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Remote Identification of Polar Bear Maternal Den Habitat in Northern Alaska

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ABSTRACT. Polar bears (*Ursus maritimus*) give birth in dens of ice and snow to protect their altricial young. During the snow-free season, we visited 25 den sites located previously by radiotelemetry and characterized the den site physiognomy. Seven dens occurred in habitats with minimal relief. Eighteen dens (72%) were in coastal and river banks. These “banks” were identifiable on aerial photographs. We then searched high-resolution aerial photographs (n = 3000) for habitats similar to those of the 18 dens. On aerial photos, we mapped 1782 km of bank habitats suitable for denning. Bank habitats comprised 0.18% of our study area between the Colville River and the Tamayariak River in northern Alaska. The final map, which correctly identified 88% of bank denning habitat in this region, will help minimize the potential for disruptions of maternal dens by winter petroleum exploration activities.

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

RÉSUMÉ. Les ours polaires (*Ursus maritimus*) donnent naissance dans des tanières de glace et de neige afin de protéger leurs petits qui sont nidicoles. Durant la saison libre de neige, on a visité 25 lieux de mise bas repérés précédemment par télémétrie et on a caractérisé la structure physiologique de ces lieux. Sept tanières étaient localisées au sein d’habitats au relief très peu prononcé. Dix-huit tanières, soit 72 p. cent, se trouvaient sur des berges côtières ou fluviales. Ces «berges» étaient identifiables sur des clichés aériens. On a ensuite cherché sur des clichés aériens (n = 3000) pris à haute résolution des habitats semblables à ceux des 18 tanières. Sur ces clichés, on a cartographié 1782 km d’habitats de berges appropriés à l’établissement de tanières. Les habitats de berges constituaient 0,18 p. cent de notre zone d’étude entre la rivière Colville et la Tamayariak dans l’Alaska septentrional. La carte finalisée, qui identifiait correctement 88 p. cent de l’habitat contenant des berges propres à l’établissement de tanières dans la région, aidera à minimiser le potentiel de perturbation des tanières d’ours due aux activités de prospection pétrolière hivernales.

Mots clés: cliché aérien, Arctic National Wildlife Refuge, habitat de tanières, tanière d’ourse, interprétation de clichés, National Petroleum Reserve – Alaska, ours polaire, baie Prudhoe, *Ursus maritimus*

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INTRODUCTION

In the southern Beaufort Sea, polar bear maternal dens occur at their greatest frequency on the coastal plain in northeast Alaska and northwest Yukon Territory (Amstrup and Gardner, 1994). This same region is expected to hold large reserves of recoverable petroleum (Weeks and Weller, 1984). In particular, the “1002” area of the Arctic National Wildlife Refuge (ANWR) may contain more than 9 billion barrels of oil, making this area the most promising for oil and gas exploration in the United States (Clough et al., 1987). In addition, petroleum exploration is expanding west of Prudhoe Bay into the National Petroleum Reserve – Alaska (NPRA). Oil exploration and construction generally occur during winter, when potential damage to tundra habitats and disruption of most Arctic wildlife species are at a minimum.

In the southern Beaufort Sea, polar bears are born in dens of snow and ice (Harington, 1968; Amstrup and Gardner, 1994), which provide a relatively warm and stable environment for development of the young (Blix and Lentfer, 1979). Pregnant bears in Alaska search for suitable den sites during October and early November, and most maternal dens are established by early December (Amstrup and Gardner, 1994). Parturition is believed to occur between early December and early January (Blix and Lentfer, 1979; Lentfer and Hensel, 1980; Kolenosky and Prevett, 1983; Messier et al., 1994). The family group will remain in the den until late March or early April (Blix and Lentfer, 1979; Amstrup and Gardner, 1994; Messier et al., 1994). In northern Alaska, 50% of maternal dens occur on land, and use of terrestrial dens appears to be increasing (Stirling and Andriashek, 1992; Amstrup and Gardner, 1994).

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Because female polar bears give birth to and care for newborn cubs in dens during the winter, disturbance of denning bears may result in reproductive failure. However, this disturbance may be avoided through temporal and spatial management of human activities (Amstrup, 1993; Amstrup and Gardner, 1994). Knowledge of polar bear den chronology provides a defined boundary for temporal management (Amstrup, 1993; Amstrup and Gardner, 1994). Spatial management, however, is not possible because the location of future dens is not known. Unlike concentrated denning areas in other parts of the world (Svalbard, Russia, and Hudson Bay), dens in the southern Beaufort Sea coastal area are widely scattered and at low densities (Harington, 1968; Lentfer and Hensel, 1980; Amstrup and Gardner, 1994). Hence, visual observations of bears entering or emerging from dens are inadequate to identify potential denning habitats. A need to identify critical maternal den habitat has long been recognized (Harington, 1968; Lentfer and Hensel, 1980). Den site selection may depend on many factors, including patterns of sea ice formation (Stirling and Andriashek, 1992), hunting by humans (Stirling and Andriashek, 1992), and traditional use of substrates and geographic regions (Ramsay and Andriashek, 1986; Ramsay and Stirling, 1990; Amstrup and Gardner, 1994). Clearly, however, sufficient snow accumulation is important for establishing maternal dens (Harington, 1968; Lentfer and Hensel, 1980; Kolenosky and Prevett, 1983; Amstrup and Gardner, 1994). Because snow accumulation may depend on topographic features such as banks and bluffs (Belikov, 1980; Lentfer and Hensel, 1980; Benson, 1982), identifying these landforms is necessary to prevent human activities from disrupting maternal dens. The objective of this research was to develop a map that defines potential polar bear denning habitat in the central Beaufort Sea coast of Alaska to aid in the spatial management of human activities.

METHODS

Habitat Characterization

During July and August 1995, we revisited 25 terrestrial polar bear maternity den sites that had been previously located by radiotelemetry (Amstrup, 1993; Amstrup and Gardner, 1994) between Oliktok Point (150° W) and approximately 143° W (Fig. 1). We quantified habitat components surrounding den sites, including physiognomy ("bank" or "other" habitat), height (m), width (m), aspect, and slope (degrees). We then characterized den sites on the basis of macrohabitat (the area within 100 m of the den site) and microhabitat (the area within 10 m of the den site).

Photo Interpretation

We examined 3000 aerial photographs (scale: 2.56 cm = 457.2 m [1 inch = 1500 feet]) taken along east/west

transects over Alaskan coastal areas from the Colville River (151° W), east to the Tamayariak River (145°30' W; Fig. 1). The photos, provided by BP Exploration – Alaska, were taken as a part of standard exploratory procedures. Coverage included the area from the coastline to a mean 29 km inland (range 6.5–50.7 km; total area: 6335 km²). Photos were taken between 1981 and 1995 by twin-engine turbocharged aircraft (Cessna 320, Cessna 310, or Piper Aztec) flown at 2743 m (9000 feet) above mean terrain with a certified cartographic camera (15.4 cm [6 inch] focal length).

First we examined photos that included den sites we had visited, to confirm that features recorded at den sites could be identified from the photos. Next, we identified similar features across the study area by examining all photos. Photo interpretation was done with a pocket stereoscope. Vegetation patterns also helped to identify topographic relief. We did not map sand dunes or pingos because their orientation and exposure to prevailing winds generally preclude sufficient snow accumulation. As well, anthropogenic landscape features were not mapped. Suspected banks of the dimensions required for denning were located and drawn on aerial photos as lines or arcs. Arcs were transferred into Interactive Graphics Design Software (IGDS) MicroStation (ver. 5, Intergraph Corp., Huntsville, Alabama) digital files by a CAD operator, either through direct digitization of photos, or by placement of lines along well-defined map features, such as shorelines or mapped bluffs. The final digital map of suspected den habitat was converted to ARC/INFO format (ver. 7.0.2, ESRI, Inc., Redlands, California).

Map Verification

Field verification was required to assess the accuracy of our map. We recognized, however, that spatial errors in the mapping process and position errors of ground navigation would make an exact match of landscape features with mapped banks unlikely. To control for inaccuracies in mapping, we calculated the degree of plotting error in our measurements and converted the line coverage of bank habitat into a polygon coverage. Plotting error (in essence, a confidence interval around our mapped lines) was the maximum measured distance between features on the ground and mapped banks. Conversion from linear mapped features to polygon features was performed with the BUFFER command in ARC/INFO. BUFFER encloses point and line features within a polygon and allows the user to define the buffer distance between the feature and the polygon edge. Therefore, each mapped line was converted into a polygon feature with a width of two times the maximum distance error measured in the field (Fig. 2).

We evaluated the habitat map for precision of plotted arcs and omission of suitable habitats by examining habitat along transects throughout the study area. We generated 58 transects, oriented 45° east of true north and spaced at 3 km intervals (Fig. 3). Intersections of mapped arcs and

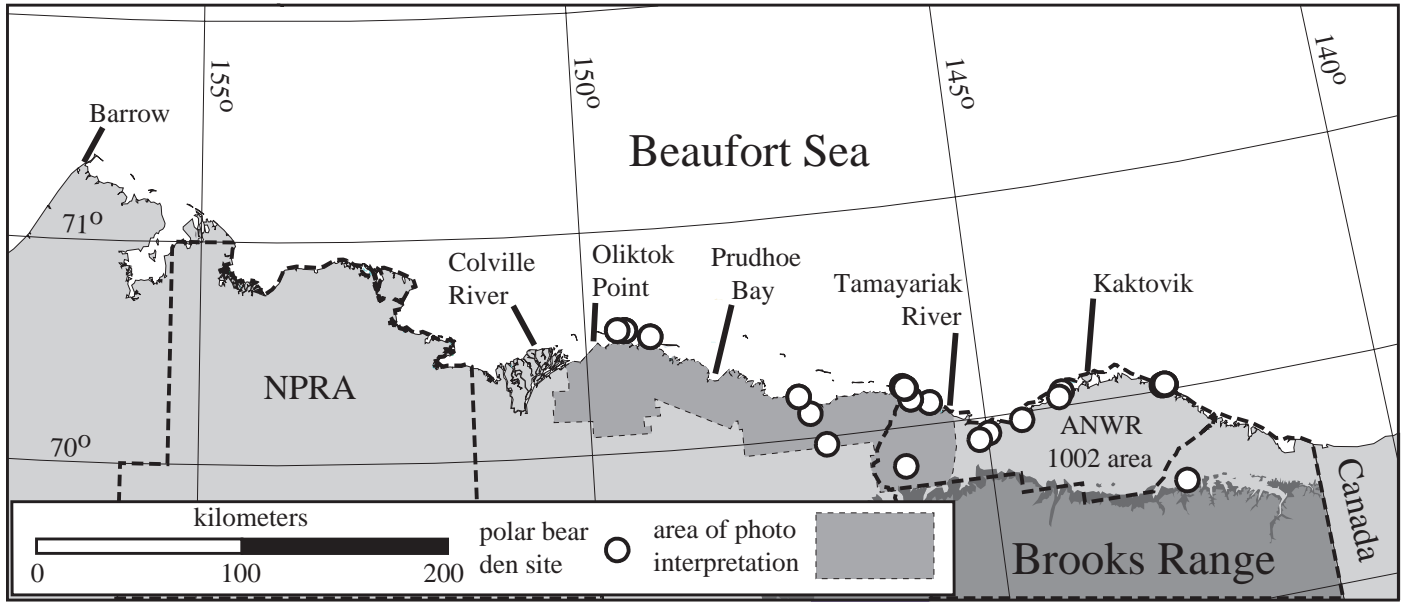


FIG. 1. Study area, place names, and polar bear den site locations used in the delineation of polar bear terrestrial den habitat in coastal northern Alaska, 1998.

transects (precision points) were recorded as nodes in the ARC/INFO node attribute table (NAT) of the transect coverage. Each node included a unique identifier and latitude and longitude. An ASCII text file was generated from the NAT and converted into an MPS (Mission Planning Station, Rockwell International, Iowa, 1996) waypoint file. Waypoint files included a waypoint (node) identifier, transect identifier, and latitude and longitude for nodes and transect endpoints. Waypoint files were downloaded from a personal computer to a Rockwell International PLGR global positioning system (GPS) receiver (PLGR, Type HNV-560C, Rockwell International, Iowa).

During August 1998, we flew transects with a Bell 206 L helicopter (speed: 80–100 km/hr; altitude: 30–50 m). Because the total number of transects exceeded aircraft resources, we selected a sample of the 58 transects. To ensure that the distribution of transects was relatively uniform in the study area, we employed a “1 in k” systematic sample (Scheaffer et al., 1986) of 20 transects. Realizing we had more helicopter time available, we selected additional transects after completing the initial 20 transects (Fig. 3). Our choice of additional transects was subjective; however, we attempted to maintain uniform coverage of our study area. We navigated to nodes and transect endpoints by using a GPS receiver mounted in the helicopter. We verified the presence and position accuracy of nodes and bank features that were not included in the habitat map (omission points) by landing near each node and then using the PLGR to navigate by foot to the exact location of the plotted feature. We recorded waypoint number, transect number, date, time, distance on the ground from the mapped node to the actual bank (m), slope of bank (in degrees), hypotenuse of bank (straight-line distance from top to bottom of bank), whether bank was vegetated and stable (soft bank) or actively sloughing (hard bank),

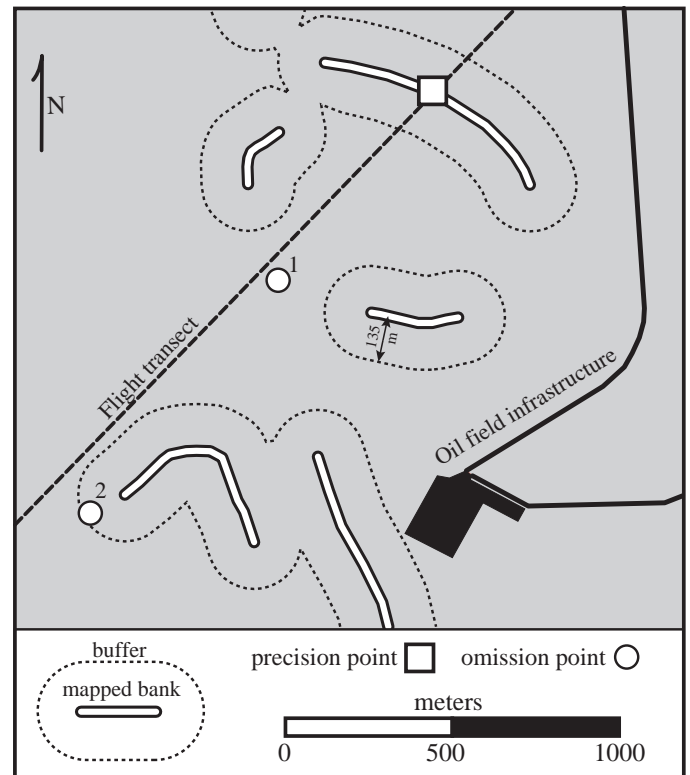


FIG. 2. Example of a precision point and omission points relative to mapped bank habitat, 135 m bank habitat buffer, and flight transect. Omission points that fall outside of buffer polygons are counted as bank habitat missed by the cartographer (point #1). Omission points that occur within buffer polygons are considered a mapped feature (point #2).

and PLGR position error. Distance from mapped nodes to actual bank features was measured with the PLGR. Slope was measured with an inclinometer (Suunto Co., Finland). Bank hypotenuse was measured with a fiberglass measuring tape. Bank height was calculated as the side of a right

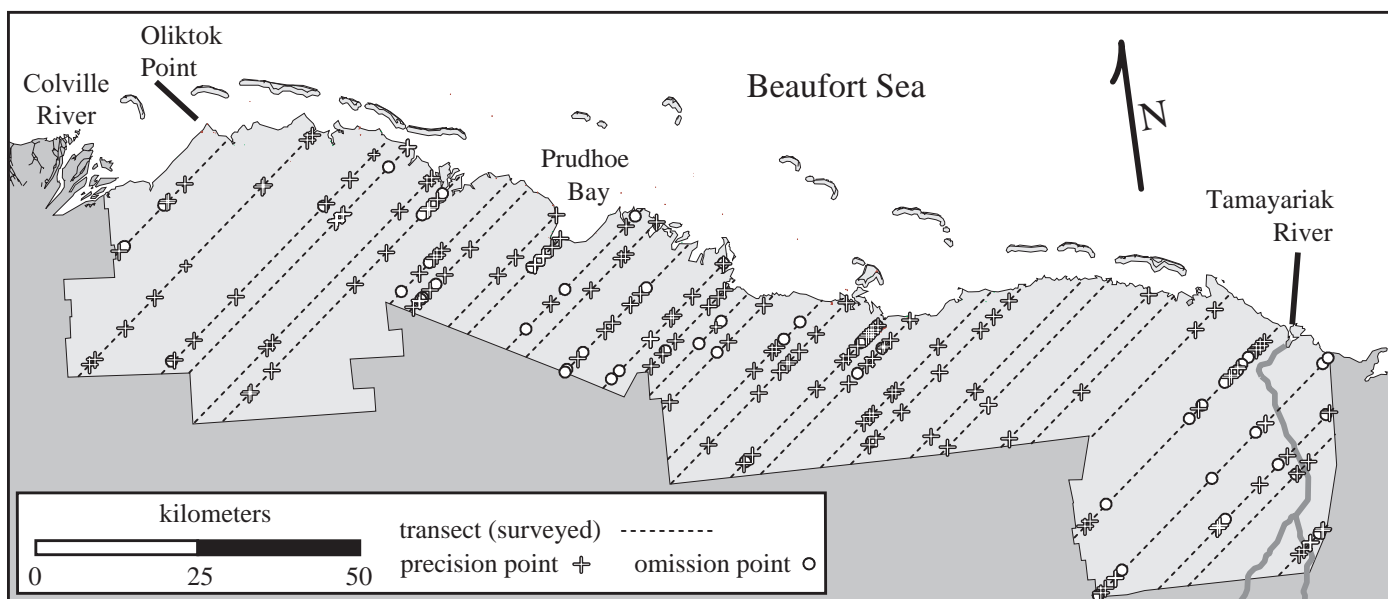


FIG. 3. Distribution of 33 transects, precision points, and omission points used to evaluate a map of terrestrial polar bear maternal den habitat in coastal northern Alaska, 1998.

triangle. Mapped nodes that failed to meet slope or height minimums (defined by actual den sites) were considered non-denning habitat and were used in the estimation of mapping error.

All observed banks that intersected transects but were not on our map were examined on the ground. We recorded the same data at omission points as we did for precision points, plus the latitude and longitude of the omission point. PLGR position error was recorded at each omission point and used to create a buffer around those points. If polygons around mapped banks and polygons around unmapped points did not overlap, the unmapped point was designated as a true omission point. The percent omission error was calculated as the number of omission points divided by the total number of nodes plus omission points.

RESULTS

Denning Habitat Characterization

We located 24 polar bear maternal den sites on the coastal plain and one in the Brooks Range foothills (Fig. 1). We defined the major land-type that could be distinguished by macrohabitat features as bank habitat. Bank habitats ($n = 18$ den sites) were found along coastal shorelines and rivers. Characteristics of bank den sites included a steep slope (mean = 40.0° ; SD = 13.5° ; range: 15.5 – 50.0°) and a height ranging from 1.3 to 34 m (mean = 5.4 m; SD = 7.4 m), with water or relatively level ground below the slope and relatively level ground above it. Because of the general east-west orientation of the coast and barrier islands, most bank den sites were oriented north ($n = 7$) or south ($n = 6$). Four den sites faced west, and only one faced east. In summer, large banks tend to be

obvious features on the otherwise flat landscape. Bank dens were sometimes located in uniform macrohabitat that had no obvious breaks, or in macrohabitat that was constantly changing. Den sites exposed to coastal wave action or swift river currents generally did not have distinguishing microhabitat features. These sites were so active (often with soil sloughing into water in summer) that any microhabitat feature in the land was short-lived. Several sites, however, did contain microhabitat features that would help to catch snow and so provide den habitat. For example, six den sites in bank habitat were in deep, narrow, gullies that extended into the bank face.

Seven dens were in a land-type that we have classified as "other." These sites were not associated with large river or coastal landscapes. The typical macrohabitat feature was usually a gentle sloping coastal plain, or a riparian zone of shallow descent, where the slope of the land was 5° or less (mean = 1.5° ; SD = 1.8° ; range: 0.3 – 5.0°). Because of the northerly flow of streams on the coastal plain, site orientation was primarily north ($n = 5$), but one site faced west and another faced east. Macrohabitat of "other" land-types was difficult to characterize, mainly because they lacked obvious landscape features to measure. Microhabitat features within these areas, however, were sometimes pronounced and contrasted with the relatively featureless macrohabitat. Microhabitats sometimes consisted of dry stream channels, usually some distance from an active stream channel, or broad, vegetated seeps. In general, microhabitats were deep and narrow features that, like bank habitats, would allow snow accumulation.

Photo Interpretation

The degree of resolution on aerial photos was sufficient to allow identification of banks, river bars, and pockets in

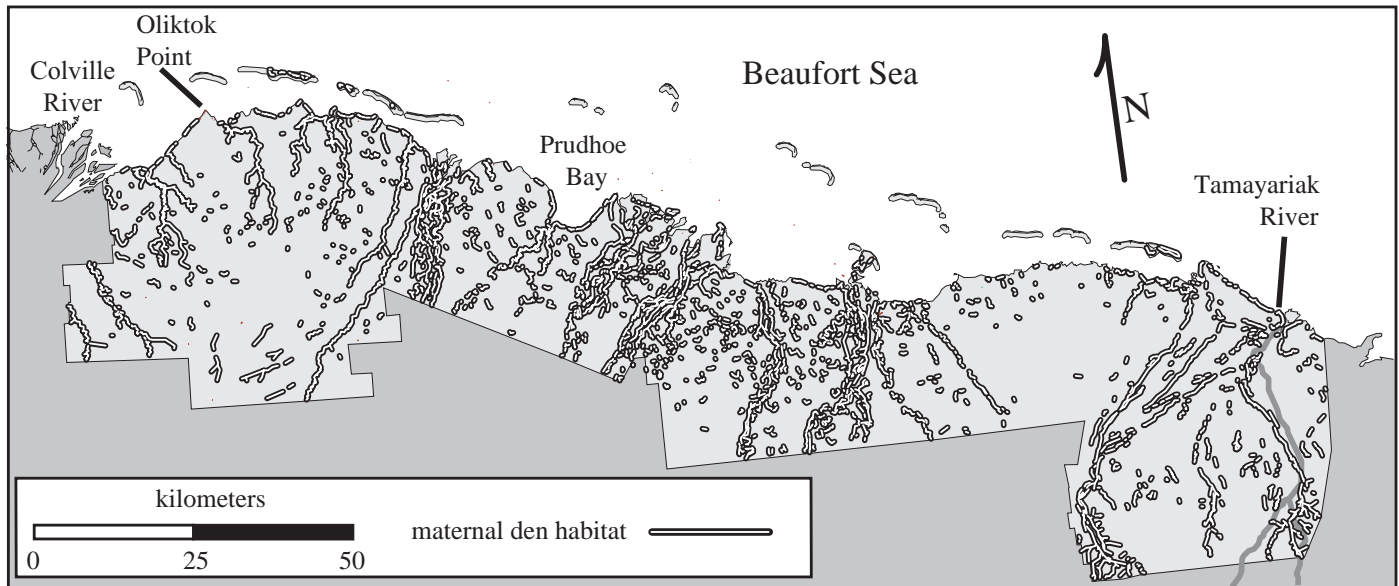


FIG. 4. Distribution of polar bear maternal den habitat in northern Alaska, 1998. Den habitat is depicted as linear features.

the landscape that were as shallow as 1 m. Because most dens (72%) were located along the coast, on barrier islands, or along rivers and streams, we mapped den habitat as linear features (Fig. 4). Some pockets of high-relief terrain far from other obvious habitats were also mapped. These pockets were surrounded by large areas of relatively featureless landscape. However, habitats we describe as “other” were not systematically detectable on aerial photos. Hence, our mapping focused on bank habitats with the majority (72%) of known den sites.

We mapped 2647 segments of bank habitat on photos of our study area. Total length of mapped banks was 1 781 814 m (mean = 673.1, SD = 980.9, min. = 19.7, max. = 18 130.5 m). Assuming a width of 6.4 m (based on mean height and slope at actual den sites), the total area of terrestrial den habitat was 11.4 km², or 0.18% of the 6335.4 km² of our study area. These potential denning habitats are represented as a digitized Geographical Information System (GIS) coverage that can be overlain on any resource development plan (Fig. 4).

Map Verification

We ground-truthed the habitat map by flying 33 transects, for a total combined distance of 1142 km. Distribution of selected transects was uniform within the study area (Fig. 3). Transects included 167 mapped nodes, of which 96 had the required slope (16° or more) and height (1.3 m or more) to be considered denning habitat. Distance from mapped features to actual features on the ground ranged from 0.0 to 135 m (mean = 23.3, SD = 24.6 m). Sixty-one suspected omission points were identified in the field. GPS position error of omission points averaged 8.5 m (SD = 2.3). After incorporating buffer distances to account for mapping inaccuracies to 61 omission points, 33 were determined to be mapped points and 28 were designated as

unmapped points (Fig. 2). Therefore, there were 200 mapped (167 + 33) and 28 unmapped nodes, giving 228 nodes in total. This translated into an omission error of 12.3% ($28 \div [167 + 33 + 28] \times 100$). Of the 200 mapped nodes, 35.5% ($[167 - 96] \div 200 \times 100$) failed to meet minimum criteria of den habitat. However, nonqualifying nodes usually were on short pieces of linear bank adjacent to qualifying habitat, or on the same linear features as qualifying habitat.

DISCUSSION

Polar bears in Alaska establish maternal dens in terrestrial habitat that can be identified through interpretation of aerial photographs. Because many dens occur in areas of active petroleum exploration, or in areas where exploration is being considered, knowledge of these habitats will be important for the welfare of polar bears. Current methods of aerial photography and GIS techniques can make this information readily available to user groups whose activities may affect polar bears in maternal dens.

Our habitat map is conservative with respect to identification of bank features. Although approximately one-third of mapped banks had features that made them marginal for denning, these features were usually mapped extensions of bank areas that were suitable. Very few true bank features were missed by the cartographer; thus, the habitat map correctly identified 88% of bank habitat, which is the primary terrestrial denning habitat used by polar bears on the coastal plain of northern Alaska. This result agrees closely with the distribution of actual polar bear dens. Of the 15 dens that were located inside the area of aerial photographs, 12 dens (80%) were within the distance error (135 m) identified for mapped banks. We believe we can further improve the habitat map, identifying omitted banks and incorrectly mapped banks,

through further photo interpretation benefiting from knowledge gained in ground-truthing.

Spatial differences between mapped locations and ground locations likely resulted from unwitting errors that occurred during the mapping process, the steps of which included locating banks on aerial photographs, transferring that information by hand to topographic maps, and digitizing identified banks from topographic maps. Banks were occasionally misidentified on the topographic maps. One line, for example, was drawn along a shallow riverbank rather than along the larger, vegetated floodplain bank lying parallel to the river but 100 m distant. The vegetated floodplain bank likely had been correctly identified on the aerial photographs but overlooked on the topographic map. Because banks were marked by hand with a pencil, many of the distance errors may be attributed to the width of a pencil mark. We also observed that some nodes were on banks that were marginal for denning. But when we traveled upstream or downstream less than 100 m, we often encountered bank features that met our criteria for minimum height and slope. This is because most den habitat is linear and tails off gradually rather than abruptly. Hence, the beginning and ending points of denning features are not easily discerned on photos or maps. We believe that the cartographer simply extended the line beyond the actual bank habitat because vegetation patterns continued while topographic relief decreased. Because the cartographer was often dependent on vegetation patterns as well as identifiable relief, some misidentification of banks in relatively featureless landscapes (such as dried lake beds or wet meadows) would be expected. Our field observations showed us that vegetation communities may also change abruptly with little change in elevation. Such situations were difficult to assess unless field observers were on the ground.

Omission points do not appear to be evenly distributed within the study area. The greatest number appeared on transects that intersected large rivers. Because most coastal plain rivers are braided, many large banks could be expected. This can make identification of all bank habitat tedious even for an experienced cartographer. Also, riparian environments are dynamic. Bank features may move considerably from one year to the next, or they may disappear completely, so aerial photographs may become obsolete within a few years. We know that many changes occurred between photo acquisition for this project and subsequent ground-truthing. Complete identification of bank features in riparian habitat may not be necessary, however, because large stream corridors are generally identified for special management, including protection of polar bear dens, even if no bank features are explicitly identified.

Aerial photography is an expensive endeavor; however, our project costs were minimized because we were able to take advantage of pre-existing photography. The coastal plain of northern Alaska has been the subject of much exploratory and survey work by the petroleum industry. Partnering with industry greatly reduced redundancy and

the costs of accomplishing management objectives. Industrial activities in other regions of the Arctic also may benefit polar bear research.

Successful denning by polar bears is dependent on a combination of weather conditions and topography (Lentfer and Hensel, 1980). Coastal bluffs and river banks are known for their ability to build drifts of windblown snow, and drift formation may be similar from one year to the next (Benson, 1982). The range of bank height and slope that we observed at den sites on the central Beaufort Sea coast is similar to that reported in other regions of the polar basin (Belikov, 1980). Research on Wrangel Island (Belikov, 1980) and Hudson Bay (Kolenosky and Prevett, 1983) suggests that polar bears select den sites for their specific topography and habitat. Thus, with adequate aerial photography, our technique may be applied in other regions where polar bears den.

Our procedure provides the best available tool for allowing resource managers and researchers to identify polar bear denning habitats in northern Alaska. Research activities that focus on maternal den ecology now have the ability to concentrate their efforts in areas where dens are most likely to occur. Managers may now combine previous knowledge of den chronology with this description of probable den distribution to manage human activities spatially and temporally. Such informed management can only reduce the likelihood of negative impacts to polar bears in maternal dens.

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