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Habitat Characteristics of Polar Bear Terrestrial Maternal Den Sites in Northern Alaska

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ABSTRACT. Polar bears (*Ursus maritimus*) give birth to and nurture their young in dens of ice and snow. During 1999–2001, we measured the structure of 22 dens on the coastal plain of northern Alaska after polar bear families had evacuated their dens in the spring. During the summers of 2001 and 2002, we revisited the sites of 42 maternal and autumn exploratory dens and recorded characteristics of the under-snow habitat. The structure of polar bear snow dens was highly variable. Most were simple chambers with a single entrance/egress tunnel. Others had multiple chambers and additional tunnels. Thickness of snow above and below dens was highly variable, but most dens were overlain by less than 1 m of snow. Dens were located on, or associated with, pronounced landscape features (primarily coastal and river banks, but also a lake shore and an abandoned oil field gravel pad) that are readily distinguished from the surrounding terrain in summer and catch snow in early winter. Although easily identified, den landforms in northern Alaska were more subtle than den habitats in many other parts of the Arctic. The structure of polar bear dens in Alaska was strikingly similar to that of dens elsewhere and has remained largely unchanged in northern Alaska for more than 25 years. Knowledge of den structure and site characteristics will allow resource managers to identify habitats with the greatest probability of holding dens. This information may assist resource managers in preventing negative impacts of mineral exploration and extraction on polar bears.

Key words: Arctic National Wildlife Refuge, den habitat, maternal den, National Petroleum Reserve – Alaska, polar bear, *Ursus maritimus*, Prudhoe Bay

RÉSUMÉ. Les ourses polaires (*Ursus maritimus*) donnent naissance et nourrissent leurs petits dans des tanières de glace et de neige. De 1999 à 2001, on a mesuré la structure de 22 tanières situées sur la plaine côtière de l'Alaska septentrional après que les familles d'ours polaires eurent évacué leurs tanières au printemps. Au cours des étés de 2001 et de 2002, on s'est à nouveau rendus sur les sites de 42 tanières de mise bas et d'exploration automnale et on a mesuré les caractéristiques de l'habitat situé au-dessous de la neige. La structure des tanières d'ourses polaires variait considérablement. La plupart étaient de simples cavités qui possédaient un tunnel servant à la fois d'entrée et de sortie. D'autres comportaient plusieurs salles et des tunnels supplémentaires. L'épaisseur de la neige au-dessus et au-dessous des tanières était très variable, mais dans la plupart des cas, la couverture de neige était inférieure à 1 m. Les tanières étaient situées sur des reliefs prononcés ou y étaient associées (surtout les rives côtières ou les berges de fleuves, mais aussi le bord d'un lac et le remblai de gravier d'un champ pétrolifère abandonné), qui se détachent nettement du paysage alentour en été et qui retiennent la neige au début de l'hiver. Même si elles étaient facilement identifiables, les formes de relief propices à l'établissement de tanières dans l'Alaska septentrional étaient plus discrètes que les habitats de tanières situés dans bien d'autres régions de l'Arctique. La structure des tanières d'ourses polaires en Alaska offrait une ressemblance frappante avec celle des tanières creusées ailleurs et elle est restée largement inchangée dans le nord de l'Alaska pendant plus de 25 ans. Les connaissances sur la structure des tanières et les caractéristiques des sites permettront aux gestionnaires de ressources de distinguer les habitats qui sont le plus susceptibles d'abriter des tanières. Cette information peut aider ces gestionnaires à prévenir les retombées négatives sur l'ours polaire de l'exploration et de l'exploitation minières.

Mots clés: Arctic National Wildlife Refuge, habitat propice aux tanières, tanière de mise bas, National Petroleum Reserve – Alaska, ours polaire, *Ursus maritimus*, Prudhoe Bay

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INTRODUCTION

Over most of their range, pregnant polar bears (*Ursus maritimus*) create dens in autumn snowdrifts. They give birth to altricial young in mid-winter and occupy the den for three to four months following parturition. Survival and development of neonates is dependent on the relative warmth and stable environment within the maternal den (Blix and Lentfer, 1979). Female polar bears are faithful to general geographic areas, rather than to specific locations, and return to the same substrate (land versus sea ice) for consecutive denning (Amstrup and Gardner, 1994). In the

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southern Beaufort Sea, the polar bear population comprises fewer than 2500 individuals with ranges extending from Barrow, Alaska (159˚ W) to Tuktoyaktuk, Northwest Territories (132˚ W), and north to approximately 74˚ N (Amstrup et al., 2001). Approximately half of annual maternal dens of this population occur on land or on landfast ice (Amstrup, unpubl. data; Amstrup and Gardner, 1994). Terrestrial denning appears to be increasing in the Beaufort Sea (Stirling and Andriashek, 1992; Amstrup and Gardner, 1994). Maternal denning in northern Alaska, unlike that in known den concentration areas of other regions of the polar basin (Harington, 1968), is sparsely distributed within a narrow margin of coastal habitat (Amstrup and Gardner, 1994). Most of those dens, however, occur between 147˚ W and the Canadian border (Amstrup and Gardner, 1994). Most polar bear terrestrial den habitat in Alaska lacks the steep relief typical of concentrated denning areas on Herald Island (Ovsyanikov, 1998), Wrangel Island (Uspenski and Kistchinski, 1972), and the islands of the Svalbard archipelago (Larsen, 1985). Alaskan den sites do not show an association with tall vegetation, which is characteristic of den sites in Hudson Bay (Clark et al., 1997). Snow accumulation sufficient for denning in northern Alaska results from drift caused by predominantly east or west winds and occurs mainly along coastal or river banks and bluffs (Benson, 1982; Durner et al., 2001). As in other areas, the distribution of snow determines the distribution of dens (Belikov, 1980; Lentfer and Hensel, 1980; Hansson and Thomassen, 1983). The relative scale of banks on the coastal plain of northern Alaska is generally subtle; however, suitable den habitat is detectable during the snow-free season and may be identified on high-resolution aerial photography (Durner et al., 2001). This identification requires knowledge of the minimum requirements for snow den structures and the underlying landforms necessary to support those conditions. These landforms are broadly dispersed, but not uniformly distributed, across northern Alaska (Durner et al., 2001:119).

In Alaska, petroleum activities currently span approximately 200 km of the Beaufort Sea coast, and proposed developments would more than double the area. Oil lease sales have recently begun west of Prudhoe Bay in the National Petroleum Reserve – Alaska (NPRA). The “1002” area of the Arctic National Wildlife Refuge (ANWR), considered potentially the most important field of recoverable oil and gas in the United States, may contain over nine billion barrels of oil (Clough et al., 1987). This area is also home to 34% of the polar bears that den on land in Alaska (Amstrup, 1993; Amstrup and Gardner, 1994; Amstrup, unpubl. data).

The annual recruitment from dens on the ANWR is a significant contribution to the population of polar bears in the southern Beaufort Sea (Amstrup, 1993). The 1987 Legislative Environmental Impact Statement to the United States Congress on oil development in the 1002 area hypothesized that “pipelines and roadways may prevent female polar bears from moving to and from inland denning areas,” that “exploration, construction, and production in the immediate vicinity of polar bear dens could cause the bears to abandon dens,” and that “production activities could create disturbances that would likely keep bears from returning to those preferred denning areas” (Clough et al., 1987:129). In addition, Clough et al. (1987:130) state: “Some adverse effects on polar bears could be reduced by documenting den locations and use areas so that oil-development activities avoid them to the maximum extent possible. Avoidance of suitable denning habitat is most important.” They also state that “conflicts with bears…could be minimized by limiting construction activities during the denning period,” and that “such data [relevant to movements and behavior] would be invaluable in learning how to predict and minimize adverse effects of industrial activities on polar bears” (Clough et al., 1987:130).

In previous papers, we have discussed polar bear movements, distribution, and the timing and location of polar bear dens (Amstrup, 1993; Amstrup and Gardner, 1994; Amstrup et al., 2000; Durner et al., 2001). Here we discuss the broader issue of den use areas (Clough et al., 1987), in further efforts to assure that our knowledge base can help protect polar bears in perpetuity.

The potential for direct and indirect interactions between polar bears and humans can only increase with greater numbers of people and more area under development. While production from established facilities continues throughout the year, most petroleum exploratory and construction activities occur during winter. This timing minimizes impacts on most Arctic habitats and wildlife, but increases the potential for disturbance of polar bear maternal dens. Direct consequences of disturbing maternal dens may include den abandonment and mortality of young. Durner et al. (2001) began to classify, describe, and map suitable denning habitats on Alaska’s northern coast. That work, however, was based on examination of relatively few dens that had been occupied mainly during the 1980s (See shaded area on Fig. 1). In this study, we used a larger number of recently discovered dens to refine our previous knowledge of habitat characteristics at den sites (Durner et al., 2001) and describe more thoroughly the structure of polar bear snow dens in northern Alaska (Lentfer and Hensel, 1980).

METHODS

Locating Dens

We captured polar bears by injecting immobilizing drugs—tiletamine hydrochloride plus zolazepam hydrochloride (Telazol®, Warner-Lambert Co.)—with projectile syringes fired from helicopters (Stirling et al., 1989). Capture protocols were approved by independent animal care and welfare committees. Polar bears were captured in

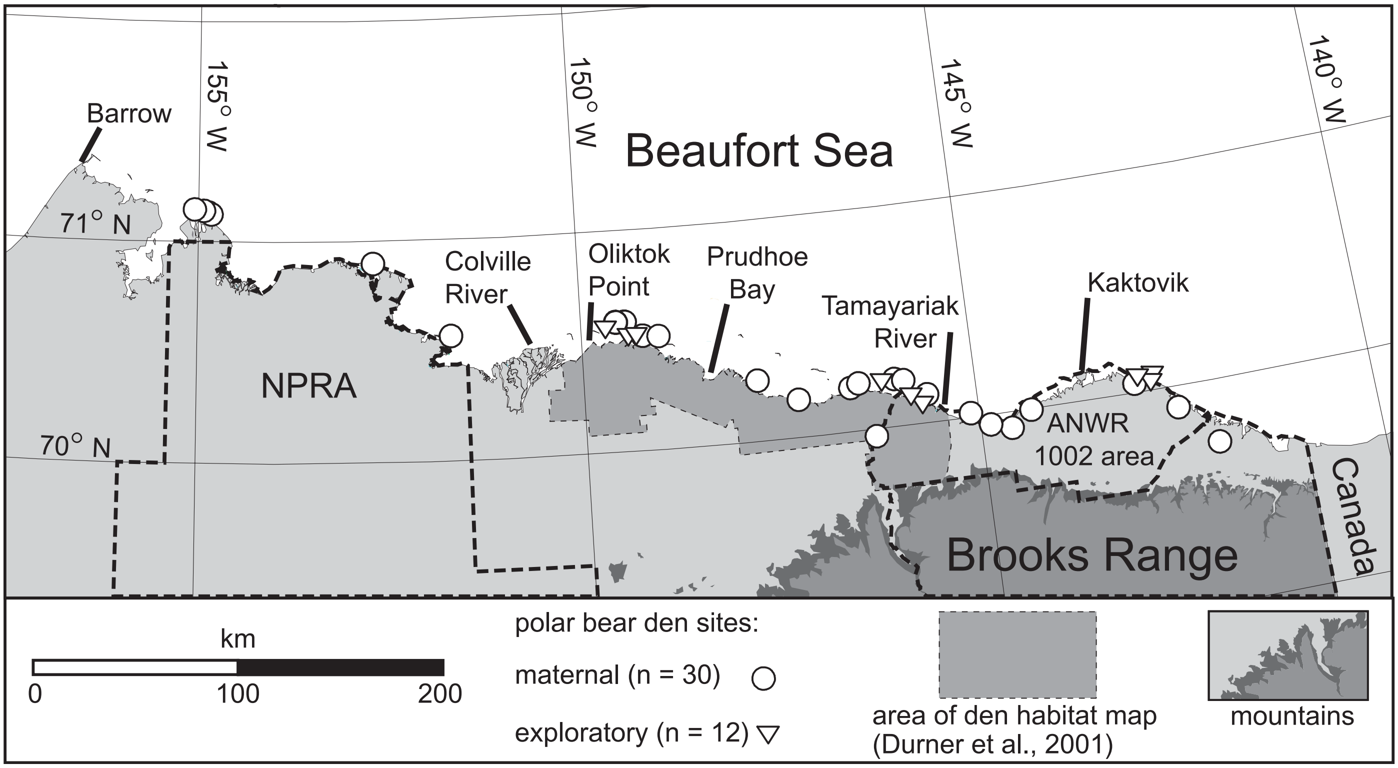

FIG. 1. Distribution of polar bear maternity dens and autumn exploratory dens examined in this study on 30 July–2 August 2001 and 13–15 July 2002. Dens were located by USGS personnel conducting field research from 1997 to 2002. Also shown are place names indicated in the text.

the Beaufort Sea and adjacent areas (Fig. 1) during March-May and October-November in 1997–2001. Satellite radio transmitters attached to neck collars, or VHF radio collars, were applied to solitary adult female polar bears (Amstrup et al., 2000).

Polar bear dens were located in three ways. We followed radio-collared pregnant females to dens by a combination of satellite and aerial radio-telemetry. We detected a few previously unknown dens while flying numerous transects over dens of radio-collared females during a survey designed to test the effectiveness of Forward-Looking Infrared sensors (FLIR Systems, Inc., Portland, Oregon) for locating maternal dens. We also obtained visual observations (incidentally, during capture and radio-tracking efforts) of a small number of dens occupied by bears that were not wearing radio-collars. Den sites were classed as either maternal dens (where a bear spent the majority of the winter and departed after the time when birth would be expected) or exploratory dens (places that a bear investigated during autumn as possible den sites but did not occupy during winter).

Den Structure

After the departure of the family in spring, we visited dens on the ground to measure and describe their structure. The location of each den was determined with a global positioning system (GPS) receiver set on averaging mode (either a military-grade PLGR, Type HNV-560C, Rockwell International, Cedar Rapids, Iowa; or civilian Garmin III Plus, Garmin International, Olathe, Kansas). Weather prevented us from visiting all dens on the ground in spring. Exact positions of those that we could not visit were determined during several aerial overpasses in GPS-equipped fixed-wing aircraft or helicopters approximately 30 m above ground level. We photographed, measured, and sketched all dens visited on the ground. We recorded tunnel height and width; length of den (including the main chamber); main chamber length, height, and width; and depth of snow over the main chamber and tunnels. We also recorded the existence of secondary chambers; the presence of stains from fur oils, urine, and feces; and evidence of digging by cubs.

Den Site Habitat

We revisited polar bear maternal den sites during the snow-free season by small, motorized boat or by flying to each site in a Bell 206 L helicopter. We landed nearby and approached each den site on foot. We focused data collection on the broad-scale habitat features that would be most useful for later remote-sensing analysis. We recorded slope of the habitat at the den site; length of the hypotenuse of the habitat feature (straight-line distance from the top to the bottom of the feature, following the slope of the feature); and slope of landscape above and below the den site. We also recorded whether the habitat feature was stable (generally vegetated and non-sloughing), active

TABLE 1. Measurements of polar bear maternal den snow structures (cm) recorded in northern Alaska during March and April in 1999–2001. Length of den includes both tunnels and chambers. Snow depth is the minimum measurement over tunnels and primary and secondary chamber ceilings.

	Number of Measurements	Mean	S.D.	Minimum	Maximum
Height of tunnel	17	49	10	36	66
Width of tunnel	19	126	56	45	290
Length of den	20	587	200	273	893
Height of chamber	19	79	13	53	103
Width of chamber	24	127	24	78	190
Length of chamber	24	148	31	110	240
Snow depth above tunnel	18	68	89	10	400
Snow depth above chamber	25	72	87	10	400

(with sloughing due to river currents or wave action), or partially stable (with incomplete sloughing). Landscape and vegetation characteristics (Jorgenson et al., 1994) above, below, and at the den site were also recorded. Height of the feature was either measured at the site or calculated as the side of a right triangle. Hypotenuse length was determined with a fiberglass measuring tape. Slope was measured with an inclinometer (Suunto Co., Finland). Aspect (averaged to cardinal points) and slope were recorded in degrees.

Throughout this paper, we frequently refer to "bank" habitat. A bank is defined as any abrupt change in topography that may catch drifting snow. Our definition includes, but is not limited to, coastal bluffs, river banks and bluffs, stream banks, and lake shores.

RESULTS

Den Structure

We examined 22 maternal dens in terrestrial habitat during late March and early April in 1999–2001. We attempted to visit all dens as soon as possible after the departure of the family group; however, weather often delayed our travel to den sites. As a result, wind-borne snow partially filled some dens and prevented us from collecting all the measurements that we intended to record. We were, however, able to obtain most measurements of important features from most dens (Table 1).

The structure of individual polar bear dens varied greatly, but the presence of a chamber where the family group spent most of the winter was common to all dens (Fig. 2). Four dens had secondary chambers apparently used near the end of the denning period. The primary and secondary chambers were oval, with average internal dimensions of 79 cm height, 148 cm length, and 127 cm width (Table 1). Primary chambers were distinguished from secondary chambers by the presence of ice in the floor and ceiling and were often discolored by fur oils and urine. Primary chambers usually included a nest-like depression where the adult and cubs spent most of their time. Cub feces were observed in primary chambers of three dens. These characteristics were not as pronounced or were absent in secondary chambers. Occasionally, soil was exposed under the floor or at the back wall of the primary chamber. Tunnels averaged 126 cm in width by 49 cm in height. Other features varied greatly among dens. Total length of the den interior (including tunnels and main chamber) ranged between 273 and 893 cm. Six dens had more than one exit, and four showed evidence of small excavations made by cubs. Mean minimum snow depths above chamber and tunnel ceilings were 72 and 68 cm, respectively.

Den Site Habitat

We revisited 35 den sites on the coastal plain of northern Alaska between 30 July and 2 August 2001. We revisited an additional seven den sites on 13–15 July 2002. The dens occurred between 142˚06′ W and 154˚59′ W and were situated 0–24.7 km (mean ± S.D. = 1.7 km ± 4.5 km) from the Beaufort Sea coastline (Fig. 1). Den site elevation ranged from 0 to 108 m (mean ± S.D. = 10 m ± 24 m) above sea level. Thirty sites were maternal dens and 12 sites were exploratory dens. We located 20 dens by conventional radio tracking, 19 by opportunistic encounters during research activities, and 3 while conducting FLIR surveys. Although there is some error in GPS positioning, we are confident that we returned to the actual sites used by bears. Our confidence was reinforced by observations of polar bear fur and feces, and sometimes shallow depressions on the ground, at 19 maternal dens. Depressions appeared to have been created simply through compaction of soft tundra vegetation by direct contact with the bear's body. This evidence was apparent after two summers at two den sites on stable habitat. A shallow soil excavation and traces of fur were found at one exploratory site.

All den sites were on landscape features that were easy to distinguish from the surrounding terrain in summer. In winter, however, many of the features where dens occurred were filled with drifted snow and only marginally detectable. Most dens were located on coastal banks (n = 29), major river and floodplain banks (n = 8), and tributaries (n = 2). Two dens were on lake shores and another on the edge of an abandoned oil field gravel pad. Thirty-one den sites occurred on active banks (Fig. 3), eight on stable banks (Fig. 4), and three on partially stable banks. Bank height ranged from 1.4 to 33.0 m (mean ±

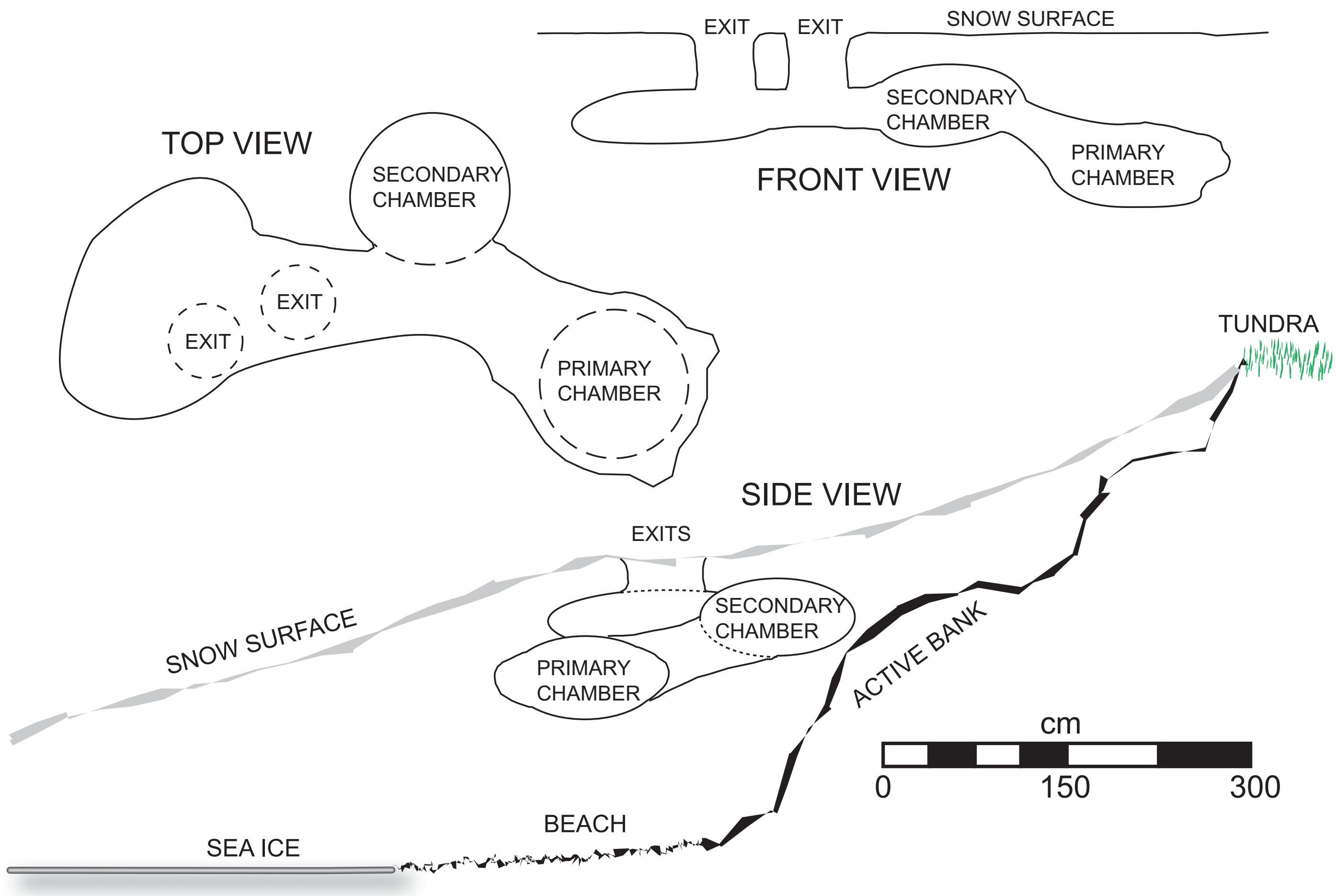

FIG. 2. Diagrams of a polar bear maternal den near Prudhoe Bay, Alaska, 10 April 2000.

S.D. = 4.4 ± 5.3 m). Bank slope ranged between 8˚ and 48˚ (mean ± S.D. = 32.2 ± 9.0˚). The aspect of dens was determined largely by the east-to-west orientation of the coast and the south-to-north orientation of rivers. Of the 42 dens, 5 dens faced east, 7 west, 13 north, and 17 south. All sites had minimal topographic relief above (range: 0–8˚, mean ± S.D. = 1.6˚ ± 1.5˚) and below (range: 0–8˚, mean ± S.D. = 1.5º ± 2.3˚) the slope where the den was located.

Habitat above the slope adjacent to the den was generally upland tundra composed of moist sedge (*Carex* sp.)–willow (*Salix* sp.), *Dryas* sp.–sedge–willow, or a similar complex of low forbs, grasses, and prostrate willows (Jorgenson et al., 1994). Vegetation on the slope (stable and semi-stable slopes only) was usually a continuation of the above-slope habitat. Habitat below the slope typically included a beach, river bar, floodplain, or body of water (lake, river, or tidewater). When present, vegetation below the slope was composed of wet sedge communities. In general, any vegetation at a den site could be characterized as low (< 0.2 m, visual estimate) tundra plant communities typical of the northern coastal plain. At one site, however, the vegetation above the slope was composed of willows and dwarf birches (*Betula* sp.) approximately 1 m in height.

DISCUSSION

Den measurements recorded in this study indicate that the structure of terrestrial dens in Alaska has not changed at least since the 1970s. Ten maternal dens inspected by Lentfer and Hensel (1980) had chambers whose mean height (78 cm), length (180 cm), and width (162 cm) were close to our mean values (Table 1). Likewise, although den habitat in northern Alaska may differ from that of other denning areas, the structure of polar bear dens in Alaska is similar to that in other locales. Larsen (1985) reported the ranges of chamber heights and widths as 70–130 cm and 110–220 cm, respectively. Polar bear dens on Wrangel Island (Uspenski and Kistchinski, 1972) had comparable chamber height (80 cm), length (165 cm), and width (140 cm) measurements. Harington (1968) recorded somewhat larger dimensions (mean values: height, 97 cm; length, 205 cm; width, 151 cm) for 14 dens in the Canadian High Arctic. Three dens (30%) measured by Lentfer and Hensel (1980) had more than one chamber. Multiple chambers have been reported from Wrangel Island (Uspenski and Kistchinski, 1972) and northern Canada (Harington, 1968). Only four (18%) of the dens we examined had secondary chambers. Exit tunnels described by Lentfer and Hensel (1980) for polar bear dens in Alaska had an

FIG. 3. Polar bear maternal den site on active coastal bank in Arctic National Wildlife Refuge, Alaska, 31 July 2001.

FIG. 4. Polar bear den site on stable lake shore near Prudhoe Bay, Alaska, 30 July 2001.

average height of 62 cm and width of 87 cm. Harington (1968) reported a tunnel height of 56 cm and width of 59 cm. Den tunnels in Svalbard ranged from 70 to 100 cm in diameter (Larsen, 1985). Polar bear dens on Wrangel Island (Uspenski and Kistchinski, 1972) had tunnel heights of 50–60 cm and widths of 70–110 cm. These dimensions differed little from the mean tunnel height and width (49 and 126 cm) that we measured at maternal dens. Our observation of digging activity by cubs (in four dens) is also consistent with other reports (Harington, 1968; Lentfer and Hensel, 1980; Hansson and Thomassen, 1983).

The presence of “ventilation holes” in polar bear dens has been observed in several regions of the Arctic (Harington, 1968; Uspenski and Kistchinski, 1972; Lentfer and Hensel, 1980). During FLIR surveys in January and November 2001, we noted small openings in the roofs of five dens. These openings could have served a ventilation function and were of a size that a female bear could have created by using her paws to scrape a hole in the ceiling of the den. The openings also could have resulted from accidental collapse of the roof due to digging by bears to enlarge the den. The holes observed over two dens seen in January were not there when the dens were first discovered. They remained open for a few days, and then apparently drifted closed. These openings appear similar to those described in two maternal dens by Lentfer and Hensel (1980). Bears may occasionally create small temporary openings in their dens, perhaps for thermoregulation and air transport (Lentfer and Hensel, 1980), but our observations suggest that they do not continuously maintain them. It is not clear to us what mechanism may have resulted in the long, narrow ventilation holes described by Harington (1968), and how it would be possible for bears to maintain them. Ventilation holes were not observed in polar bear maternal dens in Svalbard (Hansson and Thomassen, 1983). While small openings in the den may facilitate gas exchange and thermoregulation, the low frequency of encounters with this feature suggests that ventilation holes are usually ephemeral or nonexistent in maternal dens. Most likely, necessary gas and heat exchange is typically accomplished through the porous surrounding snow.

The depth and density of snow surrounding a maternal den determines the relative warmth that a polar bear experiences (Harington, 1968). Blix and Lentfer (1979) reported that temperature within a snow column was warmer near the underlying substrate (either land or sea ice) and approached ambient temperatures close to the snow surface. The dens that we observed to be in contact with the ground may be explained as attempts by the adult bear to seek an optimal thermal zone. The range of snow depths we report here (Table 1) is similar to those reported in other regions of the Arctic (Harington, 1968; Uspenski and Kistchinski, 1972; Hansson and Thomassen, 1983). This suggests that, while the underlying habitat may vary greatly among the regions where polar bears den, the requirements for maternal den structures are similar throughout the range of polar bears. Harington (1968) reported that extremely hard snow or very soft snow was unsuitable for denning. The numerous autumn exploratory dens we observed may be cases where a bear began digging into a snow berm, only to determine that the snow was too soft or too hard.

Polar bears in northern Alaska chose maternal den sites on bank features that can be readily distinguished from the dominant landscape during the snow-free season. At all sites examined during this study, we were impressed by the consistency of three measured variables: 1) the relative steepness of the den habitat; 2) the relative flatness of terrain above and below the slope; and 3) the change in elevation, or height, of the bank feature. All den sites in this study occurred on features that could be classified as bank habitat. Durner et al. (2001) reported that 28% of maternal dens occurred at sites other than banks or bluffs, where there was little topographic relief (i.e., “other” habitat). Those den site locations were made before 1997 and were determined by marking a point on a USGS 1:63 000 map while circling the den in a fixed-wing aircraft or helicopter. Because of the method used, locations of some dens included in the earlier study were not as accurate as locations determined by GPS in this study. Durner et al. (2001) were not able to identify and digitize “other” habitat consistently, which suggests that 28% of denning habitat (classified as “other”) was omitted from their map. However, our failure in this study to locate any dens in “other” habitat, despite a larger sample size and greater location accuracy, suggests that the omission of “other” habitat by Durner et al. (2001) is not a shortcoming; instead, their depiction of maternal den habitat distribution is more accurate than the authors realized. Bears will seldom den in habitat that is not capable of catching large snowdrifts. On the other hand, the minimum values of chamber height (53 cm) and snow depth above the chamber (10 cm) in Table 1 indicate that bears are capable of creating dens adjacent to banks lower than those we report here (bank height range: 1.4 m to 33 m). Our measurements of den dimensions and those reported from Svalbard (Larsen, 1985) suggest a conservative approach to habitat delineation that includes minimally acceptable den habitat in a management plan.

Durner et al. (2001) reported ranges of 1.3 to 34 m for bank height and 15.5˚ to 50˚ for slope. Bank height and slope that we measured fell largely within those ranges. Also, Durner et al. (2001) described landscape features above and below the slope as “relatively level ground.” Inclinometer measurements made during this study corroborated that result at all of the den sites we visited. This low-relief topography generally extended more than 100 m from the den location. This observation is in concordance with data from Svalbard, where most dens occurred on slopes adjacent to flat mountaintops (Larsen, 1985). Durner et al. (2001) reported that some dens occurred in microhabitat, i.e., in small gullies or polygon troughs adjacent to prominent banks. Three dens that we measured also occurred in similar features, suggesting that gullies and tundra polygon troughs may sometimes be important snow-catching agents. We did not attempt to define or measure microhabitat because it was always associated with major landscape features that we could readily identify and measure on the ground and on aerial photos.

Maternal den habitat is a requirement of polar bear life history that can be identified, and its identification should be a prerequisite of any management scenario. Petroleum activities may soon include much of the southern Beaufort Sea coast of Alaska. If this occurs, knowledge of den chronology and recognition and avoidance of den habitat will be essential to minimize industrial impacts on denning polar bears (Clough et al., 1987). This paper provides information that, when used in conjunction with den habitat mapping techniques (Durner et al., 2001), may help to achieve that objective.

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