Coastal Marine Institute

University of Alaska

Common ravens (*Corvus corax*) nesting on Alaska's North Slope Oil Fields

Abby N. Powell
Principal Investigator

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Graduate Student

Final Report
OCS Study MMS 2009-007

February 2009

Minerals Management Service
Department of the Interior

and the

School of Fisheries & Ocean Sciences

University of Alaska Fairbanks

This study was funded in part by the U.S. Department of the Interior, Minerals Management Service (MMS), through Cooperative Agreement Number M08AX12644, Contract Number M08AX12672, between the MMS, Alaska Outer Continental Shelf Region, and the University of Alaska Fairbanks.

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ABSTRACT

Resident populations of common ravens (*Corvus corax*) on the North Slope of Alaska appear to be increasing where anthropogenic resources are available. This includes numbers of ravens at the North Slope Borough's Prudhoe Bay Landfill during winter, and breeding pairs dispersed throughout the oil fields and other human settlements. The oil fields provide abundant anthropogenic resources in terms of food sources and infrastructure for nesting. In this study, we documented nest locations, nest and nest site characteristics, movements of adult and juvenile ravens, and diet of ravens breeding in the North Slope oil fields of Kuparuk and Prudhoe Bay. In addition, we collected data on marked ravens throughout Alaska from the public. We located a total of 89 nests in the oil fields from 2004-2007. From 2004-2006 we monitored nests to determine nest success and productivity and collected data on nest site characteristics. We captured and radio-tagged adult ravens, and marked both adult and juveniles with leg bands and patagial wing tags to estimate home ranges during breeding and document movements. VHF and satellite transmitters failed due to a variety of reasons, therefore data derived from these sources were limited. Ravens placed their nests on oil field infrastructure; 46% were located on processing facilities, 35% on drill sites, and the remaining on other structures including bridges, radar towers, and inactive drill rigs. Nests were built from industrial materials, at an average height of 11 m. In general, nests at Prudhoe were closer to camps, rig activities during nest building, and the landfill than nests at Kuparuk. We found evidence of nest site fidelity; some sites were used in multiple years. Nests at Prudhoe were more productive than Kuparuk in two of the three years; the average number of fledglings produced per breeding pair was 2.0 ± 0.4 at Kuparuk and 3.7 ± 0.3 at Prudhoe. We found no relationship between nest success or initiation dates with nests placed on heated substrates. Breeding phenology was similar to ravens nesting in other regions of the world. In general, incubation of eggs was initiated from late March until early May. Most nestlings fledged in mid June, corresponding to the time when other tundra-nesting birds initiate their nests. Breeding adults maintained territories ranging on average from 5-10 km^2 around nest sites until late in the nestling stage. After chicks fledged, the size of area used around the nest site increased to 4-19 km^2; however, our estimates were highly variable and sample sizes were small. Adult ravens marked during the breeding season in the oil fields were observed mostly in or near the oil fields during winter, except one seen in Fairbanks. Similarly, ravens marked as juveniles were observed in and near the oil fields (>10 wks after fledging), but were also seen south of the Brooks Range, including Beaver, Fairbanks, and Anchorage. Of juveniles marked in 2004, 18% were seen again their first year, 21% the second year, and 15% the third year. In 2007, 24% of juveniles marked in 2006 were seen again. Numbers of ravens seen at the Prudhoe Bay landfill were lowest during June and July, corresponding to nestling and fledgling stages of breeding. Sub-adults were observed at the landfill more than adults during the breeding season. Raven pellets contained mostly small mammals (55 %) and avian remains (19%). Collared (*Dicrostonyx groenlandicus*) and brown lemmings (*Lemmus trimucronatus*) composed almost half of the small mammals identified in pellet. Alaska's North Slope oil fields provide structures for nesting and anthropogenic food sources that support a resident breeding population of ravens. More research is needed to assess projected population growth and impacts to specific local prey species. Management options for decreasing raven populations include eliminating access to landfills and other food sources, and removing nests.

INTRODUCTION

Common raven (*Corvus corax*) populations have increased in many parts of their geographic range (Dare 1986, Boarman and Heinrich 1999, Preston 2005, Sim et al. 2005). Large numbers of ravens are often found in areas where anthropogenic resources (human structures and food) are abundant. Food subsidies have been shown to influence raven demography by localizing their foraging activities (Restani et al. 2001, Storch and Leidenberger 2003, Roth et al. 2004, Webb et al. 2004, Boarman et al. 2006) and improving breeding success and juvenile survival (Kristan and Boarman 2007). Increased numbers of breeding ravens are often associated with higher predation on local prey species, especially near nest sites (Skarphedinsson et al. 1990, Kristan and Boarman 2003) .

Although little is known about raven use of the North Slope prior to large-scale industrial development, they likely occurred historically in discrete areas such as along the Colville River bluffs, and bred primarily in the foothills of the Brooks Range, approximately 150 km south of the oil fields (White and Cade 1971). Raven numbers on Alaska's North Slope have increased over the last 30 years, particularly where human activities are concentrated (Day 1998, National Audubon Society 2006). Introduction of human-made structures has allowed ravens to expand their breeding range into previously unoccupied areas of the North Slope's coastal plain; the physiographic province lacking relief. Ravens are known to nest on human structures in other parts of their range (Steenhof et al. 1993, Boarman and Heinrich 1999), especially in areas without trees or topographic relief such as cliffs and bluffs (Skarphedinsson et al. 1990). Due to the unavailability of natural nest sites on the coastal plain, ravens now nest on buildings and other types of infrastructure, including radar towers at U.S. Air Force Alaska Radar System (ARS) installations.

Because ravens are opportunistic nest predators, resource managers on Alaska's North Slope have been concerned about the apparent increase in resident ravens (Truett et al. 1997, Burgess 2000). The coastal plain is an important area for breeding migratory waterfowl and shorebirds, including several federally listed species and species of concern (U.S. Fish and Wildlife U.S. Fish and Wildlife Service 1996, U.S. Fish and Wildlife U.S. Fish and Wildlife Service 2002, National Research Council 2003). Information on the diet and ecology of breeding ravens in northern Alaska is minimal (Temple 1974, Rossow 1999). Breeding ravens are foraging generalists (Marquiss 1986, Engel and Young 1989, Boarman and Heinrich 1999, Kristan et al. 2004), but in some instances may be selective predators even when other food items are available (Sara and Busalacchi 2003). Evaluating raven breeding and foraging activities in the oil fields is important for understanding the degree to which ravens are subsidized by this environment, and thus the potential for ravens to impact other nesting bird populations.

Objectives

The original objectives of this study were to quantify the summer foraging ecology of ravens in areas where human activity is spread over a large area (e.g. Kuparuk and Prudhoe Bay oil fields), where human activity is more concentrated (e.g. villages of Barrow and Nuiqsut) and where human activity is relatively lower overall (NPR-A Colville River Unit and Point Lonely). Due to the scope of this study and the logistical constraints of working on Alaska's North Slope, we confined our concentration to ravens breeding within the oil fields of Kuparuk and Prudhoe Bay. The specific objectives were as follows:

1) assess the breeding population of ravens in the oil fields of Alaska's North Slope;
2) document productivity and nest success of ravens nesting in the oil fields;
3) document movements of ravens from nesting sites to foraging areas, and between breeding and non-breeding seasons on Alaska's North Slope;
4) quantify summer diet composition.

METHODS

Study Area

Our study included the two largest producing oil fields on the coastal plain of Alaska's North Slope: Kuparuk (103,396 ha, operated primarily by ConocoPhillips Alaska Inc. and BP Alaska Inc.) and Prudhoe Bay's operating areas: eastern (EOA, 52,246 ha), western (WOA, 48,347 ha), and Milne Pt. (22,002 ha) (operated by BP Alaska Inc., herein referred to as Prudhoe). The coastal plain is the lowest physiographic region of the North Slope (Cabot 1947). These oil fields are characterized by thaw lakes, drained lake basins, polygonal patterned tundra, and pingos and are flanked to the west by the Colville River and to the east by the Sagavanirktok River (NRC 2003). Prudhoe Bay is relatively flat compared to Kuparuk. Annual temperatures ranged between -50^{o} C and 25^{o} C with an annual range of 13-18 cm of precipitation; the ground remained frozen and snow covered for 8-9 months each year (Truett and Johnson 2000). The Kuparuk and Prudhoe Bay oil fields were a mosaic of buildings and pipelines connected by a gravel road network across the tundra. In general, building density was higher in Prudhoe Bay. The town of Deadhorse, adjacent to the southern portion of EOA, covered approximately 400 ha.

We classified oil field facilities into three main types of structures. Processing facilities were large complexes of buildings 40-60 m high, with numerous protruding features on their exteriors, and were few in number (n = 18). Drill sites, by contrast, contained smaller buildings, 8-20 m high, with relatively fewer exterior features, and were more numerous (n = 117). Other infrastructure included inactive drill rigs, bridges, and ARS towers, which were variable in height (5-60 m), and were least numerous (n = 11).

Human activity levels varied spatially and temporally throughout the study area and during our study (2004 – 2007). During times of peak activity, roughly 3,000 people live and work in the oil field on a daily basis, residing in five main camps and three satellite camps (two on the road system and one offshore) that were part of remote processing facilities, or camps in Deadhorse (ConocoPhillips Department of Health Safety and the Environment, pers comm). Human activity across the oil fields was generally highest at camps, which were most numerous in the eastern region. Activity at processing facilities was generally higher than at drill sites, yet activity increased at drill sites during temporary large-scale projects (construction, drilling, and oil well projects).

Anthropogenic food sources occurred as point subsidies (landfills and dumpsters) and ephemeral subsidies (food items unintentionally discarded on the ground or in personnel work vehicles, e.g. pickup trucks). There were two North Slope Borough-operated landfills in and near the oil fields: Prudhoe Bay Landfill in the western portion of EOA, and a landfill in the village of Nuiqsut, 50 km southwest of central Kuparuk (Figure 1). Both oil companies managed food wastes to reduce accessibility to wildlife; food wastes from camps and facilities were stored in covered dumpsters until incinerated or buried daily at the Prudhoe Bay Landfill. Ephemeral subsidies were more difficult to quantify or locate, but were considered dynamic low-level subsidies relative to landfills; we assumed they were associated with human activity such as drilling rig activity.

Assessment of Breeding Population

We searched for raven nests from late April through early June in 2004-2006 and until 7 May in 2007 by driving the roads throughout the study area. We also drove to each facility, where we visually inspected for signs of raven nesting activity and discussed the presence of ravens with facility personnel. Each processing facility operated a collection of drill sites, therefore we also asked about associated areas when talking to personnel. We did not survey all of the oil fields in 2007 due to inclement weather and road restrictions. Nests found in 2007 were included in the analysis of nest site fidelity and enumeration of breeding pairs. However, data on their fates were not collected.

In an effort to learn more about this breeding population, we also documented oil field worker observations of nesting ravens in the oil fields. We conducted a total of nine interviews (43 participants) across Kuparuk and Prudhoe in 2005 using audio-recording and written notes as mandated by the managing companies (six interviews were in a group setting and three interviews were with individuals, UAF IRB 05-51). Based on the outcome of interviews in 2005, we refined questions and distributed short questionnaires to workers at ten processing facilities across the oil fields in 2006. We received 48 completed questionnaires and responses were cataloged in Microsoft Access and analyzed for content and themes.

In order to characterize nesting sites for ravens in the oil fields, we recorded aspect, materials, and substrates, and measured nest height. We also noted whether nests were placed on heated substrates such as pipes, exhaust vents, and cable trays. We stratified nest sites by infrastructure type (processing facilities, drill sites, and other infrastructure), and summarized their attributes as means ± s.d. (height) or percentages of nests on site types compared to all nests.

We also determined distance of nests to nearest nesting neighbor, worker camps, landfills, and drill rig activity in February and March using ArcView GIS 3.3 (Hooge and Eichenlaub 1997) for all known nest attempts in 2004-2006, including nests and or nest sites that were reused in subsequent years. We chose February and March because we believed they were representative of when ravens began to establish breeding territories and build nests. We used two-way ANOVAs to test for differences in distance parameters between Kuparuk and Prudhoe and site type (processing facility, drill site, or other). We included nests at Northstar Island based on reports of nesting activity by oil field workers for these analyses. We excluded nests from these analyses that were reused in subsequent years for distance to landfill and camp, as this would not change from year to year. We classified nests found in Deadhorse as Prudhoe nests due to their close proximity and low number of nests (1-2 annually).

Nest Success and Productivity

We attempted to monitor nests every 5-7 days throughout the breeding season until they either failed or fledged young. When possible, we checked for presence of eggs or chicks using a mirror and extension pole; however, because of locations of most nests on oil field structures were inaccessible, this was not often achieved. Therefore, we assumed adults on nests were incubating eggs until we observed chick-feeding behavior. On a few separate occasions, we documented observations made by oil field personnel about the stage of specific nests. Since we did not always know nest initiation or hatch dates, we back-dated from known events such as fledging. We used a 23-day interval as an average incubation period (Boarman and Heinrich 1999) and a 41-day interval from hatch until fledging based on known nestling intervals in our study. We do not include data on clutch and brood sizes because we often did not know the content of nests; estimates of reproductive success therefore are based on apparent success and are likely biased high. We defined nest success as the proportion of nests that hatched at least one young, and productivity as the numbers of fledglings produced per nest attempt. Nests with uncertain outcomes were excluded from our analyses, including two found after fledging (one in 2005 and 2006), four at sites we had no access to (2004-2006), and one abandoned shortly after we captured the breeding adult (2005). On two occasions nests were removed before we began nest searching; both oil companies removed raven nests prior to egg-laying if they were considered to impede production activities. We compared productivity among years, between Kuparuk and Prudhoe, and among infrastructure types using Kruskal-Wallis tests. Finally, because we found that some nests were located on heated substrates, we evaluated productivity, nest initiation, and hatch dates relative to heated and unheated nest substrates using Wilcoxon signed rank tests; means are presented ± standard error.

Movements of Adult Ravens

We attempted to trap breeding ravens near their nests using remote-controlled bow nets, drop-in traps, and leg-hold traps, 2004-2006 (Engel and Young 1989). Trapping began in late April and lasted from 5-8 weeks; we spent approximately 455 hours attempting to capture adult ravens over the course of this study. The most successful trapping technique (9 of 13 birds) was padded leg-hold traps placed in the beds of pickup trucks. We captured adults (5 male, 5 female) from 10 breeding pairs, and one non-breeding male in 2004. We captured two additional breeding adults (male), one in 2005 and the other in 2006.

We took morphological measurements (wing chord, culmen, tarsus length, tarsus width, bill depth) of captured birds, however in some cases not all measurements were obtained depending on handling time and apparent signs of stress (Appendix 1). We sexed females in the hand by the presence of a brood patch, but in order to definitively determine sex, we took 3-5 drops of blood from the brachial vein. The genetics lab at the USGS Alaska Science Center (Anchorage, AK) analyzed blood samples. All birds were released at the site of capture. We monitored birds twice within 12 hours of release to ensure they returned to their nests and exhibited normal flight behavior.

We banded all birds captured with a USGS aluminum leg band. In 2004, we fit nine adults (one adult died during handling) with 22-g, 1140 VHF transmitters (www.atstrack.com) and one with a 30-g, bird-borne satellite transmitter (www.northstarts.com). The two males captured in 2005 and 2006 were fit with satellite transmitters. We attached all transmitters with backpack-style harnesses (Bedrosian and Craighead 2007). In addition to transmitters, we attached a patagial wing tag made of colored vinyl to one wing (Stiehl 1983). Each patagial tag individually identified ravens with a combination of black alpha codes on different colored backgrounds; we used yellow and blue tags for Kuparuk and orange for Prudhoe.

VHF transmitters were programmed 12 hours on/12 hours off for five months and off for seven months, and were designed to last approximately two years. However, four ravens removed their harnesses and lost their transmitters. Additionally, one raven was electrocuted on a power line in 2004, one transmitter failed in 2005, one did not return to breed in the oil fields, and one did not breed during the course of the study. Thus, only one VHF transmitter remained functional in 2006. We attempted to track individuals with functional transmitters 1-2 times daily between 0600 and 2000, depending on the time each transmitter was on. After locating the birds, we attempted to observe them for a period of 30 minutes without influencing their behaviors.

We summarized all data collected on movements of adult ravens from radio-tracking, family resightings, landfill counts, and opportunistic observations, using the Animal Movement Extension in ArcView (Hooge and Eichenlaub 1997). In addition, we estimated home range sizes during nesting and post-fledging states using minimum convex polygons (MCP). The MCPs were estimated in two ways; first using locations from our observations only, and then by combining our locations with those reported by people working in the oil fields. We only used reports that included a date, exact location, and tag color with an alpha code.

The satellite transmitters were also designed to last approximately two years; duty cycles were programmed to transmit 5 hours every 36 hours for four months during the breeding season, then switched to 5 hours on every 72 hours for eight months. Locations were downloaded from Service Argos. The satellite transmitters deployed in 2004 and 2006 failed shortly after the ravens were released; in 2004, the bird removed its antenna, and in 2006 transmission ceased for unknown causes. We obtained locations for the male fitted with a satellite transmitter in June 2005 until the transmitter failed in May 2006, however, this bird did not appear to be part of the oil field breeding population at that time.

Locations for the male with the working satellite transmitter were summarized for the period of transmission, from June 2005 to May 2006; these locations were used to create MCPs and maps. Although this bird did not breed during the year it was tracked, we divided the data into four seasonal periods based on phenology in our study area and the breeding cycle of ravens elsewhere in their North

American range (Boarman and Heinrich 1999): June - August (post-fledge), September - January (nonbreeding), February - March (nest building), and April - May (nesting).

We summarized satellite locations for the satellite transmittered male for June 2005 to May 2006 using locations supplied by Service Argos classified as 0, 1, 2, and 3. We filtered locations by selecting the highest quality locations within a transmission period; class 3 is higher than 2 and so on. We used class 0 locations for transmission periods without class 1, 2, 3 locations, but omitted unlikely 0 locations within each transmission period, given the elapsed time and distance of the location relative to other 0 locations within the same period. We chose to use class 0 locations though their estimated error >1000m in order to supplement higher quality locations and broaden our description of his home range. Finally, because transmission periods have multiple locations of the same class, we randomly selected one location from each period to arrive at a single data point per transmission period.

Movements of Juvenile Ravens

We used hand-held nets to capture a total of 96 fledglings during this study. We also collected morphological measurements (same as the adults) from juveniles (Appendix 2), with the addition of gape, plumage, and eye color characteristics. We identified 39 as male and 29 as female using genetic tests from blood samples as described above, the rest were of unknown sex. All juveniles were marked with USGS leg bands and patagial wing tags (as described above), with the exception of five in 2005 that were marked only with leg bands. We used different colors for patagial tags to distinguish birds marked as juveniles from those marked as adults. In 2004, we used white for all juveniles, but tags were attached to the right wing to identify birds from Kuparuk and the left wing for birds from Prudhoe. In 2005 and 2006 we used the same scheme (right/left) for wing attachment, but also used different colors for each area; tan for Kuparuk and red for Prudhoe (Appendix B). Individuals were identified by alpha code. We released fledglings near their nests and monitored them each once within 12 hours of release.

In 2005, we fit four juveniles with 22-g, 1140 VHF transmitters (www.atstrack.com) and tracked them for a short period to study timing of dispersal; however, three died within three weeks of capture. The remaining bird was tracked using VHF telemetry until the end of August; it was not seen again after we left the oil fields at the end of the breeding season.

Because juveniles were marked with patagial tags, we were able to identify individual family groups from fledging until late August. We used locations of re-sighted families (5 in 2005, 17 in 2006) to estimate home range sizes during the period between when juveniles left the nest and when they were independent of adults. We also collected sightings of marked adult and juvenile ravens from the oil field community and general public outside of the oil fields in Alaska from 2004-2007 via phone calls, emails, and our website (www.rap.uaf.edu/raven).

Landfill Use

We visited the landfill located in the Prudhoe Bay oil fields, from late April through August each year (19 visits in 2004, 51 in 2005, 50 in 2006, and 3 in 2007) to count ravens and identify any marked individuals. We estimated the maximum number of ravens observed during a 15-minute, vehicle-based, observation period. We summarized landfill use by reporting maximum number seen each month.

Diet Composition

We collected regurgitated pellets from areas around and under raven nests in June and July 2004 (n = 149) and May through June 2005 (n = 198). We first removed all existing pellets in order to ensure that subsequent pellets collected reflected what birds were eating during the breeding season. We separated and identified animal remains and other food items (eggs, garbage, etc.) in the lab following standard procedures (Stiehl and Trautwein 1991). We identified animal remains to species or higher taxonomic level when possible using reference items from the UAF Museum. In addition to pellets found around nests, we also collected a total of 33 prey remains from 2004 and 2005 combined, and 38 eggshells in 2004 only. We only collected eggshells in 2004 at Prudhoe because of additional field assistance there. We used frequency of occurrence of items in pellet analysis (percent total of pellets containing a specific food item). Anthropogenic materials (trash and domestic animal remains) found in pellets were included in this summary. In addition to pellet analysis, we documented any observations of ravens with food items during VHF tracking, re-sighting, and nest observations. We also examined the contents of caches we found near nest sites.

RESULTS

Assessment of Breeding Population

We documented a total of 89 raven nests from 2004-2007; 18 in 2004, 21 in 2005, 25 in 2006 (Figure 1), and 25 in 2007 (Figure 2). We found evidence of nest site fidelity (or nest site reuse/occupancy); 22% were used in all four years, 15% in three years, and 22% in two years. Overall, nest site fidelity was higher in Prudhoe (73%) than Kuparuk (41%).

Nest Site Characteristics

Nests were built primarily on processing facilities (n = 41), drill sites (n = 31), and to a lesser extent other types of infrastructure (n = 17; bridges, inactive drill rigs, radar tower). Of the nests used in all four years (n = 9), most (77%) were on processing facilities with fewer nests on drill sites (11%) and on other infrastructure (11%). Of the breeding adults marked in 2004 (n = 9), two returned to the same nests at processing facilities in all three subsequent years. One adult nested at the same drill site from 2004 - 2006. Another adult marked in 2004 returned to the same nest on a processing facility in 2005 and 2006, but nested on the neighboring facility (< 200 m from previous nest site) in 2007. Two other marked adults were observed nesting at different sites each year. One nested 5.6 km from its 2004 nest in 2005, and 1.3 km from its 2005 nest in 2006. The other bird nested 600 m from its 2004 nest in 2005 and 2006. The two other adults known to be alive at the end of the 2004 breeding season were not observed in the study area in the following breeding seasons.

Interview and questionnaire participants reported that seven of the 18 processing facilities were used as nest sites over many years, dating back to the early 1980’s. Ravens began to use these processing facilities three years after the first structures were built in the oil fields. Oil field workers indicated that use of drill sites by nesting ravens dated back to the mid 1990’s. Most of the processing facilities (86%), and only half of the drill sites historically used by nesting ravens were used during our study. Although use of other infrastructure types was not mentioned in either the interview process or questionnaires, informal conversations with oil field workers indicated that bridges in Kuparuk were used prior to our study.

Nests were built primarily out of industrial materials. We found nest materials to include survey markers, plastic, wire, metal objects, and driftwood, while oil field workers added observations of welding rods, road delineators, nine wire, strips of metal banding, survey sticks, rubber, fiberglass, insulation, reflectors, pipe blanket insulation, and corrosion tubing. Nest height ranged from 3-30 m, but averaged 11.0 ± 7.2 m (Table 1). Raven nests were placed primarily on pipes and structural support beams of buildings, bridges, and large tanks. Nests placed on structural beams were most common at processing facilities and other infrastructure, nests on pipes were found only at processing facilities and drill sites, and nests on exhaust vents were found only at drill sites. Nests were placed on heated substrates (e.g. pipes, exhaust vents, and cable trays) only at processing facilities and drill sites, and half of all nests were oriented to the south. South-facing nests were most common at drill sites and other infrastructure (Table 1).

Proximity of raven nests to nearest neighboring ravens was not different between Kuparuk and Prudhoe, or among site types, with an overall average distance between nests of 10.4 ± 2.1 km (Table 2). Distances of nests to a landfill, camps, and rig activities during nest building were all much shorter at Prudhoe than Kuparuk, but did not differ among infrastructure type (Table 2).

Nest Success and Productivity

We do not know exactly when ravens began nest building in the oil fields because we did not arrive there until April of each year. Ravens started egg laying in late March until mid-May, with most nests initiated in April (Figure 3). The nestling stage (hatch until fledge) lasted from mid-April through early June. Fledging occurred from early June until mid July, with most chicks leaving the nest in June (Figure 3).

Overall nest success was high (94 %) and higher at Prudhoe than Kuparuk in every year (Table 3). It should be noted that our estimates of nest success are biased high as we excluded those nests we had no information prior to hatch (e.g. nests could have been initiated and lost before we found them). Ravens in the oil fields produced an average 2.9 ± 0.3 fledglings per pair, with a maximum of seven. We found no difference in productivity among years ($X^2 = 5.9$, $P = 0.51$), although more fledglings were produced per pair in 2006 (3.7 ± 0.4, n = 22) than in 2004 (2.9 ± 0.5, n = 18) or 2005 (2.3 ± 0.5, n = 19). Kuparuk, however, consistently produced fewer fledglings per pair (2.0 ± 0.4) than Prudhoe (3.7 ± 0.3; $z = -2.94$, n = 59, $P < 0.05$) (Table 3).

Pairs nesting on drill sites produced fewer fledglings (1.9 ± 0.4, n =22) than those nesting on processing facilities (3.6 ± 0.3, n = 27) or other infrastructure (3.6 ± 0.6, n = 10; $X^2 = 8.48$, $P < 0.05$). However, we found no relationship between productivity, nest initiation, or hatch date with nests located on heated or unheated substrates.

Movements of Adults

Breeding ravens were most often observed near their nests, but the breeding population as a whole used a noticeable portion of the oil fields (Figures 4 & 5). Due to our small sample sizes, we pooled data collected using VHF telemetry with our systematic observations, and in general, when we also added all observations (our own and oil field workers), size estimates of use areas increased (Table 4). In general, areas used by breeding pairs were smaller during the nestling stage than during post-fledging (Table 4). In all years combined, the post-fledge use area was estimated as 8.2 ± 12.5 km^2 using our observations only, and 11.9 ± 15.2 km^2 using all observations combined. Use areas by females during the nestling stage were smaller (1.0 ± 1.4 km^2, n = 7) than post-fledge (14.6 ± 21.4 km^2, n = 8), whereas use areas for male ravens were similar between nestling (2.8 ± 3.9 km^2, n = 5) and post-fledge (4.1 ± 2.5 km^2, n = 6) stages. We had less data for ravens nesting in Kuparuk, so we were unable to compare use areas between the sites. However, some breeding territories at Prudhoe overlapped with each other and the landfill (Figure 4), whereas Kuparuk territories showed no overlap (Figure 5).

Movements of marked adults outside of the breeding season varied. Of the marked adults that bred in 2004 (n = 8), seven were observed in the oil fields the following winter (Figure 6). Two adults that nested in 2005 and half of the 2006 breeding adults (n = 7) were observed in the oil fields during the subsequent winters. In 2005, one male was observed in Pt. Lay, and two adults (one male, one female) were observed near an exploratory drilling rig, approximately 70 km west of Kuparuk, during the non-breeding season. One marked female was observed in Fairbanks, 600 km from her nest site, during the winter in 2007.

The non-breeding male with a satellite transmitter was observed in the oil fields during all seasons. He abandoned his nest early in 2005; for the rest of that breeding season he covered an area of 6,681 km^2, and his movements increased from September - January to cover an area of 9,066 km^2 (Figure 7). From

February - March 2006 the area he covered decreased to 5,019 km^2, and then increased to 5,928 km^2 April - May 2006; he did not breed in either year.

Movements of Juveniles

Of juveniles marked in 2004 (n = 33), 18% were observed again during their first year, 21% in the second year, and 15% in the third year. Juveniles marked in 2005 (n = 5) were not seen again in any subsequent years, but we observed 24% of those marked in 2006 (n = 50) within the oil fields up to early May 2007. Juveniles (n = 9) from the 2004 and 2006 cohorts were observed across the North Slope in 2004-2006. Five juveniles dispersed further south to Anchorage, Fairbanks, and Beaver; one was seen first in Beaver, then Fairbanks (Figure 8). One juvenile marked in 2004 returned to the oil fields in summer 2005 after being observed in Fairbanks during the previous winter. There were a few cases of known mortalities. Six juveniles were found dead at on or near power transformers in 2005 (n = 1) and 2006 (n = 5), all at Prudhoe. All of these birds were electrocuted as evidenced by direct observation or the presence of singed feathers.

Landfill Use

Ravens were most abundant at the Prudhoe Landfill in April and May, and least abundant in June (Figure 9) in all years. In general, use of the landfill by ravens was minimal during brooding, chick rearing, and fledging periods. Marked juveniles (10 male, 8 female) were observed using the landfill 10 weeks after fledging. In addition, subadults marked as juvemiles in previous years were seen at the landfill in all months (Figure 9). Two marked adults (one male, one female) that nested < 5 km from the landfill were observed there on occasion from 2004-2006 during the breeding season.

Diet Composition

More than half (55%) of raven pellets collected during the breeding season contained mammalian remains (Table 5). Northern collared lemmings occurred in 30% of the pellets, followed by brown lemmings, tundra voles and singing voles. Avian remains were found in 19% of the pellets, in addition to small amounts of eggshell fragments and parts of ducks (bills). Anthropogenic food items were identified in 12% of the pellets.

Of the prey remains (n = 33) collected in the same areas as pellets, 15 % were avian, 12 % mammalian, and 66 % unidentified bones. Eggshells (n = 38) were identified primarily as goose (57%), duck (32%), ptarmigan (5%), and unidentified species (5%). We located raven caches near (50-200 m) their nest sites. Caches were commonly found in snow piles at the end of the facility gravel pad or on the tundra. Not all caches could be accessed for safety reasons, but items we observed in them included: small mammal entrails, eggshells, and anthropogenic materials. Although we only observed ravens caching food on buildings and other infrastructure occasionally, oil field workers indicated they often cached food on the facilities.

We identified and classified 65% of all food items (n = 105) we observed ravens feeding on during the breeding season: small mammals (32%), eggs (18%), and birds (9%). The remaining unidentified items appeared to be prey of some type and not anthropogenic in origin.

DISCUSSION

Characteristics of the Breeding Population

The North Slope oil fields supported approximately 20-25 breeding pairs of ravens each year; the size of the total resident population (breeders and non-breeders) is still unknown. Ravens breeding in the oil fields showed some nest site fidelity, particularly to nests located on processing facilities. We saw evidence of nest site fidelity both in terms of the same nest being used in subsequent years by unmarked pairs, and by a few marked adults returning to the same nests in multiple years. Site fidelity is observed in other raven populations nesting on human-made structures (Steenhof et al. 1993, Kristan and Boarman 2007), but nest site fidelity of individuals is not well documented (Boarman and Heinrich 1999). In a few cases, we observed that marked individuals displaced from their territory by unmarked ravens still remained in the general study area.

Ravens are known to be selective regarding nest substrates (natural and anthropogenic) in other parts of their range. For example, ravens nesting on transmission line towers in Idaho and Oregon preferred specific tower types and sections over others (Steenhof et al. 1993), and ravens selected the tallest trees in a forested area of Wyoming (Dunk et al. 1997). Use of processing facilities, both historically and during this study, suggests they are important nest sites. Processing facilities have more opportunities for nest placement at various heights and substrates, some of which are heated or in close proximity to heat. Additionally, human activity at processing facilities was higher than at other sites, which may be beneficial because of increased food availability and foraging opportunities for ravens nesting there. Fidelity to drill sites may be lower than processing facilities because they have fewer nest substrates, fewer heated substrates, and lower human activity overall. It was more common for drill site nests to be on heated substrates and facing south than nests at processing facilities (other infrastructure does not produce heat), however, we found no relationship between heated substrates and timing of nesting or productivity.

Nest densities were higher near food subsidies in urbanized areas in the Mojave Desert (Kristan and Boarman 2007). We could not quantify the spatial and temporal availability of point subsidies, other than landfills and camps, in the oil fields. There were more nests each year at Prudhoe, however, where there were more camps and close proximity to a landfill. Kuparuk also had fewer and more dispersed infrastructure than Prudhoe. The relationship between anthropogenic resources and nest distribution in the oil fields remains unclear. Territoriality may be important given the similar distances between raven nests at Kuparuk and Prudhoe, despite the different densities of infrastructure at these two areas,.

Breeding phenology of ravens nesting in the oil fields, despite extreme temperatures during nest initiation, was similar to ravens nesting in more temperate regions of North America as well as other areas in Alaska and Iceland (White and Cade 1971, Skarphedinsson et al. 1990, Dunk et al. 1997, Kristan and Boarman 2007). Timing of the nestling stage did not overlap with other tundra-nesting birds, but young ravens left their nests during the period of nest initiation (early-mid June) for shorebirds (Liebezeit 2004) and king eiders (*Somateria spectabilis*) (Powell et al. 2005).

Nest success was higher in the oilfields than elsewhere (Stiehl 1985, Boarman and Heinrich 1999); it is unlikely that ravens nesting in the North Slope oil fields have many nest predators. Despite the high proportion of nests that hatched at least one egg, productivity of ravens breeding in the oilfields was similar at Prudhoe to ravens breeding in Iceland, Wyoming, Idaho, and Oregon (Skarphedinsson et al. 1990, Steenhof et al. 1993, Dunk et al. 1997). The lower productivity seen at Kuparuk in 2004 and 2005 was similar to common ravens breeding in California and Oregon, and Chihuahuan ravens (*C. cryptoleucus*) nesting in Texas (Stiehl 1985, Burton and Mueller 2006, Kristan and Boarman 2007).

Although our estimates of apparent nest success were biased high, it was obvious that most mortalities occurred during the nestling stage. Causes of chick mortality in the oil fields were unknown, but it is likely they may have been related to food supplies during the nestling stage; again, the presence of potential predators of chicks still in the nest was low. Ravens nesting within 1 km of human settlements and campgrounds in Washington produced more fledglings per pair than those nesting farther away (Marzluff and Neatherlin 2006). Productivity of ravens nesting closest to developed areas was higher than undeveloped areas in California (Kristan and Boarman 2007). Higher survival of juveniles to time of departure from natal territories was shown to be linked to distance to anthropogenic food sources in California (Webb et al. 2004). It is possible that the higher productivity at Prudhoe was related to the closer proximity of nests to the landfill and other potential food sources such as camps.

We found no evidence that ravens nesting on heated substrates were more productive, or initiated their nests earlier. However, ravens nesting on processing facilities and other infrastructure were more productive overall than those at drill sites. Age and experience affect productivity in other corvids (Reese and Kadlec 1985), but we could not determine this in our study because of the largely unmarked breeding population. More research is needed to determine the causes of differential productivity within the oil fields.

Seasonal Movements

The breeding population of ravens in the oil fields appears to be resident year round. We were unable to determine whether ravens remained on or close to their breeding territories during winter, as observed for other northern populations (as reviewed in Skarphedinsson et al. 1990). However, the one raven fitted with a satellite transmitter did not breed during the period his transmitter was working, but remained largely within the study area all year.

Breeding adults foraged close to their nests during the nestling stage, and moved greater distances away from nest sites once fledging occurred, a pattern observed for breeding ravens in central California and Poland (Roth et al. 2004, Roesner and Selva 2005). It was difficult to compare movements of ravens nesting in the oil fields to other studies; our limited sample size and methodological constraints contributed to large variation in estimates of use areas. However, our estimates of home range during nesting tended to be larger than those reported for ravens nesting in southern California (Linz et al. 1992, Boarman and Heinrich 1999, Roth et al. 2004). Given our sample sizes, we were unable to determine a relationship between use areas and distance to food sources; there is some evidence that home range sizes may increase with distances to food sources in other areas (Engel and Young 1992, Roth et al. 2004).

Most adult ravens in the oil fields appeared to remain in or near the oil fields after the breeding season, with the exception of one adult observed in Fairbanks. Winter home ranges and movements are likely to be larger for many adult ravens than during summer, because of food scarcity and relaxation of territoriality. In Maine, adult and sub-adult home ranges varied from 190-3,100 km^2, decreasing substantially from late winter to early spring (Heinrich et al. 1994).

Juveniles made movements greater than 800 km from the oil fields in their first year and in one case, returned in the subsequent year. Little is known about juvenile movements during their first few years; juveniles in Greenland moved an average 218 km during their first winter from their natal territory, and in one instance more than 800 km (Restani et al. 2001). Likewise, juveniles in Iceland moved up to 386 km from their natal areas, but it varied among sites (Skarphedinsson et al. 1990). We may continue to get more information on juvenile dispersal, natal site fidelity, and age at first breeding with continued monitoring of this marked population of ravens.

Food Resources

As in most other populations, ravens in the oil fields were generalist predators and scavengers, with small mammals and birds (and their eggs) as important components of the diet. Similar small mammals species were observed in pellets of winter roosting ravens in Umiat, Alaska (Temple 1974). Mammals and birds were also major components of pellets from ravens nesting in Oregon and California; in California pellets also contained trash for pellets collected from nests close to anthropogenic food subsidies (Stiehl and Trautwein 1991, Kristan et al. 2004). One caveat of pellets analyses is that many items such as avian remains and eggs are more digestible than small mammal bones, and thus underrepresented (Redpath et al. 2001). It was also difficult to assess the importance of anthropogenic foods for oil fields ravens because these foods (excluding bones and packing material) were highly digestible. Anthropogenic foods may be important to ravens in the oil fields, particularly during winter. During breeding, nests in the oil fields were all associated with human food subsidies, and we were unable to determine the importance to overall diet.

Raven use of the Prudhoe landfill was minimal during the post-fledging stage in June and July. The marked decrease in raven numbers during this period could be explained by: 1) increased availability of tundra-nesting birds and small mammals as prey items, 2) increased competition and aggression with gulls at the landfill, and 3) interactions with aggressive breeding adults defending territories within the landfill vicinity. Shorebirds and eiders initiate nests in this area during this time, while small mammals are likely to be more abundant and active. Numbers of glaucous gulls (*Larus hyperboreus*) in Prudhoe peak in September and are relatively low in June and July (Noel et al. 2006), yet remain higher than ravens throughout most of the summer. Raven use of landfills changes seasonally or with changes in human activity in neighboring areas (Restani et al. 2001, Boarman et al. 2006). In Alberta, Canada, raven use of landfills increased in relationship to decreased temperatures and deeper snow depths in winter (Preston 2005). Although our landfill counts did not include winter months, use of the Prudhoe landfill seemed to be similar to an arctic landfill in Greenland: use by subadults and non-breeding adults year round, by juveniles in summer and autumn, and by breeding adults primarily in the autumn and winter (Restani et al. 2001). Although few breeding adults in the oil fields used the landfill during summer, two adults nested less than 5 km from the landfill and were observed on occasion at or near it. During winter, the male raven with a satellite transmitter occurred in the vicinity, and other marked adults were observed at or near (< 5 km) the landfill. Christmas Bird Counts at Prudhoe ranged from 54-129 ravens at the landfill during the years of this study (National Audubon Society 2006). Prudhoe landfill employees often commented about seeing more ravens over the winter than during the summer.

Conclusions

Alaska's North Slope oil fields provide ravens with nesting sites and roost sites in the form of infrastructure and food sources from landfills and other point subsidies. Raven numbers have increased during winter, and productivity, particularly at Prudhoe, is consistent with other thriving raven populations. Although we cannot yet estimate recruitment rates into the breeding population, we now have a marked population of juveniles that may provide future information with continued monitoring.

Impact of ravens nesting in the oil fields to tundra-nesting birds needs more study, particularly with focus on the prey base. Nest phenology indicates this population is likely to affect other nesting birds throughout their breeding season. During this time, impacts to prey species may be localized to areas near the natal site until the juveniles disperse. Management actions recommended for reducing raven predation on endangered desert tortoises (*Gopherus agassizii*) include reducing access of ravens to anthropogenic food sources, particularly landfills (Boarman 2003). The oil companies should be commended for their policies to eliminate the occurrences of point subsidies such as food/trash, and should continue their efforts. Finally, discouraging nesting by avoiding construction of new nesting structures may not be possible, but removal of nests with eggs in them would likely have the greatest impact, as ravens that nest at sites where they experience low reproductive success are unlikely to return in subsequent years (Boarman 2003, Tryjanowski et al. 2004).

ACKNOWLEDGMENTS

We thank the following research institutes, industries, and agencies for financial support and/or collaboration: UAF Coastal Marine Institute, NSF Regional Resilience and Adaptation Program, Center for Global Change, U.S. Geological Survey Alaska Cooperative Fish and Wildlife Research Unit, ConocoPhillips Alaska, Inc., BP Exploration (Alaska), Inc., Minerals Management Service, Bureau of Land Management, U.S. Fish and Wildlife Service, and North Slope Borough. We could not have conducted this study without the considerable logistical support provided by B. Streever and C. Rea. We also thank personnel at the North Slope Borough Prudhoe Landfill and the communities of Kuparuk and Prudhoe. We are extremely grateful for the field assistance provided by M. Pavelka, K. Barnes, M. Cunningham, E. Lester, T. Thomas, F. Merrill, J. Swanson, R. Darvill, J. Klima, J. Cunningham, and M. Miller, G. Penner, and several oil field workers. M. Miller also assisted with processing and analyzing pellets. The staff at the University Alaska Museum Department of Mammalogy provided valuable assistance with specimen identification. We thank ABR for preparing the map of raven nests for 2004-2006. P. Martin, T. Swem, and D. Nigro also provided important contributions to this study. Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by U.S. Government.

STUDY PRODUCTS

Presentations

Backensto, S., A. N. Powell, G. Kofinas, C. Gerlach, and E. Follmann. The Common Raven (*Corvus corax*) on the North Slope of Alaska. 28 March 2007. Alaska Cooperative Research Unit Review. Fairbanks, AK.

Backensto, S., A. N. Powell, G. Kofinas, C. Gerlach, and E. Follmann. The Common Raven (*Corvus corax*) on the North Slope of Alaska. 6 February 2007. Coastal Marine Institute Annual Research Review. University of Alaska. Fairbanks, AK.

Backensto, S., A. N. Powell, G. Kofinas, C. Gerlach, and E. Follmann. The Common Raven (*Corvus corax*) through the eyes of oil field workers: Local knowledge in Alaska's North Slope Oil fields. 7-9 February, 2006. 11th Annual Alaska Bird Conference. Juneau, AK.

Backensto, S., A. N. Powell, G. Kofinas, C. Gerlach, and E. Follmann. The Common Raven (*Corvus corax*) on the North Slope of Alaska. 30 March 2005. Alaska Cooperative Research Unit Review. Fairbanks, AK.

Morse, J., and S. Backensto. Don't Mess with Black Birds: Ravens, Oystercatchers, and Resilience. 10 March 2005. Alaska Bird Observatory Seminar Series. Fairbanks, AK.

Backensto, S., A. N. Powell, G. Kofinas, C. Gerlach, and E. Follmann. The Common Raven (*Corvus corax*) on the North Slope of Alaska. 14-16 March, 2005. Minerals Management Service (MMS) – Alaska Outer Continental Shelf (OCS) Region 10th Information Transfer Meeting (ITM). Anchorage, AK.

Backensto, S., A. N. Powell, G. Kofinas, C. Gerlach, and E. Follmann. The Common Raven (*Corvus corax*) on the North Slope of Alaska. 8 March 2005. Coastal Marine Institute Annual Research Review. University of Alaska. Fairbanks, AK.

Backensto, S., A. N. Powell, G. Kofinas, C. Gerlach, and E. Follmann. Industrial Opportunivores. Alaska Public Lands Saturday Seminar Series. 26 March 2005. Fairbanks, AK.

Backensto, S., A. N. Powell, G. Kofinas, C. Gerlach, and E. Follmann . The Common Raven (*Corvus corax*) on the North Slope of Alaska. 9 February 2005. National Park Service Brown Bag Lunch. Fairbanks, AK.

Backensto, S., A. N. Powell, G. Kofinas, C. Gerlach, and E. Follmann. The Common Raven (*Corvus corax*) on the North Slope of Alaska. 28 October 2004. FWS Brown Bag Lunch. Fairbanks, AK.

Backensto, S., A. N. Powell, G. Kofinas, and C. Gerlach. The Common Raven (*Corvus corax*) on the North Slope of Alaska: Wildlife Management and the Human Dimension (poster). 10 March 2004. Tenth Alaska Bird Conference and Workshops. Anchorage, AK.

Backensto, S., A. N. Powell, G. Kofinas, and C. Gerlach. The Common Raven (*Corvus corax*) on the North Slope of Alaska: Wildlife Management and the Human Dimension (poster). 25 February 2004. Alaska Cooperative Research Unit Review. Fairbanks, AK.

Backensto, S., and A. N. Powell. The Common Raven (*Corvus corax*) on the North Slope of Alaska: Wildlife Management and the Human Dimension (poster). 28 October 2003. HARC Patterns, Connections, and Methods Workshop. Seattle, WA.

Backensto, S., and A. N. Powell. The Common Raven (*Corvus corax*) on the North Slope of Alaska: Wildlife Management and the Human Dimension (poster). 27 October 2003. SEARCH Open Science Meeting. Seattle, WA.

Backensto, S., and A. N. Powell. The Common Raven (*Corvus corax*) on the North Slope of Alaska: Wildlife Management and the Human Dimension (poster). 30 April 2003. Cooper Ornithological Society Meeting Annual Meeting. Flagstaff, AZ.

Reports

Powell, A. N., and S. Backensto. 2007. Foraging ecology of common ravens (*Corvus corax*) on Alaska's Coastal Plain and its relationship to oil and gas development, p. 99-110. *In* Coastal Marine Institute [ed.], Annual Report No. 14. OCS Study MMS 2008-014. University of Alaska. Fairbanks, AK.

Powell, A. N., and S. Backensto. 2006. Foraging ecology of common ravens (*Corvus corax*) on Alaska's Coastal Plain and its relationship to oil and gas development, p. 26-36. *In* Coastal Marine Institute [ed.], Annual Report No. 13. OCS Study MMS 2007-014. University of Alaska. Fairbanks, AK.

Powell, A. N., and S. Backensto. 2005. Foraging ecology of common ravens (*Corvus corax*) on Alaska's Coastal Plain and its relationship to oil and gas development. *In* Coastal Marine Institute [ed.], Annual Report No. 12. University of Alaska. Fairbanks, AK.

Powell, A. N., and S. Backensto. 2004. Foraging ecology of common ravens (*Corvus corax*) on Alaska's Coastal Plain and its relationship to oil and gas development, p. 81-89. *In* Coastal Marine Institute [ed.], Annual Report No. 11. OCS Study MMS 2005-055. University of Alaska. Fairbanks, AK.

LITERATURE CITED

Bedrosian, B., and D. Craighead. 2007. Evaluation of techniques for attaching transmitters to common raven nestlings. Northwestern Naturalist **88:** 1-6.

Boarman, W. I. 2003. Managing a subsidized predator population: reducing common raven predation on desert tortoises. Environmental Management **32:** 205-217.

Boarman, W. I., and B. Heinrich. 1999. Common Raven (*Corvus corax*). *In* A. Poole and F. Gill [eds.], Birds of North America. Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington D.C.

Boarman, W. I., M. A. Patten, R. J. Camp, and S. J. Collis. 2006. Ecology of a population of subsidized predators: common ravens in the central Mojave Desert, California. Journal of Arid Environments. **67:** 248-261.

Burton, J. P., and J. M. Mueller. 2006. Chihuahuan raven (*Corvus cryptoleucus*) reproductive success and nest spacing in the southern high plains of Texas. The Southwestern Naturalist. **51:** 48-51.

Cabot, E. C. 1947. The Northern Alaskan Coastal Plain Interpreted from Aeiral Photgraphs. Geographical Review. **37:** 639-648.

Dare, P. J. 1986. Raven *Corvus corax* populations in two upland regions of north Wales. Bird Study. **33:** 179-189.

Day, R. H. 1998. Predator populations and predation intensity on tundra-nesting birds in relation to human development. ABR, Inc. for U.S. Fish and Wildlife Service.

Dunk, J. R., R. N. Smith, and S. L. Cain. 1997. Nest-site selection and reproductive success in Common Ravens. Auk. **114:** 116-120.

Engel, K. A., and L. S. Young. 1989. Evaluation of techniques for capturing common ravens in southwestern Idaho. North American Bird Bander. **14:** 5-8.

Engel, K. A., and L. S. Young. 1992. Movements and habitat use by common ravens from roost sites in southwestern Idaho. Journal of Wildlife Management. **56:** 596-602.

Heinrich, B., D. Kaye, T. Knight, and K. Schaumburg. 1994. Dispersal and association among common ravens. Condor. **96:** 545-551.

Hooge, P. N., and B. Eichenlaub. 1997. Animal movement extension to ArcView. *In* U.S. Geological Survey. Alaska Science Center, Anchorage.

Kristan, W. B. I., and W. I. Boarman. 2003. Spatial pattern of risk of common raven predation on desert tortoises. Ecology. **84:** 2432-2443.

Kristan, W. B. I., and W. I. Boarman. 2007. Effects of anthropogenic developments on common raven nesting biology in the west mojave desert. Ecological Applications. **17:** 1703-1713.

Kristan, W. B. I., W. I. Boarman, and J. J. Crayon. 2004. Diet composition of common ravens across the urban-wildland interface of the West Mojave Desert. Wildlife Society Bulletin. **32:** 244-253.

Liebezeit, J. 2004. Nesting success and nest predators of tundra-nesting birds in the Prudhoe Bay oilfield - 2004: preliminary results. Tundra-bird Productivity Studies. 34.

Linz, G. M., C. E. Knittle, and R. E. Johnson. 1992. Home range of breeding common ravens in coastal southern California. Southwestern Naturalist. **37:** 199-202.

Marzluff, J. M., and E. A. Neatherlin. 2006. Corvid response to human settlements and campgrounds: Causes, consequences, and challenges for conservation. Biological Conservation. **130:** 301-314.

National Audubon Society. 2006. Christmas Bird Count. www.audubon.org/bird/cbc/. 10/10/07.

National Research Council. 2003. Cumulative environmental effects of oil and gas activities on Alaska's North Slope. National Academies Press, Washington, D.C.

Noel, L. E., S. R. Johnson, and W. J. Gazy. 2006. Oilfield development and glaucous gull (Larus hyperboreus) distribution and abundance in central Alaskan Beaufort Sea Lagoons, 1970-2001. Arctic. **59:** 65-78.

Powell, A. N., R. Suydam, and R. L. McGuire. 2005. Breeding biology of king eiders on the coastal plain of northern Alaska. Coastal Marine Institute. University of Alaska. 40.

Preston, M. I. 2005. Factors affecting winter roost dispersal and daily behaviour of common ravens (Corvus corax) in southwestern Alberta. Northwestern Naturalist. **86:** 123-130.

Redpath, S., R. Clarke, M. Madders, and S. J. Thirgood. 2001. Assessing raptor diet: comparing pellets, prey remains, and observational data at hen harrier nests. Condor. **103:** 184-188

Reese, K. P., and J. A. Kadlec. 1985. Influence of high density and parental age on the habitat selection and reproduction of black-billed magpies. Condor. **87:** 96-105.

Restani, M., J. M. Marzluff, and R. E. Yates. 2001. Effects of anthropogenic food sources on movements, survivorship, and sociality of common ravens in the Arctic. Condor **103**:399-404.

Roesner, S., and N. Selva. 2005. Use of the bait-marking method to estimate the territory size of scavenging birds: a case study on ravens *Corvus corax*. Wildlife Biology **11**:183-191.

Roth, J. E., J. P. Kelly, W. J. Sydeman, and M. A. Colwell. 2004. Sex differences in space use of breeding common ravens in western Marin County, California. Condor **106**:529-539.

Sim, I. M. W., R. D. Gregory, M. H. Hancock, and A. F. Brown. 2005. Recent changes in the abundance of British upland breeding birds. Bird Study **52**:261-275.

Skarphedinsson, K. H., O. Nielsen, T. Skarphedinsson, S. Thorstensen, and S. A. Temple. 1990. Breeding biology, movements, and persecution of ravens in Iceland. Acta Naturalia Islandica **33**:1-45.

Steenhof, K., M. N. Kochert, and J. A. Roppe. 1993. Nesting by raptors and common ravens on electrical transmission line towers. Journal of Wildlife Management **57**:271-281.

Stiehl, R. B. 1983. A new attachment method for patagial tags. Journal of Field Ornithology **54**:326-328.

Stiehl, R. B. 1985. Brood chronology of the common raven. Wilson Bulletin **97**:78-87.

Stiehl, R. B., and S. N. Trautwein. 1991. Variations in diets of nesting common ravens. Wilson Bulletin **103**:83-92.

Storch, I., and C. Leidenberger. 2003. Tourism, mountain huts and distribution of corvids in the Bavarian Alps, Germany. Wildlife Biology **9**:301-308.

Temple, S. A. 1974. Winter food habits of ravens on the Arctic Slope of Alaska. Arctic **27**:41-46.

Tryjanowski, P., A. Surmacki, and J. Bednorz. 2004. Effect of prior nesting success on future nest occupation in raven Corvus corax. Ardea **92**:251-254.

U.S. Fish and Wildlife Service. 1996. Spectacled Eider Recovery Plan. 157.

U.S. Fish and Wildlife Service. 2002. Steller's Eider Recovery Plan. 29.

Webb, J. W., Jr., W. I. Boarman, and J. T. Rotenberry. 2004. Common raven juvenile survival in a human-augmented landscape. The Condor **106**:517-528.

White, C. M., and T. J. Cade. 1971. Cliff-nesting raptors and ravens along the Colville River in arctic Alaska. The Living Bird **10**:107-150.

Table 1. Characteristics of common raven nests in Alaska's North Slope oil fields 2004-2007. Nest height is mean ± s.d., all others are percents within each infrastructure type.

Nest Characteristics	Facility n= 21	Drill site n = 23	Other n = 11	Total Nest Sites n = 55
Height	13.6 ± 6.8	7.9 ± 3.9	12.5 ± 11.2	11.0 ± 7.3
Aspect				
North	19.0	4.3	9.1	10.9
South	38.1	65.2	45.5	50.9
East	23.8	8.7	0	12.7
West	4.8	13.0	9.1	9.1
Other	14.3	8.7	36.4	16.4
Substrate types				
Heated Substrate	33.3	43.5	0	29.8
Exhaust vent	0	21.7	0	9.1
Structural beam	38.1	8.7	100	41.8
Cable tray	19.0	13.0	0	12.7
Communication Tower	0	8.7	0	3.6
Pipe	28.6	26.1	0	21.8
Platform ladder	14.3	0	0	5.5
Tank platform/beams	0	21.7	0	9.1

Table 2. Distance (mean km ± s.e.) of common raven nests to neighboring nests and potential food sources in Alaska's North Slope oilfields, 2004-2007.

Distance (km)	Infrastructure Type				Site		
	Facility	Drill Site	Other	*P*	Kuparuk	Prudhoe	*P*
Nearest Neighbor	13.2 ± 5.3	7.1 ± 5.2	8.4 ± 7.3	ns	9.0 ± 5.1	10.2 ± 4.7	ns
Landfill	28.4 ± 1.6	25.4 ± 1.6	23.5 ± 2.2	ns	40.8 ± 1.6	10.7 ± 1.4	< 0.001
Camp	5.6 ± 1.8	11.7 ± 1.8	10.1 ± 2.3	0.06	14.7 ± 1.7	3.6 ± 1.6	< 0.001
Rig Activity, February	4.7 ± 1.2	7.8 ± 1.2	7.1 ± 1.6	ns	8.9 ± 1.2	4.2 ± 1.1	<0.01
Rig Activity, March	9.0 ± 1.4	11.1 ± 1.3	8.0 ± 1.9	ns	14.5 ± 1.3	4.2 ± 1.2	< 0.001

Table 3. Reproductive success of ravens nesting in Alaska's North Slope oilfields, 2004-2006. Nest success is the proportion of nests that had one egg hatch, fledge success is the proportion of nests that had at least one young fledge. Sample sizes are different because we only used nests with known outcomes in each category; there are more nests included fledge success because we had limited information on the egg and chick stage for most nests.

	Nest Success		Fledge Success		Productivity
	percent	n	percent	n	mean ± s.e.
Kuparuk					
2004	83	6	50	8	1.6 ± 0.7
2005	83	6	33	9	1.2 ± 0.6
2006	89	9	88	8	3.4 ± 0.7
Prudhoe					
2004	100	10	100	10	3.9 ± 0.4
2005	100	10	90	10	3.2 ± 0.7
2006	100	13	86	14	3.9 ± 0.5
Total	94	54	76	59	3.0 ± 0.3

Table 4. Territory sizes (km^2; mean ± s.d.) during the nestling and post-fledge periods for common ravens nesting in Alaska's North Slope oil fields, 2004-2006.

Period	Kuparuk			Prudhoe		
	Field Observations	All Observations	n	Field Observations	All Observations	n
Nestling						
2004	5.2 ± 4.0	-	3	0.9 ± 0.6	1.0 ± 0.7	5
2005	-	-	0	0.4	-	1
2006	0.1	10.2	1	0.2 ± 0.1	-	2
Post-fledge						
2004	11.2 ± 9.7	11.5 ± 10.3	3	15.9 ± 27.9	16.7 ± 27.4	5
2005	10.3	-	1	4.1 ± 4.1	4.8 ± 5.5	5
2006	6.7 ± 11.3	18.7 ± 20.6	5	6.5 ± 4.9	10.2 ± 10.1	12

Table 5. Contents of pellets (n = 347) collected from under and around raven nests in Alaska's North Slope oil fields 2004-2005. Number of pellets is the count of pellets containing one or more of that item; percent is proportion of total pellets containing that item and thus does not add up to 100%. Unidentified bones included small mammals and some bones believed to be chicken and pork (anthropogenic sources). Anthropogenic items consisted of human-made materials. Unclassified remains represent pellets with items we were unable to classify.

Class	Contents	Number of Pellets	% Pellets
Aves			
	Total remains (feathers, bones)	66	19.0
	Eggshell fragments	29	8.3
	Duck remains	4	1.1
Mammalia			
	Total remains (hair, feet, bones)	192	55.3
	Total small mammal jaws	174	50.1
	Dicrostonyx groenlandicus	106	30.3
	Lemmus trimucronatus	35	10.0
	Microtus miurus	5	1.4
	Microtus oeconomous	15	4.3
	Cleithronomus rutilus	1	0.2
	Sorex spp.	2	0.5
Insecta	*Coleoptera spp.*	2	0.5
Osteichythes		2	0.5
Unidentified Bones		88	25.2
Anthropogenic		40	11.5
Unclassified remains		113	32.4

Figure 1. Locations of raven nests found in Alaska's North Slope oil fields, 2004-2007.

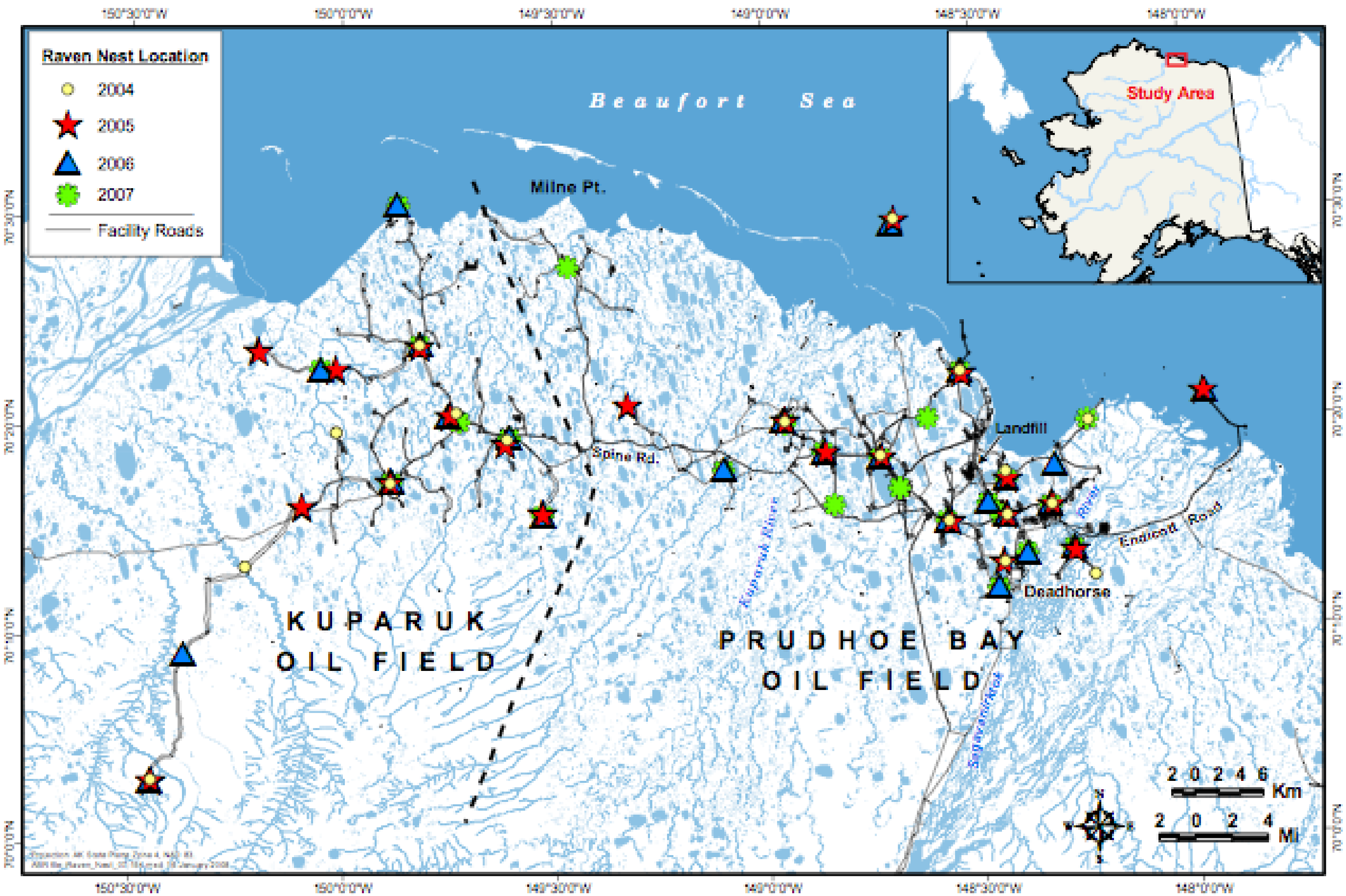


Figure 2. Locations of raven nests found in Alaska's North Slope oil fields, 2007.

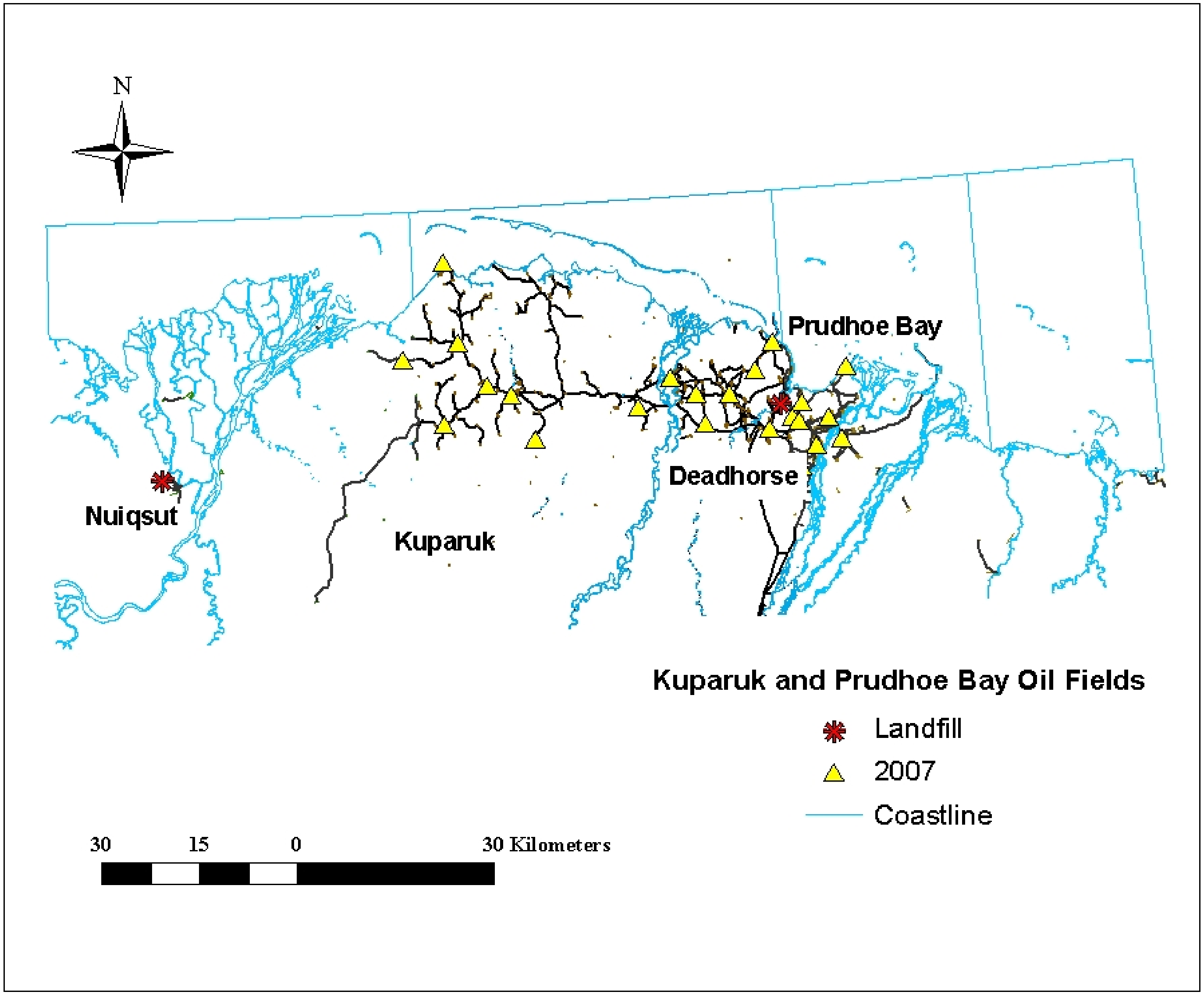


Figure 3. Breeding phenology for ravens nesting in Alaska’s North Slope oil fields, 2004-2006.

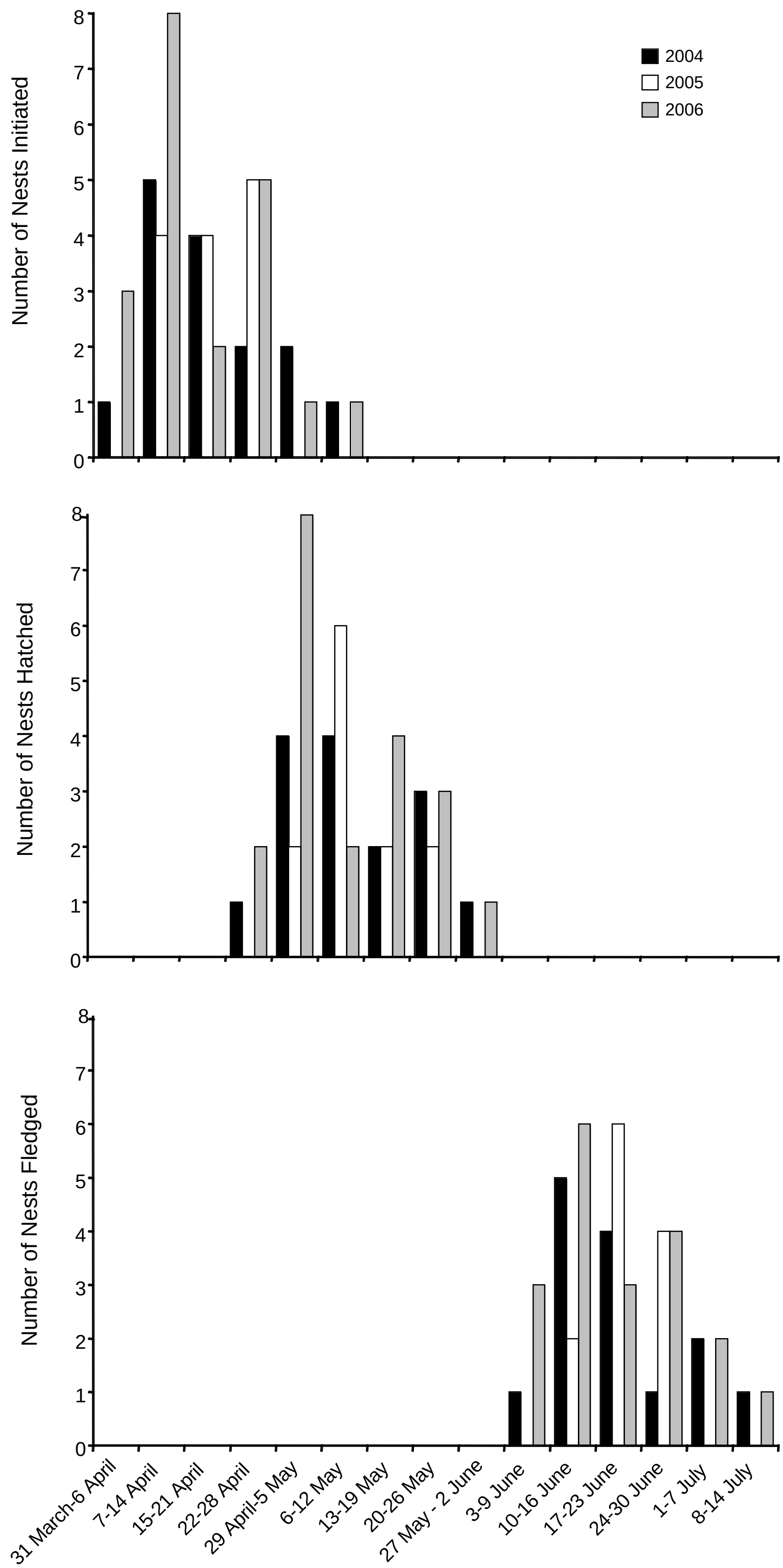


Figure 4. Breeding territory estimates for ravens nesting in Prudhoe Bay, Alaska, 2004-2006. Estimates include a core use area (65% of locations) in dark grey and use area (95% locations) in light grey. Territories outlined in yellow indicate years were combined.

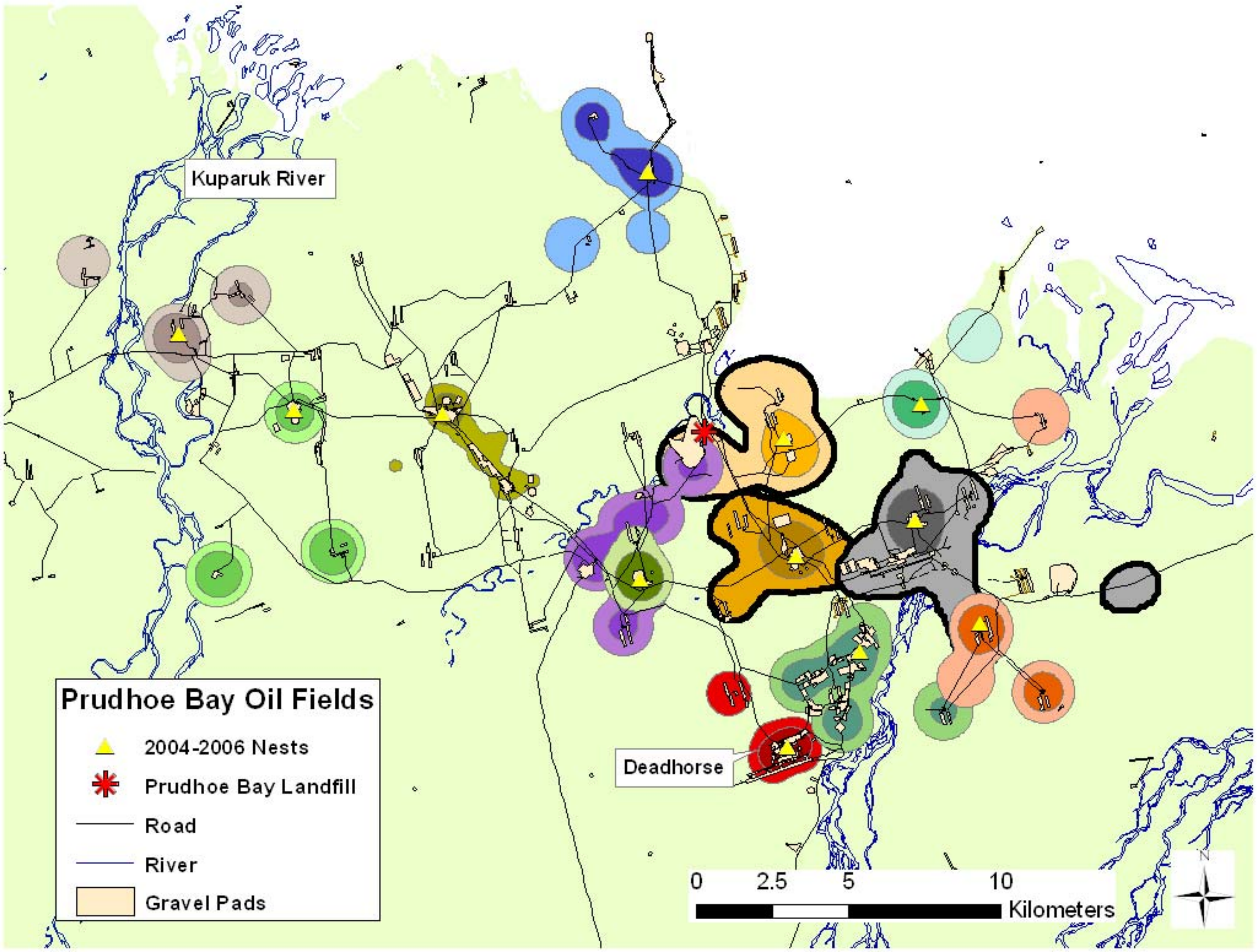


Figure 5. Breeding territory estimates for ravens nesting in Kuparuk, Alaska, 2004-2006. Estimates include a core use area (65% of locations) in dark grey and use area (95% locations) in light grey. Territories outlined in yellow indicate years were combined.

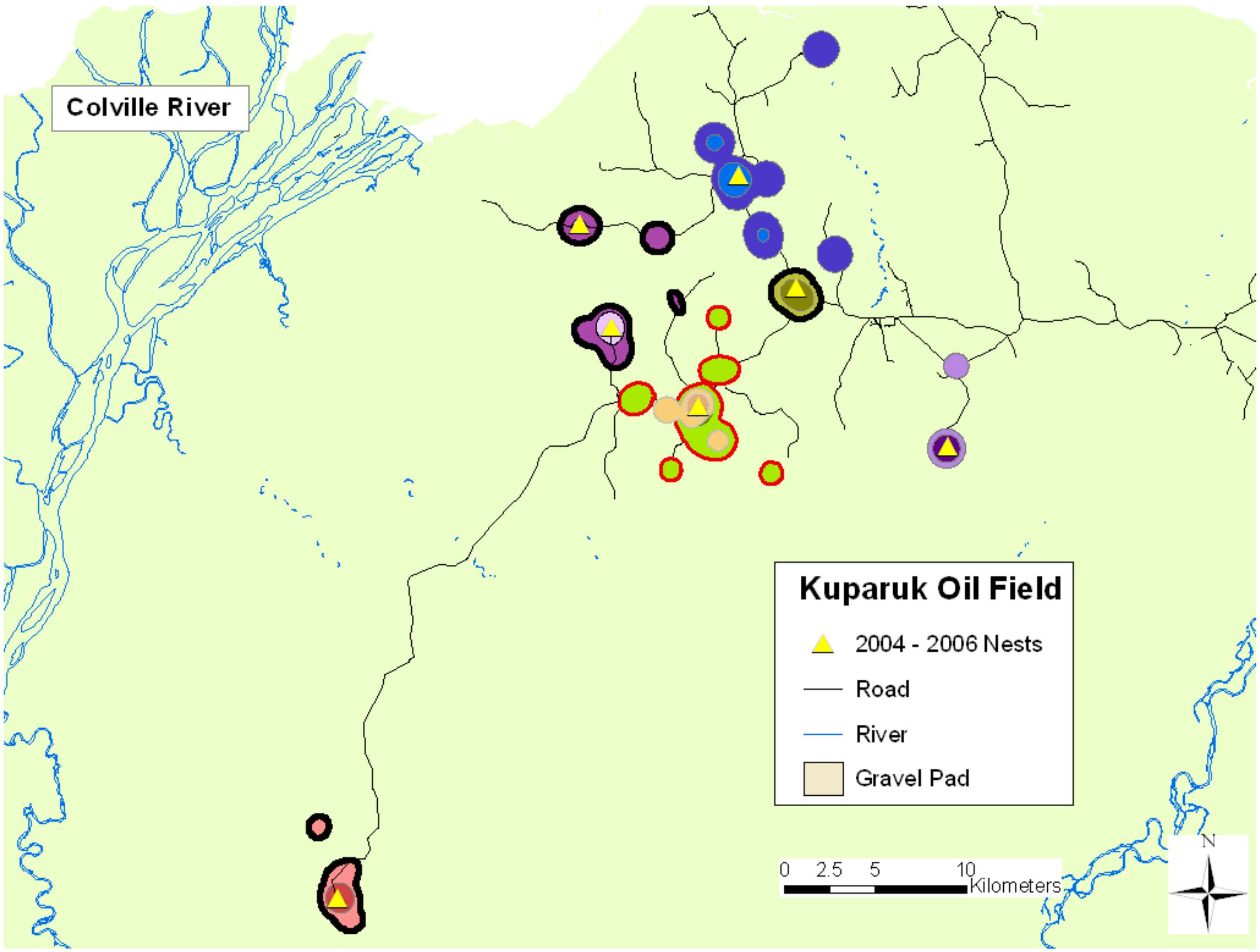


Figure 6. Non-breeding (September-March) locations, 2004-2007, of adult ravens marked during the breeding season in Alaska's North Slope oil fields. Each shape indicates an individual raven.

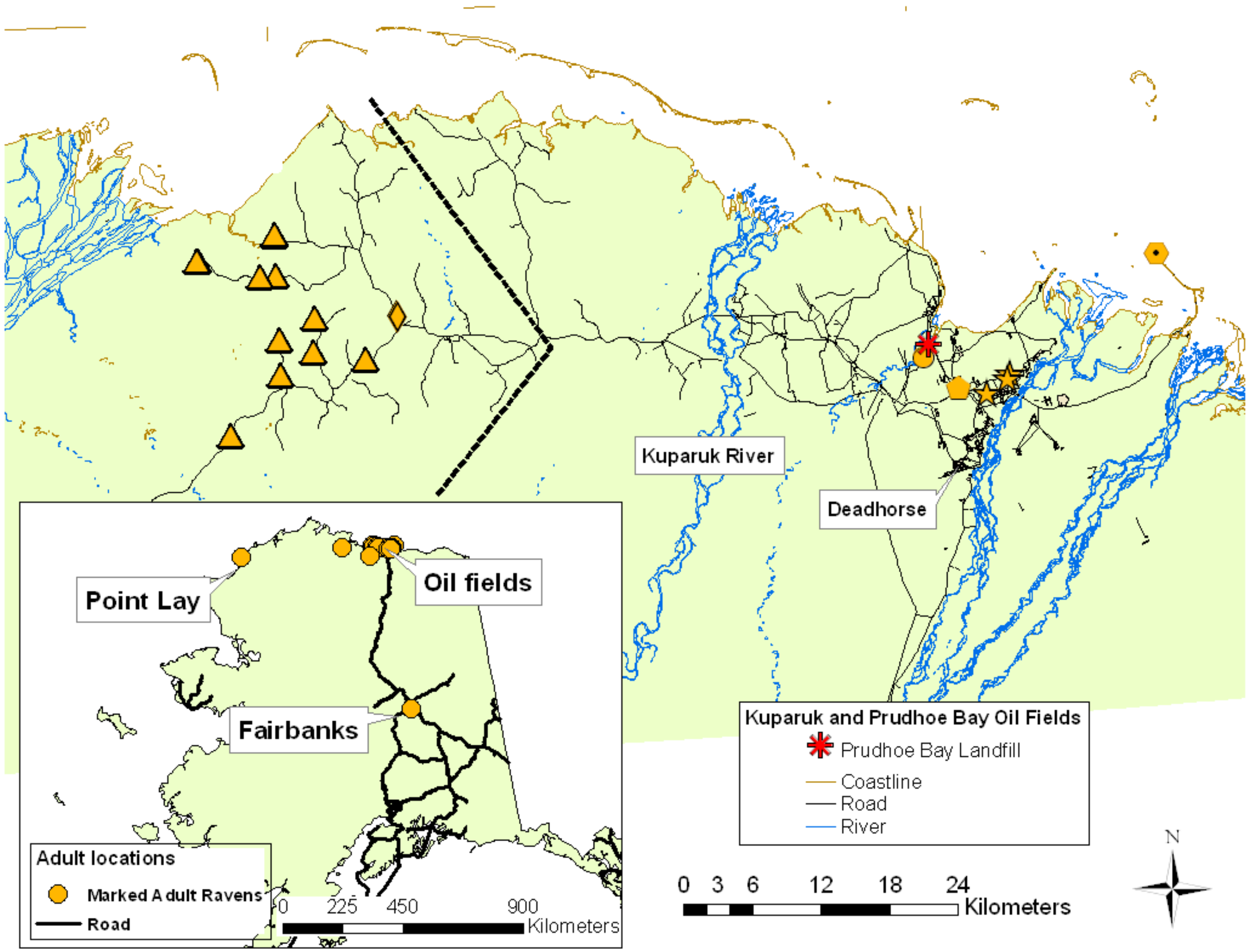


Figure 7. Locations of an adult male raven fitted with a satellite transmitter at Kuparuk, Alaska, 2005; this bird did not breed during the time it was transmitting location data.

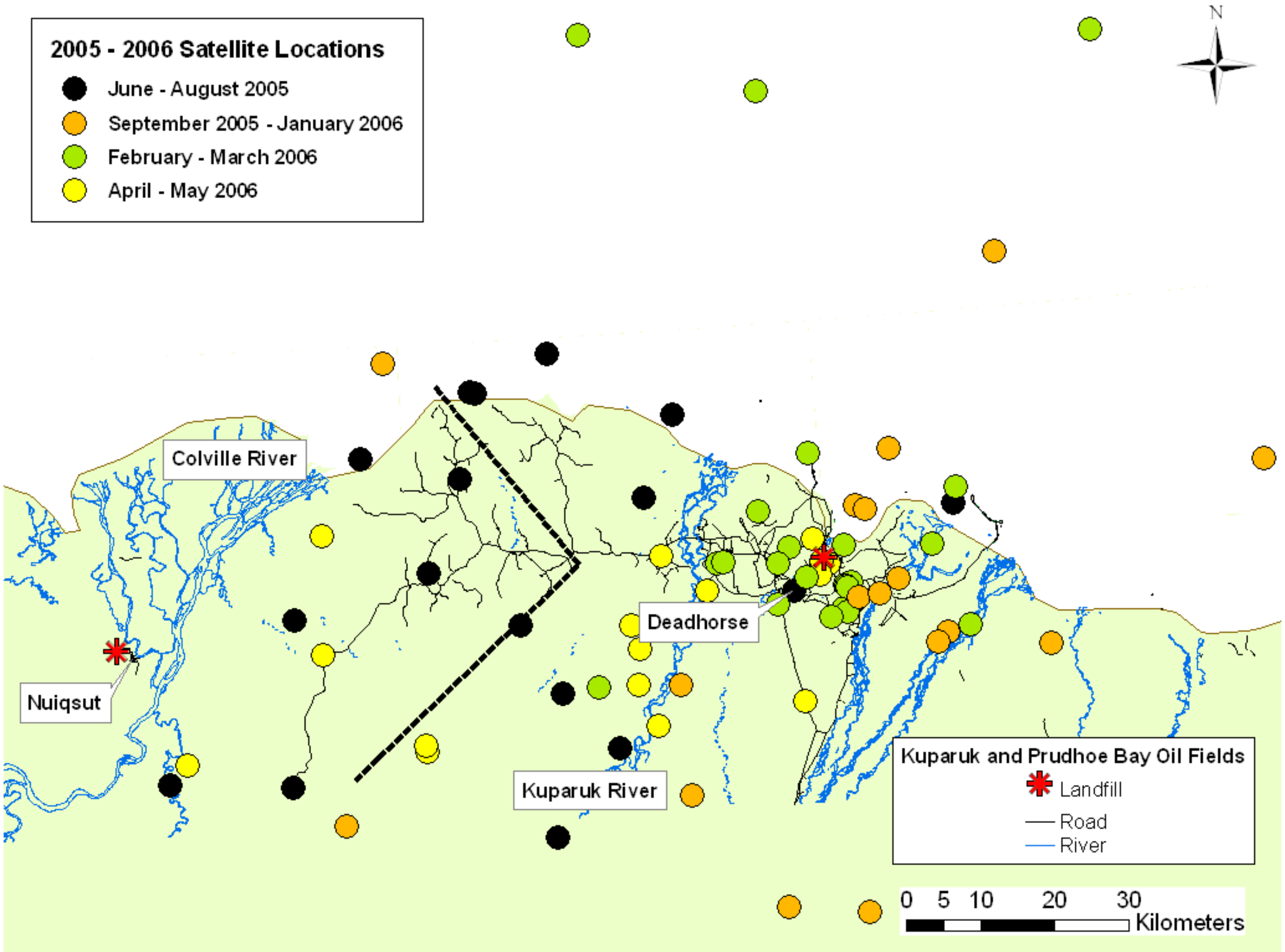


Figure 8. Locations (2004-2007) of juvenile ravens marked with patagial tags in 2004 and 2006 in Alaska's North Slope oil fields. Locations are for juveniles after the fledging period (September and later).

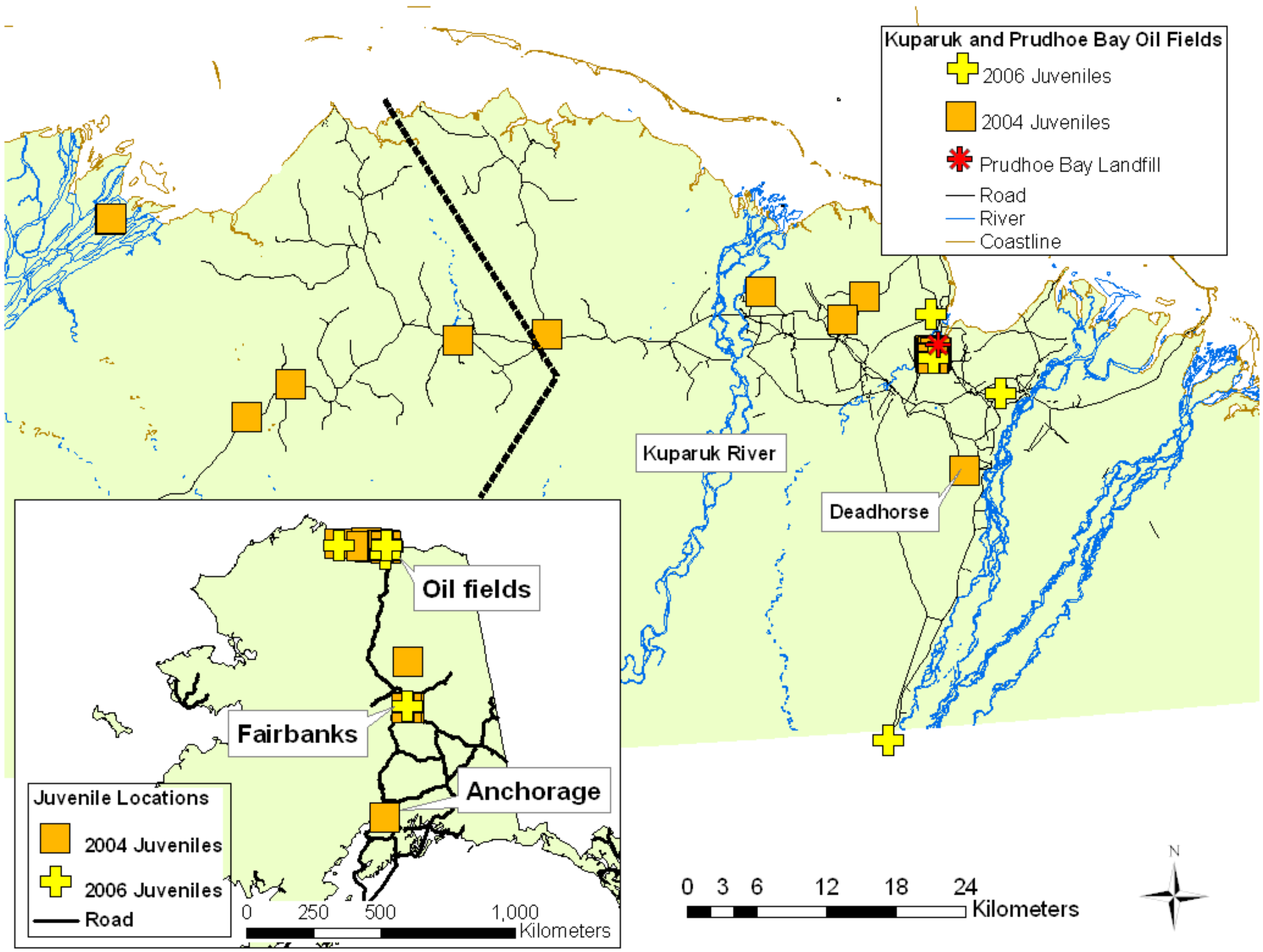
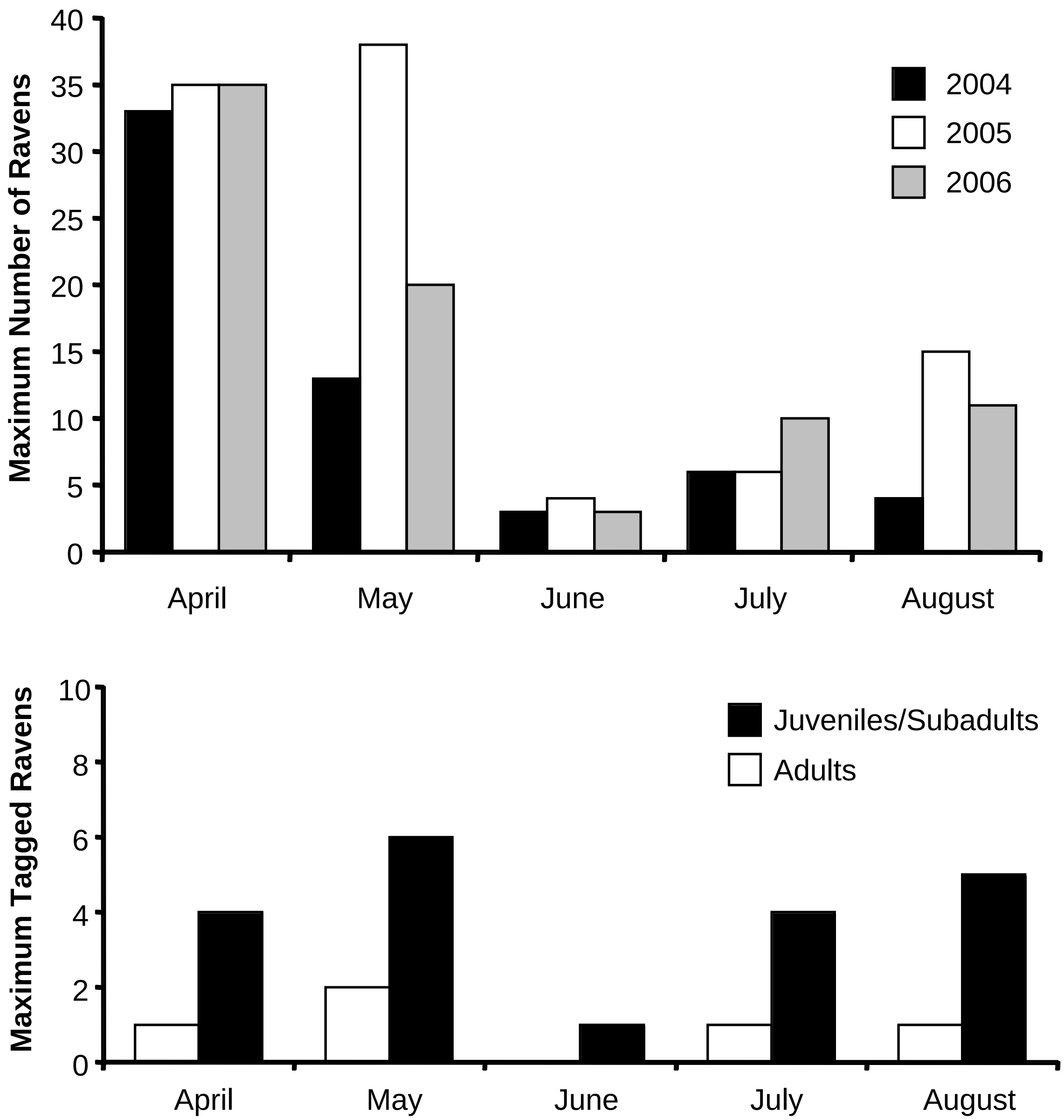


Figure 9. Use of the Prudhoe landfill by adult and juvenile/subadult ravens during the breeding season, 2004-2006.



Appendix 1. Leg band and patagial tag identification, and morphological measurements of adult ravens captured at Alaska's North Slope oil fields, 2004-2006.

Date of Capture	USGS Band Number	Sex	General Location	Nest Site	Tag Color	Alpha Code	Weight (g)	Wing Chord (mm)
4/30/2004	155715941	F	Kuparuk	KCS	Yellow	OE	1355	415
5/1/2004	155715504	F	Kuparuk	2T	Yellow	OZ	-	-
5/10/2004	168708945	M	Kuparuk	CPF3	Yellow	OX	1520	434
5/16/2004	173716138	F	Kuparuk	CPF2	Blue	EA	-	-
5/18/2004	173716123	M	Kuparuk	2P	Blue	JA	1510	433
5/20/2004	173716125	M	Kuparuk	2L	None*	None	1490	445
5/22/2004	173716101	F	Prudhoe	FS1	Orange	AZ	1410	442
5/26/2004	173716102	M	Prudhoe	GC1	Orange	CZ	1580	449
5/26/2004	173716103	M	Prudhoe	FS3	Orange	EZ	1570	450
5/29/2004	173716104	F	Prudhoe	FS2	Orange	HZ	1230	431
5/29/2004	173716126	M	Prudhoe	LPC	Orange	JZ	1390	462
4/27/2005	173716132	M	Kuparuk	1J	Blue	AA	1600	454
5/29/2006	173716134	M	Prudhoe	Endicott	Blue	KA	1500	462

* Adult died during banding.

Appendix 2. Leg band and patagial tag identification, and morphological measurements of juvenile ravens captured at Alaska's North Slope oil fields, 2004-2006.

Date of Capture	USGS Band Number	Sex	General Location	Nest Site	Patagial Tag Color	Alpha Code	Weight (g)	Wing Chord (mm)
6/7/2004	173716105	-	Prudhoe	FS2	White	AY	1230	335
6/7/2004	173716106	-	Prudhoe	FS2	White	CY	1220	317
6/7/2004	173716107	F	Prudhoe	FS2	White	HY	1040	321
6/7/2004	173716108	-	Prudhoe	FS2	White	EY	995	311
6/11/2004	173716109	-	Prudhoe	FS1	White	JY	1100	308
6/11/2004	173716610	-	Prudhoe	FS1	White	KY	1290	316
6/14/2004	155715502	M	Kuparuk	CPF2	White	EC	1340	328
6/14/2004	173716111	-	Prudhoe	WDSA	White	AX	1140	168
6/14/2004	173716112	F	Prudhoe	WDSA	White	CX	1140	314
6/14/2004	173716113	M	Prudhoe	WDSA	White	EX	1340	294
6/14/2004	173716114	-	Prudhoe	WDSA	White	HH	1280	312
6/14/2004	173716115	-	Prudhoe	WDSA	White	JJ	1140	305
6/14/2004	173716116	-	Prudhoe	WDSA	White	KK	1140	324
6/15/2004	173716127	F	Kuparuk	CPF2	White	AC	1040	337
6/15/2004	173716128	M	Kuparuk	CPF2	White	CC	1360	351
6/15/2004	173716130	F	Kuparuk	CPF2	White	HC	1170	322
6/15/2004	173716117	M	Prudhoe	GC1	White	XY	1120	324
6/15/2004	173716118	-	Prudhoe	GC1	White	ZY	1120	327
6/16/2004	173716119	-	Prudhoe	GC1	White	NY	1220	339
6/17/2004	173716120	M	Prudhoe	GC1	White	MY	1280	339
6/19/2004	173716124	M	Kuparuk	2T	White	JC	1250	-
6/19/2004	173716129	M	Kuparuk	2T	White	LC	1040	-
6/22/2004	173716121	-	Prudhoe	L5	White	LY	1250	314
6/22/2004	173716122	-	Prudhoe	L5	White	PY	1285	315
6/22/2004	173765401	M	Prudhoe	L5	White	TY	1170	295
6/24/2004	173765402	-	Prudhoe	DS16	White	HX	1300	345
6/24/2004	173765403	-	Prudhoe	DS16	White	JX	1235	365
6/24/2004	173765404	M	Prudhoe	DS16	White	XX	1220	355
6/24/2004	173765405	-	Prudhoe	Colleen	White	KX	940	345
6/29/2004	173765406	-	Prudhoe	MPAD	White	WX	1130	318
7/1/2004	173765407	F	Prudhoe	MPAD	White	PX	1060	327
7/4/2004	173765408	M	Prudhoe	FS3	White	WY	900	367
7/13/2004	173716131	F	Kuparuk	2P	White	KC	990	320
6/16/2005	155715509	-	Prudhoe	FS1	None	None	-	321
6/17/2005	155715510	-	Kuparuk	CPF3	None	None	1060	360
6/20/2005	155715511	-	Prudhoe	GC2	None	None	1380	341
6/20/2005	155715512	-	Prudhoe	GC2	None	None	1270	339
6/21/2005	155715513	-	Prudhoe	GC2	None	None	1020	338
6/24/2005	173765410	-	Prudhoe	GC2	Red	AW	1050	330
6/24/2005	173765411	M	Kuparuk	CPF2	Tan	WE	1075	337
6/25/2005	173765412	-	Prudhoe	WDSA	Red	EW	1200	349
6/25/2005	173765413	-	Prudhoe	WDSA	Red	HW	1225	333
6/25/2005	173765500	-	Prudhoe	WDSA	Red	CW	1000	335

Date of Capture	USGS Band Number	Sex	General Location	Nest Site	Tag Color	Tag Code	Weight (g)	Wing Chord (mm)
6/27/2005	155715514	M	Prudhoe	LPC	Red	KW	1125	332
7/1/2005	173765409	F	Prudhoe	FS3	Red	PW	975	376
7/7/2005	155715551	F	Kuparuk	CPF2	Tan	LM	1350	387
6/9/2006	155715552	M	Prudhoe	FS1	Red	JW	1225	348
6/9/2006	155715553	F	Prudhoe	FS3	Red	LL	1020	343
6/9/2006	155715554	M	Prudhoe	FS3	Red	LA	1140	336
6/9/2006	155715555	M	Prudhoe	FS3	Red	LH	1180	353
6/9/2006	173716135	-	Prudhoe	Connex	Red	LW	-	316
6/9/2006	173716136	M	Prudhoe	FS3	Red	WW	1120	325
6/9/2006	173716137	M	Prudhoe	Connex	Red	MW	1140	326
6/9/2006	173716147	F	Prudhoe	Connex	Red	TW	940	312
6/9/2006	173716149	-	Prudhoe	Connex	Red	UW	-	333
6/10/2006	173716151	F	Prudhoe	RFR	Red	LX	1080	302
6/10/2006	173716154	F	Prudhoe	RFR	Red	MX	1120	342
6/11/2006	155715566	M	Kuparuk	CPF3	Tan	ZL	1180	349
6/11/2006	173716146	F	Kuparuk	CPF3	Tan	EL	1020	325
6/11/2006	173716152	F	Kuparuk	CPF3	Tan	CL	1080	297
6/12/2006	155715503	M	Prudhoe	FS2	Red	XZ	1160	308
6/12/2006	173716140	M	Prudhoe	FS2	Red	XY	1160	304
6/12/2006	173716142	F	Prudhoe	FS2	Red	XC	1000	303
6/14/2006	155715556	-	Prudhoe	Endicott	Red	LP	1280	341
6/14/2006	173716141	-	Prudhoe	Endicott	Red	LE	1100	332
6/14/2006	173716139	F	Prudhoe	Endicott	Red	LU	1040	321
6/15/2006	155715506	F	Kuparuk	CPF2	Tan	KL	1140	332
6/15/2006	155715557	F	Kuparuk	CPF2	Tan	WL	1040	335
6/15/2006	155715558	F	Kuparuk	CPF2	Tan	LL	1120	332
6/15/2006	155715559	F	Kuparuk	CPF2	Tan	ML	1140	334
6/15/2006	173716143	F	Kuparuk	CPF2	Tan	HL	980	343
6/16/2006	155715561	M	Prudhoe	WDSA	Red	YC	1160	347
6/16/2006	155715562	M	Prudhoe	WDSA	Red	YH	1220	351
6/16/2006	155715580	-	Prudhoe	WDSA	Red	YA	1160	356
6/16/2006	173716144	M	Prudhoe	WDSA	Red	YP	1160	357
6/19/2006	155715563	M	Prudhoe	DS3	Red	YE	1260	335
6/19/2006	155715564	M	Prudhoe	DS3	Red	YJ	1100	357
6/19/2006	155715565	M	Prudhoe	DS3	Red	YK	1140	349
6/19/2006	173716145	-	Kuparuk	DS3	Red	YM	1100	328
6/24/2006	155715567	M	Kuparuk	2P	Tan	HM	1230	347
6/24/2006	155715568	M	Kuparuk	2P	Tan	KM	1200	331
6/24/2006	173716165	-	Kuparuk	2P	Tan	AM	1030	321
6/24/2006	173716200	F	Kuparuk	2P	Tan	EM	1020	330
6/25/2006	173716166	F	Prudhoe	MPAD	Red	LZ	1100	327
6/26/2006	155715510	-	Prudhoe	L3	Red	XA	1070	324
6/26/2006	155715569	M	Prudhoe	L3	Red	XP	1240	325
6/26/2006	155715570	M	Prudhoe	L3	Red	XT	1200	345
6/26/2006	155715572	F	Prudhoe	L3	Red	XE	940	288
6/29/2006	155715573	-	Prudhoe	GC2	Tan	LT	1210	343

Date of Capture	USGS Band Number	Sex	General Location	Nest Site	Tag Color	Tag Code	Weight (g)	Wing Chord (mm)
6/29/2006	155715574	M	Kuparuk	Kalubik	Tan	AJ	1190	332
6/29/2006	155715579	M	Kuparuk	Kalubik	Tan	LK	1120	342
6/29/2006	173716167	M	Kuparuk	Kalubik	Tan	AL	1200	333
7/1/2006	155715575	F	Kuparuk	1J	Tan	XJ	1060	332
7/1/2006	155715576	M	Kuparuk	1J	Tan	KJ	1290	342
7/1/2006	155715577	M	Kuparuk	1J	Tan	CJ	1310	335
7/1/2006	155715578	M	Kuparuk	1J	Tan	LJ	1200	338

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principals of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.