CHAPTER 3

REASSESSING THE 1990S BAFFIN BAY DATA FOR BIAS AND COMPATIBILITY WITH THE 2010S DATA

KEY FINDINGS

- This chapter evaluates patterns in the 1990s physical MR data, including non-random and incomplete sampling, and the resulting potential for bias in estimates of demographic parameters.
- The 1990s MR sample size was small (average 229 total captures per sampling year), relative to the 2010s (average 470 total biopsies per sampling year), and the number of recaptures in the 1990s was low. There were few dead recoveries during the period between MR sampling studies (1998-2010), particularly in the latter years. Small sample sizes make it difficult to estimate demographic parameters and assess subpopulation trend, limiting both the strength of inference that can be drawn from the 1990s data and our ability to quantify and reduce bias in estimates of demographic parameters.
- The spatial distribution of polar bear physical captures and biopsy samples for the MR studies in the 1990s and 2010s was significantly different. In the 2010s, a larger fraction of bears were captured inland from the coastline, and inside fjords along Baffin Island.
- The difference in distribution of captures between sampling periods was not due to changes in habitat use. Analyses of satellite telemetry data from adult females, providing an unbiased assessment of land use between decades, showed no differences in distance inland or elevation for onshore bears between the 1990s and 2010s. Thus, the difference in capture distributions were a function of different sampling effort, with less effort expended away from coastlines and inside fjords in the 1990s.
- Consistent with the differences in sampling effort and temporary emigration between the 1990s and 2010s, there were significant differences in the composition of the MR samples (e.g., the proportion of bears within each age-sex class) between these two periods. Specifically, adult females were under-represented in the 1990s samples.
- The spatially-defined sampling area (km^2) in Nunavut encompassed the capture and biopsy locations in both decades and represented a minimum area sampled. The sampling area in the 1990s survey was less than ½ of that sampling in the 2010s. The 2010s sampling area encompassed most fjords along the coast and more inland habitat. To evaluate potential biases associated with the smaller sampling area of the 1990s, MR analyses and estimated parameters were compared from two datasets: (1) all 2010s MR data, and (2) a geographic subset of the 2010s MR data that was comparable to the sampling area in the 1990s (Chapter 5).

- In the 1990s there was likely a high degree of temporary emigration from the sampling area on the Baffin Island coast because bears used sea ice offshore in Baffin Bay or in the archipelago in summer. Significantly less sea ice was available in the 2010s and temporary emigration was lower. In the 1990s, $\leq$30% of radio-collared female bears were inside the sampling area during the MR sampling periods, compared to 70-80% in the 2010s. This suggests that a potentially significant proportion of bears were not available for capture each year during the 1990s, though sample sizes for analysis were small. Completely random temporary emigration from the sampling area should not result in biased demographic parameters. However, the degree of temporary emigration in the 1990s appeared variable and dependent on environmental conditions; and small samples sizes made it difficult to rule out significant bias.

- Additional sources of temporary emigration in the 1990s were non-random and linked to the reproductive cycle of females. Adult females in reproductive classes that were likely pregnant in fall moved farther inland on Baffin Island (e.g., to find suitable denning habitat), compared to non-pregnant females, which likely contributed to the under-sampling of adult females in some years in the 1990s because of the lack of inland sampling.

- There also were technical challenges with the 1990s MR data. Within the 1990s MR data there was uncertainty in identifying bears that were located with the aid of radio-telemetry vs. those located by standard search (i.e., random encounter). Original capture records could not be located and were inferred by comparing available information to the capture history files compiled for the 1990s BB demographic analysis. This uncertainty could result in bias, because knowing which bears were located by telemetry was important in the most-supported MR models for the 1990s data.

- Relative to the 2010s data, the 1990s data were characterized by relatively small sample sizes, incomplete geographic sampling, a likely higher degree of temporary emigration for bears that remained on sea ice during the summer, and potential non-random temporary emigration for adult females that moved farther inland to den. These issues led to an increased potential for bias in estimates of survival and abundance from the 1990s data. As a result, demographic parameters estimated from 1990s and 2010s BB data are not directly comparable and there is a limited ability to evaluate subpopulation trends.

3.1. Background

Accurate knowledge of demographic parameters (e.g., survival, abundance) is important for wildlife management decisions such as determining sustainable harvest levels and evaluating subpopulation viability. Mark-recapture (MR) studies are used to estimate demographic parameters because it is generally not feasible to monitor every individual in a subpopulation.

The results from MR studies can be biased by several factors, including heterogeneity in recapture probability (*p*) that is not accounted for through the choice of sampling design or modeling approach (Williams et al. 2002). The magnitude of bias is generally largest for abundance (Pollock et al. 1990) although estimates of survival probability can have meaningful bias as well (Devineau et al. 2006). Estimating accurate and unbiased demographic parameters for polar bears is particularly challenging. First, sample sizes are relatively small due to challenging environmental and logistical conditions, and the high cost of Arctic fieldwork. Second, polar bears are often distributed across large landscapes at low densities. Only a fraction of the study subpopulation may be accessible to researchers, and this fraction may change from year to year based on environmental conditions and logistical constraints. This limits sample sizes, leads to difficulty in delineating subpopulation boundaries, and means that the effective study subpopulation may be different than the biological population of interest. Third, the high mobility of polar bears and inter-annual variability of their sea-ice habitat can lead to nonrandom movements (i.e., temporary emigration) with respect to the sampling area. Fourth, female bears may be less-observable or unobservable for several months when pregnant or associated with maternal dens, leading to an 'unobservable state'. Fifth, the three-year reproductive cycle of polar bears makes it difficult to estimate reproductive rates and their relationships with environmental conditions. Finally, relatively long-term datasets are required because of the long life span of polar bears and high inter-annual variability in the Arctic environment.

In recent years, methodological advances have led to an increased ability to detect, quantify, and mitigate bias in demographic parameters from MR studies arising from the challenges listed above. Advances include noninvasive genetic methods to increase sample size

(Lukacs and Burnham 2005); multiple sampling occasions per year under a “robust design” (Kendall et al. 1997); spatially-explicit models to account for heterogeneity in recapture probability as a function of site fidelity (Royle et al. 2014); models with “unobservable states” to account for temporary emigration (Schaub et al. 2004); and models that integrate data from multiple sources (Peñaloza et al. 2014). Some of these methods have been employed for polar bears, whereas others have not been used due to lack of familiarity or practical limits on the types of sampling that can be conducted.

The MR study of the Baffin Bay subpopulation 2011-2013 incorporated noninvasive genetic sampling and modelled live-recapture and dead-recovery data in the same analytical framework. Both of these approaches increased sample sizes and reduced susceptibility to some types of bias. Nonetheless, there remained major challenges to the application of MR models to the Baffin Bay data, and in this chapter we evaluate sampling and biological issues that have the potential to introduce bias in estimates of survival and abundance. Similar investigations of bias have become a standard part of MR studies for polar bears (e.g., Regehr et al. 2010), and are necessary to understand the strength of inference that can be drawn from MR studies. In this chapter we focus on reassessing the 1990s BB data because, compared to the 2010s data, the 1990s data had smaller sample sizes, reduced geographic coverage, and other uncertainties and limitations. This assessment directly informs our ability to compare results from the 1990s and 2010s data and evaluate trends in polar bear survival and abundance between sampling periods.

<u>Distribution of Mark-Recapture Sampling on Baffin Island</u>

Prior to the 2011-2013 survey of the Baffin Bay subpopulation, MR sampling occurred during several periods. Initial sampling was conducted during the 1970s (northern Baffin Island

and Bylot Island, near Lancaster Sound), early 1980s (east-central Baffin Island), and late 1980s to early 1990s (Canada and Greenland, as part of movement studies; Figure 5.2; Taylor et al. 2005). Early sampling efforts were generally restricted to spring-time and primarily occurred on landfast and nearshore pack ice. These studies documented that an unknown but likely large proportion of the subpopulation was on sea ice farther offshore during the spring and therefore unavailable for capture. We excluded these early data from present analyses (*cf*. Taylor et al. 2005, in which these early data were included) because the early sampling occurred in a different season (i.e., spring) and was spatially variable and restricted. Additionally, lack of tissue samples from early sampling precluded genetic identification for use in the present study.

In 1993 –1995 and 1997, more systematic sampling occurred during fall ice-free seasons (during September and October) on Baffin and Bylot islands (Figure 3.1). There was no fall sampling in 1996 due to logistical and resource constraints. These data formed the core of the study reported by Taylor et al. (2005) who estimated the number of polar bears in Baffin Bay at 2,074 (95% confidence interval: 1544-2604) in 1998. Taylor et al. (2001) indicated that a large majority of polar bears were onshore in summer retreat areas on Bylot and Baffin islands during the autumn. Taylor et al. (2005) reported that search effort during the 1990s was uniform and systematic across the coastal regions, islands, and inland reaches of Baffin Island. Consequently, Taylor et al. (2005) suggested that the autumn onshore sampling in 1993-1995 and 1997 provided improved coverage of the subpopulation and more reliable abundance estimates compared to those derived from the 1980s BB data, which Taylor et al. (2005) suggested were biased low.

In 2011-2013 we completed a second fall-time MR sampling study (August – October) on the coasts of Baffin Island (Figure 3.1). Data from West Greenland were also collected (see

Chapter 5, Figure 5.8). During this study, new data on movements and spatial distribution of bears were also obtained via satellite telemetry in BB and KB. This information was used to assess subpopulation boundaries (Chapter 2) and habitat use relative to the 1990s (Chapter 4), but also to improve MR study design (i.e., stratify the study site; Chapter 5) with the objectives of reducing heterogeneity in capture probabilities and more efficiently allocating survey effort. The 2011-2013 study (see Chapter 5) was largely modeled after Taylor et al. (2005) in that bears were targeted during the ice-free season, to obtain estimates of abundance and vital rates that might be comparable to Taylor et al. (2005) therefore useful for assessing trend.

Here we compare the spatial and temporal distribution of physical captures and biopsy sampling on Baffin Island for sampling 1993-1995 and 1997 vs. sampling during 2011-2013 (referred to as the “2010s”). The goal is to evaluate whether there were important differences in sampling, which could lead to different biases or different definitions of the effective study subpopulations (e.g., if a large group of bears was systematically missed in one study period, then the effective study subpopulation for that period would be smaller). Field records (e.g., Global Positioning System helicopter logs, navigation maps) delineating survey effort 1993-1995 and 1997 were unavailable. Therefore, we plotted sighting data from Taylor et al. (2005) in a Geographic Information System (GIS; ArcMap 10.2, ESRI, Redlands, California, USA) to examine the spatial distribution of captures compared to the 2010s. We also used historic and current radio telemetry data to identify whether potential differences in capture locations were influenced by changes in the onshore movements and habitat use of polar bears.

Methods – Maps of physical capture and biopsy sampling locations (hereafter collectively referred to as “captures”) on Baffin Island suggested that captures in the 1990s were more limited to coastal areas, whereas captures in the 2010s included bears located farther from the coast and deep inside fjords, including higher altitudes (Figure 3.1). We examined the hypothesis that the discrepancy in capture locations across periods reflects differences in sampling effort rather than a shift in the onshore distribution of bears. We calculated the distance to the nearest coastline and the distance to the smoothed outer Baffin Island coastline for each capture location in the 1990s and 2010s. The smoothed coastline followed the contour of the true physical coastline of Baffin Island, but was smoothed across fjords with a straight segment orthogonal to the fjord direction. We smoothed fjords only when the distance across the mouth of the fjord was $\leq$ 7 km using an Azimuthal Equidistant projection (WGS84 datum). We calculated the distance to both coastlines (original and smoothed) for all captures of independent bears (i.e., age 2 or older) that were located on mainland Baffin and Bylot islands (i.e., not on offshore islands) and were successfully genotyped.

We compared the distance-to-coast results to locations of radio-collared bears onshore during the 1990s and 2010s to evaluate whether differences in capture locations reflected differences in sampling effort or differences in the distribution of bears. Given that recent analyses of movement data suggest significant changes in sea-ice habitat use and onshore timing (Chapter 4), we considered the possibility that bears had also changed their behavior and habitat use while on land. First, we verified that the sample of 1990s bears collared in the fall on Baffin Island were comparable to the sample of 2010s bears collared in the spring in West Greenland, by assessing what fraction of spring-collared bears used the area on Baffin Island where bears were collared in the fall (see details in Chapter 2). Overall, 92% of the 2010s spring-captured bears used the fall collaring area. This suggests that, although radio-collaring occurred in different seasons and areas across the two time periods, the collared bears exhibited similar movement and habitat use patterns, and therefore provided comparable data for evaluating onshore habitat use across time periods.

Using satellite telemetry data, we calculated the distance inland from the smoothed coastline and Digital Elevation Model (DEM) elevation (m) for all locations of collared female bears during summer months (August-October). We used land covariates derived from the 22 m^2ASTER GDEM for all positions in Canada (http://www.jspacesystems.or.jp/ersdac/GDEM/E/4.html). We only used adult female bears on Baffin Island and calculations excluded resident bears that remained year-round on the Melville Bay glacier ice.

We also examined distance to the smoothed Baffin Island coastline for adult females as a function of reproductive status (captured alone, as mating pairs; or with COY, yearlings, 2-year old cubs) to evaluate whether this factor may have influenced temporary emigration with respect to the sampling area (particularly the nearer-shore sampling area in the 1990s). For this specific analysis (reproductive state examination) we only examined adult females in the year of collar deployment because their reproductive status was known at the time of capture in spring, thus could be assumed in fall. We excluded bears on sea ice during August-October.

Results – The mean distance of captures to the smoothed coastline was smaller in the 1990s ($\bar{x}$= 5.1 km, SD = 7.2, n = 438) compared to the 2010s ($\bar{x}$= 8.6, SD = 11.9, n = 766, Mann-Whitney U test: z = 3.4, P < 0.001). Detailed results are provided in Table 3.2. Furthermore, a greater proportion of independent bears were captured near the smoothed coastline during the 1990s than the 2010s (Figure 3.2). For example, 84% of captures occurred within 10 km of the smoothed coastline during 1993 – 1997, compared to 72% of captures during 2011 – 2013. Similarly, one independent bear was captured > 35 km from the smoothed coastline during the 1990s sampling, whereas 28 independent bears were sampled > 35 km from the smoothed coastline during the 2010s. The corresponding analysis using satellite telemetry found no significant differences in the distance of adult females from the smoothed Baffin Island coastline between the 1990s and 2010s; adult female bears on average in the 1990s were about a mean 17 km from the smoothed coast in August and September, where as in the 2000s they were about 13 km in those months, however standard errors were overlapping (Figure 3.4). Also, there were no differences in the mean monthly elevation used by adult females on Baffin Island between the 1990s and 2010s (Figures 3.4 and 3.5).

Satellite telemetry analyses further documented differences in the inland distance of adult females on Baffin Island as a function of reproductive status. Females that were most likely available to breed and become pregnant in spring (e.g., those captured alone, with 2 year old cubs, or as mating pairs in spring) were significantly farther inland in fall than adult females captured with COYs or yearling cubs (Table 3.2). This was especially pronounced for adult females captured in mating pairs (on average 27-35 km inland).

In contrast to analyses based on distance to the smoothed coastline, the distance of captures to the true coastline (not smoothed) was consistent between sampling periods (Figure 3.3), averaging 1.8 km (SD = 2.8) in the 1990s and 1.5 km (SD = 2.5) in the 2010s. This suggests that the difference in capture locations between the two sampling periods was largely due to less effort spent searching and capturing bears in the inland portions of fjords in the 1990s compared to the 2010s. For adult females, mean distances to the true coastline were 6.4 km (SD: 8.0) and 10.2 km (SD: 12.6) during the 1990s and 2010s, respectively (Figures 3.2 and 3.3).

Summary – The distribution of polar bear captures on Baffin Island differed significantly between sampling in the 1990s and 2010s. Specifically, the capture data indicate an under-representation of bears in fjords and inland regions during the 1990s (see also Chapter 5). Satellite telemetry location data, which were collected from independent bears over several years and were not influenced by which areas were searched in any given year, did not suggest a shift in the onshore distribution of polar bears. Given that no changes in adult female use of land habitats was detected (also see Chapter 4 terrestrial resource selection), the differences in capture distribution can be attributed to differences in sampling. During the 1990s, capture effort was concentrated on islands, along the outer coastline, and near the mouths of fjords (Figures 3.2 and 3.4). During the 2010s, these areas were searched as well as the inland portions of fjords. This is particularly prominent in central and northern Baffin Island, where no captures were recorded beyond the mouths of fjords during the 1990s. In contrast to the southern parts of Baffin Island the central and northern parts have a higher and more mountainous terrain. Finally, satellite telemetry data also indicate that adult females in different reproductive status show a non-random pattern of moving farther inland, likely in search of locations to construct maternal dens. These findings suggest a non-random probability of being a temporary emigrant as a function of the multi-year reproductive state. Taken together, these findings suggest that restricted geographic sampling in the 1990s likely led to higher probabilities of temporary emigration from the sampling area during that time period, compared to the 2010s. Furthermore, the probability of being a temporary emigrant appears non-random. Variable and non-random temporary emigration is known to introduce bias into estimates of survival and abundance under some conditions (Peñaloza et al. 2014).

<u>Size of the Mark-Recapture Sampling Area on Baffin Island</u>

Following from the previous section, we calculated the sizes of the effective MR sampling areas on Baffin Island in the 1990s and 2010s.

Methods – We delineated the sampling areas based on the spatial distribution of capture locations. We first used ArcGIS to create 99% kernel density contour around all capture locations in each time period. We then adjusted this contour on a point-by-point basis to ensure that the final estimated sampling area was within 1 km of the outermost capture locations. The sampling area did not extend offshore, except in a few cases in the 1990s where there were offshore points, in which case the boundary was kept within 1 km of those points. When capture locations occurred inside a fjord, it was assumed that sampling effort occurred everywhere from the mouth of that fjord to the capture location.

Results – The size of the MR sampling areas differed significantly between the 1990s and 2010s. The estimated sampling area was ~28,700 km^2 in the 1990s and ~60,200 km^2 in the 2010s. The 2010s sampling area included most fjords along the Baffin Island coast and reached farther inland than the 1990s (Figures 3.6 and 3.7). Furthermore, the 1990s sampled area was almost entirely contained within the 2010s sampling area (Figure 3.8). This made it possible to subsample the 2010s capture data, using the restricted 1990s sampling area, for the purpose of evaluating the influence of the size of sampling area on estimates of abundance from the two time periods (see Chapter 5).

<u>Temporary Emigration Related to the Availability of Sea ice</u>

Previous sections in this chapter documented a smaller onshore sampling area in the 1990s, which likely resulted in higher and potentially non-random temporary emigration from the sampling area in the 1990s. Here we evaluate temporary emigration related to the availability of sea ice, which declined between the two study periods in all months of the year, including the summer when sampling on Baffin Island occurred. We used satellite telemetry data to assess the fraction of adult females that were located in the sampling area vs. out of the sampling area (including on the sea ice) in the 1990s compared to the 2010s.

Methods – For each year of sampling in the 1990s and 2010s, we used the specific date range when sampling occurred (Table 3.3) to calculate the proportion of independent collared bears located inside the sampling area, as well as the proportion of locations from each individual bear that were inside the sampling area. First, we identified independent adult females that were wearing functional radio-collars during the sampling period. To ensure that location data were independent, we did not include locations from the same sampling period on which an adult female was captured and fitted with a radio-collar. For example, if a bear was captured and collared on October 1, 1993, locations from that individual through October 8, 1993 were not used (Table 3.3). However, locations from that individual in 1994 and 1995 were considered independent and included in analyses. If a bear was captured in spring of a given year, her location data were considered independent by fall of that year. We considered a bear to be located inside the sampling area if that bear had 1 (or more) telemetry location inside the sampling area.

We evaluated average sea-ice conditions in Baffin Bay during each sampling period for the 1990s and 2010s to determine whether bears that were located outside of the sampling area, were located on sea ice. For each sampling period, we mapped mean sea-ice concentration during the week that encompassed the mid-point of the sampling period, using the Passive Microwave data (SMMR/SSMI) sea-ice concentration dataset from the National Snow and Ice Data Center (see Chapter 4). We then superimposed independent bear locations on the sea-ice concentration map, and visually examined whether bears located outside of the sampled area were in an area with a substantial concentration of sea ice and therefore likely using the sea ice.

Results – Table 3.3 shows the date range of MR sampling in each year. There were a maximum of 13 independent adult female bears transmitting with satellite collars during the 1990s sampling periods. The number of individuals declined over the course of the 1990s study because most collars were deployed at the beginning of the study and some collars failed (Table 3.4). The largest number of transmitting independent bears occurred in 1993, and by 1997 there were none. There were also a maximum of 13 transmitting independent bears during a given sampling period in the 2010s, although sample sizes remained higher through the 2010s due to longer collar attachment periods (Table 3.4). We found large differences in the proportion of transmitting independent bears using the sampling areas between 1990s and 2010s. In the 1990s, 0-20% of females occurred within the sampling area during the MR sampling period (Table 3.4, Figure 3.9 - 3.11). In the 2010s, 67-80% of females occurred within the sampling area during the MR sampling period (Table 3.4, Figure 3.12 - 3.14).

Sea-ice availability in Baffin Bay declined between the 1990s and 2010s. In the 1990s, a substantial amount of sea ice was available in offshore central Baffin Bay; within the Canadian archipelago, including around Devon Island; and in Lancaster Sound and Kane Basin (Figures 3.15-3.21). In 1993, when the largest proportion of independent bears was offshore during the sample period (Figure 3.15), there was a persistent area of sea ice available in central Baffin Bay. In other years in the 1990s, some bears were located on the advancing sea ice forming in northern Baffin Bay (Figures 3.15-3.17). In contrast, in the 2010s all bears (excluding resident bears in Melville Bay) were distributed on land on Baffin Island or in Kane Basin (Figures 3.18-3.20) during the sampling periods. There were no bears on offshore ice in the 2010s, because sea ice had melted completely in central Baffin Bay by July (see Chapter 4). The differences in sea-ice conditions between the 1990s and 2010s can been seen clearly using juxtaposed sea-ice concentration maps (Figure 3.21).

In addition to relatively fewer adult females being present in the sampling area during the 1990s, most bears with >1 location in the sampling area did not spend the entire sampling period there, but rather were passing through (Table 3.5). In the 1990s, approximately 44% of locations received for bears that used the sampling area, were located inside the sampled area (see Chapter 1 for information on location filtering and subsampling). In the 2010s, approximately 94% of locations received for bears that used the sampling area, were located inside the sampled area. Although sample sizes were small and unevenly distributed across years, the higher probability of bears in the 1990s being located outside the sampling area appeared largely due to the presence of sea ice, whereas in the 2010s sea ice was absent and bears exhibited reduced summertime movement rates (see Chapter 4).

Summary – Temporary emigration from the sampling area during the autumn sampling period has the potential to introduce bias into estimates of demographic parameters from this study. Our analyses suggest that the proportion of adult females (and presumably other sex and age classes) in the sampling area was likely lower in the 1990s compared to the 2010s, for two reasons. First, some bears located inland in the 1990s were not available to capture teams because there was apparently limited inland search effort, and in particularly bears were not captured in the deep inland portions of fjords. Furthermore, the location of bears from the coast—and therefore the susceptibility of bears to capture—appeared related to reproductive status, in which case the probability of being a temporary emigrant may have been nonrandom. Second, a proportion of radio-collared polar bears used offshore ice in the 1990s, whereas sea ice was less available in the 2010s and therefore a substantially higher proportion of bears were likely inside the sampling area. Because of small sample sizes that varied across years, we were unable to calculate precise estimates of temporary emigration rates or to evaluate the magnitude and direction nonrandom patterns (e.g., Markovian dependence) in a statistically rigorous manner. Nonetheless, multiple lines of evidence indicate higher temporary emigration in the 1990s, compared to the 2010s. The most likely effect of temporary emigration is an unknown but potentially meaningful negative bias in estimates of survival and abundance (Schaub et al. 2004, Devineau et al. 2006, Peñaloza et al. 2014).

Additional sampling considerations

Small sample sizes lead to multiple challenges into MR studies, including high variance in estimated parameters, small-sample bias, susceptibility to bias due to violation of modeling assumptions (e.g., un-modeled heterogeneity in recapture probability), and limited options for quantifying or mitigating bias (Williams et al. 2002). Compared to the 2010s data, sample sizes in the 1990s were small and had a low proportion of recaptures (Table 3.1). For example, the entire dataset for adult females (F2+ age group) included only 5 animals recaptured by standard search in 1995, and 14 animals recaptured by standard search in 1997 (note that numbers in Table 3.1 are higher, because they include “likely” recaptures and re-sightings of bears located by radio telemetry; see below). Furthermore, there were relatively few dead recoveries during the interim period when no sampling occurred (1998-2010), particularly in the later years. For example, an average of 1.3 research-marked females per year were recovered in the harvest, from 1998-2010. Conceptually, it is apparent that the small number of live recaptures during 1990s live-encounter sampling, the gap years between 1990s and 2010s sampling, and the small number of dead recoveries during the gap years contain a limited amount of information and will lead to estimates of demographic parameters that have substantial uncertainty and low resolution (i.e., that few demographic parameters can be estimated, requiring the estimation of “average” parameters over years or groups of animals).

There were significant differences in the composition of the MR samples (i.e., the proportion of bears within each age-sex class, based on initial captures) between the 1990s and 2010s in Baffin Bay (Table 3.1). There were more adult and sub-adult male captures in the 1990s, whereas there were more sub-adult and adult female captures in the 2010s. The proportion of total female captures in the1990s was less than the 2010s (mean annual proportion of age 2+ female captures : total 2+ captures, 1990s: 0.42; 2010s: 0.53; Table 3.1). Given the spatial segregation of bears by sex and age-classes and reproductive states (see section Distribution of Mark-recapture Sampling on Baffin Island), the apparent under-representation of females in the 1990s samples likely reflects at least in part the coastal-focused sampling protocols during that period, rather than true differences in the composition of the subpopulation (although we cannot rule out progressive depletion of males through the 2010s due to high harvest).

Development of an Individual Covariate to Explain Inland Habitat Use

Given the apparent differences in sampling effort between the 1990s and 2010s, the spatial segregation of bears by sex and age class, and differences in the composition of capture samples, we hypothesized that proximity to the coastline may explain variation in recapture probabilities. We also wanted to explore whether proximity to the coastline for an individual bear was nonrandom across years (e.g., whether bears captured inland were more likely to be recaptured inland). We assigned capture locations to either coastal or inland categories, using a threshold of 2 km from true and smoothed coastlines, and compiled contingency tables for individuals captured in multiple sampling periods. For individuals captured three or more times, we used only an individual's first two capture events and included only those bears initially captured as independent animals, since the locations of cubs-of-the-year and yearlings were dependent on the location of their mothers.

Use of inland areas appeared nonrandom. Individual polar bears initially captured inland from the true coastline were more likely to be recaptured inland in subsequent years (all data: $\chi^2 = 10.4$, $P = 0.0012$; 1990s only: Fisher's exact test $P = 0.10$; 2010s only: Fisher's exact test $P = 0.02$). Similarly, bears initially captured inland of the smoothed coastline were more likely to be recaptured inland (all data $\chi^2 = 18.1$, $P < 0.0001$), a pattern which was driven largely by the 2010s (Fisher's exact test $P < 0.0001$; 2010s only: Fisher's exact test $P = 0.21$; 1990s only). As such, we incorporated a proximity to coastline covariate for modeling recapture probability in demographic analyses (see Chapter 5).

<u>Challenges with Using the 1990s Radio Telemetry Data</u>

Some aspects of the 1990s radio-telemetry data were uncertain or unavailable, presenting challenges to the use of these data in the current analysis. As part of a study examining subpopulation delineation and spatial ecology (Ferguson et al. 1997, Taylor et al. 2001), a sample of adult female polar bears was fitted with satellite radio-collars in Baffin Bay (from both Canada and Greenland) during the 1990s. Some of these bears ($n = 14$) were captured on Baffin and Bylot Islands during autumn 1993 – 1997. Taylor et al. (2005) report that collared bears and their dependent young were often relocated using VHF during the 1990s study period. The probability of locating and recapturing a bear with a collar is likely higher than the probability of recapturing a bear without a collar. Therefore, a radio telemetry covariate, describing whether a bear was wearing a functional radio-collar that could have allowed it to be located by telemetry, was important for explaining variation in recapture probabilities; and all of the most-supported models in the 1990s included a radio telemetry covariate (Taylor et al. 2005). Taylor et al. (2005:209) reported that “The probability of autumn recapture was lower for females and yearling cubs than for adult males and sub-adults, except for radio-collared females and their young” which indicates that radio-collared females were recaptured using radio-location data. Unfortunately, the data archives did not include complete information on which bears were wearing functional radio-collars and located using VHF. Furthermore, in some cases where records could be located, there were inconsistencies among databases and historical hard-copy files. This presented a challenge to MR modeling because the live-capture data in the 1990s were sparse, particularly for adult females, and we anticipated that the additional records for bears likely recaptured using VHF would be important for explaining patterns in survival and recapture probability (see Taylor et al. 2005). To address this issue, we manually reviewed capture histories and covariates compiled for the previous Baffin Bay analysis. We compared these historical files with our available records to identify events in which a bear was likely located via VHF (see also Chapter 5). Based on this, we added 7 recapture events of 5 age 2+ individuals previously in the dataset, and 6 capture events of 5 age 2+ individuals not previously included in the dataset. We believe that this protocol accurately incorporated most of the data for polar bears captured by VHF in the 1990s, although some uncertainty remains given that the original data were not available.

Ramifications of Issues with the 1990s Baffin Bay Data

It is difficult to estimate demographic parameters and detect trends in parameters, for long-lived animals using short time-series of live-encounter data, especially when recapture rates are low, environmental variation is high, and the entire study subpopulation is not exposed to sampling effort on each occasion (Williams et al. 2002). The analyses described above identify specific challenges with 1990s Baffin Bay MR data that arise from both sampling issues and environmental factors. These challenges may lead to bias in estimates of survival and abundance, and ambiguity in the definitions of parameters being estimated (e.g., whether a model is estimating apparent survival, which reflects emigration from the study subpopulation, or true survival).

Survival – A statistical assessment of trends in polar bear survival between the 1990s and 2010s is not possible due to the short duration of live-encounter sampling periods, the large gap between 1990s and 2010s live-encounter sampling, low recapture probabilities, low numbers of dead recoveries, changes in the sampling area between the 1990s and 2010s, and evidence for changes in polar bear movements with respect to the sampling area. This conclusion was supported by computer simulations (T. Arnold, University of Minnesota, unpubl data) in Program MARK to generate datasets that resembled the actual Baffin Bay data but included a known effect (e.g., large reduction in survival), and evaluating the power of MR model to detect such effects (T. Arnold, University of Minnesota, unpublished data). In the context of small and variable sample sizes, a primary challenge for estimating survival is the difficulty of delineating temporary vs. permanent emigration from the study area, and the effects of emigration on estimates of survival. MR modeling was performed using Burnham models, which assume that emigration from the study subpopulation is permanent. Burnham models directly estimate the probability of permanent emigration (*F*) based on patterns in live-encounter data in conjunction with harvest data collected from an area that is larger than the MR sampling area. Under the Burnham model, the survival parameter (S) is technically defined as true survival (i.e., does not include an emigration component). However, research-marked bears that are harvested outside the sampling area may be temporary rather than permanent emigrants (i.e., the bears could have returned to the sampling area in future years, if they had not been killed), and the short duration of the study, small sample sizes, and likely high interannual variability in the probability of being a temporary emigrant (e.g., as related to sea-ice availability) make it difficult to delineate temporary vs. permanent emigration. Simulations suggested that the Baffin Bay data were too sparse to fit Barker models, which relax the assumption that emigration is permanent, and are capable of estimating temporary emigration rates, including non-random temporary emigration. The consequence of using Burnham models either with *F* estimated or with *F* fixed = 1 (i.e., assuming no permanent emigration if *F* is estimated), is that variation across individuals and sampling occasions in the probability of being a temporary emigrant is not explicitly accounted for, and therefore exists as variation in recapture probabilities. Heterogeneity in recapture probabilities has the potential to introduce bias into estimates of S (Schaub et al. 2004). The directionality of bias is often negative and its magnitude tends to increase in the final years of a study (Devineau et al. 2006). Furthermore, non-random patterns in temporary emigration are known to cause bias in estimates of survival (Kendall et al. 1997), and the availability of adult females for capture in the 1990s was related to their multi-year reproductive cycle. Interpretation of trends in survival between the 1990s and 2010s is further complicated because radio-telemetry data suggest changes in fidelity to the MR sampling study area between the epochs, and because the geographic extent of the MR study area itself changed. We conclude that estimates of survival from the current MR analysis of Baffin Bay data must be interpreted with caution. Although estimates of survival provide the basis for discussion and ecological interpretation, they are unlikely to be directly comparable between the 1990s and 2010s, and will require further analysis (e.g., regarding different assumptions about movements between epochs) if used in matrix-type models for subpopulation projections.

Abundance – Estimating abundance is one of the more difficult challenges in wildlife management (Williams et al. 2002). Deriving accurate estimates of abundance and evaluating trends in abundance over time require an appropriate study design and, especially, consistent distribution of sampling effort in time and space. In the current study, the difference between the distributions of captures in the 1990s and 2010s suggest that the sampling area on Baffin Island expanded substantially from the 1990s to the 2010s. Specifically, sampling was spatially restricted to a portion of the subpopulation's fall range during the 1990s, thus excluding bears with seasonal fidelity to inland areas. Furthermore, an unknown but potentially significant portion of the Baffin Bay subpopulation may not have been exposed to sampling in the 1990s due to the higher presence of sea ice, which some bears used throughout the year rather than coming onto land. We conclude that the abundance estimate in the 2010s, based on MR data from the entire sampling area, is not directly comparable to the previous 1990s abundance estimate. To investigate the extent to which differences in sampling affected abundance estimates from the 1990s and 2010s, we used the 1990s sampling area to create a subset of the 2010s data, and subsequently derived a 2010s abundance estimate based on this restricted subset of the data. We included only those 2011 – 2013 capture events that were located within the estimated 1990s sampling frame and completed supplemental demographic analyses (see Chapter 5). This analysis helped evaluate the potential biases associated with the more restricted area of onshore sampling on Baffin Island in the 1990s. However, it did not address the potential effects of polar bears using the sea ice in the 1990s. When there is temporary emigration from the sampling area, estimates of abundance from Burnham models represent the "superpopulation" (defined as all animals with a probability of moving through the sampling area, even if not every animal was actually in the sampling area on every sampling occasion). If temporary emigration from the sampling area is completely random, it will not introduce bias into estimates of abundance. However, nonrandom temporary emigration (e.g., if some individuals are often or always temporary emigrants) has a similar effect on estimates of demographic parameters from MR models as un-modeled heterogeneity in recapture probability, and generally introduces negative bias into estimates of abundance (Kendall et al. 1997).

MR model covariates – 1990s sampling bias may also impact the individual, geographic fidelity covariate (proximity to smoothed coastline). Analyses did not suggest a significant relationship between initial and subsequent capture locations in the 1990s, but this may be due to sampling (e.g., not enough effort was expended inland, to identify animals with fidelity to inland areas). The relationship is driven by the 2010s data. Also, the radio telemetry covariate may be biased in some unknown direction due to the uncertainty as to whether the subsequent capture of a collared bear was facilitated by the radio tracking. Sensitivity analyses outlined above may help better understand potential biases. Given the differences between the 1990s and 2010s, including epoch effects for the binary 'proximity to smoothed coastline' is important.

3.2. Literature Cited

Born, E.W. and R. Dietz. 2009. Polar bear *Ursus maritimus*. Pages 81-88 *in* D. Boertmann, A. Mosbech, D. Schiedek, and K. Johansen, editors. The Eastern Baffin Bay. A preliminary strategic environmental impact assessment of hydrocarbon activities in the KANUMAS

West area. NERI Technical Report No. 720, National Environmental Research Institute, Aarhus University, Denmark. http://www.dmu.dk/Pub/FR720.pdf.

Born, E. W., A. Rosing-Asvid, and D. Andriashek. 1992. Tagging of polar bears in NW Greenland, 2-19 May 1992. Report on field work. Unpublished report, Greenland Fisheries Research Institute, Copenhagen, Denmark, 6 pp. Available at Greenland Institute of Natural Resources, P.O. Box 570, 3900 Nuuk, Greenland.

Born, E. W., A. Heilmann, L. K. Holm, and K. L. Laidre. 2011. Polar bears in Northwest Greenland: an interview survey about the catch and the climate. Monographs on Greenland, Man and Society Volume 41. Museum Tusculanum Press, University of Copenhagen, Copenhagen, Denmark.

Devineau, O., R. Choquet, and J-D. Lebreton. 2006. Planning capture-recapture studies: straightforward precision, bias, and power calculations. Wildlife Society Bulletin 34:1028–1035.

Ferguson, S. H., M. K. Taylor, E. W. Born, A. Rosing-Asvid, and F. Messier. 1999. Determinants of home range size in polar bears. Ecology Letters 2:311–318.

Ferguson, S. H., M. K. Taylor, E. W. Born, A. Rosing-Asvid, and F. Messier. 2001. Activity and movement patterns of polar bears inhabiting consolidated versus active pack ice. Arctic 54:49–54.

Ferguson, S. H., M. K. Taylor, and F. Messier. 1997. Space use by polar bears in and around Auyuittuq National Park, Northwest Territories, during the ice-free period. Canadian Journal of Zoology 75:1585–1594.

Kendall, W. L., J. D. Nichols, and J. E. Hines. 1997. Estimating temporary emigration using capture-recapture data with Pollock’s robust design. Ecology 78:563–578.

Lukacs, P. M., and K. P. Burnham. 2005. Review of capture–recapture methods applicable to noninvasive genetic sampling. Molecular Ecology 14:3909–3919.

Peñaloza, C. L., W. L. Kendall, and C. A. Langtimm. 2014. Reducing bias in survival under nonrandom temporary emigration. Ecological Applications 24:1155-1166.

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs 107:3–97.

Regehr, E. V., C. M. Hunter, H. Caswell, S. C. Amstrup, and I. Stirling. 2010. Survival and breeding of polar bears in the southern Beaufort Sea in relation to sea ice. Journal of Animal Ecology 79:117–127.

Rosing-Asvid, A. 1993. Tagging of polar bears in NW Greenland, May 1993. Report on field work. Unpublished report, Greenland Fisheries Research Institute, Copenhagen, Denmark, 8 pp. Available at Greenland Institute of Natural Resources, P.O. Box 570, 3900 Nuuk, Greenland.

Royle, J. A., R. B. Chandler, R. Sollmann, and B. Gardner. 2014. Spatial Capture-Recapture. First edition. Academic Press, Waltham, Massachusetts, USA.

Schaub, M., O. Gimenez, B. R. Schmidt, and R. Pradel. 2004. Estimating survival and temporary emigration in the multistate capture–recapture framework. Ecology 85:2107–2113.

Taylor, M. K., S. Akeeagok, D. Andriashek, W. Barbour, E. W. Born, W. Calvert, H. D. Cluff, S. Ferguson, J. Laake, A. Rosing-Asvid, I. Stirling, and F. Messier. 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., J. Laake, P. D. McLoughlin, E. W. Born, H. D. Cluff, S. H. Ferguson, A. Rosing-Asvid, R. Schweinsburg, and F. Messier. 2005. Demography and viability of a hunted population of polar bears. Arctic 58:203–214.

Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. Analysis and Management of Animal Populations. Academic Press, San Diego, California, USA.

Table 3.1. Summary table of live captures and dead recoveries during the mark-recapture study of the Baffin Bay polar bear subpopulation in Nunavut, Canada, and Greenland, 1993 – 2010. Shaded cells indicate that data were not possible due to an absence of marking or recapture.

	Initial captures						**Live recaptures**				**Dead recoveries**					
	Females			*Males*			*Females*		*Males*		*Females*			*Males*		
	Coy	**Yrl**	**2+**	**Coy**	**Yrl**	**2+**	**Yrl**	**2+**	**Yrl**	**2+**	**Coy**	**Yrl**	**2+**	**Coy**	**Yrl**	**2+**
1993	14	8	53	12	8	61					0	0	1	0	0	0
1994	26	13	65	16	9	77	0	5	0	14	0	0	3	0	0	7
1995	15	11	62	19	11	85	4	11	4	23	0	2	6	1	0	8
1996												1	8		0	7
1997	22	10	60	19	13	113		20		31	0	0	6	0	1	9
1998												0	3		0	11
1999													3			9
2000													0			8
2001													2			8
2002													0			11
2003													0			7
2004													1			7
2005													2			3
2006													3			6
2007													1			2
2008													2			4

2009													2			0
2010													0			1
2011	2	23	163	1	20	148		5		5	0	0	4	0	0	20
2012	40	30	221	35	30	192	3	41	0	54	0	0	8	0	2	14
2013	28	15	121	16	15	90	4	48	5	55	0	1	8	1	0	20
Totals	**147**	**110**	**745**	**118**	**106**	**766**	**11**	**130**	**9**	**182**	**0**	**4**	**63**	**2**	**3**	**162**

Table 3.2. Metrics for adult females satellite collared in the 1990s (fall) and 2010s (spring) for the distance inland from the outer Baffin Island coast. Distance is reported in km.

		August			**September**			**October**		
Adult Female Accompanied by	**N**	**Mean distance inland**	**SD**	**Count of locations**	**Mean distance inland**	**SD**	**Count of locations**	**Mean distance inland**	**SD**	**Count of locations**
1990s										
2YR	1							5.6	4.4	3
AM	0									
COY	15	10.8	14.2	10	19.7	15.1	13	9.6	5.9	46
YRL	12	6.0	5.6	3	18.0	17.8	25	8.4	5.8	41
ALONE	5				8.8	9.4	6	13.4	11.8	8
2010s										
2YR	5	13.5	9.3	25	27.0	8.3	20	16.2	13.5	11
AM -in spring	2	27.1	10.2	9	32.6	12.0	5	35.1	9.3	4
COY	2	5.5	4.8	3	7.5	4.3	13	3.6	4.3	11
YRL	7	3.5	5.0	20	6.8	6.2	33	6.2	7.3	27
ALONE	6	11.9	10.8	25	16.3	7.6	22	14.4	7.8	18

Table 3.3. Time periods when the BB fall sampling period occurred in each decade. These dates were used to asses if independent bears were in or out of the sampled area.

Year of sampling	Start	End
1993	23 August	8 October
1994	7 September	19 October
1995	17 September	19 October
1996	n/a	n/a
1997	21 September	29 October
2011	4 September	14 October
2012	26 August	29 September
2013	20 August	11 October

Table 3.4. The overall fraction of independent collared adult female (AF) bears found in the sampling range by year.

Year of sampling	n independent collared bears	n independent AF bears in the sampled area (minimum of n=1 location during date range)	% independent AF bears in the sampled area for each decade
1993	13	3	23
1994	5	1	20
1995	1	0	0
1997	0		
2011	12	8	67
2012	13	11	85
2013	6	4	67

Table 3.5. Independent BB adult female bears with satellite collars transmitting during the MR sample periods. Bears listed are only those that used the sampled area on Baffin Island for each decade. The fraction of locations inside the sampled area is shown for each bear.

YEAR + capture season	ID (PTT + Year)	Start Date	End Date	n independent bears during this year	n independent bears in the sampled area	Fraction of total locations inside sampled area during the sampling dates	Proportion of locations
1993		**23-Aug**	**8-Oct**	**13**	**3**		
fall	199111062	27-Aug	16-Sep			1/4	0.25
spring	19922718	24-Aug	7-Oct			1/8	0.13
fall	19922700	25-Aug	25-Aug			1/1	1.00
1994		**7-Sep**	**19-Oct**	**5**	**1**		
spring	19922701	8-Sep	6-Oct			2/6	0.33
2011		**4-Sep**	**14-Oct**	**12**	**8**		
spring	201068010	6-Sep	8-Oct			8/9	0.89
spring	2011105814	24-Sep	10-Oct			4/4	1.00
spring	201074768	6-Sep	12-Oct			8/8	1.00
spring	2011105809	6-Oct	6-Oct			1/1	1.00
spring	200974767	6-Sep	12-Oct			10/10	1.00
spring	2011105817	4-Sep	14-Oct			10/10	1.00
spring	2011105816	4-Sep	14-Oct			5/5	1.00

spring	200968005	6-Sep	12-Oct			10/10	1.00
2012		**26-Aug**	**29-Sep**	**13**	**11**		
spring	201074774	29-Aug	26-Sep			6/7	0.86
spring	2012105829	29-Aug	26-Sep			5/7	0.71
spring	201068010	12-Sep	24-Sep			2/3	0.67
spring	2011105814	29-Aug	26-Sep			5/7	0.71
spring	201074768	27-Aug	28-Sep			7/8	0.88
spring	2011105808	29-Aug	26-Sep			7/8	0.88
spring	2011105809	6-Sep	6-Sep			1/1	1.00
spring	200974767	27-Aug	28-Sep			1/9	1.90
spring	200974771	29-Aug	26-Sep			8/8	1.00
spring	2011105813	29-Aug	22-Sep			2/6	0.33
spring	200968005	27-Aug	27-Aug			1/1	1.00
2013		**20-Aug**	**11-Oct**	**6**	**4**		
spring	2013105818	20-Aug	11-Oct			12/12	1.00
spring	2013128265	20-Aug	11-Oct			14/14	1.00

Figure 3.1. Locations of polar bears sampled in Baffin Bay during the 1990s (August – October, 1993 – 1995, 1997, red) and 2010s (August – October, 2011 – 2013, blue). Sampling in Greenland in the 2010s occurred near Melville Bay but is not shown. Note the absence of captures in fjords on Baffin Island during the 1990s in the inset.

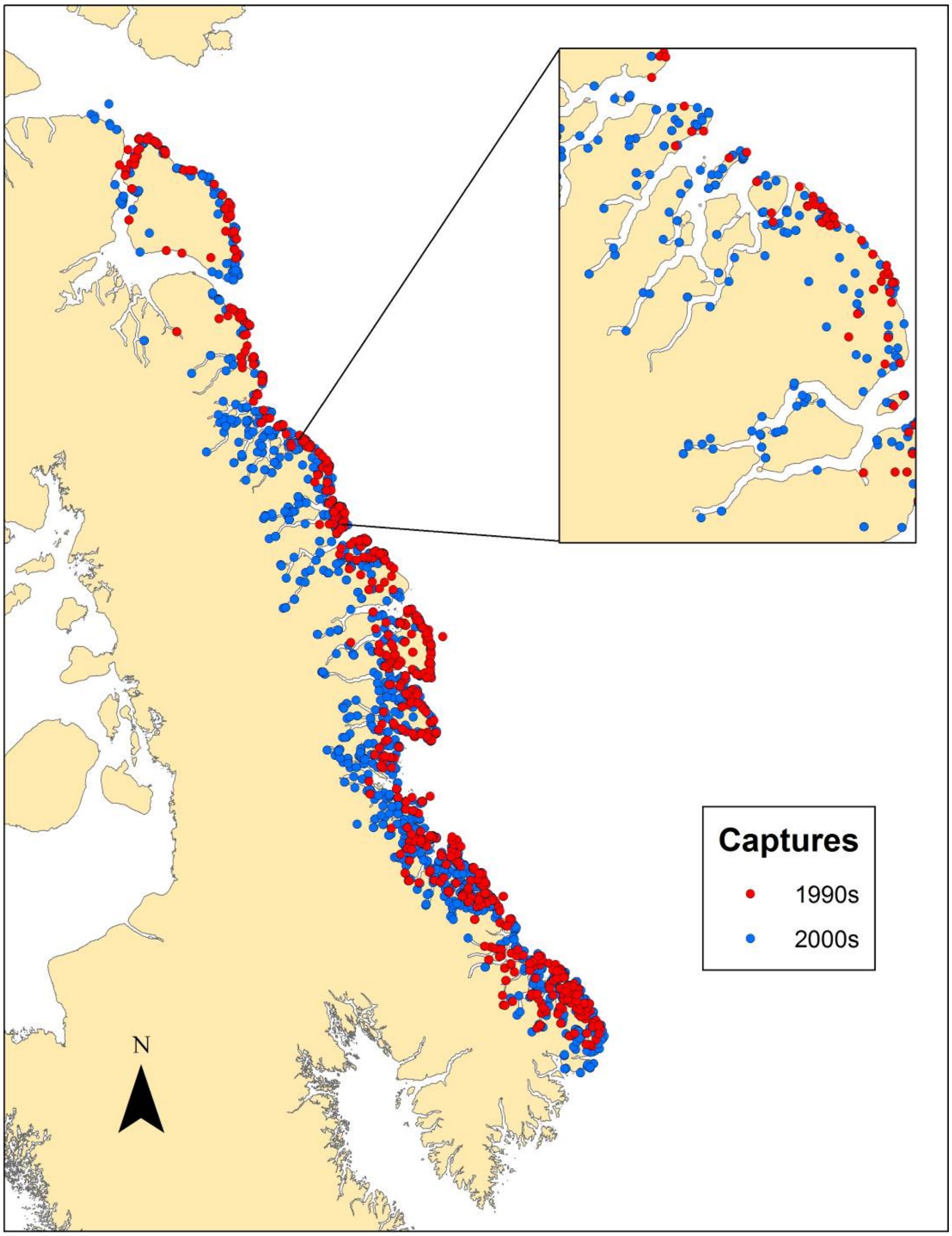

Figure 3.2. Distances independent bears were captured from the smoothed coastlines of Baffin and Bylot Islands during fall-time sampling in the Baffin Bay subpopulation, 1993 – 1997 and 2011 – 2013.

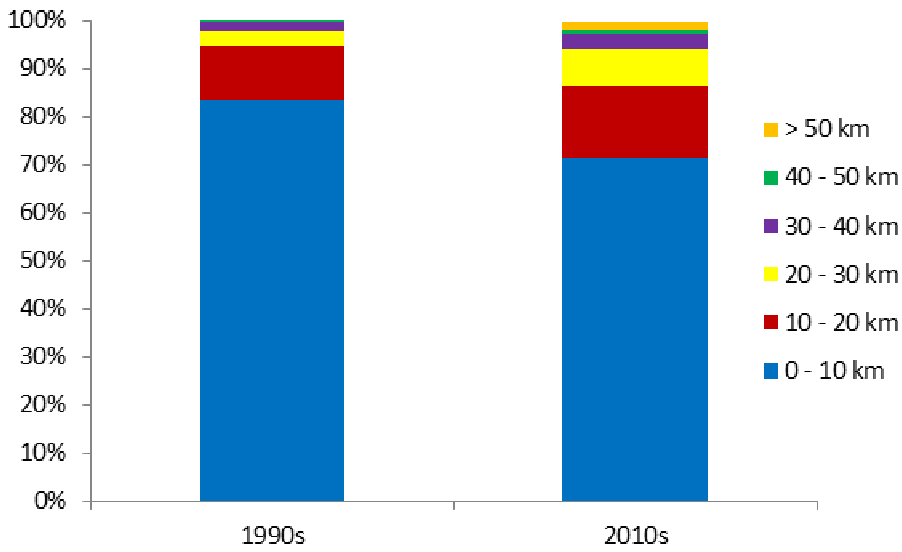

Figure 3.3. Distances independent bears were captured from the true coastlines of Baffin and Bylot Islands during fall-time sampling in the Baffin Bay subpopulation, 1993 – 1997 and 2011 – 2013.

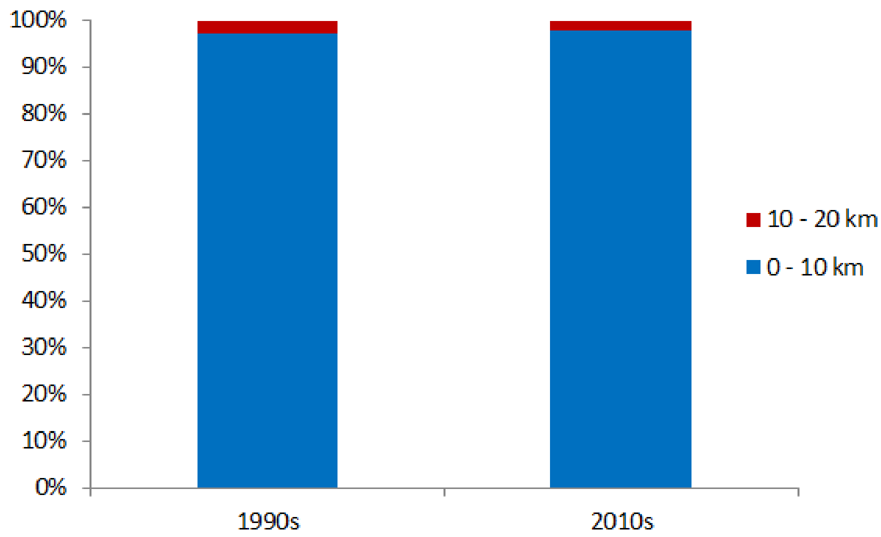

Figure 3.4. Distance to smoothed Baffin Island coastline shown in all summer months using satellite telemetry data from adult females in the 1990s (red) and 2010s (blue) located on Baffin Island. Shaded regions represent 2 SE from the mean. Numbers above represent numbers of telemetry locations for each month. There was no difference in distance inland (or distance to the outer Baffin Island coast) between decades.

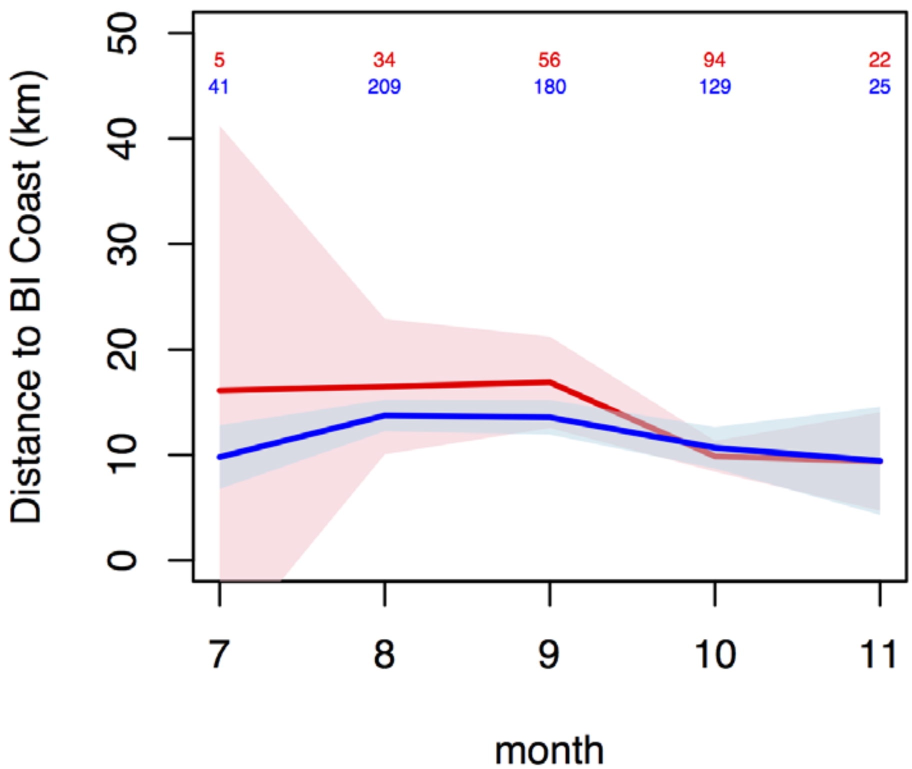

Figure 3.5. Elevation of adult female polar bears on Baffin Island shown in all summer months using satellite telemetry data from the 1990s (red) and 2010s (blue). Shaded regions represent 2 SE from the mean. Numbers above represent numbers of telemetry locations for each month. There was no difference in elevations used by polar bears across months between decades.

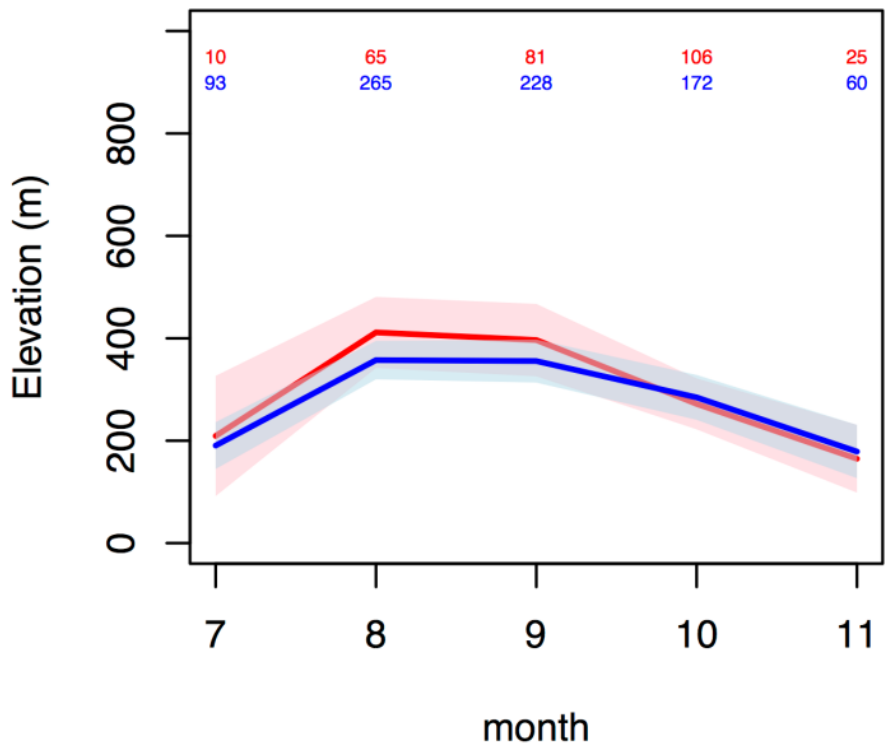

Figure 3.6. The delineation of the sampled area shown with a red outline for the 1990s with capture locations collected during the MR sampling.

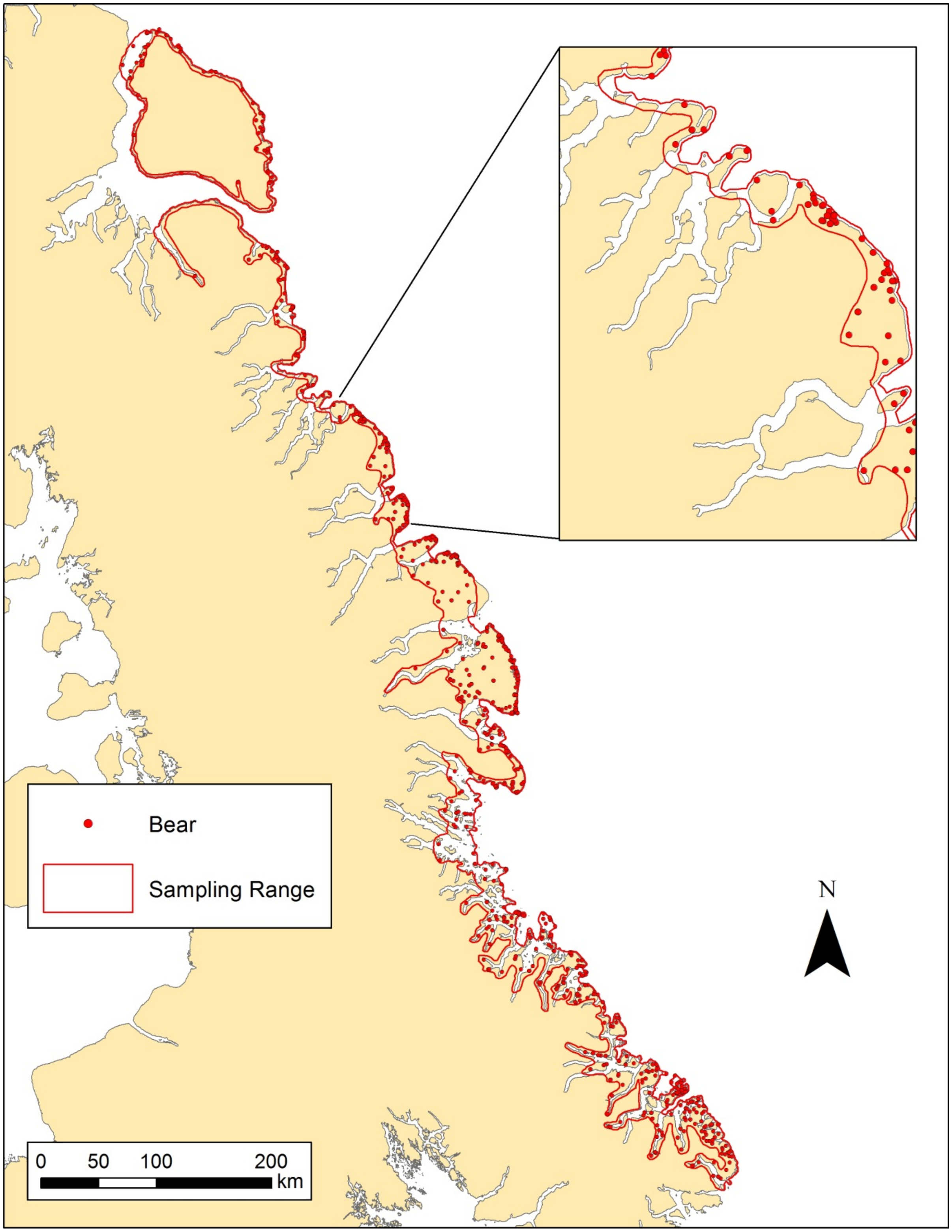

Figure 3.7. The delineation of the sampled area shown with a red outline for the 2010s with biopsy locations collected during the MR sampling (2011-2013).

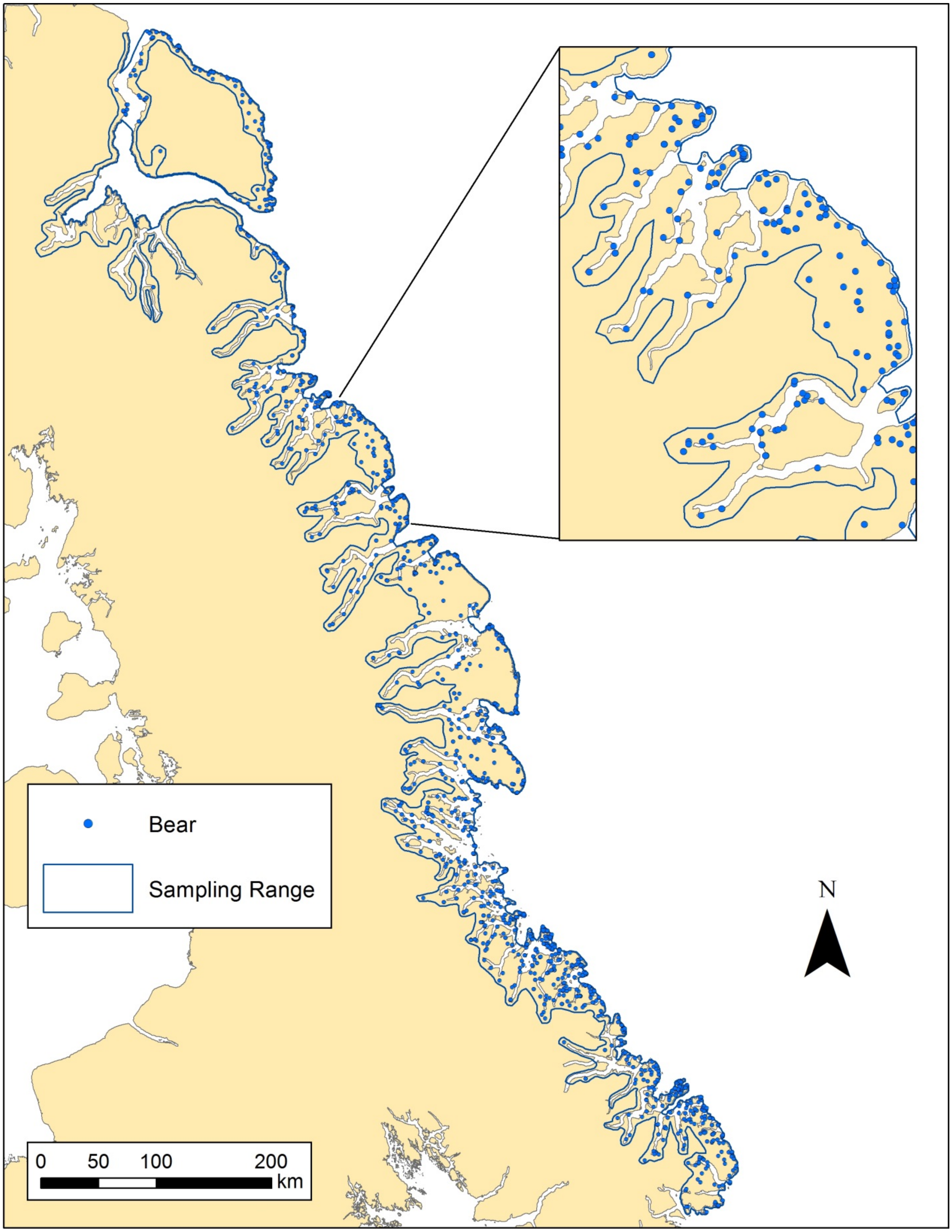

Figure 3.8. Geographic sampling ranges for the MR in the 1990s and 2010s.

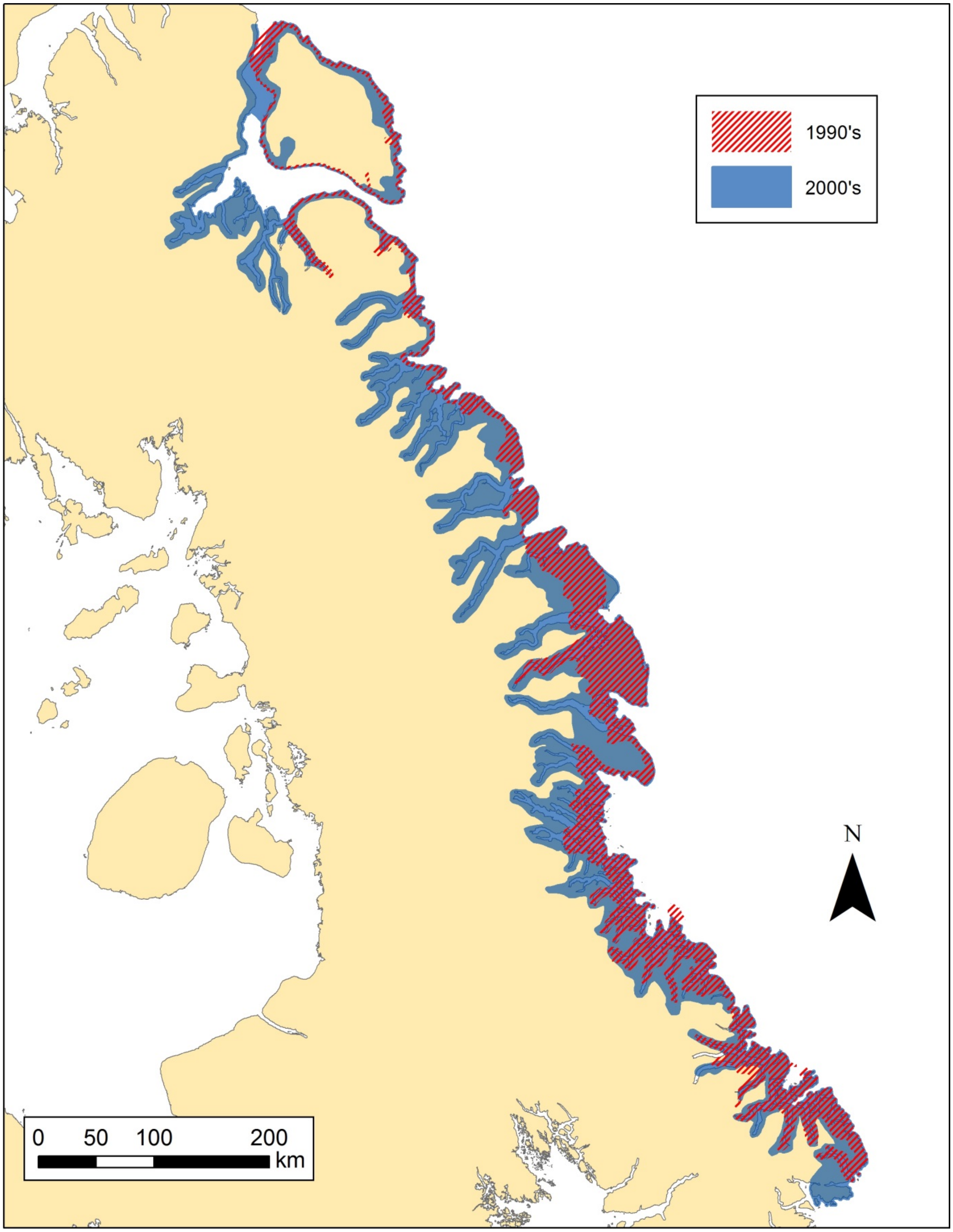

Figure 3.9. All telemetry locations from independent adult female bears with satellite collars transmitting during the 1993 sampling period dates (See Table 3.3). The 1990s sampled area for the MR study is shown in the red outline. Bears in central BB are on sea ice (Figure 3.15).

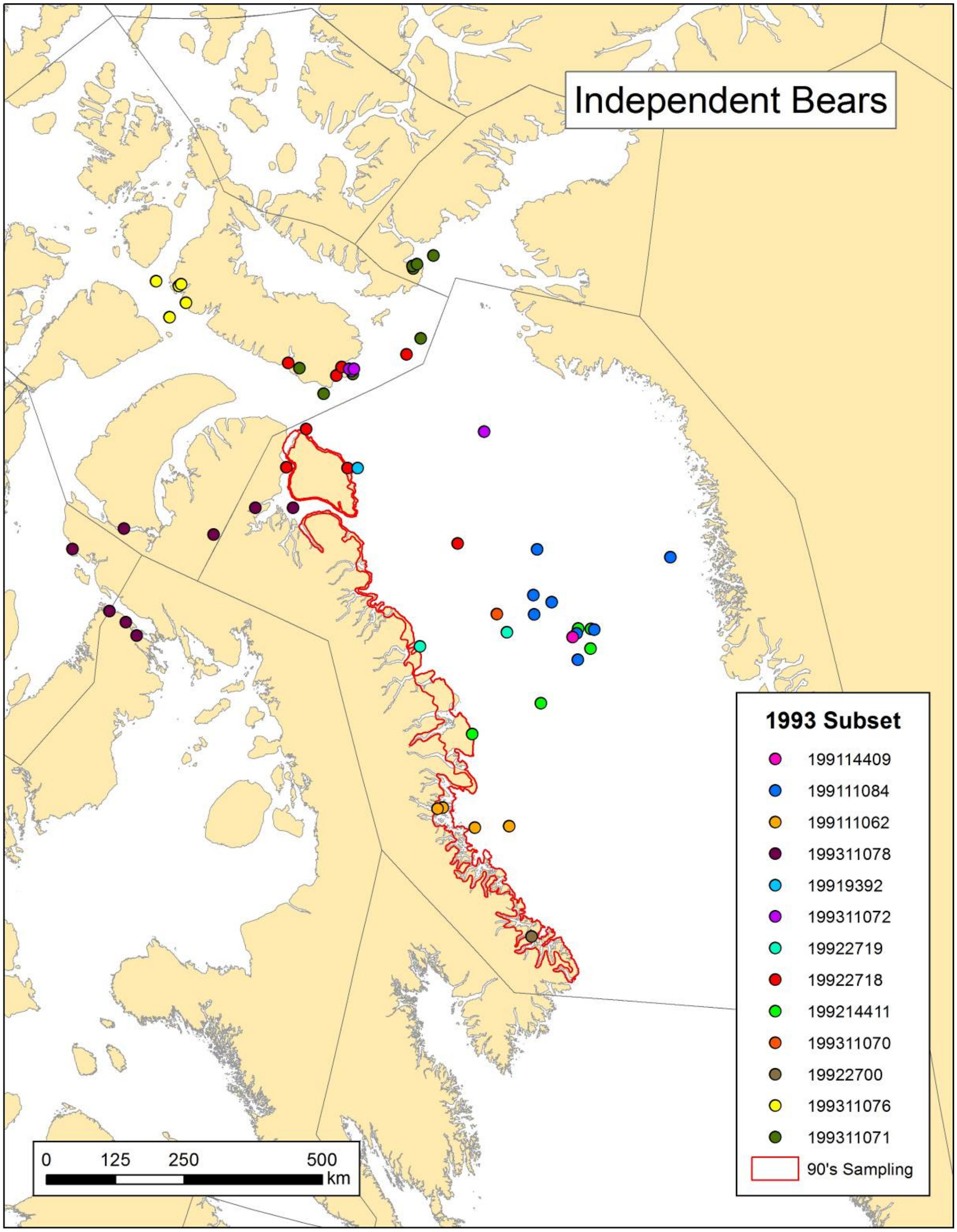

Figure 3.10. All telemetry locations from independent adult female bears with satellite collars transmitting during the 1994 sampling period dates (See Table 3.3). The 1990s sampled area for the MR study is shown in the red outline.

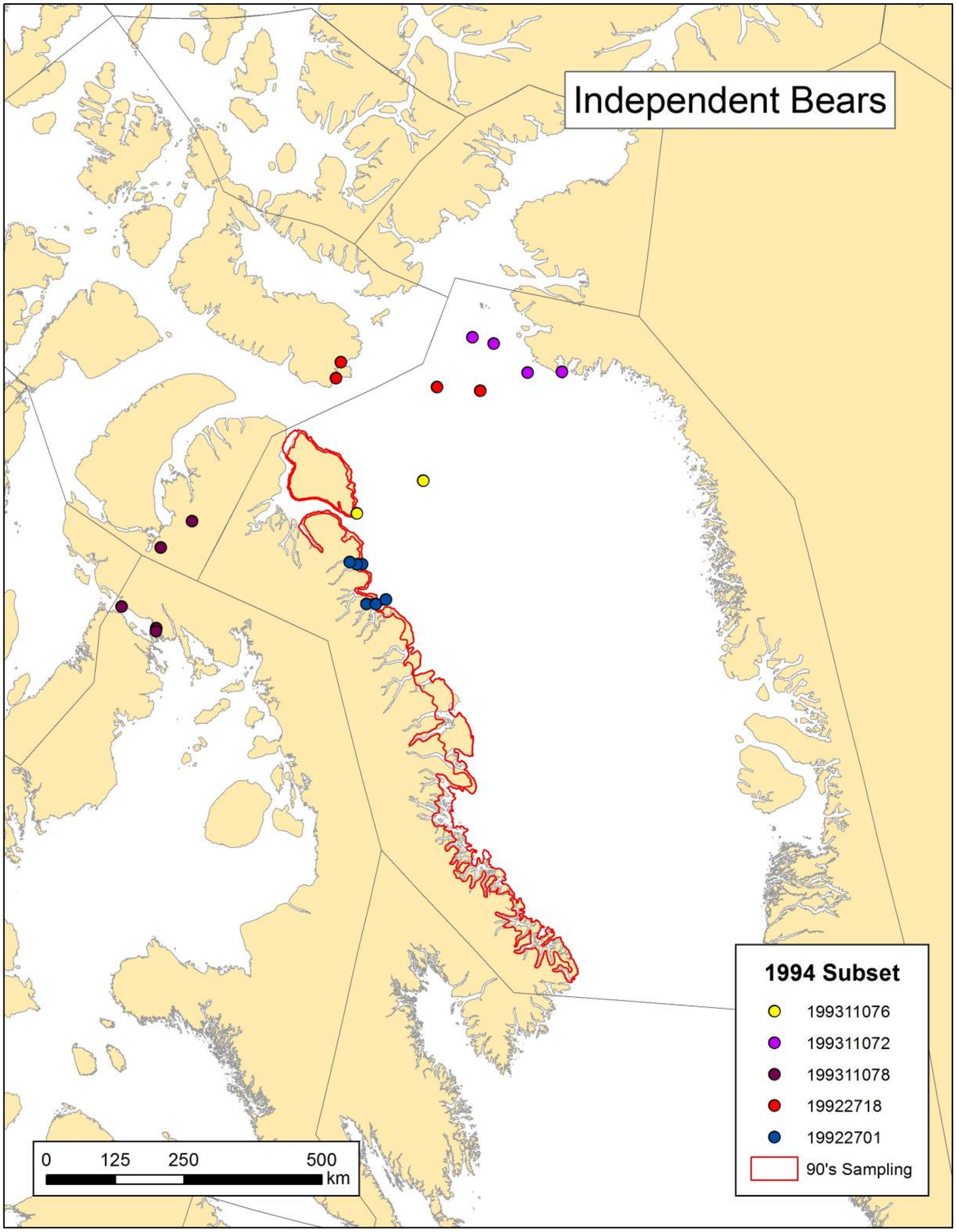

Figure 3.11. All telemetry locations from independent adult female bears with satellite collars transmitting during the 1995 sampling period dates (See Table 3.3). The 1990s sampled area for the MR study is shown in the red outline.

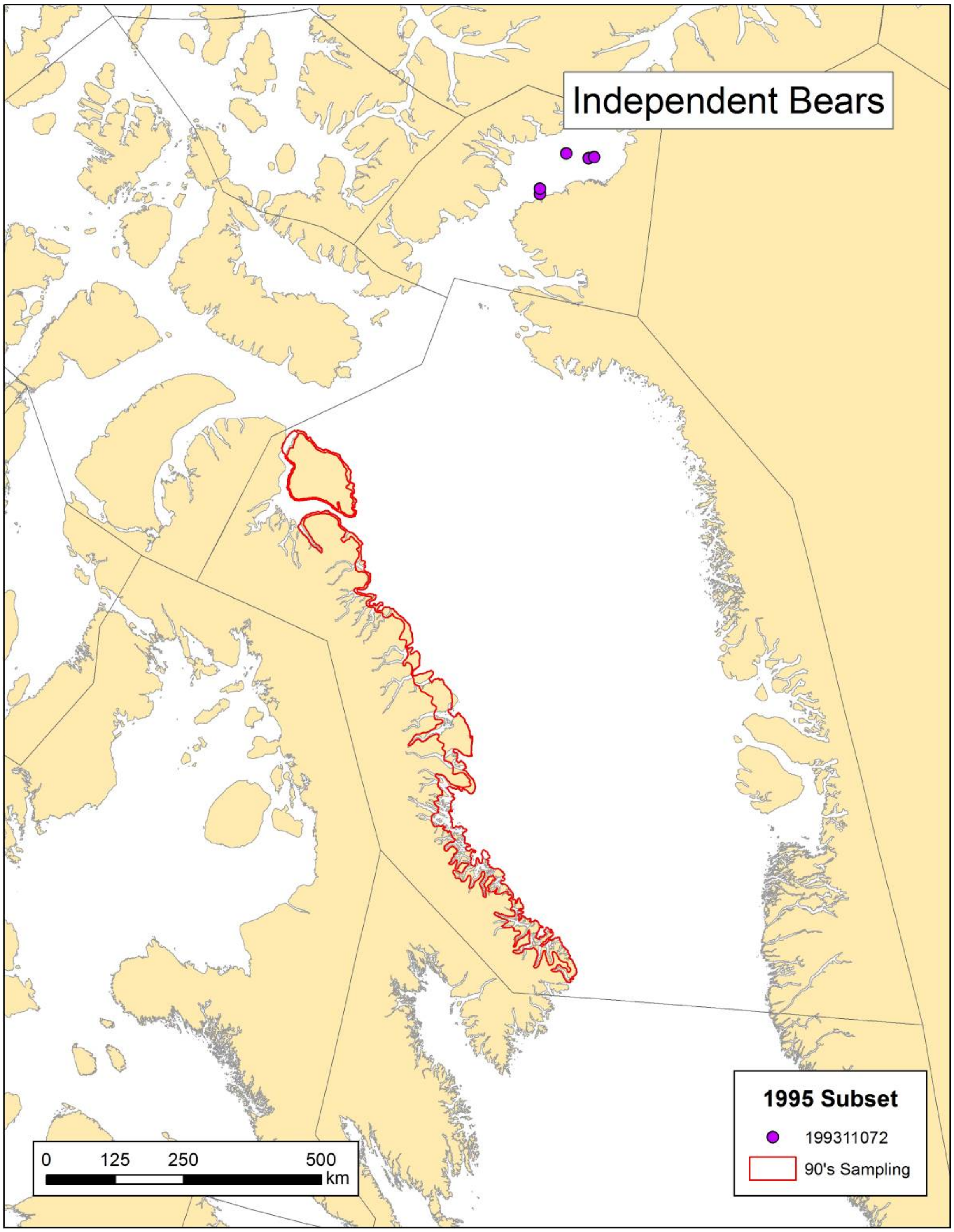

Figure 3.12. All telemetry locations from independent adult female bears with satellite collars transmitting during the 2011 sampling period dates (See Table 3.3). The 2010s sampled area for the MR study is shown in the blue outline.

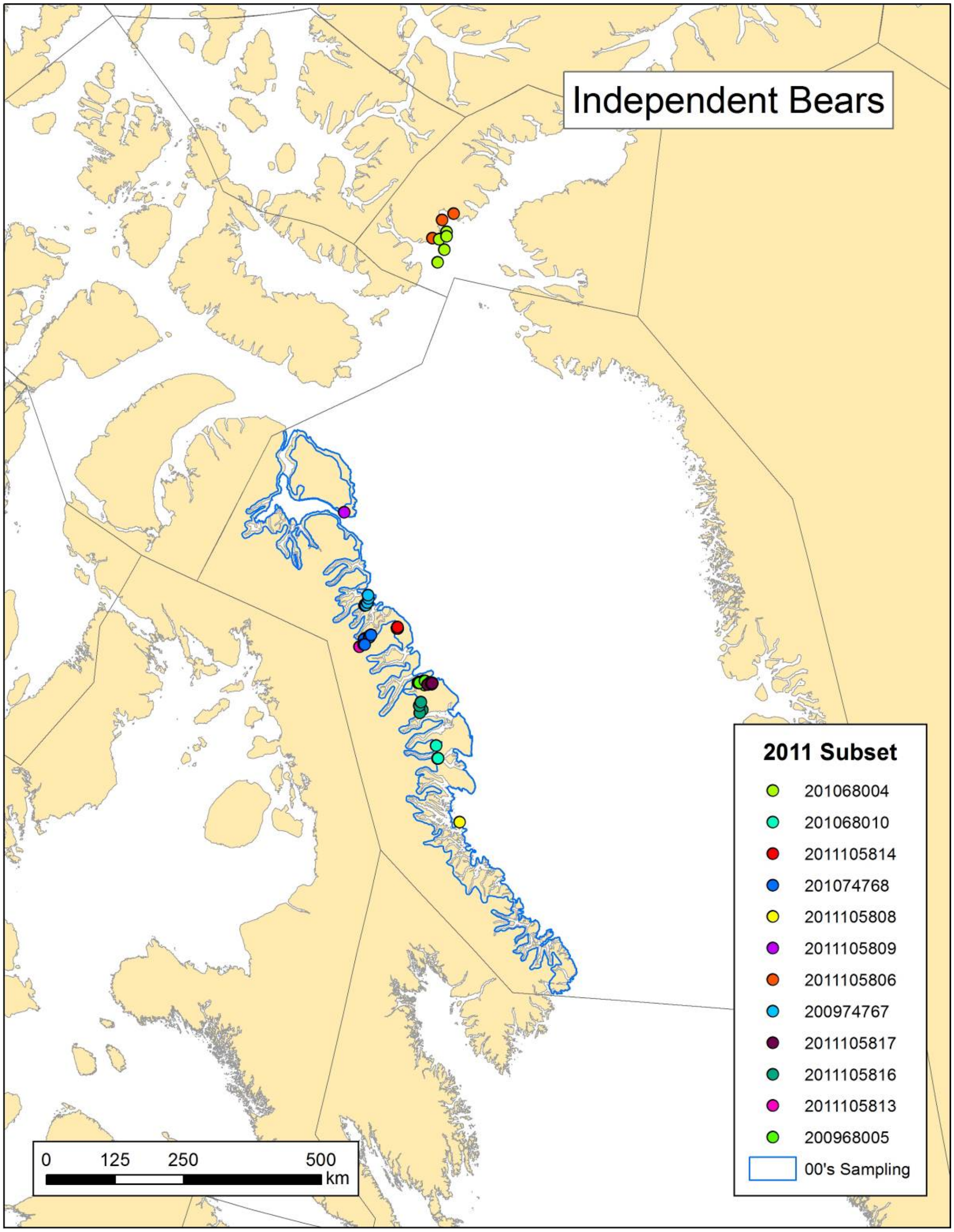

Figure 3.13. All telemetry locations from independent adult female bears with satellite collars transmitting during the 2012 sampling period dates (See Table 3.3). The 2010s sampled area for the MR study is shown in the blue outline.

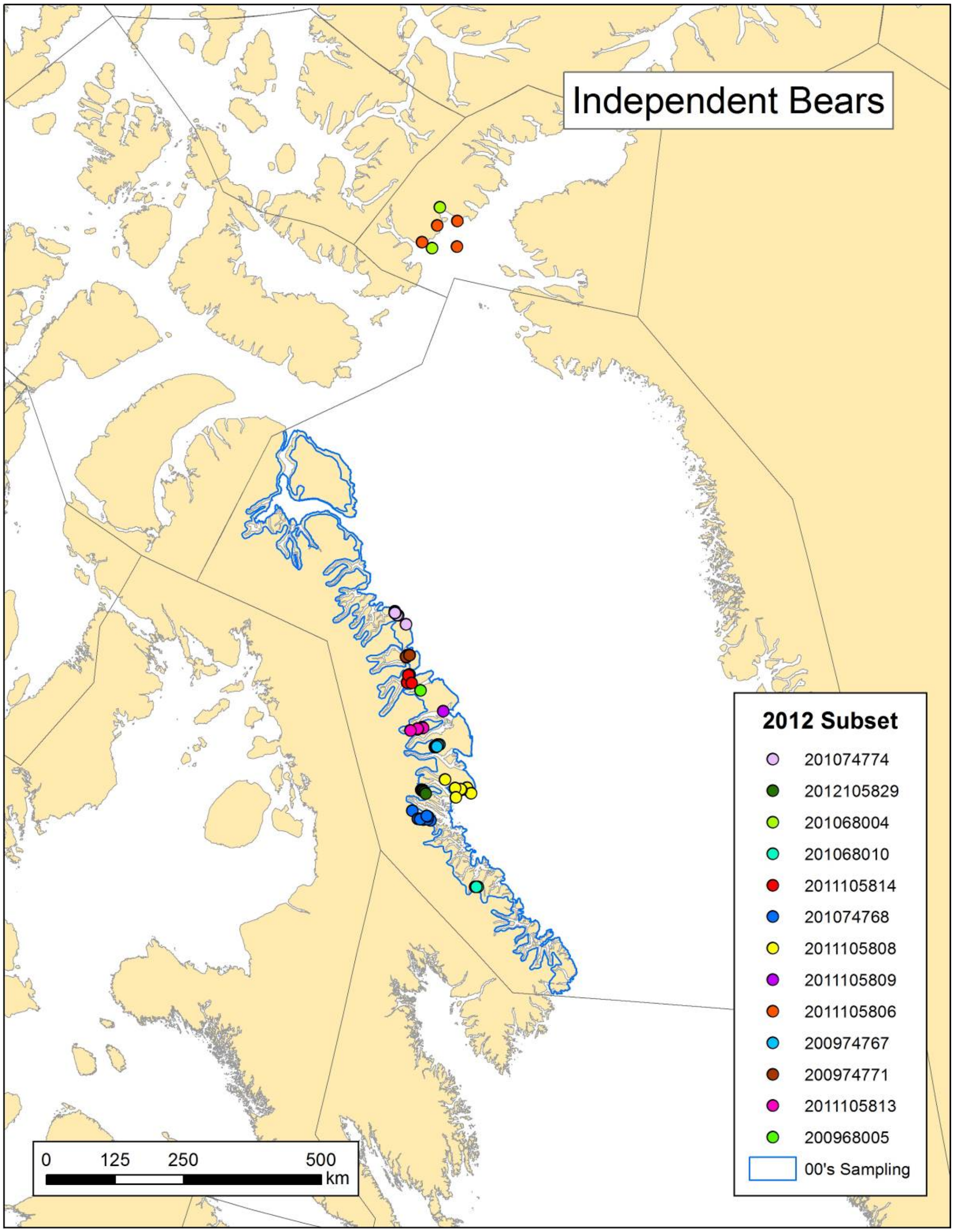

Figure 3.14. All telemetry locations from independent adult female bears with satellite collars transmitting during the 2013 sampling dates (See Table 3.3). The 2010s sampled area for the MR study is shown in the blue outline.

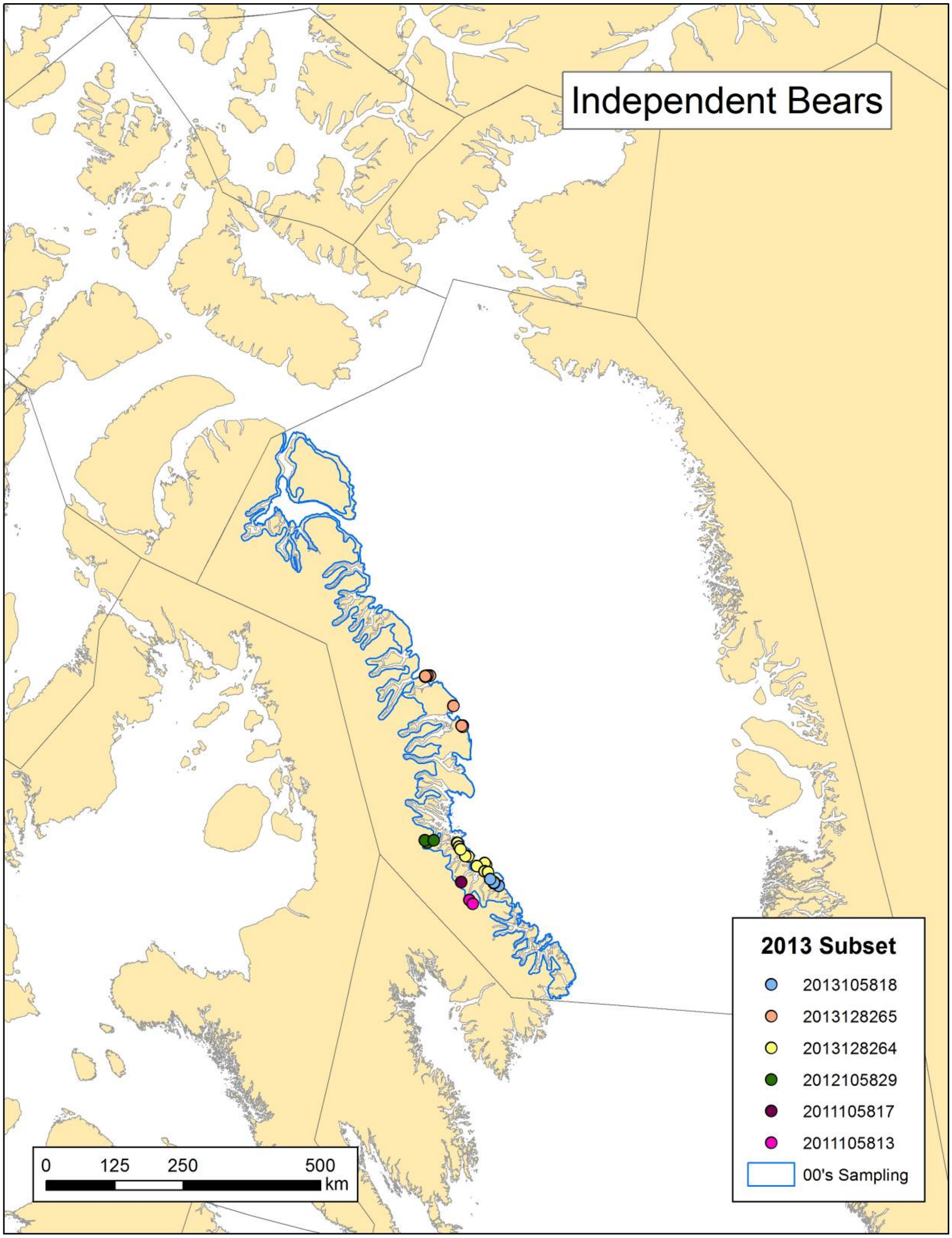

Figure 3.15. Distribution of weekly mean sea-ice concentrations (SSMI) during the mid-point of the sampling period in 1993 (August week 4). Sea ice is shown in 25 km^2 pixels. Locations of independent AF bears during the 1993 sampling period are shown.

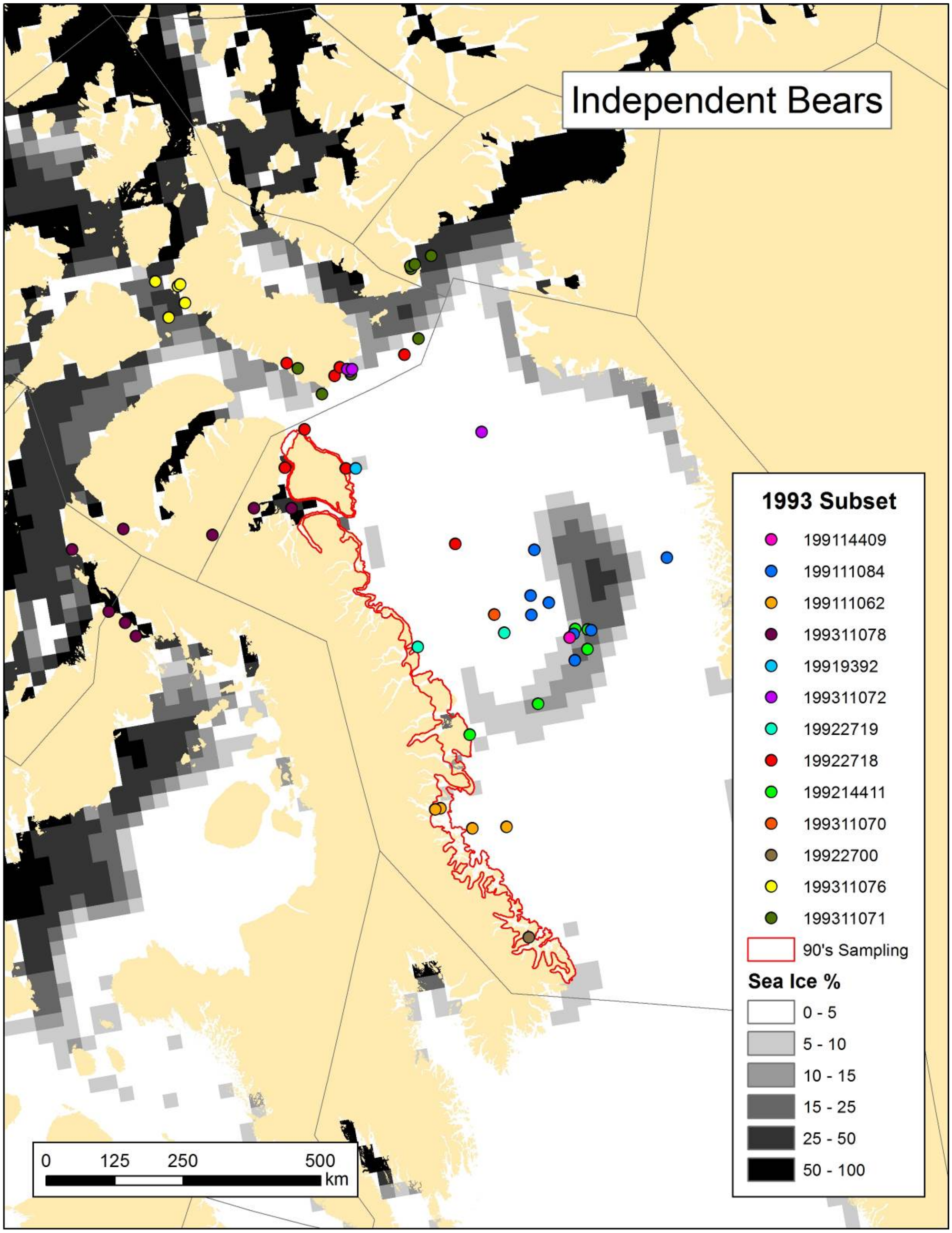

Figure 3.16. Distribution of weekly mean sea ice concentrations (SSMI) during the mid-point of the sampling period in 1994 (October week 1). Sea ice is shown in 25 km^2 pixels. Locations of independent AF bears during the 1994 sampling period are shown.

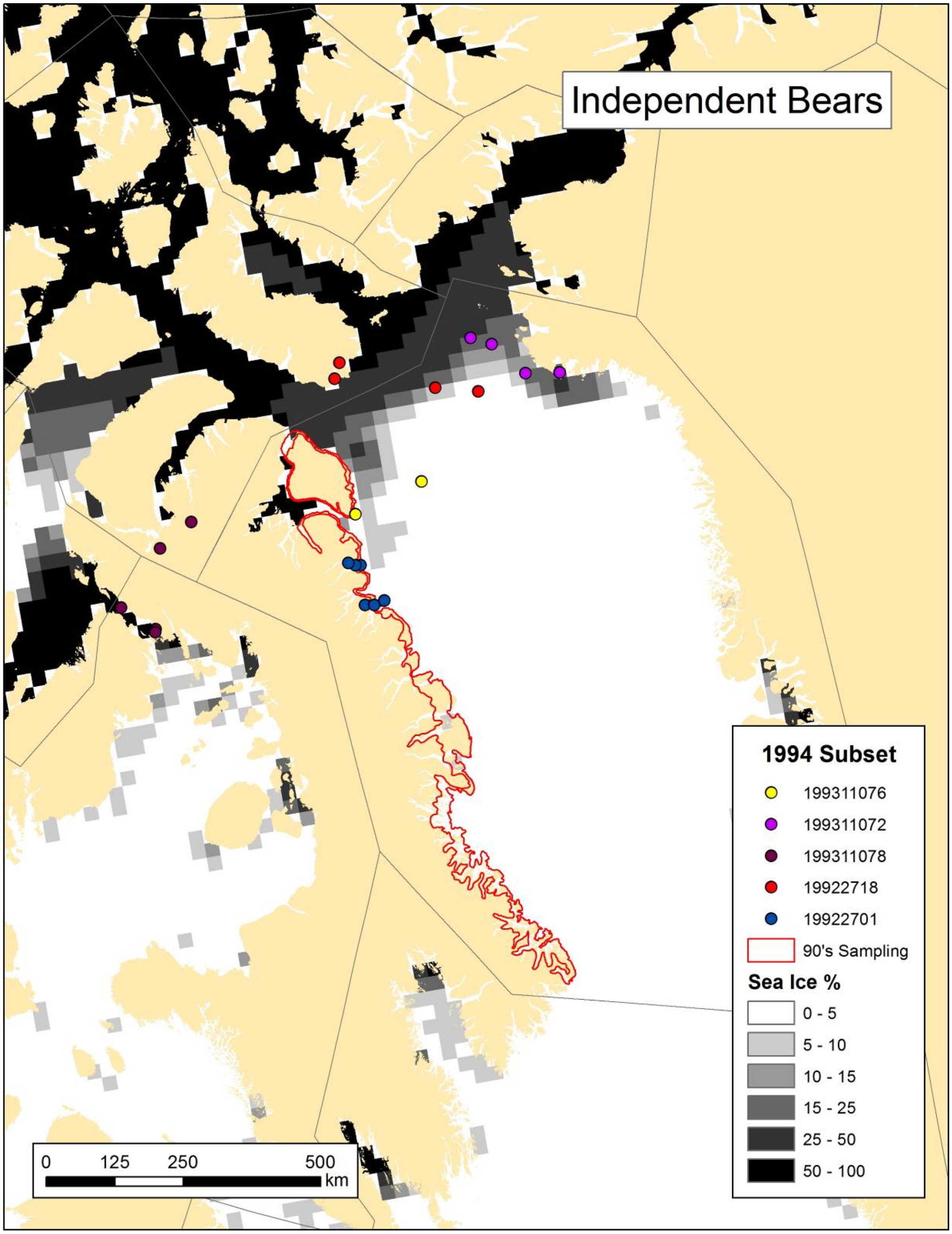

Figure 3.17. Distribution of weekly mean sea-ice concentrations (SSMI) during the mid-point of the sampling period in 1995 (October week 2). Sea ice is shown in 25 km^2 pixels. Locations of independent AF bears during the 1995 sampling period are shown.

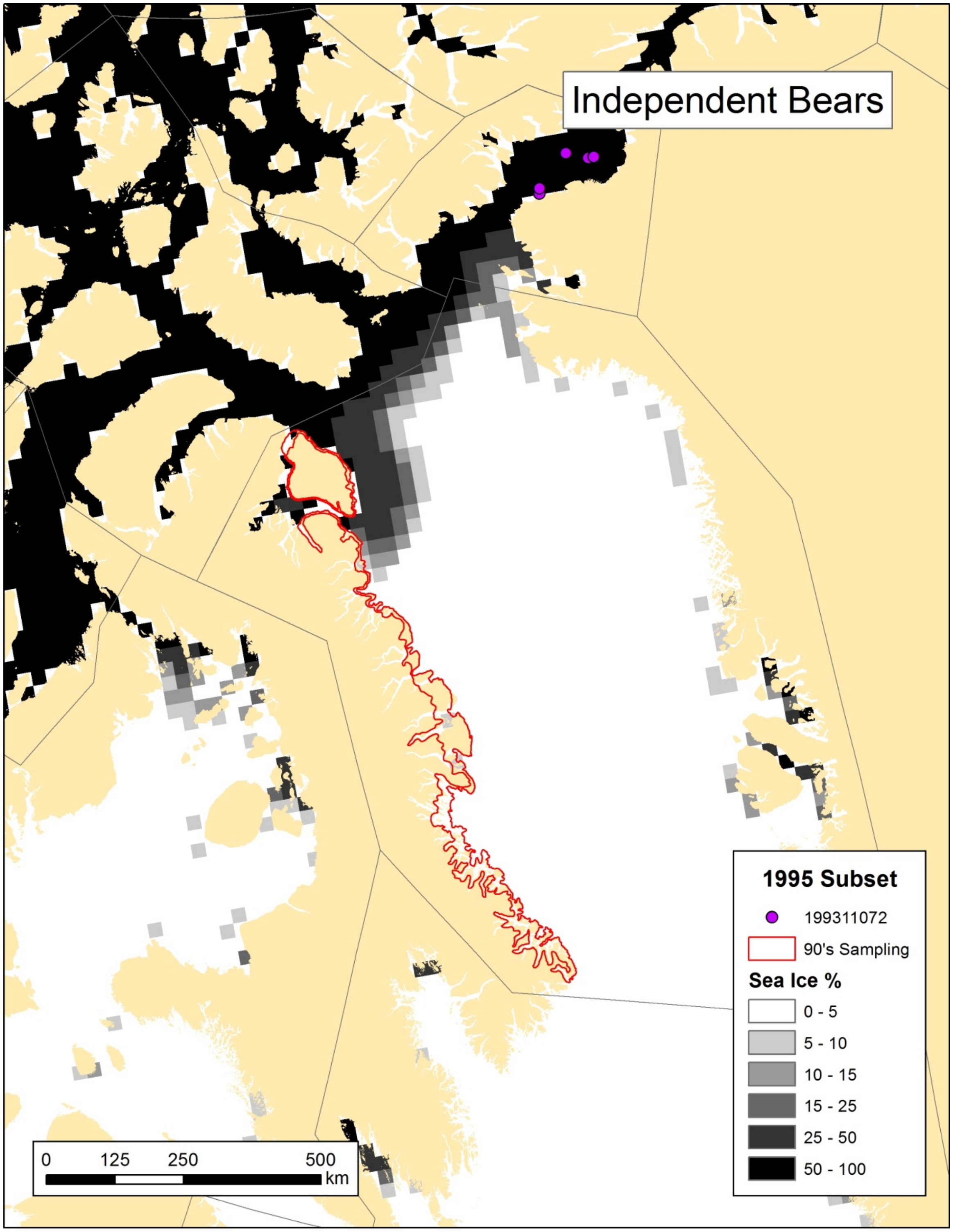

Figure 3.18. Distribution of weekly mean sea-ice concentrations (SSMI) during the mid-point of the sampling period in 2011 (September week 3). Sea ice is shown in 25 km^2 pixels. Locations of independent AF bears during the 2011 sampling period are shown.

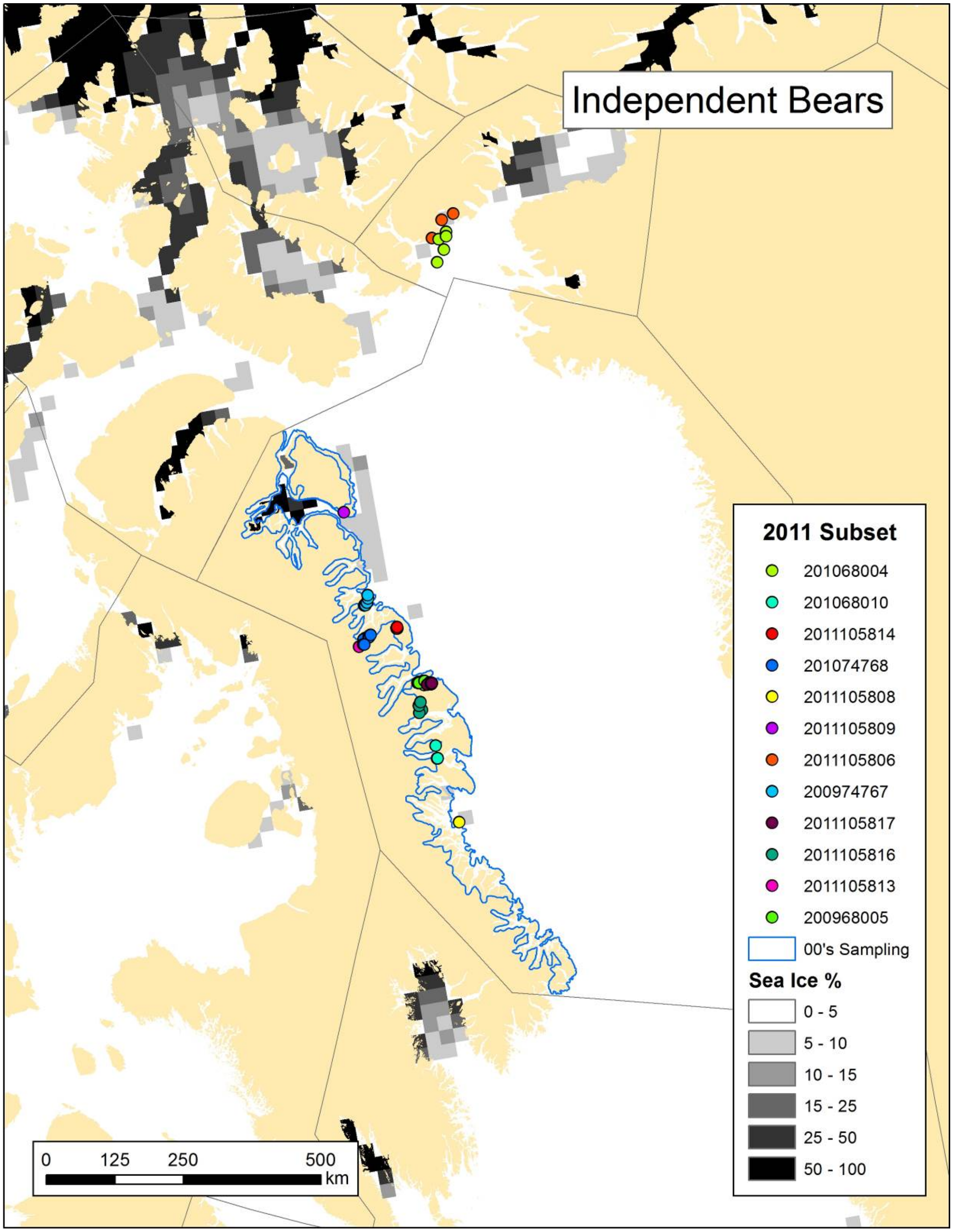

Figure 3.19. Distribution of weekly mean sea-ice concentrations (SSMI) during the mid-point of the sampling period in 2012 (September week 2). Sea ice is shown in 25 km^2 pixels. Locations of independent AF bears during the 2012 sampling period are shown.

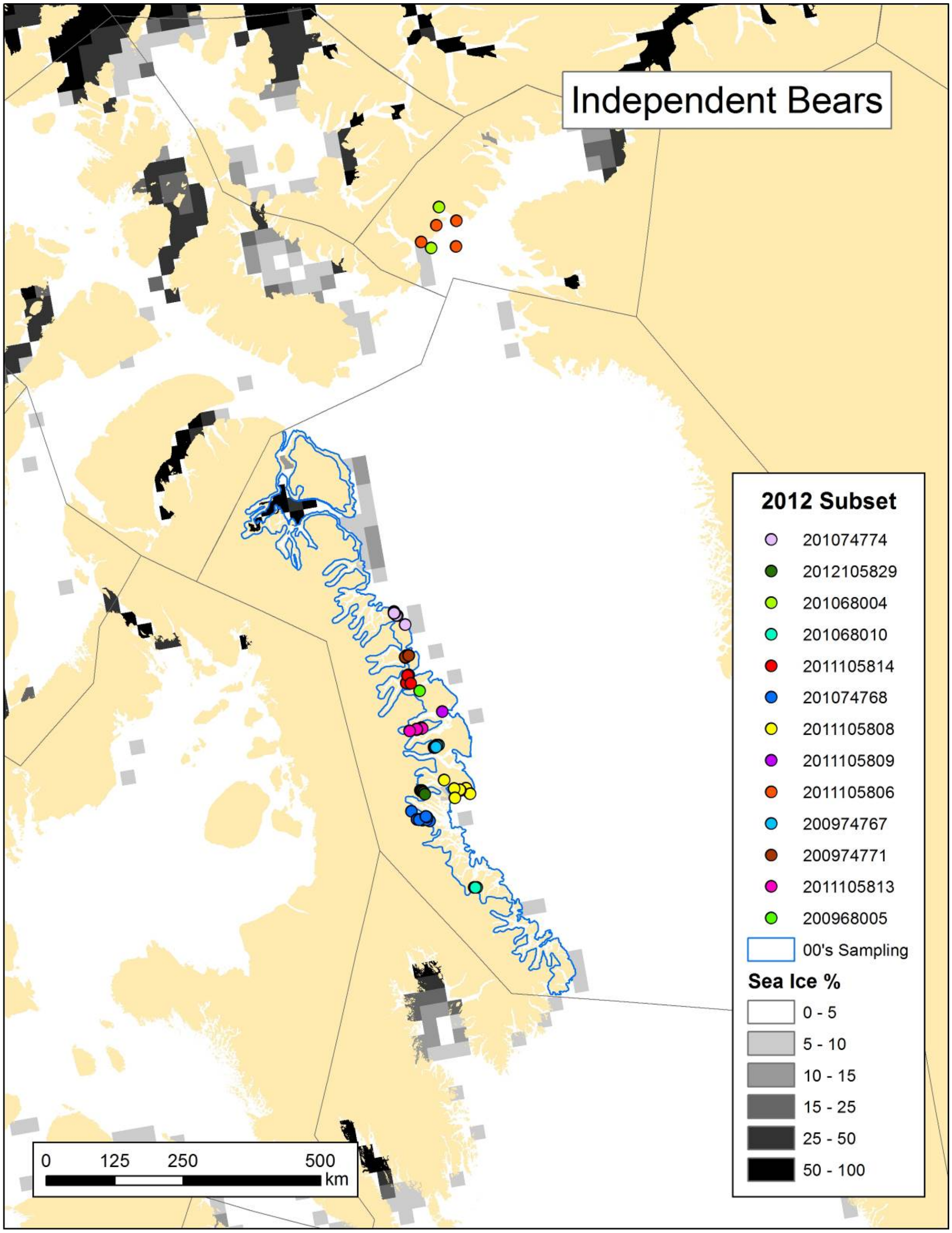

Figure 3.20. Distribution of weekly mean sea-ice concentrations (SSMI) during the mid-point of the sampling period in 2013 (September week 3). Sea ice is shown in 25 km^2 pixels. Locations of independent AF bears during the 2013 sampling period are shown.

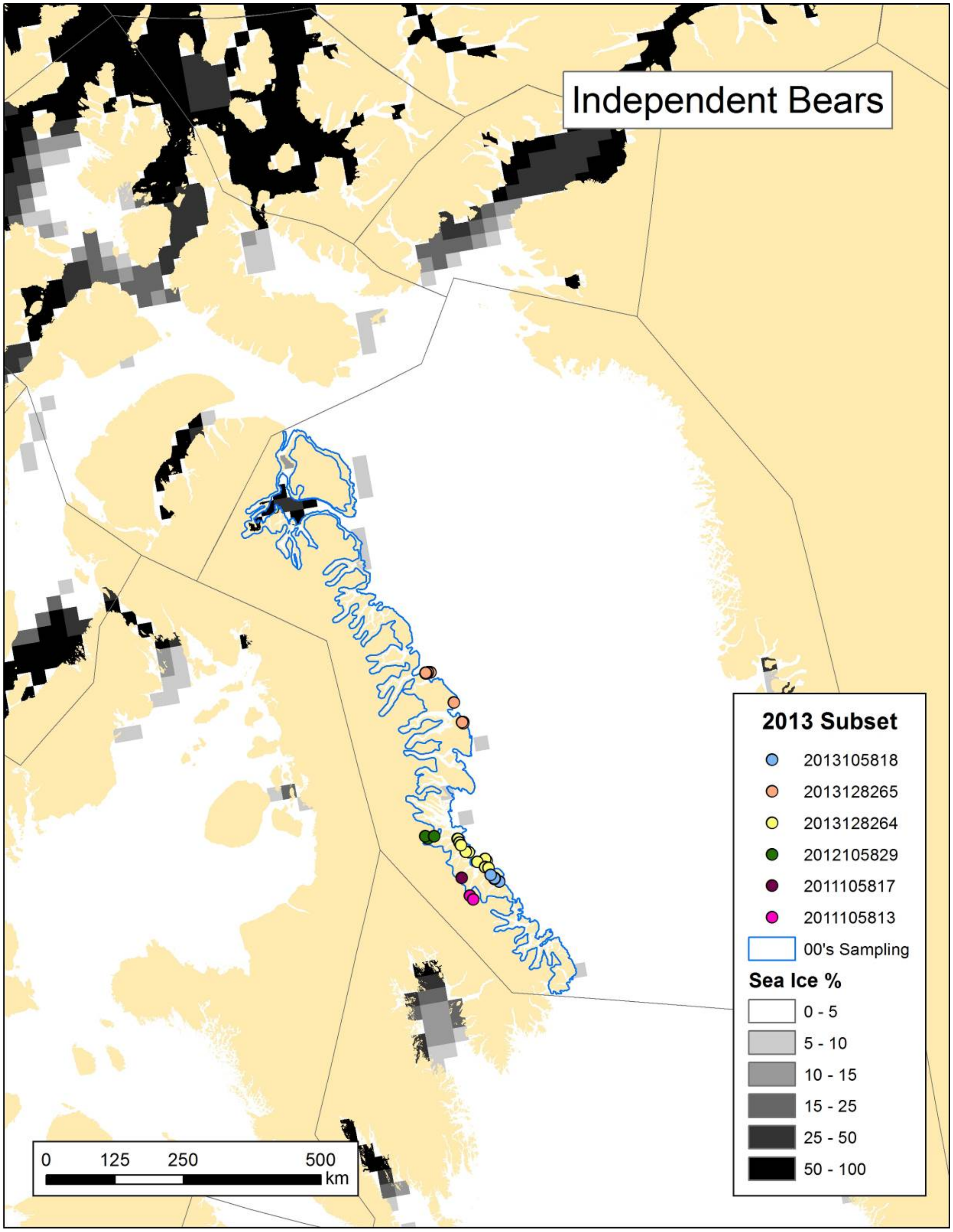

Figure 3.21. Distribution of sea-ice conditions (SSMI) during 1990s MR (top left to right 1993, 1994 and 1997) and 2010s MR (bottom left to right 2011, 2012, and 2013). Independent bears transmitting during the sampling are shown for reference. Note sampling occurred in 1997 but there were no independent collared bears for assessment of presence in the sampling area.