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

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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 subpopulaton 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, Sciullo 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). Prevett 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) 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 ≥ 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)*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.

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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 Location	Year	N	M-CAP	WH bears	SH bears
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.

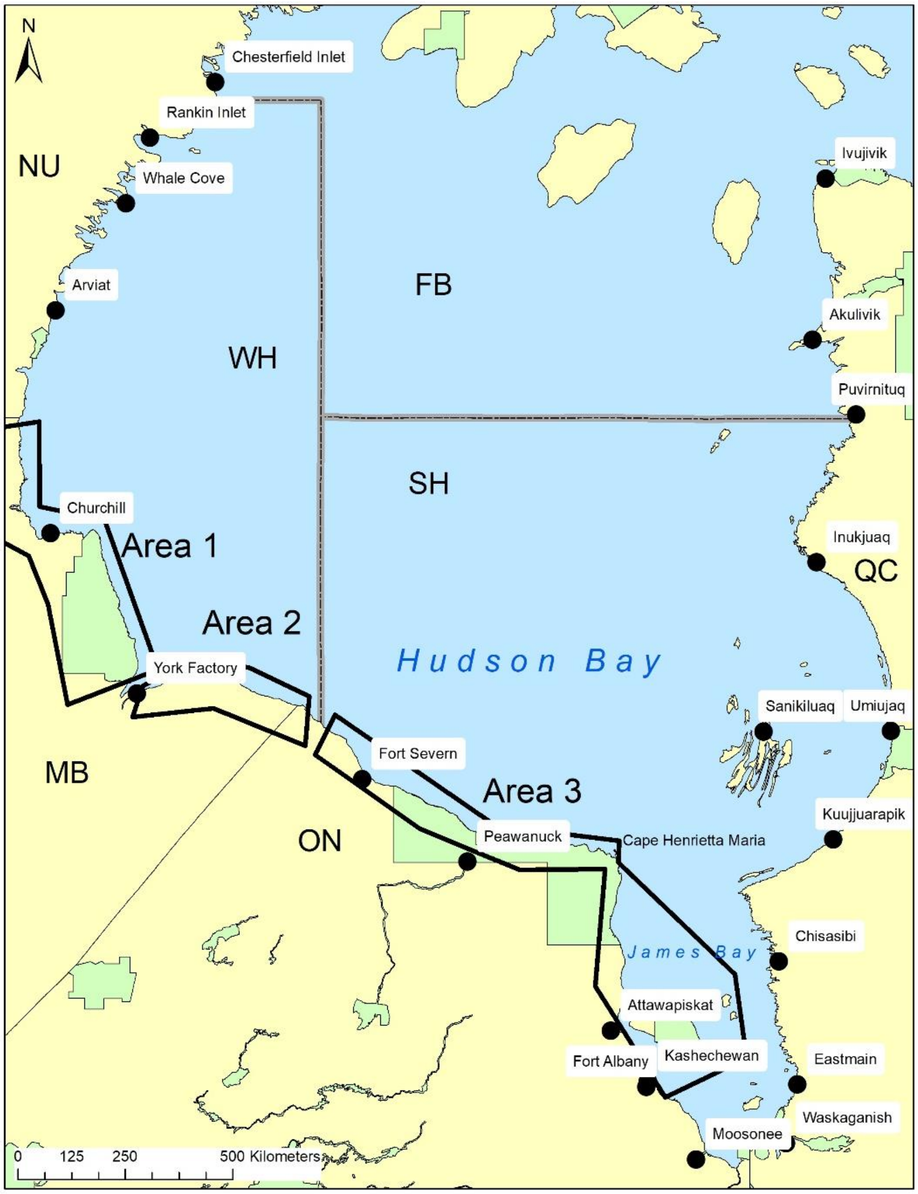

Figure 1. Hudson Bay showing the management boundaries (dashed lines) between the Western Hudson Bay (WH), Southern Hudson Bay (SH), and Foxe Basin (FB) polar bear subpopulations and geographic sampling areas 1, 2 and 3.

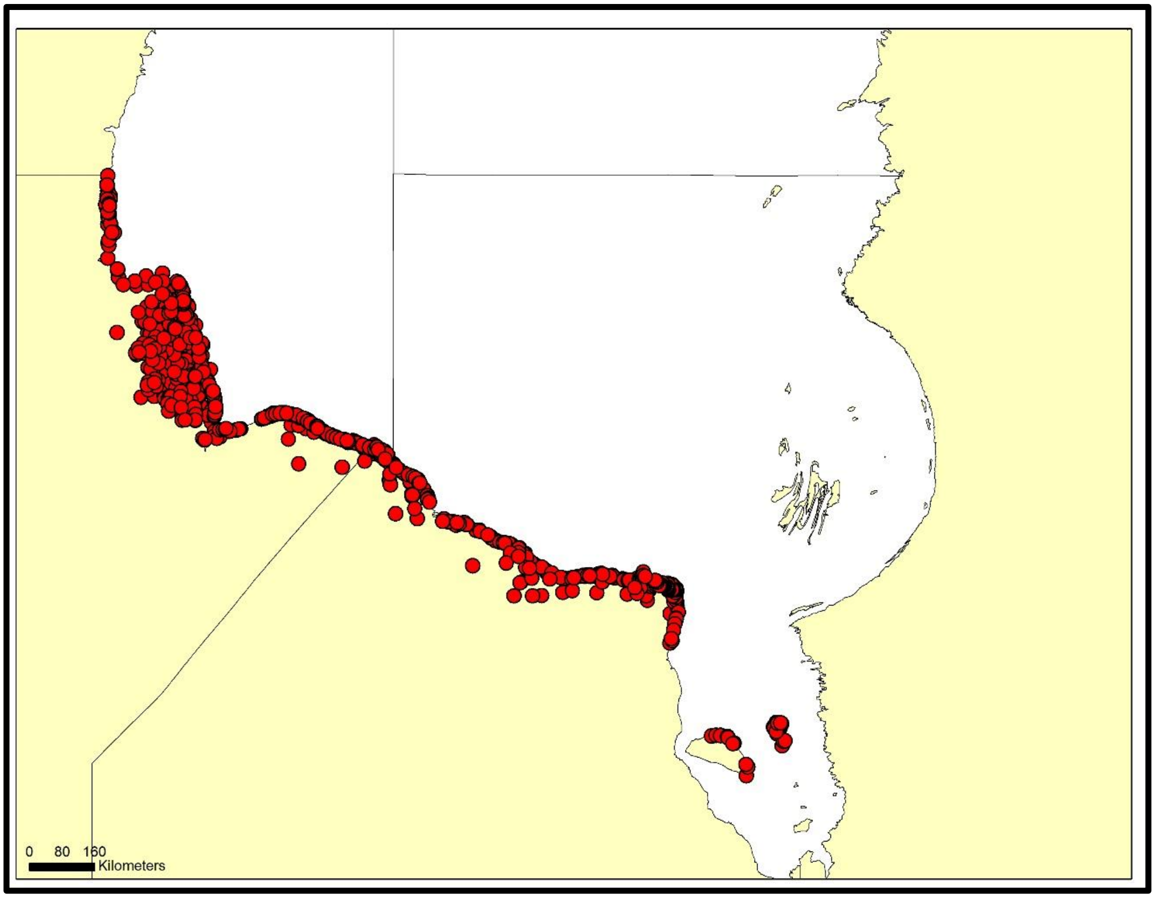

Figure 2. The spatial distribution of polar bear tissue samples collected via biopsy or physical capture between 2017 and 2022.

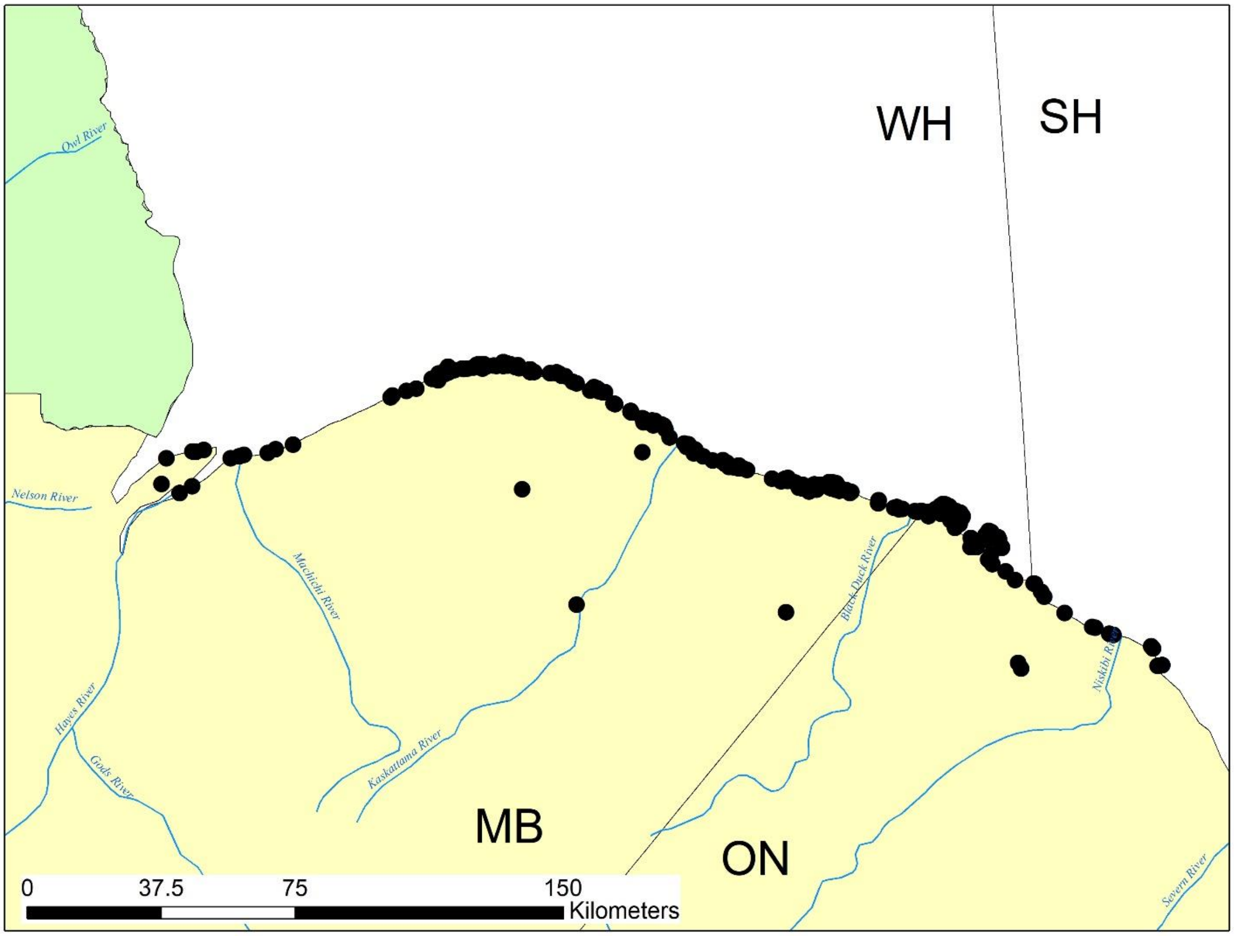

Figure 3. Locations where polar bear samples were collected, 2017-2019 in Area 2 and Area 3.

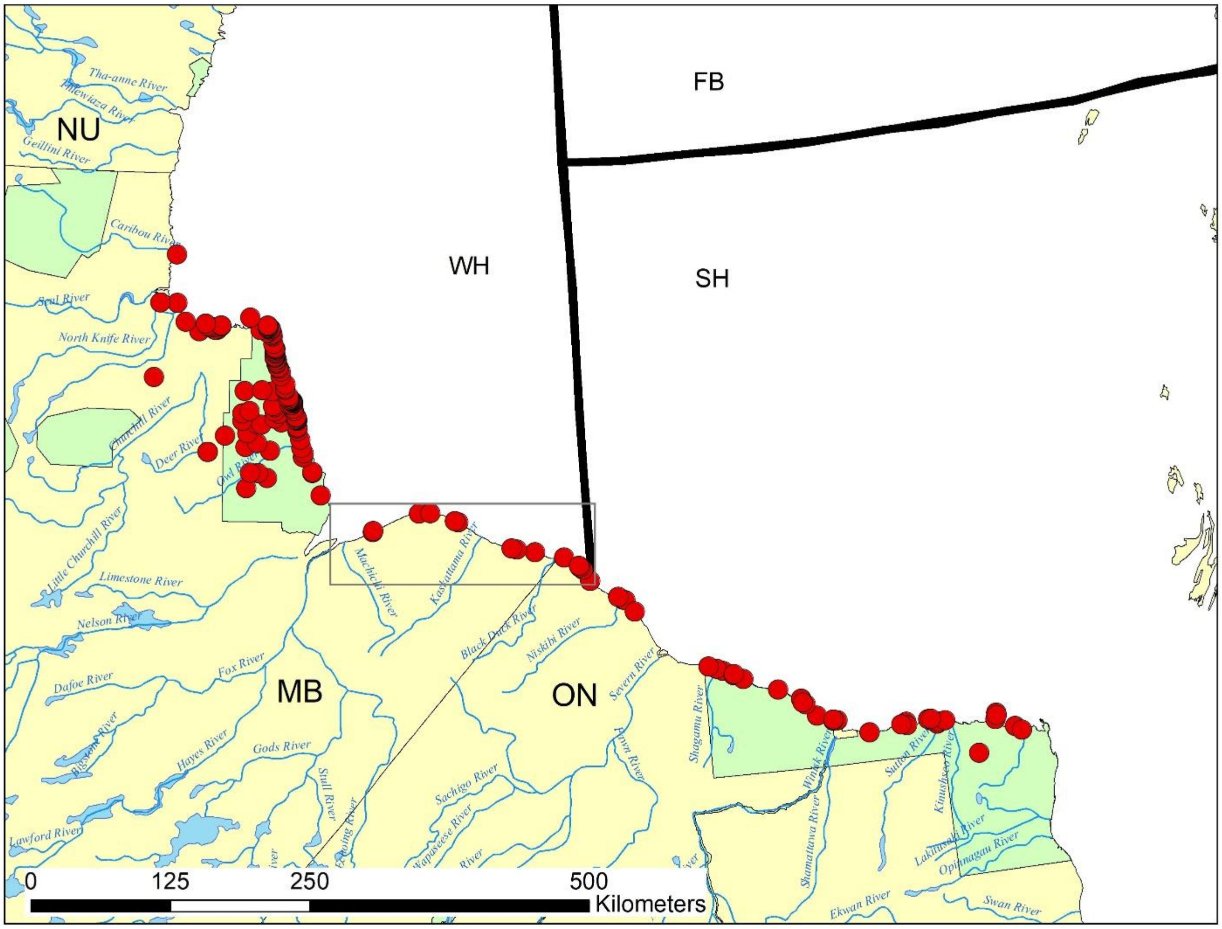

Figure 4. Previous capture locations of 100 bears sampled in Area 2 (grey rectangle) from 2017 to 2019 (Figure 3) that matched individuals tagged before 2017 and were identified in the WH and SH genetic database. No bears have been physically captured and tagged along the Ontario coastline since 2009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

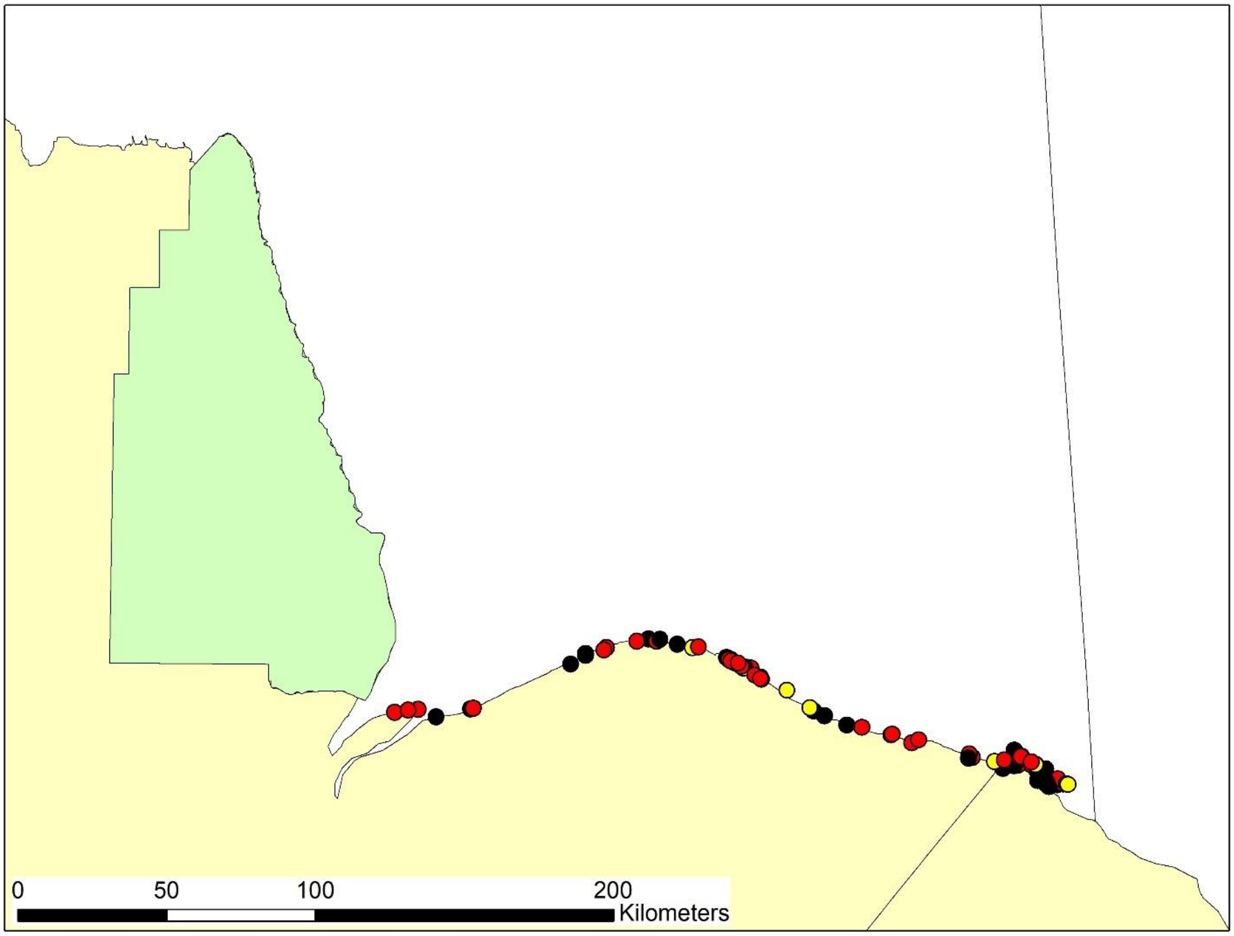

Figure 5. Locations of polar bears biopsied in 2021 in Area 2 that matched individuals previously sampled in WH (red circles) both SH and WH (yellow circles) and first-time captures (black circles).

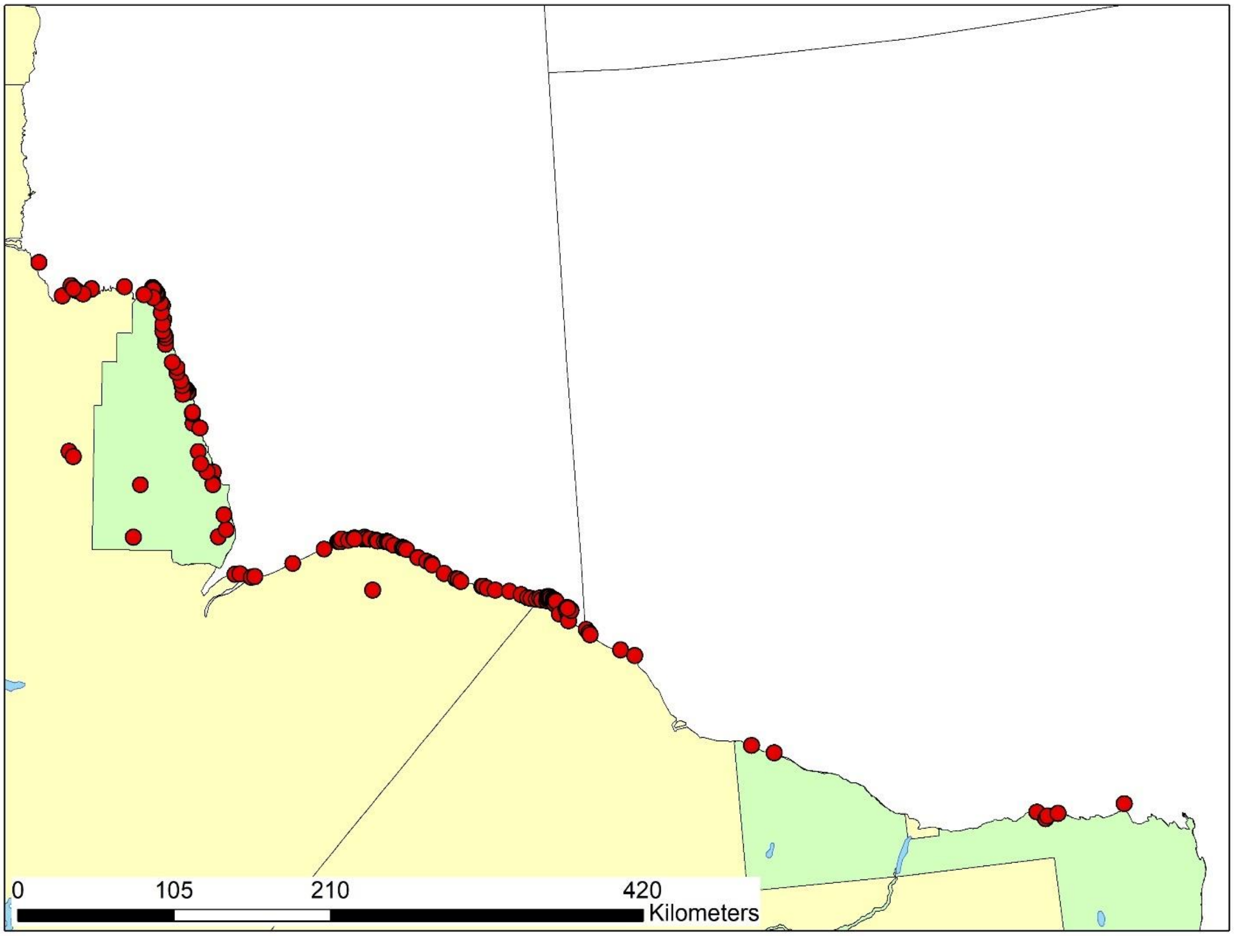

Figure 6. Previous sampling locations for 96 bears (capture or biopsy from Figure 5) that were biopsied in Area 2 in 2021.

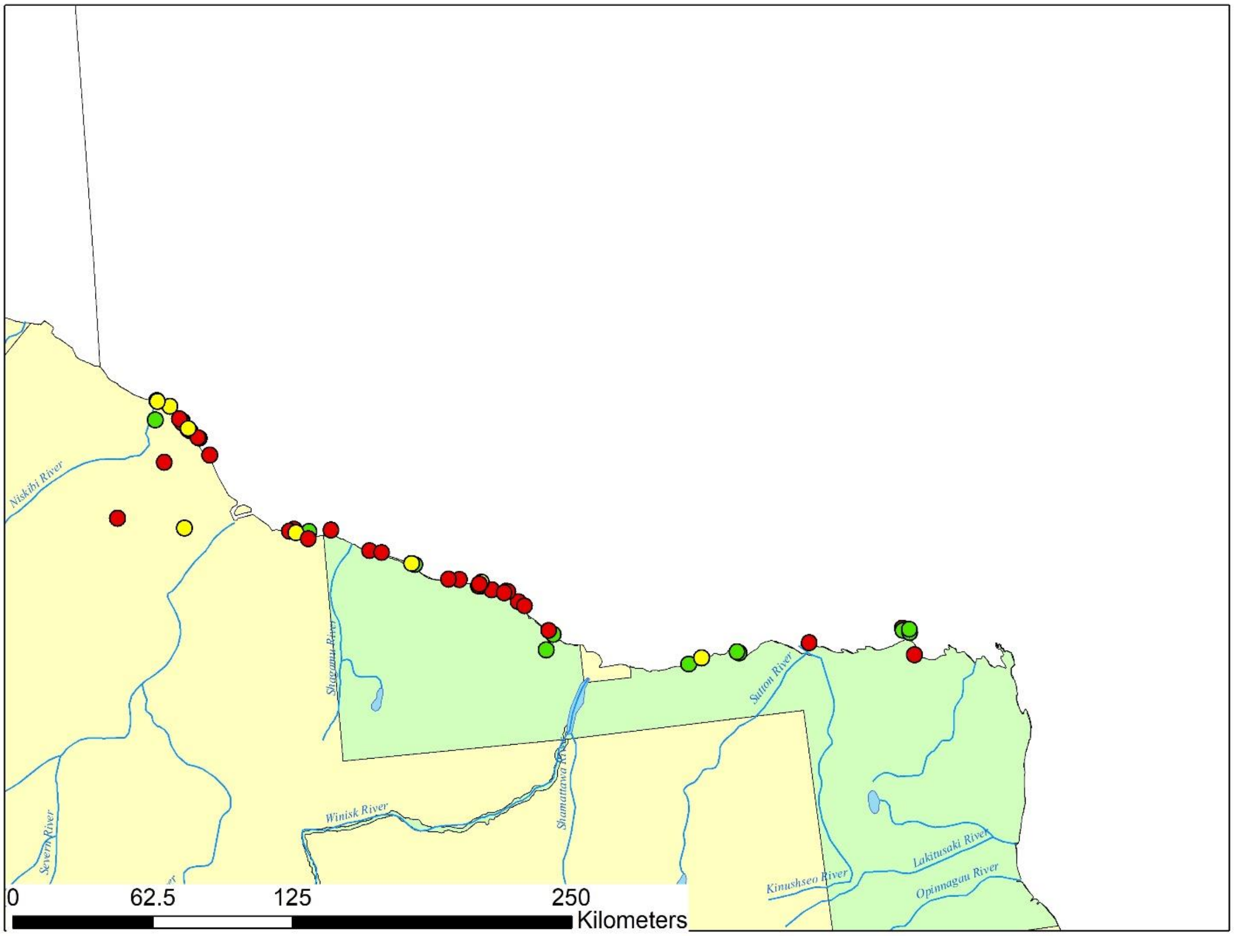

Figure 7. Sampling locations of 65 bears biopsied in SH in 2021 that were previously sampled in WH (red circles), both WH and SH (yellow circles), and only SH (green circles).

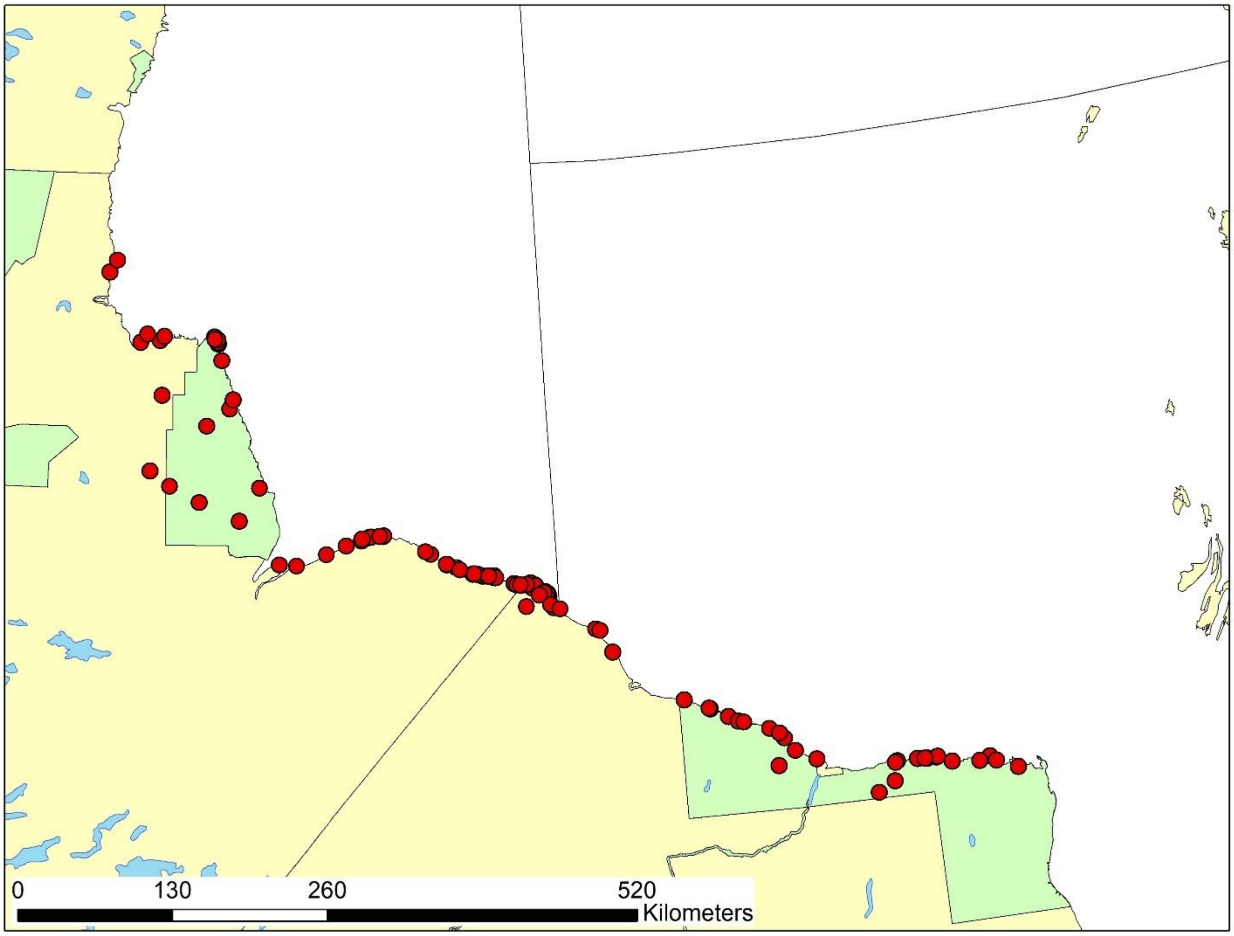

Figure 8. Previous sampling locations for 65 bears (Figure 7) that were biopsied in 2021 in SH.

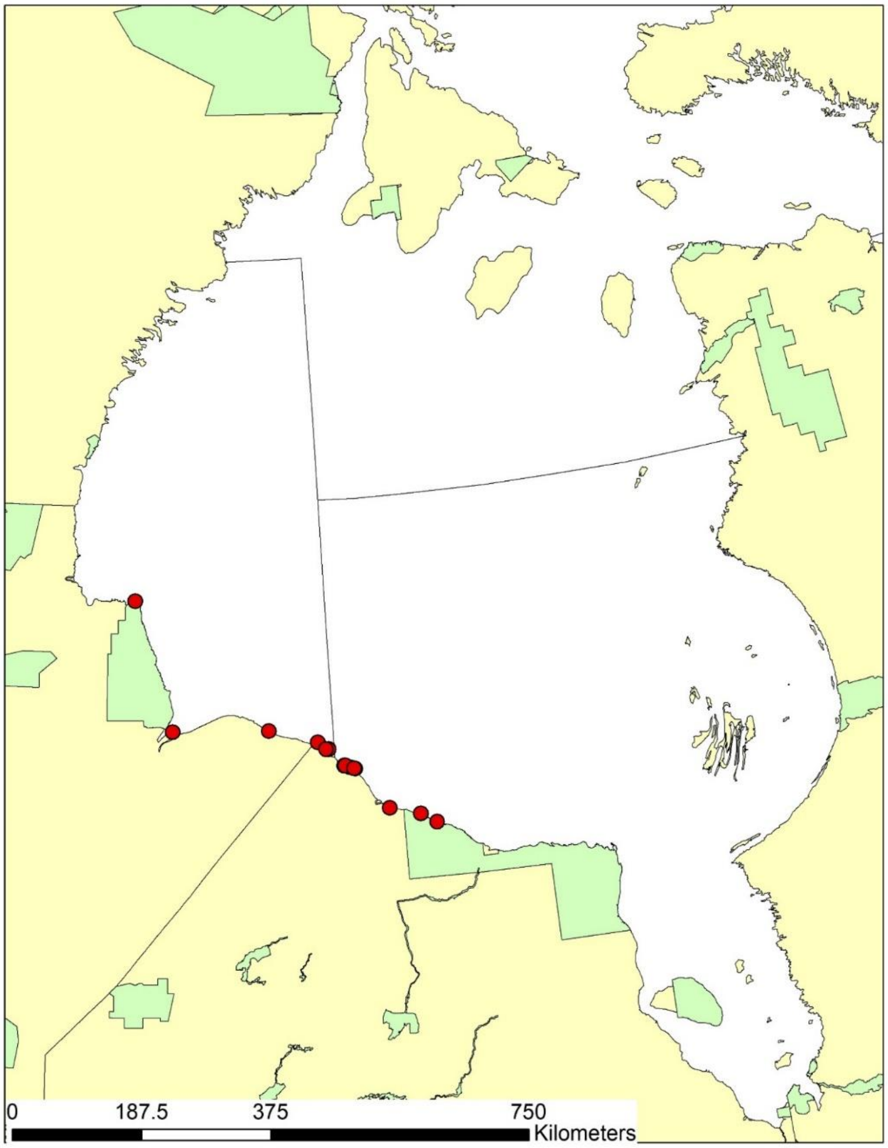

Figure 9. Distribution of bears in WH in 2021 that were resampled in SH in 2022 (i.e WH locations represent 2021 while SH locations represent 2022 for the same bears).

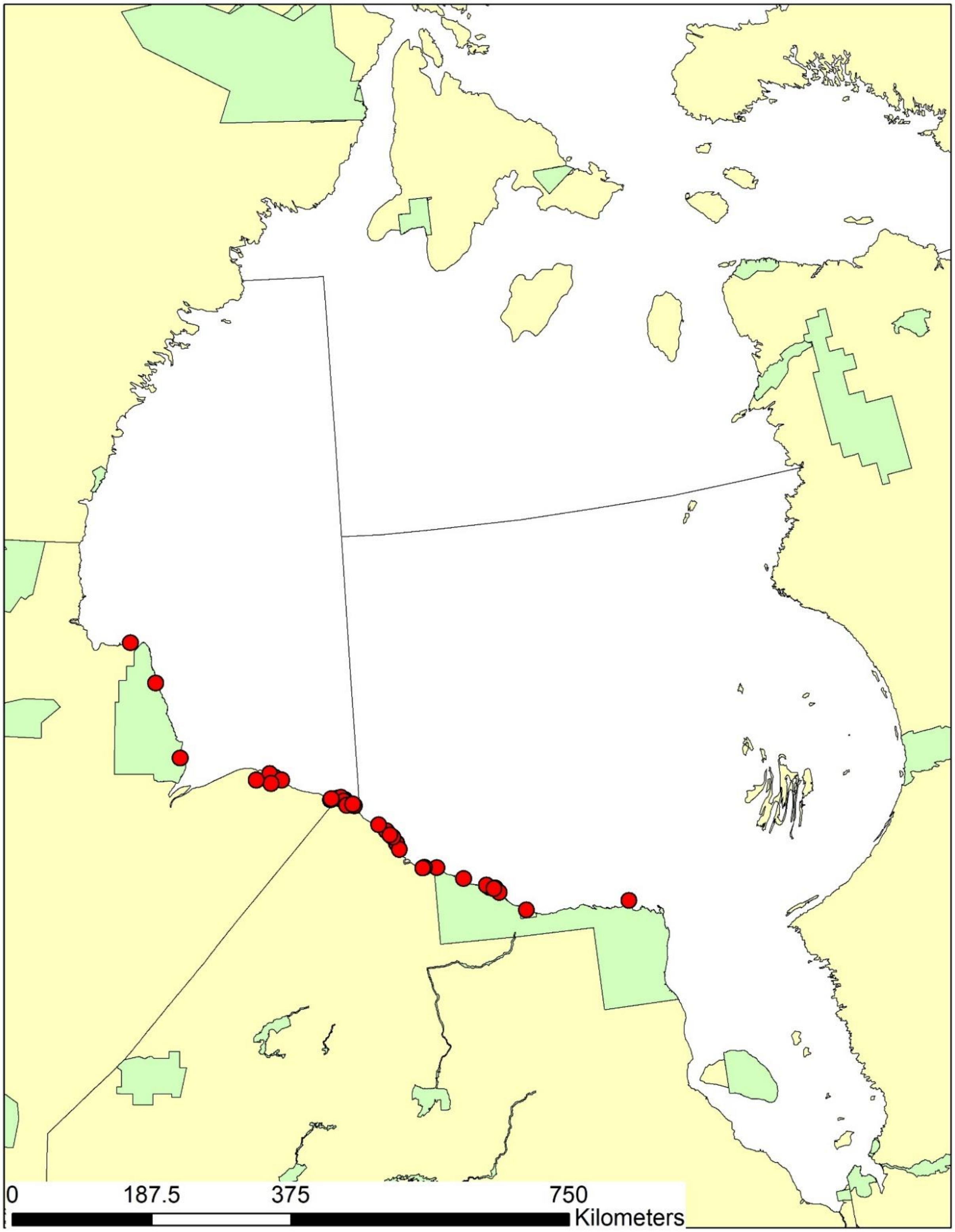

Figure 10. Distribution of bears in SH in 2021 that were resampled in WH in 2022 (i.e SH locations represent 2021 while WH locations represent 2022 for the same bears).

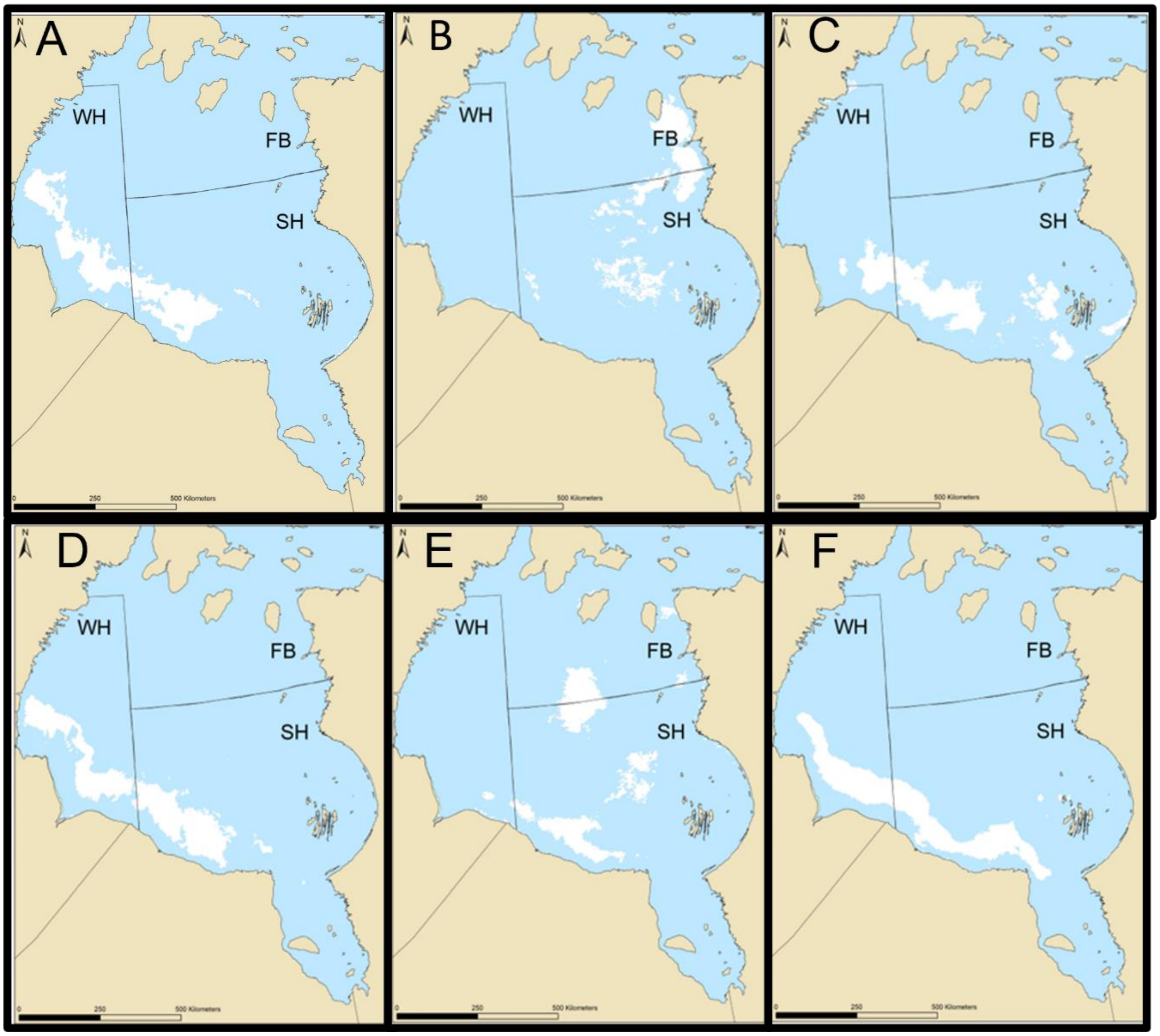

Figure 11. Remnant ice (sea ice cover ≥ 30% when sea ice extent was 10% of winter maximum) in Hudson Bay (excluding James Bay) in 2017 (A), 2018 (B), 2019 (C), 2020 (D), 2021 (E) and 2022 (F).

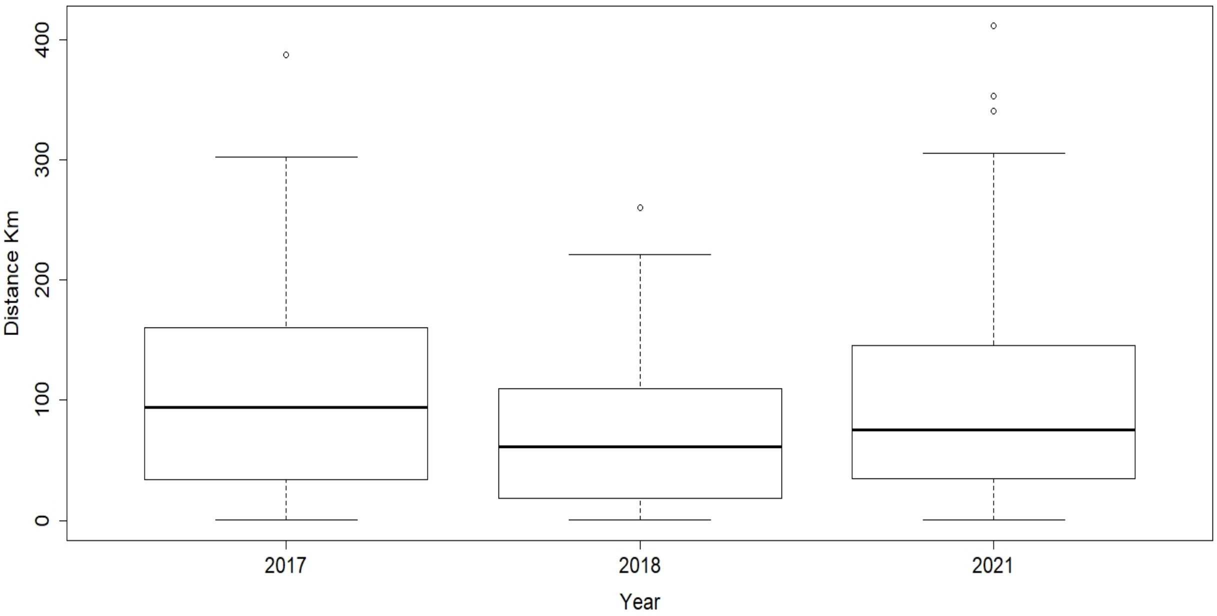

Figure 12. Boxplot of displacement distance (Km) for adult males sampled in consecutive years 2017 (2017/2018, n=32), 2018 (2018/2019, n=80) and 2021 (2021/2022, n=113) in Hudson Bay. Inter quartile range represents 25th and 75th percentile, solid line represents the median and whiskers indicate range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

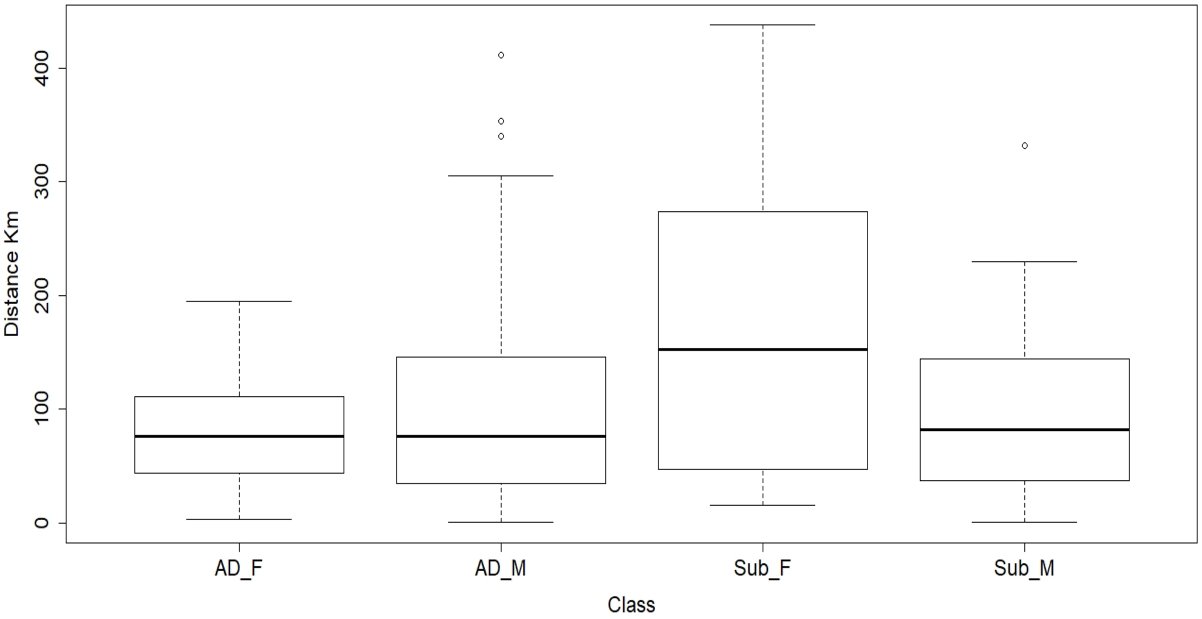

Figure 13. Boxplot of displacement distance (Km) for adult females (AD_F, n = 27), adult males (AD_M, n=113), subadult females (Sub_F, n=20), subadult males (Sub_M, n=29) sampled in late August/September in 2021 and 2022 in Hudson Bay. Inter quartile range represents 25th and 75th percentile solid line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