POLAR BEAR RESEARCH IN ALASKA

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INTRODUCTION

Since the 13th Working Meeting of the Polar Bear Specialist Group the U.S. Geological Service (USGS) has seen the completion of many research projects and the start of many new ones. Much has been accomplished and yet we have new challenges awaiting us. This report summarizes our focal questions and progress in those areas.

The spring of 2005 was the fifth year of a five-year effort to determine the current population size of polar bears in the southern Beaufort Sea through mark-recapture methods. We continue to improve analysis techniques and populations estimations for the polar bear population in the Beaufort Sea and assist the

Canadian Wildlife Service with the population in Hudson Bay. We have advanced methods of using radio-telemetry data to delineate wildlife populations. This has allowed us to understand the distribution of polar bear populations that occur in Alaska and adjacent Canada. A practical application of this work includes helping resource managers to allocate harvest of polar bears in the Beaufort Sea region. Also, our new estimates of population density have allowed us to revisit the potential risks and effects of oil spills on polar bears in the Beaufort Sea. In late 2003 we were awarded funding to investigate the effects of climate change on polar bears in Alaska. Progress has also been made in the modeling of polar bear and sea ice relationships and preliminary results were included in conference proceedings published in early 2004.

We continued to develop methods of protecting maternal dens by completing our studies of Forward-looking Infrared (FLIR) sensors as a means for detecting denning polar bears. We have refined our understanding of denning habitats in the central Alaskan coast, and extended our map of denning habitats to include those on the Arctic National Wildlife Refuge. Likewise, we are evaluating Interferometric Synthetic Aperture Radar (IFSAR) for delineating polar bear den habitat in the National Petroleum Reserve – Alaska. Rare opportunities to observe the post-emergence behavior of polar bear families at den sites have presented themselves. These observations have allowed us to begin to understand the range of natural behaviors and some responses to human activity. We have worked with private agencies and industry to assess industrial sounds and vibrations received in artificial polar bear dens.

During winter and spring of 2003 we and our colleagues with the Canadian Wildlife Service encountered three rare events of intraspecific killings by polar bears. These predation events appeared to be nutritionally motivated and, we suspect, may be tied to changes in sea ice quality due to climate warming. A study of establishing paternity with genetic fingerprinting suggests reproductive patterns of polar bears may not be that different from other Ursids. Preliminary analysis suggested that a relatively small number of the possible males dominate most the breeding. A study on the trophic levels of different foods consumed by polar bears is nearly complete, as is an investigation of the influence of diet on biomagnification of organochlorines in polar bears. Finally, we are continuing the collection and long term archival of marine mammal tissues, including polar bears.

New studies are also slated to begin in 2005. We have continued to search for funding sources to test the feasibility of Radio Frequency Identification (RFID) tags as an alternative marking system for capture-recapture studies. We have, through collaboration with the University of Alaska and the Alaska Department of Fish and Game, secured new funding for this potentially valuable project. We also are collecting an array of tissue samples for a new project to develop methods for determining health and immune status of free ranging polar bears and examining “emerging” contaminants.

WESTERN HUDSON BAY POPULATION ANALYSIS

The polar bear population in Western Hudson Bay (WHB) is the most intensively studied polar bear population in the world; population metrics and capture-recapture data have been collected consistently since the early 1980’s (Ramsay and Stirling 1988). In addition to the wealth of scientific data, unique ecological aspects make WHB an ideal area to study polar bear biology and population dynamics. First, during the summer months Hudson Bay is ice-free and the bears are confined to a limited geographic area to which they show a high degree of fidelity (Derocher and Stirling 1989). Also, as one of the southern-most polar bear populations, population dynamics in WHB may be among the first to respond to climatic warming in the Arctic ecosystem (Derocher et al. 2004, Gough et al. 2004).

Several articles have appeared in the recent scientific literature concerning the status of WHB polar bears in relation to climate change (e.g. Stirling and Derocher 1993, Stirling et al. 1999, Stirling et al. 2004). The prevailing view of the research community is that the WHB population is under increasing nutritional stress. A causal link is hypothesized between this stress and a decrease in the polar bears’ ability to access their primary prey, ringed seals (*Phoca hispida*). Decreased access to ringed seals is presumably related to earlier ice breakup, which forces the bears onto land earlier and prolongs their seasonal fast (Stirling et al. 2004). However, not all indicators of the status of bears in WHB suggest a struggling population. Like many communities in the Canadian Arctic, Churchill, Manitoba has experienced an increase in the number of bears that visit the town prior to freeze-up each fall. Some might conclude, more numerous bear sightings in town suggest an increasing population.

The most recent quantitative analysis of WHB capture-recapture data was published nearly 10 years ago (Lunn et al. 1997). In 2005 the Canadian Wildlife Service (CWS), in collaboration with the U.S. Geological Survey (USGS), completed a comprehensive analysis of the WHB capture-recapture data for the period 1984-2004. This analysis includes data collected by the CWS as part of their ongoing capture-recapture study, as well as data collected by the Manitoba Department of Conservation for bears handled in the vicinity of Churchill.

The 2005 WHB population analysis consisted of 3 main stages: (1) exploratory data analysis (EDA); (2) goodness-of-fit (GOF) assessment; and (3) open population capture-recapture analysis and abundance estimation. The primary purposes of the EDA were to ensure quality control, to establish an intuitive understanding of major patterns in the data (Tukey 1980), and to revisit the various ecological metrics that have been reported for the WHB polar bear population (Stirling et al. 1999). The EDA did not reveal any major departures in the published ecological metrics that have been used as indicators of the WHB population status.

The GOF analysis, performed in programs RELEASE (Burnham et al. 1987) and U-CARE (Choquet et al. 2002), looked for major patterns in the data, tested whether the data met the standard capture-recapture modeling assumptions (Pollock et al. 1990), and identified a suitable "global" model. GOF also estimated the variance inflation factor $\hat{c}$, which adjusts variance estimates to account for un-modeled overdispersion in the data (White et al. 2001). After partitioning the data by age and sex (Sendor and Simon 2003), the GOF analysis did not identify any unmanageable lack of fit in the data.

The capture-recapture analysis, performed using program MARK (White and Burnham 1999) and open population software in S-PLUS (Amstrup et al. 2005), consisted of a survival analysis using conditional open population (e.g. Cormack-Jolly-Seber [CJS]) models per Lebreton et al. (1992), followed by abundance estimation using a Horvitz-Thompson (HT) type estimator (McDonald and Amstrup 2001). Symmetric 95% confidence intervals were derived using the method of Laake (Taylor et al. 2002). Inference regarding survival rates was based on the CWS-only portion of the dataset, as these data were collected with the goal of minimizing violations of capture-recapture assumptions (Lunn et al. 1997). Inferences regarding population size were based on the integrated CWS and Manitoba Conservation datasets because we believe that handlings in Churchill vicinity accessed a portion of the WHB population (e.g. subadult males) under-represented in the CWS samples.

The analysis culminated in a CJS model with 6 parameters for apparent survival probability and 22 parameters for capture probability. Apparent survival rates for prime adult (5≤age≤19) males and females were stable over the course of the study at 0.893 (SE = 0.012) and 0.929 (SE = 0.010), respectively. A statistical correlation was established between the timing of WHB breakup and survival rates for all other age classes (0≤age≤1, 2≤age≤4, age≥20) (Fig. 1). This provides quantitative evidence for a population-level effect of the climate-related nutritional stressors that have been identified in the WHB population (Derocher and Stirling 1996, Stirling et al. 2004).

Following the survival analysis, the low-AIC_c model for the CWS-only dataset was generalized to accommodate differences between the CWS and Manitoba Department of Conservation sampling protocols. A parsimonious model was selected for inference regarding capture probabilities (and ultimately abundance). There was a marked increase in the capture probability of bears handled by Manitoba Conservation vs. bears captured exclusively by the CWS, presumably related to geographic effects as well as the behavioral response of more frequent returns to the town of Churchill following an initial visit (this effect was strong for subadults, non-existent for prime adults).

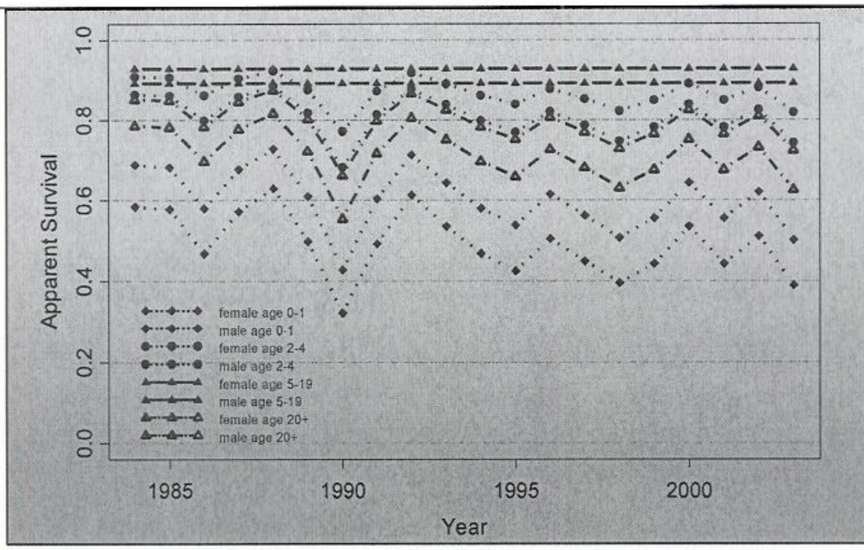


Figure 1. Estimates of sex- and age-specific apparent survival and 95 % CIs for polar bears in WHB.

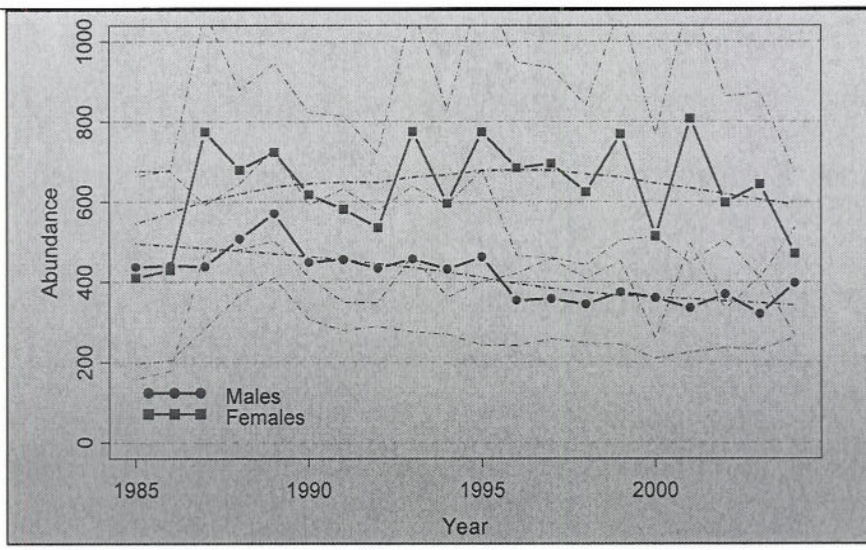


Figure 2. Sex-specific estimates of size, 95 % CIs, and trend for the WHB population of polar bears derived by applying a HT type estimator to capture probabilities estimated by the low-AIC CJS model for the combined CWS and Manitoba Conservation dataset.

While the number of females has remained relatively stable (with perhaps a slight decline in recent years), the male component of the WHB population has been declining since the late 1980's (Fig. 2). Possible explanations for this phenomenon are: (1) increased ecological sensitivity of males to less spring foraging as a result of earlier ice breakup; and (2) sexual bias in mortality due to hunting (approximately 70% of the bears harvested from the WHB population are male). The post-1990 downward trend in WHB population size was evident in every reasonable CJS model considered, as well as several types of models not reported here (e.g. Jolly-Seber lambda estimation methods [Pradel 1996], an *ad hoc* implementation of the robust design [Kendall et al. 1997], and the Manly-Parr with age model [Manly et al. 2003]).

The unequivocal conclusion of this analysis is that the size of the WHB polar bear population has been gradually decreasing for years. The WHB population size declined from about 1200 individuals in 1988 to about 1000 individuals in 2004 (Fig. 3). It is also worth noting that, while the average population size for 2000-2004 was 964, the average population size for this period based on the low-AIC_c model for the CWS-only dataset was 798 (Fig. 3).This population decline is consistent with changes in vital rates (e.g. survival) observed in the current and previous analyses.

Furthermore, the availability of both rigorous capture-recapture data (collected by CWS) and reliable records regarding which individually-identified bears visit the town of Churchill (collected by Manitoba Conservation) offers a unique opportunity to resolve the apparently contradictory phenomena of a declining population and an increasing number of bears being seen near communities. In this case, the answer is simply that a larger portion of the WHB population is visiting the town of Churchill each year. This response makes biological sense: if the population is experiencing increasing nutritional stress, more bears will be lured into the Churchill vicinity by the odor (and potential reward) of food in the town dump.

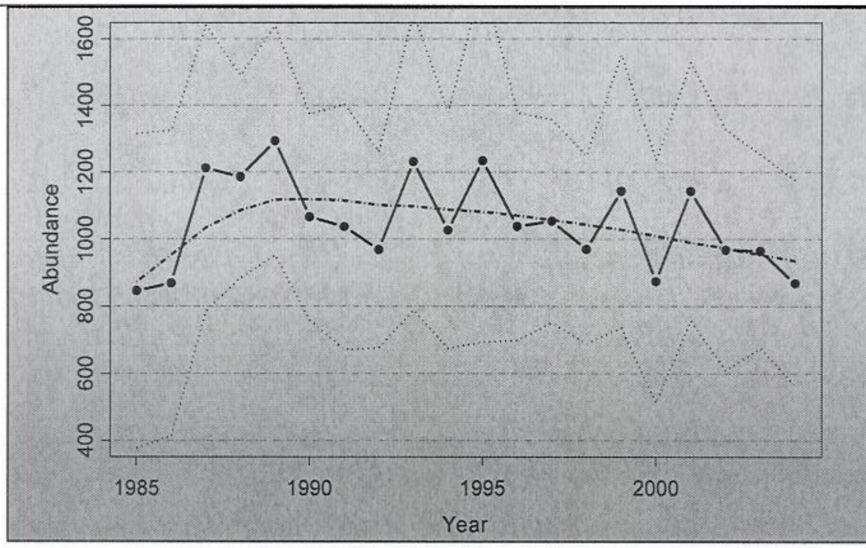


Figure 3. Estimates of abundance and 95 % CIs for the WHB polar bear population. This chart illustrates a decline from about 1200 individuals in 1988 to about 1000 individuals in 2004.

USING RADIOTELEMETRY TO ALLOCATE HARVESTS AMONG POLAR BEAR STOCKS OCCUPYING THE BEAUFORT SEA REGION

Effective implementation of the "Polar Bear Management Agreement (Agreement) for the Southern Beaufort Sea" (Agreement; Treseder and Carpenter 1989, Nageak et al. 1991) between Inupiat hunters of Alaska and Inuvialuit hunters of Canada is dependent on the best information on the discreteness and overlap of neighboring polar bear populations. The three recognized populations in the Beaufort and Chukchi Seas, northern Beaufort (NBS), southern Beaufort (SBS) and Chukchi Sea (CS) (Lunn et al. 2002) have traditionally been presented with hard boundaries that do not account for this overlap. With this study we improve the efficacy of the Agreement through a new analytical procedure that quantifies the degree of overlap between adjacent populations and allows for better management of the harvest of polar bears in the Beaufort and Chukchi Seas.

We analyzed locations of satellite radio-collar (PTT) equipped polar bears captured by scientist with the USGS and the Canadian Wildlife Service between 1985 to 2003 in the Beaufort and Chukchi Seas. Our study area was a prediction grid of 660 square cells (5 km on each side) extending from west of Wrangel Island (Russia) east to Banks Island (Canada), and from near the North Pole southward into the Bering Sea. We used a 2-dimensional Gausian kernel density estimator to calculate individual home ranges and Ward's clustering algorithm (Johnson and Wichern, 1988; Norusis, 1994) to assign membership to one of three populations. We then calculated population ranges by combining relocations of all members of each population and smoothing and scaling the raw frequencies of locations in each population with a 2-D Gaussian kernel density estimator. Relative probabilities that a member of each population would occur in each cell of our grid were calculated by scaling kernel density estimates for each cell for each population so that they summed (integrated) to 1. The relative probability of occurrence of bears from each population in each grid cell was calculated using an estimate of the size of each population. Multiplying scaled density estimates of each population within each cell by the estimated size of each population yielded expected numbers of bears from each population in each grid cell. We tested for seasonal differences by calculating the relative probabilities and associated standard errors for each cell on an annual (year-round) basis, and for the fall (September – January) and winter (February – May) - seasons during which bears are most frequently hunted. We tested for differences between annual and seasonal relative probabilities by calculating *t*-like test statistics for each cell in the grid. Grid cells in which these values exceed 1.96 revealed significant differences between the annual and seasonal values at the 0.05 level.

We used 15,308 locations of 194 female polar bears wearing satellite radio collars to delineate populations and estimate encounter probabilities. We used 6151 satellite relocations from 92 PTT-equipped bears that clustered into the CS population, 6410 locations from 71 SBS bears and 2747 locations from 31 NBS bears. Probability values allowed distributions of each population to be illustrated by 50% and 95% kernel estimates of the intensity with which bears from each population used different portions of the study area (Fig. 4). No "t" values were >1.96. Hence, significant differences between seasonal and annual

P's were absent. Relative probabilities of these three populations varied greatly across the study area (Fig. 5). Near Barrow, Alaska, 50% of harvested bears are predicted to be from the Chukchi Sea population and 50% from the southern Beaufort Sea population (Fig. 5 and 6a). Nearly 99% of the bears taken by Kaktovik hunters are from the SBS (Fig. 6b). At Tuktoyaktuk, Northwest Territories, Canada, 50% are from the southern Beaufort Sea and 50% from the northern Beaufort Sea population (Fig. 6c), while bears harvested near Baillie Islands are mostly from the NBS population (Fig. 6d).

Coefficients of Variation (CVs) for harvest probability estimates were small across most of our study area, lending credence to these estimated probabilities (Fig. 6). The probability of occurrence of bears from each population can be displayed on a very fine scale for each cell in our grid (Fig. 6) or as maps with contour lines that delineate population subunits (Fig. 7). This new analytical approach allows previously accepted population management units to be subdivided in ways that will greatly improve the accuracy of allocation of harvest quotas among hunting communities and jurisdictions while assuring that harvests remain within the bounds of sustainable yield.

Amstrup, S.C., G.M. Durner, I. Stirling, and T.L. McDonald. 2005. Using radiotelemetry to allocate harvests among polar bear stocks occupying the Beaufort Sea region. ARCTIC 00:000-000, in press.

Amstrup, S.C., T.L. McDonald, and G.M. Durner. 2004. Using Satellite radio-telemetry data to delineate and manage wildlife populations. Wildlife Society Bulletin 32:661-679.

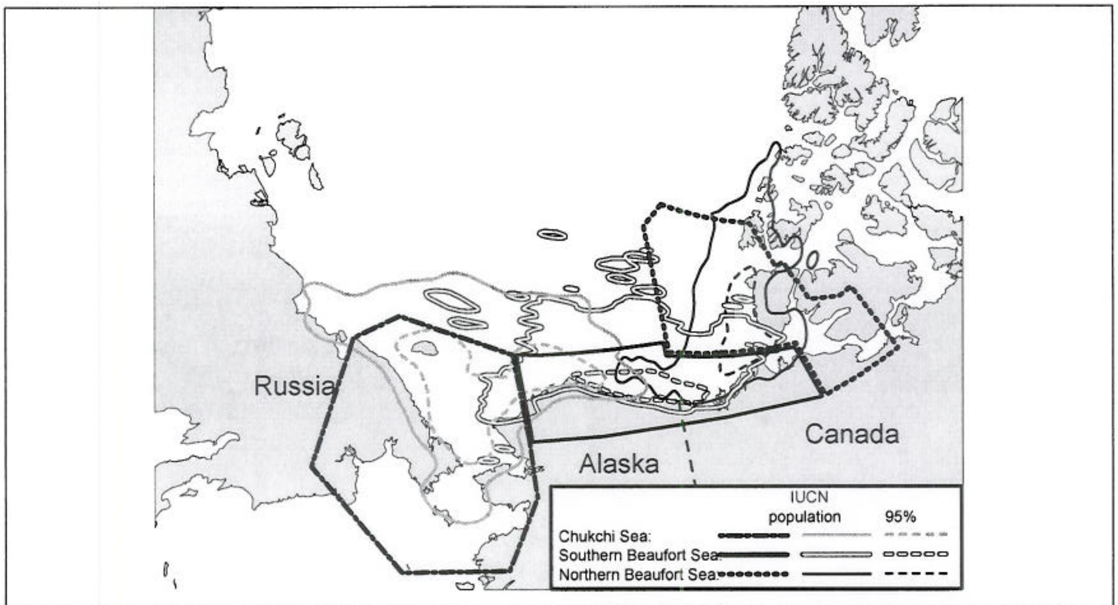


Figure 4. Intensity of use or boundary contours (50% and 95%) for 3 populations occupying the Beaufort Sea region. Also shown are previously identified boundaries for the same populations (Lunn et al., 2002).

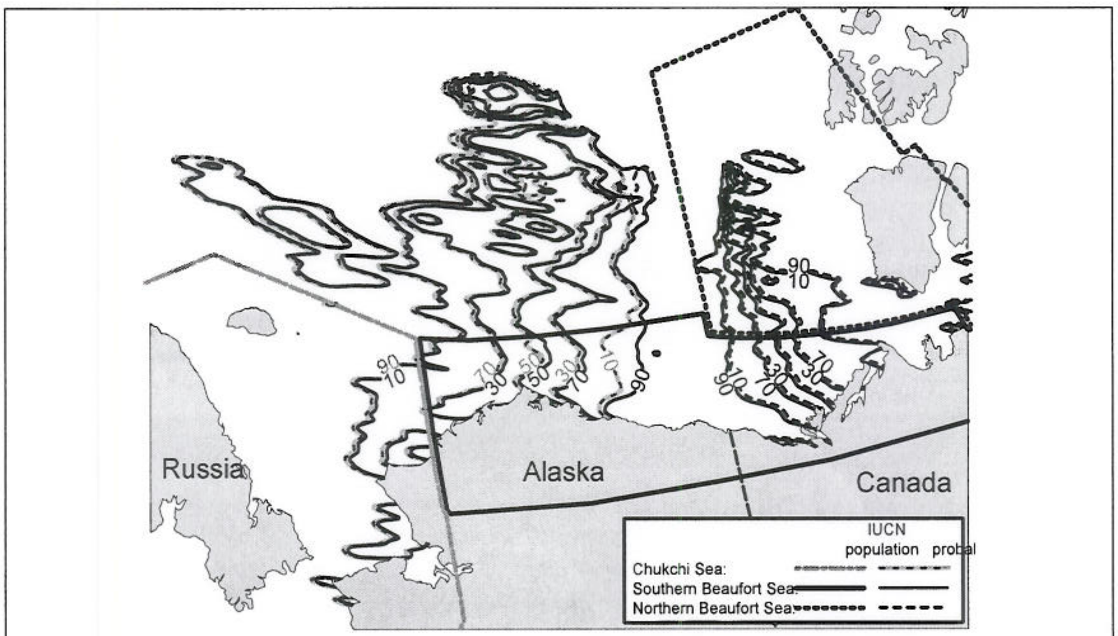


Figure 5. Contours of the relative probability of occurrence for members of 3 populations of polar bears identified from radiotelemetry data in the Beaufort Sea region.

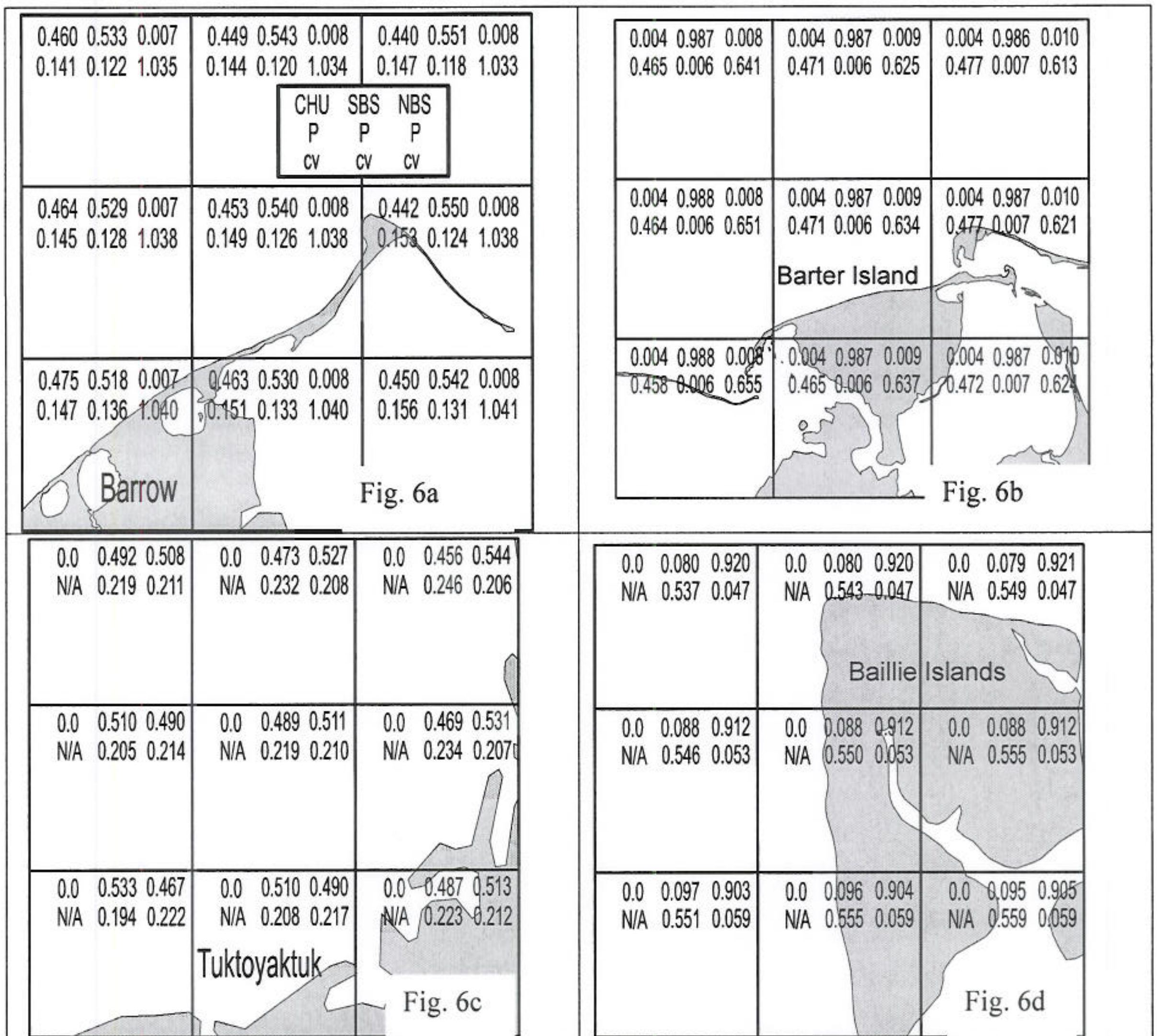


Figure 6. Estimated probabilities (p_i) and coefficient of variation (cv) of harvesting a polar bear from each of 3 populations in individual grid cells near Barrow (a), Barter Island (b), Tuktoyaktuk (c), and Baillie Islands (d).

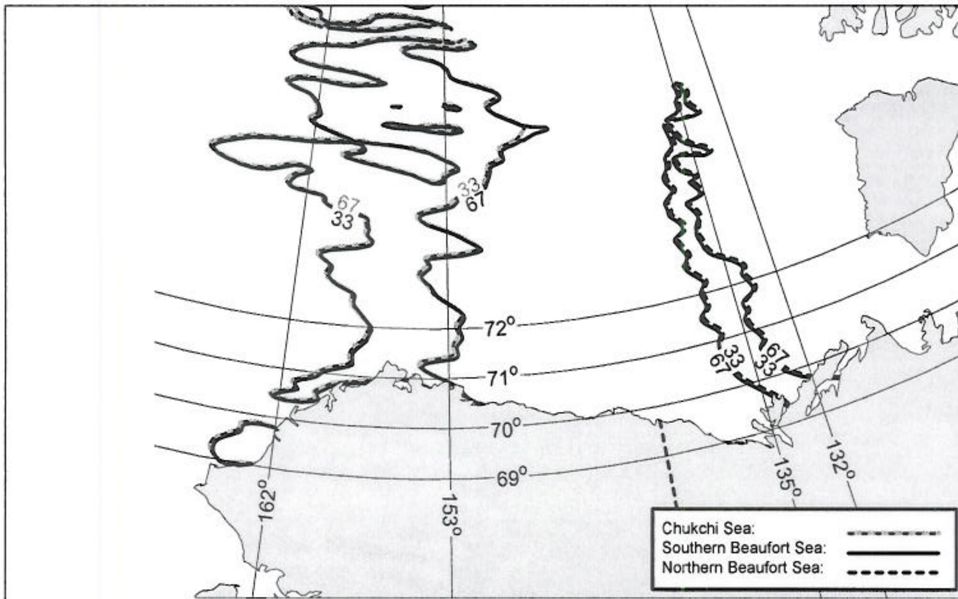


Figure 7. Example hypothetical polar bear hunting subunit boundaries in the SBS based upon 50% relative probabilities. Bears taken between 135° and 153° longitude would be classified as SBS polar bears, and would be allocated to the SBS harvest quota. Only half of the bears taken between 153° and 162° and between 132° and 135° would be allocated to the SBS harvest quota.

ESTIMATING POTENTIAL EFFECTS OF HYPOTHETICAL OIL SPILLS ON POLAR BEARS

Polar bears are most common near the continental shelf, an area also preferred for hydrocarbon exploration and development. We used our ability to predict polar bear occurrence (see previous section) to estimate the impact of oil released by hypothetical spills from the existing North Star Oil production facility, and the site of the proposed Liberty production facility, in the central Beaufort Sea. We estimated the number of bears, and standard errors, likely to occur in each 1.00 km^2 cell of a grid superimposed over our study area. Oil spill footprints for September and October, the times during which we hypothesized effects of an oil-spill would be worst, were estimated using real wind and current data collected between 1980 and 1996. We used ARC/Info software to calculate overlap (numbers of bears oiled) between oil-spill footprints and polar bear grid-cell values.

Numbers of bears potentially oiled by a 5912 barrel spill ranged from 0 to 27 polar bears for September open water conditions, and from 0 to 74 polar bears in October mixed ice conditions. Median number of bears oiled by the 5912 barrel spill from Liberty in September and October were 1 and 3 bears; equivalent values for NorthStar were 3 and 11 bears. Calculated variances of estimated bear densities were very low, and essentially all variation among oil spill scenarios was the result of differences among those scenarios and not the result of variation in the bear data. In October, 75% of trajectories from the 5912 barrel spill at Liberty oiled 9 or fewer bears while 75% of the trajectories affected 20 or fewer polar bears at Northstar. Northstar Island is nearer the flaw zone than Liberty, and is not sheltered from deep water by barrier islands. Those characteristics bring more polar bears into close proximity with the island and also would allow oil to spread more effectively and more consistently into surrounding areas. By comparison, oil spills at Liberty were much more erratic in the areas they covered and the numbers of bears impacted. Hence, larger numbers of bears were consistently exposed to oil by North Star simulations than those modeled for Liberty. This difference was especially pronounced in October spill scenarios (Figures 8 and 9). In October, the land fast ice, inside the shelter of the islands and surrounding Liberty, dramatically restricted the extent of most oil spills in comparison to North Star which lies outside the barrier islands and in deeper water. At both locations, oil-spill trajectories affected small numbers of bears far more often than they affected larger numbers of bears. At Liberty, the number of bears affected dropped off much more quickly, however, than they did at North Star. From the standpoint of polar bears, the proposed Liberty Island production site involves less risk than the existing facility at North Star Island.

Amstrup, S.C., G. M. Durner, and T.L. McDonald. 2005. Estimating potential effects of hypothetical oil spills on polar bears. In prep.

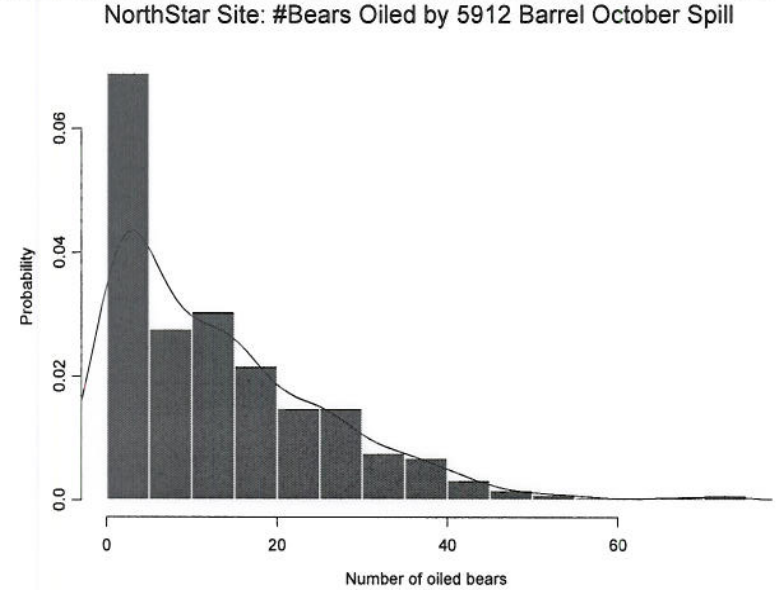


Figure 8. Numbers of bears estimated to be oiled by simulated oil spills from the North Star site during the month of October. Shown here is the frequency histogram resulting from 499 simulated spills (trajectories) of 5912 barrels of crude oil. October conditions were predominated open and refreezing sea-water and mixed new and older ice.

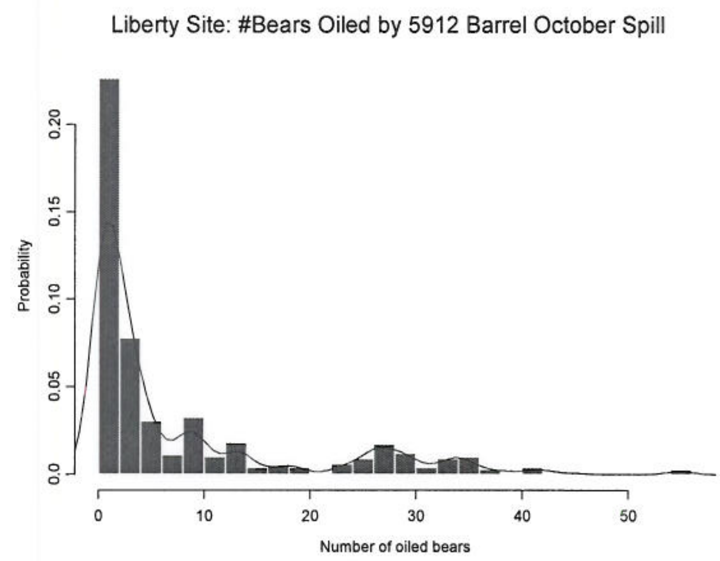


Figure 9. Numbers of bears estimated to be oiled by simulated oil spills from the Liberty site during the month of October. Shown here is the frequency histogram resulting from 495 simulated spills (trajectories) of 5912 barrels of crude oil. October conditions were predominated by open and refreezing sea-water and mixed new and older ice.

USE OF SEA ICE HABITAT BY FEMALE POLAR BEARS IN THE BEAUFORT SEA

Polar bears depend on ice-covered seas to satisfy life history requirements. Modern threats to polar bears include oil spills in the marine environment and degradation of the sea ice environment as a result of climate change. Managers need practical models that explain the distribution of bears in order to assess the impacts of these threats. Here, we explored the use of discrete choice models to describe habitat selection by satellite radio-collared female polar bears in the Beaufort Sea.

We analyzed 1780 satellite-radio locations from 53 polar bears, collected from 1997 – 2001, sea ice data derived from the National Ice Center and the Canadian Ice Service charts, and ocean depth data. Each bear location was compared to approximately 100 available random locations. Using stepwise logistic regression we generated resource selection models of habitat use for four seasons. We set the critical level of covariate entry as $\alpha \leq 0.1$ for the adjusted score χ^2 (Klein and Moeschberger 1997). Each forward selection step was preceded by a backward removal step, where the variable with the smallest Wald χ^2 value was dropped from the model, provided that $\alpha > 0.1$. We performed cross-validation of the final models by creating a map of RSF values for each season and comparing this map to the distribution of an independent source of polar bear location data.

Models generated for each of four seasons confirmed complexities of habitat use by polar bears and their response to numerous factors (Table 1). Bears preferred shallow water areas where different ice types intersected. Variation among seasons was reflected mainly in differential selection of total ice concentration, ice stages, floe sizes, and their interactions. Distance to the nearest ice interface was a significant term in models for three seasons. Water depth was selected as a significant term in all seasons, possibly reflecting higher productivity in shallow water areas.

Our cross-validation indicates close concordance of an independent set of polar bear locations with RSF derived from an average of sea ice conditions during this study. In every season, the majority of polar bear locations fell within the highest RSF regions (Fig. 10). This preliminary test indicates that seasonal RSF models can predict polar bear distribution based on prior sea ice charts and bathymetry data. This greater understanding of polar bear's sea ice preferences is an important step in understanding

how climate change will influence the distribution of polar bears in Alaska.

Durner, G.M., S.C. Amstrup, R. Nielson, and T.L. McDonald. 2004. Using discrete choice modeling to generate resource selection functions for female polar bears in the Beaufort Sea. Pages 107 – 120 *in* S. Huzurbazar, ed., Proceedings of the 1st Conference on Resource Selection Modeling. January 2003, Laramie, Wyoming.

Table 1. Seasonal discrete choice models predicting relative probability, w(x), of an adult female polar bear selecting a point in the landscape characterized by x, in the Beaufort Sea, 1997 – 2001.

Season	Model (standard errors are in parentheses below coefficients)
Spring	$w(x) = \exp\{-0.0002402(\textit{depth}) + 0.52481(\textit{vastfloe}) + 3.99265(\textit{totcon})\}$
Summer	$w(x) = \exp\{-0.01085(\textit{edge}) + 6.58263(\textit{oldice}) - 4.93599(\textit{oldice}^2)\ 0.0003382(\textit{depth}) + 1.21442(\textit{firstyr}) + 4.52479(\textit{youngice}) - 0.29138(\textit{edge*youngice})\}$
Autumn	$w(x) = \exp\{-0.00152(\textit{depth}) - 0.02968(\textit{edge}) + 3.99265(\textit{totcon}) + 0.000000231511(\textit{depth}^2) - 2.70505(\textit{totcon}^2)\}$
Winter	$w(x) = \exp\{-0.00170(\textit{depth}) + 0.000000349299(\textit{depth}^2) + 0.44398(\textit{vastfloe}) + 1.94584(\textit{youngice}) - 0.00524(\textit{edge}) + 0.47312(\textit{firstyr})\}$

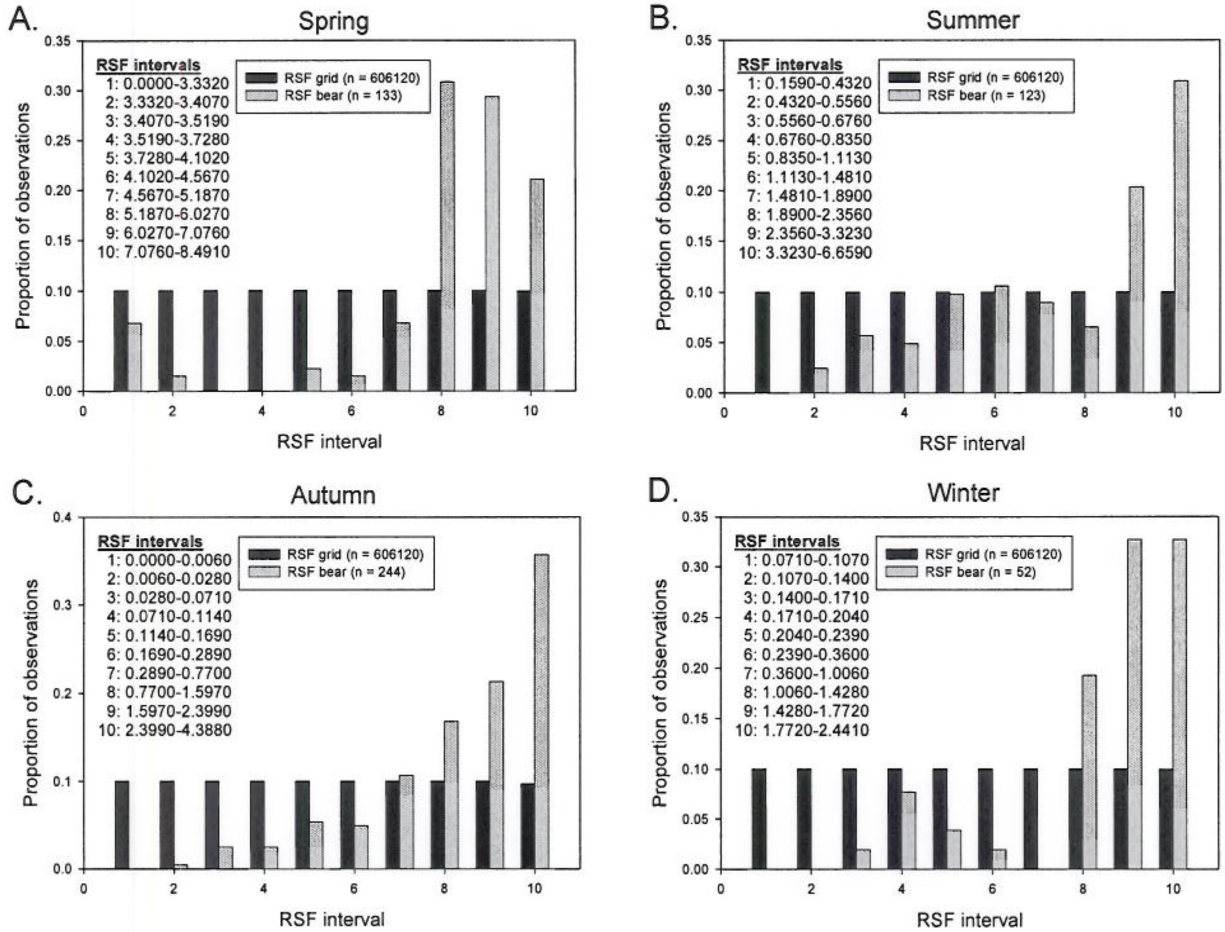


Figure 10. Comparing the seasonal distribution of RSF values in the Beaufort Sea to RSF values at known polar bear locations during 2002. Grid RSF values were calculated from averaged ice data derived from NIC and CIS charts between 1997-2001.

DETECTING DENNING POLAR BEARS WITH FORWARD LOOKING INFRA-RED IMAGERY (FLIR)

Polar bears give birth in snow dens in mid winter, and remain in dens until early spring. Survival and development of neonates is dependent on the stable environment within the maternal den. In Alaska, petroleum related activities currently span approximately 200 km of the Alaskan Beaufort Sea coastal area. New and proposed developments are expected to dramatically expand the area influenced by petroleum activities. These activities are a potential threat to denning polar bears, especially as they might disturb denning females.

To help manage and mitigate potential disruptions of to polar bear denning, we tested the ability of Forward Looking Infrared (FLIR) viewing devices to detect the heat signature of maternal polar bear dens. We tested this concept by flying transects over habitat containing known dens with FLIR equipped aircraft. We recorded flight and weather conditions at each observation and tallied whether or not the den was detected.

We viewed bank and bluff habitat features in which known dens were located with a FLIR Safire II mounted on the nose of a Bell 212 helicopter (Fig.11). Transects were flown at approximately 800 ft AGL and 40 kts. To avoid interference from solar warming of the landscape, we attempted to fly transects at night or during civil twilight of the Arctic winter. Transects were ground referenced by GPS, and all were video recorded. Transects included other thermal signatures (hotspots) known not to be dens. We also recorded verification flights during which the helicopter hovered over each hotspot at low altitude and varying view angles. We visited most dens multiple times and noted whether known dens were detectable.

We conducted FLIR surveys, between 1999 – 2001, on 23 known polar bear dens on 67 occasions (1 to 7 times each; Fig. 12). Four dens were never detected (17%), but 3 of those only were visited under marginal conditions. Nine dens were detected on all visits and 10 dens visited more than once were detected on some flights and not on others (Fig.12). Detection was dependent on weather conditions and solar radiation. For every one-degree (C) increase in temperature dew-point spread, the odds of detecting a den increased 3X. We were 4.8X more likely to detect a den when airborne moisture (snow, blowing snow, fog etc.) was absent than when it was present, and we were approximately 28X more likely to detect a den at night than we were after sunrise. Our data suggest some dens never will be detectable with FLIR. Conversely, we feel FLIR surveys conducted during conditions that maximize odds of detection will locate most dens most of the time and can be an important management/mitigation tool.

Amstrup, S.C., G. York, T.L. McDonald, R. Nielson, and K. Simac. 2004. Detecting denning polar bears with forward looking infra-red imagery (FLIR). BioScience 54:337-344.

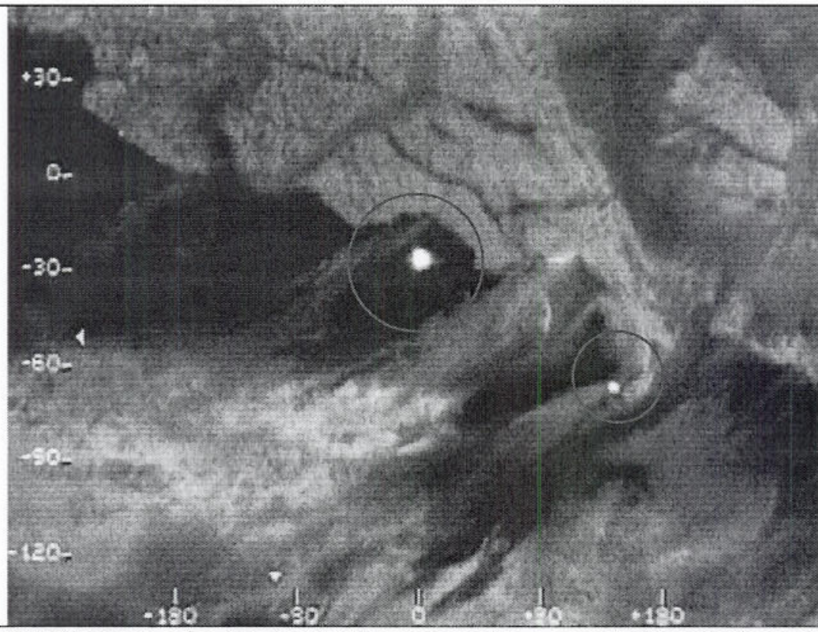


Figure 11. FLIR image of a two polar bear dens in a coastal bank in northern Alaska,

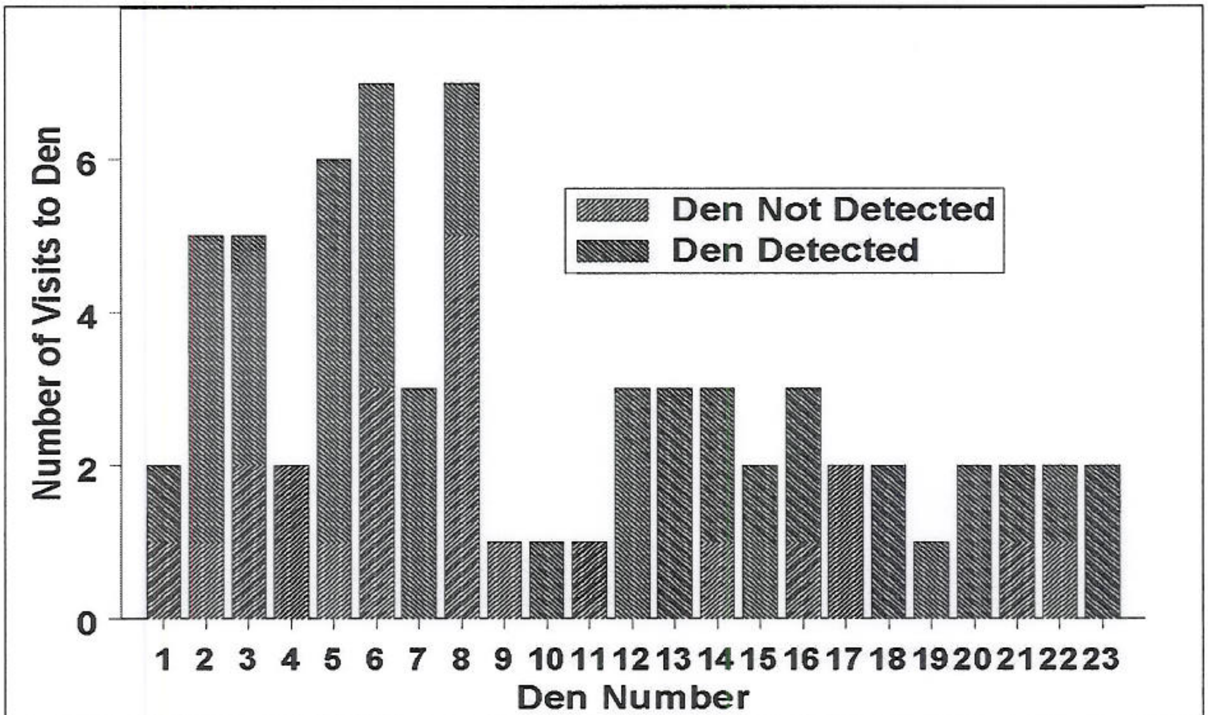


Figure 12. Summary of detections and detection failures for 23 polar bear dens by FLIR in northern Alaska, 1999 – 2001.

POLAR BEAR MATERNAL DEN HABITAT ON THE ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA

Successful reproduction in polar bears is dependent on landscape features that catch enough autumn snow to allow females to dig dens to protect newborn cubs (Blix and Lentfer, 1979). In 2001, we identified denning habitats in the central coastal plain of northern Alaska through interpretation of high resolution landscape photography (Durner et al., 2001). This knowledge, incorporated in a geographic information system (GIS), will help managers develop a resource management plan to protect polar bears in maternal dens. This can reduce or eliminate potential conflicts between human activities and denning bears by simply avoiding habitats that polar bear prefer (Clough et al., 1987).

Interest continues on opening the 1002 area of the Arctic National Wildlife Refuge (ANWR) for petroleum extraction. The ANWR coastal plain, however, is an important region for polar bear denning. Also, our prior map included only a small portion of the northwest ANWR. Here, we proceed where we left off in our earlier work and describe a maternal den habitat map for the coastal plain of the ANWR. This map provides managers with the unique opportunity to consider polar bear maternal den habitat as a part of a decision making process in any management plan for the ANWR.

Methods followed those of Durner et al. (2001). We examined high resolution color aerial photographs (n = 1655; scale: 2.56 cm = 457.2 m) taken along east/west transects within the ANWR coastal plain and adjacent coastal islands from the east side of the Canning River to the Canada border and south to the southern border of the 1002 area or the foothills of the Brooks Range (Fig. 13). We identified linear features that could hold ≥ 1 m of snow. The final map was provided as an ARCVIEW shapefile (ESRI, Redlands, Ca.). We verified the final map for precision and omission of qualifying den habitats with aerial survey and on the ground measurements. Mapped den habitat also was compared the distribution of the known locations of 38 dens and tested for uniformity on the landscape.

A total of 3621 km of den habitat was mapped within the coastal plain of the ANWR (Fig. 13). This habitat represented only 23.2 km^2, or 0.29 %, of the 7994 km^2 ANWR coastal plain but had a relatively uniform distribution. Our ground-truthing revealed that our photo-interpretation correctly identified 91.5 % of available den habitat on the ANWR. Further confidence was demonstrated by comparing the distribution of 39 polar bear dens located in recent years, within the area of our habitat map. Of those, 33 (84.6 %) were within 145 m of mapped bank habitat. Our map of den habitat on the ANWR indicates 38 % more den habitat than on the central coastal plain of northern Alaska and greater distributional uniformity (Durner et al., 2001), suggesting that more bears may use the ANWR coastal plain for denning simply because there appears to be more den habitat per unit of area. Habitats that polar bears prefer for giving birth to their young constitute a critical life history component that may be easily incorporated, with the information provided here, into a resource management plan for public lands.

Durner, G.M., S.C. Amstrup and K. Ambrosius. 2005. Polar bear maternal den habitat on the Arctic National Wildlife Refuge, Alaska. ARCTIC 00:000-000, in press.

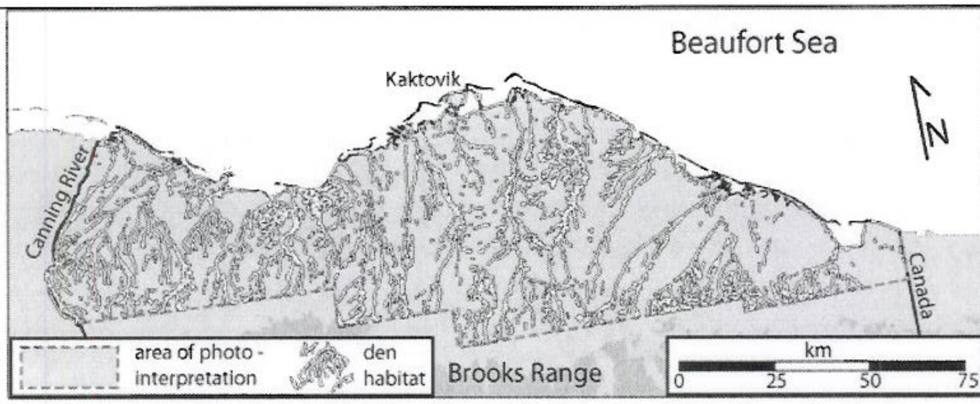


Figure 13. Study area and the distribution of polar bear maternal den habitat, on the ANWR, Alaska, August 2004.

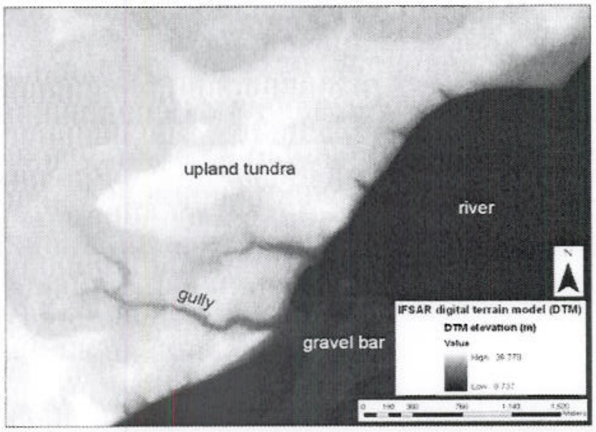
MAPPING POLAR BEAR MATERNAL DEN HABITAT IN NORTHERN ALASKA WITH INTERFEROMETRIC SYNTHETIC APERTURE RADAR DATA – AN INITIAL EVALUATION

While much of the northern Alaska coastal plain has been mapped for potential polar bear maternal den habitat, the distribution of den habitat in the National Petroleum Reserve – Alaska (NPRA) is largely unknown. We have identified many polar bear maternal dens in NPRA, indicating that NPRA is an important denning region. Previously, however, the distribution of suitable denning habitats there has not been known. This is an important management limitation because petroleum exploration in NPRA is ongoing. Because high resolution aerial photography is not available for NPRA, we investigated the use of very high resolution Interferometric Synthetic Aperture Radar (IFSAR; Intermap Technologies Corp., Ontario, Canada) digital terrain model (DTM) data for delineating polar bear maternal den habitat. Raster format IFSAR data has a resolution (horizontal cell dimension: 5 × 5 m; vertical cell resolution: 0.01 m) that lends itself well to identifying fine-scale landscape features. We used ARC/INFO tools to identify DTM pixels whose elevation difference with neighboring cells was ≥ 1.0 m. Specifying 1.0 m elevation difference would effectively identify polar bear maternal den habitat (Durner et al. 2001).

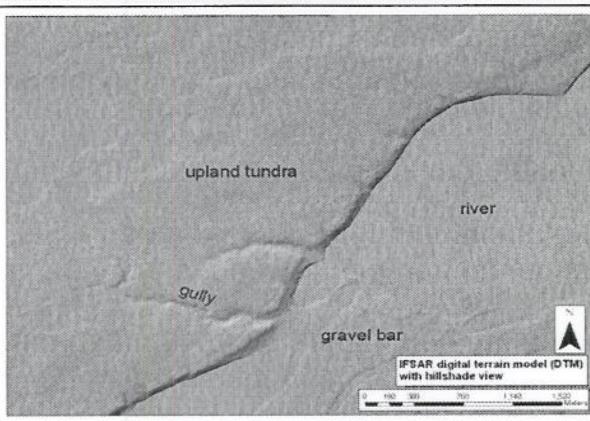
We examined 89 IFSAR tiles in NPRA (total area of 10,670 km^2) and identified 37 km^2 of polar bear den habitat (0.35 % of the total study area). Den habitat was readily apparent along coastlines, riverbanks and lakeshores (Fig. 14). Limited ground-truthing showed that six (17 %) precision points did not meet the specified height to be classified as den habitat (precision error: 17.1 %). Of the 29 precision points that met our criteria for den habitat, 22 (77 %) of those fell directly on the ground-level feature. Two of these may be explained by incorrect IFSAR processing. At both waypoints, we encountered abrupt hedges of willows between 1-2 m in height, suggesting errors in the Intermap algorithms. Nine omission points were identified during ground-truthing. This translates into an omission error of $9 \div (35 + 9) \times 100 = 20.4$ %.

The distribution of eight polar bear dens largely agreed with the distribution of mapped den habitat (Fig. 15). In every case dens occurred directly on or within 30 m of den habitat delineated with IFSAR. IFSAR data indicated polar bear den habitat throughout the coastal areas of NPRA. Den habitat occurred where expected, i.e., coastal and river banks and lake shores. The distribution of den habitat derived from IFSAR appears similar to the distribution of den habitat identified using standard aerial photo interpretation techniques in other regions of the Alaska coastal plain. Den habitat on the NPR-A shows a uniform distribution and it represents a fraction of the total landscape (0.35 % of total area).

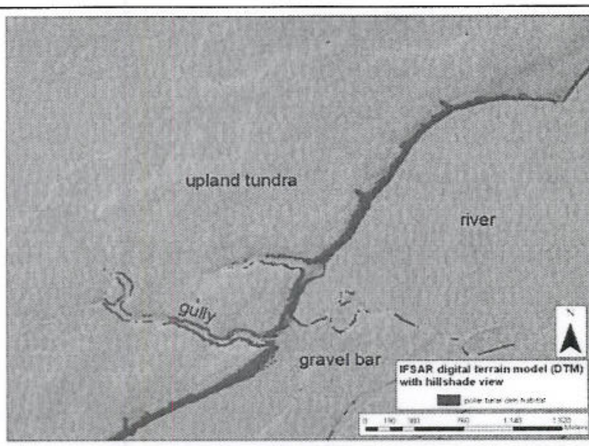
Two shortcomings are apparent in this application of IFSAR. Because the IFSAR DTM twice identified banks where there was a hedge of willows demonstrates that algorithms used to filter structures and vegetation to produce the DTM are not always successful. Secondly, our analysis of IFSAR shows a relatively high omission error rate (20.4 %). This may suggest that the horizontal resolution (5 m) may not be sufficient to capture some narrow landscape features. Despite these shortcomings, IFSAR presents several advantages over standard photogrametric methods for mapping and identifying habitat. First, the data are already interpreted by Intermap, negating the need to have personnel physically examine remotely gathered landscape data and interpret that data. Second, features identified on maps are typically right on or very close to where they occur on the ground. Third, as standard GIS format, it is relatively easy to apply GIS tools to IFSAR data for analysis.



a. Elevation data are represented in 5 m pixels where light shades are high elevations and dark shades are low elevations.

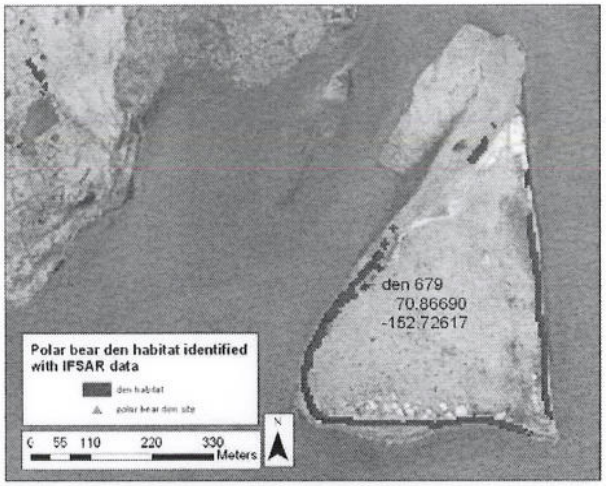


b. The same area as Figure14a, but with a hillshade view, shows an abrupt bank interspersed with gullies, between upland tundra and a river.



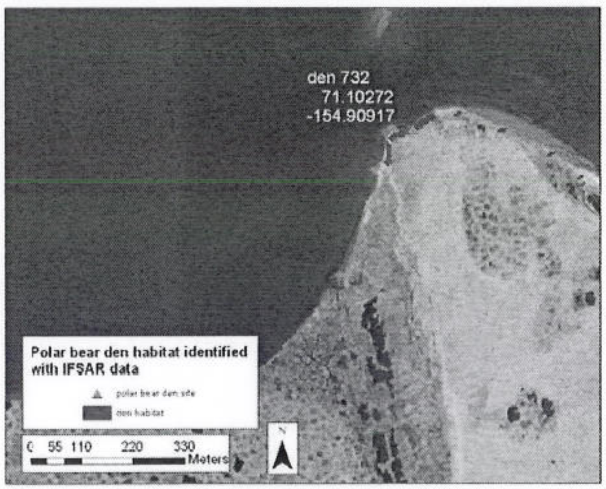
c. Polar bear den habitat is identified where the difference between neighboring pixels is ≥ 1 m.

Figure 14. IFSAR digital terrain model data for a portion of the NPR-A, Alaska.



a. IFSAR delineated den habitat at den 679.

b. Ground-level features at den 679.



c. IFSAR delineated den habitat at den 732.

d. Ground-level features at den 732.

Figure 15. IFSAR den habitat of polar bear den 679 (a and b) and den 732 (c and d) in the NPRA, Alaska.

NORTHERN ALASKA POLAR BEAR DEN SITE BEHAVIOR AND RESPONSE TO HUMAN DISTURBANCE

The activity budgets of undisturbed animals provide a basic understanding of their behavior patterns as well as a benchmark against which human impacts can be evaluated. Denning in polar bears is an integral part of the reproductive process rather than a response to resource scarcity, and involves only pregnant females (Ramsay and Stirling 1988). From entry until emergence, the den's primary role is to provide a secure environment for the gestation and bearing of young. Following den emergence, however, continued den residence is beneficial in that it provides opportunities for acclimatization to the harsh arctic environment, development of locomotor skills, and an increase in body weight and overall size. It seems unlikely mothers and cubs would emerge and remain for weeks at the den site if the only function of dens was to provide a suitable environment for gestation and parturition. However, polar bears at den sites forage minimally, are susceptible to predation, and are thought to be sensitive to anthropogenic disturbance. Depending on the cub's maturation level, disruption that results in premature abandonment of the den could reduce cub survival. During the winters of 2002-03, several radio-tagged polar bears denned in close proximity to the Prudhoe Bay oil field (Fig. 16). This provided an opportunity for us to document the post-emergence behavior of family groups at den sites in Alaska.

We used focal scan sampling procedures to document the behavior of radio-tagged polar bears from observation blinds positioned approximately 400 m from dens. Using computers we continuously logged behaviors of adult polar bears. We visited den sites daily to determine when bears first emerged. Upon emergence, our observations continued daily, weather permitting, until family groups abandoned the den site.

We logged 459 hours of direct observation at 8 den sites in March of 2002 and 2003. Eight adult female polar bears were observed outside their dens a total of 37.5 hours (8.2% of total observation time) during 40 focal observation sessions. Additionally, we recorded activities of 5 cubs during 11 focal observation sessions.

Polar bear families remained at den sites from 1.5 to 14 days (0 = 8.1 ± 5.1 days, N = 8) post-emergence. Lunn et al. (2004) reported similar results for Hudson Bay females and cubs with a range of 4 to 18 day stays near their den sites following emergence (0 = 8.7 ±1.8 days, N = 8). Diurnal activity for bears at all dens was trimodal (Fig. 17), with peaks in the early morning, mid-day, and evening. In both years of study, mothers and cubs were mostly in the den during observation periods (91.8%). Hansson and Thomassen (1983) similarly reported that adult females and their cubs spent 80.6% and 85.5% of their time, respectively, in dens in the Svalbard region of Norway. Adult female polar bears in Alaska were inactive (e.g., sitting, standing and resting behaviors) 49.5% of the time while outside the den, whereas cubs were inactive only 13.4%. Hansson and Thomassen (1983) provided the only other study with comparable activity data, noting that females were inactive 66.4% and cubs 41.6%, while outside the den. Since adult females we observed spent > 91% of their time in dens, inactivity accounted for > 95% of their total activity budget.

The lengths of in-den and outside den time periods we observed varied significantly between years (2002: in-den 1.79 h, outside den 0.49 h; 2003: in-den 4.82 h, outside den 0.18 h; N = 46, t-statistic = -2.848, P = 0.003; N = 62, t statistic = 2.3038, P = 0.012). Bears may have chosen to remain in their dens longer in 2003 due to significantly colder weather than the year previous (-25.2EC vs. -20.6EC; N = 732, t-statistic =12.31, P < 0.000), although it was not significantly windier (-4.5 m/s vs. -4.6 m/s; N = 732, t-statistic = 0.863, P < 0.194).

Anecdotal observations of polar bear reactions to human activity showed a variety of responses. Activity budgets of 2 maternal groups which denned within 1 km of a heavily used ice road were compared with those of 4 maternal groups denned in undisturbed areas. Notably, female polar bears at den sites near the ice road exhibited significantly fewer bouts of vigilant behaviors (t-statistic = -5.5164, df = 4, P = 0.003), than bears at undisturbed den sites (Fig. 18). Although the percentage time spent in vigilant behaviors at sites near the ice road was not significantly different than at undisturbed sites (t-statistic = -1.8902, df = 4, P = 0.066), results suggest a real difference exists. The most likely explanation for these observations is that bears exposed to heavy truck traffic habituated to it (i.e., ceased responding to stimuli that lack negative consequences). The critical question, however, is whether or not there are negative consequences associated with a reduction in vigilance. Clearly, additional work is needed to refine our understanding of human disturbance and its effects on denned bears.

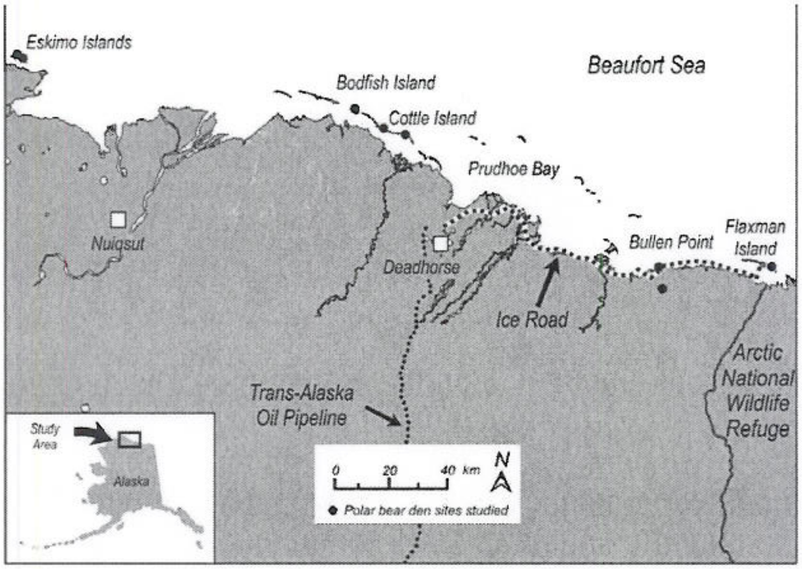


Figure 16. Location of the study area and polar bear dens during March 2002 and 2003, near Prudhoe Bay, Alaska.

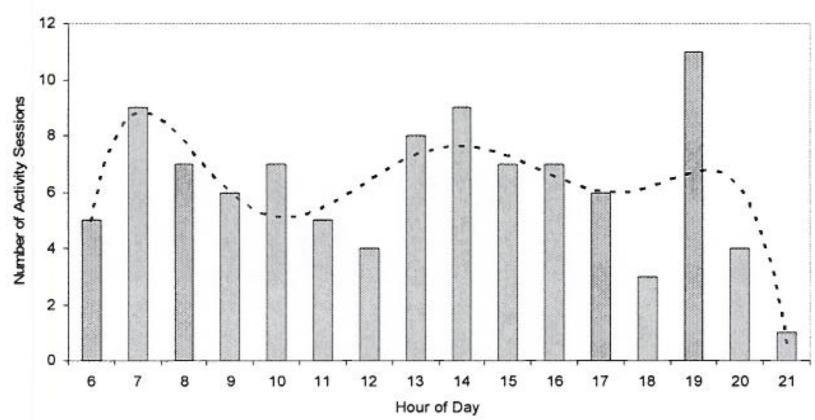


Figure 17. The temporal pattern of polar bear activity (n = 8) at den sites, North Slope, Alaska. Dashed line represents the smoothed mean.

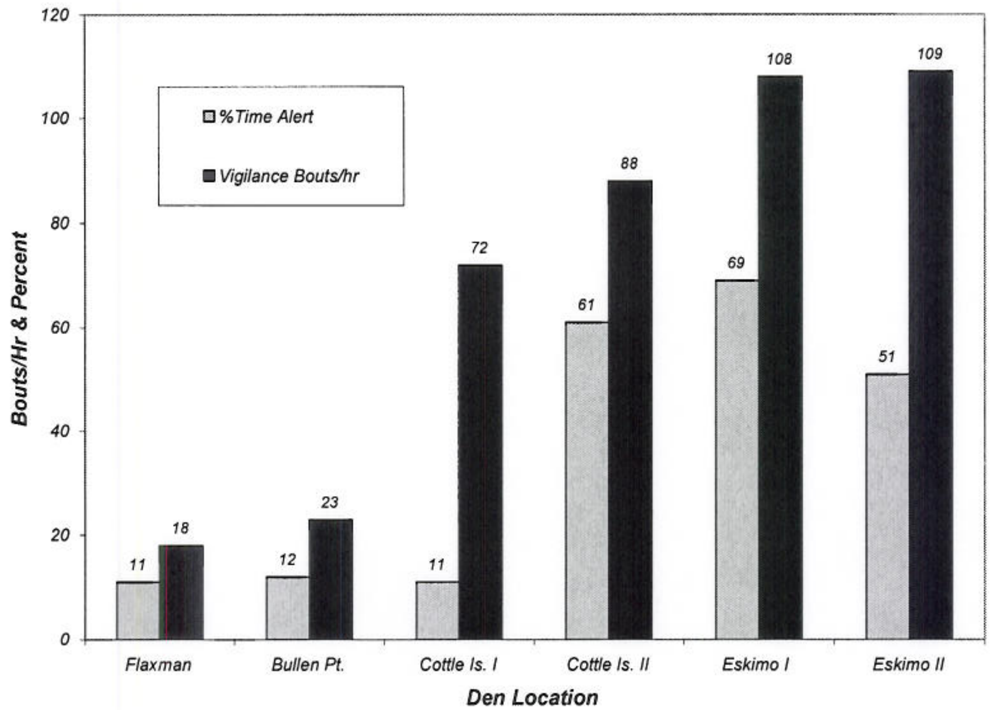


Figure 18. Amount of time spent alert and bouts of vigilance per hour at polar bear den sites, North Slope, Alaska 2002-2003.

ASSESSMENT OF INDUSTRIAL SOUNDS AND VIBRATIONS RECEIVED IN ARTIFICIAL POLAR BEAR DENS, FLAXMAN ISLAND, ALASKA

Expansion of winter-time petroleum exploration and development in the arctic has increased concerns that oil and gas activities could disturb denning polar bears, resulting in premature den abandonment and cub mortality. In the Beaufort Sea, female polar bears usually enter maternity dens from late October through early November and emerge with cubs in late March or early April. The period of denning coincides with the time of greatest industrial activity in northern Alaska. Dens are excavated in snow drifts on land or offshore pack ice. Amstrup and Gardner (1994) reported that 47% of maternal dens found in Alaska occurred on land. Bears denning on land are more likely to be exposed to industrial activities than bears denning on the offshore pack ice. Indeed, two maternity dens were located within 2.8 km (1.7 mi) of a production facility in

1991 (Amstrup 1993), and, recently, female polar bear dens have been found near industrial activities on Flaxman Island. Due to this temporal and spatial concordance, there are valid concerns that noise and vibration caused by industrial activities may disturb denning bears.

Potential sources of noise and vibration during winter include exploratory drilling, vibroseis, production facilities, ice-road and ice pad construction, and aircraft traffic. Although Blix and Lentfer (1992) documented sound levels from petroleum-related activities at artificial dens, there is currently a lack of pertinent information that is necessary to determine how industrial noise and vibration effects on polar bears should be mitigated. Effects of industry-produced noise and vibration could include loss of denning habitat because pregnant females may avoid denning in the vicinity of the noise and vibration source, and reduced cub survival due to premature den abandonment.

As a part of research efforts, biologist with the USGS, Alaska Science Center, document the locations of polar bear maternal dens in Alaska. This information is provided to the U.S. Fish and Wildlife Service (USFWS), who in turn uses this data to manage industrial activities relative to denning polar bears. The oil and gas industry communicates with the USFWS to determine the location of known dens relative to their activities. In an effort to minimize disturbances to denning polar bears, the petroleum industry is required to avoid all known polar bear dens by 1.6 km (1 mi), unless given special permission by the USFWS after obtaining a Letter of Authorization (LoA) allowing incidental taking. This 1.6 km buffer around dens was arbitrarily established, and has been questioned. Hence, there is a need to understand the potential exposure levels of industrial noise and vibrations on polar bears in dens.

In March 2002, biologists from USGS, USFWS, LGL Alaska Research Associates, Inc. (LGL), JASCO Research LTD, and Exxon Mobil Production Co., collected noise and ground vibration data at four artificial dens in polar bear habitat on Flaxman Island, in northern Alaska. The study site was selected for its close proximity to ongoing remediation activities involving the use of heavy equipment and blasting. We conducted measurements to determine the absolute sound levels of various industrial activities and estimate potential noise and vibration exposure to denning polar bears.

Comparison of sound levels, measured with microphones placed outside and inside the dens, permitted estimation of the sound-insulating properties of the dens. Vibration data were acquired from sensors placed in the tundra and snow of the den floors. Measurements of noise and vibration were made for the following vehicles: front-end loader, grinder, gravel hauler, fuel truck, pickup truck, Hägglunds tracked vehicle, and a Tucker Sno-Cat. A single blast event, which was used to cut a well pipe, was recorded in the dens. In addition, noise and ground vibration data were obtained for Bell 212 and Bell 206 helicopters during maneuvers around the dens.

Sound level and ground vibration measurements were made as vehicles approached and passed (speed: 17 – 32 km/hr) all four den sites along the ice road connecting two remediation pits, although data from only one or two dens are presented in this report for brevity. Vehicle traffic sounds were reduced between 30 dB and 42 dB by the snow surrounding the artificial dens (Table 2). Most vehicle noise was undetectable within the den when the source was 500 m away. In two instances, however, vehicle sounds were detectable at distances greater than 500 m from the source. Vibrations for all ground vehicles, except the Hagglunds, were not detectable beyond 90 m (Table 3).

Table 2. Received sound pressure levels (SPL; re 20 µPa) and distances of closest point of approach (CPA) of all-terrain tracked vehicles at Dens 5 (D5) and 7(D7). Separate values for Range to Background are provided where significant difference was noted between the two dens.

Vehicle	CPA (m)	In-den SPL at CPA (dB)	Outside den SPL at CPA (dB)	In den SPL background (dB)	In-Den Range to background (m)
Hägglunds BV206	18	55	85	30	D5-400 D7-1000
Tucker Sno-Cat	20	38	80	27	400
Gravel Hauler (Empty)	12	47	84	30	D5-500 D7-2000
Gravel Hauler (Loaded)	12	48	87	30	500
Front End Loader	12	43	81	27	500
Pick-up truck	12	37	71	25	100
Fuel truck	12	50	80	29	300

Table 3. Vehicle ground vibration metrics and corresponding distances of closest point of approach (CPA) of all-terrain tracked vehicles.

Vehicle	CPA (m)	Ground acceleration at CPA (mm/s^2)	Snow acceleration at CPA (mm/s^2)	Snow velocity at CPA (µm/s)	Range to acceleration < .5 mm/s^2 (m)
Hägglunds BV206	18	10	11	13	90
Tucker Sno-Cat	20	1.2	1.5	1.9	30
Gravel Haul (Empty)	23	3.8	5.5	3.1	40
Gravel Haul (Loaded)	23	3.7	4.2	2.5	60
Front End Loader	22	8.0	8.5	3.5	60
Pick-up truck	22	1.5	1.5	1.3	43
Fuel truck	12	Data unavailable.			

The general broadband sound pressure levels for seven vehicles that operated on Flaxman Island during this study, and accompanying background noise, show an approximately a 15 dB range between the loudest and quietest vehicles (Fig. 19). Background sound energy, primarily caused by wind turbulence on the microphones, dominated measurements of vehicle noise below 10-20 Hz. Plots of sound level versus range for all vehicles monitored include shaded regions indicating the typical range of background noise levels (Fig. 19). It is important to note that vehicle noise results were obtained by filtering the data to remove background noise levels. If this step had not been taken then wind noise levels would have been much higher and would have contaminated the broadband measurements of vehicle noise.

The Hägglunds tracked vehicle produced some of the loudest sound pressure levels recorded detectable at far distances, while noise generated from the Tucker Sno-cat and pick-up trucks were hard to detect above in-air background levels.

The maximum distance vehicle noise was detected above background noise in the dens ranged from < 500 m to 2000 m. In-den sound pressure levels (SPL) for vehicles at the closest point of approach ranged from 37 – 55 dB re 20 µPa. The Hägglunds tracked vehicle produced the loudest noises near the den, while the Tucker Sno-Cat and pick-up trucks produced the lowest. Helicopter noise was well above background levels in the den until helicopters were at least 1000 m from the den. The maximum noise level measured was 82 dB (flat – slow) for the Bell 206 as it hovered 16 m directly above the den. Noise signatures suggests that the Bell 212 and the Bell 206 produce similar broadband noise levels, however, noise from the 212 was concentrated at lower frequencies, suggesting that the Bell 206 may be more audible to polar bears if their hearing is more sensitive to frequencies above 50 Hz than below.

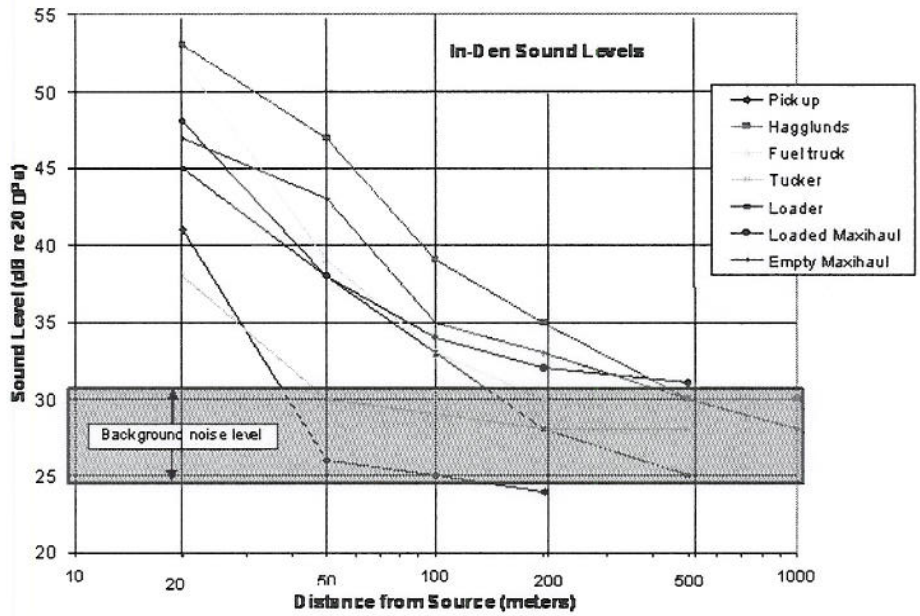


Figure 19. Broadband levels of in-den sound as a function of distance from source. The shaded background level refers to recorded ambient noise during the time of study.

The artificial dens were found to be very good at reducing noise exposure. The snow surrounding the man-made dens reduced the level of outside sounds by 25 dB at 50 Hz, and by 40 dB at 1000 Hz. The in-den ambient noise levels for the man-made dens were typically very low. Third-octave band levels for ambient noise levels were less than 40 dB below 100 Hz, and less than 20 dB for bands greater than 100 Hz. Low frequency sound levels were directly related to wind speed. Results of this study are summarized in a consultant's report. Within the next year, we hope to incorporate them into a manuscript for publication.

MacGillivray, A., Hannay, D., Racca, R., Perham, C. J., MacLean, S. A., and Williams, M. T. 2003. Asssessment of industrial sounds and vibrations received in artificial polar bear dens, Flaxman Island, Alaska. Final report to ExxonMobile Production Co. By JASCO research Ltd., Victoria British Columbia and LGL Alaska Research Associates, Inc., Anchorage, Alaska. 60p.

INTRASPECIFIC KILLINGS AND CANNIBALISM AMONG POLAR BEARS IN THE SOUTHERN BEAUFORT SEA

Intraspecific killing has been reported among polar bears, brown bears (*Ursus arctos*), and black bears (*U. americanus*). Although foraging for food is one motivation for such killings and subsequent cannibalism, the ecological factors mediating such events are poorly understood. During 24 years of research on polar bears in the SBS region of northern Alaska and 34 in northwestern Canada, we only have seen 2 incidents of intraspecific killings in Alaska which appeared nutritionally motivated. In contrast to this, Alaskan and Canadian research teams discovered 3 confirmed instances of intraspecific predation and cannibalism between 24 January and 10 April 2004. These were discovered while conducting ongoing polar bear research in this region. One of these, the first of this type ever reported for polar bears, was a parturient female removed from her maternal den on a barrier island off of Alaska's north coast. The predating bear was clearly hunting in a known maternal denning area and apparently discovered the den by scent. Three other known polar bear dens near the predated one were abandoned in late winter, perhaps in response to the hunting behaviors of this bear. A second predation event involved an adult female just out of her den with a new cub, and the third was a yearling male. We hypothesize that the unusual frequency of such killings in the Beaufort Sea may reflect nutritional stress related to the longer ice-free seasons that have predominated in this region in recent years. A manuscript describing this event is being drafted mutually by the Alaskan (USGS and USFWS) and Canadian (CWS) research teams.

Smith, T.S., S.C. Amstrup, I. Stirling, C. Perham, and Gregory W. Thiemann. 2005. Intraspecific killings and cannibalism among polar bears in the Beaufort Sea. Submitted to Polar Biology.

ESTABLISHING PATERNITY WITH GENETIC FINGERPRINTING

Polar bears are the most mobile of all quadrupeds, their movements are more variable than most other bears, and surprisingly, male polar bears appear to be no more mobile, in some locales and at some times of the year, than female polar bears. This suggests that a breeding pattern different from that in other bears is possible.

To explore breeding patterns in polar bears, we extracted DNA from blood and tissue samples amplified the DNA using PCR, and used acrylamide gel electrophoresis to sequence the samples and identify specific alleles. Scores obtained were used to determine how closely individual polar bears might be related. Mother-offspring and sibling pairs were known because family groups often are captured together during spring fieldwork. Such physical evidence of paternity is not available because male polar bears accompany females only during breeding.

In a preliminary analysis of a limited number of microsatellite loci, we were able to exclude many male polar bears from consideration as fathers of our sampled offspring, and we noted that a small number of male bears were the putative fathers of large portions of the sample of cubs. This pattern is similar to that observed in limited samples from grizzly bears. This similarity in paternity patterns suggests that despite expansive movements over a moving substrate, some male polar bears still figure out a way to dominate other males in terms of breeding success just as do terrestrial bears. We are currently reassessing this pattern by evaluating a larger number of microsatellite loci for a larger number of male bears.

ALASKA MARINE MAMMAL TISSUE ARCHIVAL PROJECT

The banking of environmental specimens under cryogenic conditions for future retrospective analysis is an important part of wildlife health and environmental monitoring programs. The goal of the Alaska Marine Mammal Tissue Archival Project (AMMTAP) is to collect tissue samples from marine mammals for archival in the National Biomonitoring Specimen Bank (NBSB) at the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland, USA. Samples are collected under exacting protocols and stored under the best conditions so that they can be analyzed for a variety of environmental parameters in the future.

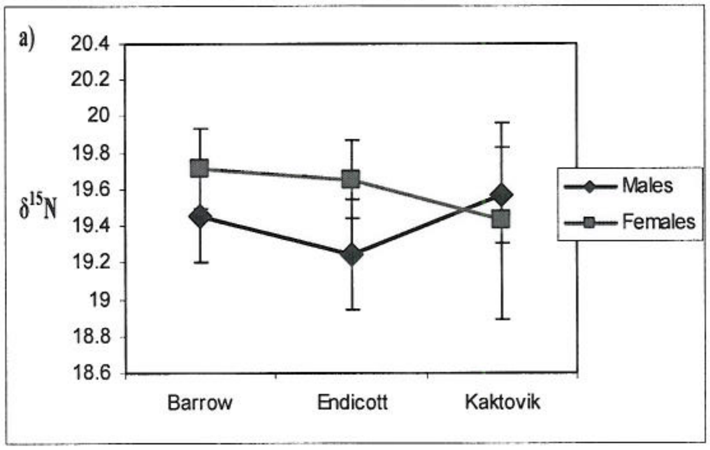
This program was brought under the umbrella of the Alaskan Polar Bear Project in 1998. It began, however, under the National Oceanic and Atmospheric Administration's (NOAA) National Ocean Service Outer Continental Shelf Environmental Assessment Program in 1987. The USGS, Alaska Biological Science Center (ABSC), the NOAA Fisheries, Office of Protected Resources (NMFS), and the NIST conduct this partnership project. Minerals Management Service (MMS) is the primary client agency for the AMMTAP providing programmatic guidance and review.

A substantial part of the sample collection is from Arctic species and, since most of the animals sampled are from Alaska Native subsistence harvests, the project relies on cooperation and collaboration with several Alaska Native organizations and local governmental agencies. Through AMMTAP, samples are collected for real-time contaminant monitoring in the Marine Mammal Health and Stranding Response Program. In addition, the project has provided samples and/or data for many research programs, both inside and outside the U.S., on a variety of subjects, including: genetics research, the circumpolar distribution of chlorinated hydrocarbons in beluga whales, baseline levels of trace elements in tissues, the identification of arsenic and mercury species in marine mammal tissues, biomarker research, nutritional studies, and studies on potential human health effects of Alaska Native subsidence foods.

WINTER DIET OF SOUTHERN BEAUFORT SEA POLAR BEARS: THE IMPORTANCE OF BOWHEAD WHALES INFERRED FROM STABLE ISOTOPE ANALYSIS

Polar bears are the top carnivore in the arctic marine ecosystem. Ringed seals (*Phoca hispida*) likely representing the majority of their annual diet. This dependency on ringed seal likely varies temporally and spatially based on availability of sea ice, ringed seals and other prey sources. Polar bears also feed on bearded seals (*Erignathus barbatus*), beluga whales (*Delphinapterus leucas*), and walrus (*Odobenus rosmarus*). They also scavenge beach cast carcasses of gray whales (*Eschrichtius robustus*), and they feed intensively on remains of bowheads landed by native subsistence hunters (*Balaena mysticetus*). Bowhead whales represent a food source which is lower in trophic level than ringed seals. We used stable isotopes $\delta^{15}N$ and

$\delta^{13}C$ to help determine the importance of low trophic level prey in the diet of 139 free ranging polar bears sampled along Alaska's Beaufort Sea coast in spring 2003 and 2004. The $\delta^{15}N$ values ranged from 18.2 % to 21.4 % with a mean of 19.5 % (SD=0.70) in 2003 and 19.9 % (SD=0.68) in 2004 (Fig. 20). Two-element three-source mixing models indicated that low trophic level prey, such as bowhead whale, may have composed 10-27 % (95%CI) of the diet of southern Beaufort Sea polar bears in 2003, and 0-16 % (95% CI) of the diet in 2004, (Fig. 21). Bearded seals appeared to comprise a very small proportion of prey consumed during both 2003 and 2004. We found little significant variation in isotope signatures between sex, capture location, age, or weight of polar bears. This suggests there may be little sex or age segregation among polar bears in regard to scavenging lower trophic level prey bowhead whales. Our data suggests that relatively few whale carcasses are necessary to make a significant contribution to the diet of polar bears in the southern Beaufort Sea. Observations also confirm that most polar bears probably presently have little opportunity to scavenge bowhead carcasses. The importance of beach scavenged foods to polar bear diets, howoever, may increase with prolonged open water seasons due to climate warming. It should be noted that the mixing models of the type employed in this analysis, often result in erroneous proportions that do not sum to 1 (Ben-David and Schell 2001). Working out the complications with mixing models remains a challenge with regard to dietary information these isotope values convey. Nonetheless, with refinement of the mixing models and their inputs, we are hopeful that important information on polar bear dietary patterns may emerge.



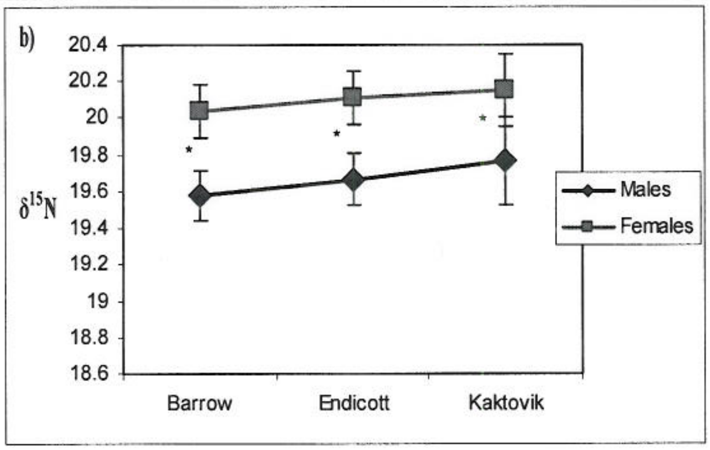


Figure 20. $\delta^{15}N$ signatures of polar bear red blood cells captured in spring 2003 (a) and 2004 (b), separated by sex and capture location (±SE).

* indicates a statistically significant difference between sexes.

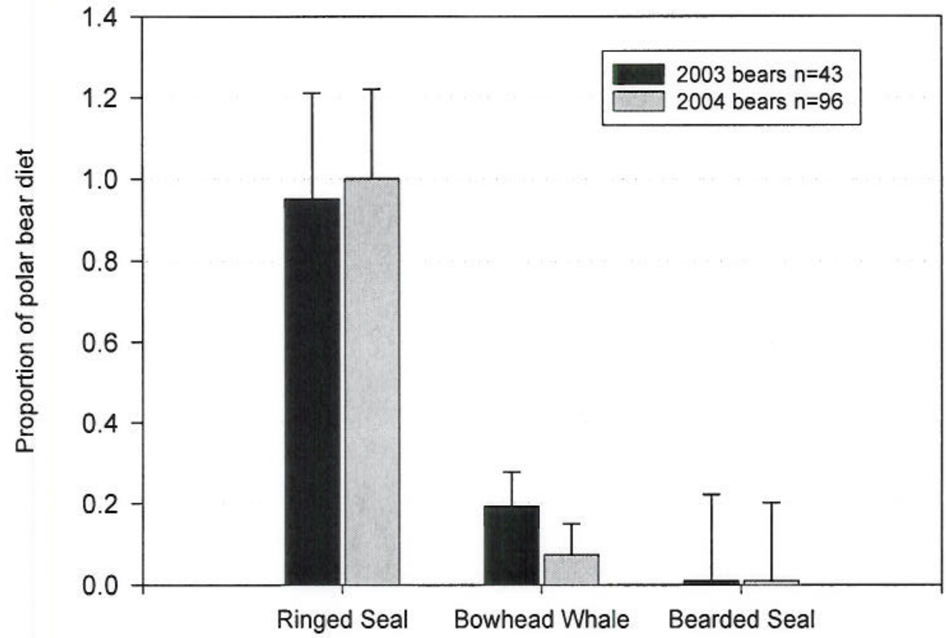


Figure 21. Dietary proportions of the three food sources for southern Beaufort Sea polar bears in the winters of 2002-2003 and 2003-2004. All means were calculated using the Isoerror model (Phillips and Gregg 2001) which includes 95%CI around all diet estimates.

INFLUENCE OF DIET ON BIOMAGNIFICATION OF ORGANOCHLORINE POLLUTANTS IN POLAR BEARS

Although studies of tissues collected under AMMTAP have been a small part of the program, we plan to expand such studies as time and resources are made available. Along these lines we have initiated a collaborative effort with the North Slope Borough Department of Wildlife Management, and the University of Alaska Fairbanks to investigate the influence of diet on biomagnification of organochlorine pollutants in polar bears.

Varying concentrations of organochlorine (OC) contamination have been found in the tissues of polar bears throughout their range. Many of these organic pollutants are biomagnified with each trophic transfer in the food web and are found at extremely high concentrations in polar bears when compared to background environmental levels.

However, contaminant burdens can vary greatly among individual polar bears within the same subpopulation. This variation has not been explained fully by capture location, age, sex, condition, or reproductive status of the bear. Although ringed seal

(*Phoca hispida)* may represent the majority of their annual diet throughout the arctic, Beaufort Sea polar bears are opportunistic predators and consume a variety of species including bearded seal (*Erignathus barbatus*), beluga whale (*Delphinapterus leucas*), and walrus (*Odobenus rosmarus*), as well as scavenge on the carcasses of bowhead whales (*Balaena mysticetus*) landed by native subsistence hunters. Through dietary pathways, these species expose polar bears to a variety of contaminant profiles and burdens, ranging from the comparatively pollution free tissues of the lower trophic level bowhead whale to the more contaminated tissues of the ringed seal which represent a high trophic level.

Analysis of this data is currently underway in collaboration with Environment Canada and Dr. Derek Muir. A publication is planned for winter 2005-06. An additional paper is also planned incorporating the chemical data and the isotope data previously mentioned.

FUTURE PROJECTS:

RADIO FREQUENCY IDENTIFICATION (RFID) TAGS FOR GRIZZLY AND POLAR BEAR RESEARCH

Grizzly bears (*U. arctos*) and polar bears are important species for subsistence communities along the Beaufort Sea coast for food, fur, and for their cultural importance. Much of our current knowledge about bear populations, habitat use, movements, and interactions with oil and gas activities on the Alaska northern coast (North Slope) has been the result of repeated captures of tagged individuals. Application of existing and emerging Radio Frequency Identification (RFID) technology, currently used for military and commerce, has the potential to significantly increase the sample size of marked bears by decreasing the cost of recapturing bears. Another advantage of RFID tags is that fixed point readers could be installed on towers or other structures where bears frequently travel or concentrate. This would make remote recaptures possible.

An RFID system contains two major components: tags and a reader. The tags are currently capable of transmitting 100 m under laboratory conditions when interrogated by the reader. Neither the current generation of readers (receivers) nor the tags has been attached to large mammals under arctic environmental conditions where aircraft are used extensively. The goal of this research and development project is to modify the RFID system and test its feasibility for grizzly and polar bear research and management by modifying the tags so they can be attached to bear ears and by modifying the reader for use in aircraft and land vehicles. Testing the RFID system will initially focus on grizzly bears marked during 2005 for the Oilfield Grizzly Bear Project before being tested on polar bears. RFID tags will be deployed on polar bears in spring 2006.

EMERGING ORGANIC CONTAMINANTS IN BLOOD AND ADIPOSE OF ALASKA POLAR BEARS AND RELATIONSHIP WITH HEMATOLOGICAL-BASED EFFECTS ASSESSMENT

Based on studies in Svalbard (Norway) there is concern contaminants have resulted in immune compromised polar bears (e.g., reduced life expectancy & reproductive performance, Wiig et al. 1998). Persistent organic pollutants (POPs) and heavy metal concentrations in polar bear appear to vary widely geographically and within populations of bears. Some aspects of POPs biotransformation have been addressed (Letcher et al., 1998) and potential interactions with molecular plasma constituents (Skaare et al., 2001) and highly selective accumulation of some enantiomers (Wiberg et al., 2000) may have a direct role in immune suppression. However, these data result from study of one population of polar bears.

Specific Aims (long term objective and specifics proposed)

Aim #1: Develop clinical (molecular and biochemical) battery of assays for determining health and immune status of free ranging Alaska polar bears using samples of subcutaneous adipose tissue and blood (including serum and plasma) in relation to "emerging" contaminants impacts.

Aim #2: Develop *in vitro* immune bioassays for testing the effects of well studied (OCs) and emerging contaminants on immune functions (i.e., contaminant and potential pathogen interactions) from polar bears.

POLAR BEAR PROJECT PUBLISHED MANUSCRIPTS FOR THE PERIOD 2001-2005:

Amstrup, S.C. 2003. Polar bear, *Ursus maritimus*. Pages 587-610. *In* Wild Mammals of North America: Biology, Management, and Conservation. *Edited by* G.A. Feldhamer, B.C. Thompson, and J.A. Chapman. John Hopkins University Press, Baltimore. pp. 587-610.

Amstrup, S.C., T.L. McDonald, and G.M. Durner. 2004. Using Satellite radio-telemetry data to delineate and manage wildlife populations. Wildlife Society Bulletin 32:661-679.

Amstrup, S.C., G. York, T.L. McDonald, R. Nielson, and K. Simac. 2004. Detecting denning polar bears with forward looking infra-red imagery (FLIR). BioScience 54:337-344.

Belchansky, G., D.C. Douglas, I.N. Mordvintsev, and N.G. Platonov. 2004. Estimating the time of melt onset and freeze onset over the Arctic sea-ice area using active and passive microwave data. Remote Sensing Environment 92:21-39.

Belchansky, G., D.C. Douglas, and N.G. Platonov. 2004. Duration of the Arctic sea ice melt season: regional and interannual variability, 1979 – 2001. Journal of Climate 17:67-80.

Durner, G.M., S.C. Amstrup, and A.S. Fischbach. 2003. Habitat characteristics of polar bear terrestrial maternal den sites in northern Alaska. ARCTIC. 56(1): 55-62.

Durner, G. M., S. C. Amstrup, T. McDonald, C. Smith, and W. Johnson. 2001. Predicting the numbers of polar bears impacted by oil spills. Society for Marine Mammalogy, Abstracts, 14th Biennial Conference on the Biology of Marine Mammals, November 28 – December 3, 2001, Vancouver, B. C., Canada.

Durner, G.M., S.C. Amstrup, R. Nielson, and T.L. McDonald. 2004. Using discrete choice modeling to generate resource selection functions for female polar bears in the Beaufort Sea. Pages 107 – 120 *in* S. Huzurbazar, ed., Proceedings of the 1st Conference on Resource Selection Modeling. January 2003, Laramie, Wyoming.

Kern, J.W., T.L. McDonald, S.C. Amstrup, G.M. Durner, and W.P. Erickson. 2003. Using the bootstrap and fast fourier transform to estimate confidence intervals of 2-D kernel densities. Environmental and Ecological Statistics. 10:405-418.

Manly, B.F.J., T.L. McDonald, S. C. Amstrup, and E.V. Regehr. 2003. Improving size estimates of open animal populations by incorporating information on age. BioScience 53(7): 666-669.

McDonald, T.L., S.C. Amstrup, and B.F.J. Manly. 2003. Tag loss can bias Jolly-Seber capture-recapture estimates. Wildlife Society Bulletin. 31(3): 814-822.

Simac, K., S. Amstrup, G. Weston York, T. McDonald, G. Durner, and A. Fischbach. 2001. Forward looking infrared (FLIR): a new method for detecting maternal polar bear dens. Society for Marine Mammalogy, Abstracts, 14th Biennial

Conference on the Biology of Marine Mammals, November 28 – December 3, 2001, Vancouver, B. C., Canada.

Smith, T.S. and B.A. Johnson. 2004. Modeling the effects of humans activity on Katmai brown bears (*Ursus arctos*) through the use of survival analysis. ARCTIC 57:160-165.

Smith, T.S., and S.T. Partridge. 2004. Dynamics of intertidal foraging by coastal brown bears in southwestern Alaska. Journal of Wildlige Management 68:233-240.

Stone, R.S., G. Belchansky, S. Drobot, and D.C. Douglas. 2004. Diminishing sea ice in the western Arctic Ocean. Pages S32 – S33 *in* D.H. Levinson and A.M Waple, eds., State of the climate in 2003. Bulletin of the American Meterological Society 85(6), June 2004.

MANUSCRIPTS ACCEPTED FOR PUBLICATION (IN PRESS):

Amstrup, S.C., G.M. Durner, I. Stirling, and T.L. McDonald. 2005. Using radiotelemetry to allocate harvests among polar bear stocks occupying the Beaufort Sea region. ARCTIC 00:000-000.

Durner, G.M., S.C. Amstrup and K. Ambrosius. 2005. Polar bear maternal den habitat on the Arctic National Wildlife Refuge, Alaska. ARCTIC 00:000-000.

MANUSCRIPTS SUBMITTED FOR PUBLICATION OR IN PREP:

Amstrup, S.C., G. M. Durner, and T.L. McDonald. 2005. Estimating potential effects of hypothetical oil spills on polar bears. In prep.

Smith, T.S., S.C. Amstrup, I. Stirling, C. Perham, and Gregory W. Thiemann. 2005. Intraspecific killings and cannibalism among polar bears in the Beaufort Sea. Submitted to Polar Biology.

Smith, T.S., S. T. Partridge, S. C. Amstrup, and S. Schliebe. 2005. Northern Alaska polar bear (*Ursus maritimus*) den site behavior and response to human disturbance. In prep.

REFERENCES

Amstrup, S. C. 1993. Human disturbances of denning polar bears in Alaska. Arctic. 46:246-250.

Amstrup, S. C., and C. Gardner. 1994. Polar bear maternity denning in the Beaufort Sea. Journal of Wildlife Management. 58(1):1-10.

Ben-David, M., and D. M. Schell. 2001. Mixing models in analysis of diet using multiple stable isotopes: a response. Oecologia. 127:180-184.

Blix, A. S., and J. W. Lentfer. 1992. Noise and vibration levels in artificial polar bear dens as related to selected petroleum exploration and developmental activities. Arctic. 45:20-24.

Blix, A. S., and J. W. Lentfer. 1979. Modes of thermal protection in polar bear cubs - at birth and on emergence from the den. American Journal of Physiology. 236:R67-R74.

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society Monograph No. 5.

Choquet, R., A. M. Reboulet, R. Pradel, O. Gimenez, and J. D. Lebreton. 2002. User's manual for U-CARE. Mimeographed document, CEFE/CNRS, Montpellier, France.

Clough, N. K., P. C. Patton, and A. C. Christiansen, eds. 1987. Arctic National Wildlife Refuge, Alaska, coastal plain resource assessment: Report and recommendation to the Congress of the United States and final legislative environmental impact statement. U.S. Fish and Wildlife Service, U.S. Geological Survey, and U.S. Bureau of Land Management, Washington, D.C. Two volumes. 1306 pp.

Derocher, A. E., N. J. Lunn, and I. Stirling. 2004. Polar bears in a warming climate. Integr. Comp. Biol. 44:163-176.

Derocher, A. E., and I. Stirling. 1990. Distribution of polar bears (*Ursus maritimus*) during the ice-free period in western Hudson Bay. Canadian Journal of Zoology. 68:1395-1403.

Derocher, A. E., and I. Stirling. 1996. Aspects of survival in juvenile polar bears. Canadian Journal of Zoology. 74:1246-1252.

Durner, G. M., S. C. Amstrup, and K. J. Ambrosius. 2001. Remote identification of polar bear maternal den habitat in northern Alaska. Arctic. 54:115-121.

Gough, W. A., A. R. Cornwell, and L. J. S. Tsuji. 2004. Trends in seasonal sea ice duration in Southwestern Hudson Bay. Arctic. 57(3):299-305.

Hansson, R., and J. Thomassen. 1983. Behavior of polar bears with cubs in the denning area. International Conference on Bear Research and Management. 5:246-254.

Johnson, R. A., and D. W. Wichern. 1988. Applied Multivariate Statistical Analyses. Second edition. Prentice Hall, Englewood Cliffs, New Jersey. 607 pp.

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.

Klien, J. P., and M. L. Moeschberger. 1997. Survival analysis, techniques for censored and truncated data. Springer, New York.

Lebreton, J.-D., K. P. Burnham, J. Clobert, and D. R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs. 62:67-118.

Letcher, R. J., R. J. Norstrom, and D. C. G. Muir. 1998. Biotransformation versus bioaccumulation: Sources of methyl sulfone PCB and 4,4'-DDE metabolites in the polar bear food chain. Environmental Science & Technology. 32:1656-1661.

Lunn, N. J., S. Schliebe, and E. W. Born, editors. 2002. Polar Bears. Proceedings of the Thirteenth Working Meeting of the IUCN/SSC Polar Bear Specialist Group. Occasional Paper of the IUCN Species Survival Commission No. 26. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland. 153 pp.

Lunn, N. J., I. Stirling, D. Andriashek, and G. B. Kolenosky. 1997. Re-estimating the size of the polar bear population in western Hudson Bay. Arctic. 50:234-240.

Lunn, N. J., I. Stirling, D. Andriashek, and E. Richardson. 2004. Selection of maternity dens by female polar bears in western Hudson Bay, Canada and the effects of human disturbance. Polar Biology. 27:350-356.

Manly, B. F. J., T. L. McDonald, S. C. Amstrup, and E. V. Regehr. 2003. Improving size estimates of open animal populations by incorporating information on age. BioScience. 53:666-669.

McDonald, T. L., and S. C. Amstrup. 2001. Estimation of population size using open capture-recapture models. Journal of Agricultural, Biological, and Environmental Statistics. 6:206-220.

Nageak, B. P., C. D. Brower, and S. L. Schliebe. 1991. Polar bear management in the Southern Beaufort Sea: An agreement between the Inuvialuit Game Council and North Slope Borough Fish and Game Committee. Transactions of the North American Wildlife and Natural Resources Conference. 56:337-343.

Norusis, M. J. 1994. SPSS Professional Statistics 6.1. SPSS, Inc., Chicago, Illinois. 385 pp.

Pollock, K. H., J. D. Nichols, J. E. Hines, and C. Brownie. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs No. 107.

Pradell, R. 1996. Utilization of capture-mark-recapture for the study of recruirtment and population growth rate. Biometrics. 52:703-709.

Ramsay, M. A., and I. Stirling. 1988. Reproductive biology and ecology of female polar bears (*Ursus maritimus*). Journal of Zoology (London). 214:601-634.

Sendor, T., and M. Simon. 2003. Population dynamics of the pipistrelle bat: effects of sex, age and winter weather on seasonal survival. Journal of Animal Ecology.

72:308-320.

Skaare, U. J., A. Bernhoft, Ø. Wiig, K. R. Norum, E. Haug, M. D. Eide, and A. E. Derocher. 2001. Relationships between plasma levels of organochlorines, retinol and thyroid hormones from polar bears (*Ursus maritimus*) at Svalbard. Journal of Toxicology and Environmental Health, Part A. 62:227-241.

Stirling, I., N. J. Lunn, J. Iacozza, C. Elliott, and M. Obbard. 2004. Polar bear distribution and abundance on the southwestern Hudson Bay coast during open water season, in relation to population trends and annual ice patterns. Arctic. 57(1):15-26.

Stirling, I., and A. E. Derocher. 1993. Possible impacts of climatic warming on polar bears. Arctic. 46:240-245.

Stirling, I., N. J. Lunn, and J. Iacozza. 1999. Long-term trends in the population ecology of polar bears in western Hudson Bay in relation to climatic change. Arctic. 52:294-306.

Taylor, M. K., J. Laake, H. D. Cluff, M. Ramsay, and F. Messier. 2002. Managing the risk from hunting for the Viscount Melville Sound polar bear population. Ursus. 13:185-202.

Treseder, L., and A. Carpenter. 1989. Polar bear management in the southern Beaufort Sea. Information North. 15(4):2-4.

Tukey, J. W. 1980. We need both explanatory and confirmatory. American Statistician. 34(1):23-25.

White, G. C., and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study. 46(supplement):120-138.

White, G. C., K. P. Burnham, and D. R. Anderson. 2001. Advanced features of program MARK. *in* R. Field, R. J. Warren, H. Okarma, and P. R. Sievert, editors. Wildlife, Land, and People: Priorities for the 21st Century. Wildlife Society, Bethesda, Maryland.

Wiberg, K., J. Letcher, C. D. Sandau, R. J. Norstrom, M. Tysklind, and T. F. Bidleman. 2000. The enantioselective bioaccumulation of chiral chlordane and alpha-HCH contaminants in the polar bear food chain. Environmental Science and Technology. 34:2668-2674.

Wiig, Ø., A. E. Derocher, M. M. Cronin, and J. U. Skaare. 1998. Female pseudohermaphrodite polar bears at Svalbard. Journal of Wildlife Diseases. 34:792-796.