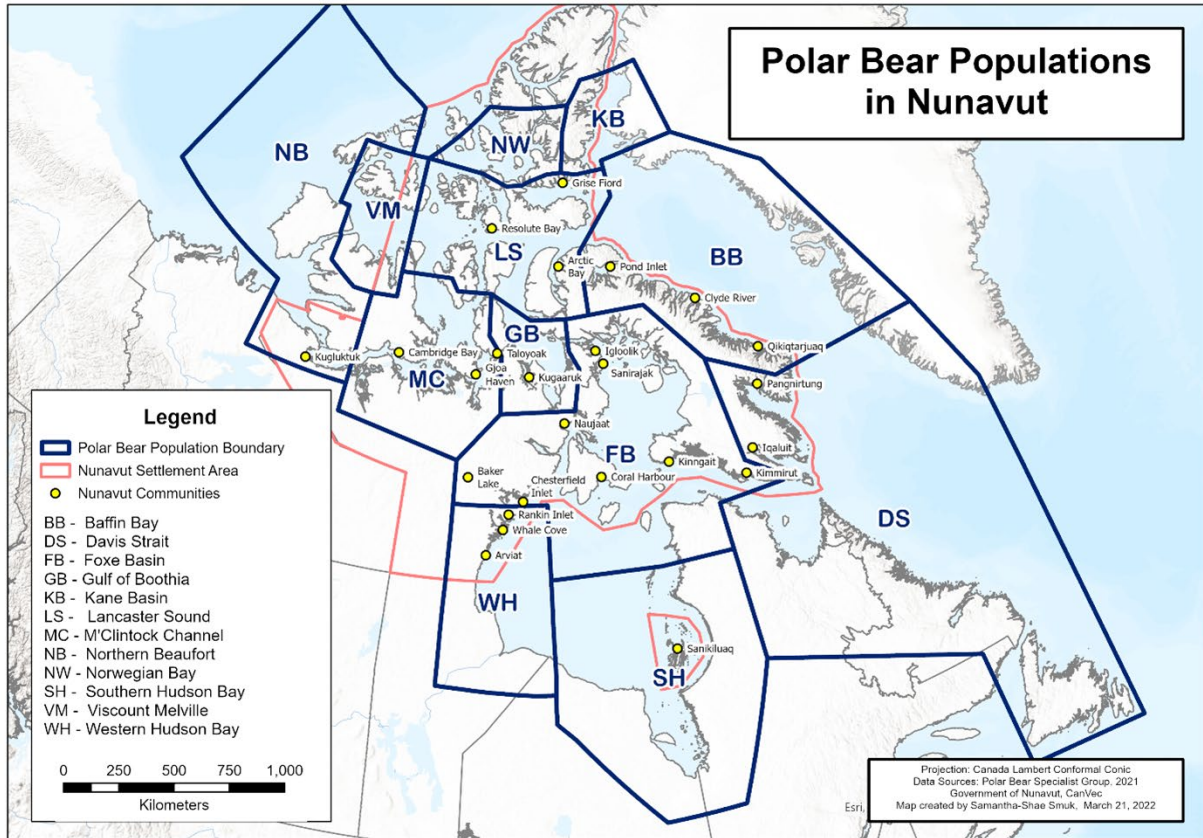


Figure 1. Overview of Nunavut polar bear subpopulations (WH = Western Hudson Bay, SH = Southern Hudson Bay).

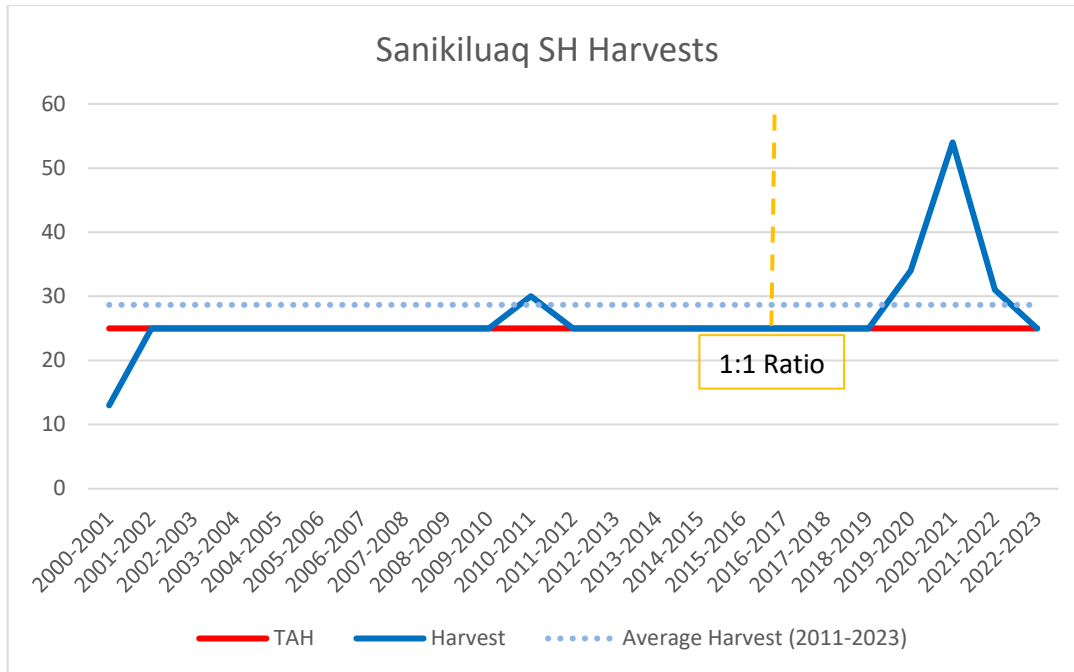


Figure 2. Overview of the Southern Hudson Bay polar bear Total Allowable Harvest (TAH), total and average harvest since 2000.

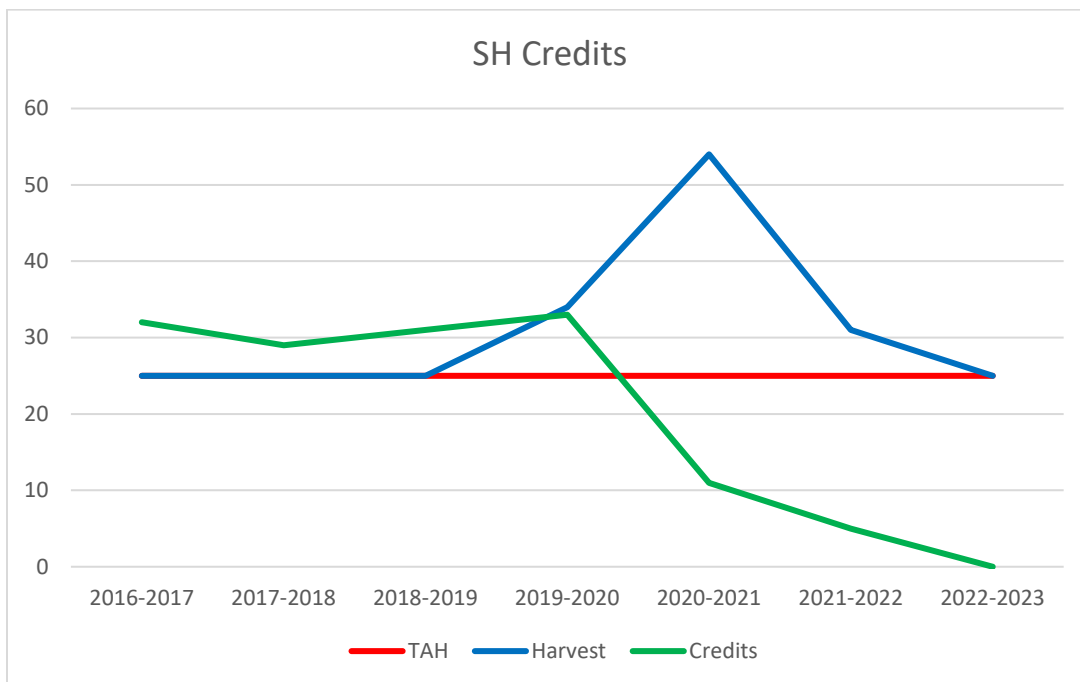


Figure 3. Overview of the Southern Hudson Bay polar bear credits since 2016.

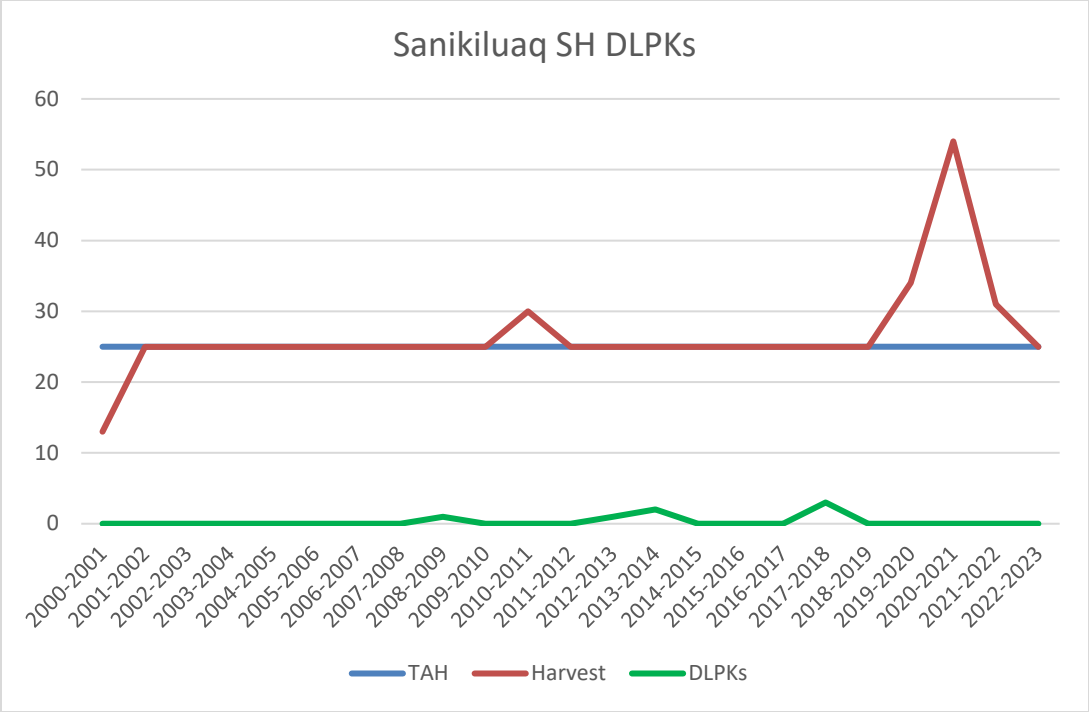


Figure 4. Number of Defence of Life and Property polar bear kills (DLPKs) in Southern Hudson Bay since 2000.

Introductions



Alyssa (“Uh-Liss-Uh”) Bohart
Polar Bear Biologist
Department of Environment
Government of Nunavut



Joe Northrup
Regional Biologist
Wildlife Research and
Monitoring Section
Ontario Ministry of Natural Resources
and Forestry

- Since 2021 there has been a transition at the Department of Environment in the Government of Nunavut
 - Tragic loss of our Polar Bear Biologist Markus Dyck in an accident
 - Two Polar Bear Biologists resigned last year
 - There are two new biologists continuing the program



Survey Process



1. Create a study design

Survey Process



1.



2. Consult on study design and get feedback

Survey Process



3. Incorporate feedback into study design

Survey Process

1.



4. Fly the survey

Survey Process



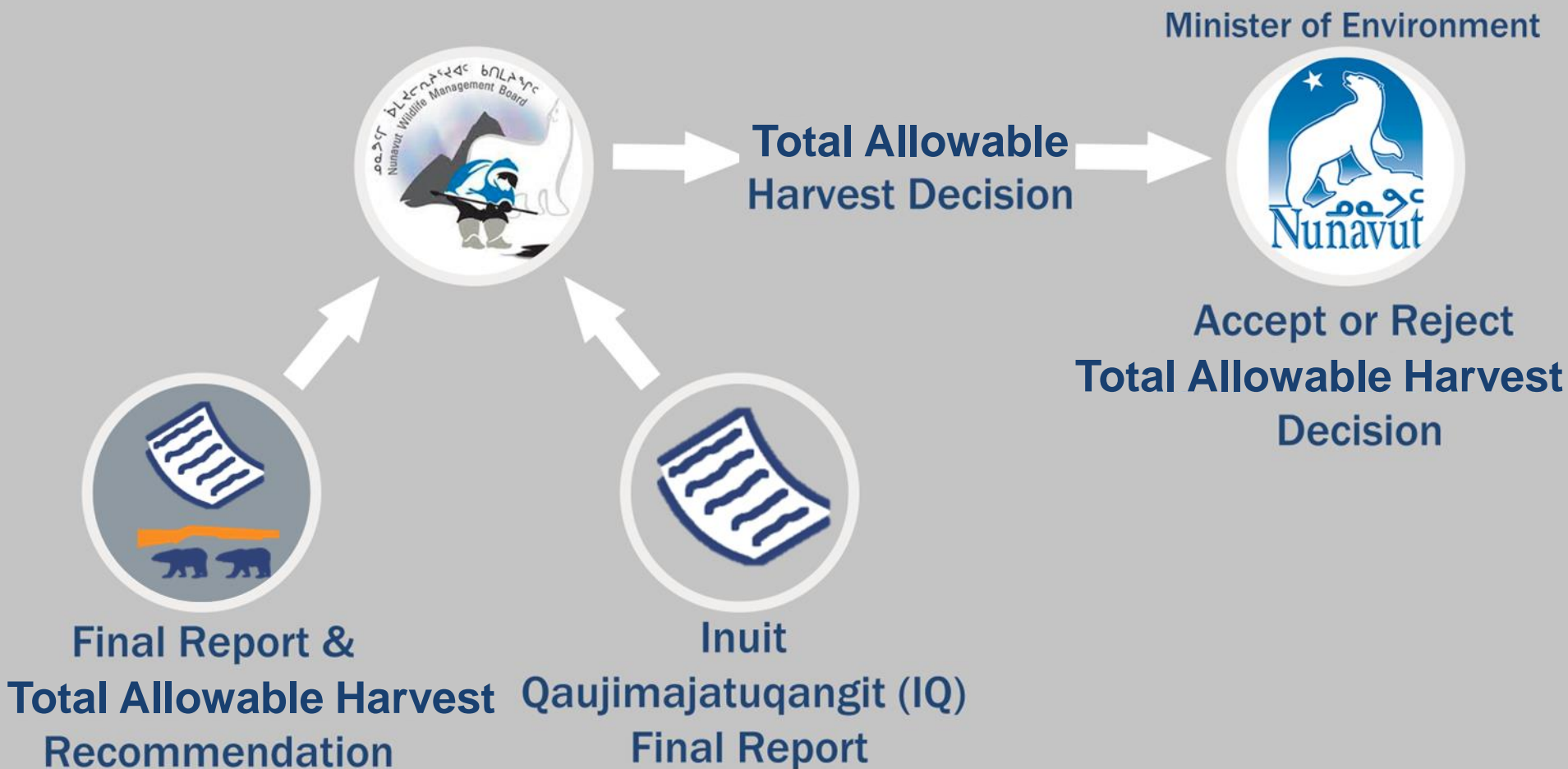
5. Analysis & Writing Final Report

Survey Process



6. Consulting on Final Report

Survey Process



7. Total Allowable Harvest Decision-Making

Survey Process

Minister of Environment



Accepts

Regional Wildlife Boards



Accept or Reject
Total Allowable Harvest
Decision

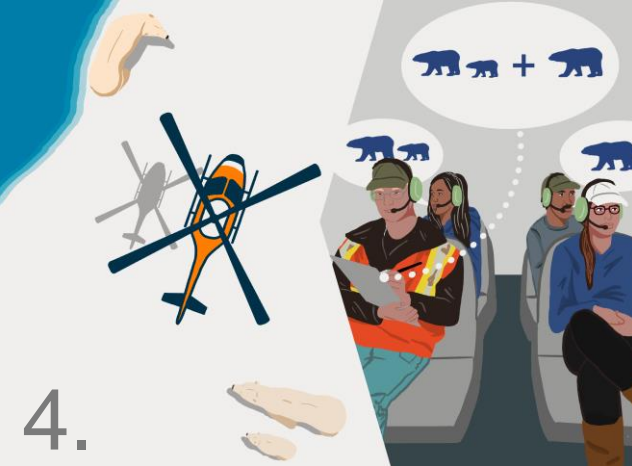
Decide how many
tags each community gets



Send tags to
communities

7. Total Allowable Harvest Decision-Making

Survey Process



Minister of Environment

Regional Wildlife Boards



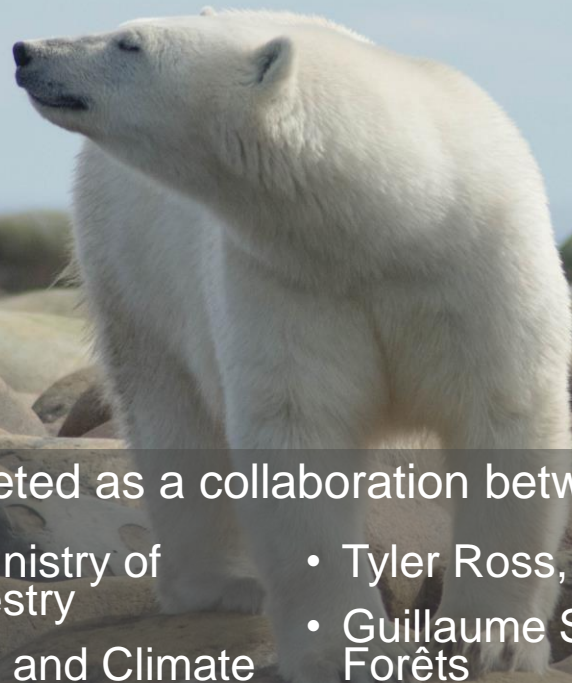
7.



Accepts



Southern Hudson Bay 2021 Aerial Survey Study Results



This study report was completed as a collaboration between:

- Joseph Northrup, Ontario Ministry of Natural Resources and Forestry
- Nicholas Lunn, Environment and Climate Change Canada
- Kevin Middel, Ontario Ministry of Natural Resources and Forestry
- Martyn Obbard, Ontario Ministry of Natural Resources and Forestry
- Tyler Ross, York University
- Guillaume Szor, Québec Ministère des Forêts
- Lyle Walton, Ontario Ministry of Natural Resources and Forestry
- Jasmine Ware, Government of Nunavut

Thank You



Québec



Ontario



Canada

Environment and
Climate Change Canada

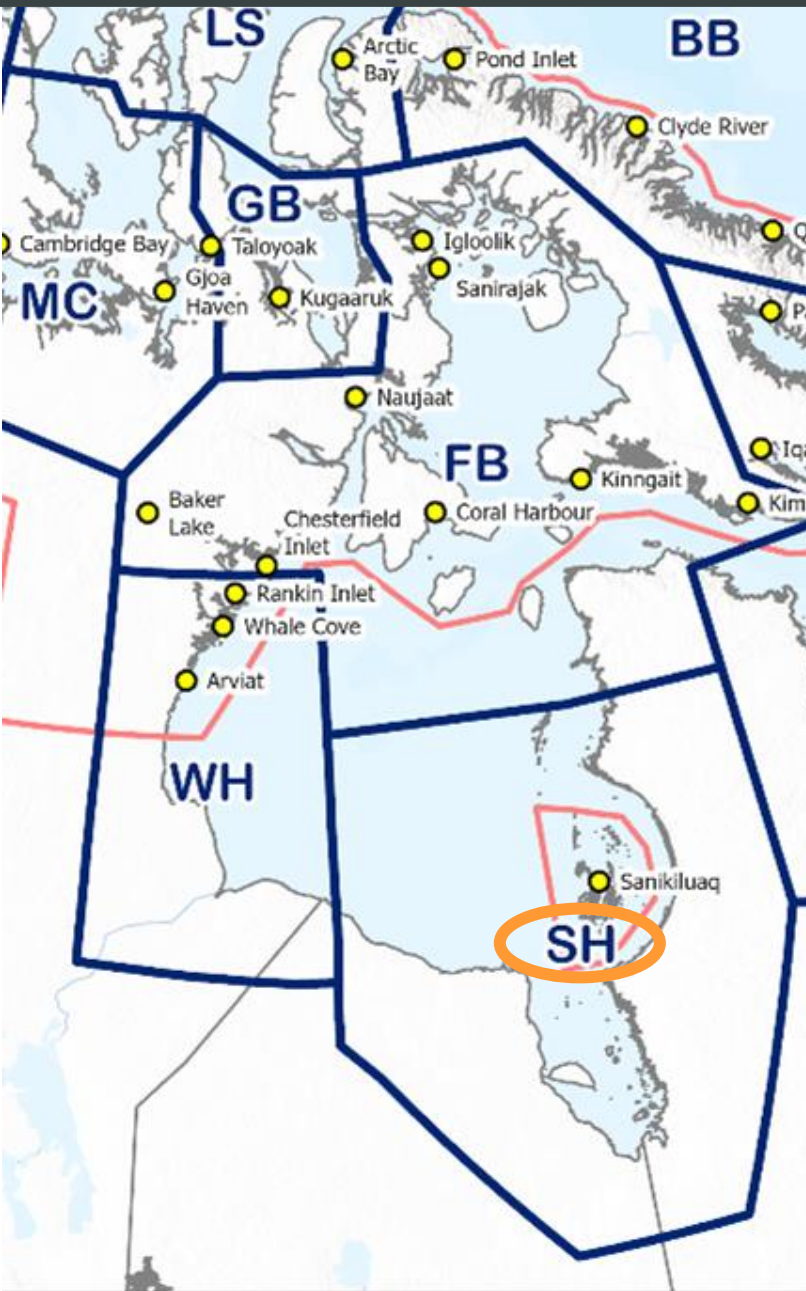
Environnement et
Changement climatique Canada



This work would not have been possible without the participation and support of the HTOs and the following observers:

- S. Weetaltuk
- Q. Napartuk
- J. Kasudluak
- M. Arnasuk
- P. Ippak
- J. Ippak
- C. Takatak

Southern Hudson Bay Subpopulation



- Previously aerial surveyed in 2011 and 2016

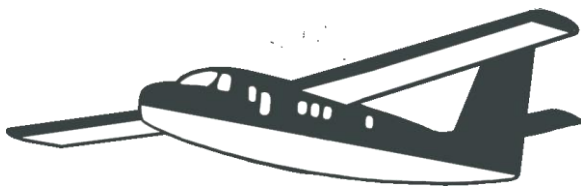
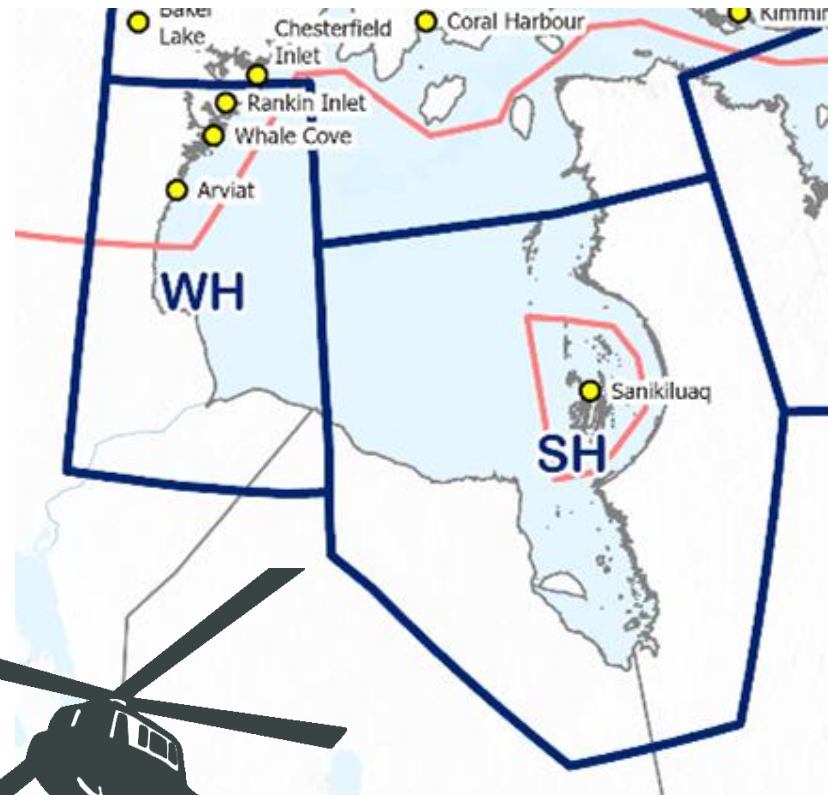


- Biopsy darting studies done by Environment and Climate Change Canada and Ontario Ministry of Natural Resources and Forestry
 - Western & Southern Hudson Bay
- Agreement that the **number of human-bear conflicts has increased over time**
- Frequent studies needed to **detect sudden changes** in bear population when using aerial surveys



Aerial Abundance Surveys

- Surveys were done in 2011, 2016, and 2021
- Surveys done in **late August-early September**
- Bears **on land**
- Western (WH) and Southern Hudson (SH) Bay **done at same time**





What is an Aerial Abundance Survey?

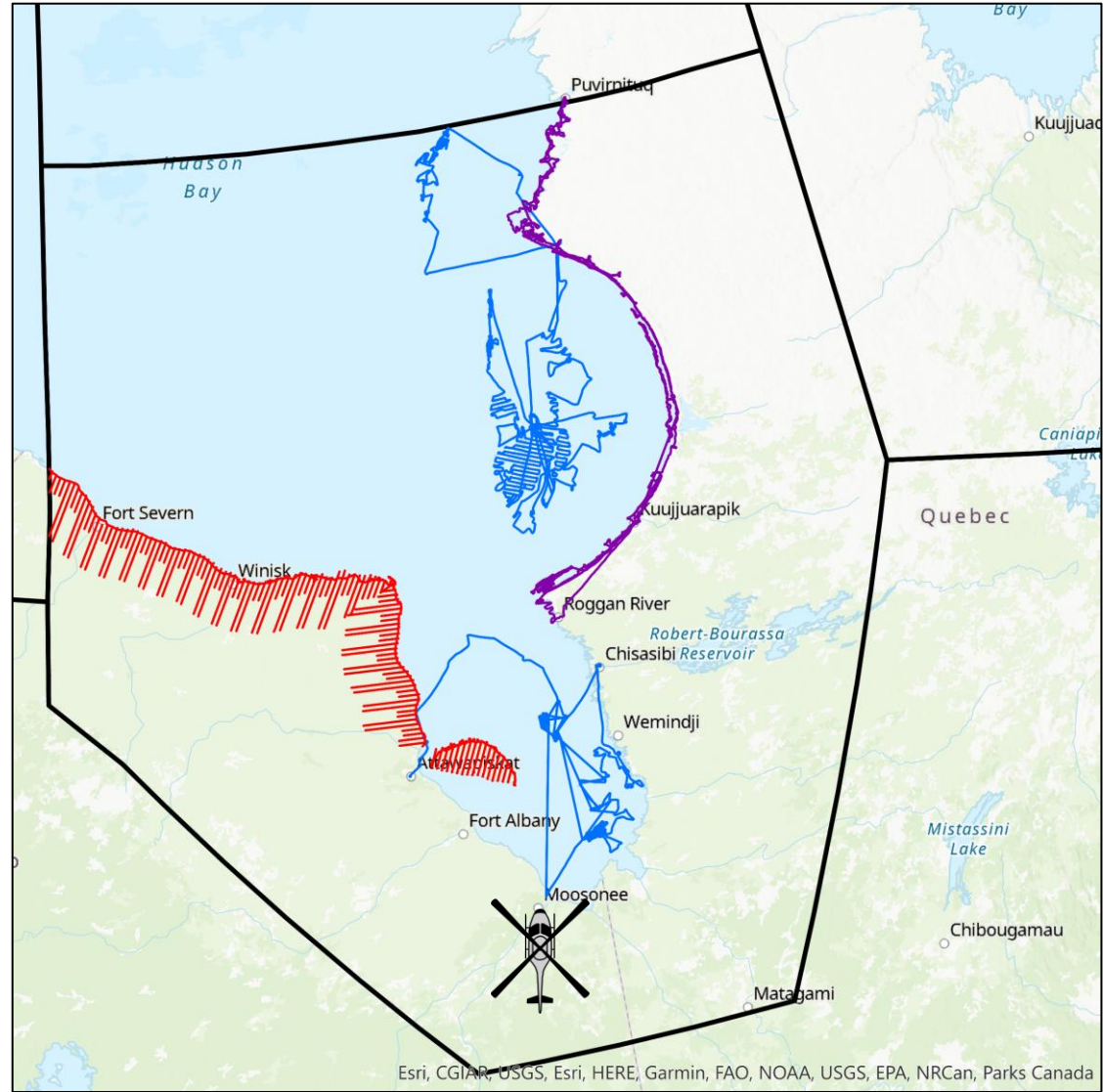
- Collect data to **estimate the abundance** of a species
- **Distance sampling, double observer, and census** method
- Strata and transects based on **past survey data, harvest data, and community feedback**





Aerial Abundance Surveys

- Used same transects as 2011 & 2016 study
 - Except reduced coverage of inland Quebec after discussion with communities
- Transects determined using:
 - 2011 survey and results
 - Traditional Knowledge
 - Telemetry data

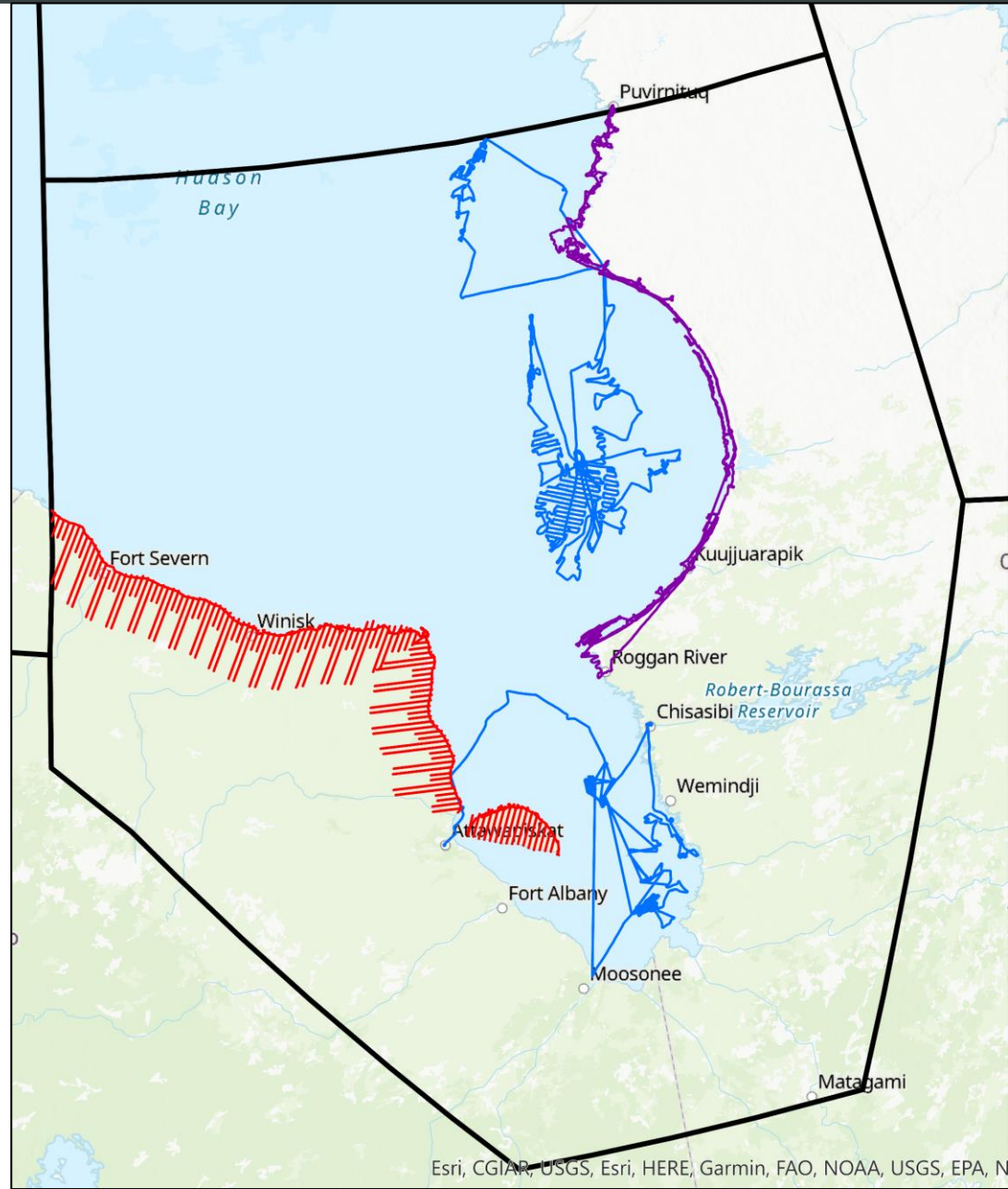


Southern Hudson Bay Subpopulation



Aerial Abundance Survey Results

- Observed more bears total than 2016 and similar to 2011
- Encountered 138 groups of bears observed
- Comparable analysis to 2016: 1003 (773 – 1302)
- 29% increase from 2016

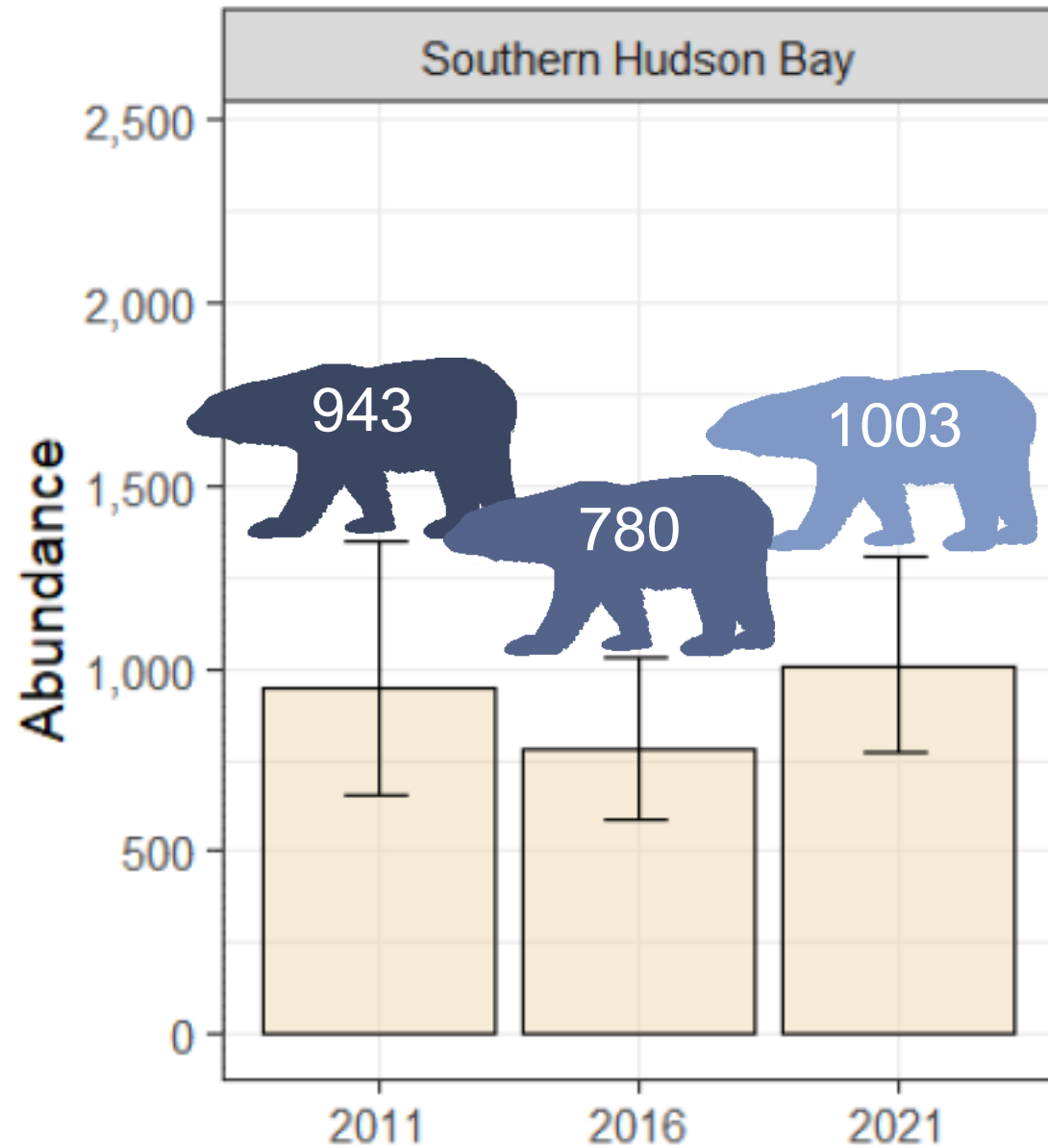


Southern Hudson Bay Subpopulation



Aerial Abundance Survey Results

- Observed more bears total than 2016 and similar to 2011
- Observed 138 groups of bears observed
- Comparable analysis to 2016: 1003 (773 – 1302)
- 29% increase from 2016

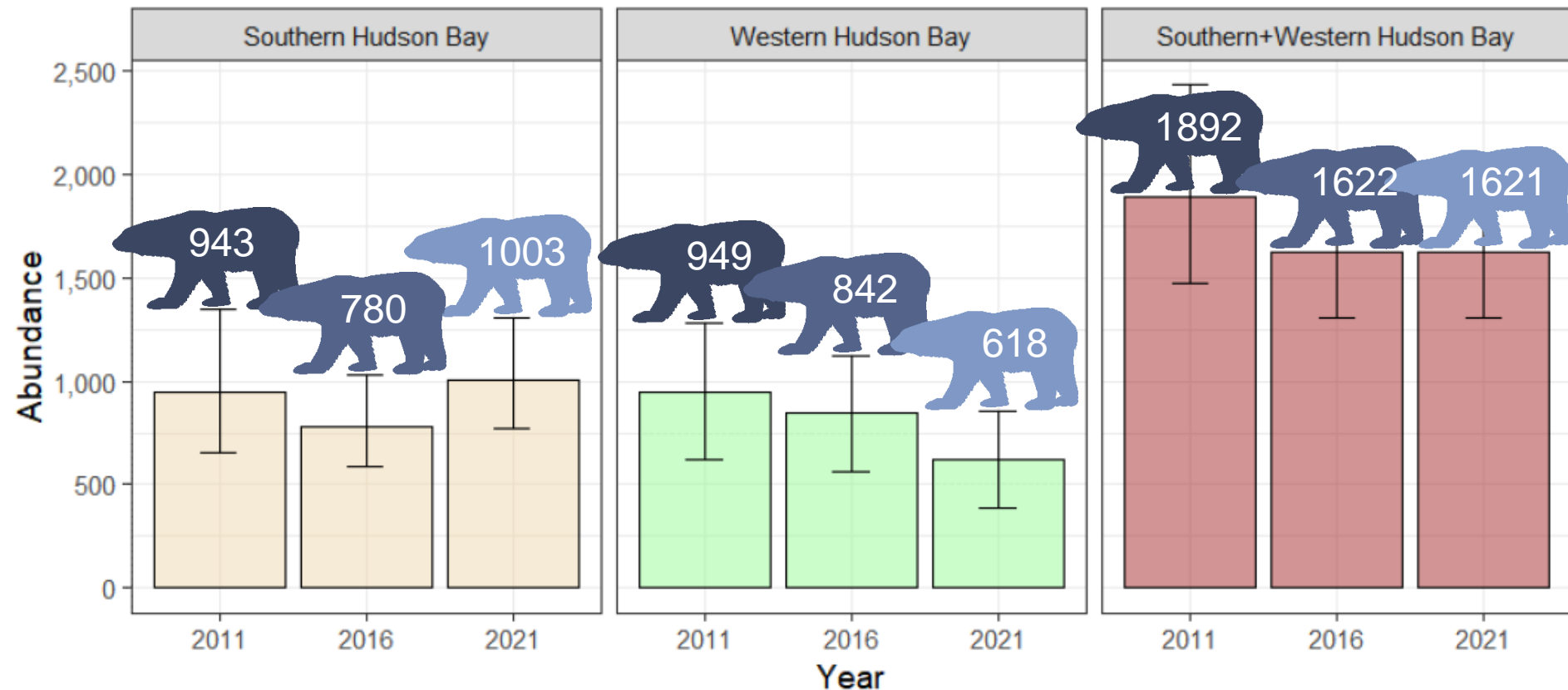


Southern Hudson Bay Subpopulation



Aerial Abundance Survey Results

- Reasons for increase?
 - Annual shifts into Southern Hudson Bay?



Biopsy Darting Report



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada

Distributional shifts of polar bears (*Ursus maritimus*) in Hudson Bay in relation to sea ice dynamics, 2017-2022 Final Report

D. McGeachy^{1,4}, N. J. Lunn¹, J. M. Northrup², V. Trim³, C. Davis⁴, A. E Derocher⁴

¹ Environment and Climate Change Canada, CW-405 Biological Sciences Building, University of Alberta, Edmonton, AB T6G 2E9

² Ontario Ministry of Natural Resources and Forestry, DNA Building B217, Trent University, 2140 East Bank Drive, Peterborough, ON K9L 1Z8

³ Manitoba Department of Natural Resources and Northern Development, Water Stewardship and Biodiversity Division, Wildlife and Fisheries Branch, Box 28, 59 Elizabeth Drive, Thompson, MB R8N 1X4

⁴ Department of Biological Sciences, University of Alberta, Edmonton, AB T6G 2E9



David McGeachy
Polar Bear Technician
Environment and Climate Change
Canada

Biopsy Darting



Biopsy Darting



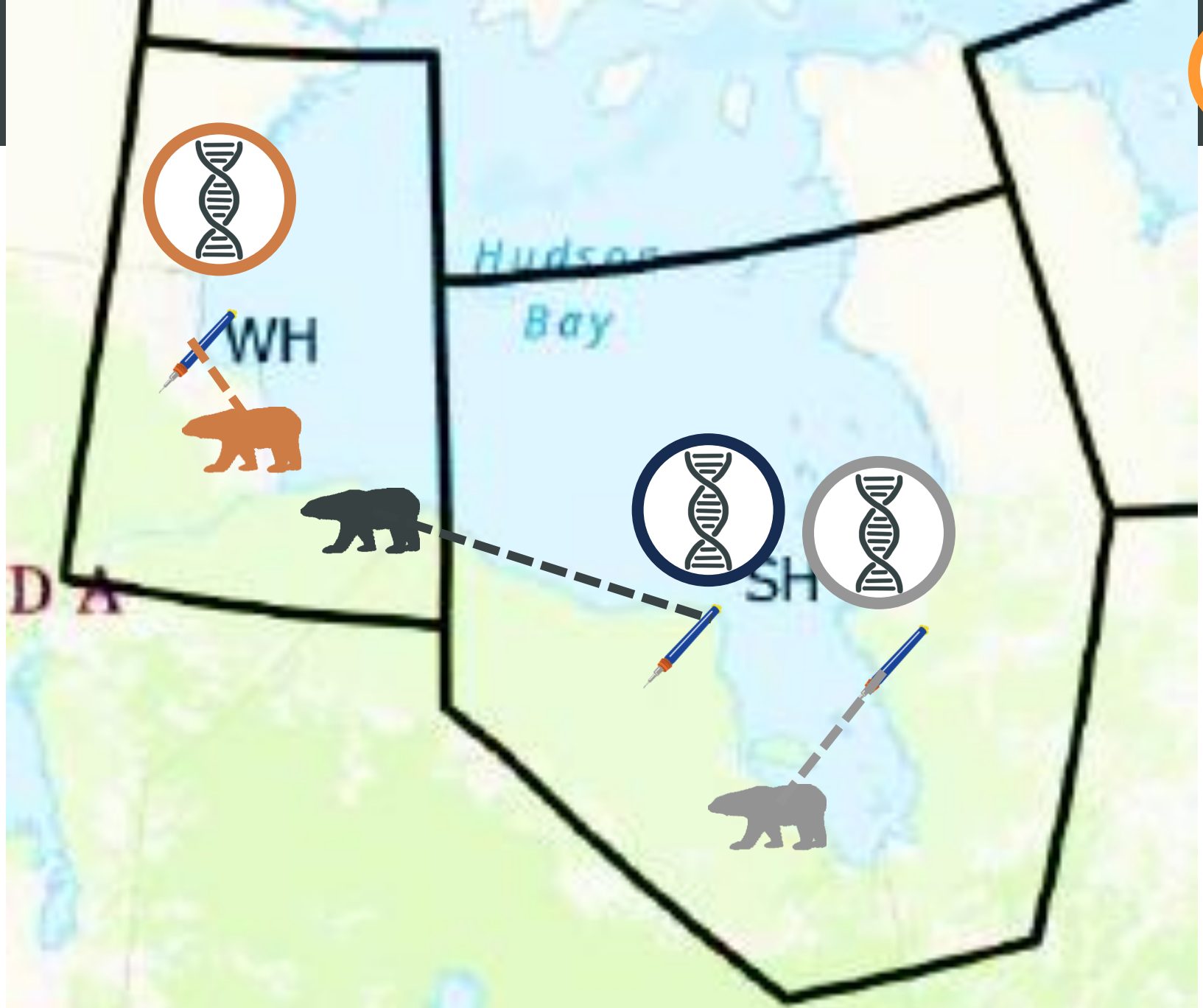
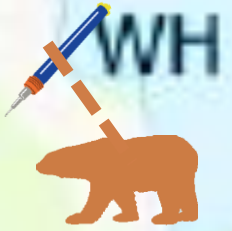
Genetics/DNA



- Biopsy sampling – bears **not physically handled** or **sedated**



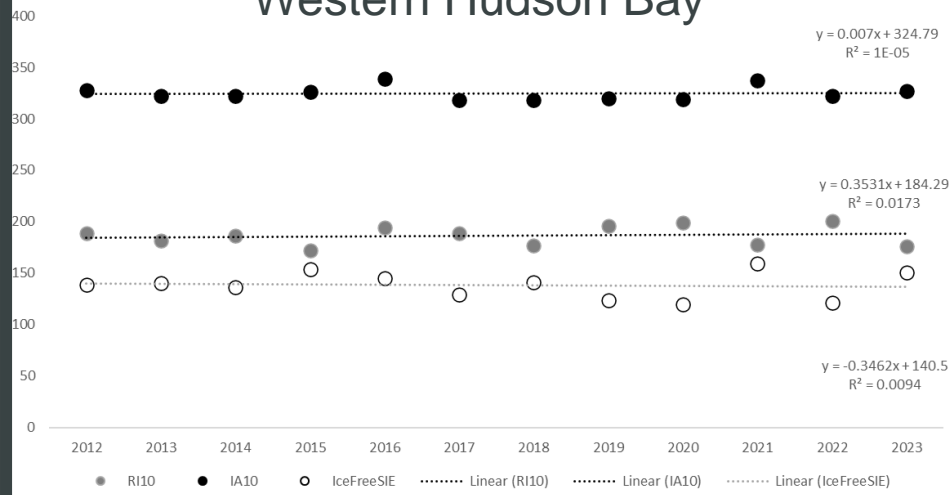




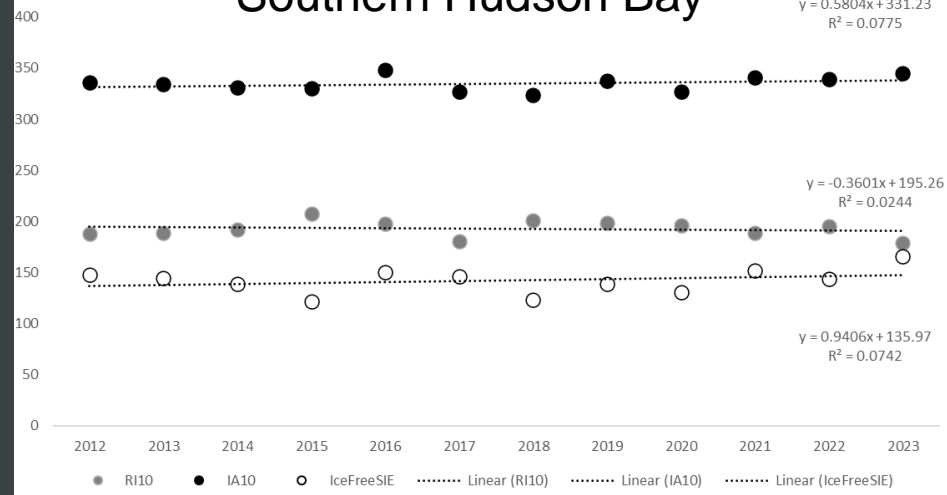
Results – Sea Ice



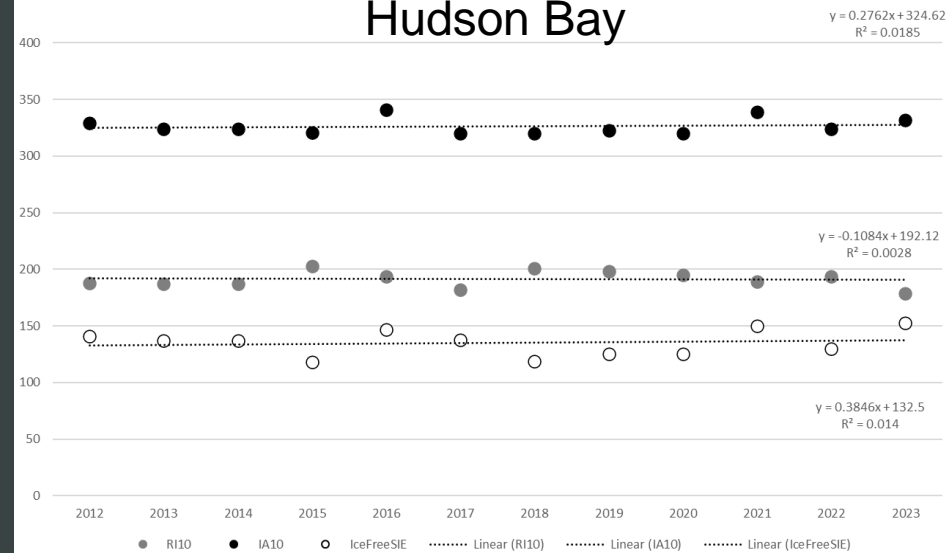
Western Hudson Bay



Southern Hudson Bay



Hudson Bay

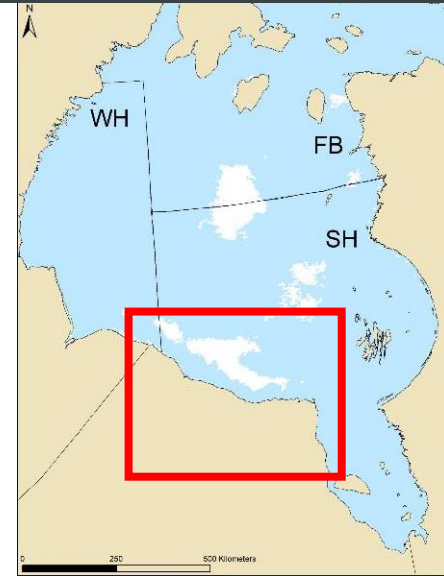
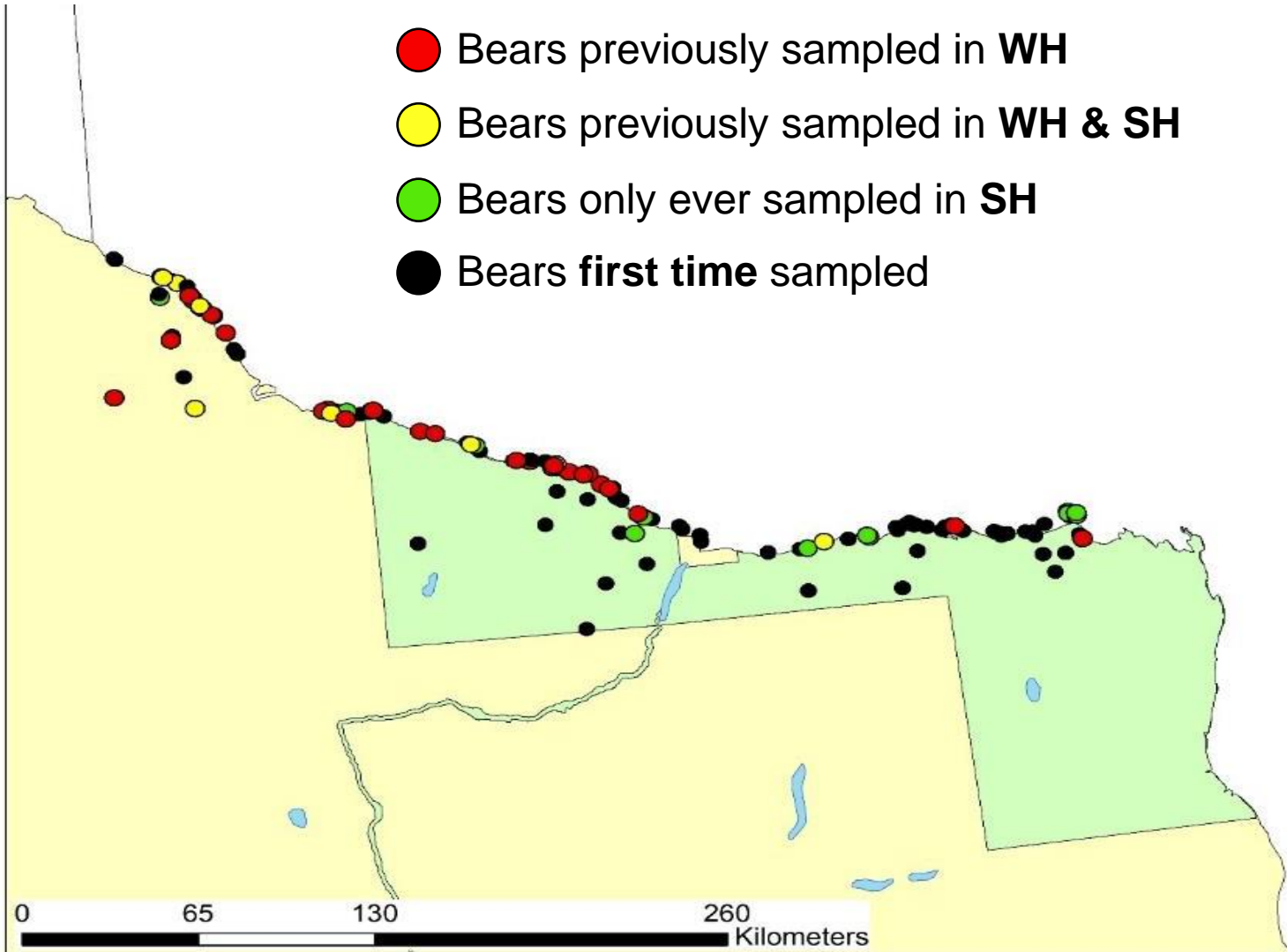


Results – 2021 SH Recaptured Bears

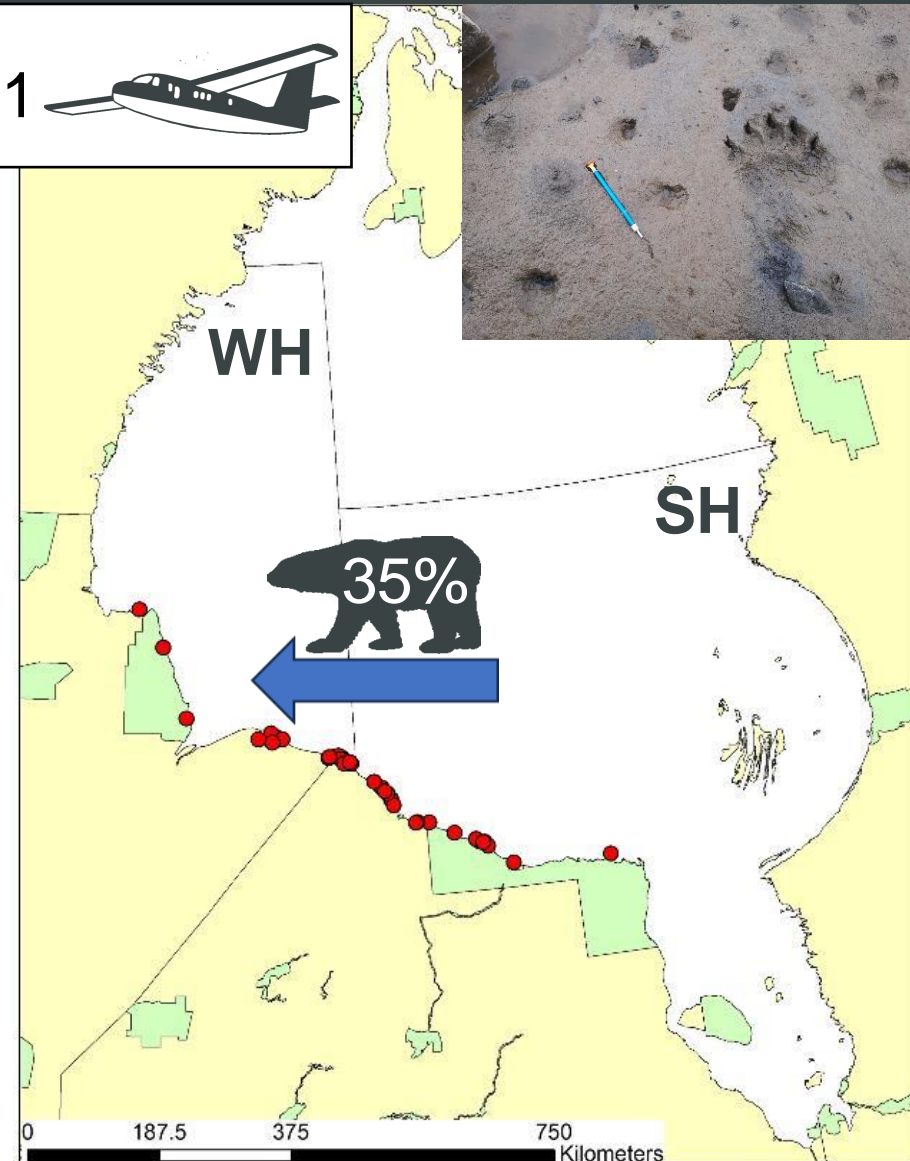
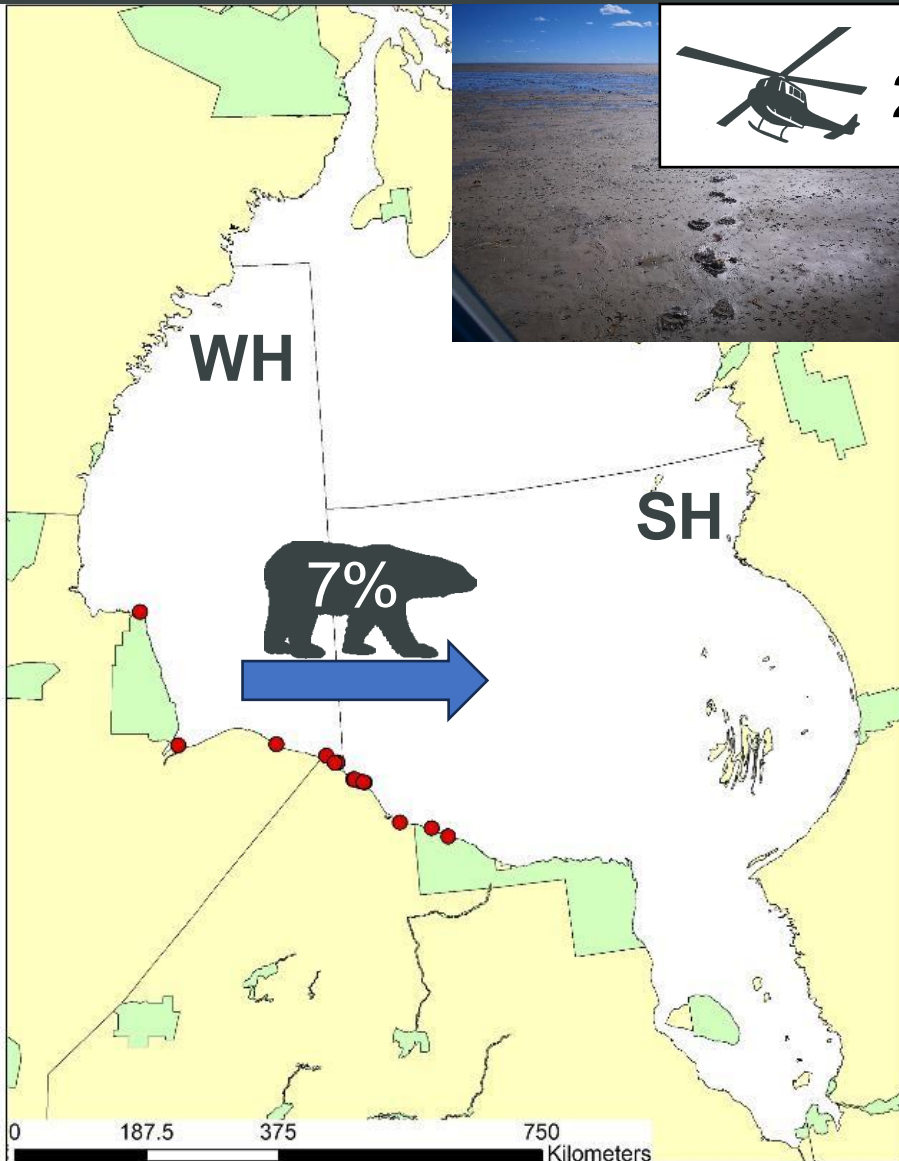


Sampling locations for bears biopsied in 2021 in SH

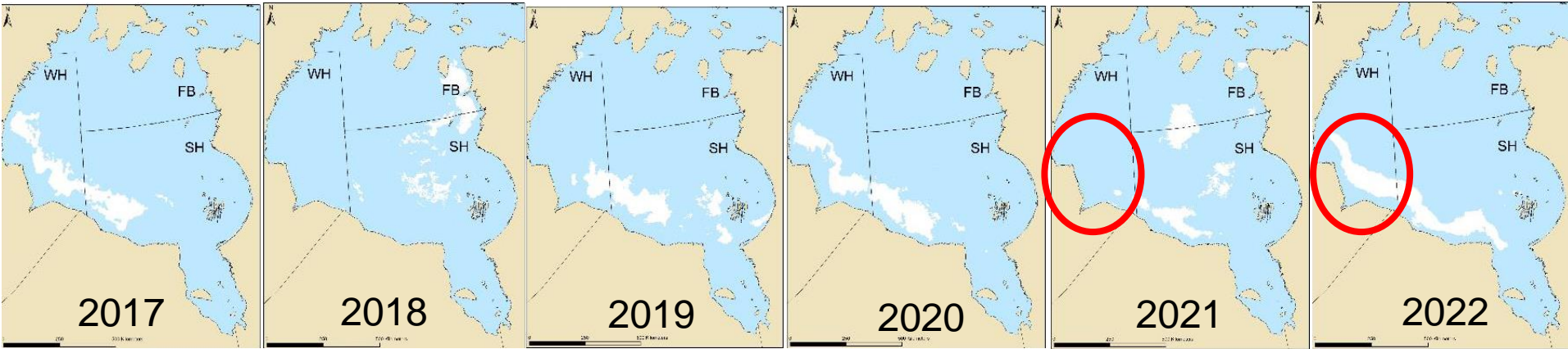
- Bears previously sampled in **WH**
- Bears previously sampled in **WH & SH**
- Bears only ever sampled in **SH**
- Bears **first time** sampled



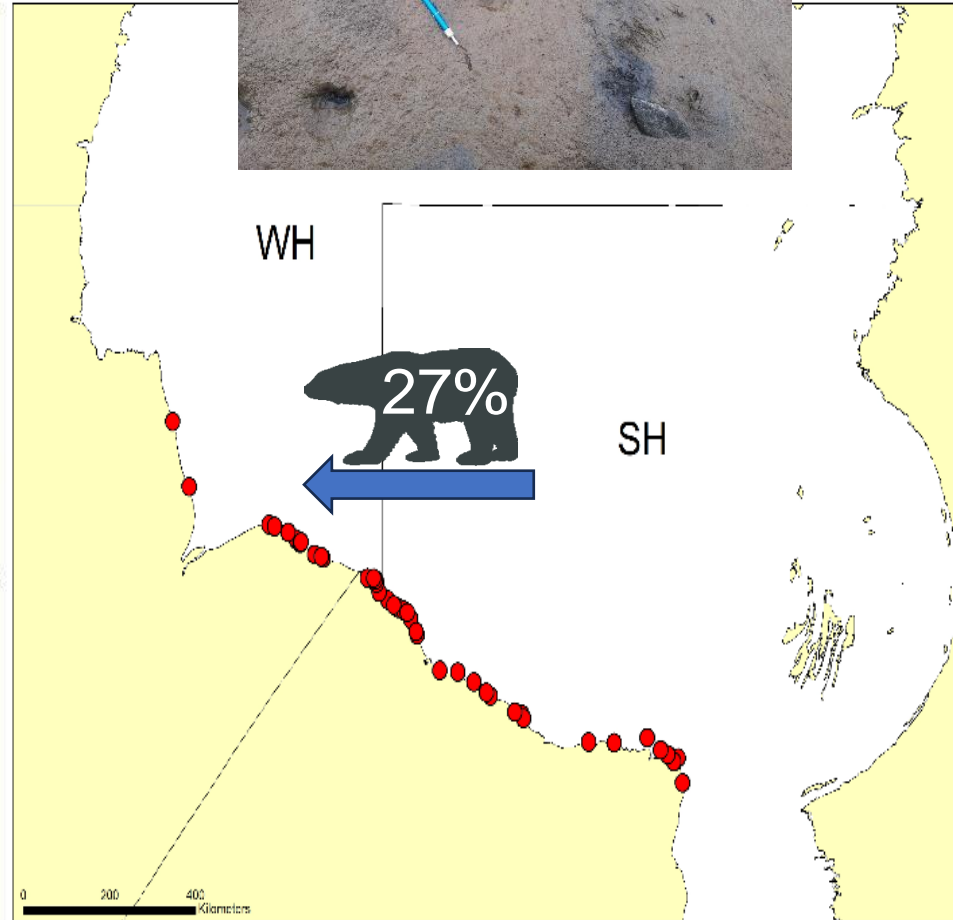
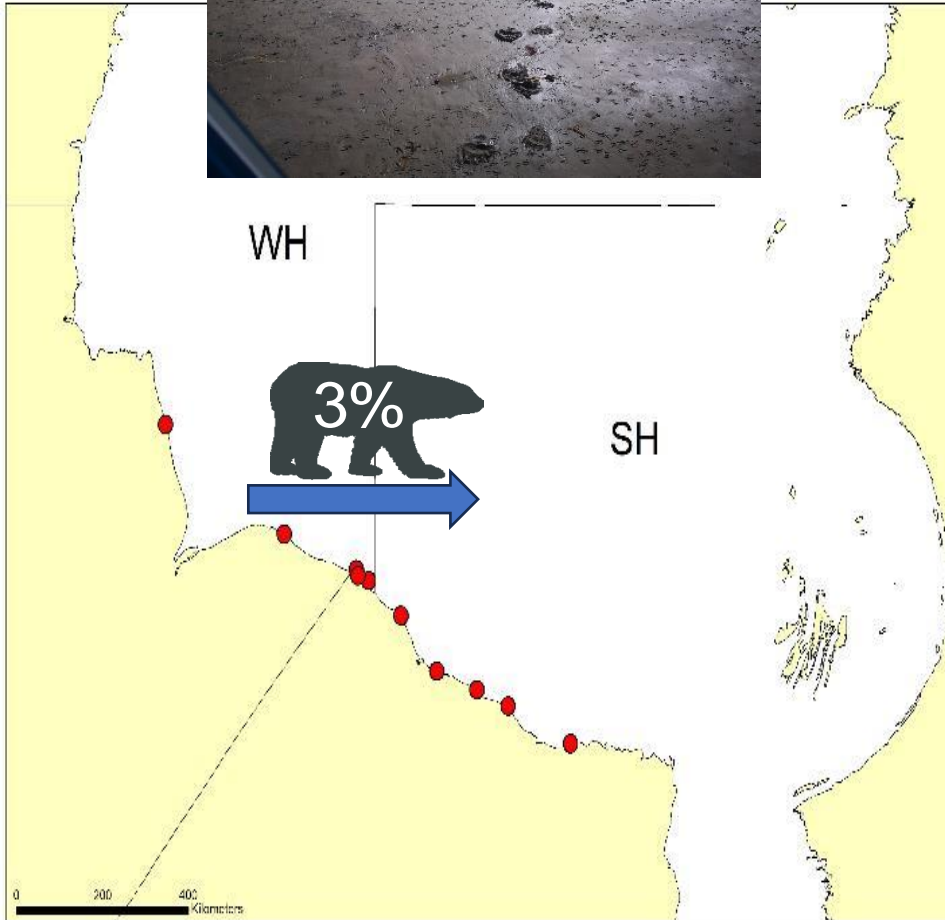
Results – WH to SH and SH to WH 2021/2022



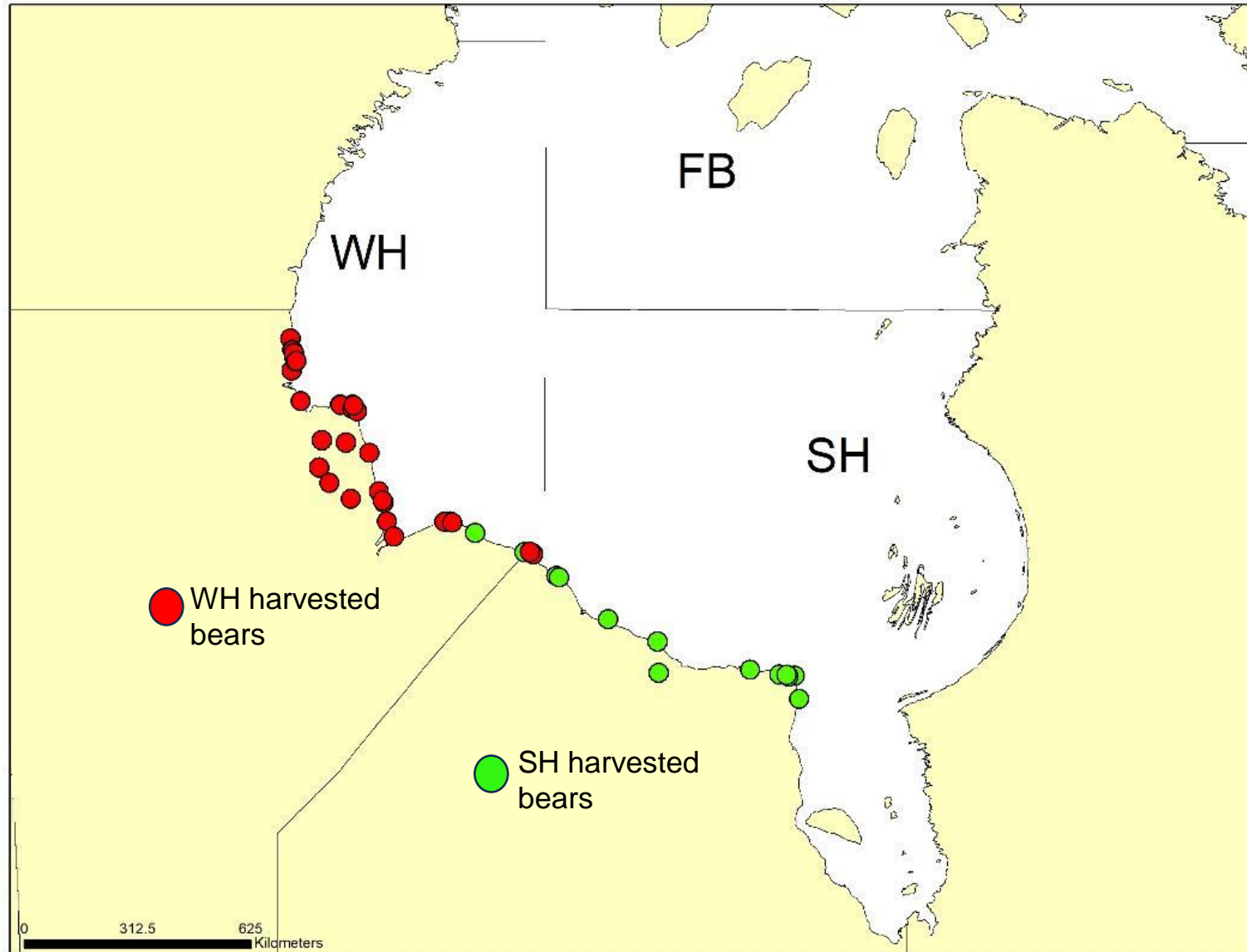
Results – Last area of consolidated ice before summer



Results – WH to SH and SH to WH 2022/2023



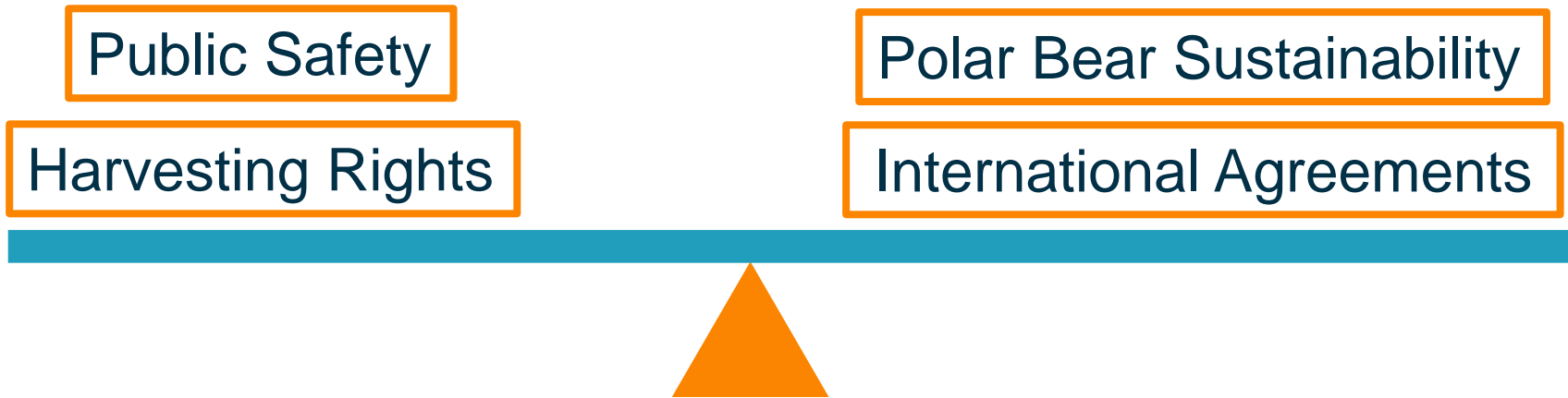
Results – WH to SH and SH live sampling of harvested bears 2017-2023





Job of the Department of Environment

- Balancing act



Total Allowable Harvest (TAH)

- The current TAH for Southern Hudson Bay is 25 bears per year.
- Department of Environment at this time is **recommending a TAH of 25.**
 - This is because of the ECCC biopsy darting results **showing movement between WH and SH**



- Do you agree that the number of polar bears **stayed relatively the same** over time?
- Are there **enough** bears to harvest? Are there **too few**? **Too many**?
- What did you observe in the bears' **body condition** over time?
- Is there anything **special** that you observed and wanted to share with us?
- Where do you **agree/disagree** with our findings?

Thank you!



Contact Info:

Alyssa Bohart



abohart@gov.nu.ca

Joe Northrup



joseph.northrup@ontario.ca

Questions?

2021 Southern Hudson Bay polar bear subpopulation aerial survey – Final report

Joseph M. Northrup^{1,2}, Eric Howe¹, Nicholas J. Lunn³, Kevin Middel¹, Martyn E. Obbard^{1,2}, Tyler R. Ross⁴, Guillaume Szor⁵, Lyle Walton⁶, Jasmine Ware⁷

¹Wildlife Research and Monitoring Section, Ontario Ministry of Natural Resources and Forestry

²Environmental and Life Sciences Graduate Program, Trent University

³Environment and Climate Change Canada

⁴Department of Biology, York University

⁵Ministère de l'Environnement, de la Lutte contre les Changements Climatiques, de la Faune et des Parcs, Gouvernement du Québec

⁶Northeast Regional Resources Section, Ontario Ministry of Natural Resources and Forestry

⁷Department of Environment, Government of Nunavut



EXECUTIVE SUMMARY

The Southern Hudson Bay (SH) polar bear subpopulation is the most southern continuously occupied area for the species, covering the eastern and southern parts of Hudson Bay and all of James Bay, as well as corresponding parts of the Ontario and western Quebec coastline, and up to 120 km inland. Polar bears in this area are hunted by Indigenous peoples for food, cultural practices, and sale of hides. As such, assessing the abundance of polar bears in the SH subpopulation is critical for monitoring the impacts of climate change on polar bears, which is the main threat to polar bear persistence, and for ensuring sustainable harvest.

Early population inventories of the SH subpopulation used physical mark-recapture methods with surveys conducted approximately every ten years and concentrating mostly along the Ontario coastline. Results of these studies suggested that the population abundance along the Ontario coastline of Hudson Bay and some inland areas was largely similar from the 1980s to the mid-2000s, despite evidence of declines in body condition and survival related to declining sea ice. In 2011, partners agreed to a less invasive, but more frequent, monitoring approach based on aerial surveys. This approach was chosen due to concerns raised by Indigenous partners about handling polar bears as well as logistical and financial challenges of physical mark-recapture studies. As a result, starting in 2011, aerial surveys have been conducted every five years. The surveys combined distance sampling and double-observer mark-recapture aerial surveys of the coast, areas up to 60 km inland and offshore islands in Hudson and James Bays. The design and methodology were established according to the known distribution of SH bears during the ice-free season and the different survey approaches were used to sample across differences in bear density. Field work for the first survey was completed in Ontario in 2011 and Quebec in 2012. This survey methodology was then repeated in 2016 in both Ontario and Quebec. In keeping with management authority goals, a comprehensive aerial survey of SH was conducted in summer 2021 that maintained a nearly identical design as the previous surveys. This report presents the results of this third survey to provide a direct comparison across the three survey periods (2011-12, 2016 and 2021).

The 2021 aerial survey was flown from August 22 – September 1, using the same methods and design as the two previous surveys. The 2021 aerial survey produced two separate estimates: 1) 1003 (95% CI 773-1302), which is directly comparable to the previous 2016 survey abundance estimate and 2) 1119 (95% CI 860-1454), which provided a more robust estimate using recent advances in statistical methods. Both estimates indicated a greater number of bears within the SH subpopulation in 2021 than in 2016.

Two main biological drivers are likely to have contributed to the greater number of bears observed within SH in 2021 relative to 2016: annual variation in the on-land distribution of bears in SH and the neighbouring Western Hudson Bay (WH) subpopulation, and improved demographic rates. It is likely that both drivers have contributed to the observed differences in abundance, to varying degrees, although there is no definitive evidence to support either driver. There appears to have been some movement of bears into SH from the WH subpopulation in 2021 around the time of the survey. A minor variation in the distribution of bears around the SH and WH border could have influenced the SH abundance estimate and may not represent an actual growth of the subpopulation. It is also possible that the greater number of bears observed in 2021 compared to 2016 was influenced in part by reduced mortality, increased birth rate, or some combination of the two. The three years preceding the 2021 survey had the longest duration of sea ice in Hudson Bay of the last decade, and harvest was lower between 2016 and 2021 than between 2010 and 2015; both factors could have contributed potential growth of the SH subpopulation.

Monitoring polar bear populations in the face of ongoing climate warming is critical for providing local communities that rely on polar bears with additional information for harvest management decision-making. Continued monitoring of reproduction, survival, and inter-annual movements within and between the WH and SH subpopulations will be critical to continue to inform management during the intervals between aerial surveys.

RÉSUMÉ

La sous-population d'ours blancs du sud de la baie d'Hudson (SBH) se trouve dans la zone la plus méridionale continuellement occupée par l'espèce. Cette zone couvre les parties est et sud de la baie d'Hudson et toute la baie James, ainsi que les parties correspondantes des côtes de l'Ontario et de l'ouest du Québec, et jusqu'à 120 km à l'intérieur des terres. Dans cette région, les Autochtones chassent l'ours blanc à des fins d'alimentation, de pratiques culturelles et de la vente de peaux. L'évaluation de l'abondance de la sous-population du SBH est donc essentielle pour suivre les répercussions des changements climatiques sur l'espèce, soit la principale menace pour la persistance de l'ours blanc, et garantir une exploitation durable.

Les premiers inventaires de la sous-population du SBH utilisaient des méthodes de marquage-recapture physique, et des relevés étaient réalisés environ tous les dix ans, principalement le long de la côte de l'Ontario. Selon les résultats de ces études, l'abondance de la sous-population le long de la côte ontarienne de la baie d'Hudson et dans certaines zones intérieures était largement similaire des années 1980 au milieu des années 2000, malgré des signes de déclin de la condition physique et de la survie liés à la réduction de la glace de mer. En 2011, des partenaires ont accepté d'utiliser une approche de suivi moins invasive, mais plus fréquente, basée sur des inventaires aériens. Cette approche a été choisie à cause des préoccupations soulevées par les partenaires autochtones concernant la manipulation des ours blancs, de même que des défis logistiques et financiers liés aux études de marquage-recapture physique. Par conséquent, depuis 2011, des inventaires aériens sont réalisés tous les cinq ans. Les inventaires combinent la méthode d'échantillonnage par distance (« distance sampling ») et la méthode de marquage-recapture à double observateur et sont réalisés le long des zones côtières, dans certains secteurs jusqu'à 60 km à l'intérieur des terres et sur les îles au large de la baie d'Hudson et de la baie James. Le plan expérimental ainsi que la méthodologie d'inventaire ont été établies en fonction de la répartition connue des ours du SBH pendant la saison libre de glace, et les différentes approches d'échantillonnage ont été utilisées en fonction de la densité d'ours attendue dans les différents secteurs inventoriés. Le premier inventaire couvrant la totalité de la sous-population du SBH, a été réalisé sur deux années, couvrant l'Ontario en 2011 et le Québec en 2012. Un inventaire réalisé selon la même méthodologie a ensuite été répété en 2016 dans les deux provinces. Conformément aux objectifs des autorités de gestion, un inventaire aérien exhaustif de la sous-population a été mené à l'été 2021, selon une méthodologie presque identique à celle des inventaires précédents. Le présent rapport fait état des résultats de ce troisième inventaire afin de fournir une comparaison directe entre les trois périodes d'inventaire (2011-2012, 2016 et 2021).

L'inventaire aérien de 2021 a été réalisé du 22 août au 1^{er} septembre à l'aide des mêmes méthodes et de la même conception que les deux inventaires précédents. Cet inventaire

a permis d'obtenir deux estimations distinctes : 1) 1 003 individus (IC à 95 % : 773-1 302), une estimation qui est directement comparable à l'estimation de l'abondance issue de l'inventaire précédent de 2016 et 2) 1 119 individus (IC à 95 % : 860-1 454), une estimation plus robuste obtenue selon une approche statistique novatrice. Les deux estimations indiquent un plus grand nombre d'ours au sein de la sous-population du SBH en 2021 qu'en 2016.

Deux facteurs biologiques principaux sont susceptibles d'avoir contribué à l'augmentation du nombre d'ours observés dans cette sous-population en 2021 par rapport à 2016 : une variation annuelle au niveau de la répartition terrestre des ours du SBH et de la sous-population voisine de l'ouest de la baie d'Hudson (OBH), et une amélioration des taux démographiques. Il est probable que ces deux facteurs aient contribué à des degrés variables aux différences observées de l'abondance, bien qu'il n'y ait pas de preuves définitives à l'appui de l'une ou l'autre de ces facteurs. Il semble y avoir eu un certain déplacement des ours de la sous-population de l'OBH vers celle du SBH en 2021 au moment de l'inventaire. Une variation mineure au niveau de la répartition des individus de part et d'autre de la frontière entre ces deux sous-populations pourrait avoir influé sur l'estimation de l'abondance de la sous-population du SBH et pourrait ne pas représenter une croissance réelle de celle-ci. Il est également possible que le plus grand nombre d'ours observés en 2021 comparativement à 2016 soit attribuable en partie à une réduction de la mortalité, à une augmentation du taux de natalité ou à une combinaison des deux. Les trois années précédant l'inventaire de 2021 ont connu la plus longue durée de la glace de mer dans la baie d'Hudson de la dernière décennie, et la récolte a été plus faible de 2016 à 2021 que de 2010 à 2015; ces deux facteurs pourraient avoir contribué à une croissance potentielle de la sous-population du SBH.

Le suivi des populations d'ours blancs dans le contexte du réchauffement climatique actuel est essentiel pour fournir aux communautés locales qui dépendent des ours blancs de l'information supplémentaire pour la prise de décision en matière de gestion des récoltes. La poursuite du suivi de la reproduction, de la survie et des déplacements interannuels au sein des sous-populations de l'OBH et du SBH, et entre elles, sera essentielle afin de fournir les informations nécessaires à la gestion de ces populations pendant les intervalles entre les inventaires aériens.

INTRODUCTION

Climate warming is causing rapid and widespread impacts to Arctic ecosystems (Post et al. 2009) where temperatures are increasing at two to four times the global average (IPCC 2013, Rantanen et al. 2022). These impacts have had profound effects on a variety of Arctic wildlife species, causing population declines, reduced reproductive output, and shifts in the food web (Regehr et al. 2007, Post and Forchhammer 2008, Laidre et al. 2015, Descamps et al. 2017, Mallory and Boyce 2018). The impacts of climate change on Arctic ecosystems have had significant consequences for Indigenous peoples that rely on Arctic species for subsistence (Durkalec et al. 2015, Laidre et al. 2015, Ostapchuk et al. 2015, Kanatami 2019). As climate change continues to alter Arctic ecosystems (IPCC 2022), it is critical to monitor impacted species to provide information to local communities for use in decision-making and to assess general impacts to people and biodiversity from a warming climate.

Polar bears (*Ursus maritimus*) exemplify the challenges facing Arctic species under a changing climate. Polar bears are dependent on sea ice for nearly every stage of their life: they hunt their primary prey from the sea-ice platform, mate and, in some locations, even den on the sea ice (Amstrup and Gardner 1994). Thus, declines in sea ice have direct implications for nutrition, reproduction and the long-term population viability for polar bears. Although sea-ice extent and duration have declined in the last few decades over the circumpolar distribution of polar bears (Stern and Laidre 2016), the impacts to polar bear subpopulations have varied, with some experiencing declines in body condition, survival and abundance (Regehr et al. 2007, Lunn et al. 2016, Obbard et al. 2016, Obbard et al. 2018) and others experiencing limited effects or even near-term benefits as areas transition from multi-year ice to thinner, annual ice or areas in which access to shallow, highly productive ecoregions remains (Regehr et al. 2018, Laidre et al. 2020, Dyck et al. 2021, Dyck et al. 2022).

Polar bears are an important cultural, nutritional and financial species to Indigenous peoples that have coexisted with them for centuries (Wenzel 2004, Henri et al. 2010, Laforest et al. 2018). The harvest of polar bears is monitored through management frameworks in various jurisdictions across Canada (Taylor et al. 2008, Lunn et al. 2018), all aiming for sustainable harvest management and continued population viability. However, the logistical and analytical challenges involved with enumerating polar bear populations, as well as the often long intervals between surveys, adds uncertainty to the achievement of this goal. Compounding uncertainty of the responses of bears to climate warming increases the complexity of identifying the sustainability of harvest levels (Regehr et al. 2017, Regehr et al. 2021). Thus, monitoring polar bear populations in the face of ongoing climate warming is critical for providing local communities that rely on polar bears with additional information for harvest management decision-making.

Polar bears are divided into 19 relatively discrete subpopulations (Durner et al. 2018) delineated using a variety of methods, including capture and recapture data, genetics, and movement data from collared individuals (Paetkau et al. 1999, Taylor et al. 2001, Amstrup et al. 2004). The Southern Hudson Bay (SH) subpopulation represents the furthest south continuously occupied area of the globe for polar bears, and, as such, is a critical location for monitoring the impacts of climate warming. The marine portions of the SH subpopulation include the eastern and southern portions of Hudson Bay and all of James Bay (Fig. 1). The subpopulation also encompasses nearly the entirety of the coastline of Ontario, large areas of the western coastline of Québec, and areas of both provinces up to 120 km inland.

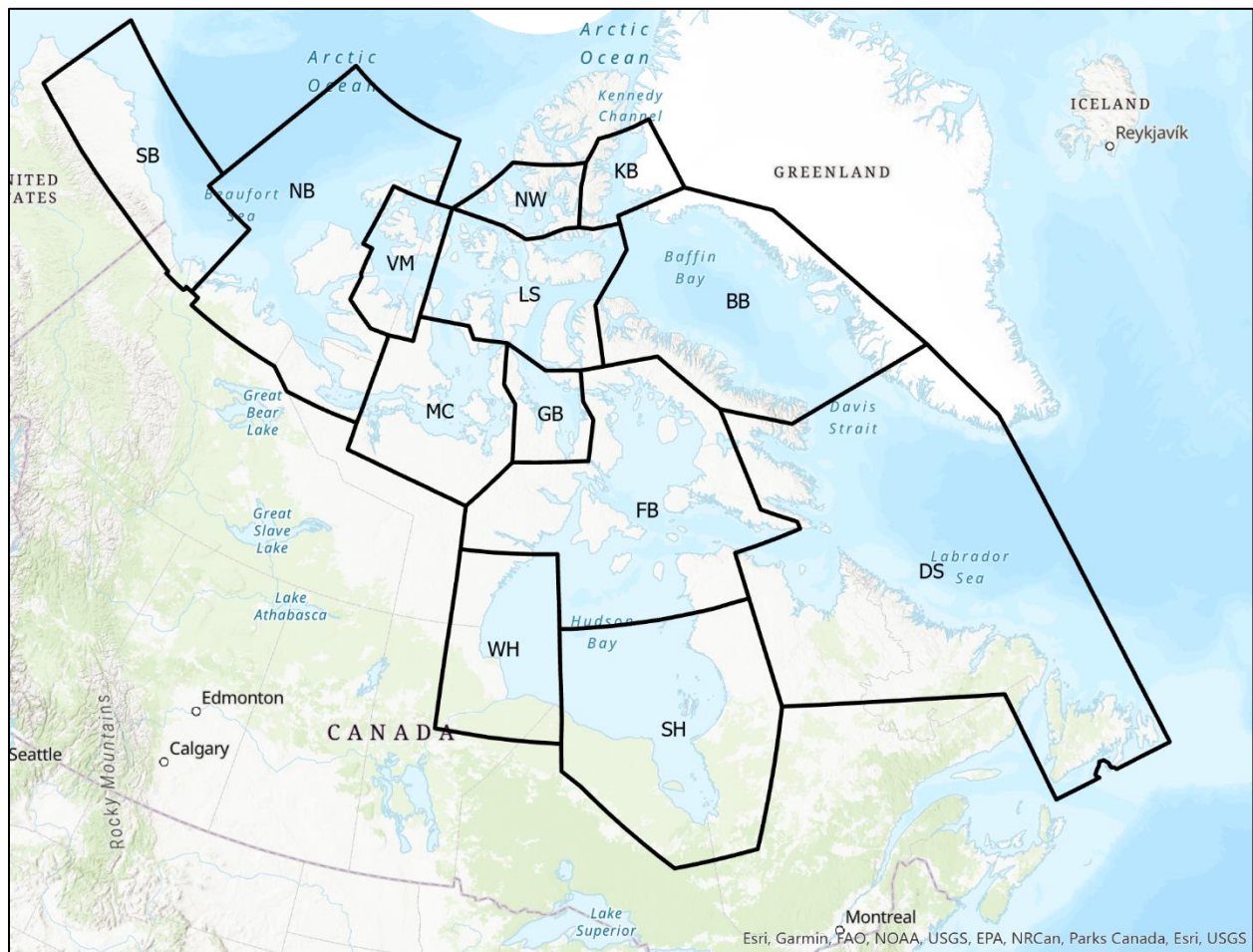


Figure 1. Boundaries of polar bear subpopulations that are partially or totally under management by Canadian jurisdictions. SB, Southern Beaufort Sea; NB, Northern Beaufort Sea; VM, Viscount Melville Sound; MC, M'Clintock Channel; LS, Lancaster Sound; NW, Norwegian Bay; KB, Kane Basin; BB, Baffin Bay; GB, Gulf of Boothia; FB, Foxye Basin; DS, Davis Strait; WH, Western Hudson Bay; and, SH, Southern Hudson Bay.

The first abundance estimate for SH was obtained between 1984 and 1986 by Kolenosky et al. (1992) using physical capture-mark-recapture conducted primarily along the Ontario coast of Hudson Bay and including some inland areas. This effort extended somewhat into the current limit of the Western Hudson Bay (WH) subpopulation and produced an estimate of 763 bears (± 323) but was later adjusted upwards to 1000 bears for management purposes because no sampling was conducted on the James Bay coast of Ontario, the Québec coast, or any of the offshore islands of James and Hudson bays (Lunn et al. 1998). During 1997 and 1998, a capture-mark-recapture effort was undertaken on Akimiski, North and South Twin Islands in James Bay. Although a formal estimate was never published for these efforts, Obbard et al. (2007) citing Obbard and Howe (unpublished data) report abundance estimates ranging from 70 to 110 bears, which were derived from several models (minimum lower confidence limit across models = 56 and maximum upper confidence limit across models = 195). Between 2003 and 2005, Obbard et al. (2007) conducted another physical capture-mark-recapture effort, covering the same area as assessed in the 1980s, but more thoroughly covering areas up to 40 km inland from the coast. Further, they reanalyzed the data from 1984-1986 excluding captures occurring outside of the current SH subpopulation boundary. This work estimated that there was an average of 641 bears (95% CI = 401-881) between 1984 and 1986 and 681 bears (95% CI = 401-961) between 2003 and 2005 in the study area, indicating the population in the surveyed area was likely very similar between the two survey periods. However, concurrent with these abundance estimates, declines in the point estimates of survival between the 1980s and 2000s were documented (Obbard et al. 2007) as well as significant declines in body condition of bears (Obbard et al. 2016). Further, the ice-free season in SH increased by approximately three weeks between the 1990s and 2010s (Hochheim and Barber 2014). Thus, while it appears that the population abundance along the Ontario coast of Hudson Bay and the areas inland was largely similar between the 1980s and mid-2000s, there was evidence that the population might be facing nutritional issues and attendant declines in survival and body condition related to declining sea ice. Concurrently, the adjacent WH subpopulation had seen similar declines in survival and body condition as well as abundance during the same period (Regehr et al. 2007, Lunn et al. 2016). Lastly, there remained areas of the subpopulation, including the Québec coast, large portions of the James Bay coast, and several James Bay and Hudson Bay islands, that had still not been surveyed rigorously enough to contribute to abundance estimates at that point (Leafloor 1990, Crête et al. 1991).

Although physical capture programs offer some of the best data for understanding polar bear vital rates and population dynamics, while also enabling the collection of data on body condition, they are logistically challenging, expensive to undertake, and take several years to produce robust estimates. Further, Indigenous peoples that coexist with polar bears have raised concerns about the handling and chemical immobilization of polar bears for scientific and management purposes (Peacock et al. 2009, Service Canadien

de la Faune 2010, Henri et al. 2010, Wong et al. 2017, <https://www.itk.ca/wp-content/uploads/2019/08/A09-06-11-Approval-of-Polar-Bear-Research-Methods.pdf> accessed November 16, 2022). Starting in 2011, management authorities for SH and WH moved to an aerial survey-based approach for enumerating these subpopulations (Stapleton et al. 2014, Obbard et al. 2015, Dyck et al. 2017). Less information is gained through aerial surveys relative to mark-recapture efforts, so, after conducting power analyses, jurisdictions agreed that surveys would occur on a more regular basis and be repeated every five years. Thus, in 2011, Obbard et al. (2016) implemented a combined distance sampling and double-observer mark-recapture aerial survey of the Ontario coast and areas up to 60 km inland along with Akimiski Island. At the time, there was insufficient funding to also Survey the Québec coast and offshore islands of James and Eastern Hudson Bay (M. Obbard personal communication), but these areas were subsequently surveyed in 2012. This was the most comprehensive survey of the SH subpopulation to date and produced an estimate of 943 bears (95% CI = 658-1350). This survey was repeated in 2016, with all areas surveyed in a single season (Obbard et al, 2018). This effort produced an estimate of 780 bears (95% CI = 590-1029), suggesting the population may have declined between 2011 and 2016. Further, the age composition of observed bears in the 2016 survey was suggestive of a poor survival of cubs to yearling stage considering few yearling bears were seen. An additional double-observer mark-recapture survey of only the coastline of Ontario, where the greatest density of bears occurs, was conducted in 2018 to examine indices of recruitment and obtain an estimate of the coastal population. This survey was an exact replicate of a portion of the 2011 and 2016 double-observer mark-recapture surveys, which allowed for a direct comparison of this portion of the population across years. The results showed that the proportion of yearlings was slightly higher in this area in 2018 than in 2016, but the number of bears inhabiting the coast was slightly lower at 249 bears (95% CI = 230-270) compared to 2016 (\bar{x} = 269, 95% CI = 214-297) and substantially lower than 2011 (\bar{x} = 422, 95% CI = 381-467; Northrup and Howe 2019).

Similar to other subpopulations in Canada, the harvest of SH polar bears has long been targeted for a 4.5% removal rate at a sex ratio of 2 males per female. This rate has been considered sustainable for polar bears (Taylor et al. 1987), though there is evidence that it may have been conservative for bears in SH over the last 20 years (Regehr et al. 2021). Polar bears in the SH subpopulation are harvested by Inuit in Nunavut and Nunavik and by Cree in Québec and Ontario, though recorded Cree harvests in Ontario were much greater in the 1970s through 1990s than at the time of this report (OMNRF unpublished data). Management authority for the SH subpopulation is complex as it is the shared responsibility of the Governments of Ontario, Québec, Nunavut, and Canada, along with the Nunavut Wildlife Management Board, Nunavik Marine Region Wildlife Management Board, the Eeyou Marine Region Wildlife Board, Hunting, Fishing and Trapping Coordinating Committee, Land Claims Organizations representing Indigenous rights,

specifically Nunavut Tunngavik Incorporated, Makivik Corporation and the Cree Nation Government in Québec, and several Cree First Nations in Ontario. The harvest of SH bears in Nunavut has been managed under a strict quota system since the 1970s, whereas harvest monitoring in Québec and Ontario remains incomplete as of this report. Total annual reported harvest within the subpopulation varies annually but averaged 48 bears between 2010-11 and 2020-21 (range 31-104; <https://www.polarbearsCanada.ca/en/polar-bears-canada/canadas-polar-bear-subpopulations>; accessed July 22, 2022).

There are sixteen coastal communities in the SH subpopulation (Fig. 2). Between 1980 and 2019, the Inuit community of Sanikiluaq, Nunavut had a total allowable harvest (TAH) of 25 bears at a male to female ratio of 2:1. The Sanikiluaq harvest was reduced to 20 bears per year for two years following the 2011-12 aerial survey. The management framework allows for annual variation in the actual harvest depending on over- or under-harvest compared to the TAH (Government of Nunavut 2019). A revision of the Nunavut polar bear harvest management system in 2019 allows the sex ratio of the harvest to reach up to one female bear for every male bear (up to 1:1). With this management change, the TAH for Sanikiluaq remained at 25 bears, indicating the potential for a greater number of female bears to be harvested after this time. Harvest reporting in Nunavut is believed to approach 100% and the average annual reported harvest for the 2010-11 to 2020-21 period was 26.2 bears (range 20 to 47 bears).

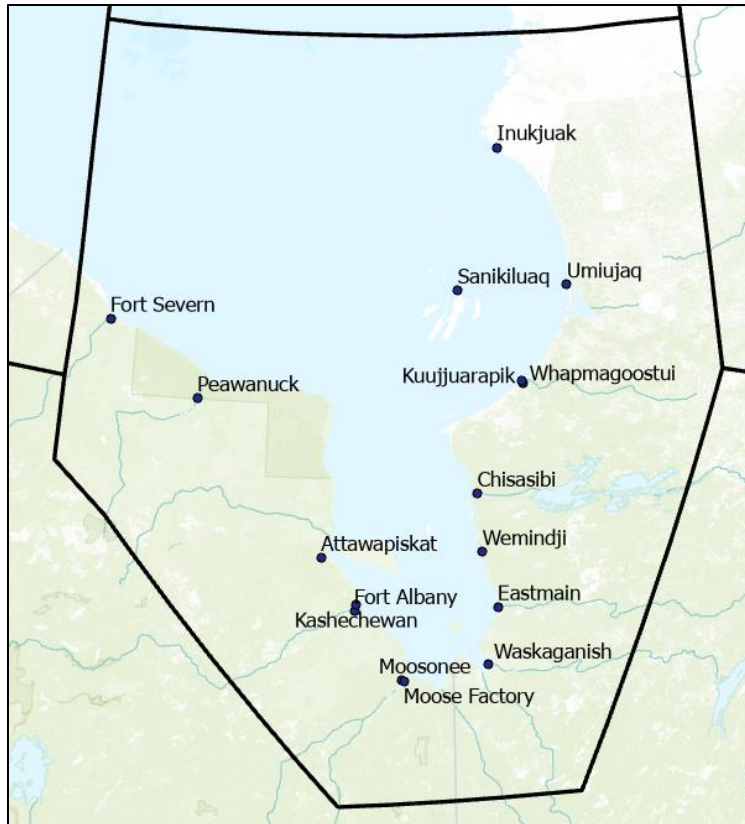


Figure 2. Coastal communities falling within the SH subpopulation boundary in Ontario, Québec and Nunavut.

In Québec, three Nunavik Inuit communities (Inukjuak, Umiujaq, and Kuujjuaraapik) and five coastal Cree communities (Whapmagoostui, Chisasibi, Wemindji, Eastmain and Waskaganish) potentially harvest from this subpopulation. There are currently no legal requirements for beneficiaries of the James Bay and Northern Québec Agreement (Québec Government 1976) to report human-caused polar bear mortalities but reporting and tagging of polar bear hides is necessary for hides to enter the domestic or international trade market. The proportion of the harvest reported to the Québec Government is currently unknown. Voluntary agreements were signed in 2011¹ and 2014² establishing harvest limits within the SH subpopulation for Nunavik Inuit and Cree of Eeyou Istchee and Ontario, and a total allowable take (TAT) was also established by the federal and Nunavut governments in 2016 for bears harvested within the Nunavik Marine

¹ A temporary voluntary limit of 26 bears for Nunavik Inuit, 25 for Inuit from Sanikiluaq, 4 for Cree of Eeyou Istchee, and 5 for Ontario Cree was established (including subsistence hunting and defense kills) for the 2011/12 harvest season.

² A temporary voluntary limit of 22 bears for Nunavik Inuit, 20 for Inuit from Sanikiluaq, and 3 bears for Ontario and Québec Cree with alternating division per harvest season for Cree was established for the 2014/15 and 2015/16 harvest seasons.

Region³. However, enforcement of those harvest limits remains problematic, and no harvest limits have been established in most of the Eeyou Marine Region nor in onshore Québec. Average annual reported harvest in Québec for the 2010-11 to 2020-21 period was 19.7 bears (range 5 to 74 bears).

In Ontario, there are three coastal Cree communities that have traditionally harvested polar bears (Fort Severn, Winisk (Peawanuck) and Attawapiskat). There are three additional Cree communities (Moose Factory, Fort Albany, and Kashechewan), and one non-Indigenous community (Moosonee) that are outside the generally occupied range of bears but occasionally have defense of life and property kills. In 1976, an informal agreement between the Ontario government and the coastal Cree First Nation Communities established that a maximum of 30 bear hides could be sealed for trade annually. The 2011⁴ and 2014² voluntary agreements also set maximum harvest limits on Ontario Cree but the proportion of the harvest that is reported to the Government of Ontario is currently unknown. Since polar bears were listed as threatened in Ontario in 2009, the sale of bear parts has been prohibited in the province.

A harvest risk assessment conducted by Regehr et al. (2021) indicated that under ongoing climate warming, harvest of polar bears in SH would likely need to decline in coming years to ensure harvest sustainability. Further, evidence outlined above suggests the SH subpopulation may be experiencing demographic challenges related to ongoing declines of sea ice. As such, there is a clear, continued need to assess the abundance of this subpopulation to monitor trend and support harvest management (Regehr et al. 2021). In keeping with management authority goals, a comprehensive aerial survey of SH was conducted in summer 2021 that maintained a nearly identical design as the previous surveys. Here we present the results of this third survey to provide a direct comparison across the three survey periods (2011/12, 2016 and 2021).

METHODS

Study area

The survey area was established according to the known distribution of SH bears during the ice-free season (Prevett and Kolenosky 1982, Obbard and Middel 2012). This area is large, topographically and vegetatively diverse, and has high variability in polar bear

³ A harvest limit of 23 bears within the Nunavik Marine Region was established for Nunavik Inuit, with at least one tag allocated to the Cree of Eeyou Istchee for harvest within the Inuit-Cree overlap area.

⁴ A temporary voluntary limit of 5 bears was established for the six coastal Cree Nations of Ontario (including subsistence hunting and defense kills) for the 2011/12 harvest season. Not all Ontario communities were included in discussion about this voluntary limit.

density. It spans large portions of the northern Ontario and northern Québec coasts and inland areas, with the islands of James Bay and Hudson Bay being part of the Territory of Nunavut (Fig. 1 and 2). The Ontario portions of the subpopulation are part of the Hudson Bay lowlands ecosystem, consisting of large wetland complexes, extensive treed areas and tundra along the coast of Hudson Bay (Fig. 3). This area has little topographic relief and the coastal portions include extensive tidal flats (Fig. 3). The Québec portion of the study area consists of a series of long and steep rocky nearshore islands forming the Nastapoka Island complex as well as a relatively flat and hilly shrub tundra shoreline. The subpopulation also includes a large number of islands in James and Hudson bays, including the large Akimiski Island, the Twin Islands and the Ottawa islands complex that are known to be used extensively by polar bears during the ice free season. Southeastern Hudson Bay also holds the Belcher islands archipelago spreading over almost 3000 km². There are numerous Cree and Inuit communities along the Ontario and Québec coast and one Inuit community on the Belcher Islands.

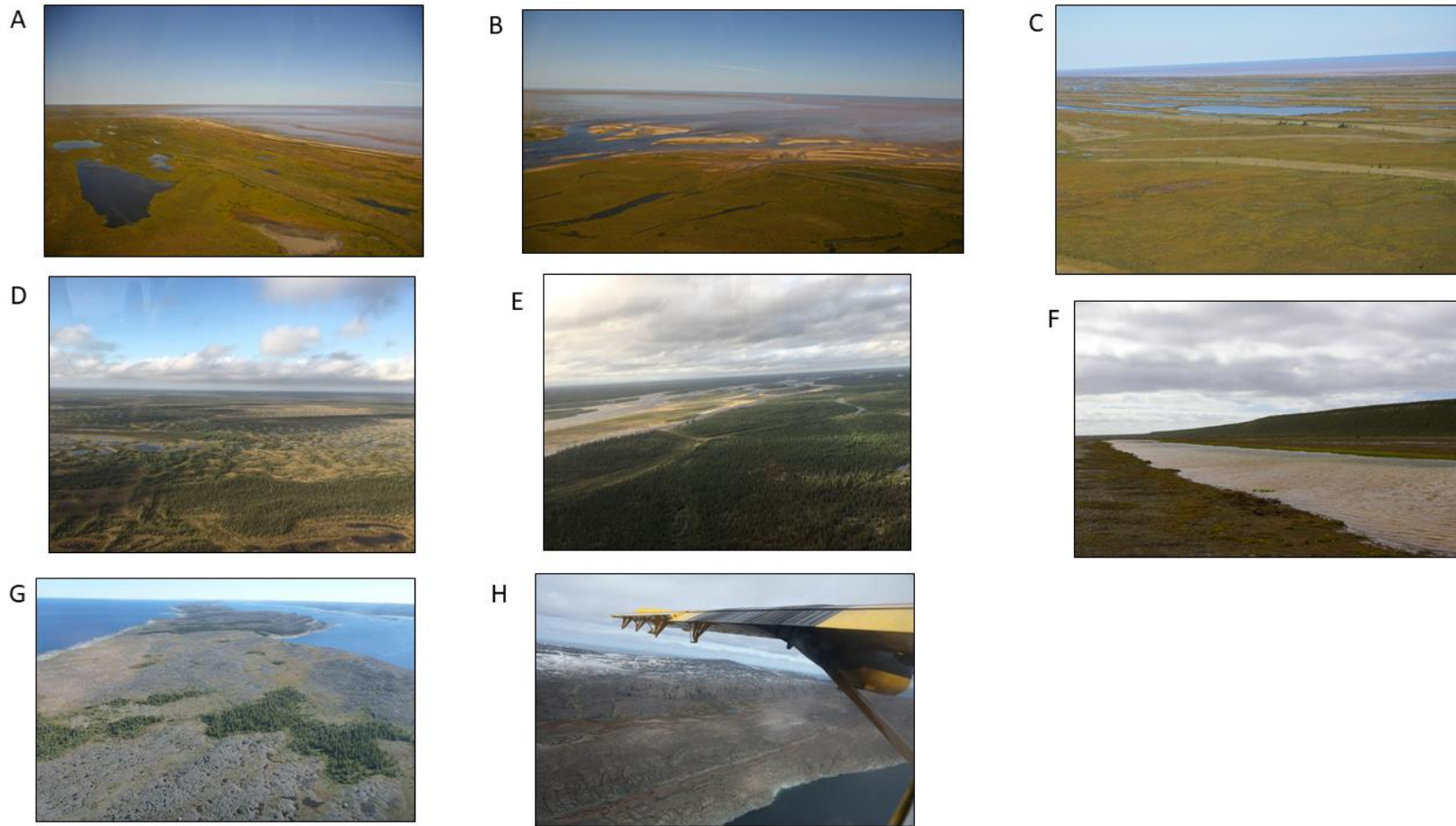


Figure 3. Representative photos of the vegetation and topography of the SH subpopulation. (A) The majority of the Hudson Bay coastline in Ontario consists of open tundra with interspersed wetlands and dry beach ridges. (B) There are extensive mudflats throughout the entirety of the Ontario coastal area. (C) Further inland from the Hudson Bay coast of Ontario is a mix of dry beach ridges, open tundra and wetlands. (D) Further inland from the Hudson Bay coast of Ontario and throughout most of the inland areas of James Bay there are interspersed treed areas, palsas and wetlands. (E) eventually, these areas give way to extensive treed areas and large riverine systems. (F) The islands of James Bay contain substantially more topography than the mainland Ontario portion of the study area. Shown here is North Twin Island. (G) The Québec coastline of James Bay is likewise more topographically diverse and consists of numerous small rocky islands. (H) Hudson Bay has numerous rocky islands where bears summer. Shown here is a portion of the Ottawa Islands.

Survey design

We followed the survey design implemented in 2011/12 and 2016 (Obbard et al. 2015, Obbard et al. 2018) to provide a comparable population estimate. The 2011 and 2012 surveys were designed based on scientific information on the distribution of bears in SH during the ice-free season and information obtained from consultation with Indigenous communities in the region. Following the 2012 survey, a second round of consultation was conducted in Québec to address points raised by Inuit communities and Makivik Corporation. This resulted in the addition of a series of inland transects perpendicular to the Québec coast along with a few additional islands in James Bay to the design of the 2016 survey to fully represent the scientific and Inuit knowledge of bear distribution in the area during the ice-free season. The surveys leverage the fact that Hudson Bay is entirely ice-free from approximately early August to late November each year during which time bears in SH are onshore. Further, females do not enter dens until October and November (Middel 2014), thus, between mid-August and the end of September, all bears are accessible (onshore) and available to be surveyed. We surveyed the subpopulation during this time and as close as possible to a similar survey being conducted in adjacent WH aimed to mirror the 2011 and 2016 WH surveys (Atkinson et al. 2022). As in past surveys (Obbard et al. 2015, Obbard et al. 2018), we subdivided the study area into regions based on expected bear density, aircraft type and survey design (Fig. 4). Past research has shown that the majority of bears in this subpopulation spend the ice-free season on the Ontario mainland, with at least 10% of the population also inhabiting the islands of James Bay and eastern Hudson Bay (Obbard et al. 2015, Obbard et al. 2018). Although bears are regularly observed during winter along the Québec coast of Hudson Bay, bears are rare in that part of their range during the summer and are mostly sighted on Long Island and the Cape Jones area (Nunavik Marine Region Wildlife Board [NMRWB] 2018). This was also confirmed by the surveys in 2012 and 2016, which failed to observe any bears along the Québec coastline or inshore (Obbard et al. 2015, Obbard et al. 2018). Thus, we divided the study area into 1) the Ontario mainland, coastline, and Akimiski Island, located in James Bay, 2) the James Bay and Hudson Bay islands, excluding Akimiski Island, 3) nearshore islands off the Ontario coast and 4) the Québec coastline and nearshore islands (Fig. 4). Note that below, we aimed to refer to these areas exactly as they are listed above whenever mentioned to reduce confusion due to the complex nature of the study design.

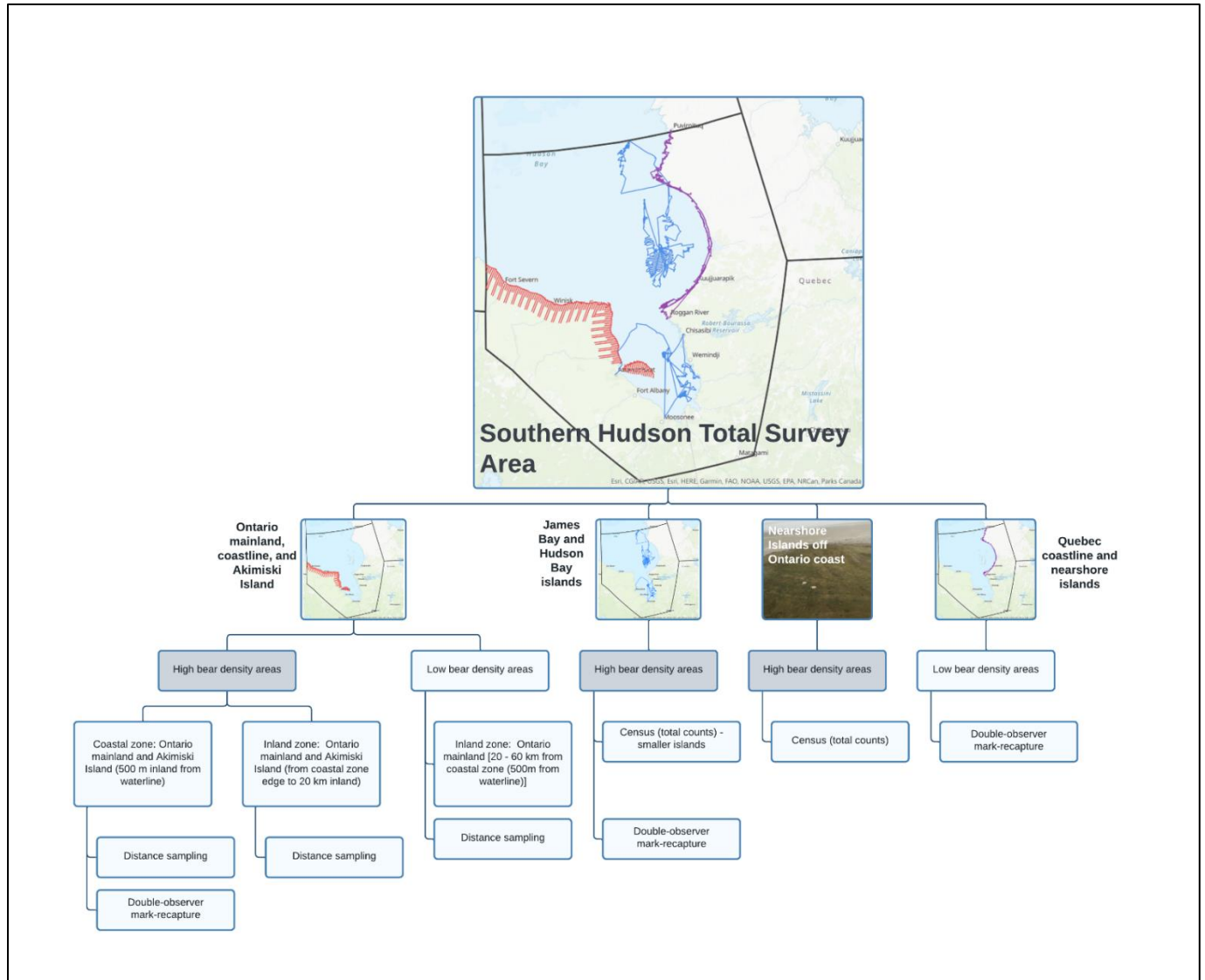


Figure 4. Schematic outlining the different survey areas, designs and analytical techniques used in SH polar bear survey in 2021.

Ontario mainland, coastline, and Akimiski Island

Most of the bears within the SH subpopulation summer on the Ontario mainland, with the majority of these bears concentrated along the coast (Kolenosky et al. 1992, Obbard and Middel 2012, Middel 2014, Obbard et al. 2015, Obbard et al. 2018). However, bears are also regularly documented far inland. Akimiski Island historically has held a high density of bears (Obbard et al. 2007), is only a short distance from mainland Ontario and is reachable via single-engine helicopter. Thus, it was surveyed in an identical manner to the Ontario mainland. We subdivided the Ontario mainland, coastline and Akimiski Island

into 2 strata (Fig. 5). We designated areas from 20 km inland out to the waterline, including exposed mudflats, and the entirety of Akimiski Island as the high-density stratum. We designated all areas between 20 km and 60 km inland as the low-density stratum. Although bears have been documented further than 60 km inland (Kolenosky et al. 1992, Lemelin et al. 2010), such occurrences appear to be relatively rare, and the timing of the survey was such that pregnant females would not yet have entered their dens, which can occur far inland. Once the high-density stratum area was delineated, we further subdivided it into a coastal zone and inland zone (Figs. 4 and 6). The coastal zone consisted of all areas 500 m inland from the approximate high-tide line out to the waterline. Depending on when these areas were flown relative to high tide, this coastal zone could consist of large expanses of mud flats and numerous spits. The inland zone of the high-density stratum was all areas from 500 m inland from the approximate high-tide line to 20 km inland.

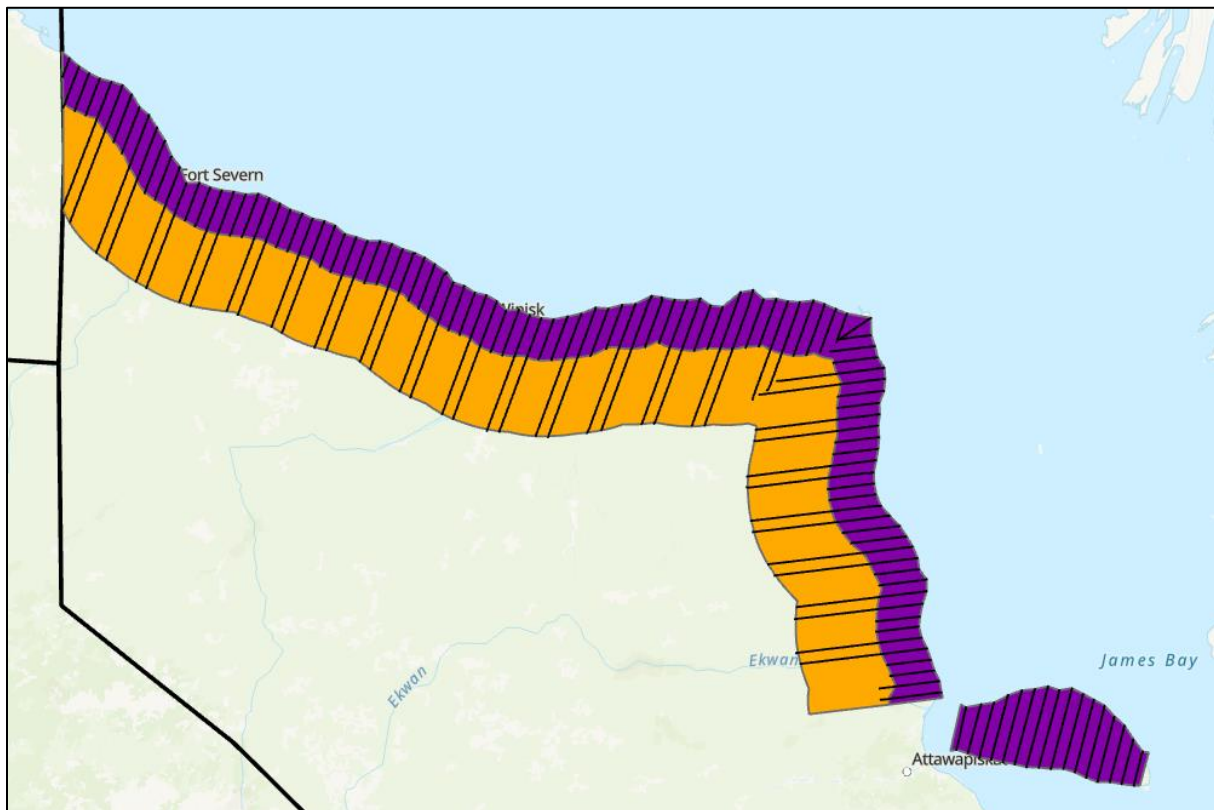


Figure 5. Flight lines (black lines) and stratum delineation for distance sampling survey of Ontario mainland, coastline and Akimiski Island. Purple shading represents the high-density stratum, consisting of all areas of mainland Ontario within 20 km of the waterline as well as the entirety of Akimiski Island. Orange shading represents the low-density stratum, consisting of all areas between 20 and 60 km from the waterline.

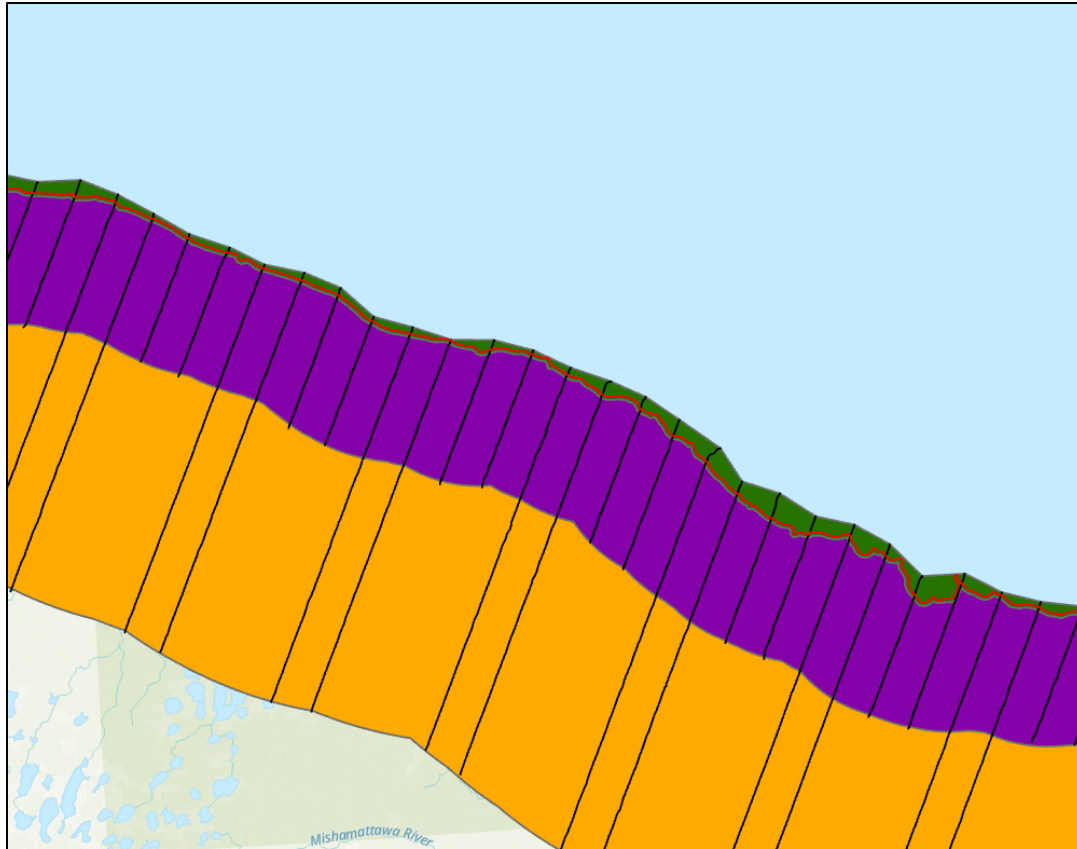


Figure 6. Close-up example of the delineation of the Ontario mainland, coastline and Akimiski Island area into different strata and survey approaches. Purple shading represents the inland zone of the high-density stratum, consisting of all areas of mainland Ontario between 20 km and 500 m from the approximate high-tide line, and the entirety of Akimiski Island further than 500 m from the approximate high-tide line. The green shading represents the coastal zone of the high-density stratum, consisting of all areas from 500 m inland from the high-tide line to the waterline. Orange shading represents the low-density stratum, consisting of all areas between 20 and 60 km from the approximate high-tide line. Red line represents the flight line for the double-observer mark-recapture portion of the survey.

Based on the above, the Ontario mainland, coastline and Akimiski Island area consisted of 3 sub-areas: 1) the coastal zone of the high-density stratum, 2) the inland zone of the high-density stratum, 3) the low-density stratum (Fig. 4 and 6). We employed two different survey techniques within these areas to address the strong variation in bear density among them. First, we employed a mark-recapture distance sampling survey covering the entirety of both the low and high-density stratum (i.e., both the inland and coastal zones in the high-density stratum). Following past surveys (Obbard et al. 2015, Obbard et al. 2018), transects were spaced 6 km apart across the entire high-density stratum including Akimiski Island (Fig. 5). Every other pair of transects was extended into the low-density stratum such that the low-density stratum was flown using pairs of transects spaced 6 km apart with the pairs separated by 18 km (Figs. 5 and 6). When present,

these transects were extended out over exposed mudflats. If transects coincided with the small nearshore islands (see below) known to hold large numbers of bears, they were truncated at these islands to exclude the islands from our distance sampling estimate because these were surveyed separately as described below in section: *Nearshore islands off Ontario coast*.

For all three survey areas of the Ontario mainland, coastline and Akimiski Island, we employed distance sampling, flying transects in a Eurocopter EC-130 helicopter at an altitude of 120 m above ground level (AGL) and a speed of 160 km/h between August 22 and September 1, 2021. The crew consisted of a pilot, navigator (front right side of helicopter) and two rear observers positioned behind the pilot and navigator. All four, including the pilot, scanned for bears. Throughout the survey, the same pilot and observers participated, and all maintained the same position in the helicopter. We erected an opaque barrier between the front and rear of the helicopter to ensure rear observers were not alerted to the presence of a bear by the movements of the front observers. Further, observers allowed sufficient time from first detection of a bear for the other observers to have detected it. Once sufficient time had elapsed, it was determined whether the front observer, rear observer or both had detected the bear. We then flew to the approximate location of where the bear was first spotted and recorded a GPS location for calculating distance from the transect line. We recorded the position of who had observed the bear (pilot only, navigator only, back right only, back left only, both observers on the left or both observers on the right), the age class and sex of the bear (adult male, lone adult female, subadult, female with cubs of the year, female with yearlings), the group size, including all dependent offspring, the body condition on a 5 point scale (5 obese, 4 above average, 3 average, 2 below average and 1 emaciated), the activity of the bear when first spotted, the general habitat where the bear was first seen (e.g., mudflat or forest), a 3 point subjective scale for visibility, the general weather, vegetation height and density surrounding the bear, each on a 3 point scale, the degree to which glare from the sun was impacting visibility on a subjective 3 point scale and lastly, whether the bear was positioned relative to the helicopter such that it was unavailable to be observed by the rear observers (i.e., was in the rear observers' "blind-spot"). The availability of the bear to be observed by rear observers was reduced for bears near the transect line, but the exact distance varied depending on the orientation of the helicopter. In crosswind conditions, the helicopter often was "crabbing" and not oriented in the same direction as the transect line (Fig. 7) which influenced the position and width of the blind-spot. Finally, if another bear was observed while collecting covariate information off the transect line, it was not included in detections as it was assumed to have not been detected from the transect line.

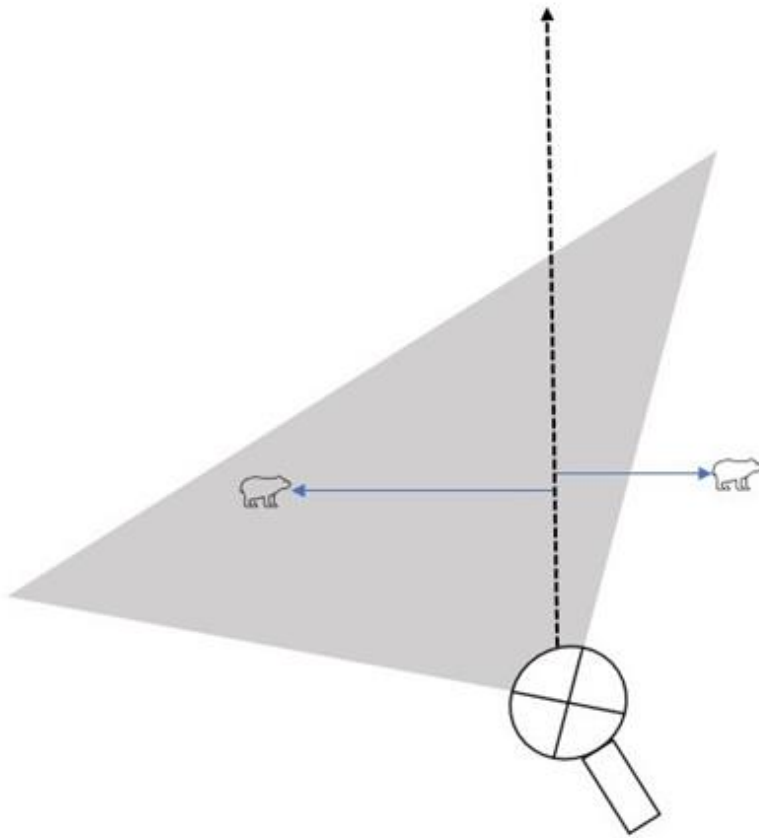


Figure 7. Schematic showing the influence of the orientation of the helicopter relative to the flight line on the ability of rear observers to observe bears on and close to the transect line. In this schematic, the dashed line represents the transect line and the gray polygon the blind-spot for rear observers. In this example, because the helicopter was oriented at an angle relative to the transect line, bears would be observable closer to the transect line for the right rear observer than the left rear observer.

In addition to the distance sampling survey, we also conducted a double-observer mark-recapture survey covering the coastal zone of the high-density stratum (i.e., the area within 500 m of the high-tide line extending out to the water line). We flew parallel to the coast at the approximate high-tide line and recorded detections of bears within 500 m inland and out to the waterline, including exposed mudflats. Observer setup within the helicopter, flight speeds, and recorded covariates were as described above. The use of both distance sampling and mark-recapture survey methodologies results in the coastal zone being sampled twice: once during the mark-recapture survey where we flew parallel to the coast and once during mark-recapture distance sampling where transects were flown perpendicular to the coast. Use of both surveys to obtain an averaged estimate (Obbard et al. 2015, Obbard et al. 2018) makes the assumption that bear position within the coastal zone is constant. Although movement of bears due to the helicopter generally

appears only slight, the coastal zone is narrow and thus the estimate would be subject to fluctuation from bears moving into or out of the zone due to the helicopter. Thus, we attempted to fly the coastal zone mark-recapture survey on the same day, but prior to the overlapping distance sampling transects. Because the coastal zone is part of the high-density stratum, which extended an additional 19.5 km inland from the edge of the coastal zone, slight movements into or out of the coastal zone do not affect our distance sampling estimate. A large number of bears would need to move >20 km in a short period of time in response to the helicopter for bias to occur.

James Bay and Hudson Bay offshore islands

The James Bay and Hudson Bay Islands were considered high bear density areas and surveyed between September 2nd and September 10th, using double-observer mark-recapture from a de Havilland DHC-6 Twin Otter airplane. The coverage was identical to the area surveyed in the 2016 study. We flew at an average altitude of 150 m AGL and at a target speed of 150 km/h. The shape, size, and topography of the islands in James and Hudson Bays required variable flight patterns to ensure comprehensive coverage. We surveyed the Belcher Islands complex in Hudson Bay, which is the largest group of islands, using transects spaced 5 km apart and running perpendicular to the coast. All other islands in James and Hudson Bays were flown in a way to ensure complete coverage of the islands. The survey crew included one pilot and one data recorder in the front seats of the airplane and four active observers positioned in the rear of the airplane (two on the left and two on the right). We again erected an opaque barrier between the front and rear observers positioned in the rear of the airplane and conducted the survey identically to the mark-recapture protocol outlined above for the coastal zone of the high-density stratum. In this survey, the pilot and data recorder only indicated that they had detected a bear if it was directly on the flight line and thus unavailable to the observers in the rear of the aircraft.

Nearshore islands off Ontario coast

Along the coast of Ontario, there are a few small islands that are known to have large numbers of bears. Survey methods of distance sampling or mark-recapture are not well suited due to the small area of the islands and high bear density. Thus, these islands were surveyed separately using a total count methodology. They were comprehensively flown with the observer setup outlined above and bears were censused on them.

Québec coastline and nearshore islands

The survey of the Québec coastline and nearshore islands was similar to the 2012 survey (Obbard et al. 2015) and was limited to the coastline and nearshore islands. Considering the absence of polar bears observed during the 2016 survey within the 20 km inland portion of the survey (Obbard et al. 2018), consultations were conducted with the three Nunavik communities (Fig. 2) to review important areas where polar bears might be observed during late summer. All communities agreed that very few bears were present inland during that time of the year but one additional coastal area, south of Cape Jones down to the mouth of Seal River, was recommended to be surveyed and was added to the survey plan (MFFP, Unpublished). The Québec coastline and nearshore islands were surveyed using an A-Star 350 B2, from August 23rd to 27th. A single transect was flown along the coastline, flying at an altitude of approximately 150 m AGL at a ground speed of 150 km/h. All nearshore islands were surveyed in a way to ensure total coverage. The crew consisted of a pilot and navigator in the front of the helicopter and two rear observers positioned behind the pilot and navigator, with an opaque divider between the front and back in order to apply the double-observer mark-recapture methodology as described above for the surveying of the coastal zone of the high-density stratum in the Ontario mainland, coastline and Akimiski Island area.

Statistical analysis of Ontario mainland, coastline and Akimiski Island distance sampling surveys

A schematic outlining how each survey and area was analyzed is shown in Figure 8. The Ontario mainland, coastline and Akimiski Island distance sampling survey was analyzed using both (1) conventional distance sampling models with covariates (multiple covariate distance sampling [MCDS]; Marques and Buckland 2003, Marques and Buckland 2004), following the analysis of Obbard et al. (2018) as closely as possible to facilitate comparisons, and (2) mark-recapture distance sampling models (MRDS; Borchers et al. 1998, Laake and Borchers 2004) to allow modelling of imperfect detection on the transect line. MCDS models assume perfect detection of bears on the transect line and underestimate abundance if this assumption is violated (Buckland et al. 2001). MRDS models include a mark-recapture sub-model to estimate probability of detection on the line thereby avoiding the assumption of perfect detection anywhere (Borchers et al. 1998, Laake and Borchers 2004). Groups of bears, rather than individuals, were treated as the unit of observation. Estimates of group abundance were multiplied by the mean group size to convert to estimates of animal abundance. We conducted replicate MCDS and MRDS analyses including and excluding data from the coastal zone. Both types of models were implemented in the 'mrds' R package version 2.2.6 (Miller et al. 2019, Laake et al. 2022).

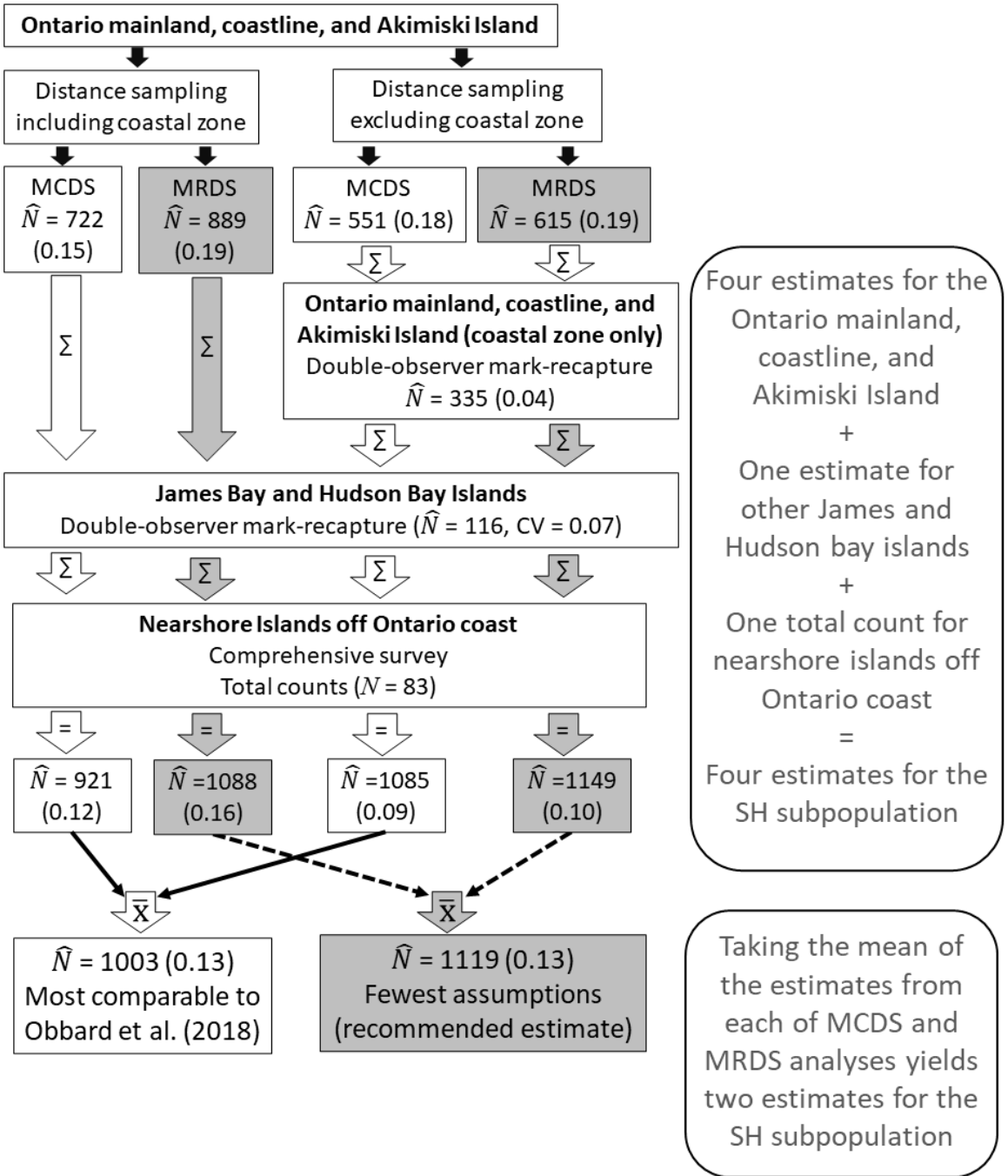


Figure 8: Schematic describing statistical analyses of data collected from different geographic areas and survey types. Geographic areas appear in bold and match those described under “survey design” above. Σ indicates summation of estimates across different geographic areas, \bar{x} indicates the mean across different estimates for the same geographic area. MCDS and MRDS refers to multiple covariate distance sampling and mark-recapture distance sampling analyses, respectively. Gray boxes and arrows indicate estimates derived using MRDS for the Ontario mainland, coastline and Akimiski Island area, while white arrows and boxes indicate estimates derived using MCDS for the Ontario mainland, coastline and Akimiski Island area. Note that because no bears were observed in the Québec coastline and nearshore islands portion of the study, that geographic region is not shown in the schematic.

For the MCDS analyses we right-truncated the data at 1750 m following Obbard et al. (2018) after verifying that distance sampling models fit the truncated data adequately (tests described below) and that abundances estimated from simple models were not sensitive to right-truncation distance. We initially considered unadjusted half-normal and hazard rate forms of the detection function as well as a uniform model with a cosine adjustment of order 1. Uniform models fit the data poorly or failed to converge so were not considered further. Potential covariates of the detection function included visibility, vegetation height, and vegetation density to match the analysis of Obbard et al. (2018). Covariates were evaluated using forward stepwise model selection where only covariates that reduced Akaike's Information Criterion (AIC; Burnham and Anderson 2002) were retained; vegetation height and density covariates were correlated so were not included in the same model. We checked whether adjustment terms (cosine of order 1 for the half-normal model, and simple polynomial of order 4 for the hazard rate model) improved the fit of the AIC-minimizing covariate models. We tested for significant ($\alpha = 0.05$) lack of fit using the X^2 goodness-of-fit test for binned distance data (Buckland et al. 2001, pp 69-71) and the distance sampling Cramér-von Mises test (Buckland et al. 2004, pp 388-389). The AIC-minimizing covariate model was selected for estimation (conditional on adequate fit), and final estimates were obtained by model averaging abundance estimates (as the AIC-weighted average abundance; Burnham and Anderson 2002) across hazard rate and half-normal models with the same covariate(s).

Data from the Ontario mainland, coastline and Akimiski Island distance sampling survey were also analyzed using MRDS models formulated for independent observers (Laake and Borchers 2004, Burt et al. 2014). Models with point independence rather than full independence were expected to be more appropriate for our data because the difference between front and rear observers' ability to see bears near the transects ensured that the correlation between detections from different observer positions increased with distance from the transect (Burt et al. 2014). We verified that simple point independence models reduced AIC relative to simple full independence models and used point independence models thereafter. We right-truncated at 2000 m because visibility was generally good in 2021 and exploratory analyses including goodness-of-fit testing indicated that this truncation distance provided a slightly better fit to simple DS models. We included distance as a covariate in all mark-recapture submodels (Buckland et al. 1993, Burt et al. 2014). We also considered a dummy covariate specific to the rear observers at short distances to account for their reduced probability of detecting groups of bears near the transect line (Wiig et al. 2022). The largest distance at which a group was recorded as unavailable to rear observers was 204 m, so all groups detected at this and shorter distances received a 1 for this "blind-spot" covariate. Other potential covariates of the MR submodel were group size, observer position (front or rear), side, the interaction between

position and side, visibility, vegetation height, vegetation density, glare, and stratum (high or low density). Because vegetation height and density were correlated but describe potentially different effects of vegetation on observers' ability to detect bears, we also evaluated a combined vegetation covariate (Table 1); only one vegetation covariate was included in any submodel. Potential covariates of the distance sampling submodel included group size, side, visibility, vegetation height, vegetation density, the combined vegetation height and density covariate, glare, and stratum. After exploratory analyses we excluded the "activity" covariate because estimated effects were weak and indicated that stationary bears were more likely to be detected, including at longer distances, than moving bears.

Table 1. Definition of vegetation covariate representing the combination of vegetation height and density. The vegetation height covariate was recorded in the field on a 3-point scale with a height of 1 indicating vegetation was <1 m, 2 indicating 1-3m and 3 indicating >3 m. The vegetation density covariate was recorded in the field on a 3-point scale with a density of 1 indicating sparse vegetation, 2, indicating moderate and 3 dense.

Vegetation height	Vegetation density	Combined vegetation covariate
1 or 2	1	1
1 or 2	2	2
1 or 2	3	not present in data
3	1	2
3	2	3
3	3	4

We evaluated support for forms of the detection function (unadjusted half-normal or hazard rate) and covariates using a forward stepwise model selection procedure intended to avoid overfitting and the inclusion of uninformative covariates in estimating models. Covariates that increased AIC relative to a simpler model without that covariate were excluded, covariates that reduced AIC were retained but if the reduction was < 2.0 we also considered parameter-reduced models excluding those covariates. This approach differed slightly from the above analysis because here we considered more covariates and thus needed to evaluate more combinations of covariates. Thus, we required a larger reduction in AIC to avoid evaluating a cumbersome number of models. An exception to this procedure was that, following Northrup and Howe (2019), we considered a model with main effects of side and position and their two-way interaction in all mark-recapture submodels even if side and position were not supported as main effects alone. We conducted model selection in 3 steps. First, we held the distance sampling model constant as the unadjusted half-normal model with no covariates and evaluated

covariates of the mark-recapture model. Next, we evaluated forms and covariates of the distance sampling model while holding the mark-recapture model constant at the AIC-minimizing model. Lastly, we created a set of models that was comprised of all combinations of the supported ($\Delta\text{AIC} < 2$) mark-recapture and distance sampling submodels. We checked whether the adjustment terms described above for MCDS models improved the fit of the AIC-minimizing distance sampling submodels. Before estimating abundance we checked for significant ($\alpha = 0.05$) lack of fit using X^2 tests across distance intervals for both the mark-recapture and distance sampling submodels, the total X^2 value across submodels, and the Cramér-von Mises test. Final MRDS estimates of abundance were obtained by model averaging across models with supported covariates and parameter-reduced models in the case of weakly-supported ($\Delta\text{AIC} < 2$) covariates.

In both the MCDS and MRDS analyses, the variance of the abundance of individual bears combined three components of variance using the delta method (Buckland et al. 2001, Miller et al. 2019): the empirical variance of the encounter rate among transects (here estimated using Fewster et al. 's [2009] estimator "S2" for systematic designs), the variance of detection probability obtained from the fitted model estimated using standard maximum likelihood methods, and the variance of group size. Where estimates were calculated by model averaging, model selection uncertainty also contributed to the variance of bear abundance (Burnham and Anderson 2002).

We post-stratified estimates of abundance by age-sex category (adult females, adult males, subadults, yearlings, and cubs) to obtain age-sex class specific estimates of abundance in the Ontario mainland, coastline and Akimiski Island portion of the survey. This was achieved by combining the estimated probability of detecting clusters of bears (and its variance) from the AIC-minimizing model fit to data from all clusters with age-sex class specific group sizes.

Statistical analysis of double-observer mark-recapture surveys

The Ontario mainland, coastline and Akimiski Island coastal zone mark-recapture helicopter survey and the James Bay and Hudson Bay islands fixed-wing mark-recapture surveys were analyzed using mark-recapture models for closed populations (Huggins 1989) implemented in the 'RMark' R package version 2.2.7 (Laake 2013, Laake et al. 2019). We conducted separate analyses of data obtained from the helicopter survey and the combined fixed-wing surveys (Fig. 8). Potential covariates of detection probability included observer position (front or rear, modelled as distinct temporal sampling occasions), group size, visibility, vegetation height, vegetation density, and position of the group relative to the aircraft (left, right, or under, coded as "under" where the group was recorded as unavailable to the rear observer). We fixed detection probability by the rear

observers to 0 for groups that passed “under” the aircraft for both the fixed-wing and helicopter surveys. We evaluated support for covariates using the same forward stepwise procedure described above for the mark-recapture and distance sampling submodels of MRDS models, except that we used the small sample bias-corrected version of AIC (AIC_c; Burnham and Anderson 2002) rather than AIC. We obtained final estimates of the number of groups of bears and its unconditional variance by model-averaging abundance estimates across models with supported covariates, and parameter-reduced models in cases of weakly supported ($\Delta AIC < 2$) covariates. We estimated the number of individual bears by multiplying by mean group size and included the variance of group size in the variance of the number of bears using the delta method.

We did not detect any bears during the mainland Québec coastal and nearshore island survey. As such, no statistical analyses were applied.

Total abundance estimates

The above analyses produced four separate estimates of bear abundance in the Ontario mainland, coastline and Akimiski Island area (see also Fig. 8): 1) an MCDS estimate for the entirety of the area (i.e., the areas overlain by the green, orange and purple polygons in Fig. 6), 2) an MCDS estimate for the low-density stratum and the inland zone of the high-density stratum (i.e., excluding the coastal zone, so the orange and purple polygons in Fig. 6) plus the estimate of the number of bears in the coastal zone (the area in green in Fig. 6) from the double-observer mark-recapture analysis, 3) an MRDS estimate for the entirety of the area (i.e., the areas overlain by the green, orange and purple polygons in Fig. 6), and 4) an MRDS estimate for the low-density stratum and the inland zone of the high-density stratum (i.e., excluding the coastal zone, so the orange and purple polygons in Fig. 6) plus the estimate of the number of bears in the coastal zone (the area in green in Fig. 6) from the mark-recapture analysis. We added the estimated number of bears on the James Bay and Hudson Bay Islands, and the census number of bears on small nearshore islands off the Ontario coast, to each of the four final estimates for the Ontario mainland, coastline and Akimiski Island area to generate estimates for the SH subpopulation. Finally, we produced two final estimates of the SH subpopulation as the mean of two subpopulation-level estimates: those calculated from estimates 1 and 2 above for the Ontario mainland, coastline and Akimiski Island area, and those calculated from estimates 3 and 4 above (see Fig. 8). Unconditional variances around these estimates were calculated in a model averaging framework assigning the two estimates equal weight. We present log-normal confidence intervals around all estimates of bear abundance. All analyses were performed using R software version 4.2.0 (R Core Development Team 2022).

RESULTS

Ontario mainland, coastline and Akimiski Island area

We detected 138 groups of bears on distance sampling transects on the Ontario mainland, coastline and Akimiski Island area, 88 excluding the coastal zone. Right-truncating at 1750 m for the MCDS analysis removed 9% of observations from both data sets, leaving 125 and 80 groups in data including and excluding the coastal zone, respectively. Right-truncating at 2000 m for the MRDS analysis removed 8% of observations from the complete data set and 7% of observations from data excluding the coastal zone, leaving 127 and 82 groups in data including and excluding the coastal zone, respectively.

In the MCDS analysis of the dataset including the coastal zone, the half-normal model without covariates minimized AIC. However, half-normal and hazard rate models with the vegetation density covariate had similar support with ΔAIC of 0.61 and 0.76, respectively (Table S1), so, for the sake of consistency with Obbard et al. (2018), we estimated abundance by model averaging across these two models (Table 2). Visibility was the only supported covariate in data excluding the coastal zone; half-normal and hazard rate models with this covariate had similar support, and all other models had $\Delta\text{AIC} > 2$ (Table S2), so we estimated abundance by model averaging across these two models (Table 2). All MCDS models considered for estimation provided adequate fits to the data (P -values associated with the χ^2 test for binned distance data and the Cramér-von Mises tests were all > 0.30). Adjustment terms did not improve fit to either data set.

Table 2. Abundance estimates (\hat{N}), standard errors (SE), coefficients of variation (CV) and 95% confidence intervals from multiple covariate distance sampling (MCDS) and mark-recapture distance sampling (MRDS) analyses of polar bear data including or excluding the coastal zone of the high-density stratum for the Ontario mainland, coastline and Akimiski island area only.

Analysis type	Coastal zone	\hat{N}	SE	CV	95% CI
MCDS	Included	722	111	0.15	535 – 974
MCDS	Excluded	551	99	0.18	388 – 781
MRDS	Included	889	170	0.19	613 – 1288
MRDS	Excluded	615	119	0.19	422 – 897

In the MRDS analysis of the complete data set, the blind-spot covariate, observer position, side, and glare were supported covariates of the mark-recapture submodel and the interaction between position and side and visibility were weakly supported ($\Delta\text{AIC} < 2$ relative to simpler models) so additional models including and excluding these latter covariates were considered. Three submodels with all supported covariates and different

combinations of weakly supported covariates had $\Delta\text{AIC} < 2$ and were crossed with supported distance sampling submodels. Glare was supported as a covariate of the distance sampling submodel (Fig. 9). The combined vegetation covariate was also supported (Fig. 9), but ΔAIC was < 2 in the case of half-normal models so we considered models excluding it. Adjustment terms did not improve fit. Three submodels had $\Delta\text{AIC} < 2$ and were crossed with the three supported mark-recapture models. All nine supported MRDS models (Table S3) fit the data adequately (P -values associated with the total X^2 value across distance sampling and mark-recapture submodels and the Cramér-von Mises tests were all > 0.65) and were included in model-averaged estimates of abundance (Table 2).

When data from the coastal zone were excluded, the blind spot covariate, observer position, side, the interaction between position and side, visibility, and glare were supported covariates of the mark-recapture submodel in the MRDS analysis. However, models with the visibility or glare covariates exhibited lack of fit that was sometimes significant at $\alpha = 0.05$ and always significant at $\alpha = 0.10$ (P -values associated with the total X^2 value ranged from 0.03 – 0.08); furthermore, these models yielded unrealistically high estimates of abundance, suggesting data were insufficient to support this level of model complexity. We therefore combined only the mark-recapture submodel with the blind spot covariate, position, side, and the interaction between position and side with supported distance sampling submodels. All other submodels that fit well and yielded reasonable abundance estimates had $\Delta\text{AIC} > 2$ relative to this submodel. Only visibility was supported as a covariate of the distance sampling submodel; it reduced AIC of the hazard rate model by < 2 so we retained models excluding it and combined four distance sampling submodels (half-normal and hazard rate with and without the visibility covariate) with the selected mark-recapture submodel (Table S4). Adjustment terms did not improve fit. All four of these models fit the data adequately and were included in model averaged estimates of abundance (Table 2). MCDS and MRDS estimates of abundance were sensitive to the form of the detection function (half-normal or hazard rate) and less sensitive to covariates.

Post-stratification of the Ontario mainland, coastline and Akimiski island observations by age-sex class based on the distance sampling data, including the coastal zone, suggests an adult sex ratio strongly skewed towards females (Table 3). Raw observations from the coastal mark-recapture survey showed a strongly male biased sex ratio (Table 4).

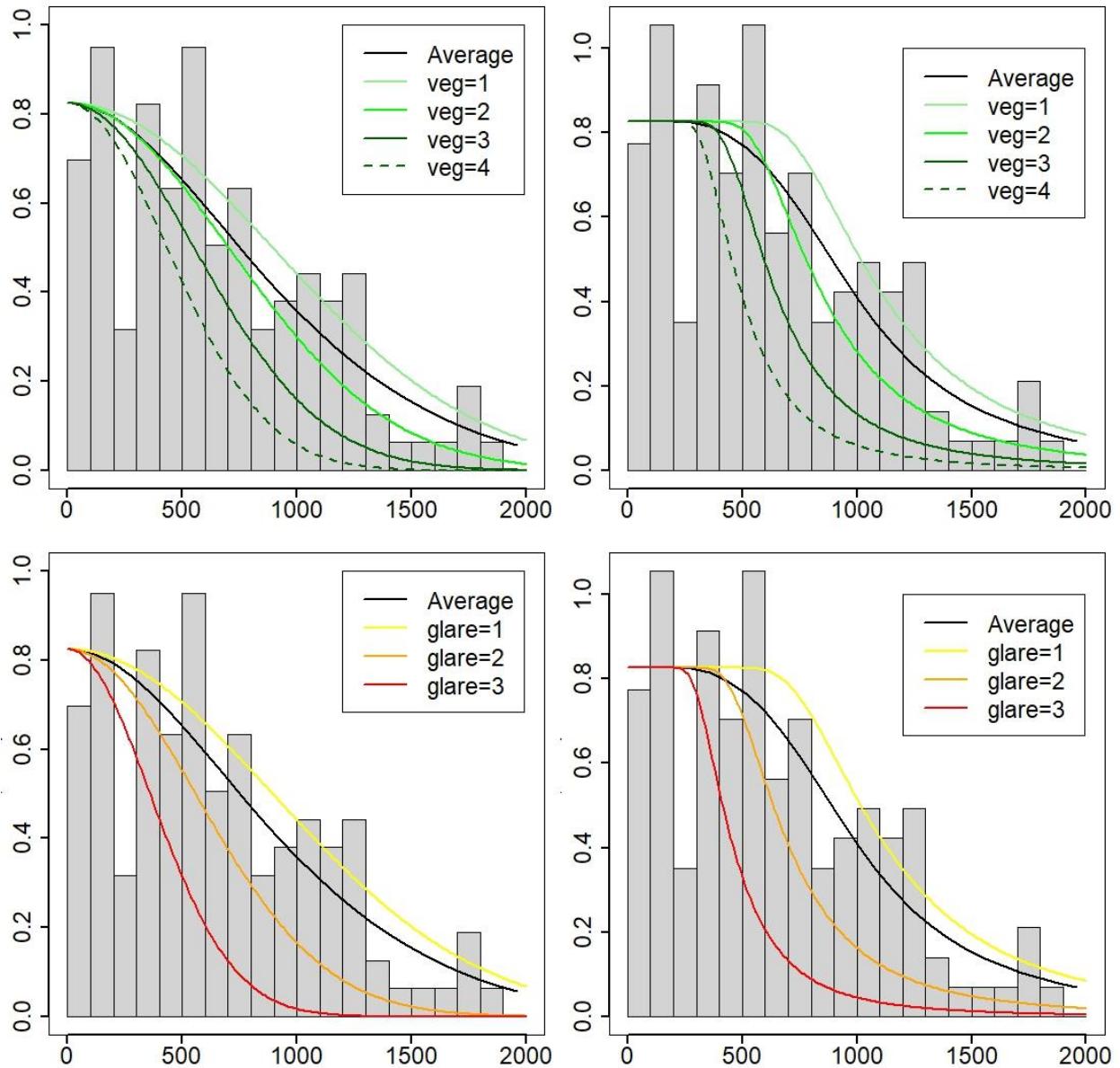


Figure 9. Half-normal (left column) and hazard rate (right column) detection functions estimated from the top two AIC-ranked mark-recapture distance sampling models fit to complete data from SH polar bears sighted from distance sampling transects in 2021 in the Ontario mainland, coastline and Akimiski island area, showing effects of supported covariates on the scale of the detection functions (the combined vegetation covariate and glare). Both models included the same covariates of both submodels; only key functions differed. The half-normal model ranked 1st and the hazard rate model had $\Delta AIC = 1.3$. Top row shows the effect of the vegetation, bottom row shows the effect of glare. When plotting effects of one covariate, the other covariate was held constant at the mean value in the data. X-axes show distance from the transect in meters, y-axes show probability of detection.

Table 3. Estimates of abundance (\hat{N}), standard errors (SE), coefficients of variation (CV), lower 95% confidence limit (LCL), upper 95% confidence limit (UCL) and the mean proportion (Prop.) of the total estimate comprised of that sex and age class, obtained from post-stratification of MRDS model fit to distance sampling observations of polar bears in the Ontario mainland, coastline and Akimiski Island portion of the survey (including coastal zone) in 2021.

Age-sex class	\hat{N}	SE	CV	LCL	UCL	Prop.
Adult female	366	70	0.19	251	533	0.40
Adult male	173	71	0.41	79	378	0.19
Subadult	59	21	0.36	30	118	0.06
Yearling	156	38	0.24	98	250	0.17
COY	167	52	0.31	91	305	0.18

Table 4. Proportions of polar bears of different sex and age classes observed during distance sampling surveys of the entire Ontario mainland, coastline, and Akimiski Island portion of SH (including the coastal zone) and from mark-recapture surveys of only the coastal zone within that portion of the study area, 2011 – 2021.

	Year	Adult female	Adult male	Subadult	Yearling	COY
<u>Distance sampling</u>						
	2011	0.36	0.20	0.08	0.15	0.19
	2016	0.34	0.19	0.06	0.05	0.30
	2021	0.37	0.20	0.07	0.18	0.18
<u>Coastal mark-recapture</u>						
	2011	0.20	0.40	0.13	0.12	0.15
	2016	0.19	0.52	0.08	0.03	0.17
	2018	0.19	0.55	0.09	0.07	0.10
	2021	0.22	0.43	0.11	0.12	0.10

No covariates of detection probability were supported in mark-recapture analyses of data from the helicopter survey of the coastal zone. Probabilities of detection were high (observer specific probability of detection = 0.87 from the null model, equating to approximately 0.98 probability that either observer detected a group of bears) and estimates of abundance were similar across all models. Multiplying the estimated number of groups from the null model by mean group size (1.567; SE 0.063) yielded an estimate of 335 bears (SE 13.9, CV 0.04, 95% CI = 309 – 363).

James Bay and Hudson Bay islands (excluding Akimiski Island)

Side and group size were weakly supported covariates in the mark-recapture analysis of data from the fixed wing survey of the James and Hudson Bay Islands. Estimated probabilities of detection were again high (observer specific probability of detection =

0.841 from the null model, equating to approximately 0.97 probability that either observer detected a group of bears) and estimates of abundance were similar across models. The estimated number of groups obtained by model averaging multiplied by mean group size (1.455; SE 0.090) yielded an estimate of 116 bears (SE 7.93, CV 0.07, 95 % CI = 102 – 133).

Nearshore islands off the Ontario coast

The comprehensive survey of the nearshore islands off the Ontario coast yielded a total count of eighty-three (83) bears.

Québec coastline and nearshore islands

No bears were observed along the Québec mainland coast and nearshore islands.

Total abundance estimates

Estimates of total abundance at the subpopulation level ranged from 921 to 1149 and were lower when using the MCDS approach which assumed perfect detection on the transect line during distance sampling surveys (Table 5). In total, we saw 148 family groups during the whole survey, including those seen while off transect or transiting. Seventy-five of these were females with cubs of the year and 73 with yearlings. The average cub of the year litter size was 1.57 ($\sigma = 0.52$) and the average yearling litter size was 1.47 ($\sigma = 0.50$).

Table 5. Estimates of subpopulation-wide abundance (\hat{N}), standard errors (SE), coefficients of variation (CV), lower 95% confidence limit (LCL) and upper 95% confidence limit (UCL) for polar bears in the Southern Hudson Bay subpopulation. Six estimates are presented representing either multiple covariate distance sampling (MCDS) or mark-recapture distance sampling (MRDS), excluding the coastal zone, including the coastal zone or averaging across these two approaches. All 6 abundance estimates include the 116 bears estimated to be on the James Bay and Hudson Bay islands as well as the 83 bears counted on the nearshore islands off the Ontario coast.

Estimate	Method and areas included	\hat{N}	SE	CV	LCL	UCL
1	MCDS including coastal zone	921	111	0.121	727	1166
2	MCDS excluding coastal + coastal zone MR	1085	100	0.092	905	1300
3	Mean of 1 & 2	1003	134	0.134	773	1302
4	MRDS including coastal zone	1088	170	0.156	802	1474
5	MRDS excluding coastal + coastal zone MR	1149	120	0.105	937	1410
6	Mean of 4 & 5	1119	150	0.134	860	1454

Discussion

The number of polar bears present in the SH subpopulation at the time of the 2021 survey was substantially higher compared to the last comprehensive survey conducted in 2016. In 2016, the subpopulation estimate was 780 (95% confidence interval 590-1029; Obbard et al. 2018), which represented a 17% decline from 2011/12 when the subpopulation was estimated at 943 (95% confidence interval 658-1350; Obbard et al. 2015). In our current work, we produced two separate estimates, one (N = 1003 95% CI = 773-1302) that assumed perfect detection on the transect line as Obbard et al. (2018) did to allow for direct comparison and one (N = 1119 95% CI 860-1454) that took advantage of a novel approach to estimating the probability of detection on the transect line while accounting for the blind spot affecting rear observers (Wiig et al. 2022). The former estimate is most comparable to the 2016 estimate, but the latter is a more robust estimate of the true subpopulation size in 2021. Both estimates indicate a greater number of bears within this subpopulation than in 2016, with the former estimate suggesting a 29% increase in the number of bears found within the subpopulation in 2021 compared to 2016.

The greater number of bears in SH in 2021 compared to 2016 has two plausible biological drivers based on the results of this survey and other available lines of evidence, both of which may be at play to varying degrees: 1) annual variation in the on-land distribution of bears in SH and WH, and 2) an increase in population growth rate due to reduced mortality, increased birth rate or both. At the writing of this report, we do not have definitive evidence for either driver, but discuss the existing evidence for each of these in turn. First, it seems likely that there was some movement of bears into SH from the adjacent WH subpopulation in 2021. An increase of nearly 30% in 5 years seems highly implausible for a species such as polar bears that has a slow life history strategy. Further, the 2016 survey showed very few yearlings, and a survey of only the coastal area in 2018 found even fewer bears than in 2016 in this portion of the subpopulation. These findings suggest that an even greater rate of increase would have to have occurred between 2018 and 2021, making it highly unlikely that all of the increase from 2016 to 2021 was from greater reproductive output or reduced mortality alone. A simultaneous survey of WH (Atkinson et al. 2022) indicated a decline of 224 bears in WH from 2016 to 2021, which numerically is the same as the increase in the estimate of SH abundance from Obbard et al. (2018) and our 2021 survey. Further, genetic identification of individuals sampled through biopsy darting conducted along the coast of SH and WH indicated that > 20% of the bears sampled in SH in 2021 had previously been sampled exclusively in WH (McGeachy et al. 2023). These joint lines of evidence suggest that there is variation in the annual on-land distribution of bears between SH and WH, with more of these bears in SH in 2021. Although the boundary between WH and SH, in northwestern Ontario, was based in part on movement and mark-recapture data, there is no major physiographic feature present and there are large aggregations of bears on offshore islands and peninsulas near the

boundary. Thus, minor variation in the distribution of these bears could greatly shift the number of individuals present in WH or SH. Prevett and Kolenosky (1982) suggested that movements of large numbers of bears occurred between the southern Manitoba coast of Hudson Bay and Ontario, though this finding was not corroborated by Stirling et al. (2004) using surveys conducted earlier in the ice-free season. Derocher and Stirling (1990), focusing on the area of WH directly south of Churchill, MB likewise did not document movements between the two subpopulations, but did not cover the area of WH closest to SH where relatively minor annual variation in distribution could lead to large shifts in the number of bears present in each subpopulation. Further, collaring data from female bears shows generally high fidelity to onshore areas (Stirling et al. 2004, Obbard and Middel 2012). However, more recently, Cherry et al. (2013) showed that ice conditions were an important predictor of annual fidelity to onshore areas in WH. Specifically, they found that when there was greater ice later in the season in SH relative to WH, bears collared in WH tended to come ashore further from their collaring location. Further, they predicted greater declines in seasonal fidelity to onshore areas with continued sea-ice decline. The biopsy darting work (McGeachy et al. 2023), in combination with ongoing physical capture (ECCC, unpublished data) covered the coast of WH from the border between Manitoba and Nunavut to the WH-SH border, along with much of the SH coast and is the most comprehensive data available to date on individual movements; these data are more comprehensive in coverage than either Derocher and Stirling (1990) or Prevett and Kolenosky (1982) and use more effective methods for documenting annual movement of individuals of all sex and ages classes than does telemetry or aerial surveys (e.g., Stirling et al. 2004, Obbard and Middel 2012).

In contrast to the above evidence for annual variation in distribution of bears leading to the increase in SH, it is possible that this increase was influenced in part by improved demographic rates in SH. Several lines of evidence support that the decline in WH from 2016 to 2021 was at least partially driven by reduced reproduction. If this is the case, then the increase in SH could not be solely driven by distribution shift. First, reproduction and recruitment in WH appear to have been low throughout the last decade relative to SH and other polar bear subpopulations (Atkinson et al. 2022). Specifically, cubs of the year comprised 7%, 11% and 9% of observations of bears in 2011, 2016 and 2021 in WH, while yearlings comprised 3%, 3% and 9% (Stapleton et al. 2014, Dyck et al. 2017, Atkinson et al. 2022). In comparison, cubs of the year comprised 16%, 19% and 14% of observations in SH in 2011, 2016 and 2021 and yearlings comprised 12%, 5% and 13% of observations (Obbard et al. 2015, Obbard et al. 2018). Further, physical mark-recapture in part of WH indicates there have been few yearlings during many of the last 10 years (ECCC unpublished data). These numbers alone suggest reproduction is substantially greater in SH than WH. WH also has seen strong evidence of changes in sex and age class ratios across the three surveys, with declines in adult females and sub-adults (Atkinson et al. 2022). Observations data from the 2011, 2016 and 2021 surveys

in SH however show quite consistent sex and age structure. However, the number of yearlings in 2021 was high and indicates a rebound from the particularly low numbers seen in 2016 (Obbard et al. 2018). Annual variability in survival of COYs to yearlings is not surprising as autumn yearling litter sizes are highly variable (Derocher and Stirling 1995). We also note that the two years preceding 2021 were two of the three years with the longest duration of sea-ice since 2011 (Figs. 10 & 11). These conditions would have been favorable for high reproductive output and survival of cubs in the previous two years. Importantly, with continued warming, these conditions are unlikely to persist and we expect low recruitment in the coming years.

The above numbers suggest that in recent years, demography is different in WH and SH, with what appears to be lower reproduction and recruitment in WH. If this is the case, then the decline seen in WH by Atkinson et al. (2022) may not be all attributable to distribution shifts of bears to SH. Following, the increase in SH would have to be at least partially due to increased population growth rate. This potential is supported by the fact that ice conditions have generally been good over the last 5 years relative to the time period between 2011 and 2016 (Fig. 10) and that SH appears to have a high capacity for growth (Regehr et al. 2021). Further, polar bear harvest in SH was lower between 2016 and 2021 than between 2010 and 2015 (37.8 bears per year compared to 58.8 bears per year; <https://www.polarbearsCanada.ca/en/polar-bears-canada/canadas-polar-bear-subpopulations>; accessed July 22, 2022). This decrease was in part driven by the exceptionally large harvest of 104 bears in the 2010/2011 harvest season, of which many were female. Such a large increase in annual harvest must have had downstream negative demographic effects due to the increased harvest of adult females, subsequently potentially depressing growth for a few years. Thus, it seems plausible that the high harvest in 2010/11 and higher average harvest early in the last decade, along with relatively poor ice years, could have driven a decline between 2011 and 2016. In contrast, a subsequent rebound to 2021 levels could be due to lower annual harvests with the resulting downstream positive demographic effects combined with better ice conditions that resulted in higher juvenile survival. However, we note again that a 29% increase over 5 years is highly unlikely for polar bears without distribution shift playing some role. Lastly, it is possible that the apparent increase in SH between 2016 and 2021 was simply sampling variance in one or both years, whereby the true difference in numbers between the surveys was exaggerated. We note that it is equally likely that the difference was underestimated, however.

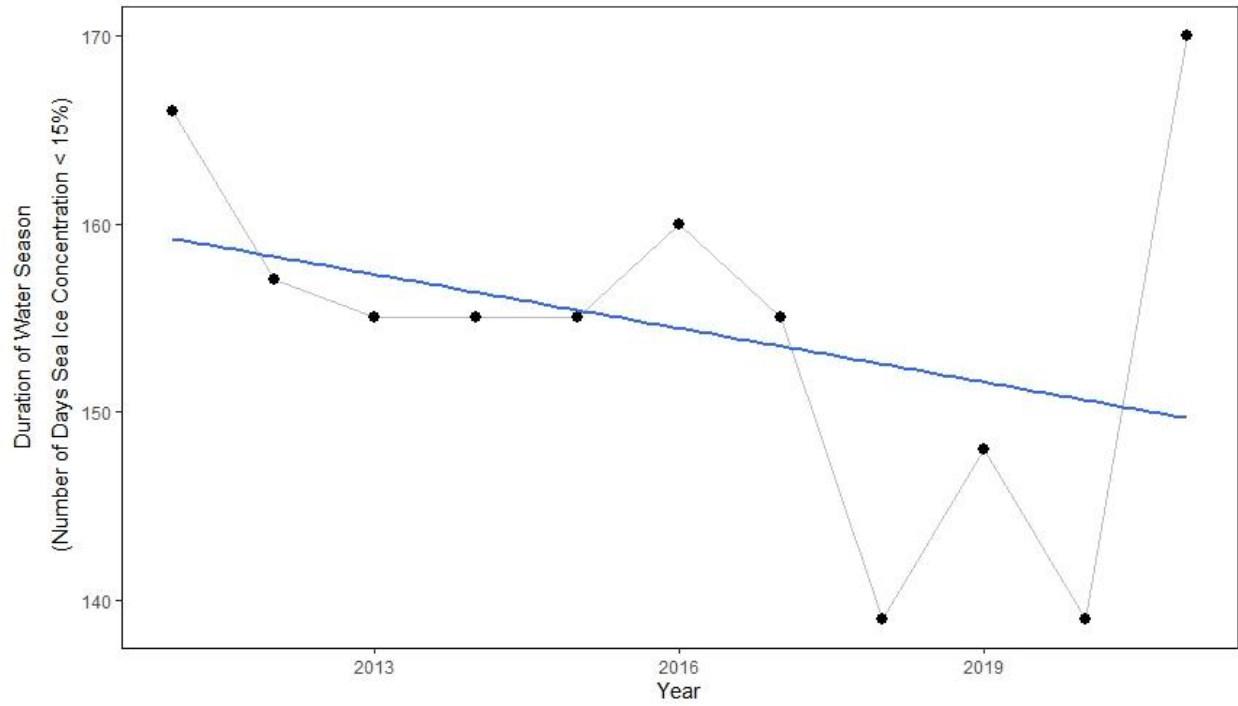
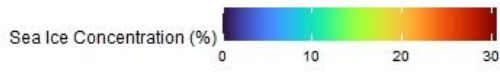
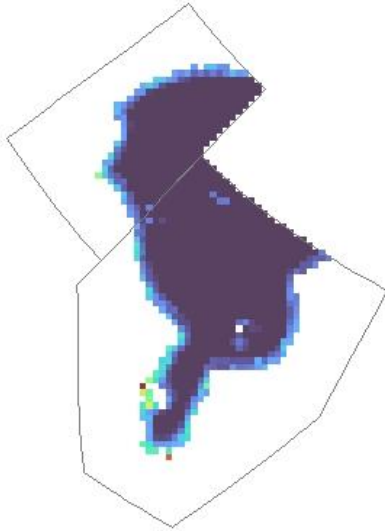
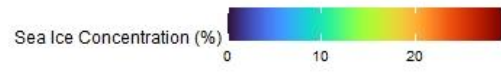
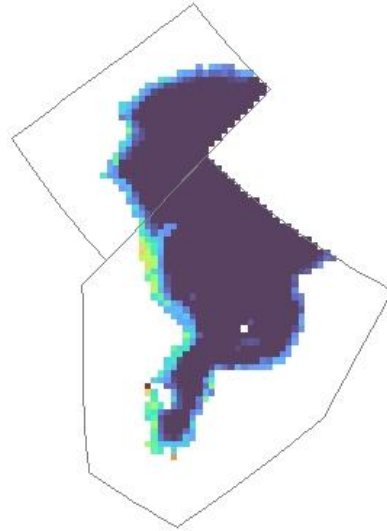


Figure 10. Duration of ice-free season in the combined Western and Southern Hudson Bay polar bear subpopulations, calculated as the number of days in which the combined area had less than 15% sea-ice concentration. The blue line represents a trend fit to the ice-free days.

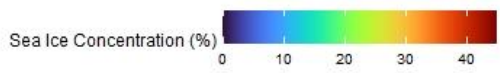
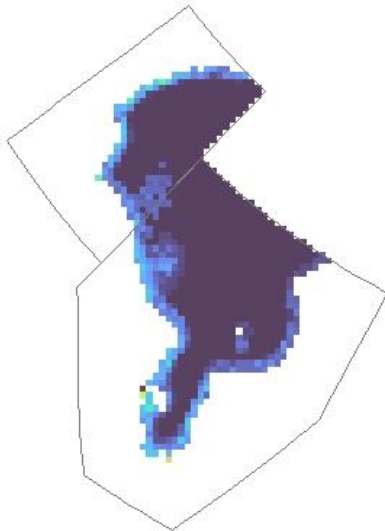
July 15 - August 15, 2011



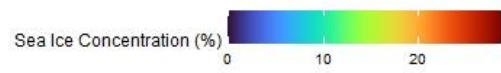
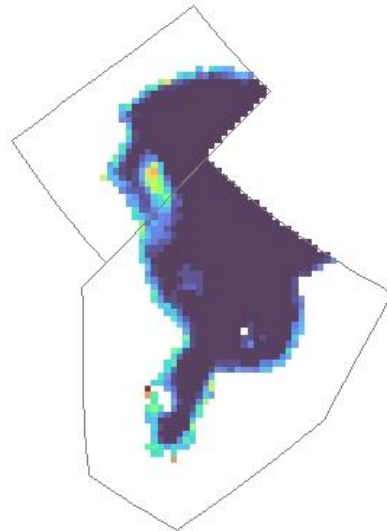
July 15 - August 15, 2012



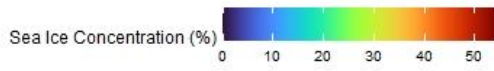
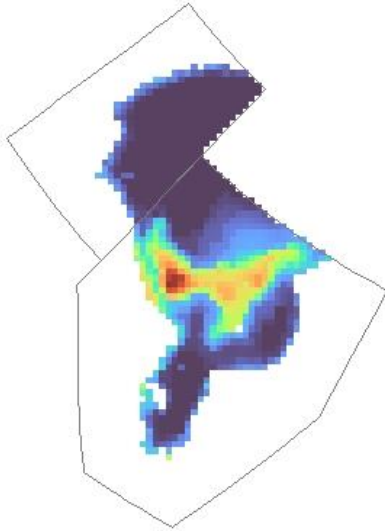
July 15 - August 15, 2013



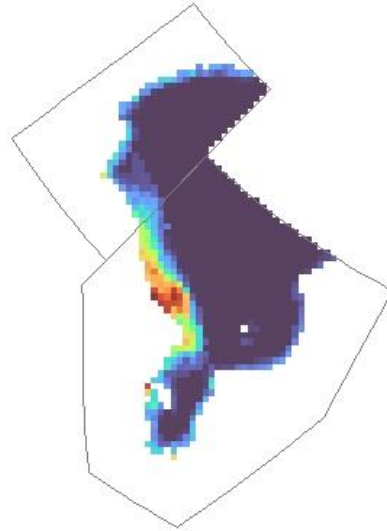
July 15 - August 15, 2014



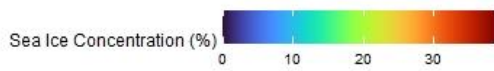
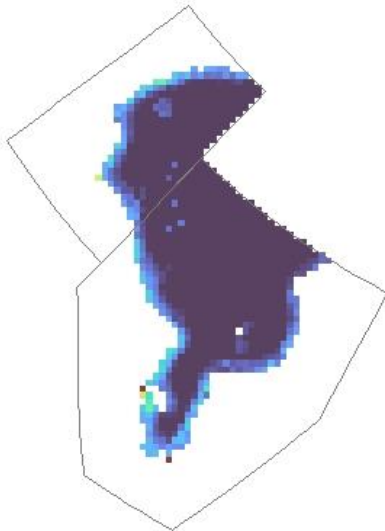
July 15 - August 15, 2015



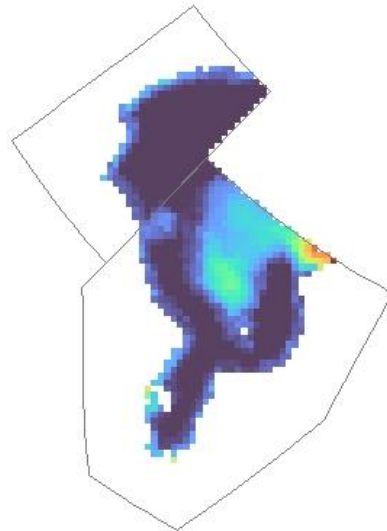
July 15 - August 15, 2016



July 15 - August 15, 2017



July 15 - August 15, 2018



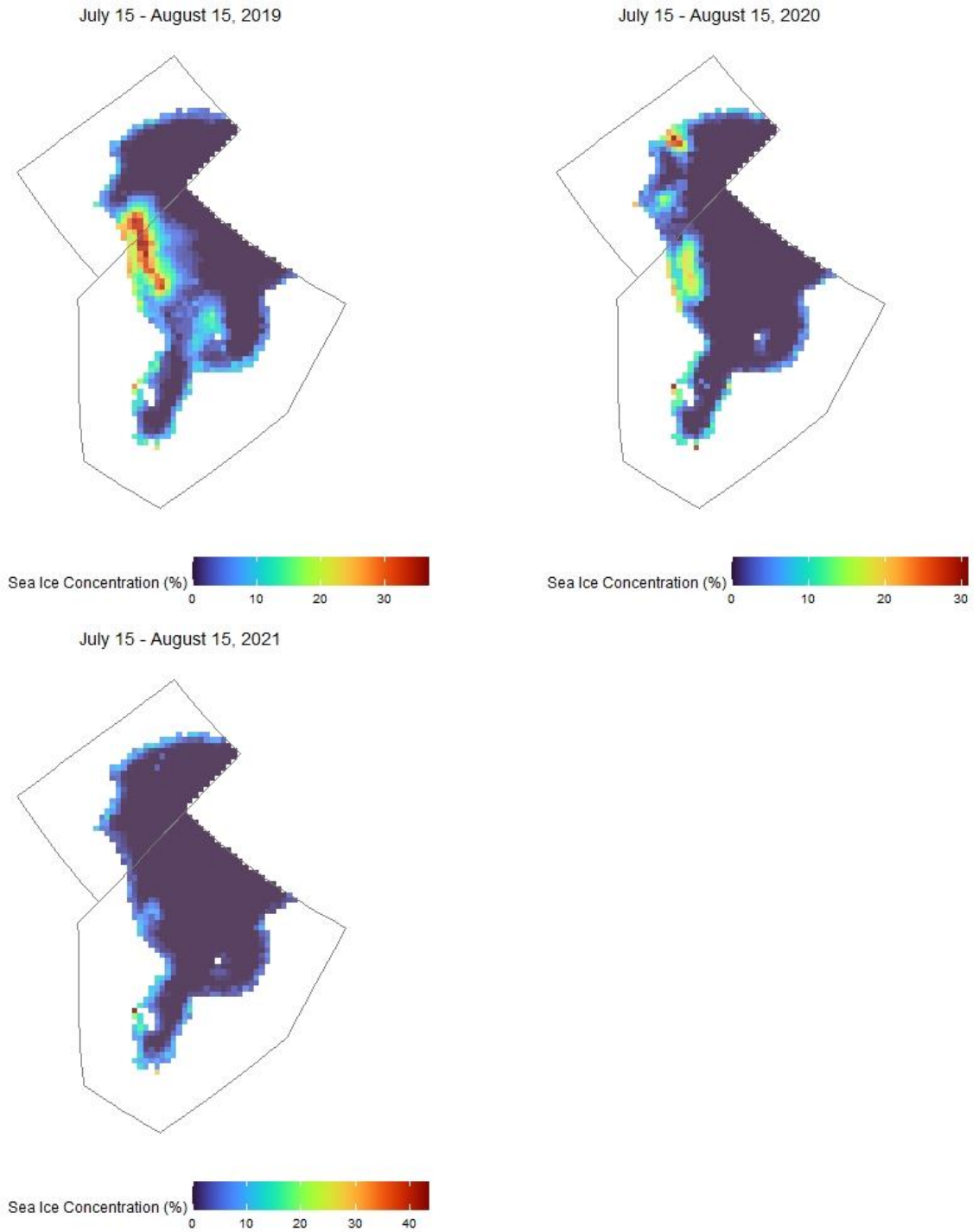
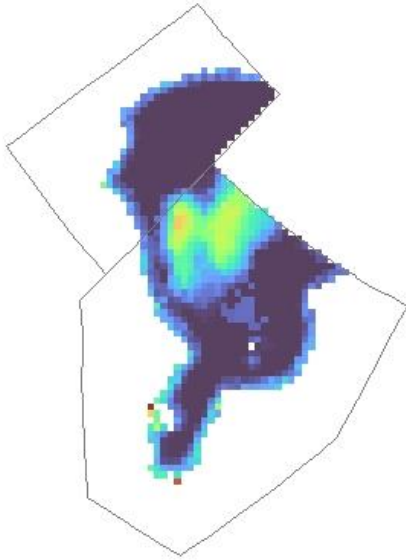
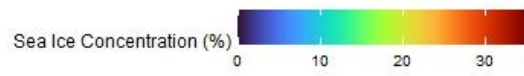
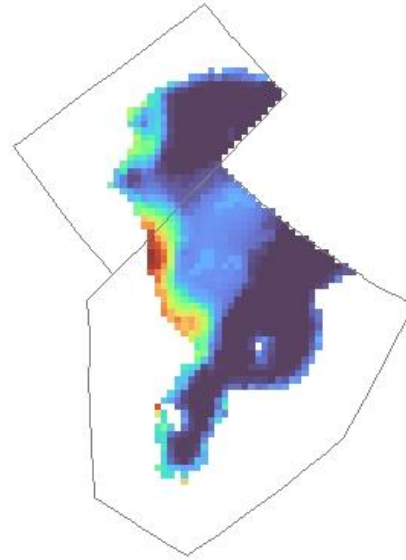


Figure 11. Average sea-ice concentration from July 15 through August 15 for each year from 2011 through 2021 for the Western and Southern Hudson Bay polar bear subpopulations.

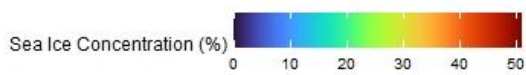
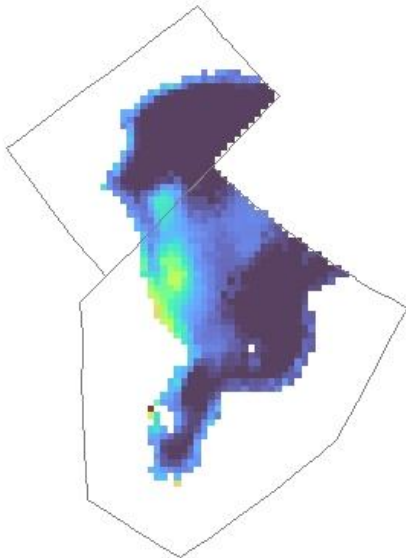
July 2011



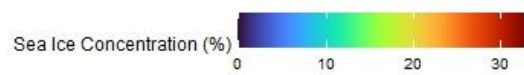
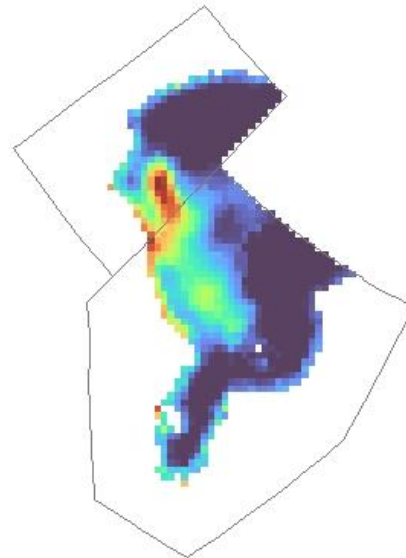
July 2012



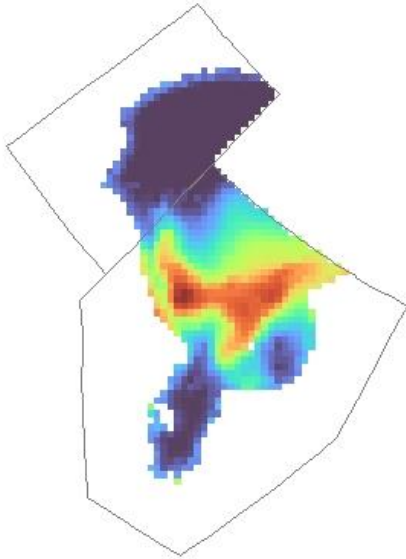
July 2013



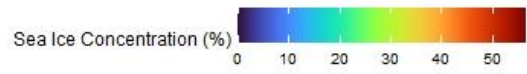
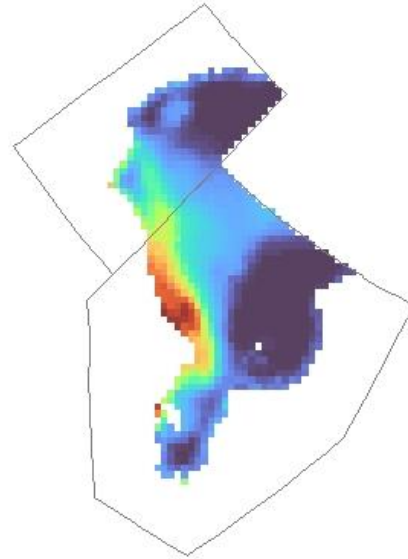
July 2014



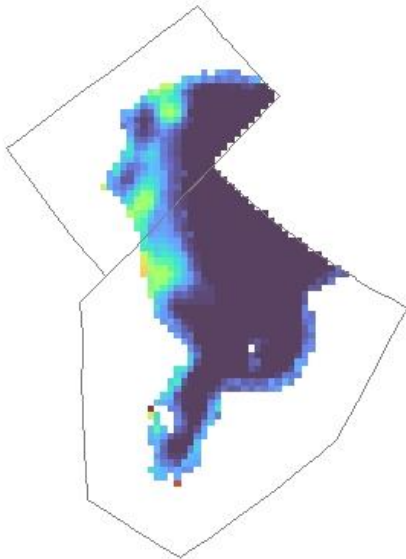
July 2015



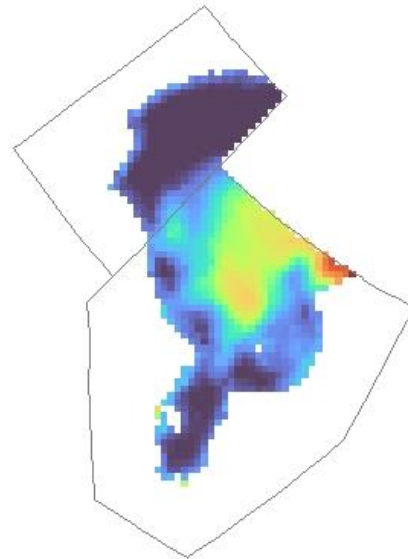
July 2016



July 2017



July 2018



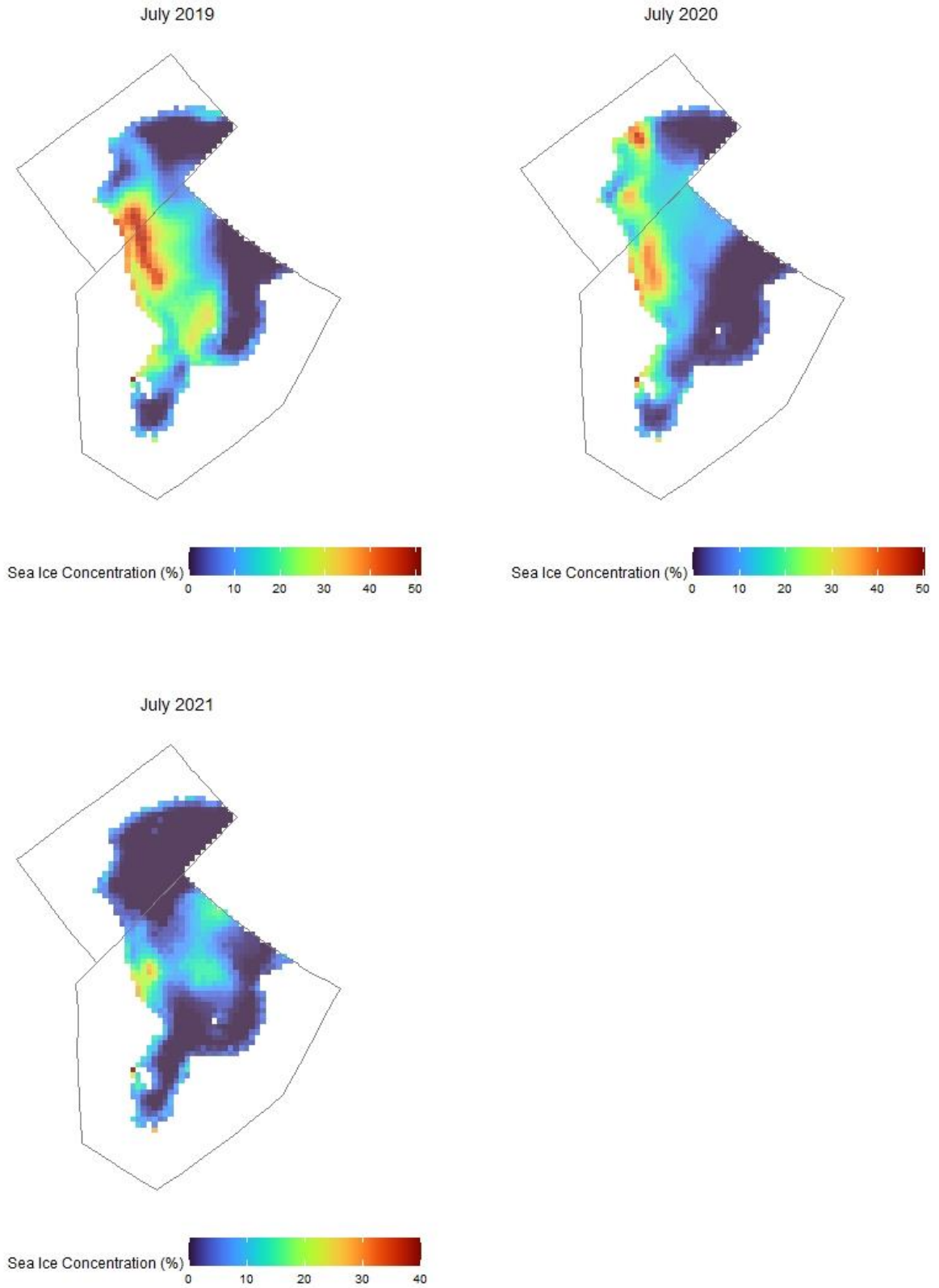


Figure 12. Average sea-ice concentration from July 1 through July 31 for each year from 2011 through 2021 for the Western and Southern Hudson Bay polar bear subpopulations.

These results have complex implications for harvest management. It is our opinion that the increase in SH is due to a combination of reduced harvest mortality during 2016-2021 relative to the 2010-2015 period and improved reproductive output due to both lower harvest levels and improved ice conditions along with annual variation in the distribution of bears between SH and WH. Resolving the degree to which each of these factors is at play is critical for harvest management. Harvest levels are set based, in part, on the number of bears within these subpopulations at the time of surveys. If there are large shifts of the broader distribution, abundances can appear higher or lower than the true number of bears available to be harvested in the respective, current subpopulation boundaries. It remains unclear however, whether such shifts in bears during the ice-free season persists through the ice season or if WH bears shift out of SH and closer to their original marking location in WH once they arrive on land the following year. Ongoing genetic biopsy work along the coastal areas of Manitoba and Ontario along with genetic identification of harvested individuals in WH and SH may help provide insight into the seasonal distribution and movements of bears under dynamic sea-ice changes.

Despite the apparent increase in bears in SH from 2016 to 2021, overall, the combined estimate of WH and SH has declined from 2011 through 2016 and appeared to remain stable between 2016 and 2021. Bears in WH and SH have experienced declines in survival and body condition at least partially related to changes in sea ice (Lunn et al. 1997, Obbard et al. 2007, Regehr et al. 2007, Lunn et al. 2016, Obbard et al. 2016, Sciuillo et al. 2016) over the last several decades. Further, both subpopulations are experiencing longer ice-free periods than in the 1980s (Stern and Laidre 2016) providing less access for bears to hunt their preferred prey. This research, in conjunction with harvest data showing high relative harvest rates between 2010 and 2015 plus the results of the 2016 surveys showing declines in abundance and low numbers of yearlings in both subpopulations (Dyck et al. 2017, Obbard et al. 2018) appeared to suggest that a decline in abundance was perhaps underway. However, between 2016 and 2021, ice conditions were more favorable for bears, on average, than between 2011 and 2016, with bears often able to remain on the ice into August (Figs. 10, 11 & 12, OMNRF and ECCC unpublished data). These years of relatively good ice conditions, combined with reduced harvest, may have buffered the population against decline. Indeed, in this current survey, reproduction appeared healthy with a high proportion of yearlings and cubs. However, 2021 was one of the shortest ice seasons of the past decade and survival of yearlings and cubs could be impacted. Our post-stratification estimates indicated that 35% of the SH subpopulation consisted of yearlings and cubs of the year. If the short ice season in 2021 equates to low survival of these bears, the current estimate could immediately become overly optimistic. Continued monitoring of reproduction, survival and inter-annual movements within and between both WH and SH will be critical to continue to inform management during the intervals between aerial surveys.

Limitations and caveats

This survey and analyses were designed and completed to allow for direct comparison to the 2016 aerial survey while taking advantage of recent conceptual advances in mark-recapture distance sampling of polar bears to avoid the underestimation of abundance that results from incorrectly assuming perfect detection of bears on or very close to the transect line. These dual estimates could cause confusion, so we provide rationale for the modelling differences and suggest the most appropriate uses for the different estimates here. In all three years of the SH survey (2011, 2016 and 2021), there were challenges in fitting MRDS models. Specifically, models with distance as a covariate of the mark-recapture submodel counterintuitively did not fit the data well and were not supported by AIC in any of the 3 surveys. Our analysis of data from 2021 suggests that the rear observers' reduced probability of detecting bears near the transect line, such that the overall probability of detecting bears apparently increased with distance near the transect, at least partially explains this lack of fit. Obbard et al. (2018) and our MCDS analyses assumed perfect detection on the transect line. However, these MCDS estimates are negatively biased if bears on the transect line went undetected during the surveys. Modelling imperfect detection on the line (MRDS analyses) yields more accurate estimates if detection probability on the line was < 1.0 , and so the best available estimate of SH polar bear abundance in 2021 is the MRDS estimate of 1119 (95% CI 860-1454) bears. Future research should analyze data from all three surveys together using a consistent analytical approach to more formally assess change in bear numbers over time.

In addition to the above caveat, the three SH surveys show that there is likely some underestimation in our distance sampling estimate. In each of the three surveys, the estimate of abundance that combines the distance sampling estimate excluding the coastal zone with the double-observer mark-recapture estimate for the Ontario mainland, coastline and Akimiski island area (lines 2 and 5 in table 5 for the current study) produced a larger abundance estimate than that of the distance sampling estimate alone (lines 1 and 4 in table 5 for the current study). In theory, these estimates should be identical because the total area included in each estimate is the same, only the method used to sample and estimate bear numbers within the coastal zone are different. However, in the 2011 survey, the estimate combining the distance sampling and coastal mark-recapture surveys was 189 bears higher (20% of the final averaged estimate), in 2016 it was 33 bears higher (4% of the final averaged estimate) and in 2021 it was 171 bears higher in the MCDS estimate (17% of the estimate) and 274 bears higher in the MRDS estimate (24% of the estimate) compared to the estimate based solely on distance sampling. We attribute these differences to the highly clustered nature of bear distribution along the coast, which lends itself to high sampling variability. This proposition is supported by our sex and age class results; we estimated through post stratification that there were 173

adult male bears in the Ontario mainland, coastline and Akimiski Island area (95% CI 79-378) when using the distance sampling survey including the coastal zone but saw 184 adult male bears during the coastal mark-recapture survey. These numbers indicate that our point-estimate of adult male bears from the distance sampling portion of the survey was an underestimate, and because adult males concentrate along the coast in large aggregations, we believe the spatial heterogeneity of this class of bears along the coast is the driving cause. This logic would also suggest that our averaged estimates (lines 3 and 6 in table 5) are likely underestimates of the total number of bears in the subpopulation and was likewise an underestimate in 2011 and a smaller underestimate in 2016. The differences across years also matches well with the evidence that bears are displaying substantial variation in their distribution from year to year. Male bears are likely the least philopatric to their summering areas because they do not need to access known inland areas for denning. Thus, if as theorized, the ice conditions in 2011 and 2021 were conducive to greater numbers of bears in SH, with fewer bears in 2016, we assume that most of these bears would be adult males, concentrating along the coast and leading to the larger differences in the estimates in 2011 and 2021 relative to 2016.

Abundance estimate of SH

In light of the above discussion of limitations, the best available evidence indicates that using the most up-to-date modeling approach, the best estimate of the number of bears present in SH in fall 2021 was 1119 (95% CI 860-1454) bears.

Conclusion

Management of polar bears in Canada makes an implicit assumption that subpopulations are discrete units. Surveys are conducted within the boundaries of subpopulations, and quotas are subsequently developed based on those results, with bears only counted against a quota if they are harvested within the bounds of a subpopulation. Although this assumption is almost certainly violated to some degree in every subpopulation, the implications for sustainable harvest of polar bears likely varies greatly depending on the degree of interchange between subpopulations that occurs when surveys to update estimates of abundance are undertaken. As first proposed by Pevett and Kolenosky (1982), our results, combined with those of Atkinson et al. (2022) and ECCC unpublished data suggest that, at least in some years, there is the potential for significant distributional shifts across the boundary between WH and SH. Therefore, these subpopulations are not acting as discrete units, which raises significant challenges for developing quotas based on management boundaries. Further complicating this issue is that much of the WH harvest occurs during the ice-free season when bears are onshore, whereas the majority

of SH harvest is on the sea ice (Government of Nunavut, unpublished data) when bears from Foxe Basin, SH, and WH are free to mix (Peacock et al. 2010). In addition, there may be strong demographic differences between these subpopulations. We suggest further research aimed at assessing interannual shifts in distribution, particularly with ongoing climate warming, examining the proportion of bears harvested in subpopulations different from the one they are present in during the survey period and continued monitoring of vital rates in both subpopulations will be key for future management decisions in WH and SH.

Literature cited

- Amstrup, S. C., and C. Gardner. 1994. Polar bear maternity denning in the Beaufort Sea. *The Journal of Wildlife Management*:1-10.
- Amstrup, S. C., T. L. McDonald, and G. M. Durner. 2004. Using satellite radiotelemetry data to delineate and manage wildlife populations. *Wildlife Society Bulletin* 32:661-679.
- Atkinson, S. N., J. Boulanger, M. Campbell, V. Trim, J. Ware, and A. Roberto-Charron. 2022. 2021 Aerial survey of the Western Hudson Bay polar Bear Subpopulation. Final Report. Government of Nunavut, Department of Environment, Wildlife Research Section, Status Report 2022-xx.
- Borchers, D. L., W. Zucchini, and R. M. Fewster. 1998. Mark-recapture models for line transect surveys. *Biometrics*:1207-1220.
- Buckland, S., J. Breiwick, K. Cattnach, and J. Laake. 1993. Estimated population size of the California gray whale. *Marine Mammal Science* 9:235-249.
- Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations.
- Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2004. Advanced distance sampling: estimating abundance of biological populations. OUP Oxford.
- Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer Science & Business Media.
- Burt, M. L., D. L. Borchers, K. J. Jenkins, and T. A. Marques. 2014. Using mark–recapture distance sampling methods on line transect surveys. *Methods in Ecology and Evolution* 5:1180-1191.
- Cherry, S. G., A. E. Derocher, G. W. Thiemann, and N. J. Lunn. 2013. Migration phenology and seasonal fidelity of an Arctic marine predator in relation to sea ice dynamics. *Journal of Animal Ecology* 82:912-921.
- Crête, M., D. Vandal, L.-P. Rivest, and F. Potvin. 1991. Double counts in aerial surveys to estimate polar bear numbers during the ice-free period. *Arctic*:275-278.
- Derocher, A. E., and I. Stirling. 1990. Distribution of polar bears (*Ursus maritimus*) during the ice-free period in western Hudson Bay. *Canadian Journal of Zoology* 68:1395-1403.

- _____. 1995. Temporal variation in reproduction and body mass of polar bears in western Hudson Bay. *Canadian Journal of Zoology* 73:1657-1665.
- Descamps, S., J. Aars, E. Fuglei, K. M. Kovacs, C. Lydersen, O. Pavlova, Å. Ø. Pedersen, V. Ravolainen, and H. Strøm. 2017. Climate change impacts on wildlife in a High Arctic archipelago – Svalbard, Norway. *Global Change Biology* 23:490-502.
- Durkalec, A., C. Furgal, M. W. Skinner, and T. Sheldon. 2015. Climate change influences on environment as a determinant of Indigenous health: Relationships to place, sea ice, and health in an Inuit community. *Social science & medicine* 136:17-26.
- Durner, G., K. Laidre, and G. York. 2018. Polar bears: Proceedings of the 18th working meeting of the IUCN/SSC polar bear specialist group, 7–11 June 2016, Anchorage, Alaska. Gland, Switzerland and Cambridge, UK: IUCN.
- Dyck, M., M. Campbell, D. S. Lee, J. Doullanger, and D. Hedman. 2017. Aerial survey of the Western Hudson Bay polar bear subpopulation: final report. . Status report 2017-xx. Nunavut Department of Environment, Wildlife Research Section, Igloolik, NU. 82p.
- Dyck, M., P. M. Lukacs, and J. Ware. 2021. Recovery From Reduction: The M'Clintock Channel Polar Bear Subpopulation, Nunavut, Canada. *Arctic* 74:509-524.
- Dyck, M., E. V. Regehr, and J. V. Ware. 2022. Demographic assessment using physical and genetic sampling finds stable polar bear subpopulation in Gulf of Boothia, Canada. *Marine Mammal Science*.
- Faune, S. C. d. I. 2010. Consultations sur la proposition d'inscrire l'ours blanc comme espèce préoccupante selon la Loi sur les espèces en péril. Service Canadien de la Faune.
- Fewster, R. M., S. T. Buckland, K. P. Burnham, D. L. Borchers, P. E. Jupp, J. L. Laake, and L. Thomas. 2009. Estimating the encounter rate variance in distance sampling. *Biometrics* 65:225-236.
- Henri, D., H. Gilchrist, and E. Peacock. 2010. Understanding and managing wildlife in Hudson Bay under a changing climate: Some recent contributions from Inuit and Cree ecological knowledge. Pages 267-289 *in* *A little less arctic*. Springer.
- Hochheim, K. P., and D. G. Barber. 2014. An update on the ice climatology of the Hudson Bay system. *Arctic, antarctic, and alpine research* 46:66-83.
- Huggins, R. 1989. On the statistical analysis of capture experiments. *Biometrika* 76:133-140.
- IPCC. 2013. Evaluation of climate models. In: climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Report 110766182X.
- Kanatami, I. T. 2019. National Inuit Climate Change Strategy. Inuit Tapiriit Kanatami.
- Kolenosky, G., K. F. Abraham, and C. Greenwood. 1992. Polar bears of Southern Hudson Bay. Polar Bear Project, 1984-1988, Final Report. . Wildlife Research Section, Ontario Ministry of Natural Resources,.
- Laake, J., and D. L. Borchers. 2004. Methods for incomplete detection at distance zero. *in* S. T. Buckland, D. E. Andersen, K. P. Burnham, J. Laake, D. L. Borchers, and L. Thomas, editors. *Advanced distance sampling*. Oxford University Press, Oxford.

- Laake, J., D. L. Borchers, L. Thomas, D. Miller, and J. Bishop. 2022. mrds: Mark-Recapture Distance Sampling. R package version 2.2.6m.
- Laake, J., B. A. Rakhimberdiev, D. Turek, B. T. McClintock, P. J.I., and C. Wood. 2019. Package RMARK: R code for mark analysis. *in*.
- Laake, J. L. 2013. RMark: an R interface for analysis of capture-recapture data with MARK.
- Laforest, B. J., J. S. Hébert, M. E. Obbard, and G. W. Thiemann. 2018. Traditional ecological knowledge of polar bears in the Northern Eeyou Marine Region, Québec, Canada. *Arctic* 71:40-58.
- Laidre, K. L., S. N. Atkinson, E. V. Regehr, H. L. Stern, E. W. Born, Ø. Wiig, N. J. Lunn, M. Dyck, P. Heagerty, and B. R. Cohen. 2020. Transient benefits of climate change for a high-Arctic polar bear (*Ursus maritimus*) subpopulation. *Global Change Biology* 26:6251-6265.
- Laidre, K. L., H. Stern, K. M. Kovacs, L. Lowry, S. E. Moore, E. V. Regehr, S. H. Ferguson, Ø. Wiig, P. Boveng, and R. P. Angliss. 2015. Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century. *Conservation Biology* 29:724-737.
- Leafloor, J. O. 1990. Summary of polar bear surveys in Ontario, 1963-1990. Unpublished report. Ontario Ministry of Natural Resources.
- Lemelin, R. H., M. Dowsley, B. Walmark, F. Siebel, L. Bird, G. Hunter, T. Myles, M. Mack, M. Gull, and M. Kakekaspan. 2010. Wabusk of the Omushkegouk: Cree-polar bear (*Ursus maritimus*) interactions in northern Ontario. *Human Ecology* 38:803-815.
- Lunn, N., I. Stirling, D. Andriashek, and G. Kolenosky. 1997. Re-estimating the size of the polar bear population in western Hudson Bay. *Arctic*:234-240.
- Lunn, N., M. Taylor, W. Calvert, I. Stirling, M. Obbard, C. Elliott, G. Lamontagne, J. Schaeffer, S. Atkinson, and D. Clark. Polar bear management in Canada 1993–1996. by: IUCN, Gland, Switzerland and Cambridge, UK, 1998.
- Lunn, N. J., M. Branigan, K. Breton-Honeyman, L. H. Carpenter, M. Dyck, G. Gilbert, J. Goudie, D. Hedman, E. Keenan, D. Lee, A. Maher, R. Maraj, M. E. Obbard, J. Pisapio, F. Pokiak, L. Staples, and G. Szor. 2018. Management of polar bears in Canada, 2009-2016. Pages 33-67 *in* G. M. Durner, K. Laidre, and G. York, editors. *Polar Bears: Proceedings of the Eighteenth Working Meeting of the IUCN/SSC Polar Bear Specialist Group*. SSC Occasional Paper No. 63. . IUCN, Gland Switzerland, and Cambridge UK.
- Lunn, N. J., S. Servanty, E. V. Regehr, S. J. Converse, E. Richardson, and I. Stirling. 2016. Demography of an apex predator at the edge of its range: impacts of changing sea ice on polar bears in Hudson Bay. *Ecological Applications* 26:1302-1320.
- Mallory, C. D., and M. S. Boyce. 2018. Observed and predicted effects of climate change on Arctic caribou and reindeer. *Environmental Reviews* 26:13-25.
- Marques, F., and S. T. Buckland. 2004. Covariate models for the detection function. Pages 31-47 *in* S. T. Buckland, D. R. Anderson, K. P. Burnham, J. Laake, D. L. Borchers, and L. Thomas, editors. *Advanced distance sampling*. Oxford University Press, Oxford.

- Peacock, E., V. Sahanatien, S. Stapleton, A. Derocher, and D. Garshelis. 2009. Foxe Basin Polar Bear Project: 2009 Interim Report. Department of Environment, Government of Nunavut, Igloolik, NU.
- Pörtner, H.-O., D. C. Roberts, H. Adams, C. Adler, P. Aldunce, E. Ali, R. A. Begum, R. Betts, R. B. Kerr, and R. Biesbroek. 2022. Climate change 2022: impacts, adaptation, and vulnerability. Contribution of working group II to the sixth assessment report of the intergovernmental panel on climate change.
- Post, E., and M. C. Forchhammer. 2008. Climate change reduces reproductive success of an Arctic herbivore through trophic mismatch. *Philosophical Transactions of the Royal Society B: Biological Sciences* 363:2367-2373.
- Post, E., M. C. Forchhammer, M. S. Bret-Harte, T. V. Callaghan, T. R. Christensen, B. Elberling, A. D. Fox, O. Gilg, D. S. Hik, and T. T. Høye. 2009. Ecological dynamics across the Arctic associated with recent climate change. *Science* 325:1355-1358.
- Prevett, J., and G. Kolenosky. 1982. The status of polar bears in Ontario. *Naturaliste Canadien* 109:933-939.
- R Core Development Team. 2022. R: a language and environment for statistical computing. R Development Core Team.
- Rantanen, M., A. Y. Karpechko, A. Lipponen, K. Nordling, O. Hyvärinen, K. Ruosteenoja, T. Vihma, and A. Laaksonen. 2022. The Arctic has warmed nearly four times faster than the globe since 1979. *Communications Earth & Environment* 3:1-10.
- Regehr, E. V., M. Dyck, S. Iverson, D. S. Lee, N. J. Lunn, J. M. Northrup, M.-C. Richer, G. Szor, and M. C. Runge. 2021. Incorporating climate change in a harvest risk assessment for polar bears *Ursus maritimus* in Southern Hudson Bay. *Biological Conservation* 258:109128.
- Regehr, E. V., N. J. Hostetter, R. R. Wilson, K. D. Rode, M. S. Martin, and S. J. Converse. 2018. Integrated population modeling provides the first empirical estimates of vital rates and abundance for polar bears in the Chukchi Sea. *Scientific Reports* 8:1-12.
- Regehr, E. V., N. J. Lunn, S. C. Amstrup, and I. Stirling. 2007. Effects of earlier sea ice breakup on survival and population size of polar bears in western Hudson Bay. *Journal of Wildlife Management* 71:2673-2683.
- Regehr, E. V., R. R. Wilson, K. D. Rode, M. C. Runge, and H. L. Stern. 2017. Harvesting wildlife affected by climate change: a modelling and management approach for polar bears. *Journal of Applied Ecology* 54:1534-1543.
- Sciullo, L., G. Thiemann, and N. Lunn. 2016. Comparative assessment of metrics for monitoring the body condition of polar bears in western Hudson Bay. *Journal of Zoology* 300:45-58.
- Stapleton, S., S. Atkinson, D. Hedman, and D. Garshelis. 2014. Revisiting Western Hudson Bay: using aerial surveys to update polar bear abundance in a sentinel population. *Biological Conservation* 170:38-47.
- Stern, H. L., and K. L. Laidre. 2016. Sea-ice indicators of polar bear habitat. *The Cryosphere* 10:2027-2041.

- Stirling, I., N. Lunn, J. Iacozza, C. Elliott, and M. Obbard. 2004. Polar bear distribution and abundance on the southwestern Hudson Bay coast during open water season, in relation to population trends and annual ice patterns. *Arctic*:15-26.
- Taylor, M. K., S. Akeagok, D. Andriashek, W. Barbour, E. W. Born, W. Calvert, H. D. Cluff, S. Ferguson, J. Laake, and A. Rosing-Asvid. 2001. Delineating Canadian and Greenland polar bear (*Ursus maritimus*) populations by cluster analysis of movements. *Canadian Journal of Zoology* 79:690-709.
- Taylor, M. K., D. P. DeMaster, F. L. Bunnell, and R. E. Schweinsburg. 1987. Modeling the sustainable harvest of female polar bears. *The Journal of Wildlife Management*:811-820.
- Taylor, M. K., P. D. McLoughlin, and F. Messier. 2008. Sex-selective harvesting of polar bears *Ursus maritimus*. *Wildlife Biology* 14:52-60.
- Wenzel, G. W. Polar bear as a resource: an overview. *Northern Research Forum*, 2004.
- Wiig, Ø., S. N. Atkinson, E. W. Born, S. Stapleton, T. Arnold, M. Dyck, K. L. Laidre, N. J. Lunn, and E. V. Regehr. 2022. An on-ice aerial survey of the Kane Basin polar bear (*Ursus maritimus*) subpopulation. *Polar Biology* 45:89-100.
- Wong, P. B., M. Dyck, A. Hunters, I. Hunters, M. Hunters, and R. Murphy. 2017. Inuit perspectives of polar bear research: lessons for community-based collaborations. *Polar Record* 53:257-270.

Supplemental material

Table S1. Multiple-covariate distance sampling (MCDS) models, degrees of freedom, Akaike's information criterion (AIC) values and change in AIC from the top model (Δ AIC) for models fit to polar bear distance sampling data collected across the entirety of the Ontario mainland, coastline and Akimiski island area in 2021. Abundance was estimated by model averaging across models marked with asterisks. See main text for description of model structure.

MCDS model	df	AIC	Δ AIC
Half-normal	1	1831.83	0.00
Half-normal + vegetation density*	2	1832.45	0.61
Hazard rate + vegetation density*	3	1832.60	0.76
Half-normal + vegetation height	2	1833.51	1.67
Hazard rate	2	1833.54	1.70
Half-normal + visibility	2	1833.64	1.80
Hazard rate + vegetation height	3	1833.78	1.95
Hazard rate + visibility	3	1835.34	3.50

Table S2. Multiple-covariate distance sampling (MCDS) models, degrees of freedom, Akaike’s information criterion (AIC) values and change in AIC from the top model (Δ AIC) for models fit to polar bear distance sampling data collected across the Ontario mainland, coastline and Akimiski island area excluding the coastal zone in 2021. Abundance was estimated by model averaging across models marked with asterisks. See main text for description of model structure.

MCDS model	df	AIC	Δ AIC
Half-normal + visibility*	2	1161.75	0.00
Hazard rate + visibility*	3	1162.84	1.09
Half-normal	1	1164.05	2.30
Hazard rate	2	1164.48	2.72
Hazard rate + vegetation density	3	1165.00	3.25
Half-normal + vegetation density	2	1165.51	3.75
Hazard rate + vegetation height	3	1165.89	4.14
Half-normal + vegetation height	2	1166.05	4.30

Table S3. Mark-recapture distance sampling (MRDS) models, degrees of freedom (df), Akaike's information criterion (AIC) values, difference in AIC from the top model (Δ AIC) and model weights (w_i) used in model averaging for models fit to polar bear distance sampling data collected across the entirety of the Ontario mainland, coastline and Akimiski island area in 2021. All models were included when model-averaging to estimate abundance. We use the top model to estimate the number of bears of different ages and sex by post-stratification. See main text for description of model structure.

Mark-recapture submodel		Distance sampling submodel				
Covariates	Key function	Covariates	df	AIC	Δ AIC	w_i
Blind spot + observer × side + visibility + glare	Half-normal	Vegetation + glare	11	2113.29	0.00	0.30
Blind spot + observer × side + visibility + glare	Hazard rate	Vegetation + glare	12	2114.60	1.32	0.16
Blind spot + observer + side + visibility + glare	Half-normal	Vegetation + glare	10	2114.68	1.39	0.15
Blind spot + observer × side + visibility + glare	Half-normal	Glare	10	2114.87	1.59	0.14
Blind spot + observer + side + visibility + glare	Hazard rate	Vegetation + glare	11	2115.99	2.71	0.08
Blind spot + observer + side + visibility + glare	Half-normal	Glare	9	2116.26	2.98	0.07
Blind spot + observer × side + glare	Half-normal	Vegetation + glare	9	2116.55	3.26	0.06
Blind spot + observer × side + glare	Hazard rate	Vegetation + glare	10	2117.86	4.57	0.03
Blind spot + observer × side + glare	Half-normal	Glare	8	2118.13	4.84	0.03

Table S4. Mark-recapture distance sampling (MRDS) models, degrees of freedom (df), Akaike's information criterion (AIC) values, difference in AIC from the top model (ΔAIC) and model weights (w_i) used in model averaging for models fit to polar bear distance sampling data collected across the Ontario mainland, coastline and Akimiski island area excluding the coastal zone in 2021. All models were included when model-averaging to estimate abundance. See main text for description of model structure.

Mark-recapture submodel	Distance submodel	sampling	df	AIC	ΔAIC	(w_i)
Covariates	Key function	Covariates				
Blind spot + observer \times side	Half-normal	Visibility	8	1359.18	0.00	0.51
Blind spot + observer \times side	Hazard rate	Visibility	9	1360.53	1.36	0.26
Blind spot + observer \times side	Half-normal	None	7	1362.06	2.88	0.12
Blind spot + observer \times side	Hazard rate	None	8	1362.41	3.23	0.10

Table S5. Estimates of polar bear abundance within the Ontario and Akimiski island coastal zone, obtained using double-observer mark-recapture methods along a coastal transect, proportion of cubs, yearlings and adults for the 4 lasts of surveys conducted in this portion of SH.

Year	Abundance estimate (95% CI) coastal transect	Proportion cubs observed coastal transect	Proportion yearlings observed coastal transect	Proportion adults observed coastal transect
2011	422 (381 – 467)	0.15	0.12	0.60
2016	269 (244 – 297)	0.17	0.03	0.71
2018	249 (230 – 270)	0.10	0.07	0.74
2021	335 (309 – 363)	0.10	0.12	0.67

**Consultation with Sanikiluaq Hunters and Trappers Association on
the 2021 Southern Hudson Bay Polar Bear Subpopulation Aerial
Abundance Survey Report**

May 13, 2023

Department of Environment
Government of Nunavut
Iqaluit, Nunavut



Executive Summary

Government of Nunavut (GN), Department of Environment (ENV) representatives conducted in-person consultations with Sanikiluaq Hunters and Trappers Association (HTA) on May 13, 2024.

The intent of this consultation was to ensure the GN and HTA could discuss the results of the 2021 Southern Hudson Bay (SH) polar bear subpopulation aerial survey, led by the Ontario Ministry of Natural Resources and Forestry in collaboration with ENV. The survey collected data in 2021. The previous abundance data for SH was collected in 2011 and 2016. The 2021 survey results suggested an increase in the polar bear subpopulation from 2016 to 2021, but when results were pooled with the 2021 Aerial Survey of Western Hudson Bay Polar Bear Subpopulation results, there was a difference of 1 bear between 2016 and 2021. Due to the limitations of an aerial survey method, it could not be determined how much of the increase was due to movement. Environment and Climate Change Canada (ECCC) have been conducting research on WH since the 1980s, including a biopsy darting project from 2017 to present. Results from this work suggested that the increase was in large part due to movement near the boundary between WH and SH in 2021, as opposed to higher reproductive rates. The goals of the consultations and presentations were to provide co-management partners with an overview of the results of the GN report and ECCC's research, collect feedback on the results presented, collect additional IQ, and to discuss the ENV harvest recommendation.

Polar bear biologists met with the Sanikiluaq HTA, which hunts from the SH subpopulation.

Support for or against ENV's harvest recommendation was not explicitly expressed by the HTA at the time of consultation. At the end of the consultation, the HTA was left with questions to discuss and send their feedback to ENV or the Nunavut Wildlife Management Board, whichever was preferred by the HTA.

The feedback and IQ collected during this consultation will be summarized when submitting Total Allowable Harvest (TAH) recommendations for the SH subpopulation to the Nunavut Wildlife Management Board (NWMB) for decision.

This report attempts to summarize the comments made by participants during the consultations.

Preface

This report represents the Department of Environment's best efforts to accurately capture all of the information that was shared during the consultation meeting with the Hunters and Trappers Association of Sanikiluaq on May 13, 2024.

The views expressed herein do not necessarily reflect those of the Department of Environment, or the Government of Nunavut.

Table of Contents

- Executive Summary**..... ii
- Preface** iii
- 1.0 Report Purpose and Structure** 1
- 2.0 Purpose of Consultation**..... 1
- 2.1 Format of Meeting** 1
- 3.0 Summary of Consultations** 2
- Appendix A** 2
- 2021 Southern Hudson Bay Polar Bear Subpopulation Aerial Survey Report Consultation Meeting Highlights..... 2
 - Participants..... 2
 - Goal of meeting: 2
 - Next Steps and Action Items: 3
 - Short term Action Items (within 4-6 weeks): 3
 - Longer term Action Items (next 2-3 months):..... 3
 - Meeting Highlights:..... 3

1.0 Report Purpose and Structure

This report is intended to collate and summarize comments, questions, concerns and suggestions provided by the Sanikiluaq Hunters and Trappers Association (HTA) regarding the results of the 2021 Southern Hudson Bay (SH) polar bear subpopulation aerial survey.

Representatives from the Department of Environment (ENV) attended the consultation along with other co-management partners and interested parties.

2.0 Purpose of Consultation

The purpose of the consultation was to discuss the newest scientific information regarding the SH polar bear subpopulation as reported in the 2021 Aerial Abundance Survey report and scientific work done by Environment and Climate Change Canada (ECCC). In addition, the Government of Nunavut (GN) also put forward a Total Allowable Harvest (TAH) recommendation during this consultation, but also discussed that management objectives can be formulated depending on the communities' needs and objectives for this subpopulation.

2.1 Format of Meeting

The meeting was held in the evening and ran for approximately 2.5 hours. Government of Nunavut Polar Bear Biologist, Alyssa Bohart, and Senior Wildlife Advisor, Jonathan Pynn, facilitated and led the meeting. Joseph Northrup, Ontario Ministry of Natural Resources and Forestry Regional Biologist planned to attend virtually, but was absent due to a work emergency. The presentation started with opening remarks from A. Bohart, and J. Pynn on who they are and what organization they are representing as well as the purpose of the consultation. This was followed by a PowerPoint presentation with an overview of the scientific survey and co-management process, historic management background, a detailed overview of the results from the 2021 polar bear aerial abundance survey, and the results from scientific work conducted by ECCC in Hudson Bay (Appendix 1). Results from the aerial abundance survey were inconclusive, whereas scientific work by ECCC aided in the explanation of the aerial abundance survey results. The participants were invited to ask questions, raise concerns, or provide recommendations throughout the meetings. At the end of the meeting, the GN position on the TAH for SH was presented. After the presentation, questions/discussion continued until the HTA adjourned the meeting. The HTA was left with discussion questions regarding the studies and SH management objectives from ENV to internally discuss and send responses to ENV or directly to the Nunavut Wildlife Management Board (NWMB).

3.0 Summary of Consultations

This summary combines the general themes and ideas generated from the HTA. For specific commentary and participants in the consultation, please see Appendix A.

Comments and questions:

- HTA had questions and expressed concerns over the welfare of bears in biopsy darting and collaring/handling projects.
- HTA identified a large presence of polar bears in 2021, damaging eider nests. This aligned with the findings of more bears in SH during the 2021 aerial survey.
- HTA shared that the ice has been thinning and is not as predictable anymore with climate change.
- HTA identified their interest in submitting their own letter to NWMB for their SH TAH decision at the October meeting. HTA did not express support or non-support for the draft TAH presented by the GN.

Appendix A

2021 Southern Hudson Bay Polar Bear Subpopulation Aerial Survey Report Consultation Meeting Highlights

Location: Qikiqtait Building (Arctic Eider Society/HTA Building)

Date/Time: May 13, 2024

Start time: 19:00

End time: 21:30

Participants

Eli Kavik (HTA Acting Manager)

Mick Appaqaq (HTA Vice-Chairperson)

Charlie Takatak (HTA Secretary-Treasurer)

Moses Appaqaq

Garry Rumbolt

Johnny Kudluarok

Alyssa Bohart, Polar Bear Biologist, GN ENV

Jonathan Pynn, Senior Wildlife Advisor, GN ENV

Kyle Ritchie, Senior Wildlife and Policy Advisor, Wildlife Management Biologist, Nunavut Wildlife Management Board

Jonah Qittusuk, ENV Conservation Officer Sanikiluaq

Lisi Kavik-Mickiyuk, Translator

Regrets: Joe Northup, Regional Biologist, Ontario Ministry of Natural Resources and Forestry

Goal of meeting:

Provide an overview of the newest scientific information regarding the SH polar bear subpopulation as reported in the 2021 Aerial Abundance Survey report and scientific work done by ECCC. Discuss the GN TAH recommendation. Discuss any questions HTA has for both studies. Collect feedback and IQ on SH management.

Next Steps and Action Items:

Short term Action Items (within 4-6 weeks):

- Email HTA the questions

Longer term Action Items (next 2-3 months):

- Provide HTA the animation of collared bears

Meeting Highlights:

Question to Group after Introductions:

The meeting began with introduction of participants. **Joe Northurup** had planned on attending virtually, but a work emergency prevented him from joining. **Alyssa Bohart** informed the HTA that if they had any questions she was not able to answer, she would pass them on to Joe. **Alyssa Bohart** presented slide show with background on the transition at the GN polar bear research group due to the loss of biologist Markus Dyck. She then presented an overview of the polar bear study process including the planning stages up to when a TAH management decision is accepted by the minister and harvest tags are distributed to communities. She then noted that the purpose of this meeting was to provide a summary of the results from the aerial abundance survey and ECCC's work to hear HTA feedback.

Aerial abundance survey background slides

- No comments received.

Aerial abundance survey methodology/field work

- **Moses:** I understand the quantity of the bears estimated during the survey. Are the bears identified if they are male or female?
- **Alyssa:** They do a visual ID from the air. We also rely on HTO members to tell us if bears seen on survey are male or female, but we can't confirm it genetically. It's kind of like an estimate.
- **Charlie:** I helped in the survey and it's harder to tell male or female from the air than when on the ground.
- **Johnny:** For the bears that have been collared, has it been known if they go long distances? Or stay in similar areas where they were collared?
- **Alyssa:** From the tracks we have seen, they travel long distances, all across Hudson Bay. We are working to get this information in an animation for existing collar data. We have a video of bears that were collared for WH and after the consultation we can show that video if they HTA would like.
- **Charlie:** As a participant to the survey, yes polar bears on land were identifiable on land, but were hard to spot in the water. We spotted some bears, but I think we missed bears that were in the water because they are hard to spot.
- **Alyssa:** Yes we've heard that too. Its hard for safety reasons to be flying over water, but there is some ongoing drone research and the focus this year is on caribou. We are hoping that this improves and we can fly over water with drones in future surveys.
- **Gary:** Do you have any records for how long of a lifespan of bears with a collar? They do affect their hunting patterns and ways they can hunt.

- **Alyssa:** The GN hasn't collared bears in over a decade. There are still bears that are collared by ECCC in Manitoba. A typical collar will last 1-3 years then should fall off. In talking with researchers who collar bears, they try to track down collared bears. They do their best to make sure the collars come off, but bears in water or in dens make it hard. Only female bears are collared. One of the most recent bears harvested with a collar was in Whale Cove; that bear was 24 years old and they've caught bears that have been close to 30 years old that had been collared, but that old of a bear is not as common. Thank you for sharing the concerns about collaring bears and the researchers that do collar bears want to not harm bears and want to understand how the collars are affecting the bears.
- **Johnny:** (Alyssa went back to flight line slide) When you mark the black lines (the subpopulation boundary) what is that? Does that show where the survey is? Sometimes the bears are more inland and not on the coast yet so you might miss bears. Were there studies being conducted in Western Hudson, Southern Hudson Bay and on the islands, and along the Quebec coast?
- **Alyssa:** The black line is the map boundary between the subpopulations. The other colour lines show the flight lines within the SH boundary. The survey estimate is for the full area, including along the Quebec coast, not just near Sanikiluaq. Thank you Johnny for letting us know that there are still some bears further inland.
- **Charlie:** How long does a collar last? 1-3 years? Battery operated?
- **Alyssa:** Yes, more commonly they last 1.5 years but sometimes can last up to three years.
- **Lisi:** Is it computerized to drop off?
- **Alyssa:** Yes, it is.
- **Charlie:** One year my father caught a bear with a collar on it (a long time ago). He gave that collar back to the government because he thought it might still be active.
- **Alyssa:** Sometimes they are! They are programmed to send data up to a satellite, but it doesn't always work, so some data is missing from the computer. When you turn in a collar, we can download all the information from the collar by plugging it into the computer. If people were interested, there was a bear harvested in Sanikiluaq this year that I have some information on and a map of the locations. I believe Jonah has more information.
- **Moses:** Come on down to the people who make the decisions as to what the quotas will be, during bear hunting season. It was the younger, the juvenile bears, we would want to harvest, but they are not harvestable now. We want the people who make the decisions to come down and hear what our traditional knowledge is on harvesting animals that we eat. Now there is a saying that we cannot harvest young bears, we can only harvest adult bears. I'd like to see those people come to here to meet with us. We should write letters allowing us to harvest younger bears.
- We would appreciate and to hear that these officials will come. As Belcher Islanders, we live off eider ducks and they are very important to us. When there are too many bears left on land, we lose many eider eggs to bears. And so that's the reason we want to see the people who make final decisions about bears.

20:05 – 20:10 Break

Aerial abundance survey methodology/field work & ECCC research

- **Jonathan in response to Moses' comments** clarified that there are exemptions for harvesting cubs/young bears.
- **Jonathan:** This is a process and there are a number of rules and regulations associated with it, but it does exist. The Regional Manager, Jeff MacDonald, and CO William Flaherty, should be here tomorrow and they can better explain how the cub exemption process works.
- Board seemed pleased that this existed as they didn't know about it; Jonah said that he was not aware of it either. Also mentioned that the decision maker they want to meet, is Minister Daniel Qavvik who is the Sanikiluaq MLA.
- **HTO general comment** made that they'd like to meet Jeff and have that explanation while he is in Sanikiluaq.

- **Alyssa:** In WH communities, people noted that it was a really windy year in 2021 and that might have pushed the ice into SH, leading to more bears being counted in SH in 2021. Did the board notice if there were any anomalies in 2021?
- **Moses:** Through Inuit Qaujimagatugangit, if we not just oral and we documented our findings and things that we noticed were different, we would have jotted them down. Unfortunately, that's the Inuit traditional way to document in your brain only and not share it on paper. I'm sure if we did have documentation as a hunter, then we would share it but as a hunter, every year and every season is different. They're always changing on a yearly basis.
- As a community member to an environment that sees a lot of climate change, through traditional knowledge, we used to go to the highest peaks to see how long the ice would stay. That is not possible today, there's so much change now. Now you can't see what the ice will be like. Due to climate change so much movement is happening so it is hard to predict how the ice is moving or how long it will stay.
- **Gary:** There was a year, I don't remember which year, there was a lot of polar bears harvested in the summer. Polar bears that got left behind by the ice and stuck on islands. We went to gather down and there was not much left to gather. There was a lot of bear damage to eider nests.
- **Group:** It was 2021.
- **Charlie:** Like Moses said earlier, traditional knowledge doesn't work the same. The ice is so much thinner now. This is one of the biggest changes we see as hunters. And it thins out fast.
- **Johnny:** In summer 2021, I participated in the eider duck nesting survey on the south end of Belcher Islands and Sleeper Islands. In both areas there was a lack of nests. There was a lot of evidence of nests, but all of those nests were empty of eggs because there was a disturbance of bears. That fall, someone from James Bay area, a Cree person, asked us what our summer was like because a lot of eiders moved into James Bay and nested there that year.

- **Charlie:** The surveys that you talked about (WH and SH), do the people in Baffin have their own studies, population studies, darting studies, and all that? And in northern Quebec? We know they harvest bears too. They must have information too about where they are darted and harvested too.
- **Alyssa:** Yes, we cycle/rotate through subpopulations to survey, since we have 12 to manage. For this year we plan on surveying Foxe Basin which includes Quebec and Baffin and northern Kivalliq. We are trying to do some biopsy darting and an aerial survey. Our colleagues in Quebec are going to focus their part of the survey in this area (pointing to northern Quebec shoreline). We plan to send harvest samples to be tested to find out if

any of the bears we've been biopsy darting in SH are being harvested in Foxe Basin. The most scientific information we have is for WH as that area is the most studied. So we might not have all the same information for other areas.

- It is very important to provide the harvest samples to the wildlife office. It helps us to answer research questions like this, but it is also very important for us to be able to defend Nunavut's harvest management system at the international level. I've been at meetings where the other countries don't allow harvest and they criticize Nunavut's management system, but it really helps when we have the records of the harvest from the communities and when you submit those samples to defend Nunavut's management system. So I just wanted to take the time to thank all of the harvesters for providing those samples because it helps keep harvesting in place.
- **Charlie:** I remember an HTA meeting that there was a survey for bears for this summer. Do you have any idea when the next survey will take place for SH?
- **Alyssa:** We don't have a definitive year, but we have been going on every 5 years. It's dependent on how much money is available because surveys are very expensive. Hopefully 2026 if we follow the cycle.
- It doesn't have to be an aerial survey. We might be able to do a biopsy survey if that is something the HTO is interested in. With biopsy darting, we'd be able to see a bit of movement data, but in the future we can come back to the HTO for consultation and discuss options on what the HTO supports.
- **Eli:** Does the NU government work with Eeyou, and Ontario and Nunavik governments when you are doing the surveys?
- **Alyssa:** In the past, we have provided funding to other governments to conduct the survey. We have provided funding for the ON and QC governments to lead the SH survey and we typically deal with WH. We still need support from other HTOs and permitting, so we work together. The ON government recruits people to help with the aerial survey.
- The GN would still come to Sanikiluaq to present the survey methods and pass along the wishes of the HTO to the ON government, but we usually aren't the ones in the field doing the survey.

TAH Discussion

- **Eli:** Since the population has increased, can Sanikiluaq request an increase to the TAH?
- **Alyssa:** That's a good lead into our next slide. At this time, our draft TAH recommendation is to keep the TAH the same, but if the HTO wants, this is something we are here to discuss and will document in our notes.
- **Moses:** I would like to start with a story. Long ago me and my older brother went seal hunting and came across a helicopter. That helicopter was tiring out a polar bear for many hours and that polar bear couldn't run and was exhausted. They finally put that bear to sleep. Inuit Qaujimajatuqangit tells us to never put any animal in that state, where you are tiring them out to the point where they are gasping for air. Do the people who do biopsy darting, are they running down a bear so much that it can hardly breathe anymore?
- **Alyssa:** They've timed how long it takes to biopsy dart a bear and that is usually less than one minute. With that short of a timespan, there's less of an impact on the bear. We recognize that chasing a bear is disturbing/stressful for a bear. We want to limit the time we are disturbing a bear so it doesn't get as stressed. There are rules in place in how we biopsy dart. Some of the rules is a temperature cutoff (don't pursue bears when it is too

hot), we don't want a bear to overheat. We don't chase bears in rocky terrain so they don't fall and hurt themselves on the rocks. Also don't want to separate moms and cubs. So from what I've seen, biopsy darting is less intrusive than drugging and collaring a bear.

- I don't know about researchers who came way before me, but researchers that I know try to do the least amount of negative impact to bears. For the GN's biopsy project in Foxe Basin, we're taking many precautions. Because the aerial survey is the most important part of the survey, we will only be darting bears if we can do it quickly and not disturb them much. We won't be darting bears in dangerous situations. We also won't biopsy dart bears near communities where the HTOs don't support it.
- **Moses:** Like I said earlier, oral history is not written. My parents and grandparents emphasized that we don't run the bears ragged and tired. Today we have snowmobiles and can get up to a bear much faster and harvest it before it's done its course of running. Harvesting a bear with Elders traditional knowledge, our elders will not eat the bear if it has been run too much, because it changes the taste of the meat on the bear. Hunters know to harvest a bear in a quick manner as it is going to feed the people.
- **Alyssa:** We had proposed that the TAH stays the same based on the fact that we're seeing the movement between the two subpopulations, suggesting that the number of all of Hudson Bay has relatively stayed the same. What it sounds like I'm hearing from the HTO is there's concerns over the number of bears having an impact on the number of eiders. Perhaps the HTO would be interested in having an increase in their TAH to address the effect on eiders? Is that correct?
- **Eli:** That was just a point of discussion, but this is something that we will discuss and get back to you on.
- **Alyssa:** This is also something you can discuss as a board after our meeting. You can make a submission to NWMB to modify the TAH request. It would be important to include some reasons in why you want a change because it helps the Board (NWMB) to understand why.
- **Kyle:** The Board (NWMB) members really appreciate HTO feedback to make these decisions. There are other opportunities to discuss this with the board. October is when the GN currently intends to present this item to the board. The Board would have a meeting in October, and you could attend virtually or in person, I'm not sure where the meeting will be yet. It would be appreciated by the board if you could participate in that decision-making. At that time, if they don't make a decision, they may choose to hold a hearing if they don't have enough information. With Sanikiluaq being mostly affected, they may choose to hold the hearing here, but I can't say for sure. A letter and participating in the October meeting would be really helpful in the decision-making process.
- **Alyssa:** We'll email the list of questions to the HTA and Lucassie will present it to the Board.
- Alyssa showed a map of the recently harvested collared bear. The collar stopped working, which is why it doesn't show the bear coming to Sanikiluaq. Bear born in 2008 and collared near ON-MB border. Last known location was May 2023 but not sure how long the data would show.
- Alyssa offered to send a collar animation of WH bears to Lucassie so he can show the Board.

Participants were thanked for attending, and their feedback.

21:30 Meeting End

The GN recommendations in the submission is:

- ENV recommends **no change to the current TAH of 25 for the SH subpopulation**. When considering the SH and WH estimates collectively between 2016 and 2021, the subpopulations remain stable under current environmental conditions and harvest levels.
- In keeping with current national and international polar bear management initiatives, ENV requests that the NWMB establish a management objective for the Southern Hudson Bay polar bear subpopulation. ENV suggests that the management objective is to **maintain current abundance**.

These are the questions that were in the presentation:

- Do you agree that the number of polar bears **stayed relatively the same** over time? **YES**
- Are there **enough** bears to harvest? Are there **too few? Too many? Yes, but too few although polar bear are important for food source, but eider ducks are more important , which the polar bears are eliminating nesting colonies at south Belchers, and north Belcher for over 10 years now**
- What did you observe in the bears' **body condition** over time? **Yes, fast no change they are eating all the eider, gulls, artic tern, black guillemot and other sea nesting ducks.**
- Is there anything **special** that you observed and wanted to share with us? **NONE, BUT TOO MANY BEARS**
- Where do you **agree/disagree** with our findings? **STABLE NUMBERS BUT, THERE ARE LOT MORE BEAR**



SUBMISSION TO THE
NUNAVUT WILDLIFE MANAGEMENT BOARD
FOR

Information: **X**

Decision:

Issue: The Qamanirjuaq Caribou herd population status and management

Background:

- The Qamanirjuaq Caribou Herd is the largest herd in the western arctic, occupying an estimated annual range of 300,000 km².
- Prior to the recorded peak of 495,665 caribou in 1994, the Qamanirjuaq herd showed signs of decline in the early 1950s. Abundance surveys of the Qamanirjuaq herd have documented considerable change from the late 1970s to present.
- An estimated 11,000 Qamanirjuaq caribou are harvested annually in Nunavut, Northwest Territories, Manitoba and Saskatchewan. Kivalliq Inuit are estimated to harvest over 8,000 Qamanirjuaq caribou per year. These values likely represent an underestimate as there remains uncertainty around the actual number of caribou that are harvested.
- The intra-territorial trade in caribou meat over the internet has accelerated harvesting and has become a conservation concern for the Kivalliq Wildlife Board (KWB). The KWB is concerned intra-territorial meat sales will continue to accelerate this decline. This is not currently being tracked or reported.
- A satellite telemetry program was initiated in 1993 and continues today. This program has supported the creation of a comprehensive location and activity database for the Qamanirjuaq herd. This database is the only source of western scientific based information examining the Qamanirjuaq herd's use of their annual range.
- Recent movements (within the last 5 years) of Qamanirjuaq caribou cows have indicated some shifts in calving-grounds, migratory corridors, spring staging areas, and summer range in the vicinity of resource development infrastructure. Additionally, the winter ranges of the Qamanirjuaq, Bathurst and Beverly herd's have shown considerable overlap over the last ten years.

Current Status

- In June 2022, the Government of Nunavut Department of Environment (ENV) completed an abundance survey of the Qamanirjuaq herd to generate estimates of adult females and the whole herd.
- Results from this survey generated an estimate of 156,540 adult female caribou, an estimate of 213,079 caribou on the calving ground and a whole herd estimate of 252,892 adult caribou.
- These results suggest that the herd is likely relatively stable. A comparison of the adult female estimates from 2022 and 2008 indicate a statistically significant decline. However, trend analysis during this period has identified a non-significant declining trend (Figure 1).
- The lack of statistical significance in regression-based trend estimates (that include 2008, 2014, 2017, and 2022 estimates) may be due to stability in the period of 2014-2017, however, it should be noted that precision of estimates (large confidence intervals) makes it difficult to track smaller changes in abundance from survey to survey.
- The whole herd estimate from the June 2022 survey is 35,352 adult and yearling caribou below that observed in June 2017. Though not statistically significant, this reduction in the mean estimate highlights the importance of continued monitoring of the herd.

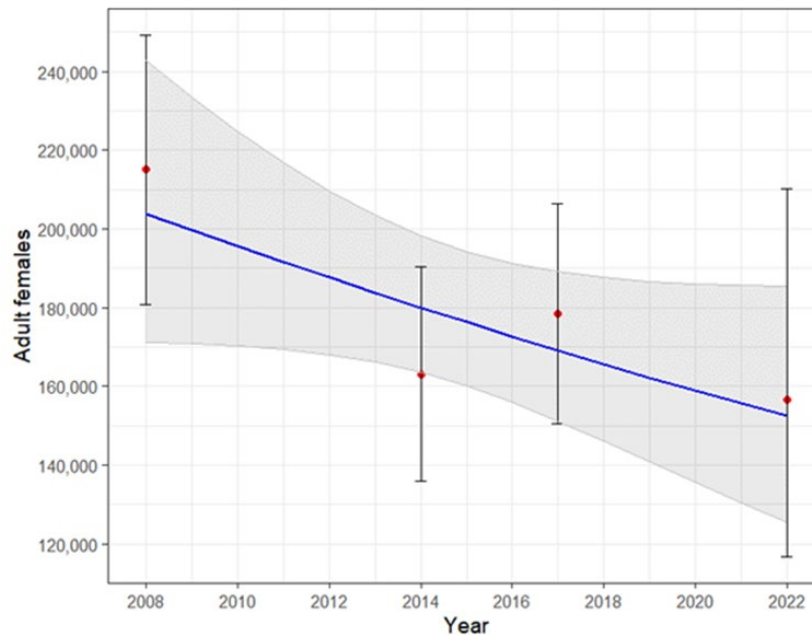


Figure 1. Predicted trends in Qamanirjuaq herd abundance from log-linear regression including the June 2022 estimate. Confidence limits on regression

predictions are given as hashed blue lines. Individual estimates are shown as red points with displayed 95% confidence limits.

Consultations

ENV staff traveled to the communities of the Kivalliq region in January and February 2024 to meet face to face with the Hunters and Trappers Organizations (HTOs) and give an update on the Qamanirjuaq caribou survey results, and other regional research results and issues. Presentations with summary results of recent surveys and other details concerning Kivalliq ungulates were given to the HTO members present.

Recommendation

ENV is not proposing any management actions for the Qamanirjuaq caribou herd at this time but recommends continued monitoring of this herd.

Estimating Abundance of the Qamanirjuaq Mainland Migratory Barren-Ground Caribou Subpopulation - June 2022

FILE REPORT

Government of Nunavut
Department of Environment
Technical Report Series – No: 01-2023

Mitch Campbell

Department of Environment, Nunavut Wildlife Research Division, Arviat, NU

John Boulanger

Integrated Ecological Research, Nelson, BC

John Ringrose

Department of Environment, Nunavut Wildlife Research Division, Pond Inlet, NU

&

David S. Lee

Department of Wildlife and Environment, Nunavut Tunngavik Inc., Ottawa, ON

14th June 2024

Disclaimer:

The conclusions and recommendations discussed within this report represent those of the authors and do not necessarily reflect the position of the Government of Nunavut.



ABSTRACT

Modern mainland migratory caribou calving ground photo surveys generally rely on the assessment of females (and where appropriate, breeding females) combined with fall composition surveys, to estimate and track herd abundance and trend. From June 2008 through June 2017, assessments of the mainland migratory Qamanirjuaq herd abundance and trend, have followed similar methods. In June 2022, we set out to estimate the abundance and trend of females in the Qamanirjuaq herd of barren ground caribou which were then used as one component to generate a whole herd estimate using fall composition studies. In June 2008, the Government of Nunavut estimated 215,049 (95% CI=180,770-249,328; CV=8.1%) adult female caribou on the Qamanirjuaq annual core calving ground, yielding a whole herd estimate of 344,078 (95% CI=287,208-400,948; CV=8.1%) adult caribou. In June 2014, the survey estimated 163,066 (95% CI=136,317-189,815; CV=8.2%) adult female caribou with a whole herd estimate of 264,718 (95% CI=220,634-308.802; CV=8.3%) adult caribou. The 2014 results confirmed a significant decline (DF=71.3; T=-2.23; P=0.029) between survey periods, indicating a 23% decline over the 6-year period. Following up on these observed declines, the herd was again surveyed in June 2017, which generated an estimate of 178,423 (95% CI=150,468-206,377; CV=7.6%) adult female caribou, and a whole herd estimate of 288,244 (95% CI=242,121-334,367; CV=7.8%) adult caribou, suggesting a non-significant decreasing trend with a yearly λ estimate of 0.98 (CI=0.94-1.01). The June 2022 (this report) abundance survey generated an estimated 156,540 adult female caribou (95% CI=116,635-210,099; CV=13.8%), which yielded a whole herd estimate of 252,892 (95% CI=188,050-340,092; CV=13.9%) adult caribou. The total number of caribou (including bulls and yearlings) estimated on the calving ground was 262,272 (95% CI=227,910-296,634; CV=6.4%) in June 2014 and 252,060 (95% CI=220,721-283,398; CV=6.1%) in June 2017, compared to 213,079 (95% CI=166,781-272,229; CV=11.5%) estimated on the

calving ground in June 2022. The overall survey results suggest that the herd appears to be relatively stable. Comparison of the 2022 to the 2008 estimate directly, indicates a significant decline. However, an analysis of regression between 2008 and 2022 is not significant. The mean of the whole herd estimate of the June 2022 survey is 35,352 adult and yearling caribou below that observed in June 2017. Though not statistically significant, this reduction in the mean estimate highlights the importance of continued monitoring of the herd. As indicated, periodic re-assessments of herd abundance are necessary to ensure that any declines can be detected and addressed by co-management partners as outlined within the Nunavut Agreement. Of equal importance is the protection of critical range to ensure healthy seasonal range remains available and accessible to Qamanirjuaq caribou. This is of primary importance to mainland migratory barren-ground caribou such as the Qamanirjuaq herd when recovering from cyclical or major declines in abundance.

Key Words: Calving Ground, Photographic Survey, Mainland Migratory Caribou, Kivalliq Region, Barren-Ground Caribou, Qamanirjuaq Herd, Nunavut, *Rangifer tarandus groenlandicus*, Population Survey.

TABLE OF CONTENTS

1.0 INTRODUCTION.....	7
2.0 STUDY AREA.....	13
3.0 METHODS	17
3.1 Visual Surveys.....	17
3.1.1 <i>Double Observer Pair (DOP) Visual Method.....</i>	21
3.1.2 <i>Systematic Reconnaissance Survey</i>	24
3.1.3 <i>Visual Abundance Surveys</i>	28
3.1.4 <i>Photographic Abundance Surveys</i>	30
3.1.5 <i>Double Observer Pair Visual Survey Analysis</i>	30
3.1.6 <i>Modelling of sighting probability variation.....</i>	33
3.1.7 <i>Data recorder observations.....</i>	34
3.1.8 <i>Analysis of trend.....</i>	35
3.2 Composition Surveys	36
3.2.1 <i>Calving.....</i>	36
3.2.2 <i>Fall/Rut.....</i>	39
3.3 Spatial studies.....	42
4.0 RESULTS	43
4.1 Layout of Survey Strata	43
4.2 Allocation of Survey Effort	49
4.3 Survey Layout Used for Estimates	52
4.4 Analysis of Survey Data	56
4.4.1 <i>Visual survey double observer pair surveys.....</i>	56
4.4.2 <i>Model selection</i>	62
4.4.3 <i>High density photo and visual survey estimates.....</i>	65
4.4.4 <i>Composition surveys to determine proportions of females</i>	69
4.5 Estimates	70
4.5.1 <i>Estimates of total caribou on the calving ground.....</i>	70
4.5.2 <i>Estimates of breeding females and other cohorts on the core breeding ground.....</i>	71
4.5.3 <i>Extrapolated estimate of total herd size</i>	72
4.5.4 <i>Estimates of trend.....</i>	74

4.6 Changes in Annual Calving Extents	79
5.0 DISCUSSION.....	84
6.0 MANAGEMENT CONSIDERATIONS	88
7.0 ACKNOWLEDGMENTS	91
8.0 LITERATURE CITED.....	93

1.0 INTRODUCTION

The Qamanirjuaq Caribou Herd is the largest herd in the western arctic, occupying an estimated annual range of 300,000 km². Caribou are an extremely important form of food security, and are socially and culturally important to the well being of the indigenous peoples of Nunavut, Northwest Territories, Manitoba, and Saskatchewan. The most recent estimates of caribou use (harvest) suggest Kivalliq Inuit utilize over 8,000 Qamanirjuaq caribou per year, followed by Manitoba Dene utilizing an estimated 2,000 caribou per year, and Saskatchewan and NWT range-based communities harvesting an unverified number of caribou per year. Both Saskatchewan and NWT aboriginal harvesters are thought to utilize approximately 500 to 1,000 animals annually (InterGroup, 2013). Within Nunavut, NWT, Manitoba, and Saskatchewan, indigenous harvesters are not required to report their barren-ground caribou harvest, resulting in insufficient data to quantify the harvest across the entire annual range of the Qamanirjuaq herd. Given these limitations, we relied on the 2004 Nunavut Wildlife Harvest study, and anecdotal reports gathered by the Beverly and Qamanirjuaq Caribou Management Board (BQCMB), to approximate the harvest (Priest and Usher, 2004). In total, an estimated 11,000 Qamanirjuaq caribou are harvested annually, which would produce an annual dollar equivalent of over fifteen (15) million dollars in food value to indigenous harvesters. These values likely represent an underestimate as there remains uncertainty around the actual number of caribou that are harvested. Within Nunavut, internet sales of caribou meat to other Nunavut communities are occurring but is not currently tracked or reported. Regardless of the accuracy of the estimated subsistence harvest, any decline in productivity, or increase in mortality herd wide, would have a significant impact on thousands of indigenous peoples across the Qamanirjuaq range.

A satellite telemetry program initiated in 1993 has supported the creation of a comprehensive location and activity database for the Qamanirjuaq herd. This

database has been providing biologists, Hunter and Trapper Organizations (HTOs), Regional Wildlife Organization (RWOs), and inter-jurisdictional and jurisdictional management boards with the only source of western scientific based information examining the Qamanirjuaq herds use of their annual range.

Recent movements (within the last 5 years) of Qamanirjuaq caribou cows have indicated some shifts in calving-grounds, migratory corridors, spring staging areas, and summer range in the vicinity of resource development infrastructure. Additionally, Qamanirjuaq winter range over the last ten years has shown considerable overlap with the Bathurst and Beverly populations of barren ground caribou (Campbell et al. 2012-A; Campbell et al. 2014).

Trend analysis of the Qamanirjuaq herd across the June 1994, 2008, 2014, and 2017 calving-ground photographic surveys indicates a declining trend (Boulanger et al. 2018; Campbell et al. 2015-A; Campbell et al., 2010). Prior to the recorded peak in Qamanirjuaq herd abundance in the mid-1990s, the Qamanirjuaq herd showed signs of decline in the early 1950's (Parker, 1972). These early findings led to an increase in scientific studies attempting to understand the underlying mechanisms responsible for the observed declines (Heard, 1985; Parker, 1972). Research interest and efforts reached a peak between the mid 1970's and late 1980's until the results of a June 1982 survey showed that the downward trend had reversed and herd abundance was increasing (Gates, 1985). This unexpected increase in abundance was not surprising to local hunters as the local knowledge of the time disagreed strongly with the late 1970s survey estimates.

Abundance surveys of the Qamanirjuaq Herd have documented considerable change from late 1970s to present. Abundance survey findings suggest the herd dropped from an estimated 43,800 caribou in 1976 to a historical low of 39,000 adult and yearling caribou in June 1980 (Heard, 1981; Gates, 1983). These earlier surveys, however, were visual only, carrying concerns that at high densities, characteristic of the Qamanirjuaq concentrated calving ground, single observer visual estimates could be imprecise. To correct this problem, Biologists developed the June barren-ground caribou calving photographic survey method first deployed on the Qamanirjuaq herd

in June 1983. The new photographic method indicated increases in abundance over the 1970's single observer visual methods and has been used since. By 1988 the herd was estimated to have increased to 221,000 (SE = 72,000), and by 1994, to 495,665 (SE = 105,426), the highest recorded abundance for the herd. By June 2008 the Qamanirjuaq subpopulation was estimated to be 344,078 (SE = 44,861) adults and yearlings (Russell, 1990; Williams, 1995; Campbell et al., 2010) which represented a significant decline from the June 1994 estimate.

From June 1983 to present, estimates of Qamanirjuaq herd size have been based on a combination of aerial photography and visual assessments of the calving ground, where the numbers of breeding cows are counted and herd abundance extrapolated using fall composition counts (**Table 1**). Up until 1994 the herd appeared to have been growing. Evidence of a decline was first detected In June 2008, at which time the Government of Nunavut estimated 344,078 (95% CI=287,208-400,948; CV=8.1%) adult caribou. A second survey flown in June 2014 estimated 264,718 (95% CI=220,634-308,802; CV=8.3%) adult caribou. The reduction in abundance between June 2008 and June 2014 was significant (DF=71.3; T=-2.23; P=0.029) suggesting a 23% decline over the 6 years between estimates. A survey flown in June 2017, estimated 288,244 (95% CI=242,121-334,367; CV=7.8%) adult caribou. Total number of caribou (adults and yearlings) estimated on the calving ground in 2017 was 262,272 (SE=16,746) in June 2014 and 252,060 (SE=15,493). Weighted log-linear regression of the adult female estimates from 2008, 2014, and 2017 suggest a non-significant decreasing trend with a yearly λ estimate of 0.98 (CI=0.94-1.01) further indicating a longer-term declining trend of 2% (CI=-6% to +1%) per year. Using a regression simulation approach for the 2008, 2014, and 2017 surveys, Boulanger et al. (2018) were further able to demonstrate that the majority of trend estimates suggested a negative trend ($\lambda < 1$). The mean λ estimate in this case was 0.975 (percentile 95% CI=0.95-1.00) which is similar to that obtained from regression analysis.

Community-based information has also raised considerable concern for the future of the herd across the Kivalliq region due to recent unpredictable movements of the herd across its spring, calving, and summer range in addition to a thriving inter-territorial

meat sales market largely between the Kivalliq and Baffin Regional communities. These concerns were heightened with a documented drop in relative densities of calving Qamanirjuaq caribou between reconnaissance surveys flown in June 2008, 2010 and 2012.

Table 1. A survey history of the Qamanirjuaq Herd showing estimates and the methods used to derive estimates. Photographic survey methods provide the most reliable results and are generally used when relative densities are high.

Year	Total Herd Size			Source
	Y _h	SE	CV	
1968	63,000			Parker, 1972 (Visual Calving-ground Survey)
1976	43,800			Calef & Hawkins, 1981 (Visual Calving-ground Survey)
1977	44,095	n/a	n/a	Heard, 1981 (Visual Calving-ground Survey)
1980	39,000	n/a	n/a	Heard & Calef, 1986 (Visual Calving-ground Survey)
1982	180,000	n/a	n/a	Heard & Calef, 1986; Gates, 1985 (Visual Calving-ground Survey)
1983	230,000	59,000	0.258	Heard and Jackson, 1990; Thomas, 1998; Williams, 1995 (Calving-ground Photo-Survey)
1985	272,000	142,000	0.523	Heard and Jackson, 1990; Thomas, 1998; Williams, 1995 (Calving-ground Photo-Survey)
1988	221,000	72,000	0.328	Heard and Jackson, 1990; Thomas, 1998; Williams, 1995 (Calving-ground Photo-Survey)
1994	495,665	105,426	0.213	Unpublished data; Thomas, 1998 (Calving-ground Photo-Survey)
2008	344,078	48,861	0.081	Campbell, Nishi, & Boulanger, 2010 (Calving-ground Photo-Survey)
2014	264,718	21,913	0.088	Campbell, Boulanger, & Lee. 2015 (Calving-ground Photo-Survey)
2017	288,244	22,438	0.078	Campbell, Boulanger, & Lee. 2018 (Calving-ground Photo-Survey)

The present work was designed to re-assess the abundance and trend of the Qamanirjuaq mainland migratory barren-ground caribou subpopulation. We designed the survey to meet the following 4 objectives: 1) Obtain an estimate for the number of females on the calving ground with a coefficient of variation of <15%; 2) Determine the trend in herd abundance since 2008; 3) Estimate the ratio of breeding females to the total number of females at peak of calving as an indicator of productivity; 4) Delineate the spatial extent of the annual calving ground and compare this to historical calving ground use.

2.0 STUDY AREA

Using annual location data collected from satellite and GPS collars between 1993 and 2013 we estimated the Qamanirjuaq caribou herd range to cover an estimated 310,000 km², (**Figure 1**). The annual range is large with its northern extents starting from the southern shores of Baker Lake and Chesterfield Inlet (latitude 57 degrees north), extending south to northeastern Saskatchewan and northern Manitoba. The Qamanirjuaq range is bounded to the east by the Hudson Bay coastline and to the west by longitude 105 degrees. The annual range covers four jurisdictions NWT, Manitoba (Man), Saskatchewan (Sask), and Nunavut (NU), and includes seven communities; Brochet Man., Tadoule Lake Man., Black Lake Sask., Wollaston Lake Sask., Arviat NU, Whale Cove NU, Rankin Inlet NU, Baker Lake NU, and Chesterfield Inlet, NU. Most of the annual range including the calving and post-calving range, as well as the spring and fall migration corridors, lie entirely within Nunavut, while the early- mid- and late-winter ranges extend into all four jurisdictions.

The Qamanirjuaq caribou annual range extends from the northern Arctic ecozone at its northeastern edge through the southern Arctic ecozone into its largest expanse in the taiga shield ecozone and ending with its southern tip within the boreal shield ecozone and at its southeastern tip within the Hudson plain ecozone (Environment Canada, 2009, **Figure 2**). Though the herd occupies five different ecozones, it rarely ranges into the northern arctic ecozone and are more commonly observed within the southern arctic ecozone during spring and summer. Dominant seasonal range within the southern arctic ecozone include spring migratory, calving, post-calving and portions of the early summer range. The Taiga Shield covers the largest portion of the Qamanirjuaq herds annual range making up most of the herds late summer, fall migration, fall rut, early winter, and late winter seasonal ranges while the Hudson Plains and Boreal shield are less commonly used across most years (Campbell et al. 2012: Environment Canada, 2001; Wiken, 1986).

The Southern and Northern arctic ecozones are dominated by open tundra largely made up of graminoid, herbaceous shrub, and ericaceous shrub habitats, with lichen mats common across aggregate glacial deposits, beach ridges, and rocky ridges. The Taiga Shield is dominated by open lichen woodlands with interspersed grasslands and shrubby habitats, While the Hudson plains and Boreal shield ecozones are more dominated by closed conifer and mixed forest, arboreal lichens, with interspersed grasslands and shrubby habitats.

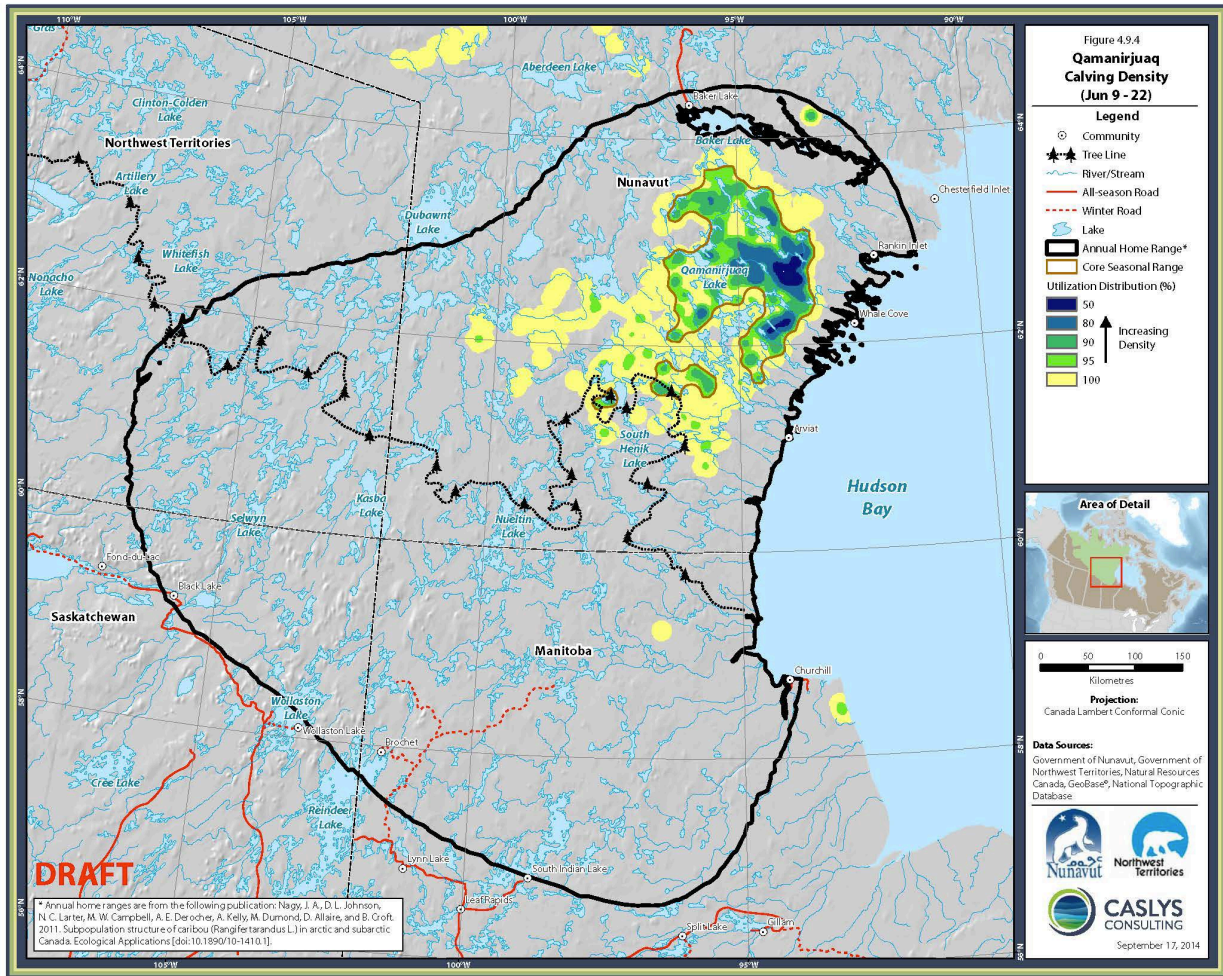


Figure 1. The annual range extents (bold black line) and annual concentrated calving area (dark blue, green, and yellow) of the Qamanirjuaq barren-ground caribou herd. Range extents were calculated using a kernel analysis of satellite and GPS collar data collected between November 1993 and April 2013 (Campbell et al. 2014).

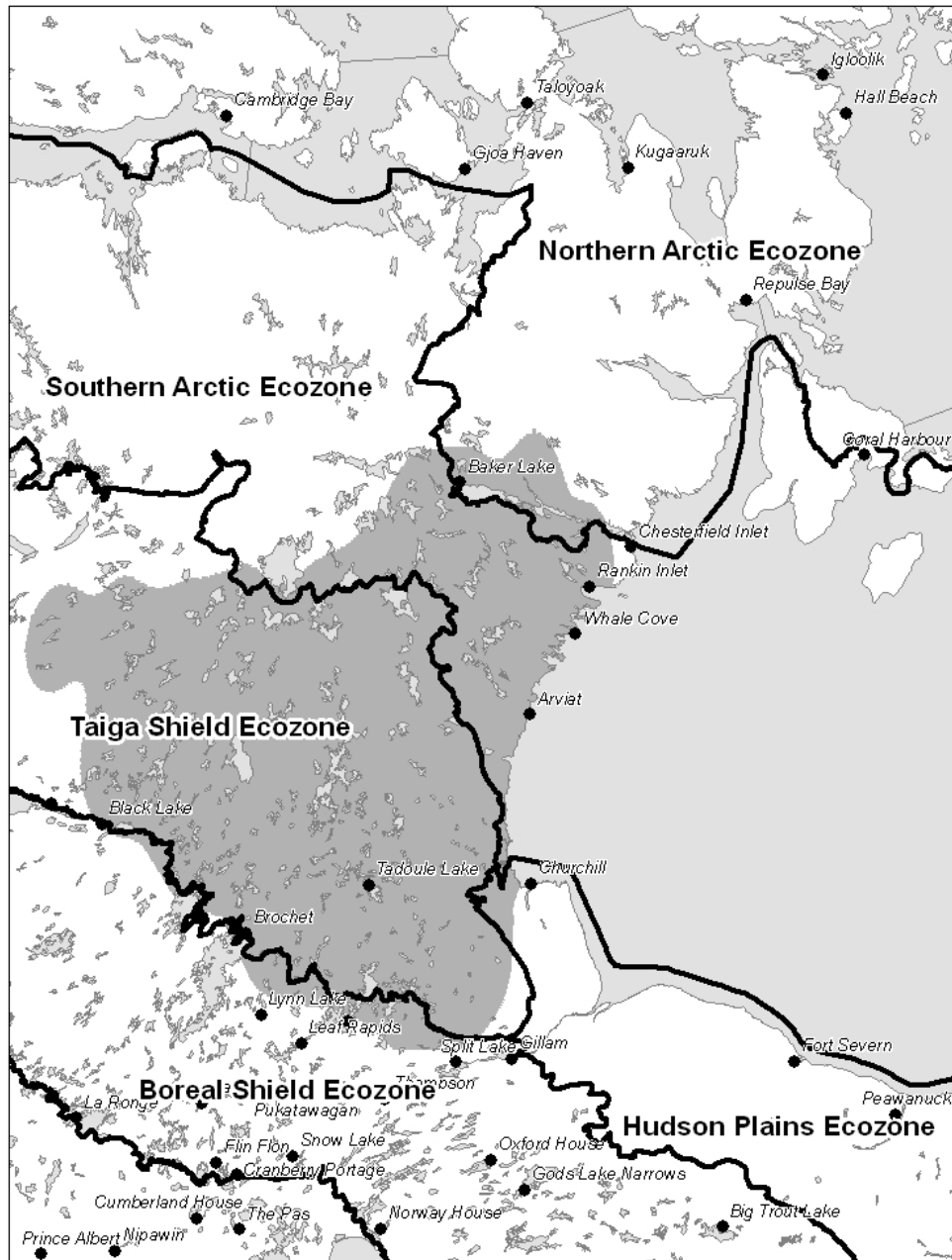


Figure 2 Ecozones of the Qamanirjuaq caribou herd annual range (1993 to 2008) (Environment Canada, 2001; Wiken, 1986). Dark shading is the known Qamanirjuaq annual range (The communities of Hall Beach and Repulse Bay have since been renamed Sanirajak and Naujaat respectively).

3.0 METHODS

The 2022 Qamanirjuaq barren-ground caribou double observer pair (DOP) visual and photographic calving ground survey was based out of the community of Rankin Inlet, Nunavut, with periodic refueling stops in the community of Arviat, 300 km south of Rankin. The survey was structured into five main components: 1) Systematic reconnaissance DOP visual survey, 2) DOP visual abundance survey, 3) Photographic abundance survey, 4) Density-based abundance strata composition surveys and 5) fall composition surveys. The systematic reconnaissance survey was initiated when GPS collar movement rates reached or fell below 5 km/day. The purpose of the reconnaissance survey was to develop strata to delineate discrete areas of similar breeding female and non-breeding female relative densities, commonly termed very low, low, medium and high. These delineated strata were then flown during the abundance phase of the survey using degrees of flying effort that would grade from high percent coverage in the highest density strata, to lower percent coverage within lower density strata. Aerial photography was utilized within the highest density strata where, in past surveys, densities have been found to be too high for accurate visual counts. The DOP visual abundance survey and the concurrent stratum-based composition surveys were used to estimate the total number of females and breeding females on the annual concentrated calving grounds, while fall composition survey results were used to extrapolate female abundance to whole herd estimates by incorporating the male to female ratio.

3.1 Visual Surveys

Two high-wing, twin engine, turbine, DeHavilland Twin Otter aircraft were used for both the reconnaissance and visual abundance surveys across the entire survey study area. Left and right observation strip widths were established using streamers attached to the wing struts (**Figure 3**). To configure the strip widths (w) on aircraft struts we used Norton-Griffiths (1978) formula:

$$w = W * h/H$$

Where:

W = the required strip width;

h = the height of the observer's eye from the tarmac; and

H = the required flying height

Based on decades of aerial wildlife survey work and analysis, the strip width was configured out to 400 meters at 122 meters above ground level (AGL) on each of the left and right aircraft struts, for a total transect width of 800 meters. All aircraft were equipped with radar altimeters to ensure an altitude of 122 meters AGL was maintained accurately while on transect. During the reconnaissance survey, caribou were classified where and when possible as adult with or without antlers, adult with or without calf, female, yearling, or bull.

The DOP method implemented during all phases of the June 2022 reconnaissance and abundance surveys is very similar to the strip transect method used in pre-2008 calving ground surveys with the exception of the addition of a second pair of observers. The double observer pair method allows for the comparison of caribou sightability between front observer pairs (primary observers) and rear observer pairs (secondary observers). Due to the high densities of observations typically encountered during barren-ground caribou surveys, we utilized a cooperative modification to the method between same side observers. This modification allows same side observers to discuss their observation as long as ample time is given to ensure each observer has actually seen

the same group. For every observation, we collected additional information (co-variates) including visibility, ground speed, percent snow cover, elevation indices, and percent cloud cover to help estimate caribou sightability and resulting most representative statistical models used to assess abundance and associated reliability. Off-transect observations were optional during the abundance phase of the survey so that observers could maintain their primary focus on effectively searching the 400-meter strip of ground between the strut markers, also termed the observation bin.

To increase data entry speed without reducing accuracy, and to reduce the time required to perform preliminary analysis of reconnaissance data for abundance survey stratification, a digital data entry system, termed the “Aerial Wildlife Survey – Observation Collector” (AWS-OC), was utilized for this survey (Campbell et al. 2012). The software was developed by the Government of Nunavut, Wildlife Research Division, in collaboration with Integrated Ecological Research, Caslys Consulting Ltd, and Nunavut Tunngavik Inc (NTI), in 2011, and originally deployed on the June 2011 Beverly mainland migratory barren-ground caribou calving ground abundance survey (Campbell et al. 2012). Since its original launch, improved hardware, and some enhancements to the AWS-OC software had been undertaken prior to its deployment in June 2022 (Boulanger et al. 2018). The AWS-OC software operates with Windows editions 7 through 10 and was developed specifically for use in both independent and dependent double-observer pair aerial caribou surveys, including distance-sampling applications, to facilitate the collection of field data, and the subsequent management of the resultant observation dataset. This tablet-based system allows for the instantaneous entering of caribou group waypoints (observations) directly into a digital database. Data entry time was cut by approximately 50% over standard hand written datasheets, with the added benefits of continuous back up onto a USB drive into a digital database with no additional data entry required.

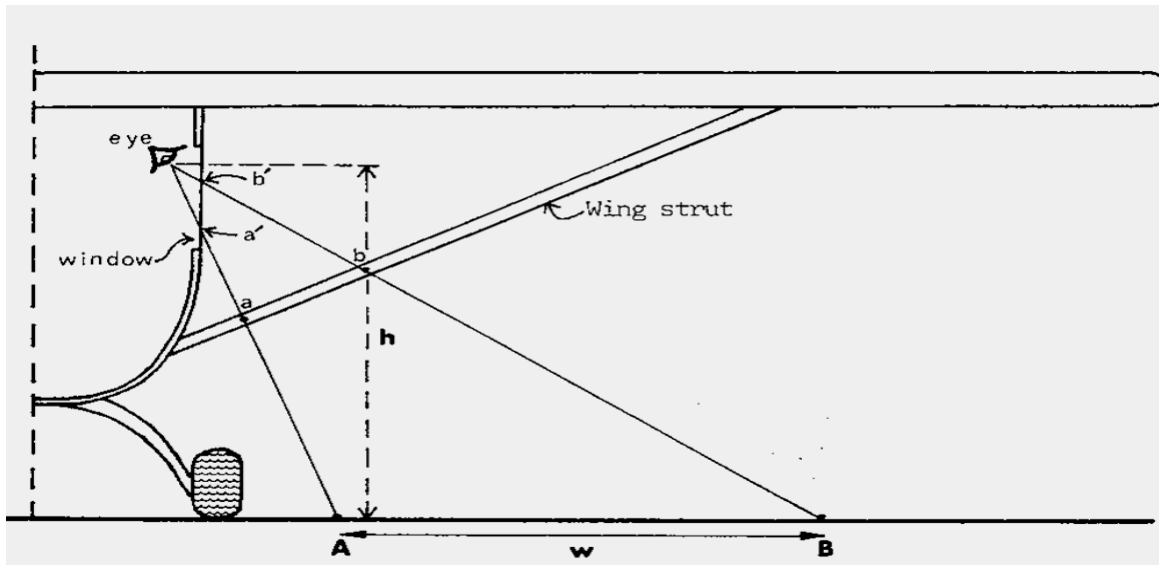


Figure 3 Schematic diagram of aircraft configuration for strip width sampling (Norton-Griffiths, 1978). w is marked out on the tarmac, and the two lines of sight $a' - a - A$ and $b' - b - B$ established. The streamers are attached to the struts at a and b , whereas a' and b' are the window marks.

3.1.1 Double Observer Pair (DOP) Visual Method.

The double-observer pair method was designed to increase the accuracy and precision of wildlife observations during visual surveys using both fixed wing and rotary wing aircraft. This method involves two pairs of observers on each of the left- and right-hand sides of the aircraft. Two “primary” or front observers who sit in the more forward seats over the wing struts and two “secondary” or rear observers who sit behind the primary observers (**Figure 4**). By design the method adheres to five basic steps:

- 1) The primary observer called out all groups of caribou (number of caribou and location) he/she saw within the 400-meter-wide strip transect before they passed halfway between the primary and secondary observer (approximately at the wing strut). This included caribou groups that were between approximately 12 and 3 o’clock for right side observers and 9 and 12 o’clock for left side observers (**Figure 4**). The main requirement was that the primary observer be given time to call out all caribou seen before the secondary observer called them out;
- 2) The secondary observer called out whether he/she saw the caribou that the first observer saw and observations of any additional caribou groups. The secondary observer waited to call out caribou until the group observed passed half way between observers (between 3 and 6 o’clock for right side observers and 6 and 9 o’clock for left side observer);
- 3) The observers discussed any differences in group counts to ensure that they had called out the same groups or different groups and to ensure accurate counts of larger groups;
- 4) The data recorder, one in front of the left side observers and the second in front of the right-side observers, categorized and recorded counts of each caribou group into “front only”, “rear only”, and “both”, while recording predetermined co-variates; and
- 5) The left two observers and right two observers switched places approximately half way through each survey day (i.e. during refueling or within a stratum) to address

observer ability and sightability differences between the front and rear seats. The recorder noted the names of the front and rear observer for all observations.

The sample unit for the survey was “*groups of caribou*” not individual caribou. Recorders and observers were instructed to consider individuals to be those caribou that were observed independent of other individual caribou and/or groups of caribou. If sightings of individuals were within close proximity (within an estimated 200 meters) to other individuals then the caribou were considered a group.

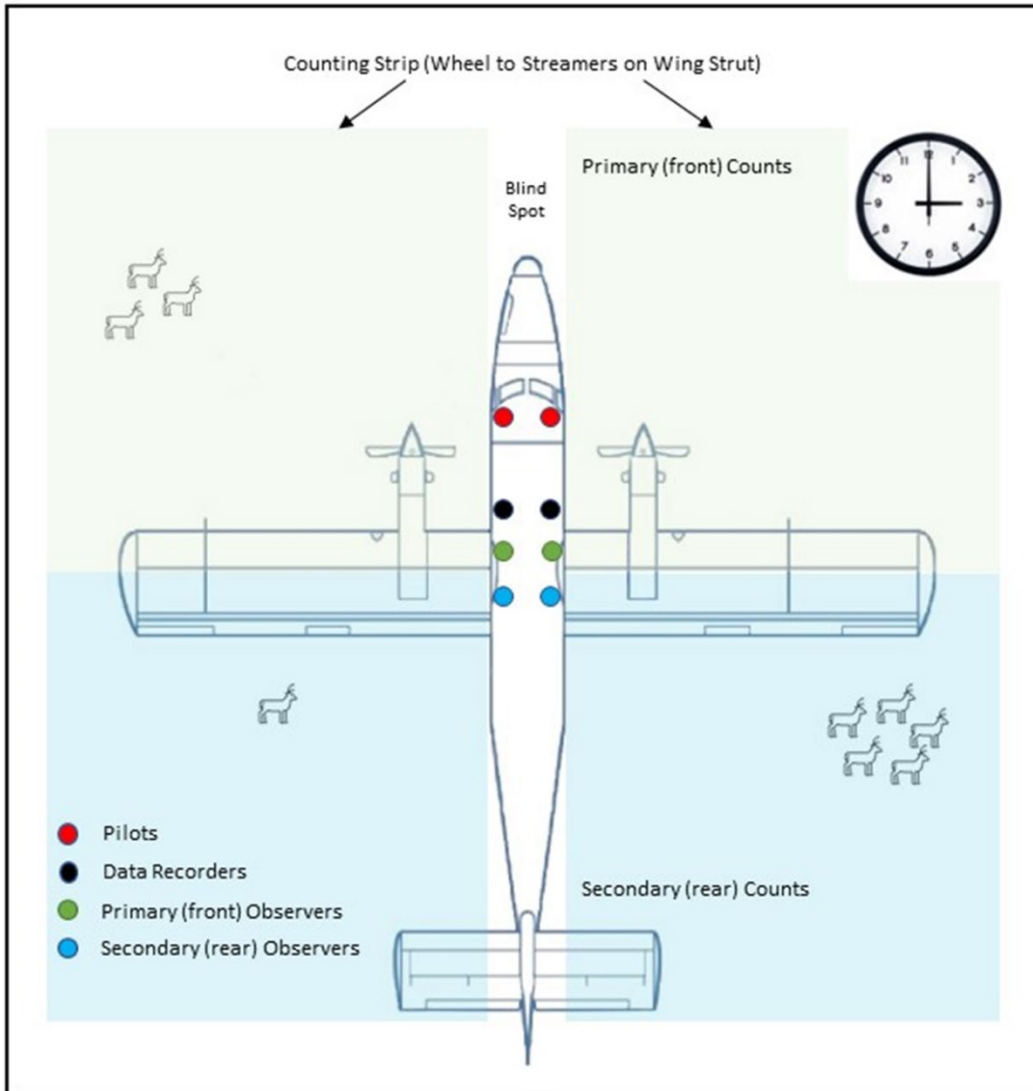


Figure 4. Observer position for the double observer pair method deployed on this survey using Twin Otter aircraft. The rear (secondary) observer (blue shaded area) calls caribou not seen by the front (primary) observer after the caribou have passed the main field of vision of the front observer (light green shading). The small hand on a clock is used to reference relative locations of caribou groups (e.g., “Caribou group at 3 o’clock” would suggest a caribou group 90° to the right of the aircrafts longitudinal axis.).

3.1.2 Systematic Reconnaissance Survey

The systematic reconnaissance survey was designed to estimate relative densities and delineate aggregations of females and breeding females (hard antlered cows or cow/calf pairs) for the purposes of stratifying the calving ground for the subsequent photo and visual abundance surveys. We used the observed locations of hard-antlered cows, newborn calves and aggregations of bulls and yearlings to delineate the spatial extent of the annual calving ground (Heard and Jackson, 1990; Thomas, 1998; Williams, 1995; Bergerud et al. 2008). The systematic reconnaissance survey of the annual calving ground was flown June 6th and 7th, 2022. Some additional reconnaissance was flown June 9th following the completion of the abundance phase and along known spring migratory corridors to ensure distributions of breeding females were not missed.

The reconnaissance survey was based on a systematic array of transects running north-south (**Figure 5**) and spaced at 10-kilometer intervals. Each transect was further divided into adjoining 10 kilometer transect segments, with each segment identified by a unique alpha-numeric code assigned to the transect station defining its northern end. The reconnaissance survey used these pre-determined transect segments (defined as one 10 km segment between two transect stations) to bin caribou observations for the purposes of calculating relative density within the segment. A rigid set of criteria governed when the 10 kilometer transect segments were flown. Criterion controlling when and where transect segments would be flown varied slightly across the calving distribution.

As the historic distribution of the Qamanirjuaq herd consistently displayed a distinct northern boundary along the leading edge of known migratory extents, while the southern, eastern, and western extents showed more inter-annual variability. For these reasons, rules controlling when to discontinue a transect varied between the northern extent of the distribution and that of the southern, eastern and western. Consecutive transect segments were flown north along the reconnaissance grid until no females and/or breeding females (hard antlered cows or cow/calf pairs) were observed within the ten-kilometer segment being flown. To further define the northern limit of breeding and non-breeding cows, parallel ten kilometer transect segments, adjacent to the

additional northern segment, would also be flown. Along the more southerly “trailing edge” of the observed caribou distribution, the reconnaissance survey continued two full transect segments (including those segments directly east and west) beyond any surveyed segment where fewer than 2 breeding females/females were observed. On the western extents where caribou densities were in excess of 5 animals per ten kilometer transect segment and/or breeding female densities below 2 per transect segment, additional western transects would be flown at 20 km spacing between transects rather than ten, to increase area coverage and to ensure aggregations of breeding females/females were not missed. We intermittently continued the reconnaissance along known spring migratory corridors to ensure distributions of females/breeding females were not missed (**Figure 6**).

Following the systematic reconnaissance but prior to the initiation of the visual and photographic surveys, all tabulated observations were entered in to ESRI GIS software to calculate relative densities of breeding females using a tool utility. The relative density tools were built in ESRI’s Model Builder (v9.1) utility and loaded into Arc Toolbox. The tools allowed us to calculate the relative density of observed caribou locations along the reconnaissance transects and associated transect segments and display these results on a map. We used vector-based analysis methods based on the following steps: 1) The survey transect segments were buffered by a user-specified width (i.e., 800 meters) yielding polygons that were 8 km² (i.e., 0.80 km wide x 10 km long); 2) The survey observations points were intersected with the derived buffer polygons; 3) The density was calculated for each polygon by dividing the number of 1+ year-old caribou by the area of the buffer polygon (#1+ year old caribou/km²); 4) The relative density (#obs/km²) is then thematically displayed on a map based on pre-defined classes or bins. The resulting graphics were then used to stratify the breeding female/female distributions into High, Medium, low, and very low-density strata to prepare for the abundance phase of the survey.

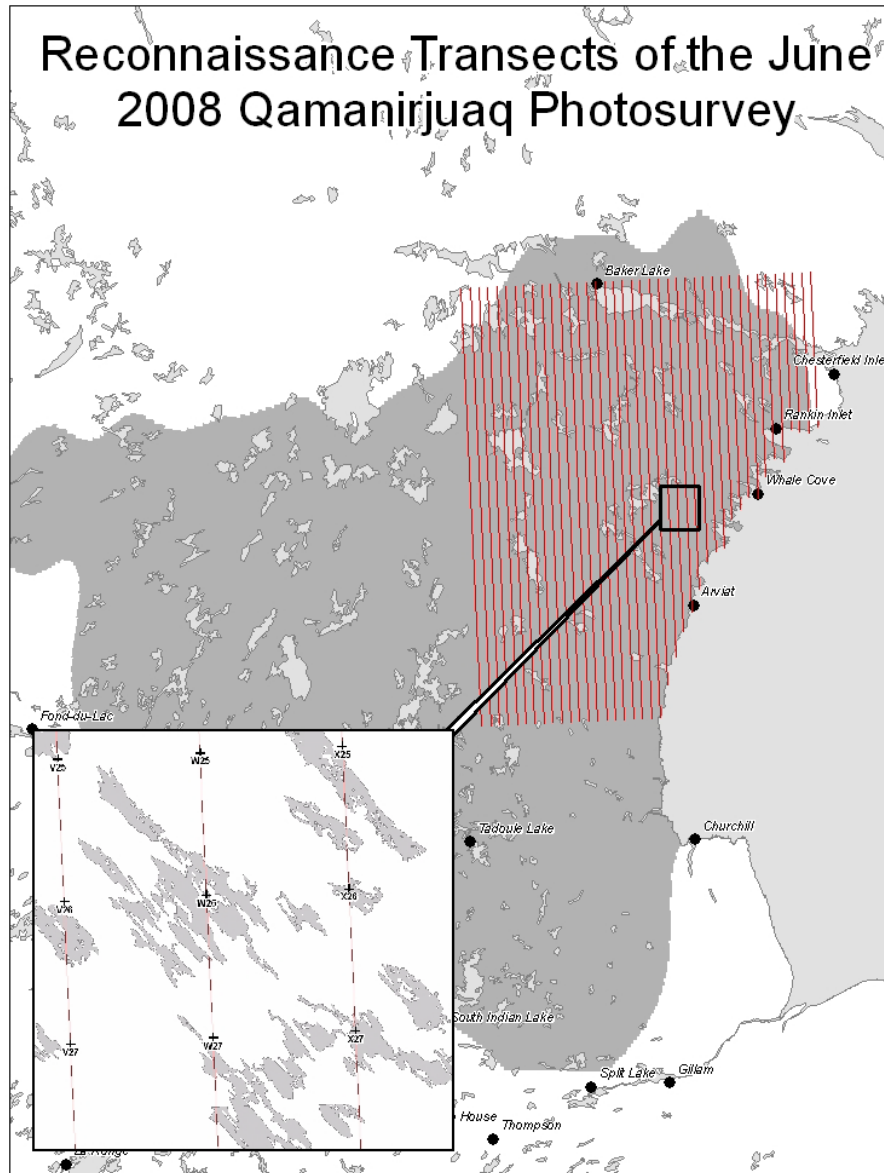


Figure 5. Potential reconnaissance transects and transect stations designed to cover the known extent of calving for the Qamanirjuaq barren-ground caribou herd in June 2022. These same transects were used in all consecutive surveys flown from June 2008 to present. Not all lines shown in this figure were flown during the 2022 survey.

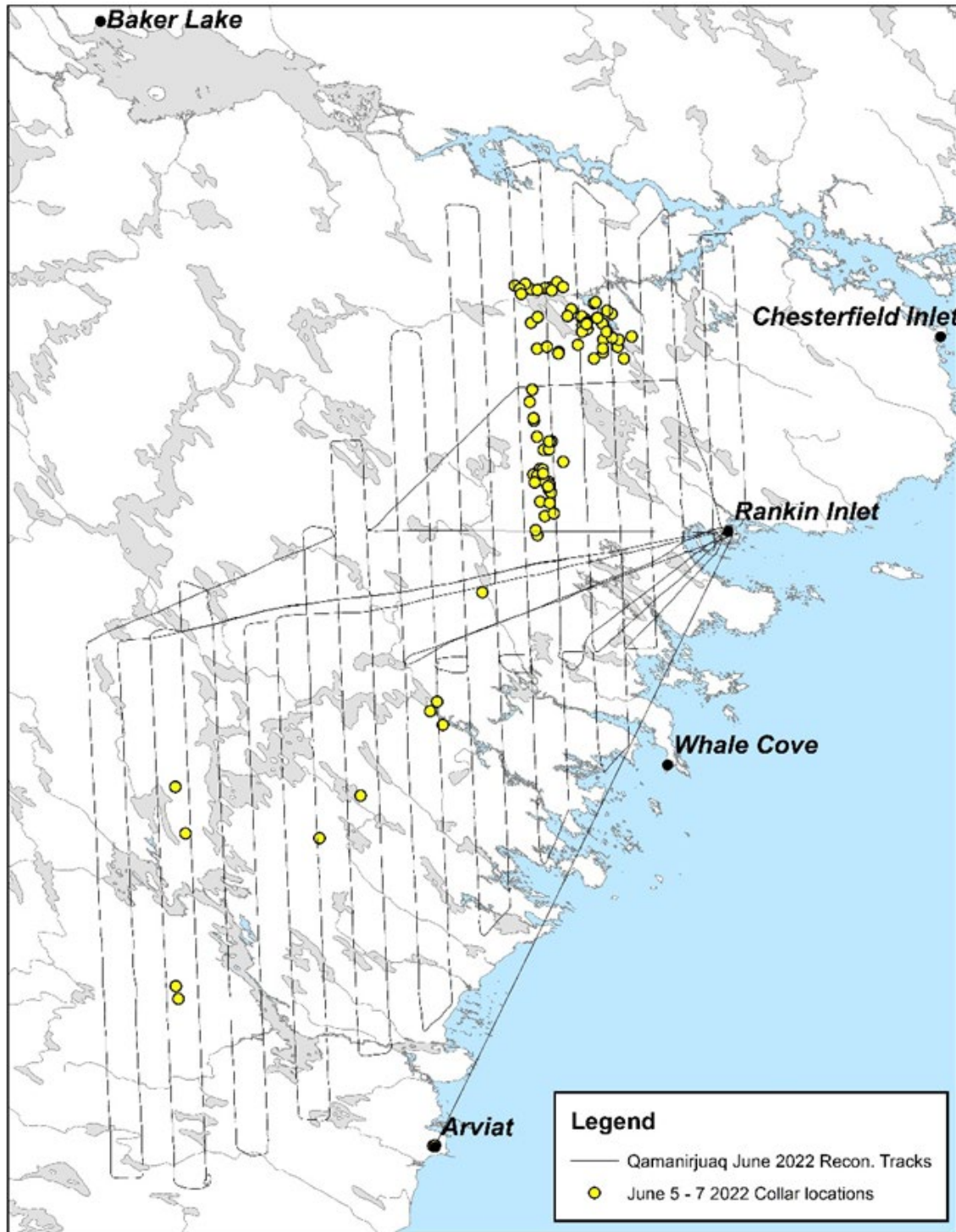


Figure 6. Qamanirjuaq Caribou Herd June calving-ground reconnaissance survey flown June 6th and 7th, 2022. Yellow dots show all collared Qamanirjuaq caribou cow locations over the same period.

3.1.3 Visual Abundance Surveys

The visual abundance survey was conducted within 4 low to medium density strata all located entirely within the breeding female/female distribution identified using reconnaissance survey results (**Figure 7**). Stratum boundaries were visually aligned with the relative density graphic to capture transect segments of similar density. All visual strata were surveyed immediately following the completion of the systematic reconnaissance of breeding female/female distributions.

The visual survey followed the same methods as the systematic reconnaissance survey with the exception of transect allocation, coverage, and alignment. Transects within each of one medium density (vis-1), one medium-low density (vis-4), and two low density (vis-3+4) strata were aligned at right angles to the longitudinal axis of the stratum to maximize the total number of transects (N). Transect spacing was allocated based on relative densities calculated within each individual stratum (**Figure 7**). Within the medium density stratum transects were placed three kilometers apart providing approximately 30% coverage, while within low and very-low density strata, transect spacing was set at 3.17 km and 10 km yielding 30% and 9% coverage respectively.

Visual survey data collected within each stratum were analyzed using Jolly's Method 2 for unequal sample sizes (Jolly 1969 *in* Norton-Griffiths 1978). Only counts of adults were used for the final population estimates. Lake areas were not subtracted from the total area calculations used in density calculations.

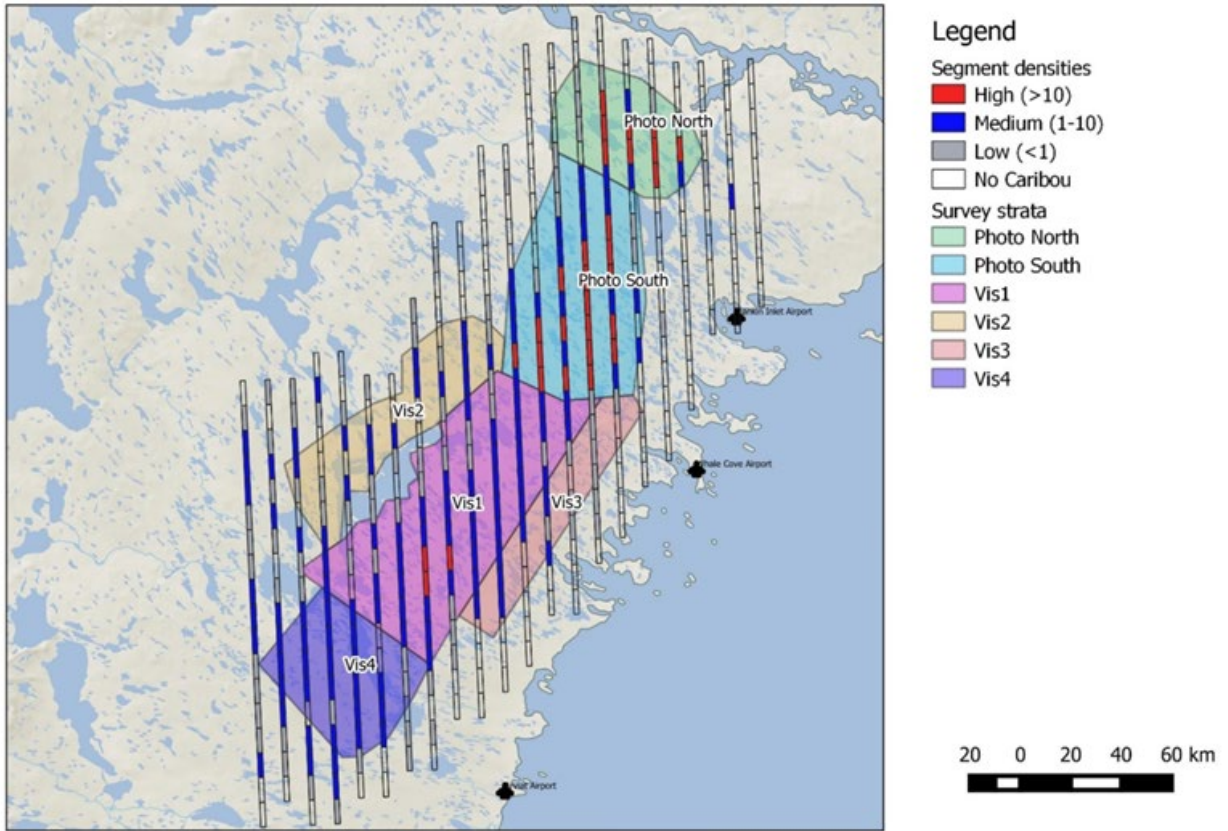


Figure 7. Reconnaissance transects with transect station relative densities overlaying strata derived using reconnaissance relative abundance segment estimates. Data collected, and strata derived during the 2022 Qamanirjuaq calving ground photographic abundance survey.

3.1.4 Photographic Abundance Surveys

Aerial photography provides more accurate abundance estimates of large mammals due to its ability to remove in-flight observer error and bias, and replace it with more controlled interpretation after the fact. This advantage is significantly increased when caribou relative densities exceed 10 to 15 caribou per kilometer squared, a point at which in flight observer error can become substantial. The photographic component of the survey used a single engine low wing Piper Malibu turbine aircraft. The aircraft was equipped with a radar altimeter and a digital camera with forward motion compensator. The photographic component of the 2022 Qamanirjuaq calving ground survey was designed to capture relative densities of adult and yearling female and breeding female caribou in excess of ten caribou per kilometer squared as close to the completion of the systematic reconnaissance survey as possible. The photographic abundance survey was completed June 8th, 2022. As in the visual survey, transect spacing within the high-density photo strata was allocated based on proportional densities and available resources (Heard, 1987). During the June 2022 survey effort, high density transect coverage ranged from 45% to 54% coverage over the photo-north and photo-south photographic strata respectfully. Approximately 4,000 photos were taken within delineated photographic abundance strata, representing an estimated 900 linear kilometers of flying.

3.1.5 Double Observer Pair Visual Survey Analysis

Removal models in the *mrds* package were used to estimate and model sighting probabilities. In this context, double observer sampling can be considered a 2-sample mark-recapture trial in which some caribou are seen (“marked”) by the (“session 1”) primary (front) observer of which some are also seen by the secondary (rear) observer (“session 2”). The second observer may also see caribou that the first observer did not see. This process is analogous to mark-recapture except that caribou are sighted and resighted rather than marked and recaptured. A group of caribou rather than the

individual caribou was the sample unit given that the sighting probabilities of caribou within a group were not independent.

In the context of dependent observer methods, the sighting probability of the secondary observer was not independent of the primary observer. To accommodate this, removal models were used which estimated p (the initial probability of sighting by the primary and secondary observer) and c (the probability of sighting by the secondary observer given that it had been already sighted by the primary observer). Note that resighting probability (c) is not equivalent to the initial sighting probability of a caribou (p). Also, the removal model assumed that the initial sighting probability of the primary and secondary observers was equal. Therefore, observers were switched midway in each survey day, and covariates were used to account for any differences that were caused by unequal sighting probabilities of primary and secondary observers (as discussed later). The combined probability that a group of caribou was seen by at least one of the observers (p^*) was therefore $1-(1-p)(1-p)$. **Figure 8** provides a conceptual argument for how p^* is estimated. It is p^* that is then used to estimate the overall sightability of caribou and adjust counts for caribou not sighted.

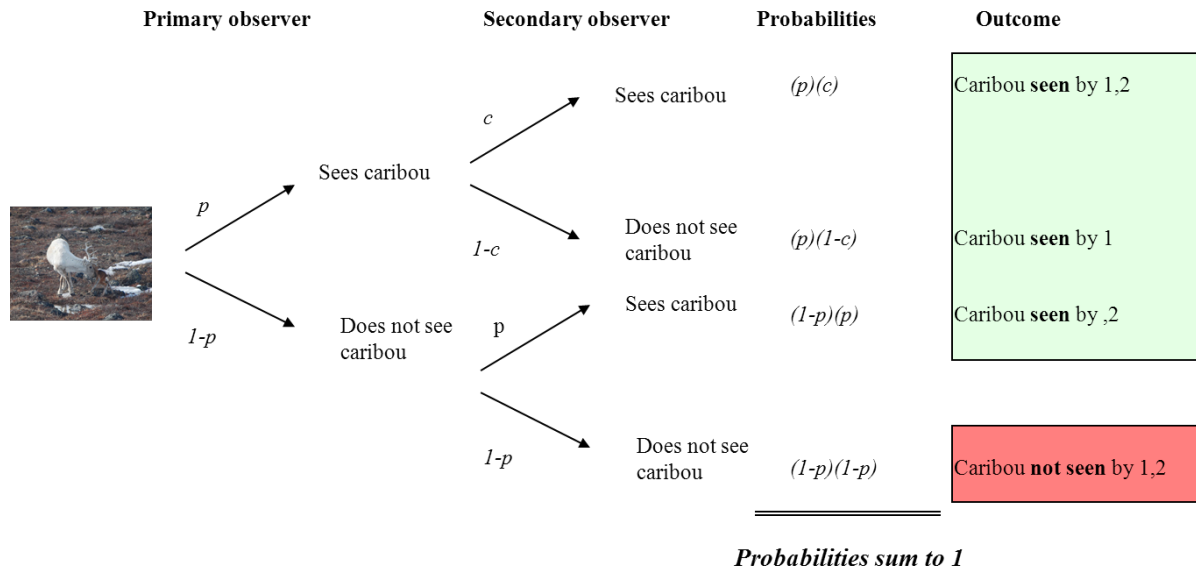


Figure 8. Conceptual diagram of how the probability of both observers not sighting a caribou group is estimated, and how the probability that at least one of the observers sees the caribou group (p^*) is estimated. The green boxes correspond to outcomes where caribou are seen and the red box corresponds where both observers do not see a caribou group. Mark-recapture methods are used to estimate sighting probabilities for the primary observer 1 and primary observer 2 (using data from when each observer is situated as the primary observer). Using these probabilities, the probability that a caribou is not seen can be estimated. In a method analogous to flipping a coin, each observer will see or not see a caribou as described by p (caribou seen) or $1-p$ (caribou not seen). Each of these outcomes can then be multiplied to obtain the probabilities for both observers combined. Because the two observers do communicate, the events are not independent and therefore the re-sighting probability of the secondary observer has to be adjusted (to c) using behavioral response removal models when the caribou was called out by the primary observer. However, since the probabilities sum to 1 it is possible to estimate the overall probability that the caribou group is sighted (p^*) as one minus the probability that none of the observers saw the caribou $(1-p_{ob1})(1-p_{ob2})$ (the red box) or by summing the probabilities in the green box.

Estimates of caribou within survey strata, and associated variance, were estimated using the mark-recapture distance sampling (MRDS) package (Laake et al. 2012) in program R program (R Development Core Team 2009). In MRDS, a full independence removal estimator which models sightability using only double observer information (Laake et al. 2008a, Laake et al. 2008b) was used therefore making it possible to derive double observer strip transect estimates. Strata-specific variance estimates were calculated using the formulas of (Innes et al. 2002) with the “S2” encounter rate estimator (Fewster et al. 2009). Estimates from MRDS were cross checked with strip transect estimates (that assume sightability=1) using the formulas of Jolly (1969) (Krebs, 1998). Data was explored graphically using the ggplot2 (Wickham, 2009) R package. GIS operations were conducted using the simple features (Pebesma, 2018) R package and QGIS software (QGIS Foundation 2020).

3.1.6 Modelling of sighting probability variation

One assumption of the double observer method is that each caribou group observed had an equal probability of being sighted. To account for differences in sightability we also considered the following sightability covariates in the MRDS analysis (**Table 2**). Each observer pair was assigned a binary individual covariate and models were introduced that tested whether each pair had a unique sighting probability. Previous analyses (Campbell et al. 2012, Boulanger et al. 2014a) suggested that the size of the group of caribou had a strong influence on sighting probabilities and therefore we considered linear and log-linear relationships between group size and sightability (**Table 2**). Cloud and snow cover, recorded by data recorders, were recorded as ordinal rankings as they changed across any given observation entry. We suspected that sightability was most likely lowest in mixed snow cover conditions and therefore we considered both categorical and linear models to describe variation in sightability caused by snow cover. Cloud cover, or the lack there of, could also influence sightability by causing glare, flat light, or variable lighting. We used the same basic strategy to model cloud cover variation and snow cover variation. Survey phase (reconnaissance or visual abundance survey) was also considered.

Table 2. Covariates used to model variation in sightability for double observer analysis.

Covariate	Acronym	Description
observer pair	obs	each unique observer pair
group size	size	size of caribou group observed
	Log(size)	Natural log of group size
snow cover	snowF	snow cover (0,25,75,100)
	snowc	continuous
cloud cover	cloudcat	cloud cover (0,10,25,75,100)
	cloud	continuous
Strata	Strata	Strata
Survey phase	Phase	Recon or visual

The fit of models was evaluated using the Akaike Information Criterion (AIC) index of model fit. The model with the lowest AIC_c score was considered the most parsimonious, thus minimizing estimate bias and optimizing precision (Burnham and Anderson, 1998). The difference in AIC_c values between the most supported model and other models (ΔAIC_c) was also used to evaluate the fit of models when their AIC_c scores were close. In general, any model with a ΔAIC_c score of less than 2 was worthy of consideration.

3.1.7 Data recorder observations

Data recorder observations, where data recorders saw caribou that were not observed by observers, were recorded for all of the observer pairs. Data recorder observations do not necessarily need to be included in analyses given that the method allows for observers to miss caribou and therefore the fact that a small percentage of caribou are only seen by data recorders is not surprising. In the context of the dependent double observer method, use of data recorder observations presents some challenges. First, observations from the data recorder are partial; the data recorder only records observations that he/she observes but are not observed by either other observer which

limits the ability to use data recorder observers as a unique third observer. In this context, data recorder observations supplement the secondary observer in “testing” the primary observer.

One approach to include data recorder observations is to pool the secondary observer and data recorder as a single observer. The main potential issue caused by this approach is that it will increase the difference in detection probabilities between the primary and secondary observer regardless of observer position therefore violating the assumption of equal detection probabilities between observers. This could be thought of as always having one primary and 2 secondary observers that have a combined higher detection probability. Because the removal estimator considers observer order, this approach could potentially cause a negative bias in detection probabilities with a subsequent positive bias in abundance estimates. This scenario would likely correspond to cases when both observers have reasonable sighting probabilities. Another scenario, that likely occurred, was where both observers were weak and not including data recorder observations substantively reduced observations leading to a negative bias in estimates. In this case, observer probabilities are low and cannot be estimated using the double observer data alone. To detect this potential scenario, we estimated detection probabilities with and without data recorder observations under that rationale that these pairs could be identified by large differences in detection probabilities with data recorder observations included and excluded. In this case observations from these pairs were potentially included in the analysis with the secondary and data recorder observations pooled.

3.1.8 Analysis of trend

As an initial step estimates were compared using a t-test (Zar, 1996) with variances and degrees of freedom calculated using the formulas of (Gasaway et al. 1986). This comparison gave an initial indication of change in population size, but did not consider the survey interval between two surveys.

Estimates of trend were derived using ratios of estimates for pooled and post stratified estimates. A simulation approach that assumed log-normal distributions of estimates

was used to test for significance between successive estimates as well as confidence limits on overall (gross) change and yearly change in estimates. Confidence limits were then derived based on the 2.5th and 97.5th percentile of the resulting distributions of gross change (GC) and annual change (with $\lambda = GC^{(1/\text{survey interval})}$).

Weighted regression analysis was also used to estimate trend from the time series of data (Brown and Rothery 1993). Each estimate was weighted by the inverse of its variance to account for unequal variances of surveys, and to give more weight to the more precise surveys.

3.2 Composition Surveys

3.2.1 Calving

Composition studies were conducted concurrently with the abundance phase photographic and visual surveys that immediately followed study area stratification. Caribou were classified as yearlings (≥ 1.0 but < 1.1 years of age termed 1+ years of age in this document), bulls, cows with calves (< 1 month old) and 0, 1, or 2 antlers, cows with udders and 0, 1, or 2 antlers, and udderless cows with 0, 1, or 2 antlers. Breeding cows were tallied as cows with calves, cows with udders, and udderless cows with antlers. Adult udderless cows with no antlers were classified as non-breeding females while all remaining adult females were classified as breeding females. All remaining caribou were classified as either yearlings or bulls. The proportion of breeding and non-breeding females was then determined using these categorizations. Bootstrap methods were used to obtain variance estimates for all strata. In this case, 1,000 resampling's of the data were used and the mean and standard deviation from resampling were used as point estimates with associated standard error as a proportion of breeding females, non-breeding females, calves, yearlings and bulls (Manly, 1997).

Composition survey effort was allocated as consistently as possible within each stratum. Selection of flight paths were based on fuel cache locations and caribou aggregations but consistently used the reconnaissance transect station locations in an attempt to maintain consistent coverage throughout the strata being sampled. GPS waypoints were recorded for all groups of caribou where they were first encountered.

June composition surveys were timed to begin concurrently with abundance photographic and visual surveys to ensure minimal movement between strata. Sampling was structured to begin at a fuel cache then proceeded to a predetermined transect station within a maximum of two (2) kilometers of the strata corner/boundary. From this station a Bell 206 Long Ranger aircraft would proceed to the next nearest transect station to the north and/or south, priority sampling the next nearest caribou group including individual caribou (**Figure 9**). At times, observed groups of caribou “pulled” the aircrew from the pre-planned flight path at which time the aircrew would stop sampling caribou groups that were seen greater than 10 kilometers (half the distance between reconnaissance transects) perpendicular to the original flight path. From this point, only caribou groups observed within this ten-kilometer buffer would be sampled and an attempt to rejoin the original flight path made. During re-positioning flights from the stratum to the fuel caches, caribou encountered within a maximum of 2 km inside of target stratum boundaries were classified opportunistically and variation of flight paths was held to within 2 km to conserve fuel and reduce deviation from the planned flight paths and fuel caches.

Estimates of the proportion of females and breeding females were then multiplied by the double observer pair estimate of all adult caribou and yearlings for each stratum to obtain an estimate of the number of non-breeding and breeding females within the survey study area extents. Variances were obtained for the combined estimate using the delta method (Seber, 1982; Williams et al., 2002) assuming no correlation between the two estimates.

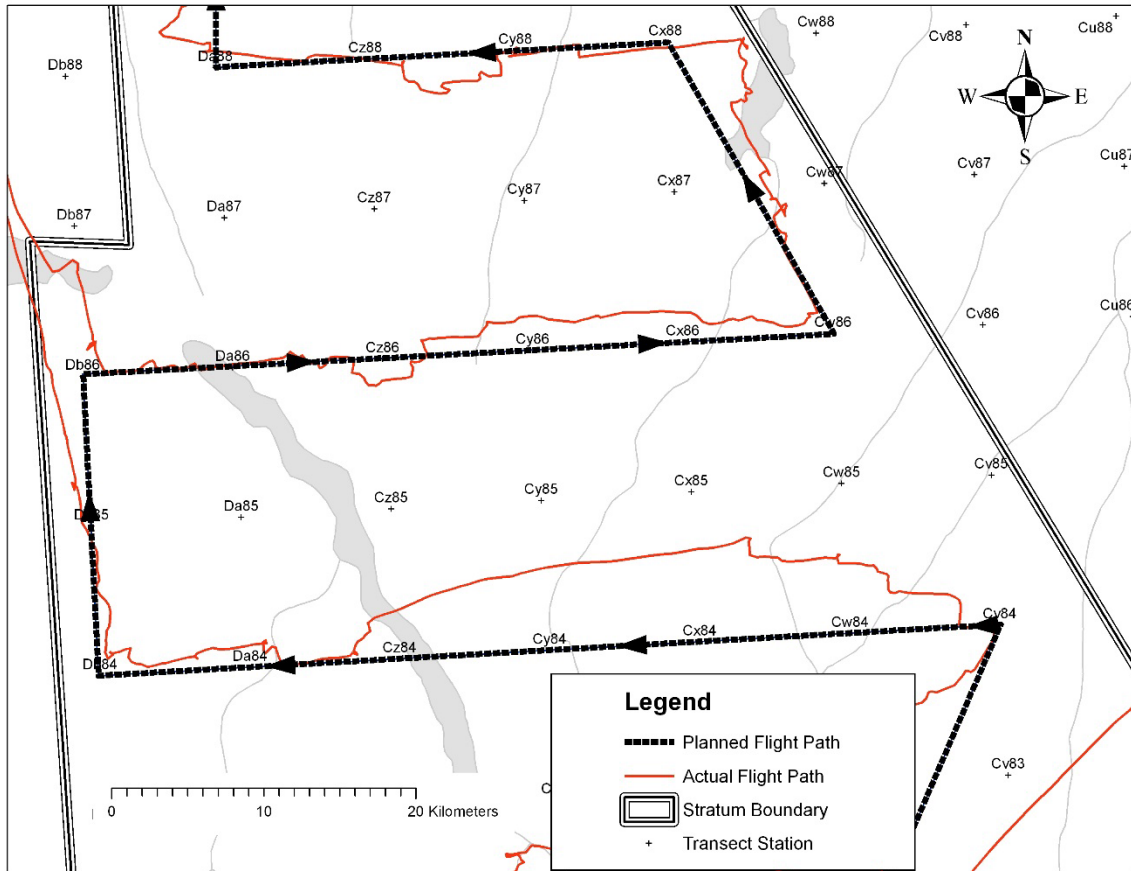


Figure 9. Strata composition flight lines vs. planned routes. Deviations were the result of observed caribou groups away from flight paths. The next nearest group would be classified up to a maximum of 10 km (half way between adjacent transects) perpendicular to the planned flight path.

3.2.2 *Fall/Rut*

The purpose of a Qamanirjuaq fall-rut composition survey is to determine the proportion of females in the population at a time of year when all age and sex classes come together into large mixed groups for the breeding season (rut). Though a combined estimate of breeding and non-breeding females, used in this report, is the most precise, and as such, represents the best indicator of population trend, for management and conservation education purposes, an estimate of total population size is desirable.

The Qamanirjuaq caribou fall composition survey was flown out of Arviat Nunavut, Tadoule Lake Manitoba, and Lac Brochet Manitoba, between October 15th and 20th 2014 (**Figure 10**). The survey itself used the locations of 20 Telonics GPS III and IV collars to locate aggregations of caribou and establish search patterns. All caribou groups encountered between and in the immediate vicinity of collared adult female caribou were classified and tracks followed to locate other groups. All collar locations were searched a minimum of twenty kilometers to the north, east, south and west of the outer most collar locations, with exceptions made when adjacent areas included boulder fields, large lakes, the Hudson Bay coast, or were restricted due to fuel limitations. Fresh tracks in snow were used in all areas to locate new groups. The search of an area represented by collared caribou cows would terminate following the cessation of fresh tracks or when a possibility of double sampling occurred. GPS tracks were also used to ensure the same groups were not re-sampled, which at times required the skipping of groups where there was a risk of mixing. Once the area around a collar or cluster of collars was thoroughly searched, the survey would proceed to the next nearest collar to begin a similar search pattern. In total, 121 groups, or 8,856 individual Qamanirjuaq caribou were classified.

To estimate the total population size, the number of non-breeding and breeding females estimated in June 2022, was divided by the product of the proportion of females in the population as determined during the 2014 fall composition studies. The proportion of females in the population assumed a 50:50 sex ratio for yearlings. We suggest that the proportion of females estimated on the calving ground is a better estimator of herd size and trend as the proportion of females pregnant, used to extrapolate a whole herd

estimate from breeding females alone, is based on dated information and for the Qamanirjuaq population, not sampled since fall 2014. It should be noted that inter-annual variation in sex ratio does occur though large changes in herd sex ratio would be considered atypical for these large mainland migratory herds (Gunn et al. 2005; Sober, 1982).

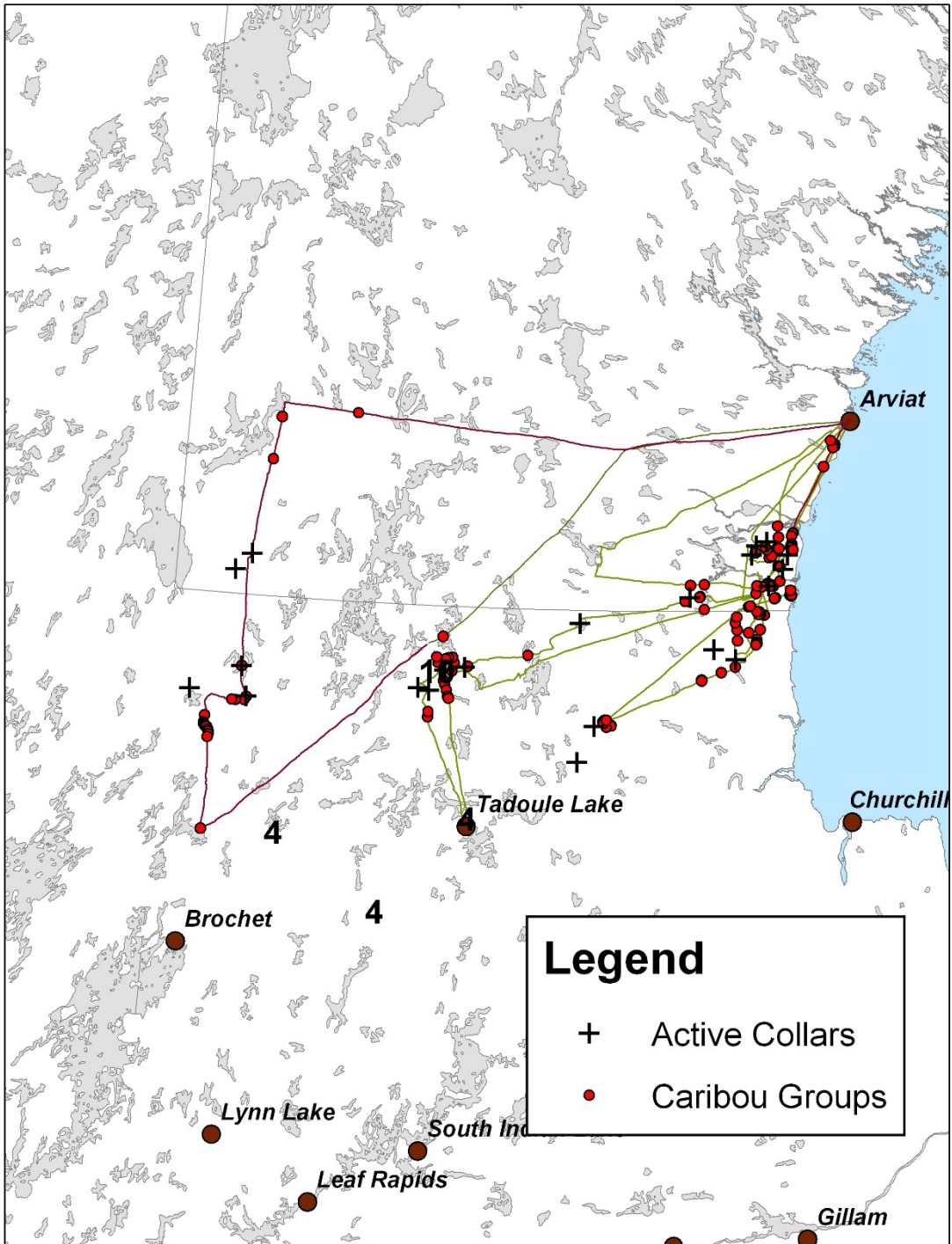


Figure 10. Qamanirjuaq fall composition flight tracks and caribou group locations, October 15 – 20th, 2014 (numbers indicate alternate fuel caches).

3.3 Spatial studies

Utilization distributions were generated for the calving season using telemetry data collected for Qamanirjuaq caribou between 2000 and 2022. Data were resampled to daily locations to address differences in sampling frequencies between collars and only locations collected between April 15th and July 3rd were considered in the analysis. All telemetry locations were attributed with a season based on the following date ranges: spring migration (April 15 – June 8), calving (June 9 – June 22), and post-calving (June 23 – July 3rd). To account for variation in the calving dates between individuals and years, each collar was reviewed and the start and end dates for the calving season were adjusted based on changes in movement pattern. Once the calving date ranges had been refined, a kernel density estimation (KDE) approach was used to generate utilization distributions for a series of data subsets to illustrate changes in calving distributions for Qamanirjuaq through time. The first calving time series examined changes in distribution over four years: 2008, 2014, 2017, and 2022. For each of the four years, the calving data were extracted and used to generate a KDE using a fixed bandwidth value of 9.5 km. The fixed bandwidth value is the average of the individual bandwidths calculated for each year using Silverman (1986). A fixed bandwidth was selected over the individual values to balance the differences in sample sizes between the four time periods. The second time series examined changes in distributions between five-year periods: 2003-2007, 2008-2021, 2013-2017, and 2018-2022. As with the single year time series, KDEs were generated for each five-year subset using a fixed bandwidth of 12.6 km. The final time series examines annual changes in calving distributions using KDEs generated for each year from 2004 to 2022. As there were fewer than 30 locations for the calving season for years 2000 to 2003, the locations for these years were pooled to provide a more representative sample of calving distributions for this period. A fixed bandwidth of 12km was used to generate the annual kernel density utilization distributions.

4.0 RESULTS

4.1 Layout of Survey Strata

Survey strata were designed based on reconnaissance survey flight density observations, and the movements of 44 collared female caribou. The threshold for the peak of calving was based upon observations of cow/calf proportions and/or when movement rates declined to less than 5 km per day for collared cows (**Figure 11**).

The Qamanirjuaq June 2022 abundance survey was the shortest on record, largely due to the relatively small geographic area within which the spring migration occurred, geographically tight aggregations of females on the calving ground, and excellent weather. The survey took a total of 5 days to complete, 2 days for the reconnaissance survey, one day for the photographic survey, two days for the visual abundance survey, and 3 days for the composition survey (**Table 3**).

Survey strata were laid out based on reconnaissance survey segment densities (**Figure 12**) and the initial fixed wing composition of caribou observed within reconnaissance segments (**Figure 13**). Unlike June 2017, the main migration path of collared caribou cows occurred within a narrow corridor inland from, but parallel to, the Hudson Bay coast, as initially determined using adult cow collar locations, later verified during the reconnaissance survey (**Figure 14**). High densities of adult female caribou were observed within the northern extents of the 2022 Qamanirjuaq herd annual concentrated calving area which were stratified into photographic strata. Further south of these higher female densities were the visual strata, mainly composed of non-breeding females, yearlings, and bull caribou. As the majority of observations and their associated densities fell below the 10 caribou/km² threshold, photographic methods were not required. Further to reconnaissance observations, the movements of collared caribou indicated that the caribou moved to the northwest in the photo stratum then circled back

to the northeast. The photo north stratum was extended to the northwest to capture this movement as well as guard against movement to the northwest which occurred during the 2017 photo survey (**Figure 15**). The lines in this area were considered a buffer and preliminary with the potential of eliminating them if movement did not occur.

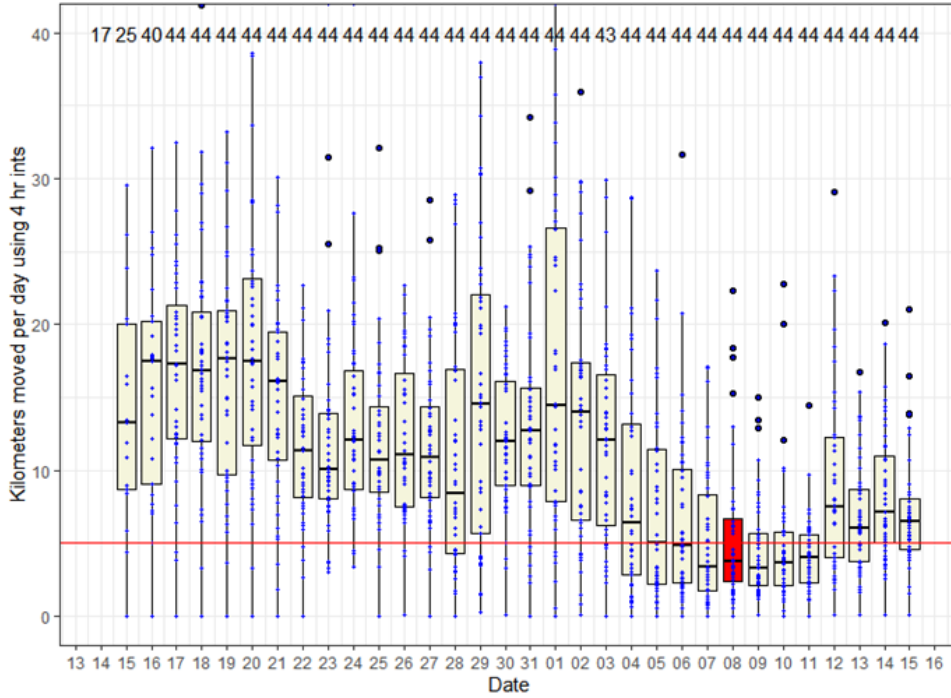


Figure 11. Collar movement rates of Qamanirjuaq cows during the June 2022 Qamanirjuaq calving ground photo survey. Sample sizes of collars are given above each boxplot. The boxplot for the primary date that the photo survey occurred is highlighted in red.

Table 3. Survey Initiation and completion dates for the June 2022 Qamanirjuaq Calving Ground Photographic Survey.

Survey Activity	Jun-06	Jun-07	Jun-08	Jun-09	Jun-10
Systematic Reconnaissance	X	X			
Visual Abundance			X	X	
Photographic Abundance			X		
Abundance Strata Composition			X	X	X

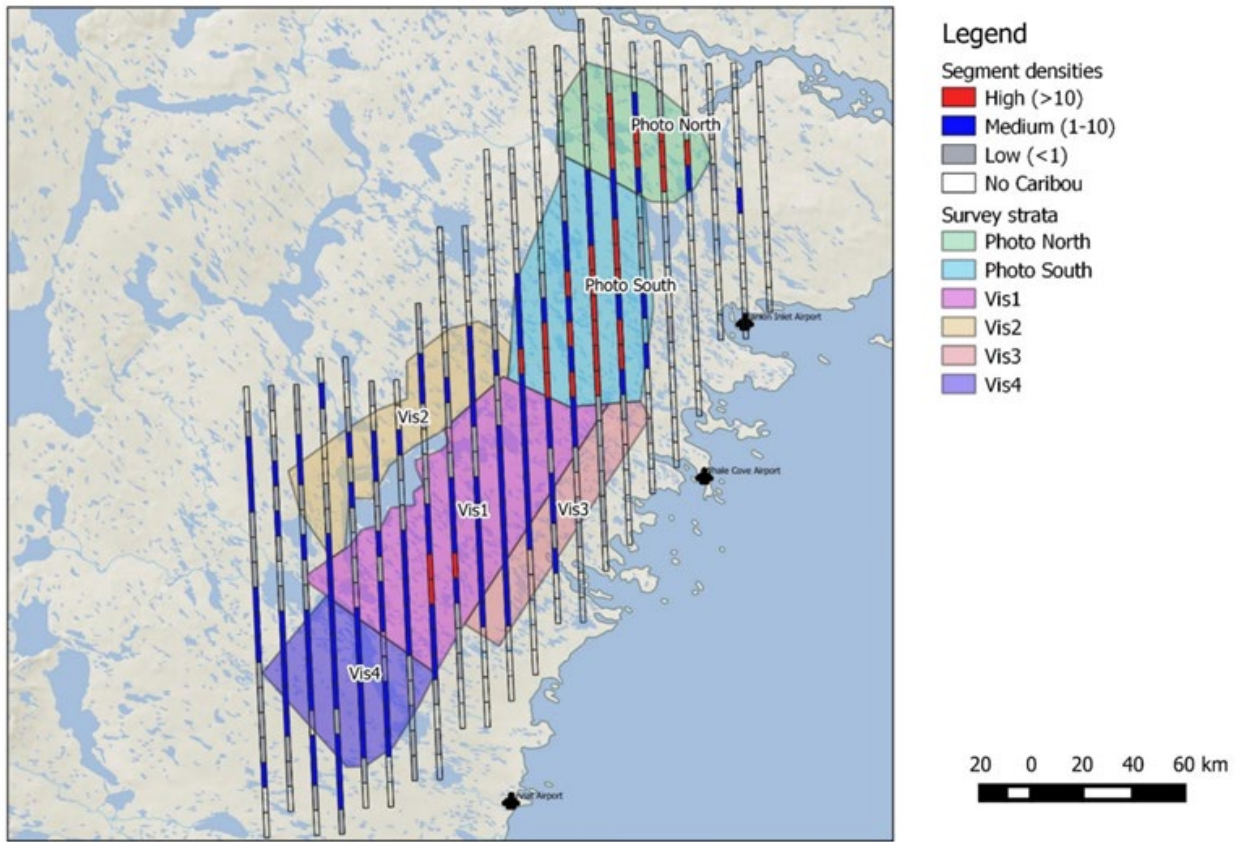


Figure 12. June 2022 Qamanirjuaq reconnaissance survey segment density.

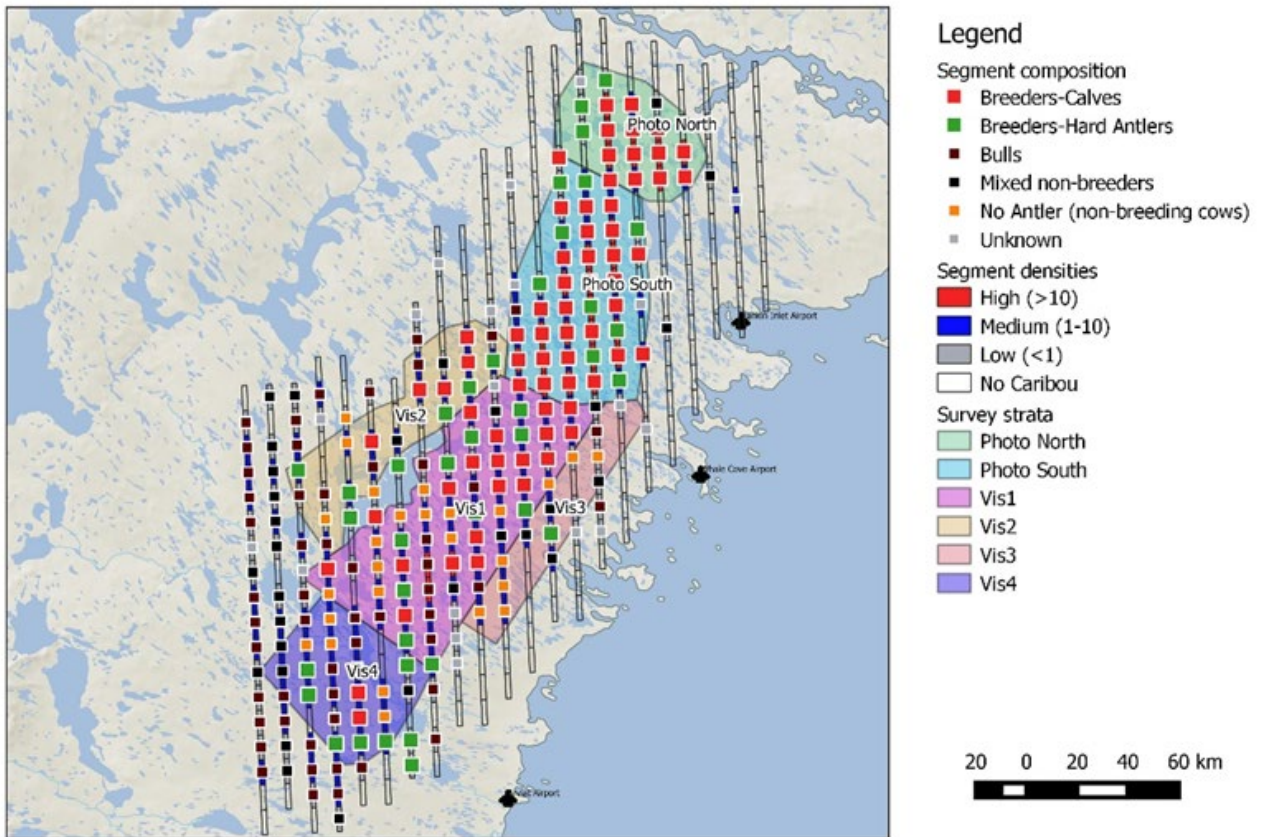


Figure 13. June 2022 Qamanirjuaq reconnaissance survey segment composition overlaid on segment densities as shown in Figure 12.

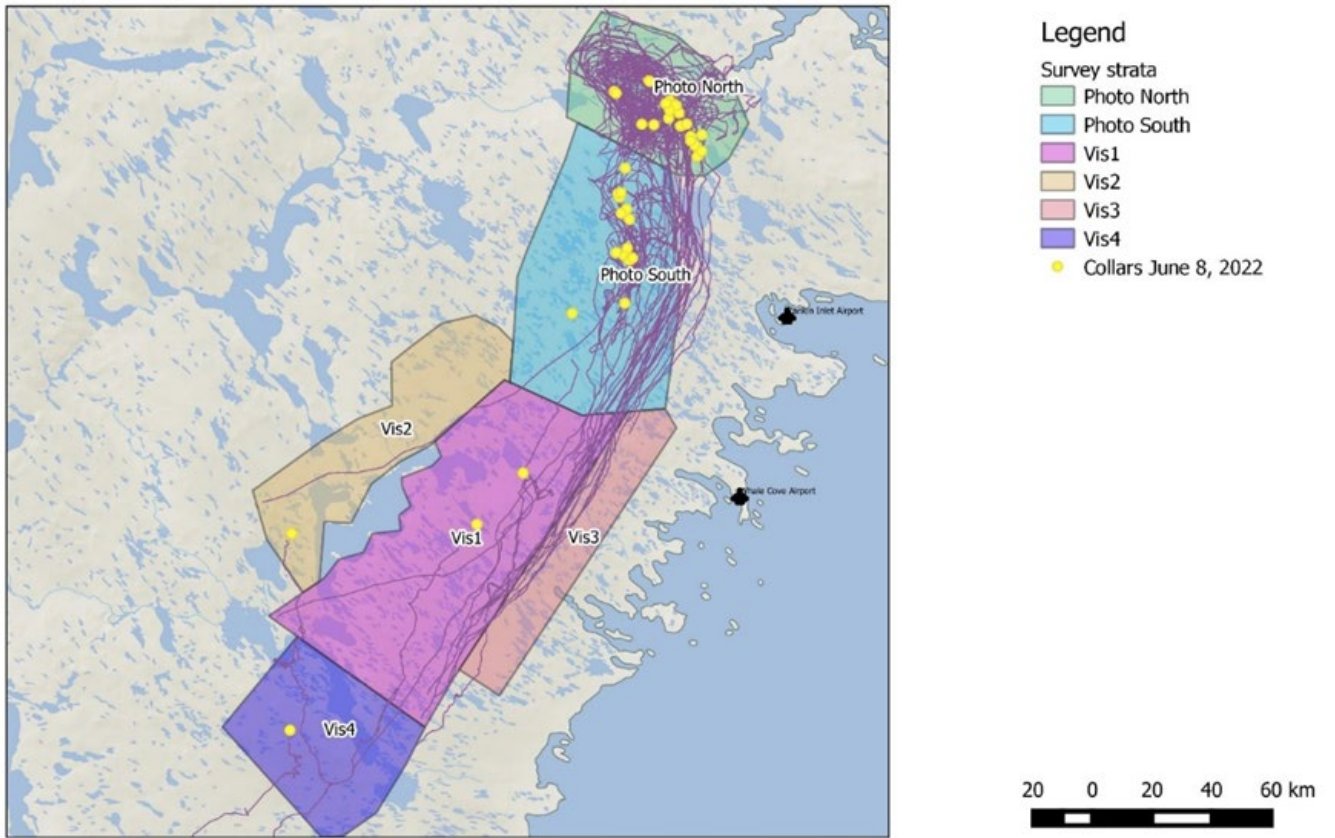


Figure 14. Qamanirjuaq June 2022 calving-ground survey collar movements from May 15 to the beginning of aerial survey observations June 8, 2022 (yellow points).

4.2 Allocation of Survey Effort

Following stratification, preliminary estimates of density were derived for each stratum which were then used to allocate the number of transects flown per strata (**Table 4**). Allocation for the photo strata was based on a limit of 5,000 to 6,000 photos total. Given that survey weather was favorable, we set a target GSD (Ground Surface Density or Ground Sampling Distance) level of 7 which would be equivalent to an estimated 5,000 photos to complete all photographic strata (**Figure 15**). A GSD 7 would provide individual photographs within which the distance between two consecutive pixel centers, as measured on the ground, would be 7 cm. We also set an approximate limit of 1,600 km of flying on transect which amounts to slightly over a day of flying for a single photo plane. Allocations suggested higher coverage for the Photo-north stratum given that the mean density was higher than the Photo-south stratum, however, the Photo-south stratum was approximately twice the size of the Photo-north strata and therefore received more transect km’s of flying.

Table 4 The June 2022 Qamanirjuaq calving-ground abundance survey transect allocations based on reconnaissance observations and achieved GSD levels within photographic (high density) strata.

Strata	area	Recon estimates			Allocation (GSD 7)				Actual flown		
		Density	N	CV	SE-based	N- Based	% effort	Coverage	Transects	Km	Coverage
North	2121.3	12.9	27,470	64.0%	23	24	45.5%	47.1	19	664	44%
South	4131.8	7.4	30,502	35.5%	17	16	54.5%	22.7	20	958	33%
										1,622	

Graphically, it can be seen that the desired resolution, coverage, and photo numbers would be achieved at either a GSD 7 or 8, with GSD 8 more desirable as it would require

fewer photographs (**Figure 15**). Given a stable high-pressure system in the survey area we judged these targets were reasonable.

The remaining strata were surveyed visually with allocations based upon the total number of kilometers that the two survey planes could fly in two days of flying assuming two trips per day with ferrying to survey strata factored into the calculations (**Table 5**). This amounted to 3,000 kilometers of flying on transect (including ferrying in-between transects). The Vis-1 strata had the highest densities of caribou outside of the photographic strata and likely the highest proportion of both breeding and non-breeding female caribou within non-photographic (Visual) strata and therefore it received higher coverage than other visual stratum. The Vis-4 stratum had higher densities, however, it was composed of mainly non-breeders and therefore received slightly lower coverage than visual 1.

Table 5. Allocations of visual strata based on 3,000 km's of flying on transect.

Strata	area	Recon estimates					Allocation			Actual flown	
		Density	N	CV	SE-based	N-based	%Effort	Coverage SE	Coverage N	transects	km
Vis1	5496.8	3.4	18,906	14.2%	39	33	72.4%	28.2%	24.0%	35	1,611
Vis2	2570.9	1.5	3,797	28.6%	23	21	13.6%	16.6%	15.0%	20	487
Vis3	1713.0	1.2	2,130	36.2%	20	22	6.5%	14.6%	15.6%	20	311
Vis4	2453.8	2.3	5,691	11.0%	5	12	7.5%	7.0%	17.4%	12	519
											2,928

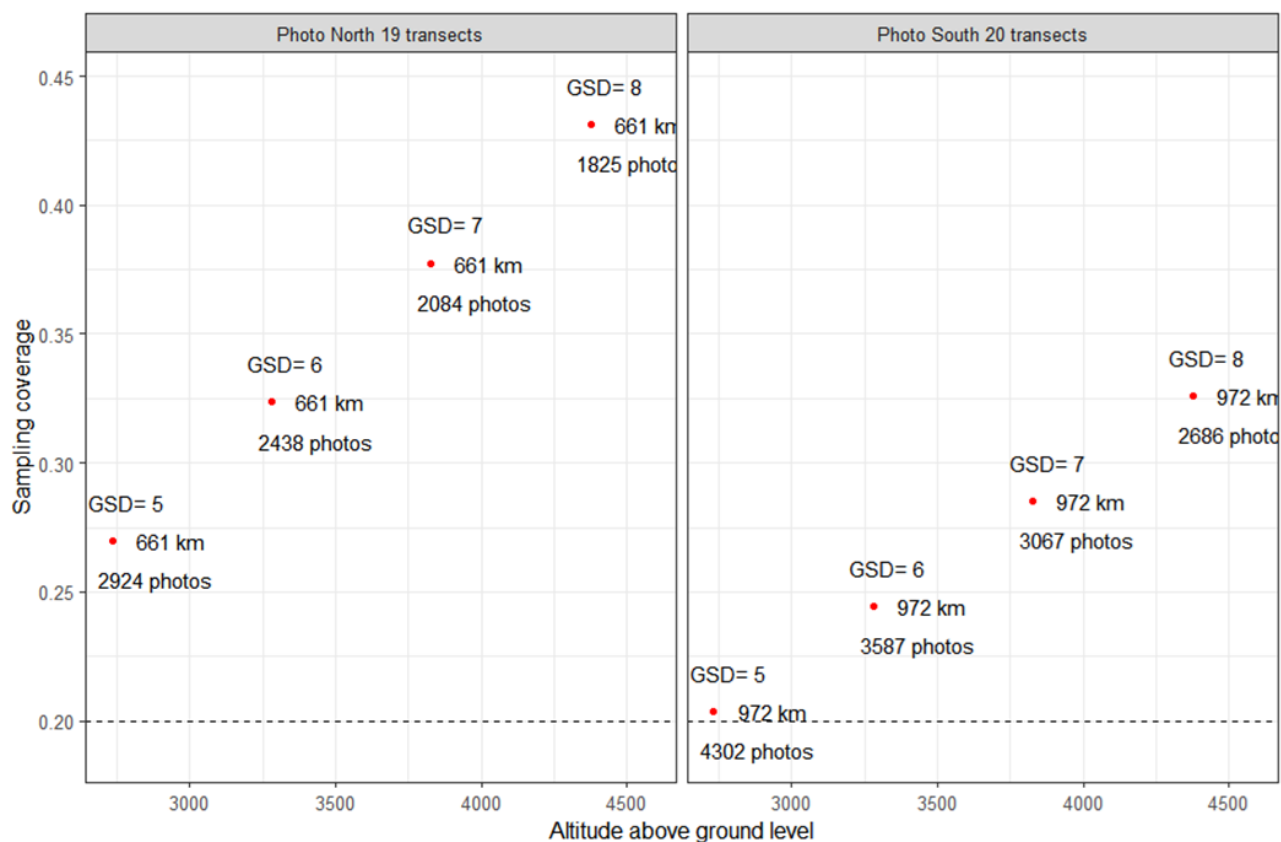


Figure 15. Strata coverage and number of photos estimated at different aircraft altitudes during the June 2022 Qamanirjuaq calving-ground photo-survey.

4.3 Survey Layout Used for Estimates

The Photo-north stratum was expanded west to buffer for potential west movement of caribou, and to capture the migration path of caribou to their annual core calving area (**Figure 16**). Inspection of the distribution of caribou on the photos revealed that caribou had moved east out of the western extents of the stratum that were initially set up as a western buffer. These lines contained few (65) caribou on transect and were therefore not representative of this high-density photographic stratum. As a result, the western most transects were removed to account for this movement within the photo-north stratum (**Figure 16**).

Table 5 summarizes the dimensions and sampling effort for each of the strata sampled. The area surveyed in each stratum was estimated by the total transect kilometers flown multiplied by the strip width of the survey (0.8 km for visual and with variable widths for photo stratum). Coverage was estimated as the area surveyed divided by the strata area. Naïve density for stratum was then estimated as the total count of caribou divided by the area surveyed. From this, it can be seen that the density of caribou on the high-photographic strata were much higher than the visual stratum.

A preliminary estimate of abundance can be gained by dividing the caribou counted by coverage (**Table 6**). This estimate is preliminary for visual surveys given that estimates are not corrected using double observer methods. However, the preliminary estimate demonstrates that the actual means of obtaining strata estimates is relatively simple. It is just the estimate of caribou counted divided by the proportion of each strata sampled (the coverage). A plot of visual and photo survey results (**Figure 17**) suggests that the high-north photo stratum delineated the core group of female caribou as defined by caribou counted on photos as well as satellite collar locations and proportions. The migration trail was then sampled by the photo south and visual transects.

Table 6. Summary of sampling and count-based results by strata. Preliminary N is estimated based on the number of caribou counted on transect divided by survey coverage.

Strata	Strata area (km ²)	Transects	Area surveyed	coverage	Caribou counted	Density on transect	Preliminary N
<u>Photo strata</u>							
Photo North	1585.0	15	664.0	41.9%	41,314	62.22	98,601
Photo South	4390.4	20	1383.4	31.5%	24,945	18.03	79,190
<u>Visual strata</u>							
Vis1	5496.8	35	1288.5	23.4%	5,323	4.13	22,748
Vis2	2570.9	20	389.4	15.1%	435	1.12	2,881
Vis3	1713.0	20	248.8	14.5%	425	1.71	2,931
Vis4	2453.8	12	415.5	16.9%	1,066	2.57	6,308

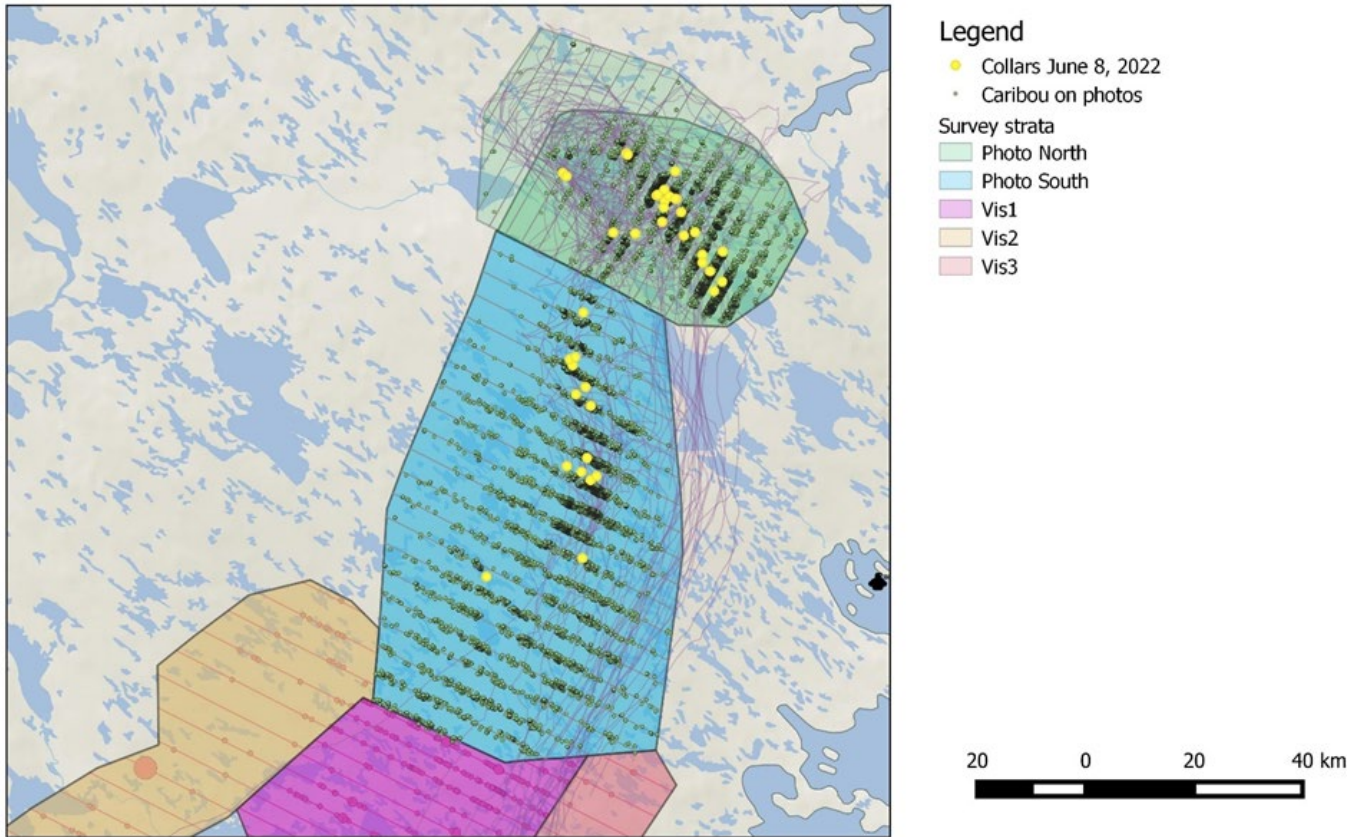


Figure 16. The 2022 Qamanirjuaq June calving-ground survey reduced photo north stratum (darker green area) in comparison to full photo-north stratum (Light green area).

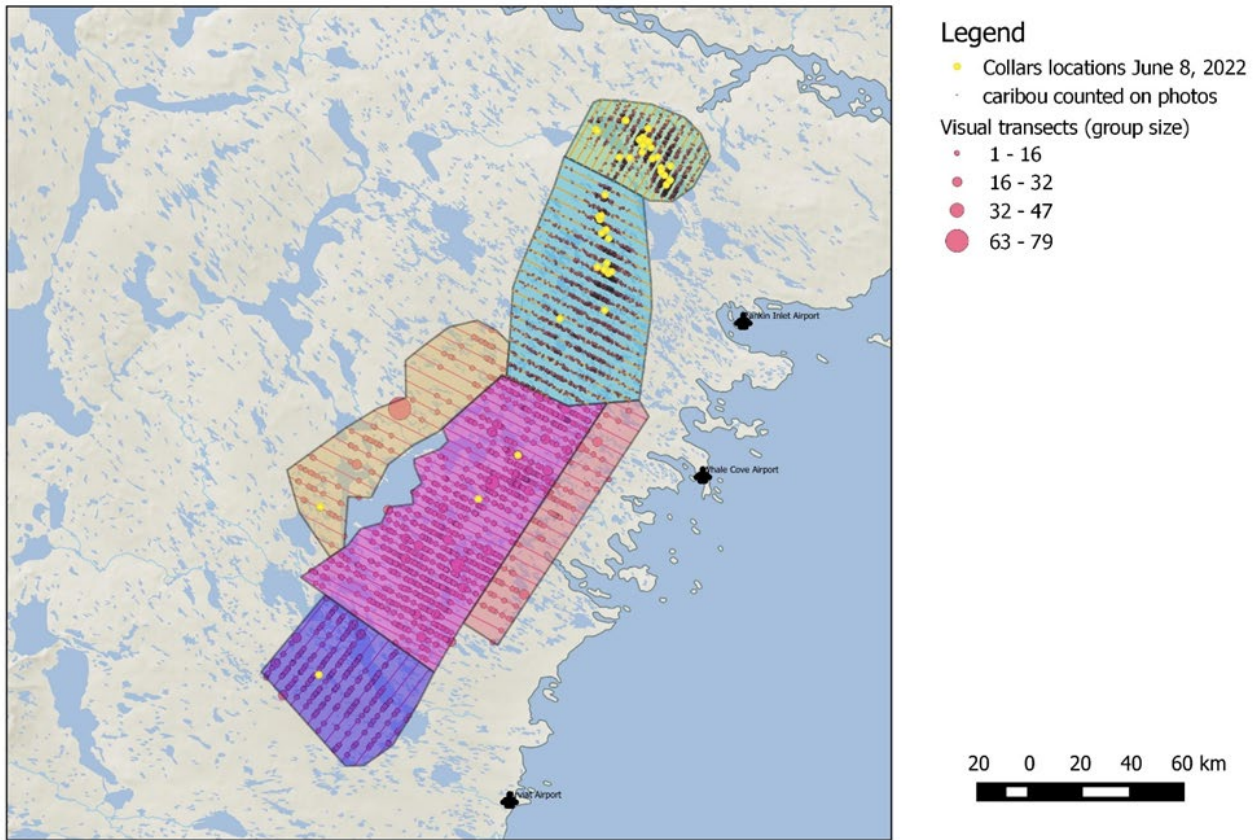


Figure 17. Summary of photo and visual survey with group sizes indicated for visual surveys and densities of individual caribou shown for photo data (light green and blue areas), for the 2022 Qamanirjuaq June calving-ground survey.

4.4 Analysis of Survey Data

4.4.1 Visual survey double observer pair surveys

The majority of caribou were seen as single caribou or small groups with few larger group sizes observed. The relative proportion of caribou not seen by both observers was highest in group sizes of 3 or less with both observers seeing the majority of group sizes that were greater than 3. Compared to previous surveys (Campbell et al. 2012), the proportion of caribou seen by both observers was high suggesting that overall sightability was high (**Figure 18**).

During the reconnaissance surveys the core of the calving ground was surveyed which led to observations of larger group sizes (**Figure 19**). This area was surveyed using the photo plane for the abundance phase of the survey and therefore the number of larger groups was lower during the abundance phase. The main focus of the analysis was to estimate sightability for the visual survey phase. For this reason, the reconnaissance survey data set was filtered to only include group sizes of 80 or less caribou which was similar to the range of group sizes observed in the visual survey. Photo strata counts increased the precision of group counts within high density aggregations, and visual strata had significantly lower densities and associated smaller group sizes. Additionally, the visual counting of areas of very-high caribou densities generally leads to a breakdown in establishing the defined 200-meter separation between groups as observers often combine groups due to the longer time it takes to count more caribou. Because of this, large groups often flow into one another yielding higher group sizes. Because the main focus of the analysis was to estimate sightability for the visual survey phase, the recon survey data set was filtered to only include group sizes of 80 or less which was similar to the range of group sizes observed in the visual survey.

Overall, there were 6 unique pairs of observers during the visual portion of the survey. Of these pairs, 5 of them switched position from primary to secondary during the survey (**Table 7**). One pair (pair 0) only occurred during the reconnaissance survey and did not switch and for this reason was not used in the analysis. Pair 2 was composed of 4

individuals given that the 2nd pairing only had 12 sightings preventing modelling of sighting probabilities. Data recorder observations mainly occurred for pair 1.

Table 7. Summary of observer pairings used in the double observer analysis.

Pair	Observers		Observation type/frequencies				
	front	rear	Both	Front	Rear	Data recorder	Total
0	JR	OS	63	11	0	0	74
1	DM	OS	413	15	125	60	613
1	OS	DM	82	6	0	16	104
2	DL	JV	441	31	9	8	489
2	JV	DL	104	5	25	5	139
2	DL	LI	9	0	0	0	9
2	LI	DL	0	2	1	0	3
3	JB	LI	574	7	14	8	603
3	LI	JB	227	5	13	2	247
4	JE	RT	80	20	7	0	107
4	RT	JE	486	13	47	1	547

A graphical representation of detections suggests most detection differences occurred when group sizes were low (**Figure 18**). Pair 1 had a higher relative frequency of missed observations than other pairs, however, some differences also existed between other pairs (**Figure 19**).

The pooled data from observer pairs (**Table 8**) suggested slight differences in proportions of caribou sighted as indicated by the proportion of caribou only observed by the secondary observer. Graphically, it can be seen that there is minimal difference between detection probabilities when data recorder observations are included except for pair 1 (**Figure 20**).

Though the reconnaissance survey phase saw variable cloud conditions, in general, survey conditions were ideal with 0% cloud during the abundance phase (**Figure 21**). Proportion of missed observations was slightly higher when cloud cover was 50% or greater during the recon survey phase, though consideration must also be given to observer experience, which would increase with every successive flying day. Snow

cover was consistent for both the reconnaissance and abundance phases of the survey with over 80% of observations recording 0% snow cover for the reconnaissance, and over 95% of observations recording within 5% to 25% snow cover for the abundance.

Table 8. Summary of double observer pairings with sample sizes and naïve detection probabilities for each pair. Observations are summarized by observation type (BO-both observers, FO-front observer, RO-rear observer). Naïve detection probabilities are based upon proportions not seen by the front observer. Single (p) and double observer (p2x) probabilities are shown. They are calculated excluding data recorder observations (no DR) and including data recorder observations (DR).

Pair	Observations (type)				Totals total	Naïve detection probabilities			
	BO	FO	RO	DR		P1x (no DR)	p2x (no DR)	P1x (DR)	P2x (DR)
1	495	21	125	76	719	0.80	0.96	0.72	0.92
2	557	38	35	13	647	0.94	1.00	0.93	0.99
3	802	12	27	10	857	0.97	1.00	0.96	1.00
4	569	33	54	1	665	0.92	0.99	0.92	0.99

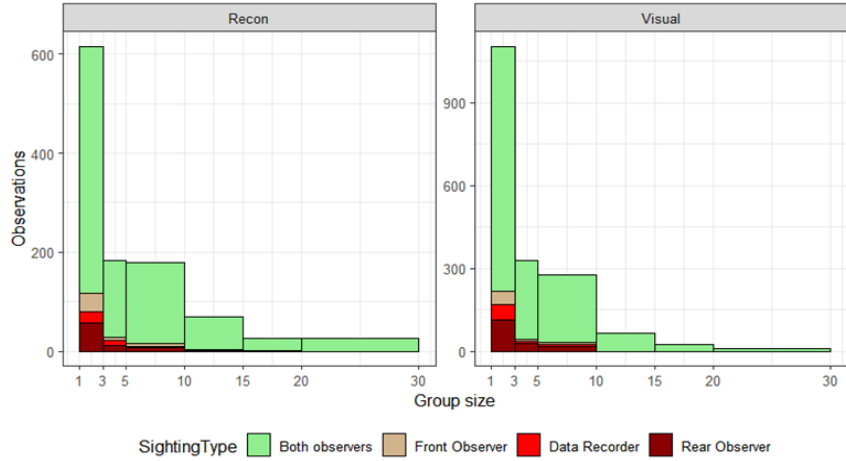


Figure 18. Distribution of group sizes observed during the visual and reconnaissance surveys (green) with observation type delineated as sub-bars (brown and reds). Group size observations of greater than 80 caribou (only observed during the reconnaissance survey) were not used in the double observer analysis. Observations greater than 30 caribou are summarized in the 20-30 bin.

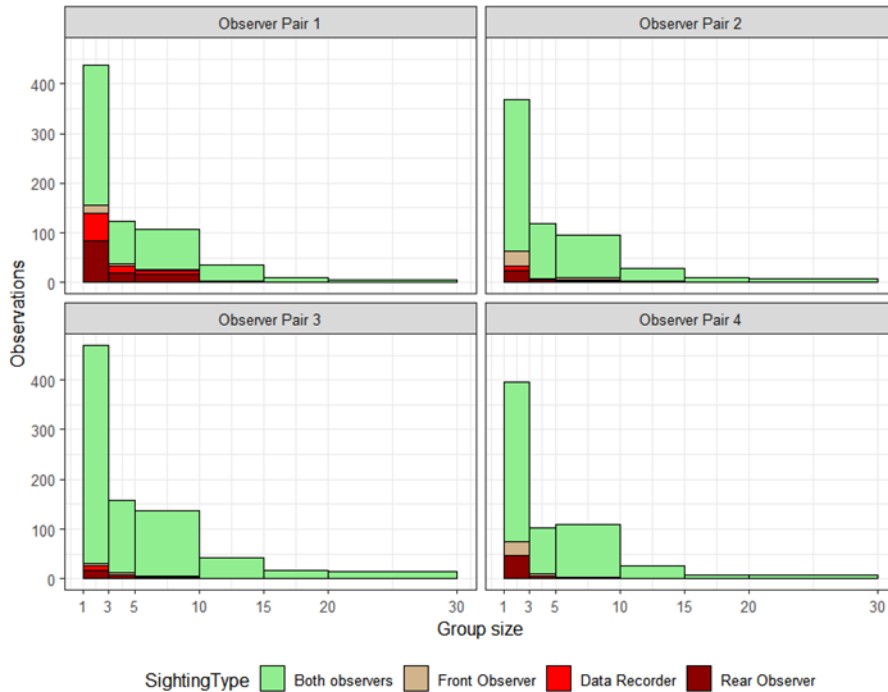


Figure 19. Graphical summary of observer pair detections by group size for the June 2022 Qamanirjuaq caribou calving-ground abundance survey.

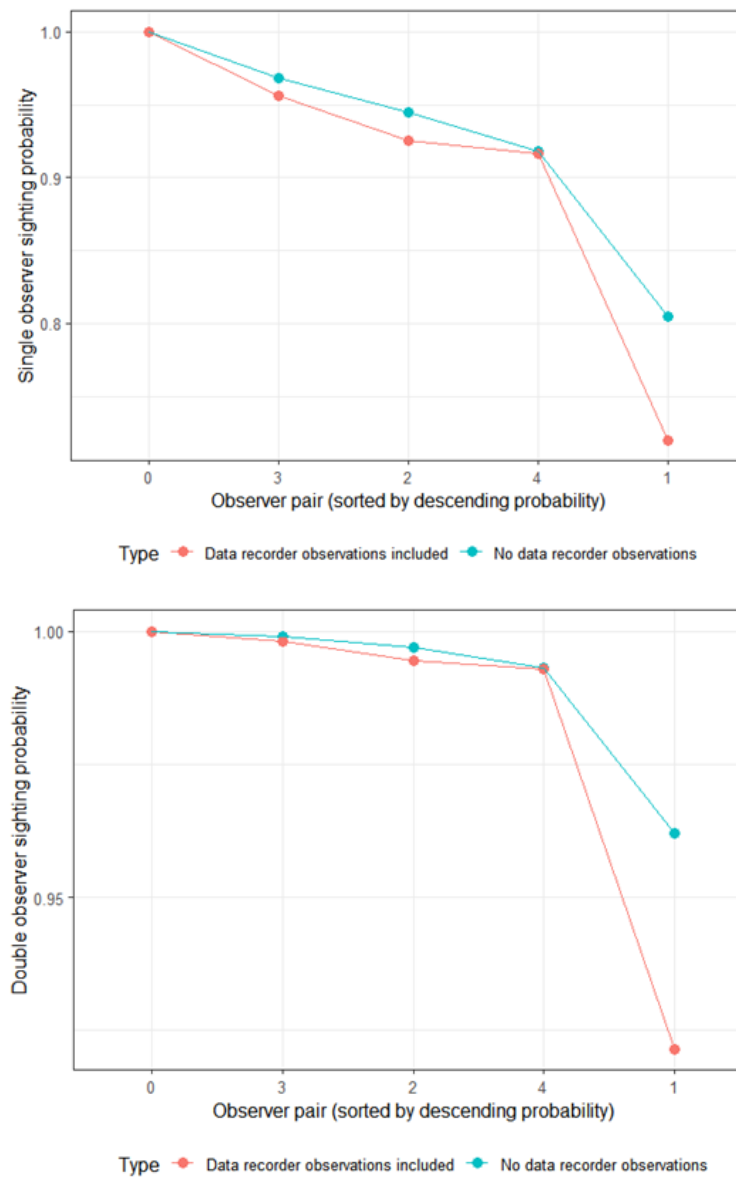


Figure 20. Graphical representation of the effect of inclusion of data recorder observations for the June 2022 Qamanirjuaq caribou calving-ground abundance survey.

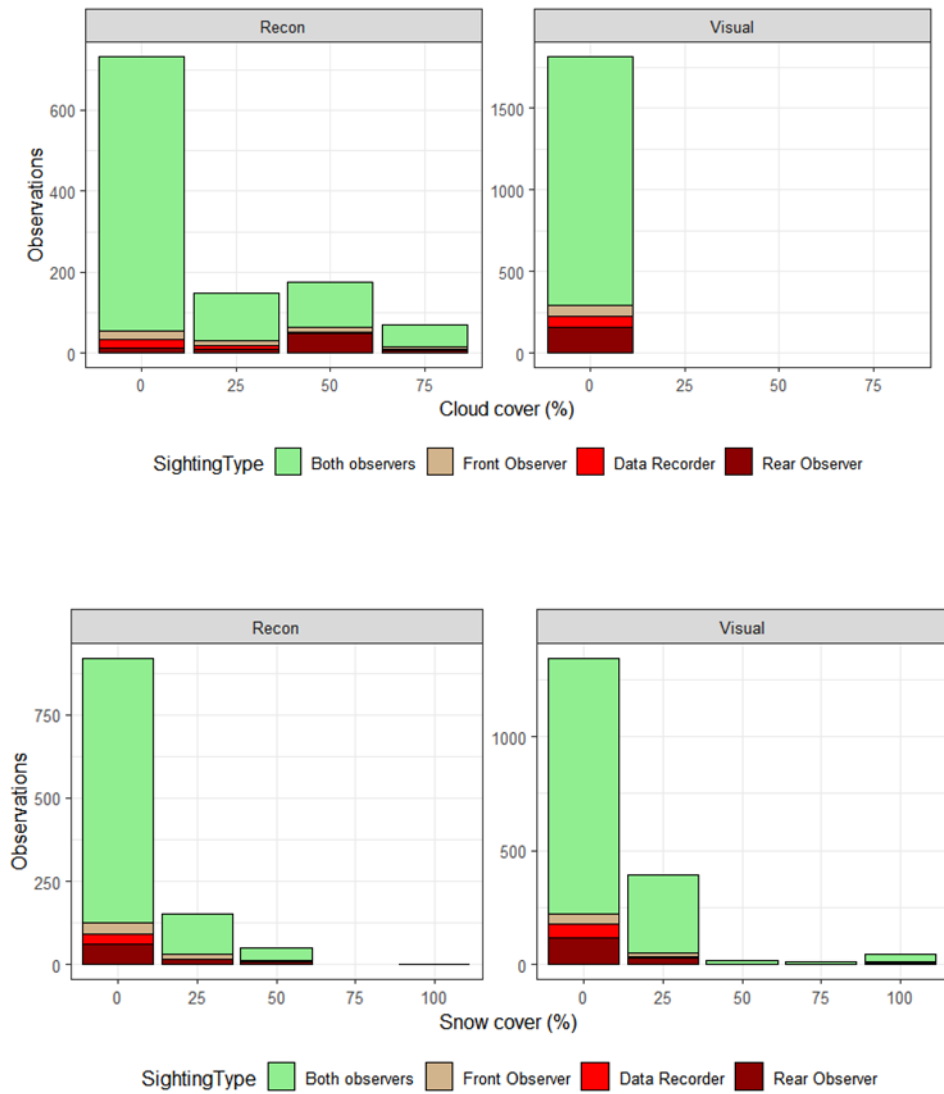


Figure 21. Summary of cloud and snow cover for observations during the recon and visual components of the survey.

4.4.2 Model selection

The general model building procedure followed a hierarchical process (**Table 9**). Initially, model building focused on determining the relative strength of each covariate with unique observer, group size, and cloud cover, showing substantially higher support than a constant model. Observer and group size were considered as additive and interactive terms, with interaction models showing higher support (model 6). Cloud cover was then considered as an additive continuous or categorical term. From this the most supported model (model 1) contained an interaction of observer (pair) and group size with an additive effect of cloud cover.

Table 9. Double observer model selection results. Main model terms are listed as columns with covariate names as defined in Table 1. Sample size adjusted Akaike Information Criterion (AICc), the difference in AICc between the most supported model for each model (ΔAIC_c), AICc weight (w_i), number of model parameters (K) and deviance is given.

No	Model	AIC _c	ΔAIC_c	w_i	K	Deviance
1	observer*size+cloudf	1790.53	0.00	1.00	11	-883.6
2	observer*size+cloudc	1807.89	17.35	0.00	9	-894.5
3	observer*size	1837.39	46.86	0.00	8	-910.4
4	observer*size+phase	1837.97	47.44	0.00	9	-909.6
5	observer*size+strata	1838.65	48.12	0.00	12	-906.6
6	observer+size	1840.96	50.43	0.00	5	-915.3
7	observer+size+phase	1841.36	50.83	0.00	6	-914.5
8	observer*log(size)	1842.62	52.09	0.00	8	-913.0
9	observer+cloudc+snowc	1868.98	78.45	0.00	6	-928.3
10	observer+cloudc	1869.73	79.20	0.00	5	-929.7
11	observer+snowc	1896.55	106.02	0.00	5	-943.1
12	observer	1897.38	106.85	0.00	4	-944.6
13	observer+phase	1899.20	108.66	0.00	5	-944.5
14	cloudf	2016.00	225.47	0.00	4	-1003.9
15	size	2031.77	241.24	0.00	2	-1013.9
16	log(size)	2036.57	246.04	0.00	2	-1016.3
17	cloudc	2053.82	263.29	0.00	2	-1024.9
18	strata	2092.80	302.27	0.00	5	-1041.3
19	snowF	2093.59	303.06	0.00	5	-1041.7
20	constant	2096.99	306.45	0.00	1	-1047.5
21	phase	2097.32	306.79	0.00	2	-1046.6
22	snowc	2098.44	307.91	0.00	2	-1047.2

The influence of observer pair, group size, and cloud cover on sighting probabilities (**Figure 24**) suggested that the largest degree of variation was due to group size and different observer pairs, however, the overall range in probabilities was not large. Furthermore, double observer probabilities (the combined probability of at least one observer in a pair sighting a caribou group) was close to 1 regardless of observer pairing or cloud cover (**Figure 22**). Lower detection probabilities did occur when cloud cover was 50% or greater, however, this only occurred during the recon survey and therefore had no effect on the visual survey estimates.

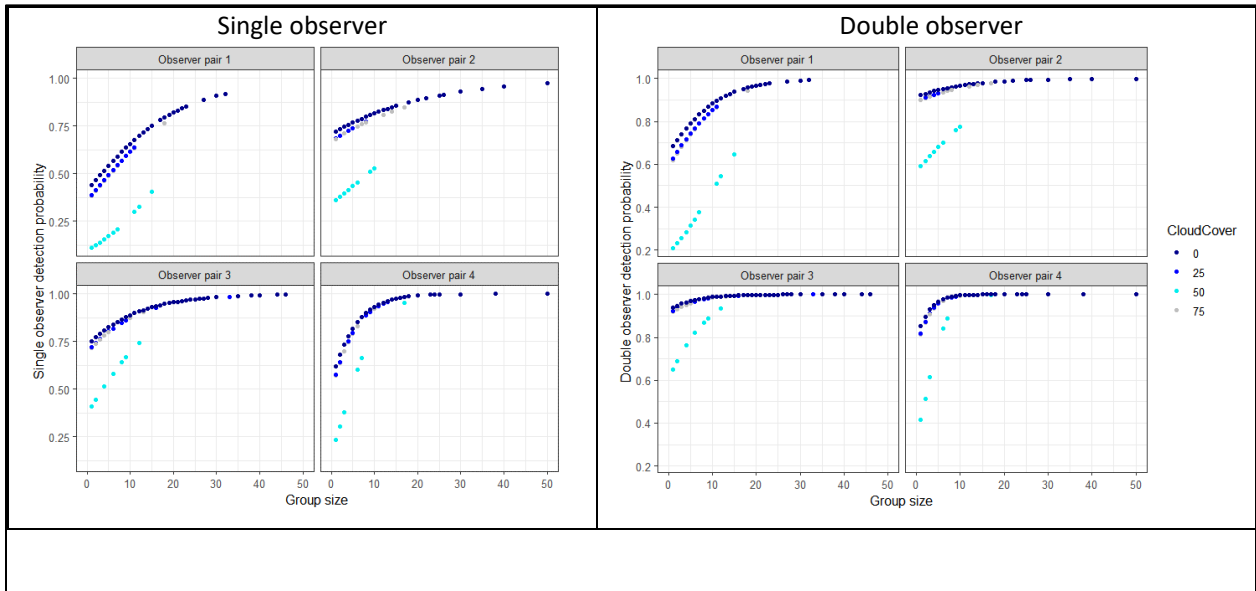


Figure 22. The Qamanirjuaq June 2022 calving-ground visual abundance survey single (left) and Double (right) observer sighting probabilities as a function observer and cloud cover.

Double observer estimates were derived in program MRDS from Model 1 (**Table 10**) and compared to non-corrected count-based estimates. In general, the estimates were very close (1.3% difference) with the total estimate for all strata being 473 caribou higher than the non-corrected estimate. As discussed later, the minimal difference in estimates was due to the larger group sizes encountered during survey (with high sightabilities (**Figure 22**)), and good survey conditions. Precision of double observer estimates was slightly higher due to the advanced methods used to estimate variance in the *mrds* package. Overall precision of estimates was quite high demonstrating that survey allocation and strata layout was optimal for obtaining precise estimates based on reasonable' km's of flying on transect.

Table 10. Double observer estimates of all caribou in each stratum and uncorrected count-based estimates for comparison purposes.

Strata	Caribou counted	Double observer (MRDS)				Count-based estimate			
		N	SE	95% CI		CV	N	SE	CV
Vis1	5,323	23,083	1640.9	19,886	26,795	7.1%	22,708	1633.6	7.2%
Vis2	435	2,880	597.9	1,823	4,552	20.8%	2,872	506.0	17.6%
Vis3	425	2,996	351.2	2,310	3,886	11.7%	2,926	458.2	15.7%
Vis4	1,066	6,313	401.1	5,405	7,374	6.4%	6,295	868.7	13.8%
Total	7,249	35,273	1826.7	31,717	39,228	5.2%	34,801	1972.2	5.7%

4.4.3 High density photo and visual survey estimates

High density photographic strata were flown at GSD 8 which resulted in an average strip width of 1.35 km (sd=0.025, min=1.28, max=1.39, n=39). Strip width and transect area was measured using geo-referenced photos for each survey line. Transect densities were estimated as the number of caribou counted on a given transect divided by the transect area (**Figure 23**). Densities were above 10 caribou per km² in the High-density Photo-North Photo on all transects except two (2) on the west-central end of the stratum, and one (1) on far east end of the stratum. Very-high densities occurred on the central lines of this stratum with very-low densities on peripheral lines especially to the west. This variation reduced overall estimate precision.

Within the Photo-south stratum most densities were at the 10 caribou per km² level with densities up to 50 caribou per km² in the central section of the stratum. For the remaining visual abundance survey strata density of caribou along transects was below 10 caribou per km² (**Figure 24**).

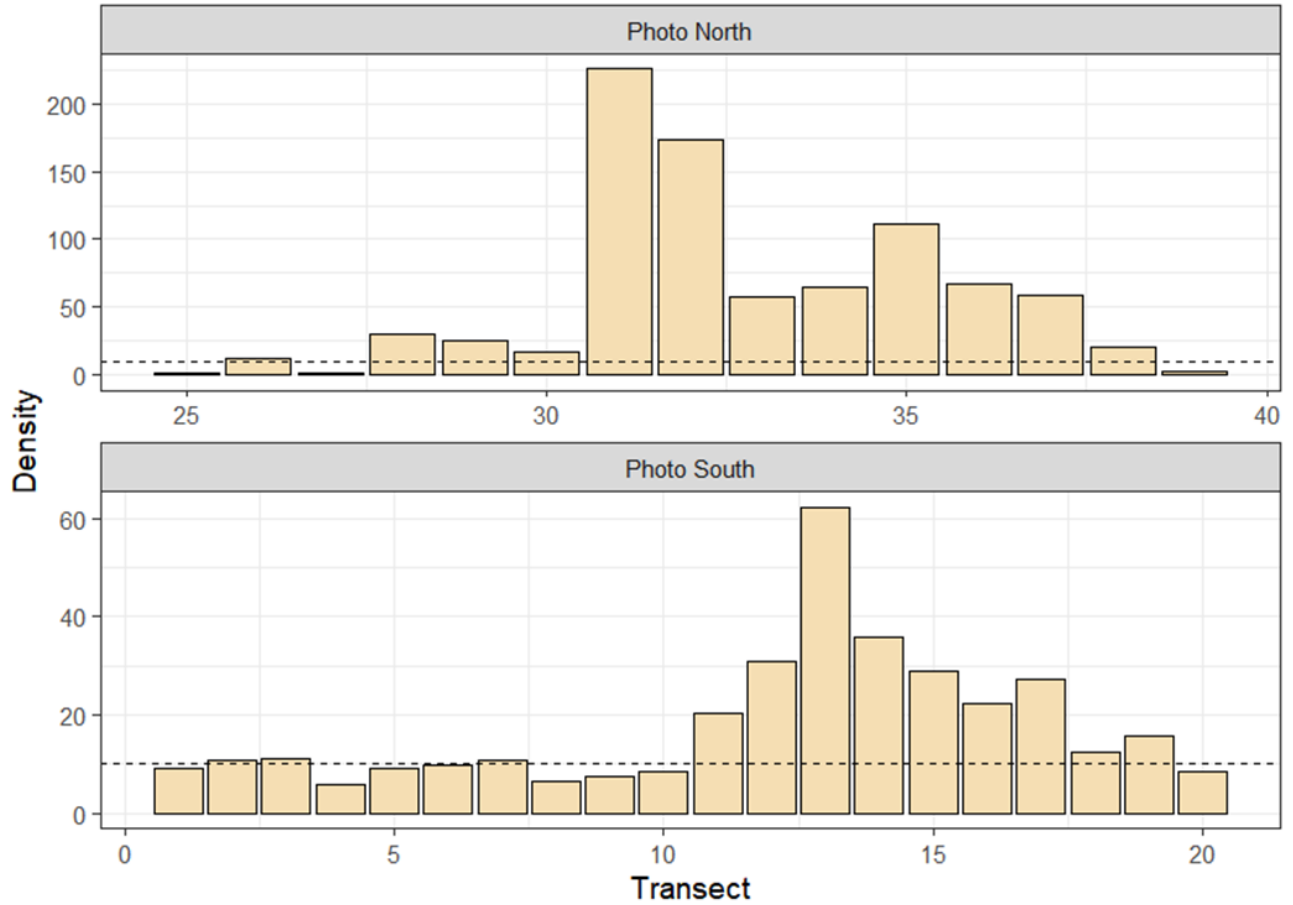


Figure 23. Estimates of caribou density (caribou per km²) on high density photo stratum by transect. Note the different y-axis scales. Density of 10 caribou per km² which denotes the level when photo plane sampling is used is given as a horizontal dashed line. Transects went from west to east for the Photo-North stratum and from south to north for the Photo-South stratum.

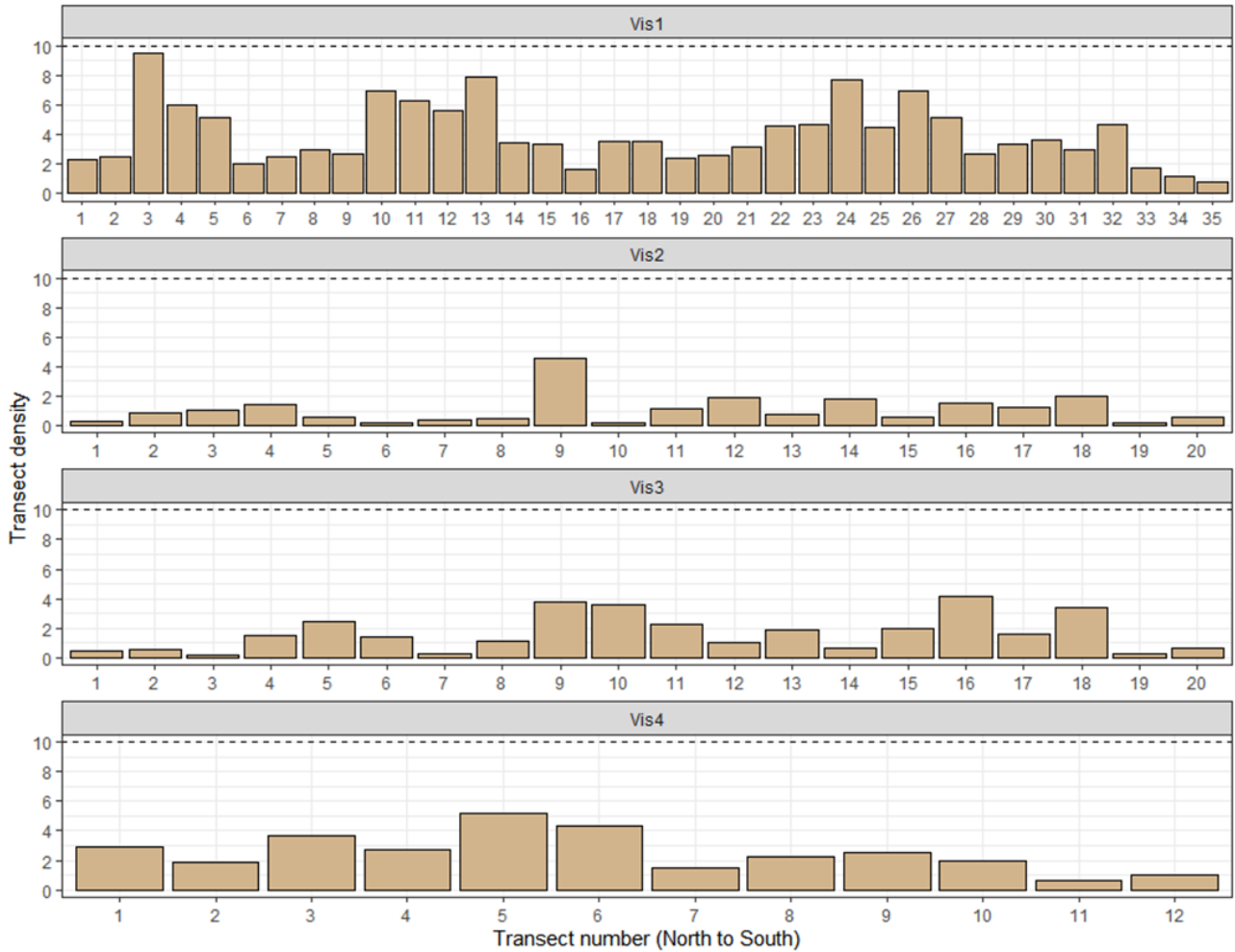


Figure 24. Transect densities within visual strata for the 2022 Qamanirjuaq calving-ground survey. The horizontal dashed line represents a density of 10 caribou per km² which denotes the level when photo plane sampling is used.

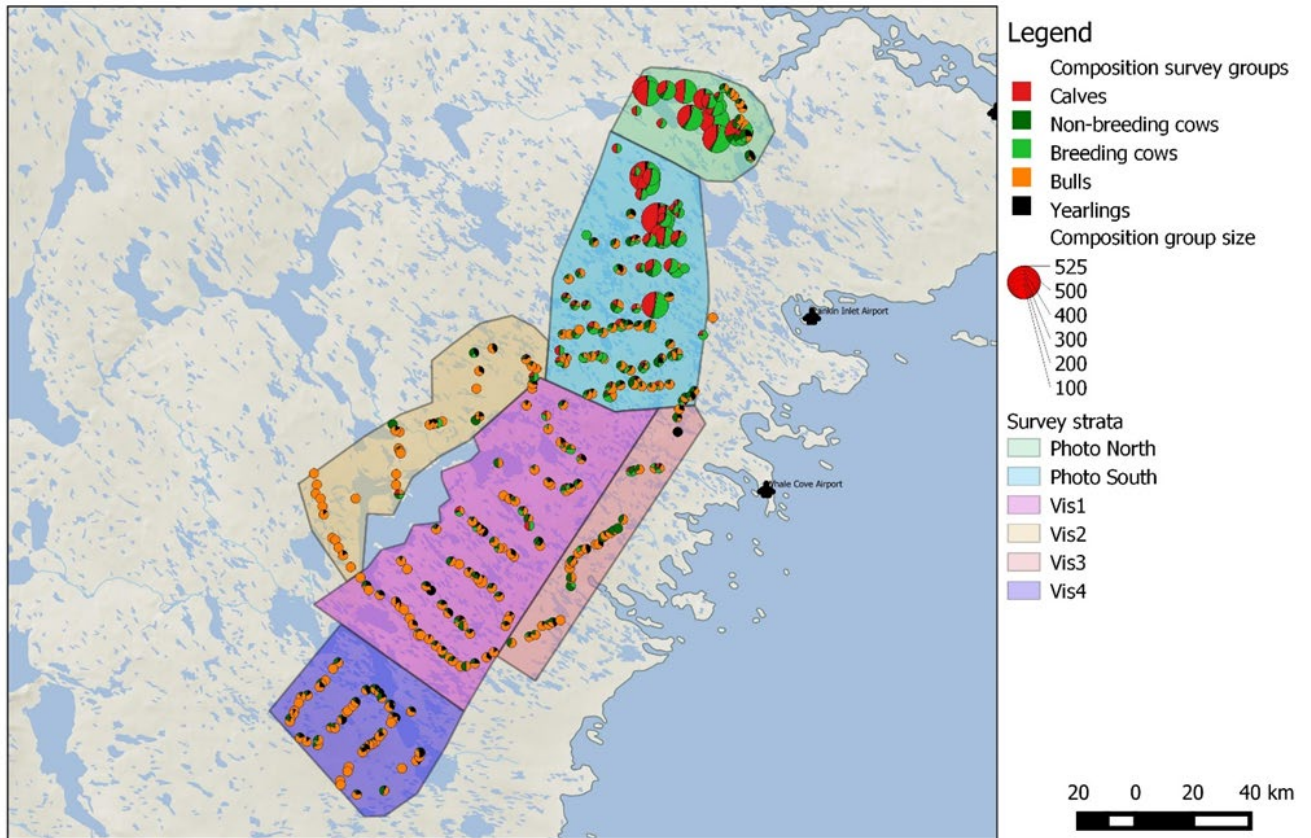


Figure 25. Summary of caribou classified for each of the core strata as listed in **Table 8** for the June 2022 Qamanirjuaq herd calving-ground abundance survey.

4.4.4 Composition surveys to determine proportions of females

Composition surveys were conducted on each of the photographic and visual survey strata (**Table 11**). A spatial representation of the composition data reveals that the majority of breeder groups including breeding and non-breeding females, occurred in the two photo strata with proportionally higher non-breeder/female groups occurring in the visual stratum as well as in the southern half of the photo south stratum (**Figure 25**). The composition data for all strata was analyzed further using a bootstrap procedure to estimate standard errors. One thousand bootstrap replications were conducted which resulted in robust standard error estimates and percentile-based confidence limits (**Table 12**). The proportion of breeding females on the calving ground (breeding females / (breeding females+non-breeding females+bulls+yearlings)) as well as other cohorts, were estimated. The proportion of adult cows was highest on the photo-north and photo-south strata with lower (<28%) in visual strata. The proportion bulls were relatively high (>50%) in visual strata.

Table 11. Summary of composition data by stratum collected for the June 2022 Qamanirjuaq caribou abundance survey.

Strata	n	Breeders	Non-breeders				Total caribou Breeder & non-breeders
		Cows ^A	Cows ^B	Bulls	Yearlings	Total	
Photo North	27	3204	270	220	149	639	3843
Photo South	87	3025	706	902	248	1856	4881
Vis1	78	80	187	810	197	1194	1274
Vis2	35	8	16	171	18	205	213
Vis3	33	13	45	120	37	202	215
Vis4	52	4	85	428	101	614	618

^AAs indicated by presence of a calf, antlers, or an udder.

^BAs indicated by absence of calf, an udder or antlers (UCO in database).

Table 12. Estimates of proportions of various cohorts from composition surveys flown during the June 2022 Qamanirjuaq caribou herd calving-ground abundance survey.

Strata	Estimate	SE	95% CI		CV
<u>Proportion breeding cows (breeding cows/(breeding cows+non breeding cows+bulls+yearlings))</u>					
Photo North	0.904	0.024	0.847	0.940	2.6%
Photo South	0.764	0.038	0.678	0.824	5.0%
Vis1	0.210	0.019	0.172	0.249	9.2%
Vis2	0.113	0.032	0.054	0.181	28.5%
Vis3	0.270	0.040	0.193	0.350	14.7%
Vis4	0.144	0.020	0.106	0.185	14.1%
<u>Proportion adult cows (cows/(cows+bulls+yearlings))</u>					
Photo North	0.834	0.040	0.741	0.895	4.8%
Photo South	0.620	0.055	0.488	0.704	8.9%
Vis1	0.063	0.014	0.039	0.093	22.4%
Vis2	0.038	0.016	0.011	0.071	42.2%
Vis3	0.060	0.022	0.021	0.111	37.0%
Vis4	0.006	0.003	0.001	0.013	48.1%
<u>Proportion of bulls (bulls)/(cows+bulls+yearlings))</u>					
Photo North	0.057	0.015	0.034	0.092	26.2%
Photo South	0.185	0.035	0.132	0.264	18.9%
Vis1	0.636	0.023	0.590	0.684	3.7%
Vis2	0.803	0.039	0.721	0.876	4.9%
Vis3	0.558	0.046	0.473	0.649	8.2%
Vis4	0.693	0.031	0.635	0.758	4.5%

4.5 Estimates

4.5.1 Estimates of total caribou on the calving ground

Estimates of the total number of caribou on the annual core calving ground and peripheral calving strata using both the visual and photo-survey data, are displayed in **Table 13**. Estimates in most strata had coefficients of variation (CV) levels of less than 20% with the exception of the photo-north stratum which had a CV of 21.4% which was due to high variation in densities observed within the strata (**Figure 23**). Vis2 also had

a CV of greater than 20%. However, the estimate of abundance was low and therefore it did not contribute significantly to the overall estimate. The resulting precision of the overall estimate of 213,079 caribou on the annual core calving ground was relatively precise with a CV of 11.5%.

Table 1. Estimates of caribou (1+year old) on the annual core calving ground from the core photo (Photo-North & Photo-South), core visual (Vis-1 & 4), and peripheral visual strata (Vis-2 & 3).

Strata	N	SE	95% CI		CV	df
Photo North	98,614	21135.8	62,594	155,360	21.4%	14.0
Photo South	79,193	12212.6	57,456	109,155	15.4%	19.0
Vis1	23,083	1640.9	19,886	26,795	7.1%	18.1
Vis2	2,880	597.9	1,822	4,552	20.8%	10.0
Vis3	2,996	351.2	2,309	3,887	11.7%	10.0
Vis4	6,313	401.1	5,405	7,374	6.4%	6.0
Total	213,079	24478.6	166,781	272,229	11.5%	14.4

4.5.2 Estimates of breeding females and other cohorts on the core breeding ground.

Estimates of the proportion of breeding females (**Table 12**) were then multiplied by the number of caribou on each stratum (**Table 13**) to derive a breeding female estimate of 133,125 (95%-CI=96,561-183,534) (**Table 14**). The estimate of adult cows (breeders and non-breeders) was 156,540 (**Table 15**) (95%-CI=116,635-210,099) suggesting that roughly 23,000 cows on the core calving ground were non-breeding (as determined by lack of calf, antler, or udder). The photo stratum, which was classified as having 90% and 76% adult females (Photo-North and Photo-South respectively), contributed the most to the overall estimate of breeding females and non-breeding females. Relatively few adult females (breeding or non-breeding) were found within the visual abundance strata.

Table 2. Estimates of breeding females from composition data and survey strata estimates (CG= Calving ground).

Strata	Caribou on C.G.		Proportion breeders		Breeding female estimate				CV
	N	CV	Estimate	CV	N	SE	95% CI		
Photo North	98,614	21.4%	0.834	4.8%	82,244	18063.8	51,633	131,004	22.0%
Photo South	79,193	15.4%	0.620	8.9%	49,100	8738.0	33,929	71,054	17.8%
Vis1	23,083	7.1%	0.063	22.4%	1,454	341.1	894	2,364	23.5%
Vis2	2,880	20.8%	0.038	41.7%	109	51.0	40	294	46.8%
Vis3	2,996	11.7%	0.060	37.3%	180	70.3	78	417	39.0%
Vis4	6,313	6.4%	0.006	51.9%	38	19.8	11	126	52.1%
Total	213,079	11.5%			133,125	20069.4	96,561	183,534	15.1%

Table 3. Estimates of adult females from composition data and survey strata estimates.

Strata	Caribou on C.G.		Proportion adult females		Adult female estimate				CV
	N	CV	Estimate	CV	N	SE	95% CI		
Photo North	98,614	21.4%	0.904	2.6%	89,147	19251.9	56,395	140,921	21.6%
Photo South	79,193	15.4%	0.764	5.0%	60,503	9803.2	43,197	84,743	16.2%
Vis1	23,083	7.1%	0.210	9.1%	4,847	561.1	3,804	6,176	11.6%
Vis2	2,880	20.8%	0.113	28.4%	325	114.6	152	697	35.3%
Vis3	2,996	11.7%	0.270	14.7%	809	152.0	534	1,225	18.8%
Vis4	6,313	6.4%	0.144	14.1%	909	141.0	623	1,326	15.5%
Total	213,079	11.5%			156,540	21612.7	116,635	210,099	13.8%

4.5.3 Extrapolated estimate of total herd size

A composition survey of the Qamanirjuaq fall rutting range was conducted October 2016 to obtain an estimate of the proportion of females in the Qamanirjuaq caribou herd. With no recent fall compositions available, we used the 2016 results to determine the proportion of females within the Qamanirjuaq herd to generate the whole herd estimate. During the fall 2016 composition survey, two main breeding aggregations of caribou were classified with 6,419 and 9,894 bulls and cows classified respectively. The

resulting estimates of bull-cow ratios, and overall proportion of cows (cows/(bulls+cows)) are given in **Table 16** (Campbell et al. 2018).

Table 4. Fall 2016 composition survey results.

Ratio	Estimate	SE	Conf. Limit		CV
Bull/cow ratio	0.616	0.026	0.566	0.664	4.1%
Proportion cows	0.619	0.010	0.601	0.639	1.6%
Calf-cow ratio	0.391	0.008	0.376	0.407	2.0%

In 2014, an alternative estimate of herd size was derived by assuming that all adult cow caribou were on the core calving ground (Campbell et al. 2012; Boulanger et al. 2015). This avoided the need of a pregnancy rate since it was assumed that all non-pregnant cows (1.5 years old and older) were on the annual core area, a method that is now successfully integrated into the Qamanirjuaq survey analysis and adopted by other mainland migratory caribou herds across Nunavut and the NWT. Using this method, the estimate of the herd is simply the estimate of females divided by the proportion of females in the herd (**Table 17**). This estimate still pertains to adult caribou and not yearlings (calves of the previous year). The resulting whole herd estimate for the June 2022 Qamanirjuaq calving ground abundance survey is 252,892 (95%-CI=188,050-340,092) 1.5+ year old caribou.

Table 5. Extrapolated population estimates for the Qamanirjuaq herd using estimates of females on the calving ground (CG) and proportion females estimated in fall composition surveys.

Survey data	Estimate	SE	CV	95% Conf. Limit	
Number of caribou on core and peripheral cg	213,079	24478.6	11.5%	166,781	272,229
Number of females (breeding+non-breeding) in core calving ground	156,540	21612.7	13.8%	116,635	210,099
Proportion females in the entire herd	0.619	0.010	1.6%	0.601	0.639
Total estimate of adult (1.5+ yr old caribou) in the herd	252,892	35153.7	13.9%	188,050	340,092

4.5.4 Estimates of trend

Various metrics can be used to estimate trends in ungulate abundance (**Figure 26**). Of these the most robust metric for some herds, including the Qamanirjuaq herd, is adult females. Breeding females will be influenced by yearly variation in pregnancy rates making extrapolation from this metric less reliable in most cases. The number of caribou on the calving ground will be influenced by how extensive the survey was in targeting bulls and yearlings which often may not occur in the vicinity of the annual core calving area. For example, in June 2008, the primary target of survey efforts on the Qamanirjuaq calving ground was adult females and therefore it is likely that bulls and yearlings were counted less than other years, resulting in a lower estimate. Herd size is based on the adult female estimate and trends in herd size will be proportional to adult females since the same assumed bull-cow sex ratio has been used for all herd size estimates. For this reason, we focus on trend estimates of adult females across all surveys.

The estimate of adult females is composed of breeding and non-breeding females. **Figure 27** shows how the proportion of breeding females varied yearly with a relatively low proportion of breeding females in 2014 and 2008. For consistency between surveys, we compared sequential estimates of adult females using a one-tailed t-test to assess if a significant decline had occurred (**Table 18**). Degrees of freedom were estimated for combined estimates for each year using variances and degrees of freedom from each of the sampled stratum (Thompson, 1992). The difference in estimates was significant for the 2008 to 2014 and the 2008 to 2022 comparison (at $\alpha=0.1$) but not significant for other comparisons. The ratio of successive estimates can also be used to estimate gross and annual change (**Table 19**) with yearly change varying from 0.95 to 1.03 between successive surveys. If the ratio of 2008 to 2022 is used to estimate annual change (λ), the resulting estimate is 0.98 (95%-CI=0.96-1.00).

Overall trend was also estimated using weighted log-linear regression of the adult female estimates from 2008 to 2022, which reveals a non-significant decreasing trend with a yearly λ estimate of 0.98 (CI=0.96-1.00) (**Table 20**). This further suggests a slightly longer-term declining trend of 2% per year which is similar to the ratio of the 2008 to 2022 estimate. However, this estimate was not statistically significant. A plot of

regression estimates demonstrates the potential of a decreasing trend when the confidence limits of individual estimates are considered (**Figure 28**).

Table 6. Comparison of adult female estimates from successive surveys using t-tests. Also included is a test comparing 2008 and 2022 estimates. P-values are from a one-tailed t-test ($H_0 N_2 \geq N_1$, $H_a N_2 < N_1$).

Years compared	N _(year 1)	SE N _(year 1)	Df _(year1)	N _(year 2)	SE N _(year 2)	Df _(year2)	t-test	Df t	p-value
2008-14	215,049	17373.9	35	163,066	13296.4	28	-2.38	61.6	0.010
2014-17	163,066	13296.4	28	178,423	13599.8	27	0.81	54.9	0.789
2017-22	178,423	13599.8	27	156,540	21612.7	18	-0.86	31.8	0.199
2008-22	215,049	17373.9	35	156,540	21612.7	18	-2.11	40.2	0.021

Table 7. Estimates of adult females for 2008, 2014, 2017, and 2022. The gross change in estimates (based on the ratio of successive N estimates) and yearly rate of change is also given.

Year	Estimate N	SE	Gross change			Yearly change (λ)		
			Estimate	Conf. Limit		Estimate	Conf. Limit	
2008	215,049	17,373.9						
2014	163,066	13,296.4	0.76	0.61	0.95	0.95	0.92	0.99
2017	178,423	13,599.8	1.09	0.88	1.36	1.03	0.96	1.11
2022	156,540	21,612.7	0.88	0.64	1.19	0.97	0.91	1.03

Table 20. Regression estimates of trend (2008-2022). The per capita rate of increase (r) is estimated as the slope term with the annual finite rate of increase (λ) estimated as the exponent of r .

Parameter	Estimate	SE	95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept	12.246	0.099	12.049	12.436	124.062	0.000
Year (r)	-0.021	0.012	-0.043	0.002	-1.804	0.213
λ	0.979		0.958	1.002		

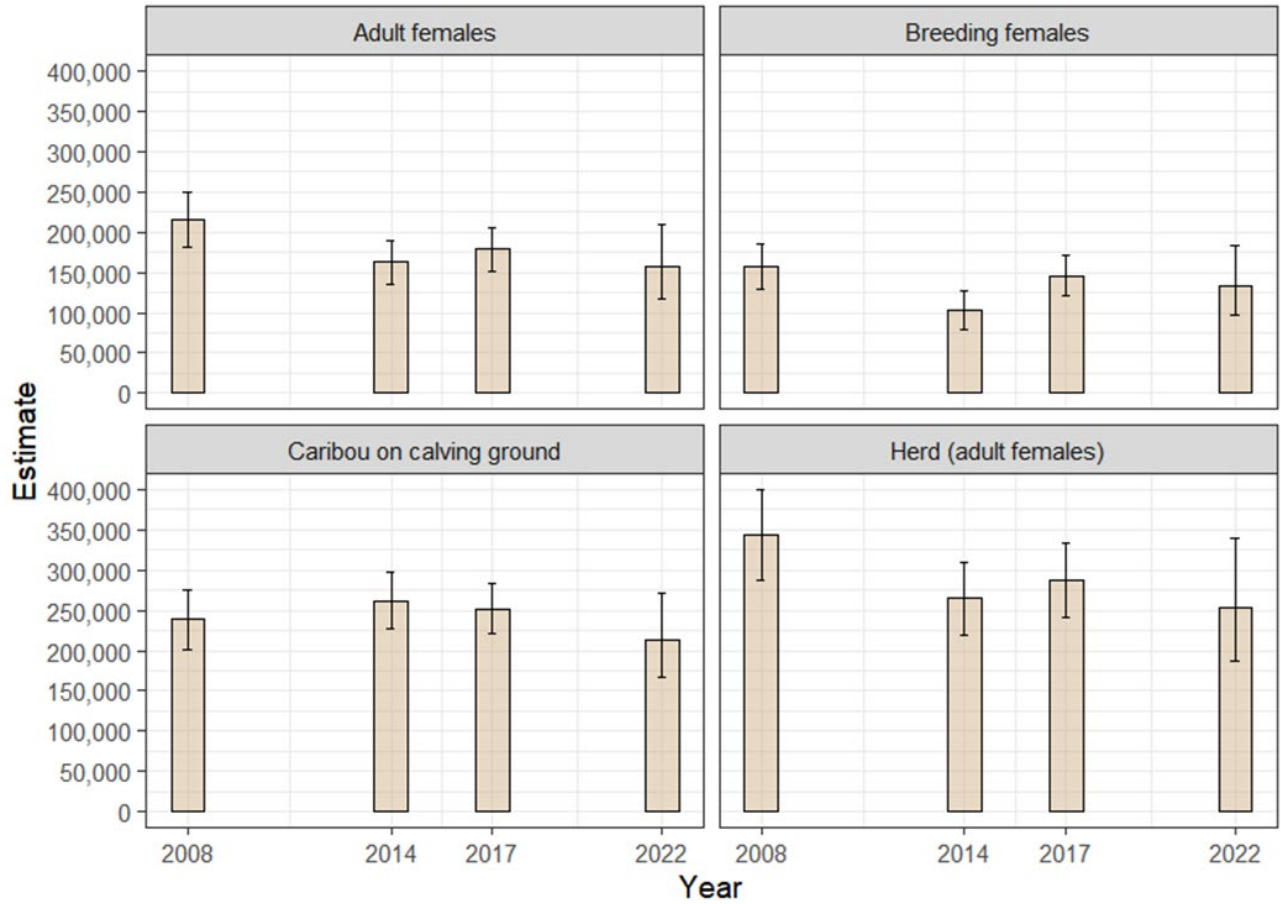


Figure 26. Estimates of Qamanirjuaq herd status using various metrics from 2008 to 2022. Estimates from previous years taken from previous survey reports (Campbell et al. 2010, Campbell et al. 2016, Boulanger et al. 2018).

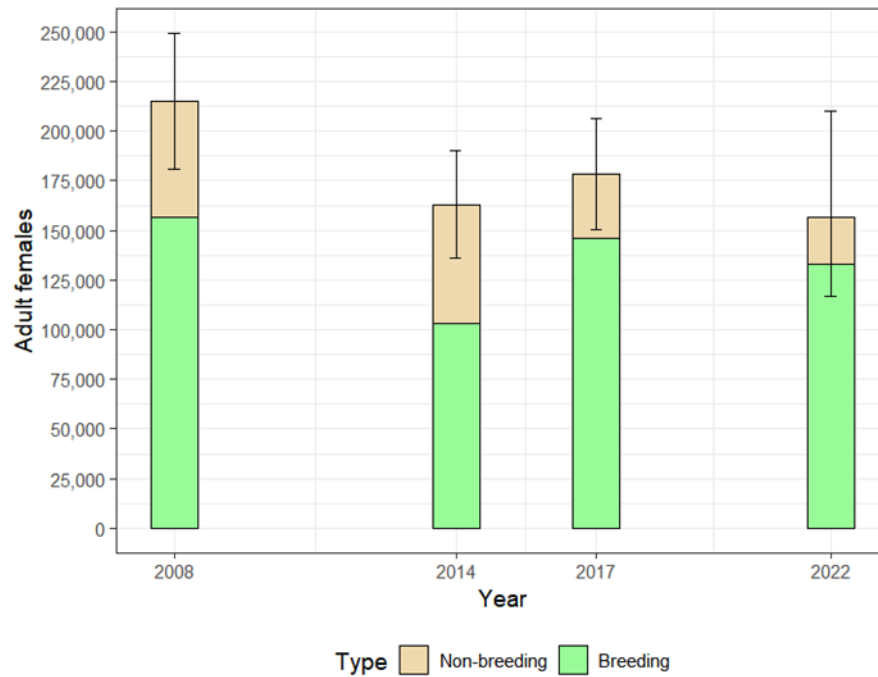


Figure 27. Estimates of Qamanirjuaq adult females, breeding females, and extrapolated herd size based on adult females (Table 18 for the 2008, 2014, 2017, and 2022 surveys).

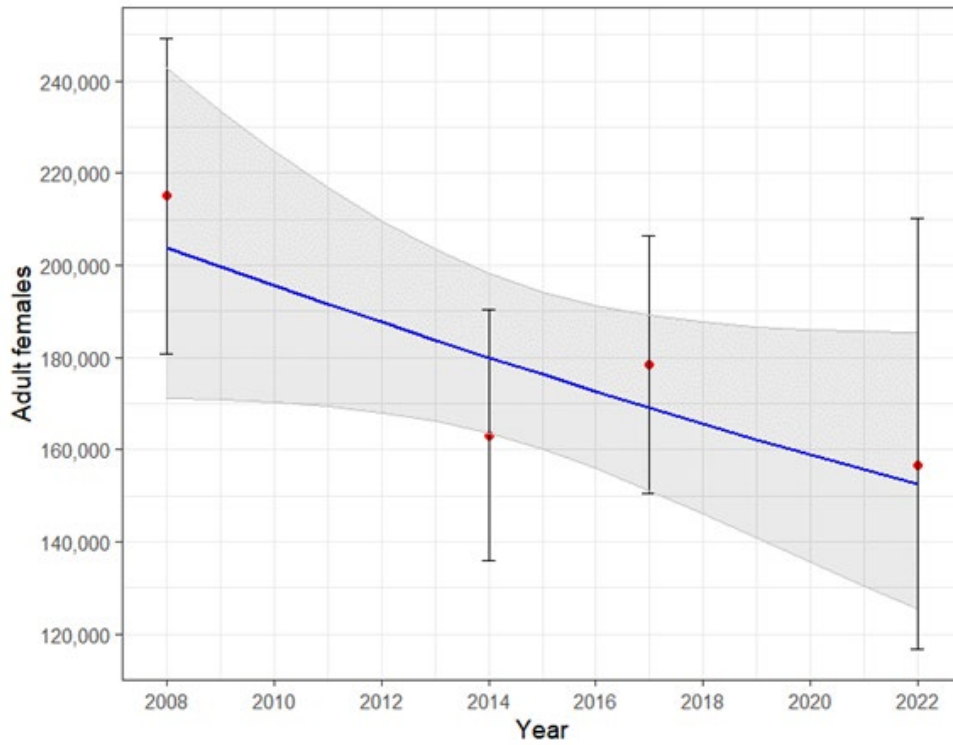


Figure 28. Predicted trends in Qamanirjuaq herd abundance from log-linear regression. Confidence limits on regression predictions are given as hashed blue lines. Individual estimates are shown as red points with displayed 95% confidence limits.

4.6 Changes in Annual Calving Extents

Qamanirjuaq mainland migratory barren-ground caribou typically do not calve in the same locations year after year but rather utilize geographically distinct annual calving grounds within a larger and more geographically predictable concentrated core calving ground (**Figure 29**). Amongst Inuit Qaujimagatuqangit (IQ) and scientific study there is general agreement that the mainland migratory caribou herds, including the Qamanirjuaq herd, cycle every 40 to 60 years (from population low to population low) (Bongelli 2020; Bongelli et al, 2022). Unfortunately, we only have useful telemetry data for the last 30 years, leaving an estimated 20-year gap in our complete understanding of the full extent of the core concentrated seasonal calving range through one complete population cycle (amongst other seasonal ranges). In the case of the Qamanirjuaq herd, both long-term monitoring studies and IQ predict that the spatial extents of annual calving grounds when examined over the long-term will remain within a geographically larger core calving ground, an area representative of the long-term calving needs of the herd (**Figure 29**).

More recently, delineated annual calving grounds have extended beyond the 2013 delineated core calving area. This finding is not entirely unexpected when considering the 20-year gap in our spatial knowledge of Qamanirjuaq herd calving through a full 40-to-60-year population cycle. To understand the herds long-term calving needs in terms of minimum spatial extents, we will need to examine a time series of seasonal range use from population low to population low. To assume we currently hold sufficient information to assess the herds spatial needs for calving, migratory, post-calving, summer, rutting and winter seasonal range, would be misleading and risk the long-term viability of the herd should an underestimate of the long-term core calving requirements of the Qamanirjuaq herd be made.

An examination of telemetry delineated annual calving-grounds for the 2008, 2014, 2017, and 2022 June calving abundance surveys suggest that the annual calving grounds (represented by the 95% utilization distribution) were substantively different, with a general geographic trend to the north and east of 2013 delineated core calving

extents when compared to an updated core calving seasonal range polygon current to 2023 using the same analytical methods (**Figure 30**). This same general trend is also seen within a 20-year assessment further broken down into 5-year segments. The results of the 5-year segmented approach suggests that the 4 survey years were representative of more normal environmental patterns and not an artifact of extreme environmental conditions known to have occurred on occasion, within long-term telemetry data (**Figure 31**). We suspect annual core calving range will see further changes as we expand the telemetry database. As more telemetry data is collected, we strongly suspect that annual core calving extents will expand to accommodate annual variations repeated throughout the population cycle. The resulting updated polygons will better predict long-term annual requirements for the herd.

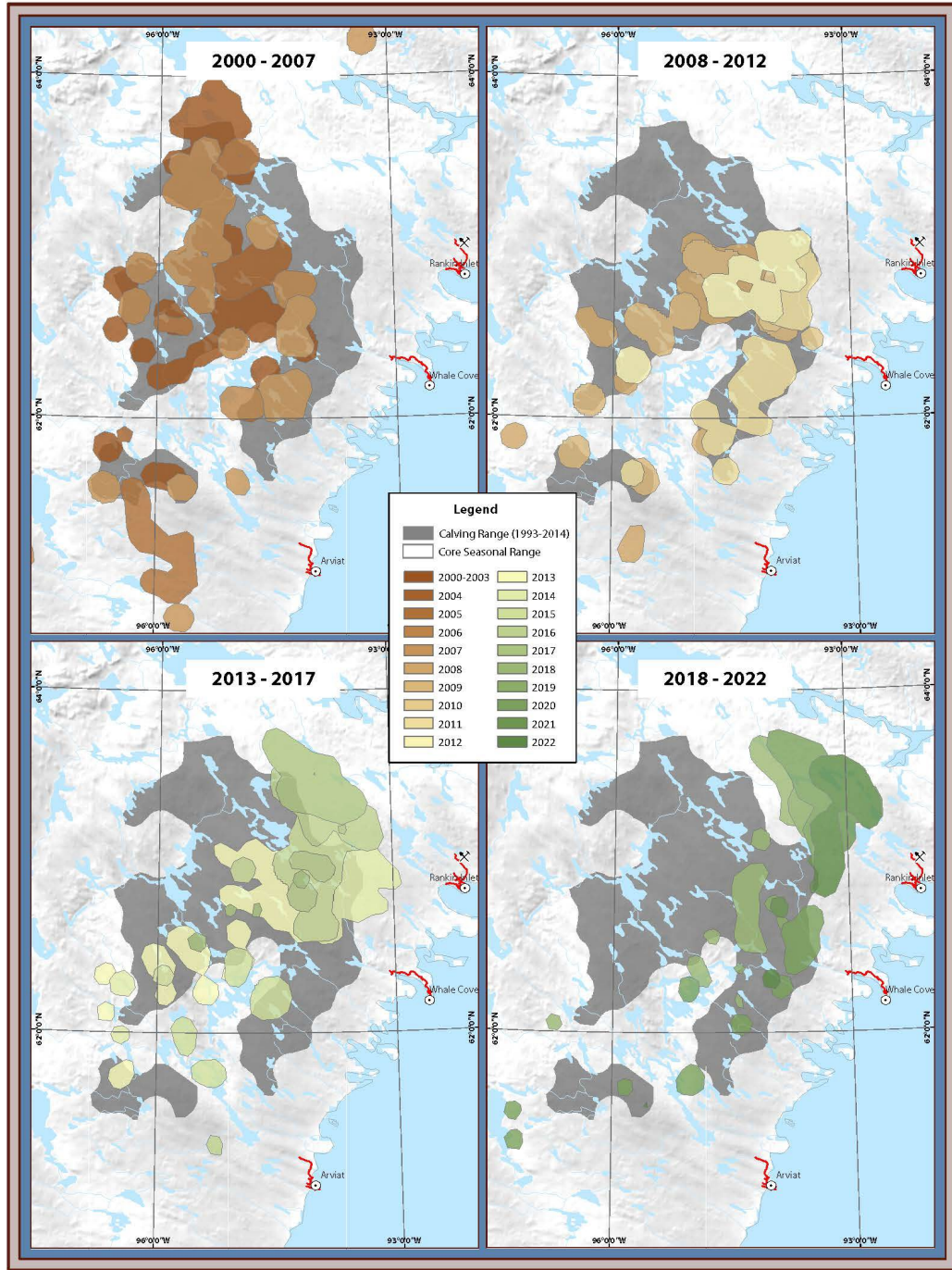


Figure 29. A representation of annual calving grounds from June 9th through June 22nd for the years 2000 through 2022. Polygons developed using a kernel density estimation (KDE) of caribou cow telemetry data.

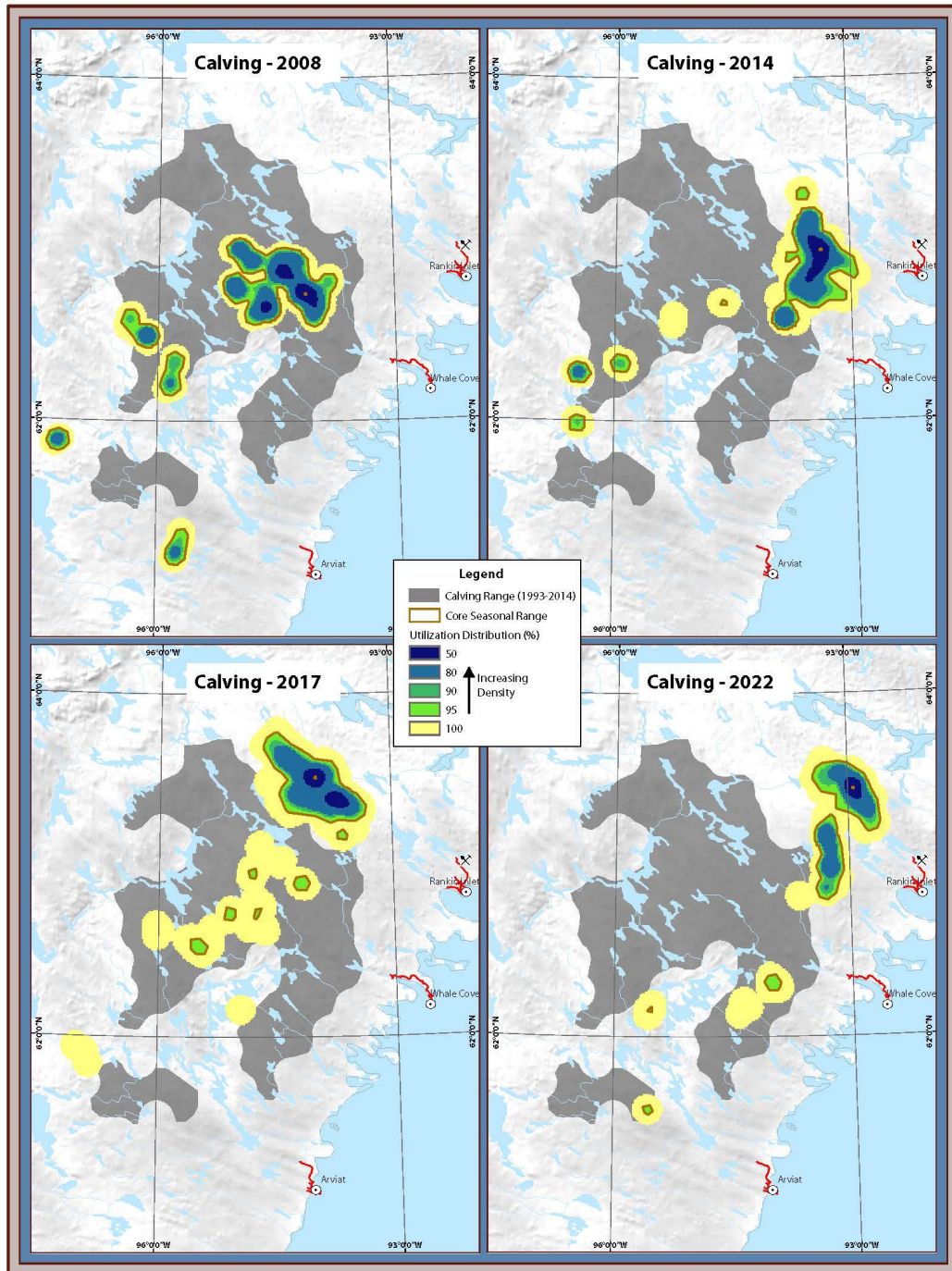


Figure 30. A spatial assessment of Qamanirjuaq Herd annual calving extents for each of the 2008, 2014, 2017, and 2022 (this report) calving-ground abundance surveys. A kernel density estimation (KDE) approach was used to generate utilization distributions.

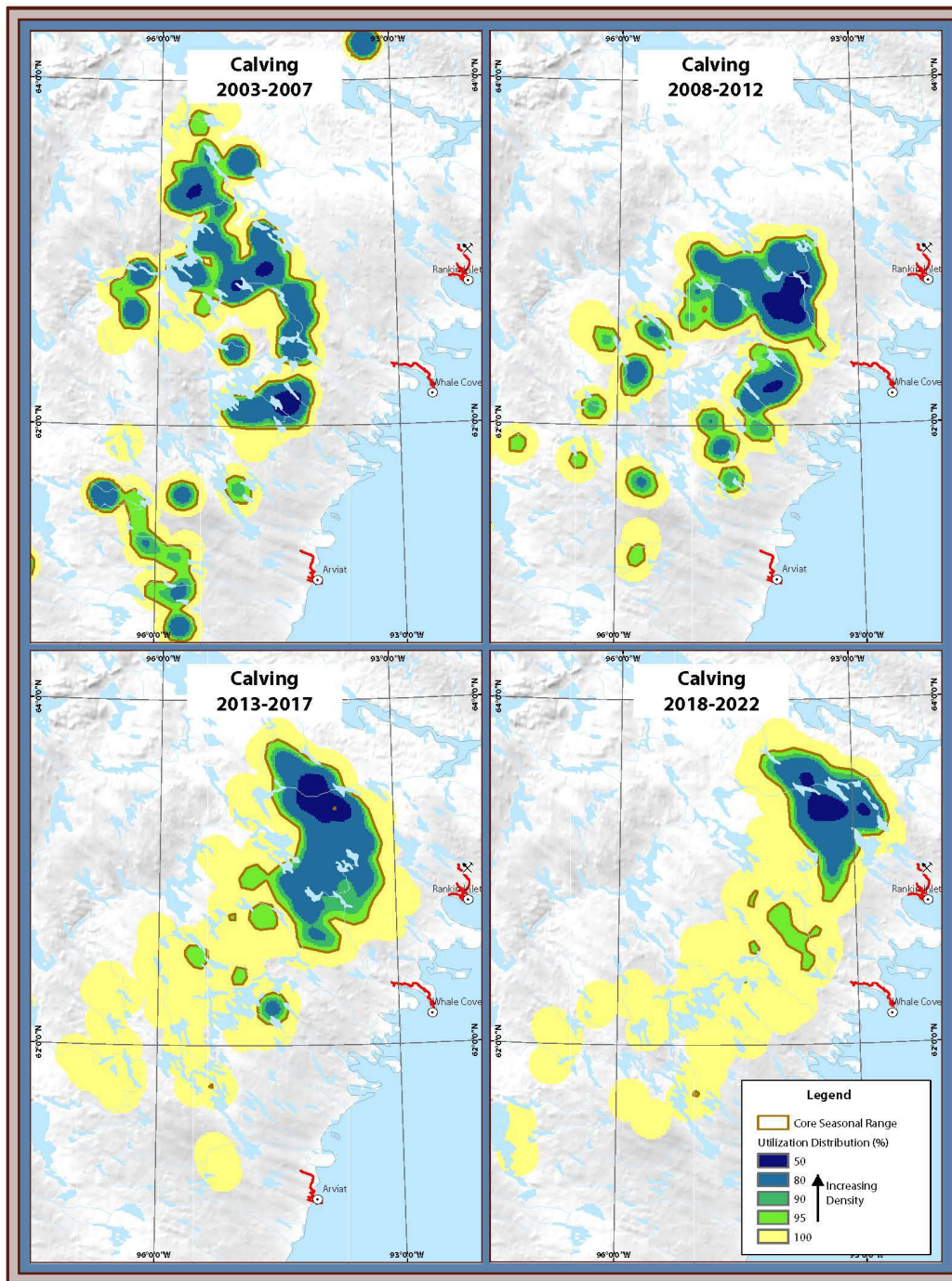


Figure 31. A spatial assessment of Qamanirjuaq Herd annual calving extents over a 20-year period broken down by 5-year increments. A kernel density estimation (KDE) approach was used to generate utilization distributions.

5.0 DISCUSSION

The overall survey results suggest that the herd is relatively stable when compared to the 2014 and 2017 estimates. However, direct comparison with the 2008 estimate along with the 2014 and 2017 estimates, suggests a slow decline. A one-tailed t-test comparison of 2008 and 2022 estimates reveals a significant decline. However, the overall trend from a regression analysis was not statistically significant.

Survey precision was lower in 2022 (CV=14% for adult females) than previous years but still within the acceptable range (CV<20%). The main reason for this lower precision of the photo-north stratum was due to a high level of aggregation (**Figure 23**) which caused high variation in densities amongst individual transects. One approach to address this issue would be to increase the number of lines and subsequent coverage in the stratum. The coverage in the photo-north stratum was reasonably high (42%) when compared with previous surveys. For example, the highest coverage in the 2017 survey was 35% in two of the photo-stratum. The approach of increasing coverage and aggressively sampling likely areas of aggregation with visual strata buffers could be considered as an approach to confront aggregation in future surveys.

Coverage in other caribou surveys, such as the Bathurst in 2012 has been as high as 72% which was due to a highly aggregated group of caribou in a small (914.2 km²) survey area (Boulanger et al. 2014b). The resulting CV for the estimate in this stratum was 8%. A randomization approach was used to assess if there was an optimal coverage level where the CV did not change with increasing coverage with no asymptote found. A coverage level of 65% was still required to obtain a CV of less than 10%.

Recently, new approaches have been developed that consider multiple sources of information to improve our estimates and understanding of trends. The demographic status of a herd can be better understood using an Integrated Population model (Schaub and Kery, 2022) that uses data from composition surveys, collar survival rates, and

calving ground surveys to provide an overall estimate of trend as well as refined estimates of demographic parameters. This approach has been used successfully to provide refined estimates of trend for the Bluenose East and Bathurst herds (Adamczewski et al. 2022, Boulanger et al. 2022). This approach will be pursued for the Qamanirjuaq herd in the future.

Our collective experience from the Bathurst Herd shows that major declines in mainland migratory barren-ground caribou subpopulations must be detected as early as possible to inform decisions to maintain the subsistence needs of Inuit and other indigenous peoples. Knowing the trend and status of the population will provide co-management partners with more options such as critical habitat protection, non-quota limitations (NQLs), commercial harvesting restrictions, in order to maintain herds or promote recovery following any major declines. All monitored indices of the herd, when examined in series, indicate that the Qamanirjuaq herd is in a continued slow decline. Therefore, lack of appropriate actions may exacerbate or prolong or halt herd recovery and place undue hardship on Inuit that harvest this herd both commercially and for subsistence. These hardships will also impact harvesters from Northern Manitoba, Northern Manitoba, and the NWT.

It is well known within the scientific literature, and amongst Northern Indigenous peoples that Barren-ground caribou undergo regular and long-term (between 50 and 70 years) cycles of abundance (Bongelli et al. 2020; Gunn, 2003; Zalatan et al. 2006; St. John, 2022). Additionally, there appears to be synchrony between the barren-ground herds including the Bluenose, Bathurst, Beverly, Leaf River, and George River mainland migratory herds that could be in response to large-scale environmental factors such as climate change and associated localized weather events and patterns, density dependant reproductive disease and parasites, and predator and human harvest effects. This also suggests that these mainland migratory caribou herd declines and associated mechanisms would impact all herds eventually. These impacts could be exacerbated by other anthropogenic effects on caribou mortality such as a growing internet market for caribou meat within Nunavut Territory, or industrial disturbance and associated avoidance behaviour and habitat loss within sensitive seasonal range such as the core calving grounds, post-calving areas and migratory routes (Panzacchi et al. 2012, Plante

et al. 2020, Boulanger et al. 2021, Boulanger et al. 2023, Severson et al. 2023). Loss of seasonal range access and availability would likely result in quantitative changes to long-term abundance through the loss of productive annual range and herd fragmentation. The impacts of anthropogenic activities such as industrial development or extractive practices on caribou and their range are uncertain, however, the scientific literature warns of the very real risk of negatively impacting caribou and their range over the long-term. With the industrial extraction of natural resources on the increase in northern North America, and more specifically within barren-ground caribou critical seasonal range, it is becoming more and more important that land use regulators and wildlife managers and biologists develop a better understanding of important seasonal range while closely monitoring herd status in order to more effectively manage anthropogenic impacts on range size and use, migratory behaviour, and herd productivity. Not doing so would work against Article 5, Part 1, Section 5, of the Nunavut Agreement as it could reduce harvesting opportunities, negatively impacting Inuit's right to harvest wildlife to meet their subsistence needs as described in the Nunavut agreement (**Figure 32**).

5.1.5 The principles of conservation are:

- (a) The maintenance of the natural balance of ecological systems within the Nunavut Settlement Area;
- (b) The protection of wildlife habitat;
- (c) The maintenance of vital, healthy, wildlife populations capable of sustaining harvesting needs as defined in this Article; and
- (d) The restoration and revitalization of depleted populations of wildlife and wildlife habitat.

Figure 32. Article 5.1.4 of the Nunavut Agreement “*The Principles of Conservation*”, an excerpt from the Nunavut Agreement Page 27 (Agreement Between the

Inuit of the Nunavut Settlement Area and Her Majesty the Queen in right of Canada, 2009).

as well as negatively impacting the harvesting rights and cultural practices of Indigenous cultures within Manitoba, Saskatchewan, and the Northwest Territories.

6.0 MANAGEMENT CONSIDERATIONS

Concerns regarding the Qamanirjuaq herd have changed little since the June 2017 Qamanirjuaq caribou calving ground abundance survey. Hunters and Trappers Organizations (HTO's) and the Kivalliq Wildlife Board (KWB) continue to communicate their concerns over the status of the Qamanirjuaq herd. Some of the most common concerns brought forward during annual consultative meetings include: 1) inter-territorial caribou meat sales, primarily between the Kivalliq and Baffin Regions, are believed to be excessive and negatively impacting the local harvest of caribou for community based food needs; 2) there is extreme concern over development in calving grounds, Key Access Corridors (mutually inclusive calving, post-calving, and spring migratory seasonal range), water crossings, and post-calving grounds, as well as concern over disturbance to migrating caribou along linear industrial infrastructure. Both peer-reviewed science and IQ agree that industrial development in calving and post-calving grounds have not been shown to be mitigated in other contexts and areas resulting in changes in caribou abundance, distribution, behaviour, and health over the long term. These impacts, should they occur, would negatively impact caribou and Inuit harvesting; 3) Many hunters from across the region have communicated their sense of a general decline in abundance, and increase in disease prevalence. These concerns suggest that conditions are changing on the Qamanirjuaq range, and that our ability to monitor these changes should be heightened so that all co-managers can effectively advocate effective management action to safeguard Nunavut's largest caribou population.

Though the regression-based trend of Qamanirjuaq herd abundance estimates between the June 2008 and June 2022 indicates a non-significant declining trend of 2% annually (Figure 28 and Table 20), the current survey results show a significant decline in mean herd abundance between June 2008 and June 2022 (Table 18). The lack of statistical significance in regression-based trend estimates (that include 2008, 2014, 2017, and

2022 estimates) may be due to stability in the period of 2014-2017, however, it should be noted that precision of estimates (large confidence intervals) is low along with lower sample sizes of survey points. Spring composition studies when examined together suggest productivity levels consistent with a slow decline. The fact that mainland migratory barren-ground caribou are well known within both scientific (Bongelli et al 2020) and local knowledge to follow long-term (40 to 60 year) population fluctuations suggests that the Qamanirjuaq herd is at high risk of further decline over the next 5 to 10 years as food resources become over utilized and as a result, harder to find.

Because of the uncertainty between the 2014, 2017, and 2022 abundance estimates, this report is not recommending any management action at this time. This report does however acknowledge the slow decline indicated by comparison of June 2008 and 2022 estimates and for this reason highlights the importance of continued monitoring of herd trend. Of equal importance is the protection of critical range to ensure healthy seasonal range remains accessible to Qamanirjuaq caribou when recovering from cyclical and/or significant declines in abundance, typical of mainland migratory barren-ground caribou herds such as the Qamanirjuaq herd. Such protections will act to secure Inuit harvesting rights by respecting the principles of conservation guaranteed to Inuit within the Nunavut Agreement which in turn will maximize harvesting opportunities and the associated health and monetary benefits that result from healthy abundant caribou populations. These actions align with Regional Wildlife Organization (RWO), HTO, and community priorities to protect caribou annual core calving areas, key access corridors, post-calving range, water crossings, and other important seasonal range across the Qamanirjuaq herd's annual range.

Initial survey results and progress have been shared with co-management partners, including representatives from the KWB, Kivalliq HTO's, Beverly Qamanirjuaq Caribou Management Board (BQCMB), Nunavut Wildlife Management Board (NWMB), and the jurisdictions of Saskatchewan, Manitoba, NWT and Canada (ECCC). Consultations with community Hunters and Trappers Organizations regarding survey results occurred in early 2024, however, co-management partners including HTO's, the Kivalliq Wildlife Board (KWB), the Nunavut Wildlife Management Board (NWMB), and the Nunavut Department of Environment (ENV), will continue to discuss survey results and

recommendations (as represented in this report) and other issues at upcoming annual meetings. The GN ENV will continue to include, investigate, and report on, any findings derived from new scientific analysis, and IQ that may provide additional insight into the mechanisms influencing Qamanirjuaq caribou herd abundance and trend.

7.0 ACKNOWLEDGMENTS

We would like to thank the following people for their contribution to the June 2022 Qamanirjuaq Herd calving-ground photographic survey. We would like to thank Leo Ikakhik, David Makkigak, Dennis Larocque, Jackie Batstone, John Etegyok, John Voisey, Oliver Shipton, and Russell Toolooktook for their tireless, keen observation skills, and for their valuable input which help lead to the successful completion of this survey. We would also like to thank Vicky Trim and Joanie Kennah from the Manitoba Department of Natural Resources and Northern Development for their assistance in survey logistics and composition studies. Environment and Climate Change Canada (ECCC), the Nunavut Wildlife Management Board (NWMB), the Government of Nunavut, and the Government of Manitoba, all contributed substantial financial support as well as human resources towards all aspects of this study. We would also like to thank the Government of Saskatchewan for supporting the participation of an experienced community-based observer through the survey's duration. We would like to thank NTI for their continued staffing support of community supported survey efforts including the this Qamanirjuaq survey. We would like to thank Bob Schnurr and Ted Dunkier from Air Tindi for their coordination of fixed winged support, and to the Twin Otter Pilots Xavier Dencausse, Abigail Guthrie, Kevin Carr, and Jeremy DeGeer, for their exceptional flying skills and for keeping our crews safe during the survey effort. We would also like to thank Vic Cobb with Custom Helicopters for his continued exceptional flying abilities during the composition phase of the Qamanirjuaq survey effort. Brayden StPierre with GeodesyGroup Inc. did an exceptional job of accurately and efficiently photographing the high-density photo strata, and Derek Fisher with GreenLink Forestry Inc. did an equally exceptional job of interpreting the photos and providing accurate caribou counts. The Kivalliq HTOs supported us from the beginning to end of this survey effort for which our entire survey team was and remains truly grateful. Finally, we would

like to thank Drikus Gissing, Director of Wildlife Research for his continued behind the scenes support, without which, these major survey efforts could not be achieved.

8.0 LITERATURE CITED

- Adamczewski, J., J. Boulanger, B. Croft, T. Davison, H. Sayine-Crawford, and B. Tracz. 2012. A comparison of calving and post-calving photo-surveys for the Bluenose-East herd of barren-ground caribou in the Northwest Territories, Canada in 2010. Environment and Natural Resources, Government of Northwest Territories.
- Adamczewski, J., J. Boulanger, J. Williams, D. Cluff, K. Clark, S. Goodman, K.-S. Chan, R. Abernathy, and J. Nishi. 2022. Estimates of Breeding Females & Adult Herd Size and Analyses of Demographics for The Bathurst Herd of Barren-Ground Caribou: 2021 Calving Ground Photographic Survey Environment and Natural Resources.
- Agreement Between the Inuit of the Nunavut Settlement Area and Her Majesty the Queen in right of Canada. 2009. Indian and Northern Affairs Canada. Catalogue No. R32-134/1993 E. ISBN 0-662-20725-4. 283 pp.
- Bergerud, A.T., S.N. Luttich, and L. Camps. 2008. The Return of The Caribou to Ungava. Queens University Press. Montreal, Quebec, Canada. 656 pp.
- Bongelli E., M. Dowsley, H.D. Cluff, M. Campbell and M. Taylor. 2022. North American barren-ground caribou cycles are driven by logistic trophic dynamics. *Authorea*, 21 pp.
- Bongelli E., M. Dowsley, V.M. Velasco-Herrera, and M. Taylor. 2020. Do North American Migratory Barren-Ground Caribou Subpopulations Cycle? *Arctic*. Vol. 73, No. 3. Pp. 326-346.
- Boulanger, J., J. Adamczewski, J. Williams, D. Cluff, K. Clark, S. Goodman, K.-S. Chan, and R. Abernathy. 2022. Estimates of Breeding Females & Adult Herd Size and Analyses of Demographics for the Bluenose-East Herd of Barren-Ground Caribou: 2021 Calving Ground Photographic Survey Environment and Natural Resources.

- Boulanger, J., M. Campbell, and D.S. Lee. 2018. Estimating Abundance and Trend of the Qamanirjuaq Mainland Migratory Barren-ground Caribou Sub-population – June 2017. GN ENV Technical Summary: No: 01-2018. 100 pp.
- Boulanger, J., M. Campbell, D. Lee, M. Dumond, and J. Nishi. 2014a. A double observer method to model variation in sightability of caribou in calving ground surveys. Unpublished manuscript.
- Boulanger, J., B. Croft, and J. Adamczewski. 2014b. An estimate of breeding females and analyses of demographics for the Bluenose East herd of barren ground caribou: 2013 calving ground photographic survey. Department of Environment and Natural Resources, Government of Northwest Territories, File Report No. 143.
- Boulanger, J., B. Croft, and J. Adamczewski. 2014e. An estimate of breeding females and analysis of demographics from the 2012 Bathurst barren ground caribou calving ground survey. Department of Environment and Natural Resources, Government of Northwest Territories File Report No. 142.
- Boulanger, J., A. Gunn, J. Adamczewski, and B. Croft. 2011. A data-driven demographic model to explore the decline of the Bathurst caribou herd. *Journal of Wildlife Management* 75:883-896.
- Boulanger, J., R. Kite, M. Campbell, J. Shaw, D. Lee, and S. Atkinson. 2023. Estimating the effects of roads on migration: a barren-ground caribou case study. *Canadian Journal of Zoology* DOI: 10.1139/cjz-2023-0121
- Boulanger, J., K. G. Poole, A. Gunn, J. Adamczewski, and J. Wierzchowski. 2021. Estimation of trends in zone of influence of mine sites on barren-ground caribou populations in the Northwest Territories, Canada, using new methods. *Wildlife Biology* 2021:10.2981/wlb.00719.
- Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. Distance Sampling. Estimating Abundance of Biological Populations. Chapman & Hall, London.

- Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: A practical information theoretic approach. Springer, New York, New York, USA.
- Buckland, S. T., J. Laake, and D. L. Borchers. 2010. Double-observer line transect methods : levels of independence *Biometrics* 66:169-177.
- Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: A practical information theoretic approach. Springer, New York, New York, USA.
- BQCMB. 2005. Beverly and Qamanirjuaq caribou management plan: 2005-2012. Beverly and Qamanirjuaq Caribou Management Board. 17 p.
- BQCMB. 1999. Protecting Beverly and Qamanirjuaq caribou and caribou range. Beverly and Qamanirjuaq Caribou Management Board. 40 p.
- Brown D. and P. Rothery. 1993. Models in biology: mathematics, statistics and computing. John Wiley and Sons. New York. 687 p.
- Calef, GW., and R. Hawkins. 1981. Kaminuriak Caribou Herd Calving Ground Survey, 1976. Wildlife Service. Government of the NWT. ESCOM Report No. **AI-41**. 15 pp.
- Campbell, M.W., A. Kelly, B. Croft, J.G. Shaw, C.A. Blyth. 2014. Barren-ground Caribou in Nunavut and Northwest Territories – Map Atlas. Government of Nunavut, Department of Environment. Government of Northwest Territories, Department of Environment and Natural Resources. Map series.
- Campbell, M.C., J.G. Shaw and C.A. Blyth. 2012-A. Kivalliq Ecological Land Classification Map Atlas: A Wildlife Perspective. Caslys Consulting Limited. Government of Nunavut, Department of Environment. Technical report Series **#1-2012**. 274 pp.
- Campbell, M., J. Nishi and J. Boulanger. 2010. A Calving Ground Photo Survey of the Qamanirjuaq Migratory Barren-Ground Caribou (*Rangifer tarandus groenlandicus*) Population – June 2008. Nunavut Wildlife Research Section. Nunavut Government. Arviat, NU. Technical Report Series No. **1-10**. 121 pp.

- Campbell, M., J. Boulanger, and D.S. Lee. 2015-A. Estimating Abundance of the Qamanirjuaq Mainland Migratory Barren-ground Caribou Sub-population – June 2014. Government of Nunavut, Department of Environment, Technical Report Series: No: 01-2016. 90 pp.
- Campbell, M., J. Boulanger, D. Lee, M. Dumond, and J. McPhearson. 2012-B. Calving Ground Abundance Estimates of the Beverly and Ahiak Subpopulations of Barren-Ground Caribou (*Rangifer tarandus groenlandicus*) – June 2011, Technical Summary. Department of Environment, Government of Nunavut.
- Campbell, M., J. Goorts, D.S. Lee, J. Boulanger, and T. Pretzlaw. 2015-B. Aerial Abundance Estimates, Seasonal Range Use, and Demographic affiliations of the Barren-Ground Caribou (*Rangifer tarandus groenlandicus*) on Baffin Island – March 2014. Department of Environment, Nunavut Wildlife Research Division, .
- Cochran, W.G. 1977. Sampling techniques, 3rd ed. John Wiley and Sons, Inc. New York. 428 p.
- Dauphine, T. C. Jr. 1976. Biology of the Kaminuriak population of barren-ground caribou. Part 4: Growth, reproduction and energy reserves. Canadian Wildlife Service Report Service No. 38. 69 p.
- Environment Canada. 2001. Narrative Descriptions of Terrestrial Ecozones and Ecoregions of Canada. <http://www.ec.gc.ca/soer-ree/English/Framework/Nardesc/efaultt.cfm>. Accessed 13 August 2001. Last Updated 08-13-2001.
- Fewster, R. M., S. T. Buckland, K. P. Burnham, D. L. Borchers, P. E. Jupp, J. Laake, and L. Thomas. 2009. Estimating the Encounter Rate Variance in Distance Sampling. *Biometrics* 65:225-236.
- Gasaway, W. C., S. D. Dubois, D. J. Reed, and S. J. Harbo. 1986. Estimating moose population parameters from aerial surveys. *Biological Papers of the University of Alaska* No 22:1-108.
- Gates, C.C. 1983. Composition of the Kaminuriak Caribou Population in the Fall of 1979 and 1981. N.W.T. Wildlife Service File Report. 25pp.

- Gates, C. C. 1985. The Fall and Rise of the Qamanirjuaq Caribou. – In: Meredith, T.C. and Martell, A.M. (eds). Second North American Caribou Workshop. McGill Subarctic Research Paper No. **40**. McGill University, Montreal. 215-228.
- GNWT. 2006. Bathurst caribou herd 2006 survey results and next steps. Department of Environment and Natural Resources Briefing Note.
- Gunn A. 2003. Voles, Lemmings and Caribou – Population Cycles Revisited? *Rangifer*, 23. 105-111 pp.
- Gunn, A., J. Nishi, J. Boulanger and J. Williams. 2005. An estimate of breeding females in the Bathurst herd of barren-ground caribou, June 2003. Department of Environment and Natural Resources, Government of the Northwest Territories. Manuscript Report No. 164. 75 p.
- Gunn, A. and M. Sutherland. 1997. Surveys of the Beverly caribou calving grounds, 1957-1994. Northwest Territories Department of Resources, Wildlife and Economic Development. File Report No. 120. 119 p.
- Heard, D.C. 1981. An Estimate of the Size and Structure of the Kaminuriak Caribou Herd in 1977. Wildlife Service, Government of the Northwest Territories. Report No. AI-**40**:40 pp.
- Heard, D. C. 1985. Caribou census methods used in the Northwest Territories. McGill Subarctic Research Papers 40:229-238.
- Heard. D. C. 1987a. Allocation of effort in stratified survey design. Department of Renewable Resources Manuscript Report No. 19. 9 pp.
- Heard D. C. 1987b. A simple formula for calculating the variance of products. Department of Renewable Resources Manuscript Report. 5 p.
- Heard, D. and G.W. Calef. 1986. Population Dynamics of the Qamanirjuaq Caribou Herd, 1968 – 1985. *Rangifer*, Special Issue No. **1**:159-166.
- Heard, D.C., Jackson, F. J. and T.M. Williams. 1990. Beverly Calving Ground Survey 2-14 June 1987. NWT Department of Renewable Resources File Report No. **22**:118 pp.

- Huggins, R. M. 1991. Some practical aspects of a conditional likelihood approach to capture experiments. *Biometrics* 47:725-732.
- Innes, S., M. P. Heidi-Jorgensen, J. L. Laake, K. L. Laidre, H. J. Cleator, P. Richard, and R. E. A. Stewart. 2002. Surveys of belugas and narwhals in the Canadian High Arctic NAMMMCO Scientific Publications No. 3.
- InterGroup Consultants Ltd. 2013. Economic Valuation and Socio-Cultural Perspectives of the Estimated Harvest of the Beverly and Qamanirjuaq Caribou Herds. InterGroup Consultants Ltd., 500-280 Smith Street, Winnipeg, MB. Report for: Beverly and Qamanirjuaq Caribou Management Board. 58 pp.
- Johnson, D. and R. Mulders. Systematic reconnaissance survey of the Beverly herd of barren ground caribou, June 2002. Department of Environment and Natural Resources Manuscript Report. in prep. v.
- Jolly, G. M. 1969. Sampling method for aerial census of wildlife populations. *East African Agricultural and Forestry Journal*. 34: 46-49.
- Krebs, C. J. 1998. *Ecological Methodology* (Second edition). Benjamin Cummins, Menlo Park, California.
- Laake, J., D. L. Borchers, L. Thomas, D. Miller, and J. Bishop. 2012. Mark-recapture distance sampling (MRDS) 2.1.0. R statistical package program.
- Laake, J., M. J. Dawson, and J. Hone. 2008a. Visibility bias in aerial survey: mark-recapture, line-transect or both? *Wildlife Research* 35:299-309.
- Laake, J., R. J. Guenzel, J. L. Bengtson, P. Boveng, M. Cameron, and M. B. Hanson. 2008b. Coping with variation in aerial survey protocol for line-transect sampling. *Wildlife Research* 35:289-298.
- Manly, B. F. J. 1997. *Randomization and Monte Carlo methods in biology*. Chapman and Hall. New York. 281 p.
- Marshall, L. 2021. Distance Sampling Survey Design: dssd R package.

- Nagy, J. and M.W. Campbell. 2012. Herd Structure, Movements, Calving Grounds, Activity Periods, Home Range Similarity, and Behaviours of Migratory and Tundra-Wintering Barren-Ground Caribou on Mainland Nunavut and Eastern Mainland Northwest Territories, Canada. Nunavut Department of Environment. Wildlife Research Section. Technical Report Series. No. 01-12. 152 pp.
- Nagy, J.A.S. 2011. Use of Space by Caribou in Northern Canada. Department of Biological Sciences. University of Alberta. Edmonton Alberta. PhD Thesis. 164 pp.
- Nagy, J.A., D.L. Johnson, N.C. Larter, M.W. Campbell, A.E. Derocher, A. Kelly, M. Dumond, D. Allaire, and B. Croft. 2011. Subpopulation Structure of Caribou (*Rangifer tarandus L.*) in Arctic and Subarctic Canada. *Ecological Applications*. **21(6)**: 2334-2348.
- Nagy, J. and D. Johnson. 2006a. Estimates of the number of barren-ground caribou in the Cape Bathurst and Bluenose West herds and reindeer/caribou on the upper Tuktoyaktuk Peninsula derived using post-calving photography, July 2006. Department of Environment and Natural Resources Manuscript Report. in prep. v.
- Nagy, J. A. and D. Johnson. 2006b. Estimates of the number of barren-ground caribou in the Cape Bathurst and Bluenose-West herds using post-calving photography, July 2005. Department of Environment and Natural Resources Manuscript Report in prep. v.
- Panzacchi, M., B. V. Moorter, P. Jordhoy, and O. Strand. 2012. Learning from the past to predict the future: using archaeological findings and GPS data to quantify reindeer sensitivity to anthropogenic disturbance in Norway. *Landscape Ecol* 28:847-859.
- Parker G.R. 1972. Biology of the Kaminuriak Population of Barren-Ground Caribou Part 1. Canadian Wildlife Service Report Series Number **20**:88pp.
- Pebesma, E. 2018. Simple Features for R: Standardized Support for Spatial Vector Data. *The R Journal* 10:439-446.

- Plante, S., C. Dussault, J. H. Richard, M. Garel, and S. D. Côté. 2020. Untangling Effects of Human Disturbance and Natural Factors on Mortality Risk of Migratory Caribou. *Frontiers in Ecology and Evolution* 8.
- Priest, H. and J.U. Usher. 2004. The Nunavut Wildlife Harvest Study. Nunavut Wildlife Management Final Report. Iqaluit Nunavut Canada. 822 pp.
- QGIS Foundation. 2020. QGIS Geographic Information System. QGIS Association. <http://www.qgis.org>.
- R Development Core Team. 2009. R Foundation for Statistical Computing, Vienna, Austria.
- Russell, H.J. 1990. A Photocensus of the Kaminuriak Herd in July 1987. Dept. of Renewable Resources Government of the N.W.T. File Report No. 97:24pp.
- Schaub, M., and M. Kery. 2022. *Integrated Population Models*. Academic Press, London, UK.
- Seber, G. A. F. 1982. *The Estimation of Animal Abundance*. 2nd edition. Charles Griffin and Company, London. 654 pp.
- Severson, J. P., T. C. Vosburgh, and H. E. Johnson. 2023. Effects of vehicle traffic on space use and road crossings of caribou in the Arctic. *Ecological Applications* 33:e2923.
- Silverman, B. W. 1986. *Density Estimation for Statistics and Data Analysis*. Monographs on Statistics and Applied Probability. New York: Springer.
- St. John J.R. 2022. Understanding Caribou Population Cycles. Undergraduate Thesis, University of Montana. Professional Papers, and Capstone Artifacts.355. 35 pp.
- Thompson, S. K. 1992. *Sampling*. John Wiley and Sons, New York.
- Thomas, D. 1998. Needed: Less Counting of Caribou and More Ecology. The Seventh North American Caribou Conference, Thunder Bay, Ontario, Canada. *Rangifer*, Special Issue No. 10:15-23.

- Thomas, D. C. and S. J. Barry. 1990. Age specific fecundity of the Beverly herd of barren ground caribou. *Rangifer Special Issue No. 3*: 257-263.
- White, G. C., and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. *Bird Study Supplement 46*:120-138.
- Wickham, H. 2009. *ggplot2: Elegant graphics for data analysis*. Springer, New York.
- Wiken, E. 1986. *Terrestrial Ecozones of Canada. Ecological Land Classification Series, No. 19*. Environment Canada. Ottawa, Ont. ISBN 0-662-14761-8.
- Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. *Analysis and management of animal populations*. Academic Press, San Diego.
- Williams, M. 1995. Beverly calving ground surveys, June 5-16, 1993 and June 2-13, 1994. Department of Renewable Resources File Report No. 114. 36 p.
- Williams, M. 1994. *Manual for conducting photographic calving ground surveys in the NWT*. Department of Renewable Resources. 15 p.
- Zalatan, R., A. Gunn, and G. H. R. Henry. 2006. Long-term abundance patterns of barren-ground caribou using trampling scars on roots of *Picea mariana* in Northwest Territories, Canada. *Arctic, Antarctic, and Alpine Research 38*:624-630.
- Zar, J. H. 1996. *Biostatistical analysis*. Third edition. Prentice-Hall, London.

SUBMISSION TO THE
NUNAVUT WILDLIFE MANAGEMENT BOARD
FOR

Information:

Decision:

Recommendation: X

Issue: Total allowable catch levels for Greenland Halibut in Subarea 0 for the 2025 and 2026 fishing seasons.



Figure 1. Greenland Halibut (*Reinhardtius hippoglossoides*).

Background

A fishery for Greenland Halibut (GHL) exists outside of the Nunavut Settlement Area (NSA) in Northwest Atlantic Fishery Organization (NAFO) Subarea (SA) 0, which is divided into a northern region, Division 0A (Baffin Bay) and a southern region, Division 0B (Davis Strait). The commercial fishing season for GHL starts on January 1st and ends December 31st. A map illustrating NAFO Subareas and Divisions relevant to the GHL fishery can be found in Appendix 1.

The GHL stock in SA 0 is part of a transboundary stock shared between Canada (Divisions 0A and 0B) and Greenland (Divisions 1A to F offshore). At the request of both countries, the NAFO Scientific Council (SC) provides advice on stock status and sustainable harvest levels. NAFO does not regulate this stock; Canada and Greenland are responsible for regulation in their own domestic waters. Canada and Greenland have a longstanding informal agreement that the Total Allowable Catch (TAC) levels established on NAFO SC advice be divided 50/50 between the two countries.

For the 2024 fishing season, the SA 0 GHL TAC was set at 16,502.5 tonnes (t). A breakdown of the current TAC between NAFO Divisions is shown in Table 1.

Table 1. Breakdown of the current Total Allowable Catch (TAC) in tonnes (t) between NAFO Divisions.

Fishing Area	Fleet/Interest	2024 Allocation (t)
NAFO Division 0A	Nunavut Special Allocation	8,604.99
	Inshore fisheries development	100.00
	Total 0A Quota	8,704.99
NAFO Division 0B	Nunavut Special Allocation	3,840.59
	Nunavik Special Allocation	402.82
	Enterprise & Special Allocation Holders	2,654.09
	Fixed Gear Competitive	900.00
	Total 0B Quota	7,797.50

In 2023, the SA 0 TAC was fully harvested.

The Division 0A GHL fishery is a commercial fishery entirely designated to Nunavut (NU) interests. In 2006 and in accordance with the decision making process set out in the Nunavut Agreement (NA), the Nunavut Wildlife Management Board (the Board) motioned to allocate 100 t of the Division 0A offshore quota for inshore fisheries development within the NSA; the motion was supported by the Minister of Fisheries and Oceans Canada (the Minister) and was allocated for the 2006 fishing season. Since the initial decision, the 100 t inshore quota has consistently been maintained and deducted from the Division 0A offshore quota. In the Board's 14 September 2023 letter to DFO Minister LeBouthillier, the Board noted the importance of surveying and assessing the utilization of the 100 t Division 0A inshore allocation. DFO has initiated conversations with Board staff on this topic and is committed to working together to optimize inshore fisheries development opportunities.

Science Information

In February 2024, Canada and Denmark (on behalf of Greenland) requested that the Scientific Council (SC) provide an overall assessment of GHL stock status and trends in the total stock area throughout their range and to specifically advise on TAC levels for 2025 and 2026. Further, it was requested that the stock status should be evaluated in the context of management requirements for long-term sustainability and the advice provided should be consistent with NAFO's Precautionary Approach (PA) Framework.

For the first time, a population model (Stochastic Production in Continuous Time, SPiCT model) was accepted by NAFO SC for the SA 0+1 (offshore) GHL stock and used to assess the status of this stock during the June 2024 NAFO SC meeting. Inputs to this model included landings data and a standardized index of exploitable stock biomass from annual survey data.

Stock assessment surveys were not conducted in 2018, 2020 or 2021 because the survey vessel was decommissioned in winter 2018 and the replacement vessel was completed in spring 2022. A survey was completed in 2019 using a commercial vessel, but it was not considered comparable to previous surveys. The lack of calibration between the previous survey vessel (*RV Paamiut*) and new survey vessel (*RV Tarajoq*) means that data from the two vessels cannot be used together to explore long-term trends in stock dynamics, which has created uncertainty about stock status. Science continues to explore a model-based approach to combine the two survey time series.

Based on model results, NAFO SC provided risk-based harvest level scenarios for SA 0+1 (offshore) GHL for 2025 and 2026 in the assessment report found in Appendix 2. Harvest level scenarios describe future projections of the standing stock biomass (B) under different fishing mortality levels (fishing pressure, F). These harvest level scenarios are used by DFO Fisheries Management to develop options to provide TAC advice and recommendations to the Minister.

NAFO SC advice for catch levels for 2025 and 2026 is as follows:

[NAFO SC] Recommendation for 2025 and 2026:

In the projection period the probability of being below B_{lim} is very low (<1 %), and the probability of exceeding F_{lim} is projected to be below 30 % for any catch less than 90 % of current TAC.

Scientific Council therefore recommends that catch should not exceed 90 % of current TAC.

The TAC recommendation as developed by NAFO SC was based on the NAFO PA Framework. The risk that the probability of F exceeding F_{lim} (i.e. the probability that the fishery is overfishing the stock) is less than 30 %. In the NAFO PA Framework, a very low probability is operationally defined as 10 %, and a low probability as 30 % (Appendix 3). Keeping the performance statistic $P < 30$ % helps prevent a healthy stock from entering a bad stock state in the future.

Consultation

The Eastern Arctic Groundfish Stakeholder Advisory Committee (EAGSAC) was created as one of a series of measures to ensure the fisheries governance regime for groundfish in the NAFO SA 0 is publicly accountable, predictable and transparent. It provides a forum for discussion and an opportunity for members to provide advice and recommendations to DFO on the management and policies related to SA0 Greenland halibut. EAGSAC membership includes Co-management Organizations, Rights Holders, Commercial Fishery Associations, Commercial Fishers, Environmental Organizations and Other Government Organizations.

An EAGSAC meeting was held on August 14, 2024, for members to share their views on the published NAFO SC science advice pertaining to SA 0 GH L TAC levels for the 2025 and 2026 fishing seasons. A meeting summary, including members' views can be found in Appendix 4. Members were also invited to provide their views to the Department in writing.

The majority of EAGSAC members are supportive of the TAC remaining at the 2024 level of 16,502.5 t, with some seeking a return to the 2022 TAC level of 18,185 t. The majority of members have also recommended that TAC be set only for one year (2025) to provide an opportunity for science advice to be updated by the NAFO SC and better inform a 2026 TAC decision. It should be noted that while an update to NAFO SC advice may be requested, NAFO SC may not have capacity to conduct a full assessment during the June 2025 stock assessment meeting.

Recommendation

TAC decisions consider many factors including: conservation; science advice; economic impacts; co-management and stakeholder views; land claim obligations and international considerations.

Potential options when the science is advising a decrease in harvest levels:

- Implement a TAC in line with science advice, which recommends that catch should not exceed 90% of the global harvest level for SA0 + 1 (offshore) of 33,305 t. This results in a global harvest level of 29,970 t, and a TAC of 14,985 t for Canada.
- Maintain the previous year's TAC (i.e. 16,502.5 t).
- Implement a TAC reduction other than that advised by NAFO SC.

As per Article 15, Part 3.4 of the *Nunavut Agreement*, DFO is seeking the advice of the NWMB for management decisions with respect to:

1. The TAC for Greenland Halibut in SA0 (offshore);
2. TAC distribution between OA and OB; and
3. The allocation of quota between fleets, including the inshore quota for fisheries development.

Prepared by: Alexis Burt, FM Biologist, Jeff Adam, Senior Regional FM Officer, and Kevin Hedges, Research Scientist, Arctic Region, Fisheries and Oceans Canada.

Date: August 28, 2024

Appendices

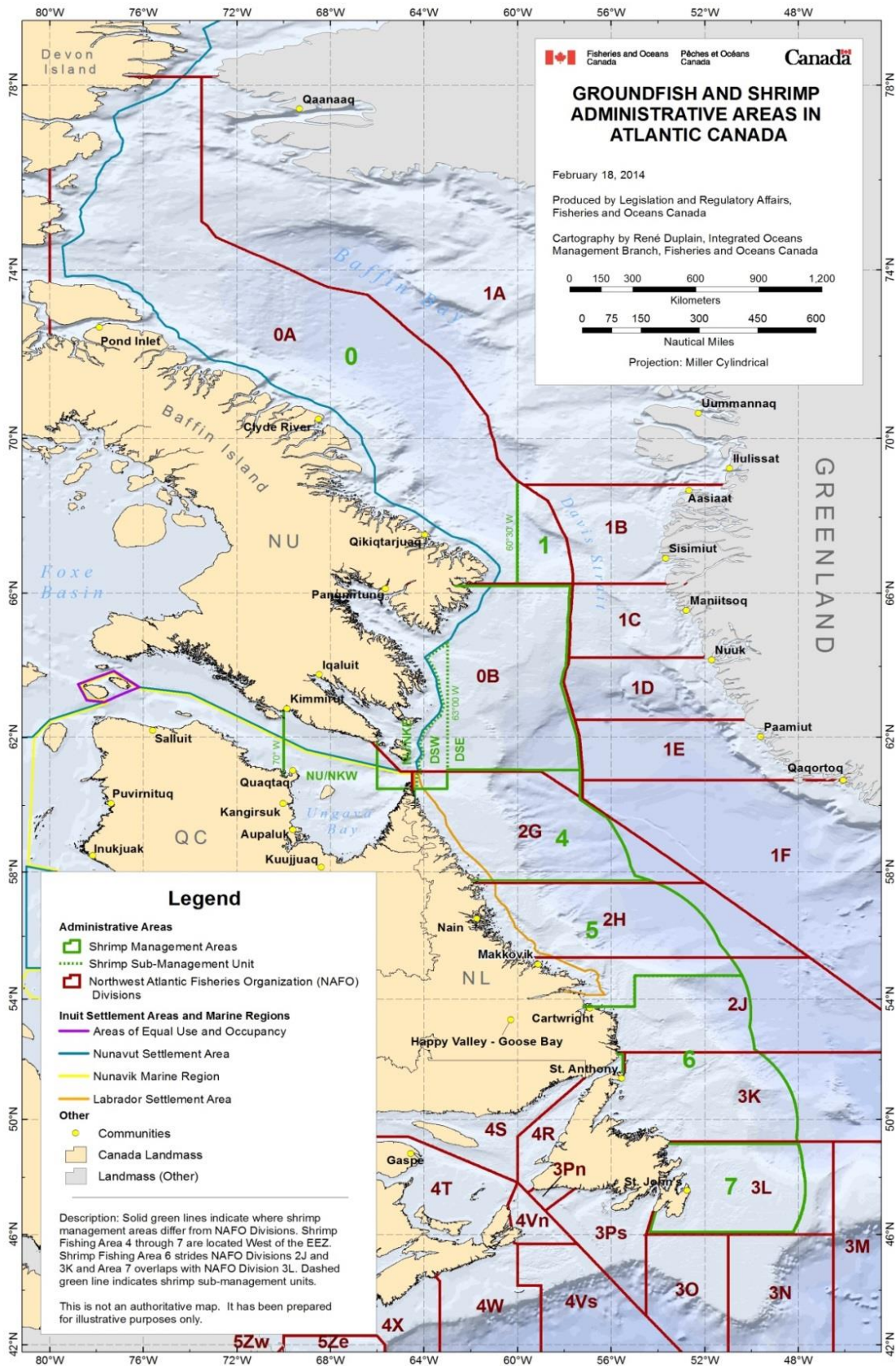
Appendix 1 – Map of groundfish and shrimp administrative areas in Atlantic Canada

Appendix 2 – NAFO SC summary sheet

Appendix 3 – NAFO SC PA Framework Testing scs24-13

Appendix 4 – Meeting summary of EAGSAC member views on 2025 and 2026 Greenland Halibut TAC

Appendix 1



Greenland halibut in Subareas 0+1 (offshore)

Advice June 2024 for 2025-2026











Recommendation for 2025 and 2026

In the projection period the probability of being below B_{lim} is very low (<1%), and the probability of exceeding F_{lim} is projected to be below 30% for any catch less than 90% of current TAC.

Scientific Council therefore recommends that catch should not exceed 90% of current TAC.

Management objectives

Canada and Denmark (on behalf of Greenland) requested that the Scientific Council provide an overall assessment of status and trends in the total stock area throughout its range. Stock status should be evaluated in the context of management requirements for long-term sustainability and the advice provided should be consistent with NAFO's Precautionary Approach Framework.

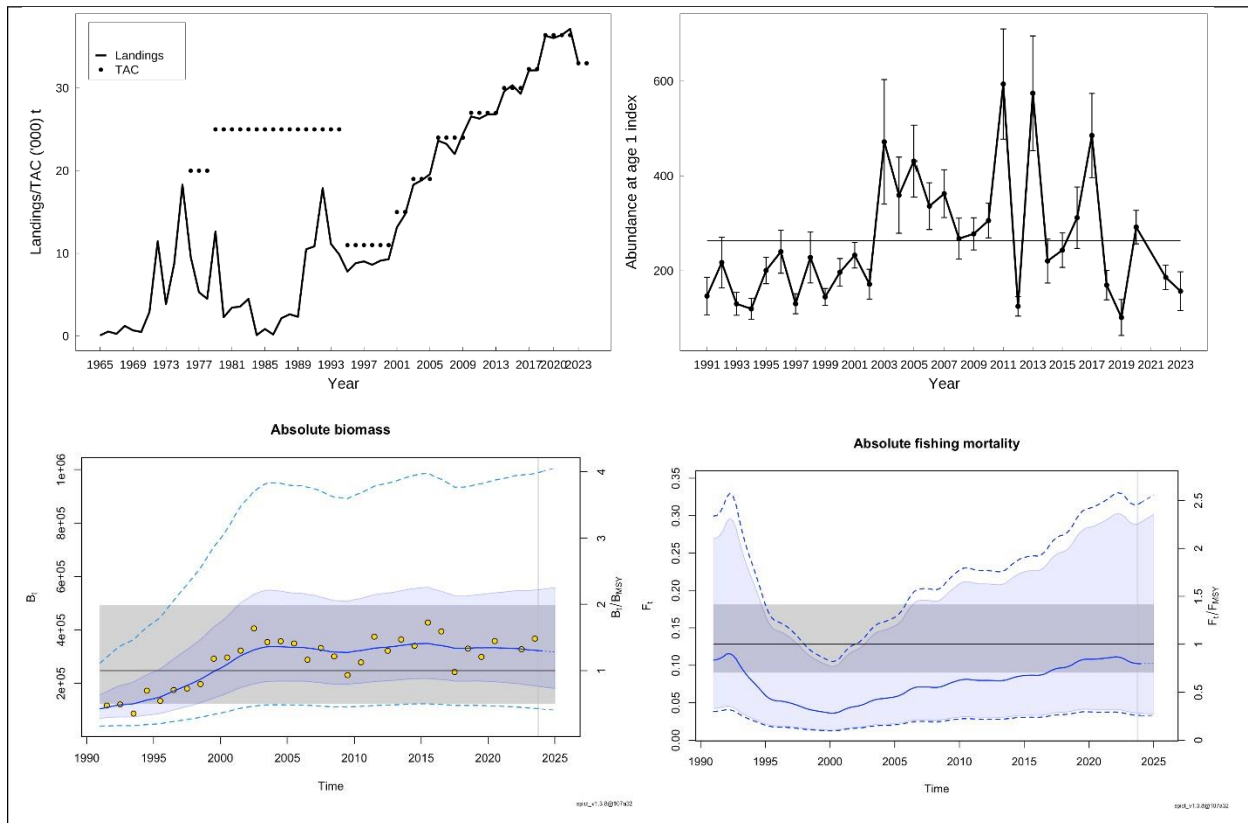
Convention Principle	Status	Comment	
Restore to or maintain at B_{msy}		$B > B_{msy}$	 OK
Eliminate Overfishing (Stock)		$F < F_{lim}$	 Intermediate
Eliminate Overfishing (Ecosystem)		TCI undefined	 Not accomplished
Apply Precautionary Approach		B_{lim} and F_{lim} defined	 Unknown
Minimize harmful impacts on living marine resources and ecosystems		Directed fishery, VME closures in effect, Effectiveness of bycatch regulations uncertain	
Preserve marine biodiversity		Cannot be evaluated	

Management unit

The Greenland halibut stock in Subareas 0+1 (offshore) is part of a larger population complex distributed throughout the Northwest Atlantic.

Stock status

Median biomass is above B_{msy} ($B/B_{msy} = 1.3$) and the probability of being below B_{lim} is less than 1%. Fishing mortality is below F_{msy} ($F/F_{msy} = 0.78$) and the probability of being above F_{lim} is 34%.



Reference points

B_{lim} is 30% B_{msy} and F_{lim} is F_{msy} (SCS 04/12).

Projections

Medium-term projections were carried forward to the year 2026 for catch scenarios with catch = TAC = 33 305t for 2024. Constant removals were applied from 2025-2026 at several levels of F ($F=0$, $F_{status\ quo}$, 75% F_{msy} , 85% F_{msy} and F_{msy}) or catch (TAC and 90% TAC). At the end of the projection period, the risk of biomass being below B_{lim} was less than 1% in all cases.

For the $F_{status\ quo}$ projections, the probability that $F > F_{lim} = F_{msy}$ in 2025-2026 was 34%, and with $2/3 F_{msy}$ the probability was 23%. At 75% F_{msy} , the probability that $F > F_{lim}$ was 30%. Projected at the level of 85% F_{lim} , the probability that $F > F_{lim}$ was 39% and for F_{msy} projections, this probability increased to 50%. For biomass projections, in all scenarios for 2025-2026 the probability of biomass being below B_{lim} was less than 1%. The probability that biomass in 2026 is less than biomass in 2024 is between 19 and 70% for all projections.

Projections with Catch 2024 = 33305 t		
Year	Yield ('000t)	Projected relative Biomass (B/Bmsy) median (80%CL)
F =0		
2024	33.3	1.3 (0.91-1.84)
2025	0	1.28 (0.89 - 1.85)
2026	0	1.4 (1.02-1.92)
Fstatusquo = 0.102		
2024	33.3	1.3 (0.91-1.84)
2025	32.33	1.28 (0.89-1.85)
2026	32.04	1.27 (0.87-1.86)
2/3Fmsy= 0.085		
2024	33.3	1.3 (0.91-1.84)
2025	27.23	1.28 (0.89- 1.85)
2026	27.39	1.28(0.91-1.88)
75%Fmsy = 0.096		
2024	33.3	1.3 (0.9-1.85)
2025	30.51	1.28 (0.89- 1.86)
2026	30.4	1.26 (0.89-1.87)
85%Fmsy = 0.109		
2024	33.3	1.3 (0.91-1.84)
2025	34.42	1.27 (0.89-1.85)
2026	33.91	1.26 (0.86-1.85)
Fmsy = 0.128		
2024	33.3	1.3 (0.91-1.84)
2025	40.21	1.28 (0.89-1.85)
2026	38.92	1.24 (0.83-1.84)
TAC = 33 305		
2024	33.3	1.3 (0.91-1.84)
2025	33.3	1.28 (0.89-1.85)
2026	33.3	1.27 (0.86-1.85)
90% TAC = 29 975		
2024	33.3	1.3 (0.91-1.84)
2025	29.97	1.28 (0.89-1.85)
2026	29.97	1.28 (0.88-1.86)

Catch2024= 333	yield ('000t)		P (F> Flim)			P(B<Blim)			P(B>Bmsy)			P(B2026 < B2024)
	2025	2026	2024	2025	2026	2024	2025	2026	2024	2025	2026	
F=0	0	0	34%	<1%	<1%	<1%	<1%	<1%	83%	81%	91%	19%
F statusquo	32.33	32.04	34%	34%	34%	<1%	<1%	<1%	83%	81%	79%	60%
2/3 Fmsy	27.23	27.39	34%	23%	23%	<1%	<1%	<1%	83%	81%	81%	53%
75 % Fmsy	30.51	30.4	34%	30%	30%	<1%	<1%	<1%	83%	81%	80%	58%
85% Fmsy	34.42	33.91	34%	38%	39%	<1%	<1%	<1%	83%	81%	78%	63%
Fmsy	40.21	38.92	34%	50%	50%	<1%	<1%	<1%	83%	81%	76%	70%
TAC	33.3	33.3	34%	36%	37%	<1%	<1%	<1%	83%	81%	79%	62%
90%TAC	29.97	29.97	34%	29%	29%	<1%	<1%	<1%	83%	81%	80%	57%

Assessment

A Stochastic Production model in Continuous Time (SPiCT) was used for the assessment of this stock. Input to this model include landings data and a standardized index of exploitable stock biomass from combined survey data.

The next assessment is expected to be in 2026.

Human impact

Mainly fishery related mortality has been documented. Other sources (e.g. pollution, shipping, oil-industry) are undocumented.



Biology and Environmental interactions

No specific studies were reviewed during this assessment.

Ecosystem sustainability of catches

The impact of bottom fishing activities on VMEs in Subarea 0 was assessed in 2016. Three areas have been designated as marine refuges, that exclude bottom contact fisheries: Disko Fan, Davis Strait and Hatton Basin. Areas in Subarea 1 have also been closed to bottom fishing to protect benthic habitats.

Greenland halibut is included in the piscivore guild. There is no EPU nor TCIs defined for this region. The ecosystem sustainability of catches cannot be evaluated. Greenland shark is a bycatch species of concern in the Subareas 0+1 (offshore) fishery given its low reproductive rate, slow growth rate and limited ecological information.

Fishery

Catches were first reported in 1965. Catches increased from 1989 to 1992 due to a new trawl fishery in Division 0B with participation by Canada, Norway, Russia and Faeroe Islands and an expansion of the Division 1CD fishery with participation by Japan, Norway and Faeroe Islands. Catch declined from 1992 to 1995 primarily due to a reduction of effort by non-Canadian fleets in Division 0B. Since 1995 catches have been near the TAC and increasing in step with increases in the TAC, with catches reaching a high in 2022. Catches decreased to 32 990t following a decreasing TAC in 2023.

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
TAC	30	30	32.3	32.3	36.4	36.4	36.4	36.4	33.3	33.3
SA 0	15.4	14.1	15.9	16.0	18.3	17.9	19.1 ²	18.3	16.4	
SA 1	14.9	15.2	16.2	16.2	18.0	18.1	17.3	18.8	16.6	
Total STACFIS ¹	30.3	29.3	32.1	32.2	36.3	36.0	36.4	37.2	33.0	

¹ Based on STATLANT, with information from Canada and Greenland authorities to exclude inshore catches.

² STACFIS estimate using 1.48 conversion factor for J-cut, tailed product.

³ Based on official catches from the Greenland Office of Fisheries Licences (GLFK) because STATLANT were not available.

Sources of information

SCR Docs. 24/013, 019, 020, 021, 022; SCS Doc. 24/14.

NAFO Precautionary Approach Working Group (PA-WG)**13 May 2024. 09:00 Halifax time****Webex****Chair: Fernando González-Costas****1. Opening.**

The meeting was opened by the Chair, Fernando González-Costas (European Union), at 09:00 hours (UTC/GMT -3 hours in Halifax, Nova Scotia) on Monday, 13 May 2024.

The Chair welcomed representatives from Canada, the European Union, Japan, the Russian Federation, and the United States of America, as well as an invited expert on Precautionary Approach Framework on Fisheries Management. A full participants list is presented in Appendix I.

a) Appointment of Rapporteurs.

The NAFO Secretariat (Dayna Bell MacCallum and Jana Aker) was nominated as rapporteur of the meeting.

b) Adoption of Agenda

The agenda was adopted as circulated (Appendix II).

2. Performance Statistics for the Management Objectives

The PA-WG reviewed the management objectives as approved by the WG-RBMS at the April 2024 meeting (COM SC Doc. 24-01). Performance statistics to measure these management objectives were presented by Mariano Koen-Alonso on behalf of the technical team and discussed by the group. The PA-WG approved the performance statistics to measure the management objectives outlined in Table 1, noting that these are the starting point to carry out the testing, but the final framework and risk levels to be established will be determined in the WG-RBMS meeting in August 2024.

Table 1. The management objectives and associated performance statistics for the testing of the precautionary approach framework. In addition to standard symbols like B and F to indicate stock biomass and fishing mortality respectively, and the related reference points and/or relevant indicators like B_{lim} , $B_{trigger}$, B_{msy} , F_{lim} , F_{msy} , and MSY, some general notation used throughout this table includes t to indicate year, t=1 or t_1 to indicate the first year of the actual projection period after the burnout period, t=x or t_x to indicate the year x of the projection period, T to indicate the final year of the projection period, which is initially defined as 50 years for the generic testing and 25 years for the specific testing, and t_{Btr} to indicate the year when the biomass reaches $B_{trigger}$ ($B_{t_{Btr}} \geq B_{trigger}$) after starting from a depleted stock state. HCR is used to indicate harvesting under a given harvest strategy from the proposed PA framework, and F=0 is used to indicate no harvesting.

Management goal	Management Objectives from RBMS Report	Operational management objective by SC PAWG	Performance Statistics	Criteria
Prevention of bad stock states arising later when the stock is in the Healthy Zone. (test runs start with non-depleted stocks)	Very low risk of stock depletion	Very low risk of stock depletion	$P(B_t < B_{lim}) \leq 0.10$	Median of the proportion of years in the projection period (t=1 to T) where the stock is below B_{lim} . A very low probability is operationalized as 10% based on the current NAFO PA. In addition to the PS itself, the distribution of these probabilities, at least for some base cases, is required to inform on the type or distribution (e.g. a wide vs narrow).
		Risk of stock falling below $B_{trigger}$	$P(B_t < B_{trigger}) \leq 0.30$	Median of the proportion of years in the projection period (t=1 to T) where the stock is below $B_{trigger}$. A low probability is operationalized as 30%. Include results for F=0 for better informing the results in terms of actual performance of the HCR vs intrinsic variability of the stock dynamics.



Management goal	Management Objectives from RBMS Report	Operational management objective by SC PAWG	Performance Statistics	Criteria
	Maintain stocks above B_{msy} more often than not	Maintain stocks above B_{msy} more often than not	$P(B_t/B_{msy} > 1) \geq 0.75$	Median of the proportion of years where $\frac{B_t}{B_{msy}}$ is greater than 1 over the projection period (t=1 to T). Since 50% is neutral, the idea of “more often than not” essentially covers the 51-99% range, so it has been operationalized here as the middle of that range (75%) until a value can be agreed upon at the PAWG and RBMS.
	Low risk of overfishing	Low risk of overfishing	$P(F_t/F_{msy} < 1) \geq 0.70$	Median of the proportion of years where $\frac{F_t}{F_{msy}}$ is less than 1 over the projection period (t=1 to T). A low probability is operationalized as 30% based on the recent NAFO MSEs.
Recovery to a good stock state when the stock is in the Critical or Cautious Zone. (test runs start with depleted stocks)	Rebuild stocks to B_{msy}	Rebuild stocks to the vicinity of B_{msy}	$P(\bar{\mu}(B_{T-10:T}) > B_{trigger}) \geq 0.80$	Proportion of scenario runs where the average biomass ($\bar{\mu}$) in the last 10 years of the projection period (T-10 to T) is greater than $B_{trigger}$. A low probability [of not rebuilding to the vicinity of B_{msy}] is operationalized as 20% based on the current NAFO PA.
	Good stock recovery performance	Monitor short term growth	$P(B_{t=5} > B_{t=1}) \geq 0.75$	Proportion of scenario runs where $B_{t=5} > B_{t=1}$ Since 50% is neutral, the idea of “more often than not” has been operationalized as 75%.
		Monitor med term growth	$P(B_{t=15} > B_{t=1}) \geq 0.75$	Proportion of scenario runs where $B_{t=15} > B_{t=1}$ Since 50% is neutral, the idea of “more often than not” has been operationalized as 75%.
	Monitor long term growth	$P(B_{t=25} > B_{t=1}) \geq 0.75$	Proportion of scenario runs where $B_{t=25} > B_{t=1}$ Since 50% is neutral, the idea of “more often than not” has been operationalized as 75%.	

Management goal	Management Objectives from RBMS Report	Operational management objective by SC PAWG	Performance Statistics	Criteria
		Time to recovery (absolute)	$Count(t_1: t_{Btr})$	Median of the number of years (t_{Btr}) to reach $B_{trigger}$ This metric has no fixed success criterion as it depends on the specific stock life-history.
		Time to recovery (relative)	$Ratio\left(\frac{Count_{\square}^{F=HCR}(t_1: t_{Btr})}{Count_{\square}^{F=0}(t_1: t_{Btr})}\right) \leq 1.2$	Median of the ratio between the number of years (t_{Btr}) to reach $B_{trigger}$ under the HCR vs under F=0. This metric has no fixed success criterion; it has been arbitrarily set here as 20% or less from F=0 until a value can be agreed upon at PAWG/RBMS.
		Time to recovery (additional years)	$t_{extra} = Count_{\square}^{F=HCR}(t_1: t_{Btr}) - Count_{\square}^{F=0}(t_1: t_{Btr})$	Median of the number of additional years (t_{extra}) to reach $B_{trigger}$ under the HCR vs under F=0. This metric has no fixed success criterion.
Sufficiently acceptable fishery performance across stock states within the Cautious and Healthy zones.	Maintain approximately MSY catches in the long-term	Maintain approximately MSY catches in the long-term	$P\left(0.8 \geq \frac{Median(C_{T-10:T})}{MSY} < 1.2\right) \geq 0.80$	Proportion of the scenario runs where the ratio between the median catch in the last 10 years of the projection and MSY is within the 0.8MSY-1.2MSY range. A low probability [of not maintaining catches approximately to MSY] is operationalized as 20% based on the current NAFO PA.
(test runs start with depleted stocks)	Good fishery performance	Measure the inter-annual TAC variation	$Median\left(\frac{ C_{t+1}-C_t }{C_t}\right) \leq 0.20$	Median of the medians of the absolute inter-annual variability in the TAC during the entire projection period. The value of 20% is being set based on recent NAFO MSE practice.

Management goal	Management Objectives from RBMS Report	Operational management objective by SC PAWG	Performance Statistics	Criteria
		Catch during the maximum recovery window	$\frac{\sum_{1:t_{max}} C_y}{t_{max}}$	<p>Median of the average catch during the period of time associated with the maximum recovery time window.</p> <p>Maximum recovery time window (t_{max}) is the longest period of time observed across HCR scenarios (e.g. upper edge, middle, and lower edge of the NAFO HCR leaf) to recover the stock to $B_{trigger}$.</p>

**2025 and 2026 Greenland Halibut (GHL) Total Allowable Catch (TAC)
Eastern Arctic Stakeholder Advisory Committee (EAGSAC) Member Views
Meeting Discussion Summary**

August 14, 2024

Chair – Jeff Adam, Senior Regional Fisheries Management Officer, Arctic Region (AR), Fisheries and Oceans Canada (DFO)

EAGSAC Member Participants

Commercial Fishery Associations:

- Nunavut Fisheries Association (NFA) – Derek Butler, representing:
 - Arctic Fishery Alliance (AFA)
 - Baffin Fisheries Coalition (BFC)
 - Cumberland Sound Fisheries Ltd (CSFL)
 - Qiqiktaaluk Corporation (QC)
- Northern Coalition (NC) – Alastair O’Rielly, representing:
 - Makivik Corporation
 - Labrador Fishermen’s Union Shrimp Company Ltd.
 - Torngat Fish Producers Co-operative Society Ltd.
 - Nunatsiavut Group of Companies
- Atlantic Groundfish Council (AGC) – Steve Devitt, representing:
 - EcoSound Fisheries
 - Ueushuk Fisheries
 - Harbour Grace Shrimp Co. Ltd
 - Ocean Choice International
 - Mersey Seafoods Ltd
 - Clearwater Seafoods Ltd (CW)
 - Nordic Ltd.

Commercial Fish Harvesters

- QC – Jerry Ward
- CW – Catherine Boyd

Government Organizations

- Government of Newfoundland and Labrador – Jake Rice
- DFO – Kevin Hedges, Research Scientist
- DFO – Kate Johnson, International Fisheries Policy

Environmental Non-Government Organizations

- Oceans North – Brynn Devine

Observers

- DFO – Sandra Moore (FM-AR), Alexis Burt (FM-AR), Dirk Algera (RM-NCR)

Purpose of Meeting:

For EAGSAC members to share their views on the Northwest Atlantic Fisheries Organization (NAFO) Subarea 0 (GHL) TAC level for 2025 and 2026. The meeting also afforded EAGSAC members an opportunity to ask DFO Science questions and seek clarification on the GHL SA0+1 (offshore) NAFO Scientific Council (SC) advice for 2025 and 2026.

Discussion:

Science advice

DFO Science (Kevin Hedges) provided answers and clarifications to stakeholder questions and comments regarding the NAFO SC advice.

- CW asked for more information regarding the stochastic surplus production model in continuous time (SPiCT model) used for developing the science advice, current and future data used for the model, and the next stock assessment.
 - DFO Science responded that the SPiCT model was adopted and accepted by the NAFO SC this past June. Every year new surveys will be conducted by both Canada and Greenland (separately) and new data will be inputted into the SPiCT model. There is a four year agreement with Greenland for Canada to continue using the *R.V. Tarajoq* to conduct annual surveys in SA0.
 - Development of a model-based calibration between the *R.V. Paamiut* and *R.V. Tarajoq* survey time series is ongoing, and once completed will aid in stock assessment efforts. The intent will be to update the single reconciled time series accordingly.
 - The fall 2024 survey data will be reviewed by NAFO SC in May 2025, used in the SPiCT model together with Greenland survey data, and model results will be presented at the NAFO SC meeting in June 2025. An updated report will be produced by NAFO SC in 2025, as the next full NAFO SC stock assessment is scheduled to occur in 2026.

- NFA referenced the July 8th presentation on the unpublished NAFO SC advice provided to EAGSAC members by DFO Science. NFA asked if the performance statistics for over fishing in the precautionary approach (PA) framework (slide 7) were weighted. NFA enquired how the NAFO PA framework, which is currently under review, might be different from the Canadian PA framework, and if any updates on the review were available.
 - DFO Science stated the performance statistics are not weighted, with three equal criteria for being in the safe zone.
 - DFO Science is not aware of any updates at this time regarding the NAFO PA framework review. The NAFO PA framework is likely to become more aligned with the DFO PA framework.

- NC expressed that the SPiCT model is new, unproven, based on little data (plus data gaps exist in the time series), has wide confidence intervals, and while it includes catch data, catch per unit effort (CPUE) from industry is not included, which could be significant. All these items lead to uncertainty in the science advice. NC asked DFO Science to address these concerns.
 - DFO Science responded that the confidence intervals are broad but were accepted by the NAFO SC. There was no debate on the confidence in the model, which is well structured and was accepted by NAFO SC. Confidence in the data will increase over time as more length and age data are collected. More data will be added over time, and science personnel are constantly

looking for ways to improve the science work and modelling.

- NC followed up by asking, given the low probability of risk (at current harvest levels), should harvest levels be reduced based on outputs with so many gaps, and given the model underestimates biomass and overestimates mortality? NC also noted survey results for the last two years have been very positive, and do not indicate “red flags”.
 - DFO Science responded there are three criteria taken into account to determine the safe zone of the stock, which are the probability of $F > F_{lim}$ (probability of overfishing, where decline in stock biomass would be expected), probability of $B < B_{lim}$ (comparable to the probability of being in the Critical Zone in the DFO PA Framework), and probability of $B > B_{msy}$ (probability of being above B_{msy} , the point where maximum productivity is achieved, which is used to inform the Upper Limit Reference in the DFO PA Framework). Most of the harvest level scenarios exceeded the 30 % threshold for $F > F_{lim}$. The table in the NAFO SC advice provides risk-based advice. The one line ($F > F_{lim} < 30\%$) is “singled out” and used in the “Grey box”, but information is provided for a range of harvest level scenarios.
 - The level of risk is not a Science decision, it is a Fisheries Management decision. The higher the TAC, the more the standing stock biomass will decrease. If harvest levels are set above the 75 % F_{msy} threshold, then TAC level decreases should be expected in the future. A key consideration is how much stability is desired in the TAC long term. A small decrease in TAC now might avoid a large decrease in a few years.
- NFA referenced slide 2 from the July 8th presentation and asked about risk based advice for the future.
 - DFO Science explained that when the request for advice was written and submitted to NAFO SC there had been no accepted model for this stock (i.e. SPiCT) and it was assumed that science advice would continue to be based on biomass and abundance indices. With the acceptance of the SPiCT model, future stock status projections can be developed, and risk-based advice can be provided.

TAC Views presented:

- Disagreement with the harvest level advice provided by NAFO SC in 2024 (NFA, NC):
 - NFA and NC will likely request a roll-over of the 2024 TAC level for 2025 and 2026 at a minimum. NC noted a case could be made to increase the TAC to previous higher levels.
- Additional science work in terms of incorporating more data and using the model-based calibration for stock assessment was requested, including having a full stock assessment at the NAFO SC meeting in 2025 (AGC, NFA, CW, QC), not just the scheduled interim update.
- AGC, NC, NFA, and the Government of Newfoundland and Labrador will provide written submissions to DFO regarding the TAC level for 2025 and 2026.
- CW will likely endorse the TAC level submission from AGC. Additionally, based on further science work (gathering more data, modelling, model-based calibration) occurring over the next year, CW recommends the TAC be set for one year (2025) only.

- NC provided the following views:
 - Dr. Hedges' explanation of the science advice offered important insights, particularly on interpreting the risk analyses presented in Table 1.3. This shows that the probability of the Biomass exceeding Bmsy is about 80% in all scenarios tested, that the risk of the Biomass falling below Blim is less than 1% in all scenarios tested and that the probability of fishing at the current TAC exceeding Flim is 34%, slightly above NAFO's PA guidance, but based on minimal and roughly estimated data, application of a new, unproven and data-poor assessment model with extensive confidence intervals. The advice of the NAFO SC appears to be based on something other than expert opinion or conclusive analyses and complies with NAFO's PA framework values by the narrowest margins with low confidence. This does not justify the industry forfeiting a further \$20 to 30 million in much needed revenue.
 - Projections derived from the model show the high level of uncertainty and further illustrate why quota reductions are not warranted. An excerpt from the NAFO SC advice on Page 70 reads: "For biomass projections, in all scenarios for 2025-2026, the probability of biomass being below Blim was less than 1%. The probability that biomass in 2026 is greater than biomass in 2024 is between 19 and 70% for all projections." Again, this demonstrates that quota reductions are not justified.
 - Since December 2022, Blue Matter, a fisheries consulting firm, has been working to interpolate the missing survey values for 2018, 2020, and 2021. Unfortunately, this work has not yet been completed due to contract/budget issues; however, it will likely have a material impact on the stock assessment.
 - NC believes that the NAFO SC's recommended TAC reduction was inappropriate and unjustified, based on an improper interpretation of the PA. The NAFO SC did not have any information to assess the stock and asserted that the absence of data constituted a risk to the stock. Applying this new population model with limited and highly qualified survey estimates, the absence of any environmental and ecosystem data, and wide-ranging confidence intervals do not make a compelling case for the quota reductions of the past two years. It absolutely does not justify further reductions in the TAC. Accordingly, the NC recommends reinstating the 2022 quota of 36,400 tons for 2025.
 - Recent survey results for 2022 and 2023 have been positive. To further mitigate the very low risk of stock decline at current fishing levels, it is advisable to review the 2024 fall survey results, together with additional data that may be available (i.e. analysis by Blue Matter) before setting the TAC for 2026.

Action:

- Meeting summary will be provided.
- Written submissions from EAGSAC members due to the Department by Friday, August 23, 2024.

**SUBMISSION TO THE
NUNAVUT WILDLIFE MANAGEMENT BOARD**

FOR

Information: X

Decision:

Recommendation:

Issue: Update on the Co-Development of the Nunavut Fishery Regulations

Background:

Fisheries in the Nunavut Settlement Area (NSA) are currently managed under existing regulations that do not reflect nor implement Inuit rights and the unique fisheries management regimes as required in the *Nunavut Agreement (NA)*. New regulations are required to provide consistency with harvesting rights and wildlife management systems established under the *NA*, to provide an opportunity to advance Canada's reconciliation efforts with Indigenous communities, support the Inuit Nunangat Policy to advance Inuit self-determination, and create a modern fisheries management regime to ensure the sustainability of fisheries in the NSA.

Fisheries and Oceans Canada (DFO) was asked to provide an update on the status on the proposed Nunavut Fishery Regulations (NFR). This information note is intended to provide a brief update on the co-development of the NFR, as well as additional information on some key elements of the proposed regulations.

History

On July 9th, 2018, DFO, Nunavut Tunngavik Incorporated (NTI), the Nunavut Wildlife Management Board (NWMB), and the Government of Nunavut (GN) released a joint statement recommitting to co-developing new fisheries regulations for the NSA. Since the joint statement release, Makivik Corporation (Makivvik) joined the discussions as there are areas of equal use and occupancy. A working group was formed to co-develop the policy positions that will inform the development of the new regulations. The working group is comprised of DFO, Justice Canada, NTI, NWMB, the GN, Makivvik, and as of 2023, the Nunavut Marine Region Wildlife Board (NMRWB).

New Mechanism to Implement Board-Minister Decisions

Under Article 5 of the *NA*, the Minister has an obligation to implement the final decisions that arise from the Board/Minister process. In the NSA, subject to a few exceptions, Inuit do not require licences for harvesting activities. As a result, relying on licences and corresponding conditions will not work to implement Board/Minister decisions in many circumstances, and there is currently no other legal pathway to implement decisions that require regulation of harvesters. The Northern Agreements Decision Implementation Order (NADIO) has been proposed as a solution to this issue and will function as a legal tool to allow the Department to implement Board/Minister decisions. The NADIO will ensure the Minister can discharge her obligations under the *Fisheries Act* and the *NA*.

The NADIO is proposed to apply within the NFR area of application (see Figure 1) that falls within the NSA, and will cover a variety of fisheries management matters as outlined in the *NA*:

- Quantitative harvest limits such as Total Allowable Harvest (TAH);
- Non-quota limitations which mean a limitation of any kind, except for a TAH, and may include limitation on season of harvest, sex of wildlife, size of wildlife, age of wildlife, or method of harvest; and,
- Monitoring and reporting requirements.

The NFR will specify that all persons to whom an order is applicable must comply, making the NADIO enforceable by fishery officers under the *Fisheries Act*. In the area of application, the NADIO would be issued only after a final decision from the Board/Minister process is made, or to implement interim decisions to address ‘urgent and unusual’ circumstances.

The NADIO will remain in place in accordance with its own terms (i.e., as defined in the final decision or until changed by the Board/Minister process); there is no pre-set maximum time limit on the duration of the NADIO. If amendments to the NADIO are required, it will need to be made through the Board/Minister decision-making process.

Note that there are no proposed changes to the Board/Minister decision-making process as outlined in Article 5 of the *NA* as part of the NFR discussions. Fisheries in the NSA will continue to be co-managed by the NWMB and DFO.

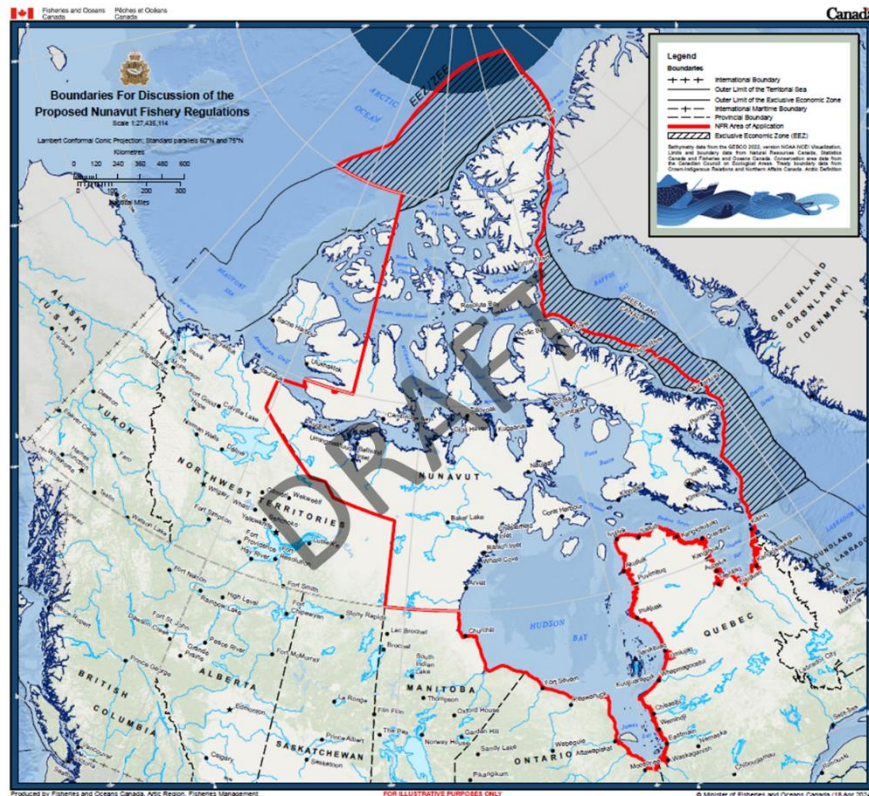


Figure 1: A map showing the proposed overall geographic area of application of the Nunavut Fishery Regulations (red line).

Communal Fish Plans

Communal Fish Plans (CFP) are being proposed as a new fisheries management tool. CFP would be developed by Inuit Wildlife Management Organizations (IWMOs) to manage Inuit harvesting of fish, including marine mammals, and may include harvest limits. CFP would apply to fisheries within the NSA and would be mandatory for stocks or populations that Inuit harvest for “bulk sales”, such as sales to fish plants, work camps or restaurants (and excluding sales directly to individual consumers). CFP would otherwise be an optional tool to support local management of fisheries and Inuit self-determination.

Enforcement of the CFP would be the responsibility of the IWMOs. However, IWMOs may request that DFO make elements of a CFP enforceable under the *Fisheries Act*. DFO would have discretion on whether to agree to these requests.

Next Steps:

The co-management partners are currently in the process of co-developing a Policy Intentions Paper (PIP), which will describe the policy and management objectives of the proposed regulations. The goal is to draft the PIP by December 2024. Following this, the intent is to distribute the PIP externally to inform consultations with rightsholders, stakeholders, and other levels of government in early 2025, including the NWMB. Letters describing the proposed area of application, and DFO’s intent to share the draft PIP, have been sent to communities and organizations representing rightsholders in Nunavut.

Submission to the Nunavut Wildlife Management Board

October 2024

FOR

Information : X

Decision:

Issue: Fisheries and Oceans Canada (DFO) Update – Marine Conservation Area

Background

As part of the Marine Conservation Targets initiative, the Government of Canada committed to advancing progress on effective management of existing marine protected areas (MPAs) and Other Effective area-based Conservation Measures (OECMs). DFO Arctic Region continues to work with partners to advance the establishment of new sites (Appendix 1) which would contribute to Canada's goal of conserving 25% of Canada's oceans by 2025, and working towards an international goal of conserving 30% by 2030.

Updates

1. *Qikiqtait and Sarvarjuaq Study Areas*

- Sarvarjuaq (the Canadian portion of the North Water Polynya) and Qikiqtait (the waters surrounding the Belcher Islands area) have been identified in the Qikiqtani Inuit Association's (QIA) 2022 Prospectus to support a regional conservation approach and contribute towards advancing Inuit-led conservation in the Qikiqtani Region.
- DFO, along with Environment and Climate Change Canada (ECCC) and Transport Canada, is leading a whole-of-government negotiation of an Inuit Impact and Benefit Agreement (IIBA) with QIA to support Inuit-led marine conservation and management opportunities in both the Sarvarjuaq and Qikiqtait study areas.
- Partners are currently advancing these sites as Ministerial Order Marine Protected Areas (MPAs) under the *Oceans Act*, which would freeze the footprint on ongoing activities in these areas for up to five years.
- The Qikiqtait and Sarvarjuaq Working Group, which has membership from QIA, Government of Canada and the Government of Nunavut, consulted with seven communities in the Qikiqtani region during two community tours held between October 2023 and June 2024. The purpose of these consultations was to share information and seek feedback on the proposed regulatory intent for Ministerial Order MPAs in each area. DFO will be sending a "What We Heard" report back to communities to ensure it has accurately captured the outcome of these consultations, and will be seeking letters of support from the hunters and trappers organizations and hamlet councils in all seven communities.
- On July 4, 2024, letters were distributed to industry and other stakeholders requesting information about their ongoing activities within the proposed boundaries of Qikiqtait and Sarvarjuaq. A second set of letters will be distributed seeking stakeholder feedback on the regulatory intent for each area.

- All Inuit rights under the Nunavut Agreement, including harvesting rights, would be respected in establishment and management of a Ministerial Order MPA under the *Oceans Act*. The NWMB's powers, duties and functions would also continue to be respected.
- Following the consultation period, DFO's regulatory approach for both sites (with all requirements under the Nunavut Agreement met), will be pre-published in the Canada Gazette, Part I.
- DFO anticipates that formal submissions of the Qikiqtait and Sarvarjuaq Ministerial Order proposals will be submitted for NWMB approval at their February 2025 meeting.
- The Working Group would welcome any advice the NWMB may have on our consultation approach or other aspects of the proposed study areas prior to our formal submission.

2. Tuvaijuittuq Marine Protected Area

- In January, 2024, the Qikiqtani Inuit Association (QIA) formally requested that DFO repeal and replace the existing Ministerial Order marine protected area in Tuvaijuittuq.
- In 2019, the area was designated as a five-year Ministerial Order marine protected area (MPA) under the *Oceans Act* to provide partners time to complete the feasibility assessment and establish a long-term protection measure if recommended.
- Following consultations, DFO received full support from the hunters and trappers associations and hamlet councils of all five associated High Arctic communities (Arctic Bay, Clyde River, Grise Fiord, Pond Inlet, Resolute Bay) in summer 2024.
- In March DFO and QIA co-presented the proposal for a second Ministerial Order MPA to the NWMB for its approval, which was received in April.
- On August 14, 2024, the new Ministerial Order MPA (Order No. 2 Designating the Tuvaijuittuq Marine Protected Area) was published in Canada Gazette, Part II which completes the designation process for this interim MPA.
- This new regulation provides five more years of protection to Tuvaijuittuq while partners work with QIA to consider an Inuit Protected and Conserved Area for the area over the long term.

3. Southampton Island Area of Interest

- DFO is working with the Kivalliq Inuit Association and the Government of Nunavut to advance the Southampton Island Area of Interest for potential designation as a new *Oceans Act* Marine Protected Area.
- The Southampton Island Area of Interest encompasses the nearshore ocean around Southampton Island and Chesterfield Inlet in the Kivalliq Region of Nunavut. The final boundary of a potential future Marine Protected Area will be based on assessments and consultation.
- All Inuit rights under the Nunavut Agreement, including harvesting rights, would be respected in establishment and management of a Marine Protected Area. The NWMB's powers, duties and functions would be respected.
- As briefed to the NWMB at its last meeting, DFO, the Kivalliq Inuit Association and the Government of Nunavut engaged five communities in the vicinity of the Southampton Island Area of Interest (Baker Lake, Chesterfield Inlet, Coral Harbour, Naujaat, and Rankin Inlet) in Winter 2023-2024, to present and seek feedback on a Marine Protected Area Proposal.
- Stakeholders were also engaged on the draft Marine Protected Area Proposal, including from mineral and petroleum, shipping, and tourism industries.

- DFO heard feedback on the area's conservation objectives; proposed boundary of a Marine Protected Area; and proposed measures that may regulate, restrict, allow with conditions, or allow activities, while respecting the Nunavut Agreement. Feedback is currently being compiled into 'What we Heard' Reports and a Questions and Answers document is being developed to be shared with those that participated in the consultations.
- This feedback will inform development of a final Marine Protected Area Proposal and brought to communities during a second community tour, tentatively planned for Winter 2024-2025 to all Kivalliq communities.
- DFO and the Kivalliq Inuit Association are working on a revised set of critical milestones.

Prepared by: Marine Planning and Conservation and Fisheries Management, Arctic Region – Fisheries and Oceans Canada.

Date: August 8, 2024

Appendix 1. Existing and potential future Arctic protected and conserved areas.



SUBMISSION TO THE NUNAVUT WILDLIFE MANAGEMENT BOARD – August 8, 2024

FOR: Information: X

Decision:

Issue: Update on the interim plan for the **Tallurutiup Imanga National Marine Conservation Area**

PURPOSE

Provide an update on the Interim Management Plan (IMP) for Tallurutiup Imanga National Marine Conservation Area (TINMCA) including progress to date, recent community consultations, next steps, and anticipated timeline to completion. The last update was given to the NWMB in spring 2020. There have been delays in finalizing the draft IMP, but the Planning Committee has made significant progress towards finalizing the plan over the past year and hopes to present the final interim management plan for NWMB approval at the February or June 2025 meeting.

BACKGROUND

The major steps in the establishment process of TINMCA under the *Canada National Marine Conservation Areas Act (2002)* are: completion of an assessment of the feasibility and desirability of the NMCA (completed in 2017); negotiation of an IIBA (completed in 2019); creating an interim management plan (underway); and establishing the NMCA in legislation (underway).

Tallurutiup Imanga is 108,000 km², located in the northern Qikiqtani region, and includes some terrestrial areas (three significant bird cliffs and all islands under 400 ha). The communities associated with Tallurutiup Imanga are Grise Fiord, Resolute Bay, Arctic Bay, Pond Inlet and Clyde River.

The Planning Committee for Tallurutiup Imanga, consisting of two representatives from QIA, one representative from Parks Canada; and one representative from the Government of Nunavut, is responsible for leading the development of the interim management plan for TINMCA. The interim plan will guide the management of TINMCA for five years while a comprehensive 10-year Management Plan is developed. The development of the IMP is informed by extensive consultation with communities, as well as input from stakeholders and the public.

The plan contains a **vision** that describes the desired future state of TINMCA in 15-20 years; management **objectives** that are broad outcomes to accomplish over the life of the plan, with associated **targets** that are more specific and will measure progress towards achieving the objectives; and a **zoning** plan that sets the management intent for different areas of TINMCA by dividing it into specific zones. Zoning describes what activities can take place in an area, when they can take place, and under what conditions. Inuit rights-based harvesting and traditional use are allowed in all zones, at all times. TINMCA contains:

- zones of strict protection to protect sensitive features that are susceptible to disturbance (e.g. cliffs with bird colonies). Only Inuit use and limited scientific research may occur.
- zones to protect specific habitats (e.g. migration corridors, nurseries) where some activities are restricted if they negatively impact the habitat;
- multiple use areas where a range of variety of activities and uses are permitted if they do not negatively impact the marine environment or Inuit rights, and
- areas identified as being of special importance for communities, where activities will be managed so that Inuit use of these areas is not impacted.

CONSULTATIONS

- Community consultations on the draft interim management plan were held in 2018 and 2019 in Grise Fiord, Resolute Bay, Arctic Bay, Pond Inlet, and Clyde River to gather information about what should be in the plan. The Planning Committee met with hamlet Councils, Hunter and Trapper Organizations (HTO) and other local organizations and held public information sessions. Approximately 300 individuals attended those consultations. The Planning Committee used what was heard at these meetings to draft the interim management plan.
- In March 2024, the Planning Committee travelled to Grise Fiord, Resolute Bay, Arctic Bay, Pond Inlet, and Clyde River, to present the draft plan to ensure that community concerns and priorities had been adequately addressed in the draft plan. Meetings were held with hamlet Councils, HTOs, CLARCs and the Nauttiguqtiit over 2 days. Open houses were also held in each community. Approximately 130 individuals attended these meetings. During these recent consultations, the Planning Committee received additional information on what needs to be protected and about threats to TINMCA (e.g.: concerns about pleasure craft and cruise ship behaviour and impacts, concerns about capacity to respond to public safety or environmental incidents). The Committee is using this information to further refine the Objectives and Targets and the Zoning plan. The Planning Committee also received comments that improved the Vision statement and will ensure this Vision reflects what the community wants TINMCA to look like in 15-20 years.

NEXT STEPS

- The Planning Committee is currently working to edit the IMP draft based on the feedback from March 2024 community consultations. Once complete, the next steps are:
- September/October 2024: Virtual meetings held with communities to validate and finalize the draft IMP.
- November/December 2024: Stakeholder and public consultations on the draft IMP.
- January/February 2025: Final edits to the IMP and approvals
- Anticipated March 2025: IMP submitted to the Aulattiqatigiit Board for approval.
- Anticipated June 2025: IMP submitted to the NWMB for approval.

QUESTIONS OR COMMENTS

If the NWMB has any comments, concerns, or questions, the Planning Committee is available to discuss these at any point.

Parks Canada: Laurent Jonart, laurent.jonart@pc.gc.ca
Government of Nunavut: Bradley Pirie, BPirie@gov.nu.ca
Qikiqtani Inuit Association: Jovan Simic, jsimic@qia.ca

