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Polar Bear Maternal Den Habitat in the Arctic National Wildlife Refuge, Alaska

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ABSTRACT. Polar bears (*Ursus maritimus*) give birth during mid-winter in dens of ice and snow. Denning polar bears subjected to human disturbances may abandon dens before their altricial young can survive the rigors of the Arctic winter. Because the Arctic coastal plain of Alaska is an area of high petroleum potential and contains existing and planned oil field developments, the distribution of polar bear dens on the plain is of interest to land managers. Therefore, as part of a study of denning habitats along the entire Arctic coast of Alaska, we examined high-resolution aerial photographs (n = 1655) of the 7994 km^2 coastal plain included in the Arctic National Wildlife Refuge (ANWR) and mapped 3621 km of bank habitat suitable for denning by polar bears. Such habitats were distributed uniformly and comprised 0.29% (23.2 km^2) of the coastal plain between the Canning River and the Canadian border. Ground-truth sampling suggested that we had correctly identified 91.5% of bank denning habitats on the ANWR coastal plain. Knowledge of the distribution of these habitats will help facilitate informed management of human activities and minimize disruption of polar bears in maternal dens.

Key words: aerial photography, Arctic National Wildlife Refuge (ANWR), den habitat, maternal den, photo interpretation, polar bear, *Ursus maritimus*

RÉSUMÉ. Les ours polaires (*Ursus maritimus*) mettent bas au beau milieu de l'hiver dans des tanières de glace et de neige. Les ours polaires des tanières qui sont la cible de dérangements occasionnés par l'être humain peuvent abandonner leur tanière avant que leurs petits ne soient prêts à survivre les rigueurs de l'hiver de l'Arctique. Puisque la plaine côtière arctique de l'Alaska renferme de grandes possibilités sur le plan pétrolier et comprend des champs pétrolifères mis en valeur ou dont la mise en valeur est planifiée, la répartition des tanières d'ours polaires sur la plaine revêt de l'intérêt chez les gestionnaires des terres. Par conséquent, dans le cadre d'une étude portant sur les habitats des tanières tout le long de la côte arctique de l'Alaska, on a examiné des photographies aériennes de haute résolution (n = 1655) portant sur une superficie de 7994 km^2 de la plaine côtière faisant partie de la Réserve faunique nationale de l'Arctique (la Réserve), puis on a cartographié 3621 km d'habitats de berges propices à l'établissement de tanières. Ces habitats étaient répartis de manière uniforme et représentaient 0,29 % (23,2 km^2) de la plaine côtière entre la rivière Canning et la frontière canadienne. L'échantillonnage des données de terrain suggérait qu'on avait correctement repéré 91,5 % des habitats de tanières de berges sur la plaine côtière de la Réserve. Le fait de connaître la répartition de ces habitats favorisera une bonne gestion de l'activité humaine et permettra de déranger les ours polaires le moins possible dans leurs tanières maternelles.

Mots clés : photographie aérienne, Réserve faunique nationale de l'Arctique, habitat des tanières, parturition, interprétation de photo, ours polaire, *Ursus maritimus*

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INTRODUCTION

Polar bears (*Ursus maritimus*) are born in mid-winter in dens of ice and snow. The relative warmth and stable temperature within the den provide the necessary environment for development of the young. Hence, successful reproduction in polar bears is dependent on landscape features that catch enough autumn snow to allow pregnant females to dig dens (Blix and Lentfer, 1979). In Arctic Alaska, winter snow depth is generally 10–40 cm, with localized patches of deep drifts (Benson, 1982). These drifts occur along coastal and river banks as well as along abrupt lakeshores (Benson, 1982; Durner et al., 2001, 2003). In the Beaufort Sea, approximately 50% of all pregnant polar bears come ashore each autumn to construct dens in these snowdrifts (Amstrup and Gardner, 1994). During winter, industrial activities in northern Alaska, such as seismic surveys and construction of ice roads and drill pads, are at their highest level. Similarly, access to inland areas by indigenous people reaches its peak during the winter months. These activities coincide with the time when denning polar bears are giving birth or nurturing neonates. While impacts on tundra vegetation and most other wildlife are minimal in mid and late winter, parturient and post-parturient polar bears are susceptible to human disturbances and may abandon dens before cubs

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are large enough to emerge (Amstrup, 1993; Lunn et al., 2004).

Many potential conflicts between human activities and denning bears may be reduced or eliminated by simply avoiding habitats that polar bears prefer (Clough et al., 1987). Locating terrestrial habitats that polar bears prefer for denning is possible through interpretation of high-resolution landscape photography (Durner et al., 2001). Durner et al. (2001, 2003) described and mapped the distribution of suitable polar bear maternal den habitat across much of northern Alaska, but not for the coastal plain in the northeast included within the Arctic National Wildlife Refuge (ANWR). Here, we proceed from where we left off in our earlier work to complete the mapping effort for the Arctic coastal plain of Alaska and further refine our methodology.

METHODS

Photo Interpretation

Methods of photo interpretation followed those of Durner et al. (2001). High-resolution color aerial photographs (scale: 1 cm = 178.6 m) were examined for den habitat. Photos were taken in 1981 with a certified cartographic camera (15.4 cm focal length), along east/west transects between the Canning River and the Canadian border, from a twin-engine turbocharged aircraft (Cessna 320, Cessna 310, or Piper Aztec) flown at 2743 m above mean terrain level. All photos were provided by the U.S. Fish and Wildlife Service. Den habitat was located on the photos with a pocket stereoscope and by interpretation of vegetation patterns. Linear features that showed elevation changes of 1 m or more were annotated on photos. Human-made landscape features, as well as sand dunes and pingos, were not mapped. Once identified on photos, den habitat was digitized and transferred to 1:63 360 base maps as line features through computer-aided drafting. The final format was provided as ARCVIEW shapefiles (ESRI, Redlands, California).

We examined photos of two areas within the ANWR coastal plain and adjacent coastal islands for bank habitat. Area 1 (1275 photos for 6426 km^2) was the 1002 area of the ANWR, from the east side of the Canning River to the Aichilik River and from the coast southward to the 1002 area's southern border (Fig. 1). Area 2 (380 photos for 1568 km^2) included the region between the Aichilik River and the Canadian border, and from the coast southward to the foothills of the Brooks Range (Fig. 1).

Uniformity of den habitat was assessed by measuring the distance between each of 10 000 random locations and the nearest mapped habitat. Simple univariate statistics were used to describe the dispersion of den habitat, with the UNIVARIATE procedure in SAS (SAS Institute, Cary, N.C.). Statistics are presented as the mean ± standard deviation.

Map Verification

We ground-truthed the final den habitat map with 127 survey transects that originated within 10 km of Kaktovik and radiated west, south, and east in a pattern similar to the spokes of a wheel (Fig. 1). Transect length averaged 58 km (range 43–75 km) with a spacing between transects of 175 m at their origin and 937–1488 m at their terminus. ARC/INFO (version 9.0, ESRI, Redlands, California) tools were used to create a GIS coverage of transects. We used a "1 in k" systematic sample (Scheaffer et al., 1986) to select 14 transects that would represent a uniform distribution of the study area (Fig. 1). The selected transects had an average length of 62 km (range 44–75 km) and a total length of 861 km and were spaced a minimum of 1050 m apart at their origin and 8900 m at their terminus.

We merged the transect coverage with the final den habitat map to identify intersections of transects with mapped habitat (precision points) to sample in the field (Fig. 1). The term "precision point" is consistent with Durner et al. (2001) and is equivalent to the term "commission" typically used in map evaluation (i.e., a mapped feature whose actual position on the ground may be different from that measured from photographs, or which may not have the characteristics assumed from the photographs). Precision points were saved as a point attribute ARCVIEW shapefile. Point data (precision points and transect start and end points) were transferred as waypoints with DNRGarmin (version 4.0, Minnesota Dept. of Natural Resources) to a Garmin GPSmap 176C global positioning system (GPS) receiver. Each record included a unique identifier and point coordinates.

From 7 to 11 August 2004, we flew transects with a Raven R-44 helicopter (speed 80–100 km/hr; altitude 30–50 m agl). This low speed and altitude were essential to visually identify suspected habitat that our mapping omitted. We flew selected transects from beginning to end waypoints, landing near each precision point to measure ground-level features. Once on the ground, we then walked to each precision point, navigating with a GPS. At each precision point we measured and recorded the following data: 1) slope of the bank face (degrees); 2) hypotenuse (to nearest 0.1 m, for calculating height of large banks); 3) bank height (directly measured on small banks); 4) distance of the bank from the actual mapped feature (for determining mapping error); and 5) GPS position error. Distances from precision points to actual bank features were measured with the GPS receiver. Slope was measured with a handheld inclinometer (Suunto Co., Finland). Bank height was measured at the site or calculated as the side of a right triangle (Durner et al., 2003). Precision points that failed to meet the minimum criteria for slope and height (≥ 16˚ and ≥ 1.3 m; Durner et al., 2001) were considered non-den habitat and were used in the estimation of mapping error (i.e., commission).

In addition to understanding how well the den habitat map represented those features that were mapped, we were

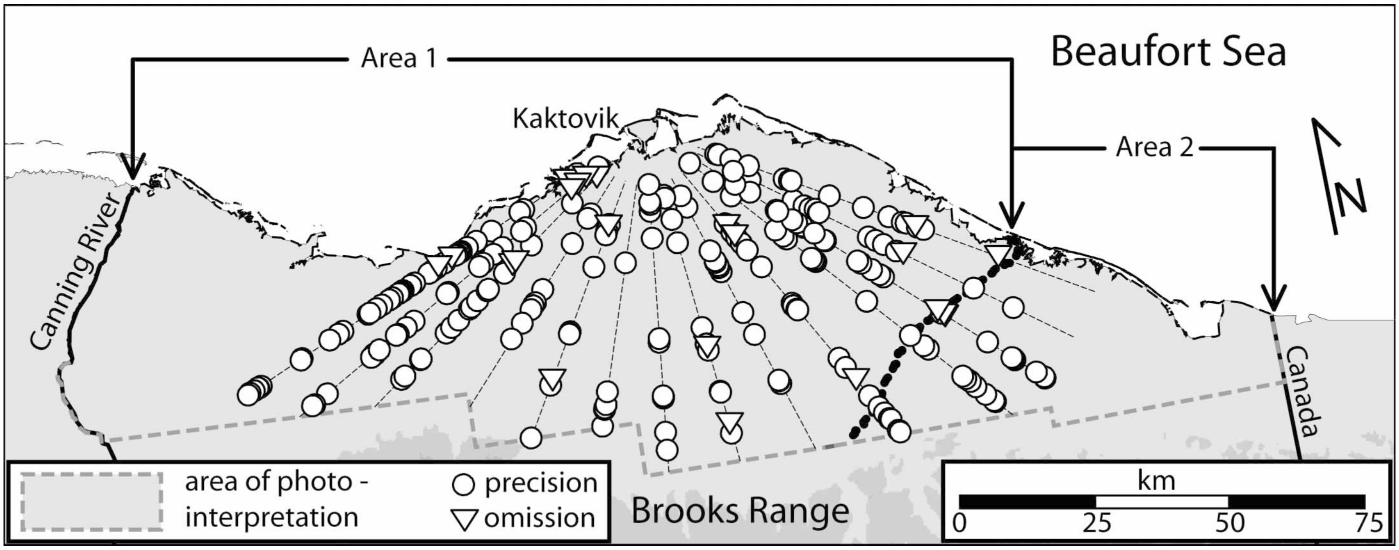

FIG. 1. Bounds of a photo-interpretive examination of polar bear maternal den habitat in two areas on the coastal plain of the Arctic National Wildlife Refuge, Alaska, showing distribution of helicopter transects (n = 14). Also shown are locations of precision points (circles, n = 224) and omission points (triangles, n = 22) used for ground-truthing a map of polar bear maternal den habitat on the ANWR coastal plain in 2004.

also interested in learning how often den habitat was missed during photo interpretation. Therefore, whenever we encountered suspected den habitat that appeared not to be mapped (i.e., an omission point), we landed and recorded the identical suite of data that was recorded at precision points.

We had previously located polar bear maternal dens on the coastal plain of the ANWR during other research efforts (Amstrup and Gardner, 1994; Amstrup, unpubl. data). Dens were located primarily by conventional radiotelemetry methods (from aircraft) or by opportunistic encounters during field capture work. We compared the distribution of our newly mapped den habitats to the known locations of those dens to provide a qualitative check of the validity of our map.

RESULTS

Photo Interpretation

We mapped a total of 3902 segments of bank habitat within the coastal plain of the ANWR (Fig. 2). Total length of den habitat was 3621 km. Assuming an average width of 6.4 m (based on mean height and slope at actual den sites; Durner et al., 2001), the total area of den habitat was 23.2 km^2, or 0.29%, of the 7994 km^2 study area. The distribution of this habitat, however, was relatively uniform: of 10 000 random locations distributed throughout the coastal plain of the ANWR, 90% were within 1937 m of a den habitat segment, and 50% were within 606 m (mean distance = 871 ± 886, maximum = 7122 m). A similar analysis within the oil field region (Durner et al., 2001) showed less uniformity of den habitat distribution, with 90% of 10 000 random points within 2589 m of a den habitat segment, and 50% within 844 m (mean distance = 1170 ± 1133, maximum = 9834 m).

Map Verification

Transects used for ground-truthing included 224 mapped waypoints, of which 172 had the required slope (≥ 16˚) and height (≥ 1.3 m) to be considered as den habitat. Distance from mapped features to actual features on the ground ranged from 0.0 to 145 m (32.0 ± 29.2 m). Forty potential omission points were discovered and investigated in the field. Of those, 34 met the minimum criteria of slope and height to qualify as den habitat. After incorporating potential errors in plotting habitat segments into our map (± 145 m), 12 potential omission points were determined to have been mapped, and 22 were designated as confirmed omission points (Fig. 2). The 236 mapped points (224 + 12) plus the 22 unmapped points suggested an omission error of 8.5% (22 ÷ [224 + 12 + 22] × 100). Of the 236 points that had been mapped, 22.0% ([224 – 172] ÷ 236 × 100) failed to meet the minimum criteria for den habitat.

Thirty-eight polar bear dens located in recent years (Amstrup and Gardner, 1994; Amstrup, unpubl. data) within the area of our habitat map were used as a qualitative check of mapped den habitat. Of those, 32 were within 145 m of mapped bank habitat. Hence, our mapped den habitat was in agreement with the distribution of 84.2% of mapped polar bear dens.

DISCUSSION

The small proportion of den habitat relative to the total study area in the ANWR is similar to that reported by Durner et al. (2001) for the central coastal plain of northern

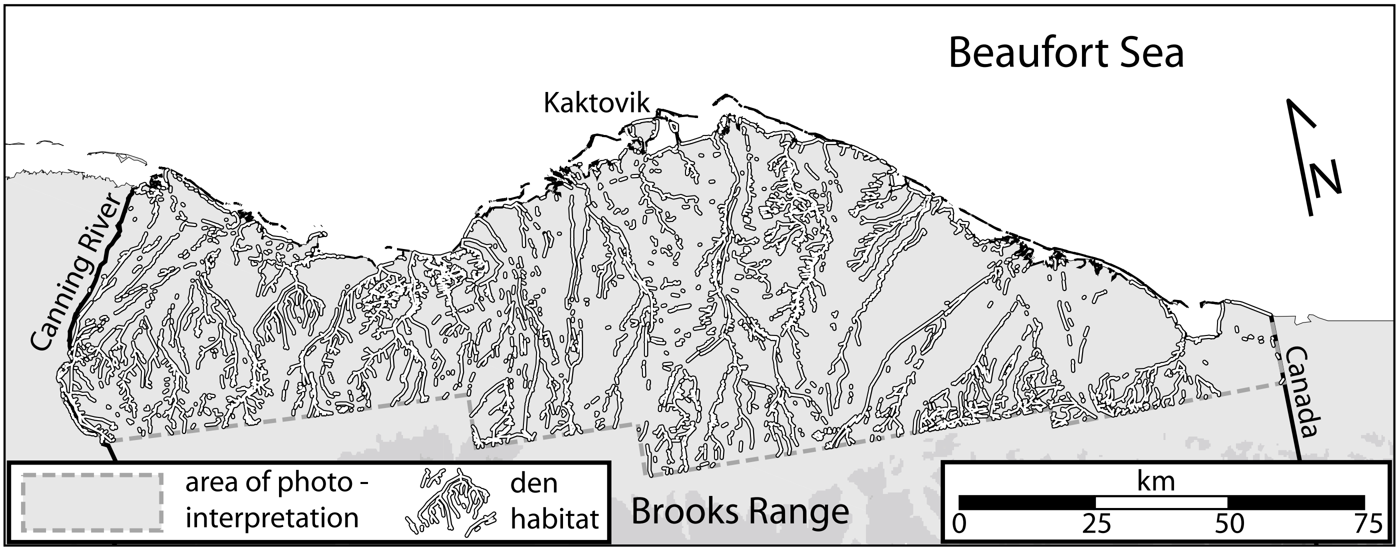

FIG. 2. Predicted distribution of polar bear maternal den habitat within the Arctic National Wildlife Refuge, Alaska, August 2004.

Alaska. Den habitat there was similar to that in other areas in that it followed the linear features of offshore islands and coastal banks, river and stream banks, and lakeshores. Although den habitat represents only a small proportion of the ANWR coastal plain, its wide distribution makes it an important landscape feature. Also, our mapping effort suggests that the coastal plain of the ANWR may have 38% more den habitat than the central coastal plain of northern Alaska (Durner et al., 2001). Den habitat on the ANWR coastal plain occupied 23.2 km^2 (0.29%) of the 7950 km^2 study area. In contrast, Durner et al. (2001) reported 11.4 km^2 within a 6335.4 km^2 study area, or 0.18%, for the central coastal plain.

This effort improved upon previous mapping in terms of correctly identifying suitable den habitat by photo-interpretation. Durner et al. (2001) reported omission error rates of 35.5% and precision error rates of 12.3%. Omission (22%) and precision (8.5%) rates derived here show that our map of polar bear den habitat on the ANWR correctly depicts the distribution and location of den habitat 91.5% of the time. The improvement in error rates between the prior work (Durner et al., 2001) and this study likely resulted from improved ability of the cartographer to identify bank habitat on aerial photos. Also, the precision error demonstrates that our photo interpretation was conservative. That is, if in doubt whether a feature met our minimum requirements for den habitat, we mapped it. Often, mapped banks that met our criteria transitioned on a continuum to flat terrain. At some point along that continuum, the slope and elevation ceased to be adequate for denning. That point, however, was often difficult to detect from photos. In plotting the "adequate" habitat, we erred on the side of caution rather than take the risk of calling a bank inadequate for denning when it was in fact adequate.

The locations of actual den sites that were known from other ongoing research in northern Alaska showed close agreement with the distribution of den habitat mapped here. Thirty-two of 38 known dens were within the 145 m error distance for mapped den habitat. Locations of 25 of those 32 dens had been determined either on the ground with a GPS receiver or by GPS fixes during low overpasses in an aircraft. Three of the six dens that fell outside of the 145 m buffer, however, had been located only by plotting positions on a USGS 1:63 000 map from an overflying aircraft. In those cases, the position error of the den site could have been as much as 500 m. This plotting inaccuracy alone might explain why those three dens were recorded as not being close to mapped den habitat. Durner et al. (2001) reported that 28% of maternal dens occurred in habitat with little topographic relief (i.e., "other" habitat). Durner et al. (2003) suggested that the importance of dens in "other" habitat may be lower than originally thought because those plotted locations also may have resulted from inaccuracies in plotting methods before the use of GPS receivers became standard practice. Regardless, our mapped habitat shows close concordance with the locations of actual polar bear dens.

Amstrup (1993:249) reported that between 1981 and 1992, "polar bears denned on ANWR more frequently than would have been expected if they denned uniformly along the mainland coast." Amstrup and Gardner (1994) reported that 80% of polar bear maternal dens on land in the southern Beaufort Sea region occurred in the northeast corner of Alaska and the adjacent Yukon Territory in Canada, and 29 of 91 dens we discovered on land in Alaska between 1981 and 2005 were on the coastal plain area of the ANWR. Lentfer and Hensel (1980) suggested that the preponderance of maternal dens in this region may be due to east-to-west patterns of coastal ice formation that allow pregnant bears access to terrestrial denning habitat sooner here than in other regions of the coast. A similar mechanism was suggested by Stirling and Andriashek (1992) to explain a higher number of dens in the region between the Alaska/Canada border and Tuktoyaktuk than in eastern areas. Our data suggest that, in addition to bears' taking advantage of autumn freeze patterns, more bears may use the eastern Alaska coast simply because it has more den habitat.

The polar bear population in the southern Beaufort Sea is unique among polar bear populations because approximately 50% of its maternal dens occur annually on the pack ice (Amstrup and Gardner, 1994). A high level of sea-ice stability is necessary for successful denning on sea ice, and reproductive failure is known to occur in polar bears that den on unstable ice (Lentfer, 1975; Amstrup and Gardner, 1994). Since 1990, however, the stable multiyear sea ice of the Beaufort Sea has declined in age and extent (Barber and Hanesiak, 2004; Rigor and Wallace, 2004; Belchansky et al., 2005). If this stable denning platform continues to decline, a greater proportion of southern Beaufort Sea bears may seek dens on land. Therefore, knowing the distribution of terrestrial maternal den habitat will be increasingly important.

Some land denning habitats for polar bears are also being altered by changing sea-ice characteristics. Increases in the temporal and spatial extent of late summer and early autumn open water in northern Alaska (Comiso, 2002) have resulted in dramatic erosion of coastal shorelines, especially coastal bluff habitats (Barnes et al., 1992; Brown et al., 2003; Jorgenson and Brown, 2005). Because 65% of confirmed dens we found on land in Alaska between 1981 and 2005 were on coastal or island bluffs, loss of such habitats is likely to alter future maternal denning distributions.

Both the decline in sea-ice quality and the loss of coastal bluff habitat may increase the importance of inshore terrestrial denning habitats for pregnant polar bears in the Beaufort Sea. Additionally, delayed autumn ice formation near shore could prevent pregnant polar bears from reaching those terrestrial denning habitats (Stirling and Andriashek, 1992; Stirling and Derocher, 1993). How these potentially competing influences will play out is currently uncertain.

In the future, our maps of den habitat may be refined through examination of satellite imagery. LANDSAT TM images may be useful in identifying persistent snowpack in late spring. Because autumn and winter snowfall and the deposition of windblown snow, as well as patterns of spring snowmelt, may be expected to vary among years, multiple years of LANDSAT TM imagery may be necessary to identify most banks that polar bears might choose. Recently, high-resolution digital terrain models have become available for other areas of the northern Alaska coastal plain. These models are generated from airborne-derived Interferometric Synthetic Aperture Radar (IFSAR) data (Intermap, 2004). The high resolution of IFSAR data (horizontal resolution: 5×5 m; vertical resolution: 0.01 m; Tighe, 2003) is such that computer modeling of polar bear den habitat may be possible (Durner, unpubl. data). IFSAR coverage for the coastal plain would greatly benefit future mapping efforts and would help us to identify changes over time in the distribution of polar bear den habitat.

The GIS-formatted version of the den habitat map for both the north-central Alaska coast (Durner et al., 2001, 2003) and the coastal plain of the ANWR are available to all prospective users at the website of the Alaska Science Center, U.S. Geological Survey: http://alaska.usgs.gov/products/.

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