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# Denning characteristics and movement patterns of female polar bears with cubs in Svalbard during the first month after emergence: implication for detecting denning locations.

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The University of Tromsø and

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## Abstract

Satellite telemetry records of temperature, activity and position data for female polar bears (*Ursus maritimus)* known to have been (n=11) and to not have been (n=15) in maternity dens during winter were analyzed during the period from December 15th to March 1st for patterns that could be used to demonstrate denning in other female bears by means of telemetry collars. Temperature was found to be the best indicator, and sufficient alone to indicate denning, due to above freezing values within the dens throughout the winter, while outside temperatures varied and were mostly below freezing. Using this signature, 34 individual females (n=64 bear-winters) out of 207 collared females (n=290 bear-winters) were with high certainty established as denning bears. Telemetry data for selected and known denning animals was analyzed for the period from September 1st to May 31st. Mean entry and breakout dates (entry – Nov.11, exit – March 28) and a mean length of denning ( 147 days) were estimated for known and selected bears. Further, females' movement was analyzed with regard to distance from the dens during the first few weeks after emergence. Distances were estimated starting from the first corresponding negative temperature transmission, taken as a break out date and for 30 days forward. Median distance of 19.7 km from the den was recorded for the day 6th after emergence and 95.5 km after 30 days. By April 20th, 33.3% of females were within 38.5 km from the den. Therefore, it appears that after emergence females spend less than one week in the denning area. However, large variability in travelled distances was present (from 0.3 km to 247 within the first week), likely demonstrating either loss of cubs or habitat selection (island vs. pelagic). Upon analysis of denning locations, 66 dens were plotted and 5 appeared to be on sea ice.


Key words: *Ursus maritimus*, polar bear, Svalbard, Spitsbergen, satellite telemetry, reproduction, spatial use.

*To my son, Artem, who loves puffins,*

*and to my grandfather who broke up through the Arctic ice…*

## Introduction

Ability to point denning females and their locations is critical for understanding the population dynamics and habitat use. Particularly now, when subpopulations in various regions of the Arctic demonstrate negative consequences due to climate change, and effects on physical condition, demography, spatial distribution and changes in seasonal use of habitat are reported, it is essential to be able to estimate the changes in population numbers, birth rate, and survival of different age groups. Reliable data on maternity denning can be a key to obtaining such knowledge. Information on distance travelled by family groups would allow getting better estimates of den locations when families are encountered during the fieldwork, and can be used in monitoring activities. Known location of the denning area could aid in estimation of cubs' age and determination of approximate emergence date when family groups are seen. Time of emergence and particularly length of stay near the den can be also indicative of physiological condition of females and reflect their pre-denning state.

### *Denning*

Descendants of the brown bear (*Ursus arctos*), polar bears evolved a capability to utilize a highly specific Arctic environment becoming a top predator in the region.

The polar bear's entire life cycle depends on presence of ice for successful hunting, breeding, dispersal, and access to the denning locations. Their denning can take place on land in areas where the topography allows accumulation of some snow or on sea ice. Females exhibit to some degree substrate and denning area fidelity (Amstrup et al. 1994). Some areas in Canada are known to have been used for denning for over 200 years (Ramsay et al. 1990).

Dens can be located along the coast, on offshore islands, on land-fast ice or on drifting sea ice (Lentfer et al 1975). They excavate the den in drifted snow, likely leaving an air hole for breathing/temperature control. Den layout varies, but often consists of a corridor and one or more chambers. On shore, polar bears may go as far as 100 km inland to their preferred areas (Ramsay et al. 1990). However, a majority stays within a few kilometers from the shore, generally <20 km (Ferguson et al. 2000). On Wrangel Island, in the western Russian Arctic, most of dens were recorded within 8 km from shore although some were as far as 25-27 km away (Uspenski and Kistchinski 1972). In Svalbard dens are even closer to the shore – usually within a kilometer inland (Larsen 1976). Recently, general distribution of denning locations has shifted north in some areas. That is believed to be the result of a change in climate patterns (Ramsay et al. 1990). In other areas, such as in the Southern Beaufort Sea, Alaska more and more bears are switching from pack ice to land denning due to the deteriorating ice conditions (Fischbach et al 2007).

On ice, bears seek out stable multiyear ice floes that are likely to stay intact even under tremendous pressures exerted by colliding floes, breakage and refreezing.

Frequently, floes may drift considerable distances during the winter (Lentfer 1975, Garner et al 1990).

## Aim of the study

The purpose of this study is two-fold. Firstly, we investigate satellite telemetry records (position, ambient temperature, and activity data) for female polar bears from Svalbard with known reproductive status to find a signature pattern allowing to can classify animals as denning or non-denning with high certainty. Secondly, we apply this signature to select as many females as possible that have been in maternity dens during winter, to look at the den entry and break out dates and in particular -the area use during the first few weeks after the emergence - to investigate the length of time spent near the den and the distance, travelled by families within the first few weeks after emergence. A main motivation is to evaluate to what extent observations of females with cubs in spring will indicate a den in the surroundings, and thus be used in studies of local reproduction.

## Materials and methods

### *Population*

The Barents Sea bears represent a continuous population that inhabits the Norwegian and the western Russian Arctic areas. Results of genetic studies of polar bears caught in Svalbard, Franz-Josef Land and Novaya Zemlya areas (Paetkau et al 1999) confirmed that there are no significant differences in allelic distribution between these groups. However, there are 3 clusters that constitute the population of the region: bears from south-eastern coastal Svalbard, pelagic Barents Sea bears, and a Franz-Josef Land cluster that overlaps with the Northern Kara Sea population (Mauritzen et al 2002). The population has a northern distribution limit and a boundary at 82° N latitude. The continental shelf edge north of Svalbard is the border between different water masses and ice types, and it marks a difference in biological productivity, thus influencing prey distribution.

Svalbard bears residing within the archipelago move onto land during the summer, while pelagic bears remain on the retreating ice and migrate seasonally. The pelagic Barents Sea bears have a north-south migration pattern, coupled with the changing extent of annual ice formation. Home ranges are smaller for near-shore females than for pelagic female bears, varying from 1,000 $km^2$ to 100,000 $km^2$ (Mauritzen et al 2001). The home ranges of the North Kara Sea population varied among individual bears, but overall the Barents and North Kara individuals demonstrate large home ranges and remain on the ice year round. The home range of the central Barents Sea group overlaps with the Svalbard polar bears. Bears in the vicinity of Franz Josef Land inhabit areas where multi-year drift ice is currently present year round (Mauritzen et al 2002).

The Barents Sea population was estimated to contain 2,650 animals based on a line transect survey conducted in 2004 (95% CI = 1900 to 3600) (Aars et al 2009). The population is unique as it has been protected from any human takings (i.e., subsistence hunting, trophy hunting, and poaching) since 1973. Around 1200 animals were taken between 1894 and 1967 (Larsen 1985). It is likely that the number of denning females and number of areas intensively used for denning increased significantly after the hunting pressure was removed (Larsen 1985).

*Data analysis*

The Norwegian Polar Institute (NPI) has been compiling a polar bear telemetry database since late 1980s. Every spring a number of “Telonics” (Telonics Inc, Mesa, Arizona) satellite telemetry collars (as well as GPS and other data-gathering tools) are being fitted onto females in Svalbard. Acquired data is processed by Argos services (Argos Data Collection and Location System) and formatted by the Information Technology team at the NPI. A total of 213 conventional collars have been employed on female polar bears in the Svalbard area from 1989 to 2009. Data used for evaluation in this study covers the period from 1991 through the spring of 2009. On average, battery lasts around 2 years. However, the actual transmitting period varied from a couple of weeks to over 3 years, providing a large amount of location, temperature and activity data. Most of the earlier Telonics collars were set to transmit every 6 days, and newer ones were transmitting every day. Transmissions occurred within a 6 hour window at the same time. Number and quality of transmissions is higher for the ranging animals as the signal is not impeded by the layer of snow or position of the animal (Lunn et al 2004). For this study we have chosen to use temperature and location as main indicators of denning-post-denning behavior (Garner et al 1990, Wiig 1998, Lunn et al 2004).

During the Part One of the study, females fitted with conventional Telonics collars one to three years prior to recapture in spring and with known reproductive status were selected for evaluation and assigned to the following groups: denning – observed with COYs (cubs of the year) in spring; non-denning – observed with yearlings or two year olds in spring; and likely non-denning – observed with no cubs or observed with yearlings or 2 y. olds in a previous year and with no obvious signs of pregnancy such as lactation/nursing next spring. Denning period was set to be from December 15$^{th}$ through March 1$^{st}$ (76 days). This time span is further described as a “bear-winter” - a well-fitting terminology adapted from Fischbach et al (2007). Temperature, activity and position data were evaluated and compared for individuals in all groups during the period whenever data were available.

During the Part Two of the study, records for all females fitted with the conventional Telonics collar were extracted and evaluated, and selection of likely maternity denning animals was made based on the previously determined “denning signature”. Once selected, position data for the presumed family groups were analyzed. In some cases an individual was evaluated more than ones (in different years).

All analysis was carried out with the help of Microsoft Excel and statistical software R (version 2.8.1.Patched, R Development Core Team 2009).

*Temperature:*

Over the period of time with available records, 3 types of collars were used, all utilizing Argos services. For the earliest collars (1989-1993), Argos transmitted the temperature directly in Celsius, but some of the transmitted values (1989-1994) were between 1000 and 30 000 (approx) and the following conversion formula was used:

*Temp = 0.0022 X transmitted value - 43.84* (ref Øystein Wiig) (1)

Due to a change in data format, some transmitted temperature values were above 49 000 due to low voltage information and in that case the following formula was used:

*Temp = (transmitted value-49152) X 0.38-42* (2)

For collars up to 2006, when the value was between 0 and 255, the formula used was:

*Temp = 0.38 X transmitted value* – 42 (3)

Probable temperature readings were deemed to be within the interval from -40 to +40 degrees Celsius and after the conversion invalid temperature transmissions were removed. First reading was kept for each period of transmission. Internal transmitter temperature for denning bears is higher than for non-denning animals. Normal body temperature for the polar bear is +37°C, and the collar transmitted the temperature that was a combination of the body heat coming from the animal attenuated by the ambient temperature. Position of the animal in the den, and den's insulating properties (i.e. amount of ice on the inner walls) would all be reflected in the temperature readings. However, it was assumed that most, if not all, readings for the denning females will be above 0°Celsius (Blix and Lentfer, 1979).

*Positions*

Telonics collars provided location information in latitude/longitude format. Positions of all Location Classes (LC), where precision is defined from Z - the lowest quality, B,A,0,1,2 and 3 – the highest, were retained for the analysis (Mauritzen et al 2002) as in most cases the number of transmissions for the denning bears was very small and of low quality. According to the Argos user manual (2008) the following precision is available for the Location Classes (LC):

3: < 250m; 2: 250m-500m; 1: 500m-1500m; 0: > 1500m.

For LC A, B and Z no precision information is available.

All positions were visually inspected and unrealistic outliers were removed. One best quality transmission was kept for each period. If 2 or more locations had the same highest-quality rating, the location closest to the best location in the previous transmission cycle was selected (Garner et al 1994, Arthur et al 1995, Amstrup et al 2004). It was assumed that bears were unlikely to travel more than a 100 km/day for periods of more than 1 day (Arthur et al 1995). For the distance analyses, latitude/longitude values were converted to the UTM coordinates with help of R. Appropriate zones were used for conversion (for the east coast of Svalbard, the Central Barents Sea and Franz Josef Land).

*Activity*

Two activity indices recorded based on the mercury switch data(1/s), activated by the animal' movement were available along with the temperature for most of the collars -

one reading gave value for the movements within the last 60 seconds before transmission and another – within the past 24 hrs before transmission. While 60 second reading proved not to be useful for this study, we have used 24 hr activity level as a reference when available and in most cases it was negatively correlated with the temperature (Fischbach et al 2007). In earlier studies it has been observed that the activity level drops significantly or disappears in transmissions from denning females (Fischbach 2007).

## Results

### *Part One*

Upon an initial review of the database, 11 females (11 bear-winters) fitted with the Telonics conventional collars, whose maternity denning status was confirmed by on the ground sightings, were selected. In addition, 15 females (15 bear-winters) were defined as non-denning or likely non-denning, based on their reproductive status in spring as observed in the field.

### *Frequency*

All known denning females' collars were set to transmit every 6 days, and the maximum possible number of days with transmissions within the defined denning period was thirteen. Out of eleven denning females two animals had no temperature readings; three had only 1 reading each; six remaining individuals had five or more temperature records (5, 8, 8, 9, 12, and 13 readings).

In the non-denning group (five animals), two collars were set to transmit every day with the maximum possible number of transmissions of 76 (gave 67 and 68 readings) and one – every 4th day, with the maximum possible number of 19 transmissions (16 readings). In the likely non-denning group (ten animals) three collars were set to transmit every day (60, 75 and 76 readings) and two – every 4th day (both gave 19 readings). For the analysis, number of transmissions from the collars with the daily and every 4th day readings was scaled down proportionally to the collars, transmitting every 6th day. Out of five non-denning and ten likely non-denning females, six was the minimum number of readings for both groups.

Thus, using the scaled values for the number of transmissions and taking 13 transmissions as a maximum possible number for the period, 45,5% of denning females had 0-1 transmissions; 80% of non-denning had 11-12 transmissions and 80 % of likely non-denning females had 12-13 transmissions (Fischbach 2007).

*Temperature*

Within the period, six known denning females showed a wide range of means (from +4.81 to +23° C). Two of them had one negative reading each (-4.58 and -1.18°C). Two females had a single negative temperature reading (-0.28 and -10.83°C). In total, four females out of seven had one negative reading within the period and in three cases it was after February 18th (Fig.1). These single negative readings were followed by positive temperatures for the following few weeks until the emergence date.

Three out of five females with cubs of various age in non-denning group had mean temperatures above 0 degrees C (+2.73, +10.79 and +9.48 degrees C). A female with 2 y. olds (collar transmitted every day) showed only positive temperature transmissions from December 15th through January 30th (37 days/transmissions out of 45 possible ones). Other two females had mean temperatures below 0 (-8.79 and -3.71ºC).

In likely non-denning group three single females had mean temperatures above 0 (+0.57, +9.41 and +7.63ºC). One single female (collar transmitting every day) showed consistent positive temperature transmissions for every day from January 31st through February 27th; another female (same type of collar) had only positive transmission for 20 days straight, from December 20th through January 10th. Other females had mean temperatures below 0ºC (ranging from -2.8 to -17.18ºC). See Table 1 in the Appendix for the full list of results.

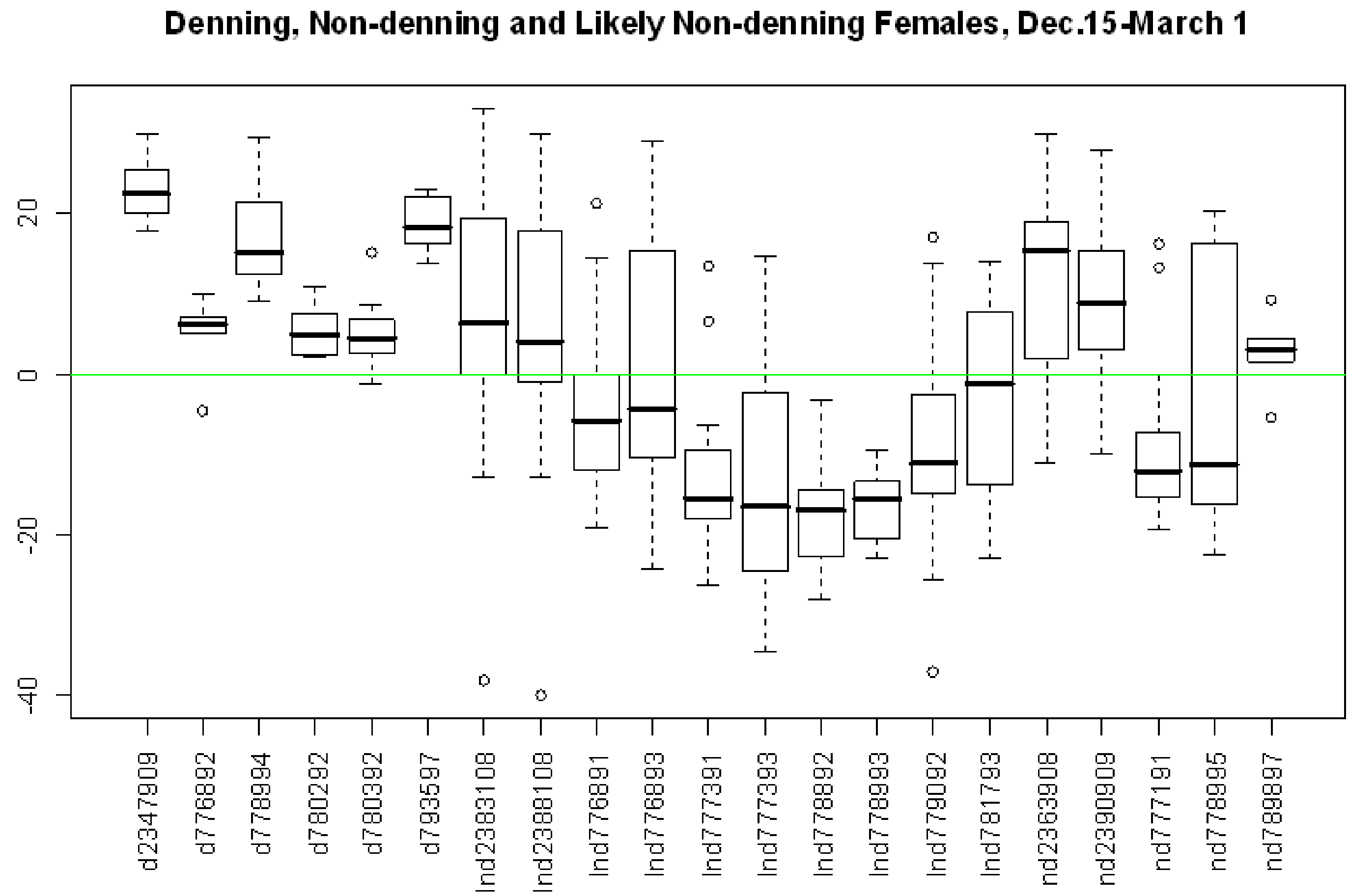


**Fig 1**. Temperature ranges for females with known status (suffix designation: d - denning, lnd – likely non-denning, n - non-denning )

*Temperature ranges*

To further explore the differences in temperature readings between the groups, an s.class(ade4) plot was used. This function performs a scatter diagram with representation of point classes. A relationship between the temperature reading (T) and the difference between two consequent temperature readings ($\Delta T = t_1$-t) for each individual (by group) was evaluated to see the differences in range of temperature fluctuations between the groups (Fig. 1, Appendix). Denning females displayed narrow temperature range, little fluctuation (mean $\Delta T$ varied from 2.68 to 6.75°C, max

$\Delta T = 16.54^{o}C$); likely non-denning (mean $\Delta T$ from 5.06 to 21.57, max $\Delta T = 66\ ^{o}C$) and non-denning (mean $\Delta T$ from 6.47 to 19.87, max $\Delta T = 35.32^{o}C$) groups showed a large degree of temperature fluctuation and wide temperature range (Table 1, Appendix). Maximum change in temperature was drastically higher in non-denning and likely non-denning groups, but there was some overlap in mean $\Delta T$ for individuals from all three groups (Fig.1 Appendix).

### *Part Two*

Based on the analysis and comparisons of available data from the first part of this study for denning, non-denning, and likely non-denning females, selection of presumed maternity denning females from the database was conducted based on positive temperature readings (above $0^{o}C$) during the minimal "in-den" period from December 15th through March 1st; one negative temperature reading within that time was allowed. At least one positive temperature transmission had to be available; females with no temperature transmissions within that period were identified as "unknown status". In this study change in temperature was not used as an indicator due to some overlap in values between the individuals from different groups and possible misidentification.

The database was reviewed and 34 females (64 bear-winters) were defined as denning based on presence of one or more positive temperature readings (above $0^{o}C$) within that period.

For 82 animals (84 bear-winters) the status could not be determined due to lost collar, short/cut transmission period, poor quality of transmissions, or end of the battery life.

Further review allowed to identify 86 individual female (131 bear-winter) as non-denning based on presence of more than one negative temperature readings within the indicated period. Those animals demonstrated strong location signals and mostly negative temperature within the indicated period.

*Entry and break out, length of denning*

It was possible to estimate den entry and breakout dates for 58 denning bear-winters and for 9 known denning females. Available data from September 1st through May 31st was reviewed for each individual. Changes in temperature were used as a primary indicator (Wiig 1995). In few cases, time of entry according to temperature readings was indicated as early as August (positive temperature readings from August, likely reflecting ambient temperature, going into September, making it impossible to determine the entry date). Most field observations from Svalbard suggest that females go in den later, not before September, and therefore, these individuals were excluded from the estimates of den entry/exit dates (Wiig 1995). Estimated mean den entry date was November 2nd (earliest – September 2nd, latest – December 17th), and mean break out date - March 28 (earliest – February 24th, latest – May 7th). Length of denning was found to be 147 days on average, with the shortest denning period of 84 days and the longest - 204 days.

*Distance from the den*

Available data from February 24th (earliest estimated breakout date) through May 31st was reviewed and maternity denning females' positions were analyzed, starting from the first corresponding negative temperature reading, to establish how far from the den they went within the first few weeks. For the analysis, eight out of eleven known denning females were also used (3 had no data for that period); to improve precision, from selected bears, only forty females (bear-winters) with three or more temperature transmissions during the denning period were chosen. One female had collar that transmitted every 4th day, and the distances for each 6th day had to be approximated.

The estimated median distance from the den was 19.7 km on day 6th and 95.5 km on day 30. During the first week minimum distance was estimated at 0.3 km and maximum at 270 km from the den (Fig.2a). During the period from Mar.1st through Mar.15th, an average distance travelled from the den was 3.7 km, and from March 15th through March 31st it increased to 34.6 km. By April 20th, 33.3% of the females (16 out of 48) were within 38.5 km from the den (Fig.2b). Distances and direction of travel was mapped for the first 30 days after emergence (Fig.3 Appendix).

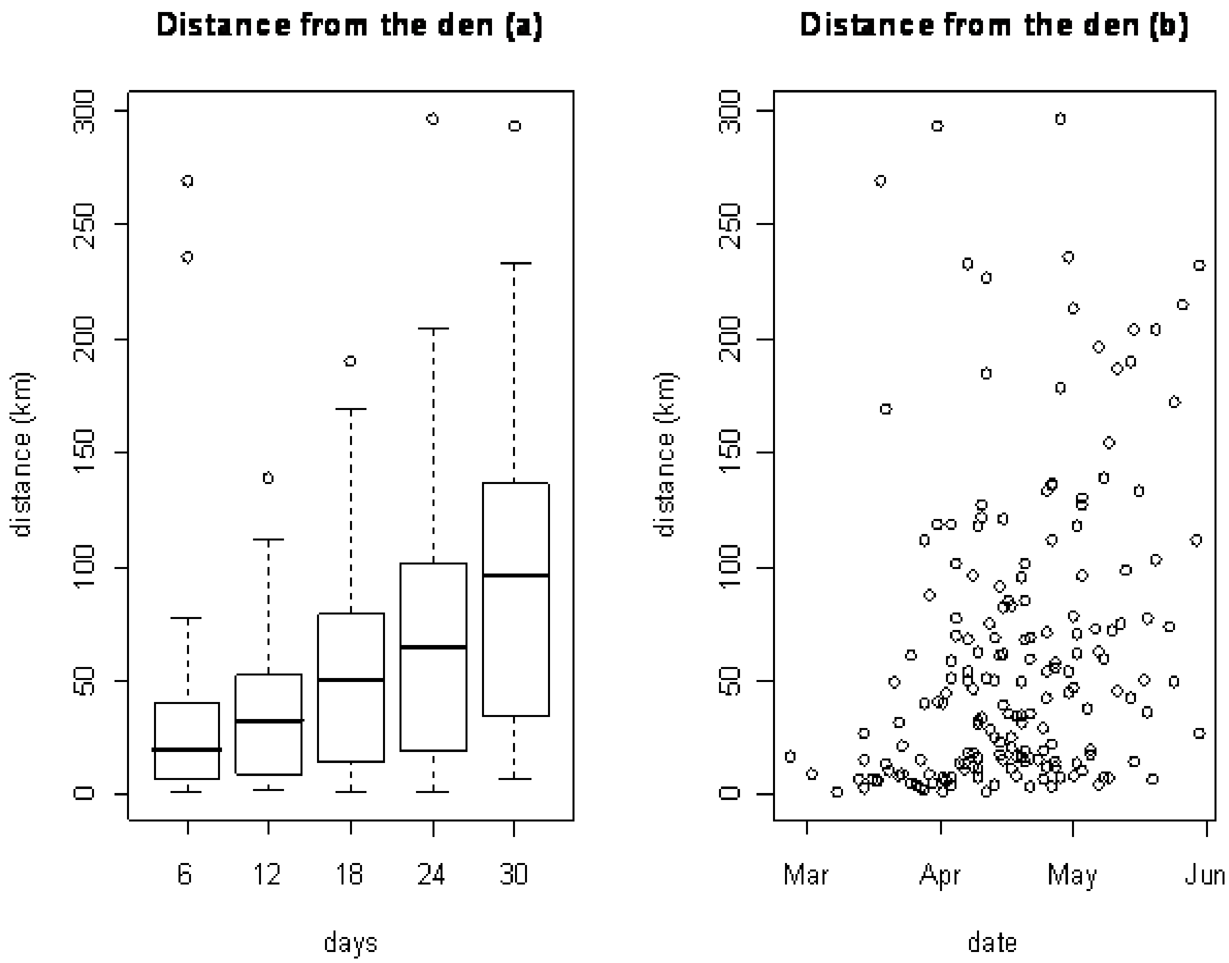


**Fig 2**. Distances travelled by denning females after emergence by number of days (a) and by calendar dates (b).

## *Denning locations*

All available denning locations for known and selected females were mapped to aid in the understanding of females' movements in the fall and after the emergence. Sixty six den locations were plotted. Five locations appeared to be on the sea ice. Four of those animals were initially captured in the Central Barents Sea. One female was caught and collared on the Hopen Island (Fig 2.Appendix)

## Discussion

According to the observations on captive bears, birth occurs from Nov.7 to January 2, similar to more southerly distributed subpopulations (Uspenski 1977). In the wild in most areas cubs are born between early December and mid January (Van de Velde et al 2003, Lentfer and Hensel 1980, Kolenosky and Prevett 1983). Derocher et al (1992) suggested that in the western Hudson Bay cubs are likely born from mid-November to mid-December (also see Lunn et al 2004); and Messier (1994) puts a birth time for bears in Viscount Melville Sound about mid-December. On Svalbard births occur somewhat later - from mid-January to mid-February (Lønø 1970). Overall, this suggests that further north cubs are born later than at lower latitudes. These data validates selection of the minimal in-den period from December 15$^{th}$ through March 1$^{st}$ for the study of denning females in Svalbard.

### *Temperature*

Temperature transmissions above 0$^{0}$C were expected for denning females (Blix and Lentfer 1979). Previous studies reported that the temperature measured inside the dens was higher than outside by 5-17$^{0}$C and showed less fluctuation (Uspenski and Belikov 1980). Readings of in-den air temperatures measured from -5,6$^{0}$ do 6,5$^{0}$ C (Belikov 1993). However, as mentioned earlier, temperature transmitted by the collar is a combination of the animal body heat and ambient temperature, thus, it is expected to be higher. Animal position, thickness of ice on the walls as well as the amount of snow on the roof, influencing insulation properties of the den, would likely have an effect on the transmitted temperature. Satellite telemetry data for known denning females was evaluated and positive mean temperatures (above +4.81$^{0}$C) during the minimal in-den period (December15$^{th}$ –March 1$^{st}$) appeared to be strongly indicative of maternal denning (Fischbach et al 2007). Therefore, only temperature readings were used to identify other denning females from the database. Temperature differences and range were also evaluated as possible indicators, but due to the low frequency of transmissions (every 6$^{th}$ day or more in most cases), it was not possible to get distinctive parameters for each group. It is likely, however, that with the collars that transmit every day, such analysis will prove useful, and the results will serve as a selection tool for selection of denning females. Significant decline in frequency of transmissions from November – December through March also appeared to reflect denning in many of the females, but not all. Similar pattern was reported from studies in the western Hudson Bay and Alaska (Lunn et al 2004, Fischbach et al 2007). A single negative reading was observed for known denning females. A number of explanations is possible for this event. It’s been observed on Wrangel Island that females can break out in January and February if there is a spell of warm weather (Belikov 1993). They might go out and then back into the den. Another possibility is that the den roof becomes very thin or collapses and temperature drops. It’s been observed that in that case female either remained in den, and possibly excavated a new chamber, or moved the family to another, temporary den. Use of maternity dens other than their own was reported in other studies in Svalbard as well as in other areas (Larsen 1976, Ovsyanikov 1998) and their use was more frequent in years with little snow (Uspenski and Belikov 1980). Occupation of temporary dens usually lasted for several days, but could be as long as 30 days (Ovsyanikov 1998).

Activity indices were not as useful in identifying the denning behavior which is reasonable as digging activity may continue in bouts after female enters the den and go on through the winter, as female expands the chamber or scrapes the ice (Larsen 1985, Belikov 1993).

It's worth noting that two out of known denning females had no transmissions within the set period (December 15th to March 1st). A reasonable explanation might be a thick layer of snow on the roof of the den and/or perhaps a peculiarity in location chosen for the den that additionally impeded the signal. In this study, only females that had one or more transmissions were defined as denning and even stricter selection was performed for females used for the distance measurements (three and more transmissions). However, in future studies, one could apply more relaxed criteria and evaluate the females that had no transmissions as possible denning females. One way to confirm their status may be an evaluation of their first and last known positions (spring and fall). Given reasonably good location records proximity of those locations could indicate a den location.

*Non-maternity denning*

Upon evaluation of the telemetry records, it became obvious that some individuals from non-denning and likely non-denning groups, including the females with COYs or yearlings as well as single adult females – spent substantial amount of time in den during the investigated period. Their mean temperature was above $0^0$C and close to that of known maternal females. This corresponds with the earlier findings that females accompanied by yearlings, 2 y. old cubs, as well as subadults and adult males were observed in winter dens when conditions were particularly unfavorable, such as during whiteouts, periods of cold weather and when access to prey is limited, and used den from 2 weeks up to 4 months (Van de Velde 2003, Uspenski 1977, Ferguson et al. 2000). On some occasions yearlings were observed in dens along with COYs (Uspenski 1977, Ovsyanikov 2005). Such use of shelters minimizes thermal stress and energy expenditure and is a great adaptation tool to the tough environmental conditions (Derocher et al. 1990; Van de Velde et al 2003).

Therefore, it's reasonable to assume that many bears are using these shelters during the winter and telemetry signature for such non-maternal denning animals may be quite similar to that of maternity denning female (mean temperature), particularly if the period is sufficiently long and overlaps with the entry and break-out dates and only a few temperature readings are available. In that case it might not be possible to distinguish between maternal and non-maternal females. However, from the available data in this study, it appears that in-den periods for known non-maternal females did not exceed 45 days, and presence of negative temperature readings within Dec.15$^{th}$ - Mar.1$^{st}$ period allowed non-denning classification, despite positive mean temperature.

Collars, transmitting every day, provide more readings allowing a better understanding of females' behavior (length of time in the shelter and a temperature range within the period).

*Entry and breakout dates, length of denning*

It appears that entry and exit dates somewhat vary among the populations across the Arctic. Den entry occurs from late September through mid-October in the western Hudson Bay (Lunn et al 2004), from late September to early November in southern Hudson Bay (earth dens, subsequently covered by snow) (Kolenosky and Prevett 1983) and from the end of October on Wrangel Island, when snow conditions are sufficient to dig a den. In years when the snow accumulation is not sufficient, females utilize the areas of old snow that outlasted through the summer (Uspenski and Kistchinski 1972, Ovsyanikov 1998). On Svalbard, bears have been observed to go on land to dig dens in wind-drifted snow in their preferred denning areas in September – November (Lønø 1970, Larsen 1985). A satellite telemetry study was conducted on collared Svalbard females and the den entry dates were estimated between September 7th and December 12th (Wiig 1995). Part of the population denning on Svalbard is very local and remains in the area year round, but those animals that range might be dependent for arrival on drift ice conditions in late October or November (Lønø 1970), which would be similar to Alaska's coastal zone bears that arrive with ice in late October or early November (Lentfer and Hensel 1980). Thus, obtained entry dates between September 2nd and December 17th appear comparable to the earlier observed range and likely represent data for local as well as for ranging females.

Denning period for a single female on Wrangel Island was observed (on site) to be 183 days (Belikov 1976). For the East Greenland female in maternity den on ice (in two different years), length was estimated at 122 and 156 days based on satellite telemetry data (Wiig et al 2003). And for the Svalbard bears maternity denning ran from 90 to over 197 days, with average length of 153 days, also based on satellite telemetry data (Wiig 1998). Results of the present study correspond with the earlier findings for Svalbard females with an average length of 147 days, but present somewhat wider range (from 84 to 204 days).

Time of emergence also varies from late February (Kolenosky and Prevett 1983, Ovsyanikov 1998, Lunn et al 2004) to mid-March (Smith et al 2007) to the end of April (Lentfer and Hensel 1980) or even early May (Uspenski 1977) and demonstrates a latitudinal gradient (in more southern population emergence occurs earlier). On Svalbard, Larsen (1976) stated that on Nordaustlandet and Kong Karls Land in 1972 most dens were opened and abandoned early - before the 1st of April and Lønø (1970) observed that most dens were abandoned between 10th and 25th of April. These data fits within the results obtained by satellite telemetry - breakout dates were reported between March 2nd and April 27th by Wiig (1995). Similar reports were made by Larsen (1985) and Hansson and Thomassen (1983). Overall, it appears that on Svalbard emergence takes place somewhat later, during the month of April, more similar to the areas of the Russian Arctic. Present study results showed March 28th as a mean break out date (range from February 24 through May 7). Again, while mean date corresponds with the earlier findings, the range appears a bit wider. This difference could reflect individual animal variability, unfavorable weather conditions late in the season or infrequent transmissions due to the failing battery, that didn’t allow to catch an earlier negative temperature transmission. Some studies also noted that the time of breakout didn’t correlate with the age/development of cubs (smallest cubs were found in open dens or dens with thinnest roofs) but rather associated with the establishment of periods of sunny weather (Uspenski and Kistchinski 1972, Uspenski 1977, Hansson and Thomassen 1983).

*Den and area use.*

Different length of time spent near den post-breakout was observed in various subpopulations and/or even in different years: from 2-3 weeks in the southern and western Hudson Bay (Kolenosky and Prevett 1983, Lunn et al 2004) to a month after emergence on Manitoba coast of Hudson Bay (Jonkel et al 1972). On Alaska's North slope families remained at their den sites for 1.5 to 14 (Smith et al 2007). On Wrangel and Herald islands, bear families remained in the open dens from 1 day to 2-3 weeks and dens with the thin roof were abandoned first (Uspenski and Kistchinski 1972, Uspenski 1977, Uspenski and Belikov 1980, Ovsyanikov 1998). In 1972 and 1973 females in Svalbard were seen leaving dens "shortly after emergence", and only 3 families were observed in dens for 12, 17 and 17 days probably due to the bad weather conditions (Larsen 1976). But in later years females were seen near dens for average of 2 weeks (Hansson and Thomassen 1982). Once they broke out, families didn't seem to range further than 100-300 m from den entrances (Uspenski 1977, Smith et al 2007, Hansson and Thomassen 1983, Uspenski and Kistchinski 1972). However, during other studies it was also observed that cubs gradually followed females on longer trips (Hansson and Thomassen 1983, Uspenski and Kistchinski 1972, Uspenski 1977). Rarely females were seen to leave the cubs alone in the den, likely when they are too small to follow her (Hansson and Thomassen 1983, Ovsyanikov 1998). Therefore, it appears that the families spend near den rather variable length of time after breaking out. Local weather conditions, cubs' physical development and possibly – physical conditions of females as well as food availability influence the amount of time spent close to the den. It's been suggested that this post emergence period is critical for developing cubs strength and skills, but represents a heavy toll on females delaying an opportunity to hunt for another 2-3 weeks, while feeding the cubs (Garner et al 1994). Observations suggest that females leave earlier if they are in poor physical condition (Garner et al 1994). However, another study showed that females remained near the den area longer if cubs were not strong enough to follow her (Hansson and Thomassen 1983). Apparently, to conserve energy, females remained inactive most of the time (mean 49.5%) while outside the den (Smith et al 2007). Low activity/movement rates right after den emergence were also observed in satellite telemetry study of two East Greenland female polar bears (Wiig et al 2003). Earlier findings by Mauritzen et al (2001) suggested that the spatial distribution of females doesn't depend or reflect their reproductive state. But even though cubs are likely to travel long distances by April (Lentfer and Hensel 1980, Garner et al 1994), movement rates of cubs in the early post-denning period were observed to be low. Families seen on their way to the sea in late March or early April moved slow, and cubs at first travelled 0.3 to 0.5 km at a time (Jonkel et al 1972). On some occasions cubs were seen riding the females for a while, on land as well as in the water (Uspenski 1977, Jonkel et al 1972, Aars 2010). In this study most of the available collars transmitted every six days, and that introduced some uncertainty to the position of the animal during the first negative temperature transmission. Female could have left shortly after the last in-den transmission and had been outside for 5 days before the next transmission. However, based on field observations, it appears safe to assume that most females spend at least a few days near the den after emergence and that the first negative reading occurs relatively close to the den site. Estimated mean distance of 19.7 km on day 6th after emergence shows that family groups probably don't spend near the den much more than a week. Precision of these estimates can be greatly improved if/when more transmissions are available – collars with higher transmission frequency are employed.

*Distance from den*

For females with cubs, the shortest distances and daily rates of movement were observed during the immediate post-denning period (March 26 – May 1st), when mean distance for March was 26.2 km but increased to 247 km in April (Garner et al 1994). Present study produced similar results with the mean of 34.6 km for the second half of March. However, the range of distances traveled within the first week ranged from 0.3 km to 270 km. This maximum distance could possibly reflect two things: a pelagic female that headed straight out for the ice with the family or a female that lost cubs shortly after emergence and headed alone fast for the feeding grounds. Cubs survival is quite low and was estimated at 55% during the first year (Wiig 1998), and 44% by the age of 20 month (Larsen 1985). Therefore, it's probable, that females that show large traveled distances shortly after emergence are those that lost their cubs and left the denning area quickly.

*Denning locations*

Denning on sea ice in Svalbard is considered to be minimal due to the ice conditions and strong currents (Larsen 1985). However, five mapped dens appeared to be located in the Central Barents Sea (CBS). Seasonal migration of bears with the drifting ice in the fall from south and south-western islands of FJL towards west, south-west and south-east and their return in spring have been reported (Parovshikov 1967 as cited in Uspenski 1977). Therefore, pregnant females headed from FJL could possibly go into den if suitable area of stable ice with enough accumulated snow was found before reaching the islands. It is also possible that these bears are pelagic, belong to the Central Barents Sea (CBS) cluster and spend most of their time on ice. Four of them were initially captured in the CBS and one – on Hopen Island. Overall, a few bears from the Central Barents Sea have been collared and it would be highly beneficial to set out more collars on bears in the area. That would allow a better understanding of their migratory pattern, reproductive ecology and habitat preferences.

Satellite telemetry is a great tool for understanding behavioral and ecological characteristics of the species. Data gathered this way presents both - a great source of knowledge and multiple challenges for the analysis. Accumulation of such information give (or will soon allow) an opportunity for the long-term trend analysis on population level and monitoring of current state as well as a better understanding of behavior of a single animal. Polar bears demonstrate great individual variability in behavior, stemming from their unique ability to adapt to their environmental conditions and collection of such long-term data is essential for understanding, managing and protecting population. A great advantage to this would be setting out more collars transmitting with high frequency (every day) and deploying them in more areas, such as the Central Barents Sea and Franz Josef Land. Presently available data remains to be further analyzed for more precise denning patterns, post-emergence behavior and migratory cycles, while coupled with further field observations.

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# Appendix

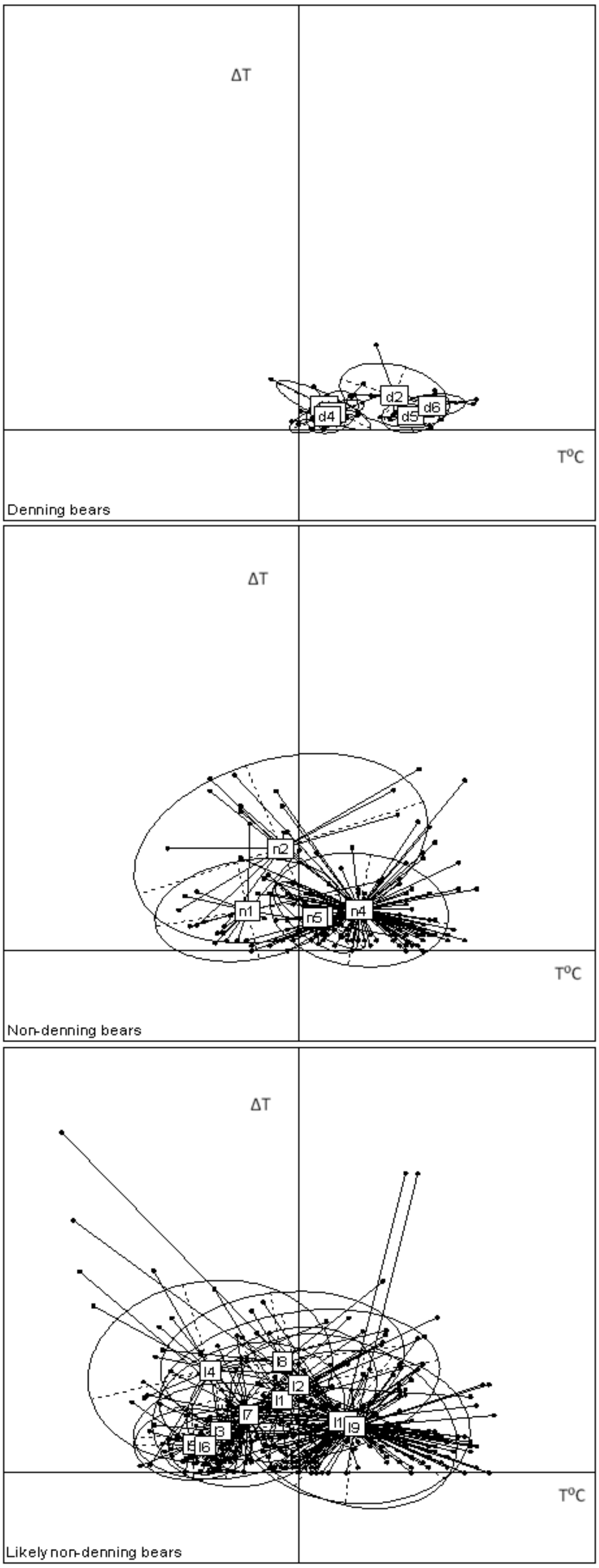


**Figure 1.** Temperature vs. difference in subsequent temperature readings in 3 groups of known denning females.

*The longest lines indicate the largest difference between the subsequent readings, thus showing the wide range of temperatures for that individual. All points are in the upper quadrants as difference is an absolute value. Placement of individual to the right or to the left from the y axes reflects its mean temperature – above or below 0°C. Otherwise, points are randomly scattered.

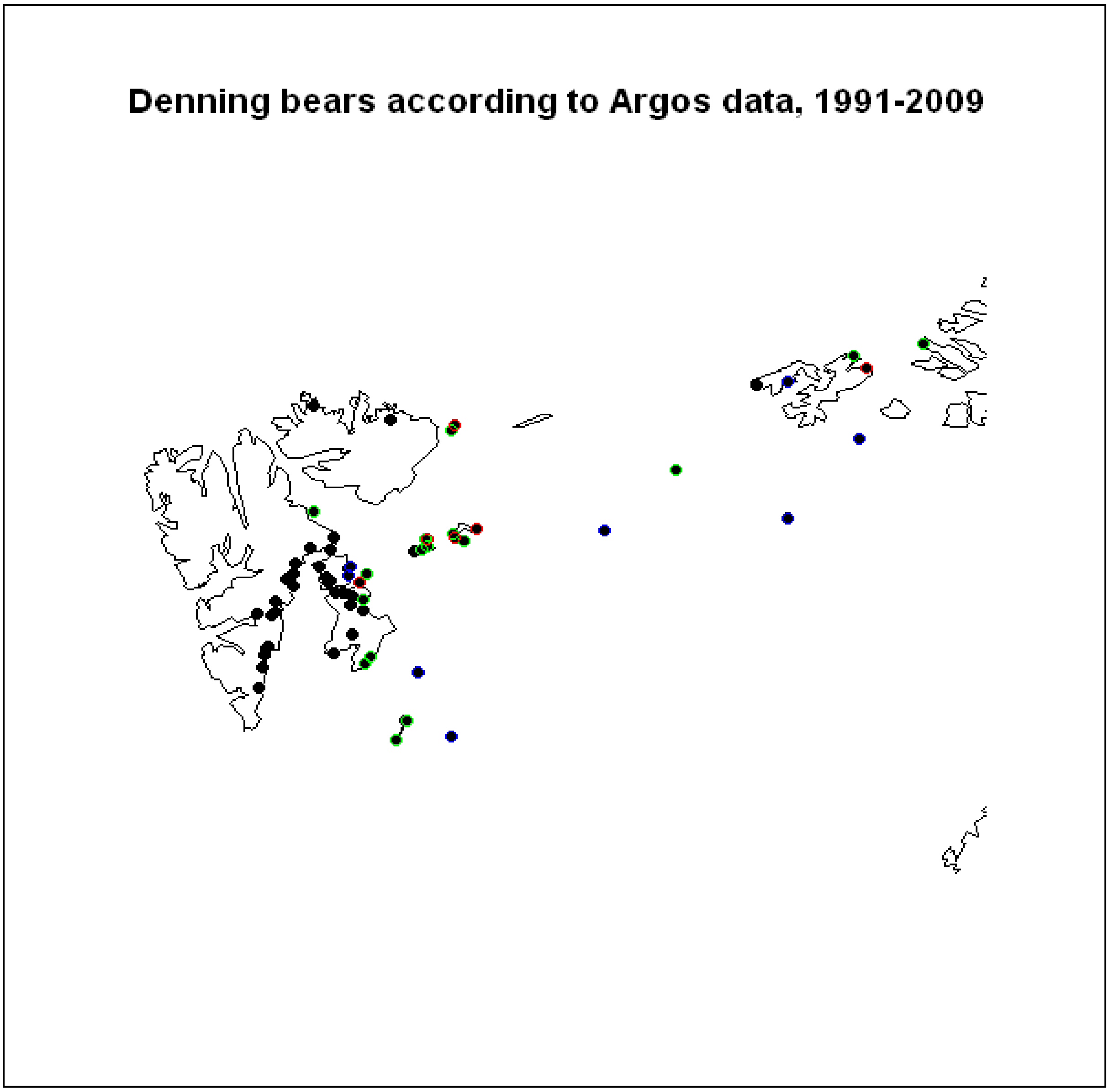


**Figure 2.** Map of 66 denning locations based on satellite telemetry location data (Svalbard – CBS - FJL).

* Bears, captured for the first time in the following areas:
Central Barents Sea - 'blue'
Hopen Island - 'green'
Kongsøya -'red'

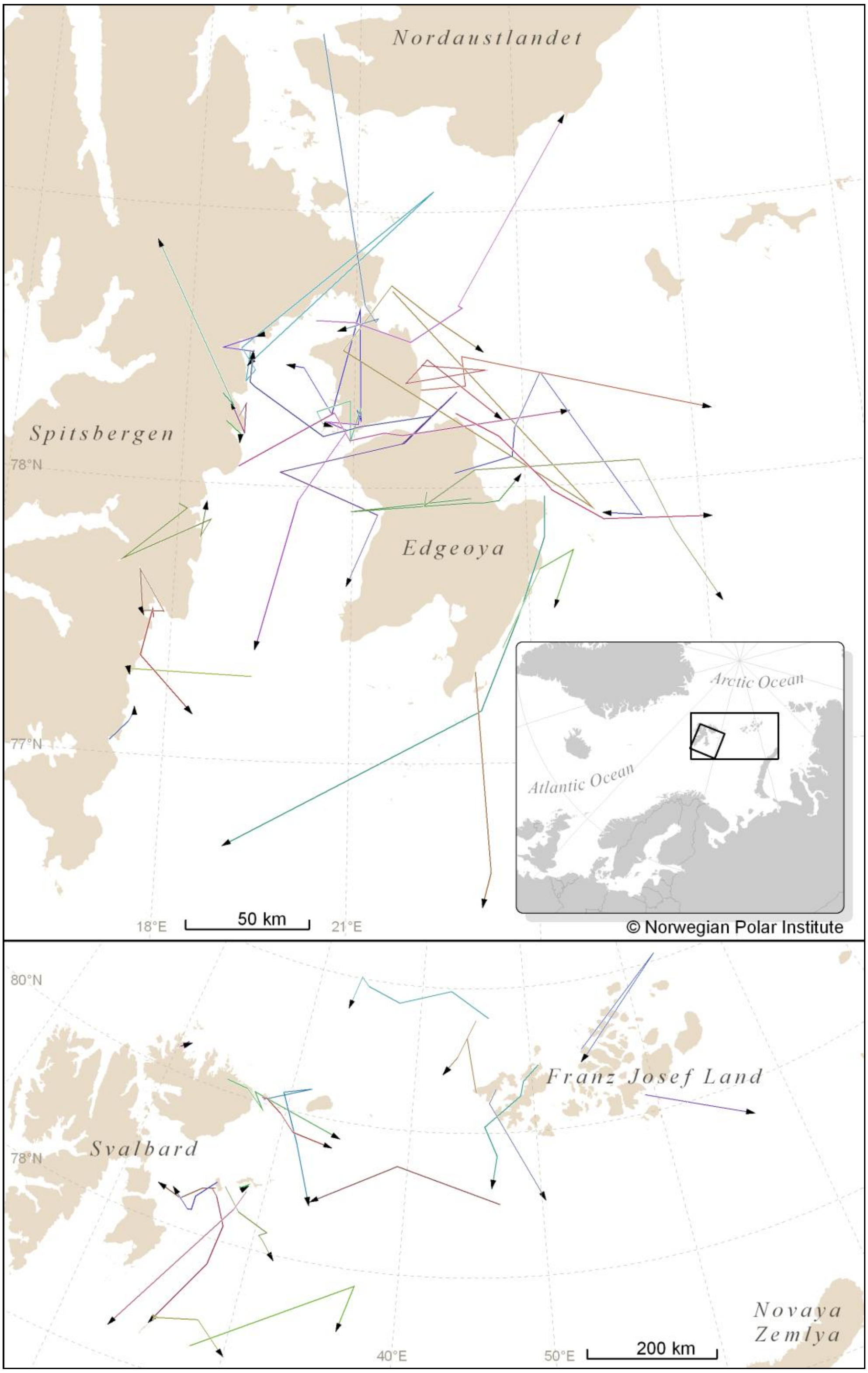


**Figure 3**. Movement of denning females during the first 30 days after emergence.*break in the line indicates a new position reading (maximum 4 readings, at 6-day intervals)

**Table 1.** Data available for the females with known reproductive status for the period from December 15th through March 1st.

| id | categ | year | freq trans | T read (n) | neg T (n) | mean T | min T | max T | neg. T(date) | mean T dif | min T dif | max T dif | pos(n) | T eval |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Fc | 1992 | 6 | 5 | 1 | 4.81 | -4.58 | 9.89 | Feb.27 | 4.75 | 0.92 | 9.82 | 1 | x |
| 2 | Fc | 1994 | 6 | 8 | 0 | 17.18 | 9.18 | 29.57 | n/a | 6.75 | 6.58 | 16.54 | 3 | x |
| 3 | Fc | 1992 | 6 | 12 | 0 | 5.39 | 2.11 | 11.06 | n/a | 3.41 | 0.06 | 8.96 | 4 | x |
| 4 | Fc | 1992 | 6 | 13 | 1 | 4.97 | -1.18 | 15.24 | Feb.19 | 2.68 | 0.12 | 7.39 | 7 | x |
| 5 | Fc | 1997 | 6 | 9 | 0 | 18.69 | 13.74 | 22.99 | n/a | 2.75 | 0.18 | 3.94 | 2 | x |
| 6 | Fc | 2009 | 6 | 8 | 0 | 23 | 18 | 30 | n/a | 4.71 | 2.00 | 7.00 | 2 | x |
| 7 | Fc | 1996 | 6 | 0 | 0 | n/a | - | - | n/a | - | - | - | 0 | - |
| 8 | Fc | 1993 | 6 | ***1*** | 1 | ***-0.28*** | - | - | Jan.20 | - | - | - | 1 | - |
| 9 | Fc | 1996 | 6 | ***1*** | 0 | ***28.89*** | - | - | n/a | - | - | - | 0 | - |
| 10 | Fc | 1998 | 6 | ***1*** | 1 | ***-10.83*** | - | - | Feb.23 | - | - | - | 0 | - |
| 11 | Fc | 1996 | 6 | 0 | 0 | n/a | - | - | n/a | - | - | - | 0 | - |
| 12 | F | 1991 | 4 | 13 | 10 | -4.33 | -19 | 21.31 | - | 12.67 | 0.12 | 35.53 | 5 | x |
| 13 | **F** | 1993 | 6 | 12 | 7 | **0.57** | -24.19 | 23.29 | - | 19.74 | 9.00 | 31.23 | 8 | x |
| 14 | F | 1991 | 4 | 13 | 12 | -13 | -24.28 | 13.5 | - | 8.04 | 1.48 | 17.59 | 12 | x |
| 15 | F | 1993 | 6 | 13 | 10 | -13.27 | -34.56 | 6.66 | - | 19.73 | 1.51 | 39.23 | 9 | x |
| 16 | F | 1992 | 6 | 13 | 13 | -17.19 | -28.08 | -3.32 | - | 5.37 | 0.08 | 13.65 | 15 | x |
| 17 | F | 1993 | 6 | 13 | 13 | -16.13 | -21.92 | -9.45 | - | 5.06 | 0.50 | 13.58 | 12 | x |
| 18 | F | 1992 | 1 | 10 | 8 | -8.50 | -37.01 | 17.1 | - | 11.25 | 0.04 | 39.03 | 8 | x |
| 19 | F | 1993 | 6 | 6 | 3 | -2.80 | -22.92 | 14.2 | - | 21.57 | 0.82 | 37.12 | 3 | x |
| 20 | **F** | 2008 | 1 | 13 | 3 | **9.41** | -38 | 33 | - | 8.80 | 0.00 | 58.00 | 10 | x |
| 21 | **F** | 2008 | 1 | 13 | 3 | **7.63** | -40 | 30 | - | 9.96 | 0.00 | 66.00 | 12 | x |
| 22 | F2y | 1991 | 4 | 11 | 10 | -8.79 | -19.44 | 16.24 | - | 7.85 | 1.41 | 24.67 | 12 | x |
| 23 | Fy | 1995 | 6 | 12 | 8 | -3.71 | -22.32 | 20.3 | - | 19.87 | 1.60 | 35.32 | 8 | x |
| 24 | **Fy** | 1997 | 6 | 6 | 1 | **2.73** | -5.3 | 9.36 | - | 6.47 | 1.37 | 14.66 | 0 | x |
| 25 | **F2y** | 2008 | 1 | 12 | 2 | **10.79** | -11 | 30 | - | 8.27 | 0.00 | 34.00 | 8 | x |
| 26 | **Fy** | 2009 | 1 | 11 | 2 | **9.48** | -10 | 28 | - | 7.61 | 0.00 | 33.00 | 10 | x |
| **Total:** | | | | | | | | | | | | | | **21** |

Table 1 (cont)

Categ – category:

Fc - female with COY(denning)

Fy - female with yearling (non-denning)

F2y – female with 2 y.old (non-denning)

F – single female (likely non-denning)

Freq trans – frequency of transmissions that a collar was set to: everyday (1), every 4th or 6th day.

T read (n) – number of temperature readings within the period, scaled

neg T (n) – number of readings below 0 degrees Celsius

mean T – mean temperature during the evaluated period

min T – lowest transmitted temperature during the evaluated period

max T - highest transmitted temperature during the evaluated period

neg. T(date) – date of the reading below 0 degrees Celsius for denning females

mean T dif – mean value for successive temperature differences ($t_1$-t )

min T dif – lowest value between successive temperature transmissions

max T dif – highest value between successive temperature transmissions

pos(n) – number of position transmitted within the period, scaled

T eval – marks whether the bear was used for further temperature analysis