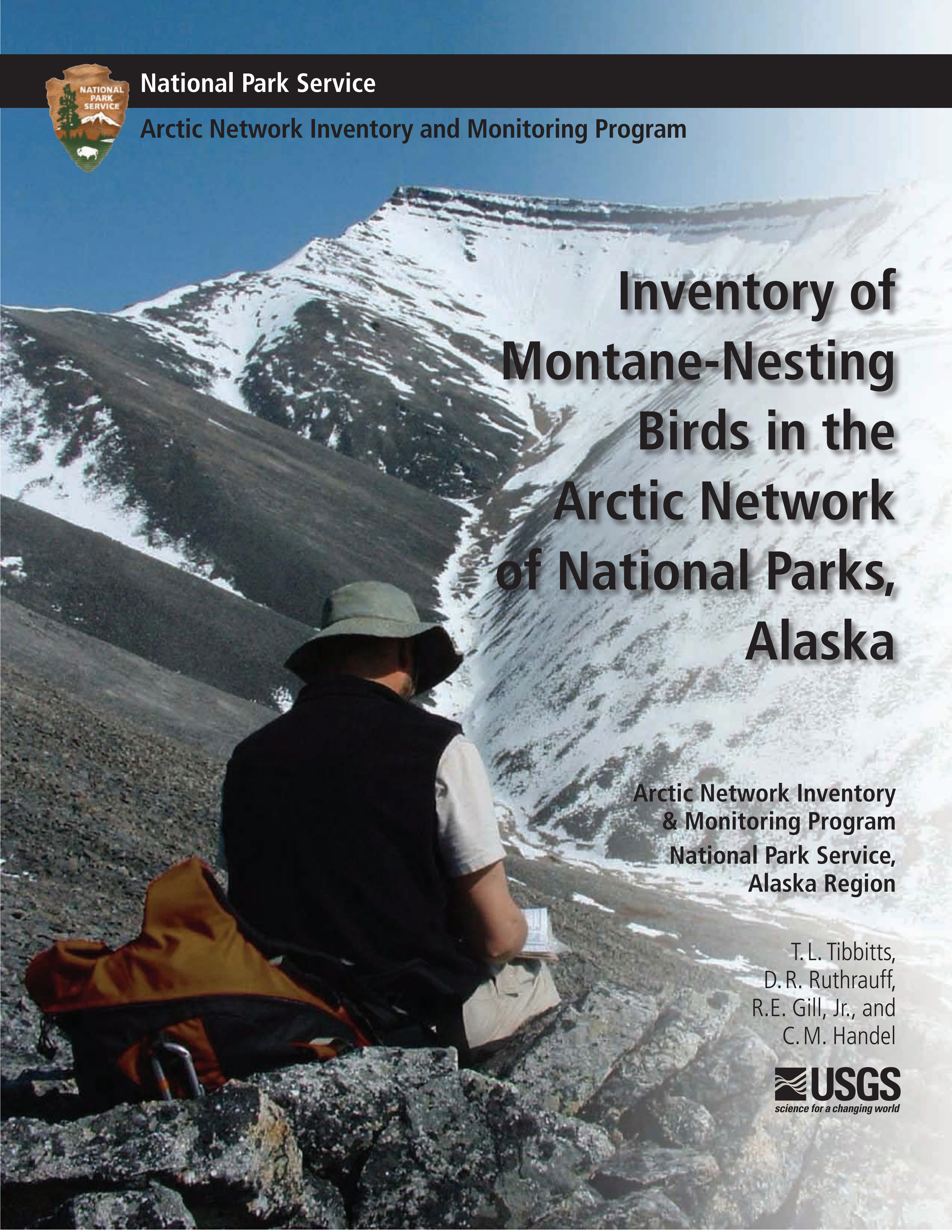
National Park Service

Arctic Network Inventory and Monitoring Program



Inventory of Montane-Nesting Birds in the Arctic Network of National Parks, Alaska

Arctic Network Inventory & Monitoring Program
National Park Service, Alaska Region

T. L. Tibbitts,
D. R. Ruthrauff,
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C. M. Handel

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Cover photo of Blain Anderson (NPS) recording point count information at the head of an unnamed creek (68.2405 N, 151.4165 W) 32 km northeast of the village of Anaktuvuk Pass, Alaska, on 6 June 2003. USGS photo by R. Gill.

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Abstract

The Alaska Science Center of the U.S. Geological Survey conducted an inventory of birds in montane areas of the four northern parks in the Arctic Network of National Parks, Alaska. This effort represents the first comprehensive assessment of breeding range and habitat associations for the majority of avian species in the Arctic Network. Ultimately, these data provide a framework upon which to design future monitoring programs.

A stratified random sampling design was used to select sample plots (n = 73 plots) that were allocated in proportion to the availability of ecological subsections. Point counts (n = 1,652) were conducted to quantify abundance, distribution, and habitat associations of birds. Field work occurred over three years (2001 to 2003) during two-week-long sessions in late May through early June that coincided with peak courtship activity of breeding birds.

Totals of 53 species were recorded in Cape Krusenstern National Monument, 91 in Noatak National Preserve, 57 in Kobuk Valley National Park, and 96 in Gates of the Arctic National Park and Preserve. Substantial proportions of species in individual parks are considered species of conservation concern (18 to 26%) or species of stewardship responsibility of the land managers in the region (8 to 18%). The most commonly detected passerines on point counts included Redpoll spp. (*Carduelis flammea* and *C. hornemanni*), Savannah Sparrow (*Passerculus sandwichensis*), and American Tree Sparrow (*Spizella arborea*). The most numerous shorebirds were American Golden-Plover (*Pluvialis dominica*), Wilson's Snipe (*Gallinago delicata*), and Whimbrel (*Numenius phaeopus*). Most species were detected at low rates, reflecting the low breeding densities (and/or low detectabilities) of birds in the montane Arctic. Suites of species were associated with particular ranges of elevation and showed strong associations with particular habitat types.

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Acronyms

ARCN	Arctic Network of National Parks
ASC	Alaska Science Center
ASG	Alaska Shorebird Group
BELA	Bering Land Bridge National Preserve
CAKR	Cape Krusenstern National Monument
CBMWG	Coordinated Bird Monitoring Working Group
CHASM	Committee for Holarctic Shorebird Monitoring
FGDC	Federal Geographic Data Committee
GAAR	Gates of the Arctic National Park and Preserve
GIS	Geographic Information System
I&M	Inventory and Monitoring
KOVA	Kobuk Valley National Park
NAD27	North American Datum 1927
NPS	National Park Service
NOAT	Noatak National Preserve
PRISM	Program for Regional and International Shorebird Monitoring
USGS	United States Geological Survey

EXECUTIVE SUMMARY

In 2001, the Alaska Science Center (ASC) of the U.S. Geological Survey (USGS) received funding from the National Park Service to conduct an inventory of birds in the Arctic Network, a group of five parks that encompasses a vast (78,000 km^2), mostly montane and roadless portion of northern Alaska. The goals of the inventory were to:

1. document the occurrence of 90% of the species of birds likely to occur in montane habitats of each park, and
2. determine the distribution and abundance of species of special concern in each park.

The sample universe for the inventory included all montane parklands (i.e., >100 m above sea level) in the four northern parks of the Arctic Network that were accessible by helicopter and foot (i.e., <30° slope). The fifth park (Bering Land Bridge National Preserve) was not included in this current effort because similar bird inventories had been conducted there previously (see below). We used a stratified random sampling design to select sample plots (10 km x 10 km in size) that were allocated in proportion to the availability of ecological strata (i.e., ecological subsections). Field work occurred over three years (2001–2003) during two-week-long sessions in late May–early June that coincided with peak courtship activity (and therefore peak detectability) of breeding birds. During these periods, we used point counts with distance estimation to collect standardized data on abundance, distribution, and habitat associations of birds. A total of 1,652 sample points were distributed among 69 plots, and vegetative cover was quantified within a 150-m-radius of each point.

This effort represents the first comprehensive assessment of breeding range and habitat associations for the majority of avian species in the Arctic Network. Over the course of the inventory we documented the occurrence of 115 species of birds, which constituted 78% of the 147 species expected to occur in montane habitats within the Arctic Network. Among the 115 species, 106 likely nested in the parks. We recorded 53 species in Cape Krusenstern National Monument, 91 in Noatak National Preserve, 57 in Kobuk Valley National Park, and 96 in Gates of the Arctic National Park and Preserve. Two species (Pine Siskin *Carduelis pinus* and Pacific Golden-Plover *Pluvialis fulva*) were new to the parks. A previous effort (1988–1989, 1991, 2000; R. Gill et al., unpubl., USGS ASC Anchorage, AK) to inventory birds in Bering Land Bridge National Preserve, the fifth unit in the Arctic Network, produced four species unique to that preserve (Rock Sandpiper *Calidris ptilocnemis*, Bristle-thighed Curlew *Numenius tahitiensis*, Cliff Swallow *Petrochelidon pyrrhonota*, and Lincoln's Sparrow *Melospiza lincolnii*).

Substantial proportions of species in individual parks are considered species of conservation concern (18 to 26%) or species of stewardship responsibility of the land managers in the region (8 to 18%). Conservation status is based on factors such as population size and trend, extent of breeding and nonbreeding distributions, and existing or potential threats to birds on the breeding and nonbreeding grounds. Stewardship species are those that are characteristic of a single avifaunal biome (e.g., Arctic, Northern Forest) and where a high proportion of the global population occurs in the region.

We detected 99 of the 115 species (totaling 9,225 birds) during 10-minute point counts. The most commonly detected passerines included Redpoll spp. (*Carduelis flammea* and *C. hornemanni*), Savannah Sparrow (*Passerculus sandwichensis*), American Tree Sparrow (*Spizella arborea*), Lapland Longspur (*Calcarius lapponicus*), American Pipit (*Anthus rubescens*) and American Robin (*Turdus migritorius*). American Golden-Plover (*Pluvialis dominica*), Wilson's Snipe (*Gallinago delicata*), and Whimbrel (*Numenius phaeopus*) were the most numerous shorebirds, and Long-tailed Jaeger (*Stercorarius longicaudus*) and Common Raven (*Corvus corax*) the most commonly detected potential avian predators. Many species were detected at low rates, reflecting the low breeding densities (and/or low detectabilities) of birds in the montane Arctic.

We used standard measures of abundance and diversity to summarize patterns of occurrence across the landscape at the level of the 14 ecological sections. Among seven sections with relatively intensive sampling, expected species richness was highest in the De Long Mountains and lowest in Western Brooks Foothills. Bird assemblages were most similar in ecological sections that were in close proximity, particularly those that shared borders. In a few ecological sections (Interior Forested Lowlands, Arctic Foothills, Endicott Mountains), single species (usually Redpoll spp. and Lapland Longspurs) dominated during point counts, but in all other sections, composition of bird assemblages was relatively even (i.e., species occurred in similar proportions on point counts). The Baird Northern and Southern mountains, the Arctic and Subarctic Brooks ranges, and the De Long Mountains were more diverse than the other sections based on relative rankings derived from a species diversity index that measured species richness and species evenness.

Elevation at survey points was highest in the eastern mountain ranges (Endicott, Schwatka, and Brooks ranges) and lowest in the near-coast ecological sections, the Noatak Basin, and the Interior Forested Lowlands. The Chukchi Sea Coastal Plain had the lowest median elevation (146 m) and the Arctic Brooks Range had the highest (991 m). Suites of species were associated with particular ranges of elevation. Among raptors, Northern Harriers (*Circus cyaneus*) and Merlins (*Falco columbarius*) were associated with relatively low elevations, whereas Rough-legged Hawks (*Buteo lagopus*) and Golden Eagles (*Aquila chrysaetos*) were observed across a broad range of elevations. Among shorebirds, Wandering Tattlers (*Heteroscelus incanus*), Surfbirds (*Aphriza virgata*), and Baird's Sandpipers (*Calidris bairdii*) occurred at relatively high elevations (>550 m). In contrast, Whimbrels, Bar-tailed Godwits (*Limosa lapponica*), Semipalmated Sandpipers (*Calidris pusilla*), Western Sandpipers (*C. mauri*), Least Sandpipers (*C. minutilla*), and Wilson's Snipe (*Gallinago delicata*) were affiliated with relatively low elevations (<550 m). American Golden-Plover (one of the most common shorebirds) was more broadly distributed, with most birds occurring at points ranging in elevation from 200 to 725 m. Jaegers, gulls, ptarmigan, and most passerines were generally found below 800 m. However, one suite of passerines (Horned Lark *Eremophila alpestris*, Violet-green Swallow *Tachycineta thalassina*, Northern Wheatear *Oenanthe oenanthe*, American Pipit (*Anthus rubescens*), Snow Bunting *Plectrophenax nivalis*, and Gray-crowned Rosy-Finch *Leucosticte tephrocotis)*, was associated with relatively high elevations (>550 m).

Six different habitat types predominated throughout the Arctic Network. Within ecological sections most of these types were patchily distributed, but mixtures of Sparsely Vegetated, Low and Tall shrub, Herbaceous, and Herbaceous-Tussock habitats dominated. Forest was the least common habitat. In general, percent cover of habitats in sections followed patterns of frequency of occurrence of the habitats.

Many species showed strong associations with particular habitat types. For instance, the high-elevation shorebirds occurred at points with high percent cover of Sparsely Vegetated habitat whereas the low-elevation shorebirds were generally associated with Herbaceous-Tussock habitat. Willow Ptarmigan (*Lagopus lagopus*) were detected at points with higher percent cover of Herbaceous-Tussock and Low Shrub habitats, whereas Rock Ptarmigan (*Lagopus mutus*) occurred more frequently in areas with Sparsely Vegetated habitat. A forest-associated assemblage of passerines included Ruby-crowned Kinglet (*Regulus calendula*), Gray-cheeked Thrush (*Catharus minimus*), Swainson's Thrush (*Catharus ustulatus*), Varied Thrush (*Ixoreus naevius*), Yellow-rumped Warbler (*Dendroica coronata*), and Dark-eyed Junco (*Junco hyemalis*). Warblers and sparrows tended to be found at points with Tall and Low shrub habitats. Eastern Yellow Wagtail (*Motacilla tschutshensis*), Savannah Sparrow, and Lapland Longspur were associated with high percent cover of Herbaceous-Tussock habitat and the passerines detected at high elevations occurred in areas with high percent cover of Sparsely Vegetated habitat.

The data from this inventory provides a framework upon which to design future monitoring programs. Such efforts can use the information on distribution and abundance of species as a baseline to monitor trends in population size. The data can also be used to maximize efficiency of surveys by allowing researchers to focus their efforts on particular areas and habitats.

The data we collected on birds in the Arctic Network warrant analyses beyond those presented here, including:

1. estimation of densities of birds by ecoregion,
2. development of models to predict occurrence of species based on landscape characteristics,
3. calculation of resource selection probability functions using variables for which information is available on a network-wide GIS, and
4. standardization of the available digital land cover maps into a network-wide GIS. This additional level of investigation would be relevant for directing future studies, particularly efforts to monitor avian resources in the Arctic Network.

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INTRODUCTION

In the late twentieth century, the avian conservation community in North America documented widespread declines among many populations of migratory and resident birds. At the same time they recognized the need for science-based monitoring programs that would not only provide information about the general status and trend of populations but also be responsive to, and integrated with, decision-making processes that involved natural resources. This need motivated researchers to coordinate their efforts and to design monitoring schemes such as those by Partners in Flight for landbirds (Rich et al. 2004), the Program for Regional and International Shorebird Monitoring (PRISM), and the Committee for Holarctic Shorebird Monitoring (CHASM) for shorebirds (Harrington et al. 2002; Skagen et al. 2003; CHASM 2004), and the Coordinated Bird Monitoring Working Group for all birds (CBMWG 2004).

Implementation of these science-based monitoring programs fell largely to land custodial agencies that needed to understand not only what birds their lands supported but also how management decisions affected these birds. The National Park Service (NPS), one of the nation's principal land custodial agencies, was specifically tasked by Congress to address such mandates through the National Parks Omnibus Management Act of 1998. This act required the NPS to establish a biological inventory and monitoring program (I&M Program) that would provide baseline and long-term monitoring information throughout all of its units. The resulting program for the NPS recognized that a continuum of efforts would be needed to first procure baseline information about the resources at hand (inventories) and second to implement programs that would assess impacts to these resources over time (monitoring).

The goal of the NPS biological inventory program is to provide comprehensive, science-based information about the nature and status of selected resources occurring within parks. Further, the information is to be readily accessible to the public and the scientific community and useful for making management decisions and advancing research programs. This goal, with respect to birds, will be met through study designs that address three objectives:

1. document through existing, verifiable data and targeted field investigations the occurrence of at least 90 percent of the species currently estimated to occur in a park;
2. describe the distribution and relative abundance of species of special concern, such as threatened and endangered species, exotics, species with declining populations, and other species of special management interest (e.g., stewardship species) occurring within park boundaries; and
3. provide the baseline information needed to develop a general monitoring strategy that can be tailored to address specific resource issues and threats within specific parks and be readily implemented by parks once inventories have been completed. The NPS envisioned all of this to be based on and promoted through geographic information system (GIS) technology.

The NPS I&M Program in Alaska was launched in 1998 with initial funding directed at the Arctic Network of National Parks (hereafter Arctic Network), a system of five large land units in northwest Alaska that includes Bering Land Bridge National Preserve, Cape Krusenstern National Monument, Noatak National Preserve, Kobuk Valley National Park, and Gates of the Arctic National Park and Preserve (Fig. 1). Together these five parks cover almost 78,000 km², or 5% of Alaska's land area and almost 25% of all NPS-managed lands in the United States. Parks range in size from the relatively small Cape Krusenstern, at 2,360 km², to the very large Gates of the Arctic, at about 33,230 km² (Table 1).

Mountains are the single dominant physiographic feature of parks in the Arctic Network (Fig. 2). Indeed, mountains are such a defining feature of arctic Alaska and Beringia in general that they account for over 20% of the land area throughout the Holarctic (excluding the Greenland ice sheet). Not surprisingly, the avifauna of the region has been strongly influenced by montane landscapes and processes. In particular, a suite of shorebird species (Fig. 3) has adapted to this environment; the majority of the world's populations of Surfbird, Great Knot, Wandering Tattler, and American and Pacific

Fig. *1.* *The Arctic Network of National Parks in Alaska straddles the Arctic Circle and includes (from west to east) Bering Land Bridge National Preserve, Cape Krusentern National Monument, Noatak National Preserve, Kobuk Valley National Park, and Gates of the Arctic National Park and Preserve.*

Fig. *2. Montane landscapes in Gates of the Arctic National Park and Preserve. USGS photos by R. Gill.*

Table 1. *Sampling effort during the inventory of montane-nesting birds in the Arctic Network, Alaska, 2001–2003.*

Attribute	Cape Krusenstern	Noatak	Kobuk Valley	Gates of the Arctic	Total
Area of park (km2)[a]	2,364	25,399	6,757	33,233	67,754
Percent montane[b]	51%	97%	66%	100%	94%
Number of plots allocated to park[c]	5	34	9	25	73
Number of sections in sample universe[d]	2	7[e]	3[e]	7	14[f]
Number of sections sampled	2	7[e]	3[e]	7	14[f]
Number of subsections in sample universe[g]	3	54	15	52	104[f]
Number of subsections with point counts	3	42	11	26	75[f]

a Values from National Park Service. Bering Land Bridge National Preserve (the only other park in the Arctic Network; Fig. 1) covers an area of 10,269 km^2.

b Values calculated from our GIS (excluding lands within park boundaries <100 m asl).

c Plot = 10 km x 10 km sampling unit.

d Section = Physiographic regions with similar geology and regional climate (Jorgenson et al. 2002). Sections are composed of subsections.

e Baird Southern Mountains and Kiana Hills were combined into single section.

f Total not additive since some ecological sections and subsections are shared between adjacent parks.

g Subsection = Portion of a section with a more narrowly defined geology composed of repeated associations of geomorphic (landform) units (Jorgenson et al. 2002).

Fig. *3. The Arctic Network is home to several montane-nesting shorebirds like the Surfbird (*Aphriza virgata*), right, and Wandering Tattler (*Heteroscelus incanus*), left. USGS photos by R. Gill.*

golden-plovers (see Appendix 1 for list of scientific names) have centers of abundance in Beringia (Irving 1960; Dean and Chesmore 1974; Tomkovich 1994, 1995; Gill et al. 1996; Piersma et al. 1996; Johnson and Connors 1996; Gill et al. 1999; McCaffery and Gill 2001; Gill et al. 2002). But Beringia has also been the site of unprecedented species differentiation among other shorebirds, particularly of the genus *Calidris*. The mountains of the Arctic Network are unique in that they support montane-nesting populations of several *Calidris* species whose nesting elsewhere is confined to interior lowlands or coastal regions (Gill and Tomkovich 2004). Features common to most of these species—with both core and peripheral montane-nesting populations—are their globally restricted breeding distributions and comparatively small population sizes.

Several distinctive passerine species (Fig. 4) such as the Gray-crowned Rosy-Finch (MacDougall-Shackelton et al. 2000), Northern Wheatear (Kren and Zoerb 1997), and American Pipit (Verbeek and Hendricks 1994) rely exclusively on montane habitats for breeding. Primarily for this reason, but often coupled with conservation concerns away from the breeding grounds, many of these montane-nesting species have been singled out as being of high conservation concern in recent regional and national migratory bird conservation planning efforts (Boreal Partners in Flight Working Group 1999; Brown et al. 2001; Alaska Shorebird Group 2000, unpubl., USFWS MBM Anchorage, AK; Rich et al. 2004). These same efforts emphasize the lack of life-history information for montane-nesting species in general, a situation that impedes implementation of effective conservation measures. In addition, the mountains of northern Alaska are home to several relatively common species whose primary breeding (and often nonbreeding) range occurs in this region. The welfare of such species is recognized as a responsibility of the land managers of the region; these species are termed "stewardship species" in the applicable migratory bird conservation plans (e.g., Boreal Partners in Flight Working Group 1999; Rich et al. 2004).

Fig. *4. Montane-nesting passerine species common to the Arctic Network include the American Pipit (*Anthus rubescens*), right, and Northern Wheatear (*Oenanthe oenanthe*), left.*

Previous Studies

Compared to many regions of Alaska, knowledge of the avifauna of the Arctic Network is fragmentary at best. Early investigations of what would become the Arctic Network mostly chronicled the occurrence of species, primarily in coastal areas or along navigable portions of major rivers (e.g., McLenegan 1887, 1889; Grinnell 1900; Hines 1963). Later efforts to inventory birds were more site-specific and comprehensive, both along the coast (e.g., Connors and Connors 1982; Schroeder 1993; Schamel et al. 1999; and R. Uhl, unpubl. field notes, NPS ARCN, Fairbanks, AK) and in the interior (e.g., Irving and Paneak 1954; Hines 1963; Campbell 1968; Dean and Chesmore 1974). But despite what appears to be a fair number of reports, information on general breeding biology—particularly the distribution and timing of nesting by montane-breeding species—is limited within the Arctic Network to three geographically disparate efforts spread over a century-long period (Grinnell 1900, Irving 1960, Kessel 1989). Slightly more effort has been directed at assessments of bird-habitat associations within the network. These include the seminal but mostly qualitative studies by Irving (1960), Manuwal (1978), and Kessel (1989) and the more contemporary, quantitative studies of bird-landscape relationships by Gill et al. (1996), Swanson (1998), and Guldager (2003).

Goals and Objectives

The body of previous studies and numerous anecdotal observations on file with the National Park Service suggests that the Arctic Network supports an avifauna numbering between 150 and 200 breeding species, only 60 to 80% of which have been adequately documented. In addition, basic information on distribution and abundance of most species is limited or nonexistent for vast regions of the Arctic Network. Noticeably lacking is a comprehensive picture of the breeding bird communities across montane landscapes, the predominant feature of the Arctic Network. To address these information needs, the Alaska Science Center (ASC) of the United States Geological Survey (USGS) received funding from the NPS I&M Program to design and implement a study that would determine the status of montane-nesting birds throughout the Arctic Network.

The underlying goals of the study were to (1) document the occurrence of 90% of the species of birds likely to occur in montane habitats of each park, and (2) determine the distribution and relative abundance of species of special concern in each park. Because use by species is often seasonal and highly variable, particularly among birds at arctic latitudes, our study focused on the breeding period and on those species that nest in montane habitats. To this end we developed a repeatable, scientifically valid sampling design suited to expansive areas with limited access. To meet the goals outlined for this study we (1) collected and summarized existing information on the distribution and abundance of all avian species occurring in upland habitats in the Arctic Network; (2) obtained and developed geographic layers such as elevation, slope, land cover, and ecoregions that were needed to characterize avian habitats; and (3) determined associations between species' distribution, abundance, and habitat characteristics—particularly for species of shorebirds and landbirds occurring on upland areas during the breeding season.

In this report we first provide a description of the study area, sampling design, data collection protocols, logistics, training, and analyses. Results are then presented in three general sections: (1) information on relative occurrence and distribution of individual species, including maps of their distribution; (2) comparisons of avian richness and diversity across ecoregions; and (3) summaries of elevation and habitat associations of species. Results are summarized and discussed and, where applicable, compared to findings of previous surveys. Finally, recommendations are presented to help guide the monitoring phase of the NPS I&M effort in the Arctic Network.

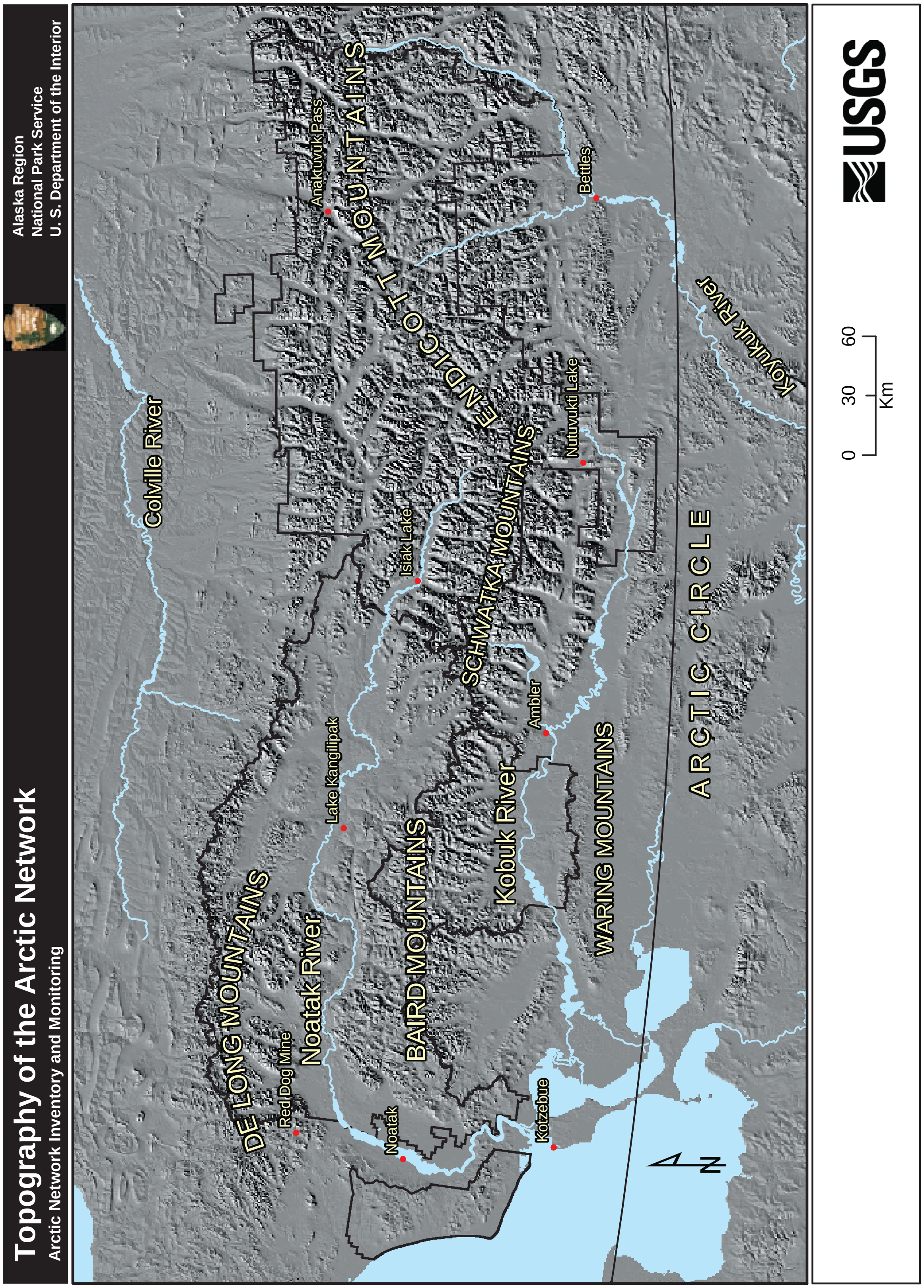

Fig. 5. *Major topographic features of the four northern parks in the Arctic Network of National Parks.*

METHODS

The Setting

The parks of the Arctic Network occur predominantly within the Brooks Range, the northern terminus of the Rocky Mountains that tends east-west across Alaska just north of the Arctic Circle. Five prominent mountain groups—the Schwatka, Endicott, Waring, Baird, and De Long—dominate the region (Fig. 5). Glaciers were the prime sculptors of the modern landscape, leaving rugged mountains and extensive U-shaped valleys. The Arctic Network has a varied climate that includes a strong maritime influence in the west, a continental regime over the interior southern portion, and arctic conditions across the north slope of the Brooks Range. The entire northern portion of the Arctic Network receives continuous daylight for at least 30 days each year, but thick, continuous permafrost is common throughout the area while snow covers the ground for over half the year.

The parks straddle the traditional boundary between the arctic tundra and boreal forest biomes, with coniferous and mixed hardwood forests reaching their northern limit along the southern flanks of the Brooks Range. Shrub thickets and tussock tundra dominate the region's interior lowlands, while alpine and moist tundra occur at higher elevations. The faunas of the Arctic Network reflect the dynamic "bottle-necking" refugia processes that define Beringia (Pielou 1991; Williams et al. 1998; Holder et al. 1999). Many species nesting in the Arctic Network show strong affinities to their Asian counterparts (and vise versa) and many spend parts of their annual cycle in Asia, Oceania, and the Americas.

STUDY AREA

The study area encompassed all five units of the Arctic Network (Fig. 1), but active fieldwork during the study period was conducted only in the four northern units. An inventory of montane-nesting birds in Bering Land Bridge was conducted in 1988–1989, 1991, and 2000 (R. Gill et al. unpubl., USGS ASC, Anchorage, AK) with relevant summary data presented here.

The northern parks encompass lands that extend from sea level to 2,553 m elevation with most (93%) of the land above 100 m. The easternmost park, Gates of the Arctic, is almost entirely montane, with only 12% of the land—mostly intermountain valleys—below 500 m elevation. Vegetation patterns in the Arctic Network follow climatic and topographic gradients. In general, ridgelines and mountaintops are bare or sparsely covered with lichens and low-growing *Dryas*, *Vaccinium*, and *Cassiope* shrubs. Mid-slopes, plateaus, and riparian corridors support various shrub, graminoid, and herbaceous communities such as open low willow thickets and the ubiquitous mixed shrub-sedge tussock tundra. Vegetative cover on lower slopes and valleys, particularly along the southern margin of the Arctic Network, consists of boreal forest communities, usually open and closed canopy spruce forests and the less dense spruce woodlands (Viereck et al. 1992; Markon and Wesser 1998; Helt et al. 2000).

Sampling Design

We defined the sampling universe as all areas within the parks ≥100 m in elevation and <30° slope. To identify potential plots, we randomly shifted (Overton 1993) an existing Alaska-wide, GIS grid with a plot size of 10 km x 10 km that had been generated for landbird surveys across the state (Handel and Cady 2004). Among 866 potential plots within the parks, we excluded 158 that had <25% area ≥100 m in elevation and an additional 44 plots with <50% area within park boundaries. We determined that we could sample 73 of the remaining 664 plots over three years during the two-week period that was optimal for surveying arctic-nesting shorebirds (Meltofte 2001; Nebel and McCaffery 2003; R. Gill et al. unpubl., USGS ASC, Anchorage, AK).

We used a stratified random sampling design to select sample plots to increase precision in estimates of abundance and to provide a more spatially balanced sample (Fancy 2000). Strata were defined by the most currently available maps of ecological types within the parks (Boggs and Michaelson 2001; Swanson 2001a, b; Jorgenson et al. 2002). Ecological sections had been mapped according to standard NPS protocol (Nowacki et al. 2001) at a scale between 1:7,500,000 and 1:3,500,000; boundaries were based on physiographic features such as geology, climate, and geomorphic deposits or landforms (ECOMAP 1993). Sections had been further subdivided into subsections, which were mapped at a scale of 1:250,000 and based on finer resolution of superficial geologic features and processes, land cover, and weather patterns (Cleland et al. 1997; P. Spencer pers. comm.).

The number of plots allocated to each park was based primarily on the expected diversity of the avifauna within its ecological subsections, with Cape Krusenstern receiving more and Gates of the Arctic fewer plots relative to their land areas (Table 1, Fig. 6, Appendices 2–3). Because of the large number of subsections in the larger parks, we combined those with similar physiographic attributes into subsection groups (e.g., mountains, uplands, and hills). We removed from the sampling universe some small polygons (0.01 to 257.2 km^2 in size, total area = 690 km^2) of 14 lowland subsections that were >100 m in elevation but unlikely to support montane-nesting birds (depicted in red in Fig. 7). We then assigned each plot to whichever subsection comprised the greatest area within the plot. Within each park, we allocated samples proportionally to the area covered by each subsection group, except that we allocated a single plot to those unique subsection groups that would have otherwise been too small to receive one. Plots were then randomly selected within each stratum (subsection group; Appendices 2, 4–6). As a contingency, we also identified a random selection of alternate plots within each stratum to sample in case we were unable to visit selected plots because of adverse snow conditions, weather, or lack of landing sites. Unfortunately, in all four instances in which we could not sample selected plots because of unstable snow conditions, the alternate plots were also inaccessible. However, it may have been possible to sample these plots in different years under different conditions. Data on the abundance and diversity of birds that was collected during the inventory was summarized and compared mostly at the section level (see below). The distribution of plots by section is depicted in Figure 7.

A total of 20 to 28 survey points were selected for each plot and allocated in proportion to the extent of different ecological subsections within each plot. Points were spaced at 500-m intervals along transects that were placed across gradients of elevation and land cover. Multiple transects within the same subsection were spaced at least one drainage apart. Figure 8 provides an example of the point allocation process and the configuration of transects on a plot.

Data Collection

Surveys were timed to coincide with the period of peak courtship activity of birds, particularly for shorebirds. This information was gleaned from the literature (e.g., Irving 1960; Campbell 1968; Gill et al. 1996; Swanson 1998; Meltofte 2001), and from long-term average measures of snow melt and green-up (Markon 2001; D. Douglas pers. comm.). These two metrics determined that work each year should be initiated between late May and early June.

Point Count Surveys

Birds were sampled with point count (e.g., Ralph et al. 1995) and variable circular plot (e.g., Buckland et al. 2001, 2004) methodologies using protocols developed by the USGS ASC Shorebird Project. Observers worked in two-person field crews with at least one member of each crew having had three to eight field seasons of experience conducting point counts of birds in arctic and/or subarctic Alaska using methodologies similar to the one described here. In addition, most observers had several years of field experience studying Alaska's avifauna. Within a crew, one person was the primary observer during point counts while the other recorded data. Primary observers retained their role across years.

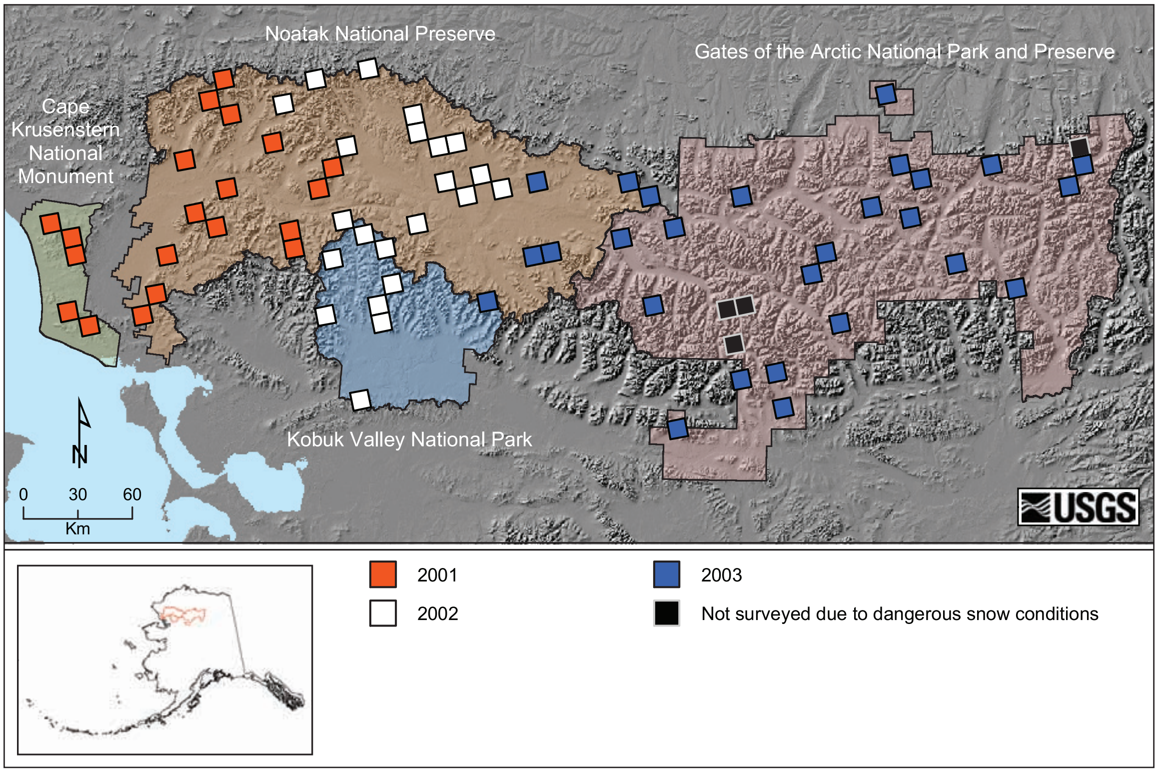

Fig. 6. *Distribution of sample plots.*

At each point we conducted two counts: (1) one of 10-minute duration where we collected detailed information on shorebirds and potential avian predators (e.g., hawks, falcons, corvids) and kept a tally of all other avian species; and (2) a subsequent count of 5-minute duration at the same location, during which we collected detailed information on landbirds (including ptarmigan) and waterbirds. By focusing on different species assemblages during the two counts, we avoided overloading observers with too much information to record, a situation that could potentially compromise data quality (Scott and Ramsey 1981; Bart and Schoultz 1984). The longer 10-minute interval allowed us to maximize detections for low density species while minimizing bias associated with movement of individuals during a point count (Rosenstock et al. 2002). The 5-minute interval was considered adequate for censusing landbirds because of their higher rates of song at this time of year (Ralph et al. 1995). Throughout the 1.5 to 2.5 days we were present at each plot, we maintained comprehensive lists of birds and mammals on standardized plot summary forms where we noted behaviors that would help determine status of species (i.e., migrant, breeder) and kept track of species detected at camp, between points, and between transects.

At the start of each 10-minute count, we recorded the following: GPS location and positional error, date, time of day, observers, elevation (using altimeter and GPS), slope (using clinometer on compass), aspect, estimated wind speed, wind direction, precipita-

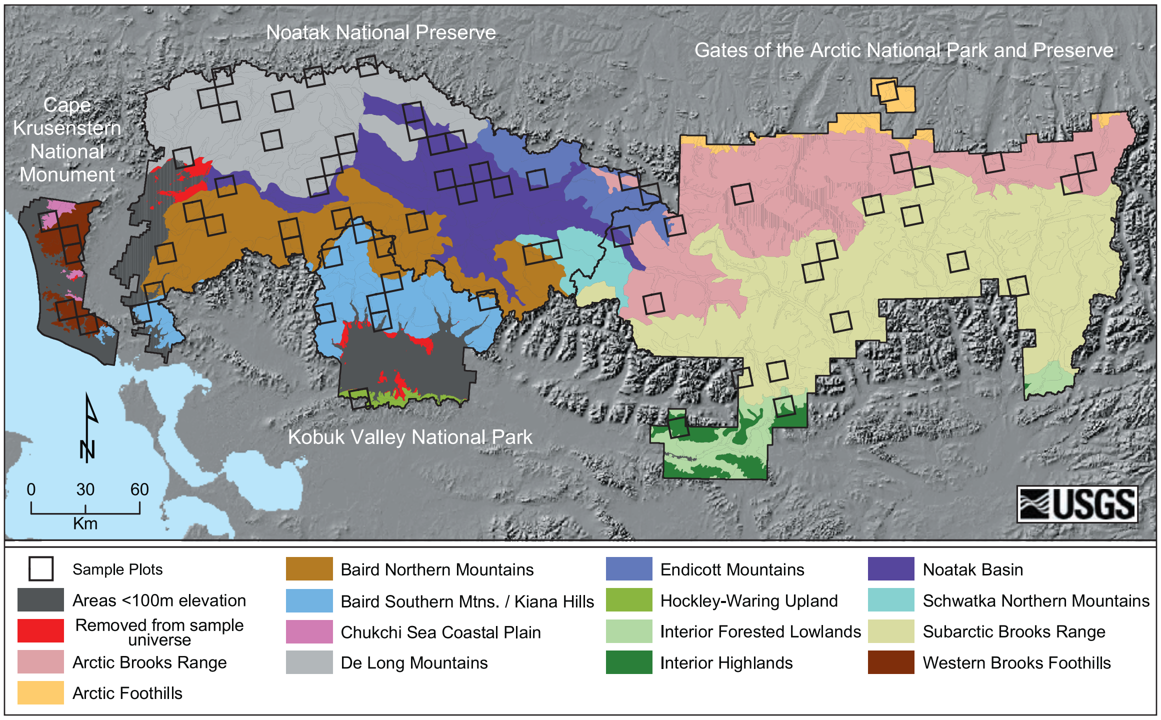

Fig. *7. Distribution of plots by ecological section.*

tion, percent cloud cover, air temperature, and percent cover of all vegetation types and snow within 150 m of the point (see below).

For each detection of a shorebird and potential avian predator during a 10-minute count and for all other bird species during a 5-minute count, we recorded elapsed time, species, number of individuals, and the radial distance of the bird(s) from the survey point. When possible, we collected additional data on each bird's behavior, vocalization(s), and microhabitat association (elevation, slope, vegetation). We used rangefinders to obtain a radial distance to individual birds. Under most field conditions rangefinders were accurate to ± 2 m. If an individual was heard but not seen, we recorded a range of distances in which it likely occurred (e.g., 70 to 120 m, 300 to 400 m) using a rangefinder to estimate the distance to landmarks on either side of the bird. When birds were beyond the limits of the rangefinder (generally >350 m), we estimated their range from topographic features on 1:63,360 scale USGS maps.

Classification of Vegetation Cover Types

For assessing both vegetation cover type within a 150-m radius of the point and habitat associations of birds detected on counts we used the Alaska Vegetation Classification System (Viereck et al. 1992). This five-level hierarchical system describes vegetation by structure (vertical and horizontal), moisture content of the substrate, and floristics (dominant species; Appendix 7). We classified vegetation at each point to level III and for many points to level IV. In addition, we created five level III cover types to help describe additional conditions and vegetation we encountered during the inventory (Appendix 7), including snow (complete snow cover), water (creek, river, lake, pond), sparsely vegetated (scree slopes, boulder fields), birch dwarf shrub (same description as the three other dwarf shrub types but dominated, in this case, by low, <15-cm tall *Betula* spp. shrubs), and shrubs emerging from snow (shrub branches poking through almost complete snow cover).

To determine the vegetative cover about a point, we used a rangefinder to define a 150-m radius and then visually estimated the percent cover of the different vegetation cover types within the circle. The percentage of each level III cover type was estimated to within ±5% and, when possible, the genus of the dominant species within each type was identified (a level IV requirement). We also took a photograph representative of the vegetation and terrain at each point.

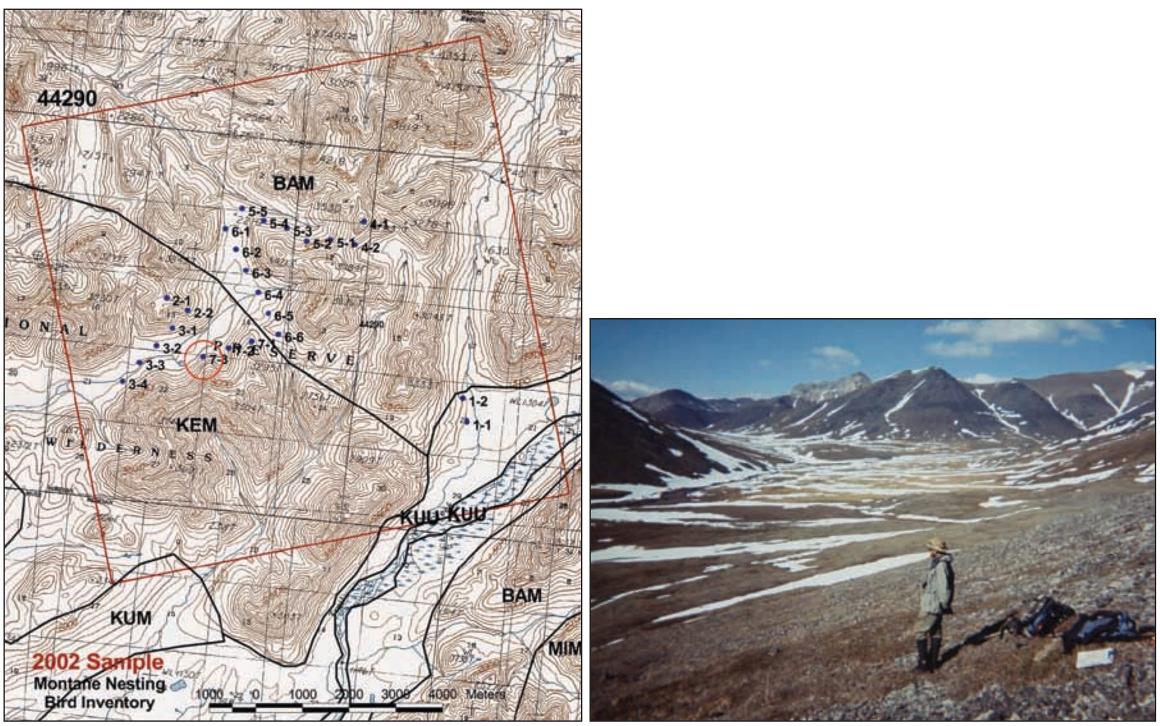

Fig. *8. Example of how point counts were allocated and transects were placed within a sample plot during the inventory of montane-nesting birds in the Arctic Network, Alaska, 2001–2003. In this plot, 24 sample points were allocated across three ecological subsections in proportion to the area of each subsection within the plot; i.e., 2 point counts were conducted in KUU (Kugururok Uplands), 9 in KEM (Kelly Mountains), and 13 in BAM (Bastille Mountains). The photograph, facing northwest, was taken in subsection KEM on transect 7, at point 3, on 4 June 2002 (location on map is circled in red). USGS photo by T. Van Pelt*

Logistics and Training

Helicopter Operations

All plots were accessed by helicopters that refueled at regional airfields (Kotzebue, Red Dog, Ambler, Bettles, Anaktuvuk Pass) or at remote fuel caches (Lake Kangilipak, Isiak Lake, Nutuvukti Lake; Fig. 5) deployed three to six weeks before field work. In 2001, we used a Hughes 500 helicopter based out of Red Dog Mine; in 2002, a Bell Jet Ranger based out of Ambler and Lake Kangilipak; and in 2003, both a Hughes 500 from Bettles, Lake Isiak, and Nutuvukti Lake and a Bell Jet Ranger from the village of Anaktuvuk Pass (Fig. 5). Straight-line distances between helicopter fueling sites and plots ranged from 30 to 125 km in 2001, 17 to 147 km in 2002, and 15 to 283 km in 2003. To conserve fuel and flight time, pilots occasionally camped at fuel caches. At several plots the helicopter stood by the entire day to move crews across impassible terrain to reach targeted subsections. Generally, crews were picked up and dropped off on a 1.5 to 2.5-day schedule, but adjustments were often made depending on the progress of each crew and factors such as local weather and the logistics involved in moving multiple crews to the next series of plots.

Communications

Crews and the pilot maintained daily scheduled contact via satellite phone. Daily contact allowed us to communicate about any safety issue and to plan the following day's schedule and thus optimize flight time and fuel consumption associated with moving crews.

Identification Skills

All observers, regardless of their experience with bird identification or aspects of the census protocol, participated in mandatory training before going into the field (Fig. 9). Aural bird identification skills were honed by listening to vocalizations (Peyton 1999) of birds expected to occur during the counts. Visual identification skills were honed during training sessions before going into the field and at staging areas before being deployed to survey plots. Participants were also instructed on the importance and process of documenting rare or unexpected species.

Distance Estimation

Being able to estimate distance accurately was essential. At least one member of each crew, and generally all participants, attended distance estimation training sessions that included hands-on trials involving estimating and measuring distances to real and simulated birds using a variety of techniques (rangefinder, ocular estimation, pacing) in representative habitats and conditions. In order for observers to recognize potential biases associated with using rangefinders, observers measured distances with a tape and a rangefinder before and after obtaining ocular estimates. We stressed that observers needed to use rangefinders to measure all distances, both to birds seen and to birds detected aurally, the latter by measuring objects near calling birds. However, for birds seen too close for the rangefinders to be used (<20 m), we paced distances and converted the measure to meters.

Assessing Vegetation

Participants studied the Alaska Vegetation Classification key (Viereck et al. 1992) and practiced using it in the field. We also reviewed forms from previous years to highlight ambiguities associated with interpreting and recording of vegetation data.

Safety

All participants were instructed in how to work safely in and around helicopters and fixed-wing aircraft, in the use of shotguns and appropriate response to encounters with bears, and in first aid and emergency communications procedures. At least one member of each crew had extensive experience traveling and working in remote areas of Alaska. Each crew carried a satellite phone and VHF radio to facilitate planning daily logistics, daily safety checks, and, if necessary, emergency communications. We sought pilots with flying experience in mountains, preferably in the Arctic during springtime. When possible, pilots filed flight plans of each day's proposed activities.

Data Management

All bird survey data were entered into an Excel spreadsheet and later transferred to an Access database. All photographs of vegetation were digitally scanned and linked to their respective point locations in the Access database. Original forms, field maps, and photographs are stored at the offices of USGS ASC in Anchorage.

All GPS data were downloaded and integrated with the bird data in the Access database. We used Garmin 12, Garmin III+, and Etrex GPS units to aid in navigation and to mark locations of point counts. All waypoints were collected in North American Datum 27 (NAD 27). Positional accuracy averaged 4.7 m ± 1.71 SD (n = 1,652 points, range 2.5 to 15.0 m).

Fig. 9. *Before going into the field, we held group training sessions (left) where we practiced the census protocol, and once in the field team (right) members prepared likely transect routes before being deployed to census plots. USGS photos by L. Tibbitts (left) and R. Gill (right).*

We used ArcView 3.3 and ArcGIS 8.3 software (ESRI 1999–2002) to establish a GIS for the study area and to summarize and present spatial data. The metadata developed for each file complied with the Federal Geographic Data Committee's (FGDC) standards for digital geospatial metadata and were compatible with the biological databases maintained by the NPS I&M Program. We used Alaska Albers Projection for all map products.

Final digital products provided to the NPS include shapefiles of the boundary of the merged park units, the sample universe, ecoregions and physiographic groups clipped to the boundary of the sample universe, plot and point locations, and survey locations in Bering Land Bridge. Other products include Access databases of the bird data, Excel spreadsheets of our expected species list and our summary of previous surveys, Word files of data forms and standard operating procedures, JPEG files of photographs depicting vegetation cover at points, and MXD files for each species depicting presence/absence on plots at the levels of ecological sections and physiographic groups. All digital data are stored on transferable media (DVD). Color hard-copy maps were produced at a scale of 1:250,000.

Analyses

Information on the occurrence of a species—defined as the detection of one or more individuals—was extracted from plot summary forms and point count datasets and used to generate a comprehensive list of species for the study area (Table 2). This information was also used to (1) determine presence/absence of each species on individual plots, (2) assess the overall effectiveness of the sampling regime at detecting birds during and between point counts, and (3) determine the status (i.e., breeder or migrant) of species within parks. These data were mapped at the plot level to derive patterns of distribution of species across the study area. In addition to the bird data, observations of mammals were taken from plot summary forms and summarized in an annotated list of species (Appendix 9).

A specific charge to all inventory efforts on NPS lands was to document through existing, verifiable data and targeted field investigations the occurrence of at least 90 percent of the species currently estimated to occur in a park. Achieving this goal was problematic because park-specific lists of species for the Arctic Network have not been finalized. The NPS is currently evaluating their species lists from the region (http://science.nature.nps.gov/im/apps/npspp/index.htm) and verifying the accuracy of records using standard protocols developed by the NPS I&M Program. In the meantime, for our study, we developed a list of species likely to be present in montane habitats of the Arctic Network based on accepted sources of reference (e.g., museum specimens, published accounts, professional opinion).

To determine the conservation status of all species detected during the inventory, we relied on assessments by groups of species experts such as Partners in Flight, Boreal Partners in Flight, and the Alaska Shorebird Group. Using entirely biological criteria to assess multiple components of a species' annual cycle, these groups derive a vulnerability score or conservation index for each species. Ranking is based on factors such as population size and trend, extent of breeding and nonbreeding distributions, and existing or potential threats to birds on the breeding and nonbreeding grounds (Boreal

Partners in Flight 1999; ASG 2000, unpubl. USFWS MBM Anchorage, AK; Carter et al. 2000; Brown et al. 2001; USFWS 2002; Rich et al. 2004;). Our list of species of concern in the parks (Table 3) also identifies species that are considered a stewardship responsibility of land managers of the region. Stewardship species are those that are characteristic of a single avifaunal biome and where a high proportion of the global population occurs in the region (Rich et al. 2004).

We summarized information on all previous surveys in the region including survey area, season, year, and species that were different from those we detected to be able to assess any changes in breeding ranges of species and to determine which species were potentially missed by our methods.

Temporal Variation in Point Count Data

Our assessment of the spatial patterns of birds was directly dependent upon the probability of detecting birds that were present during the sampling period. Detectability can vary with myriad factors, including species, habitat, observer, time of day, and time of season (e.g., Richards 1981; Robbins 1981; Skirvin 1981; Sauer et al. 1994; Nichols et al. 2000). Recording distances to individual birds allows us to model the probability of detecting a bird, given that it has provided an aural or visual cue (Buckland et al. 2001, 2004); these analyses will be presented in subsequent manuscripts. We were also concerned with potential seasonal, diurnal, and interannual variation in production of cues, including singing rates among passerines and breeding display rates among shorebirds. Such variation, if uncorrected for, could result in biased assessment of spatial distribution.

Although the survey period was relatively short each year (<16 days), we tested for seasonal trends in detections for different groups of species to determine if (a) any late-arriving migrants might have been missed early in the survey period or (b) any early-breeding species might have declined in detectability because of changes in behavior as courtship decreased and incubation commenced. We fit a generalized linear regression model to test whether there was a trend relative to survey date in the number of individuals detected per plot, given the number of points surveyed (PROC GENMOD, SAS Institute 2003). Because the count data were not normally distributed and the variance was higher than that expected for a Poisson distribution, we modeled the counts as a negative binomial distribution with a log link function. We used the deviance and Pearson Chi-square to assess goodness of fit of the model and tested strength of the linear relationship with date using the likelihood ratio test statistic (Littell et al. 2002). We examined birds in the following groups: loons and waterfowl; raptors; jaegers and gulls; shorebirds; ptarmigan; ravens and jays; and other passerines excluding redpolls, because of their erratic occurrence in large flocks flying overhead. We assigned the median date on which each plot was surveyed for those (65 of 69) plots that had been surveyed within two to three consecutive days. For the four plots surveyed on two widely disparate sets of dates, we treated each half of the survey as an independent sample and assigned each its own median date. We examined similar generalized linear models to determine whether the total number of species detected per point on each plot was related to survey date.

Table 2. *Status of birds recorded at Cape Krusenstern National Monument, Noatak National Preserve, Kobuk Valley National Park, and Gates of the Arctic National Park and Preserve*

	Status[a]			
Common name[b]	**Cape Krusenstern**	**Noatak**	**Kobuk Valley**	**Gates of the Arctic**
Waterfowl				
Greater White-fronted Goose	m-b*	m-b*		m-b*
Snow Goose	m			
Brant[c]	m	m		
Canada Goose	B	B		B
Tundra Swan	b*	b*		b*
American Wigeon		b*		b*
Mallard	b*	b*		b*
Northern Shoveler		b*		b*
Northern Pintail	b	b		b
Green-winged Teal		b		b
Greater Scaup		b		b
Harlequin Duck				b
Surf Scoter		m-b*		m-b*
White-winged Scoter		m-b*		
Black Scoter[c]		m-b*		
Long-tailed Duck[c]		b*		b*
Bufflehead		m-b*		
Common Merganser		b*	b*	m-b*
Red-breasted Merganser		b*		b*
Grouse and Ptarmigan				
Spruce Grouse[c]			b*	b*
Willow Ptarmigan[c]	B	B	B	B
Rock Ptarmigan[c]	b	B	B	B
Loons				
Red-throated Loon[c]		b*		m-b*
Pacific Loon		m-b*		m-b*
Common Loon		m		m-b*
Yellow-billed Loon[c]	m			
Hawks, Falcons, Cranes				
Northern Harrier	b	b	b	b
Northern Goshawk				b*
Red-tailed Hawk		m-b*		
Rough-legged Hawk[c]	b	b	b	b
Golden Eagle[c]	b	b	b	b
Merlin	b	b	b	b
Gyrfalcon[c]	b	b	b	b
Peregrine Falcon[c]	b		b	b
Sandhill Crane	b	b		
Shorebirds				
Black-bellied Plover		b*		b*
American Golden-Plover[c]	B	B	B	B
Pacific Golden-Plover[c]		b*		
Semipalmated Plover	b*	b	b*	b*
Greater Yellowlegs		b*		
Lesser Yellowlegs		b*		b

Table 2. *(continued)*

Common name[b]	Cape Krusenstern	Noatak	Kobuk Valley	Gates of the Arctic
	Status[a]			
Solitary Sandpiper[c]				b*
Wandering Tattler[c]	b	b	b	b
Spotted Sandpiper			b*	b*
Upland Sandpiper		B		B
Whimbrelc	B	B		b*
Hudsonian Godwit[c]		b*		
Bar-tailed Godwit[c]	B	b		m
Surfbird[c]		b	b	b
Red Knot[c]		b*		?
Semipalmated Sandpiper	b	b*		
Western Sandpiper	b			
Least Sandpiper		b		b
Baird's Sandpiper	b	b	b*	b
Pectoral Sandpiper	b*	m		m-b*
Dunlin[c]	b			
Buff-breasted Sandpiper[c]	m	m		
Long-billed Dowitcher		m		M
Wilson's Snipe	B	B	B	B
Red-necked Phalarope		b		b
Red Phalarope				b
Jaegers, Gulls, and Terns				
Pomarine Jaeger		m		
Parasitic Jaeger	B	B	B	
Long-tailed Jaeger	B	B	B	B
Mew Gull	B	B	B	B
Herring Gull				m
Glaucous Gull	M	M	m	M
Arctic Tern	B	B	B	B
Owls				
Short-eared Owl[c]	b*	b*		b*
Woodpeckers				
Northern Flicker			?	
Flycatchers				
Olive-sided Flycatcher[c]				b
Say's Phoebe	b	b	b	b
Shrikes				
Northern Shrike[c]		b		b
Jays and Ravens				
Gray Jay[c]		B	B	B
Common Raven	B	B	B	B
Larks and Swallows				
Horned Lark	b	b	b	b
Tree Swallow		b*		b*
Violet-green Swallow			b*	b*
Bank Swallow		b*	b*	b*
Chickadees				
Boreal Chickadee[c]		B	B	B

Table 2. *(continued)*

Common name[b]	Cape Krusenstern	Noatak	Kobuk Valley	Gates of the Arctic
	Status[a]			
Kinglets and Thrushes				
Ruby-crowned Kinglet		B	B	B
Arctic Warbler[c]		b		b
Bluethroat	b	b	b	b
Northern Wheatear	b	b	b	b
Townsend's Solitaire				b
Gray-cheeked Thrush[c]	B	B	B	B
Swainson's Thrush			B	B
Hermit Thrush		b*		
American Robin		B	B	B
Varied Thrush[c]		B	B	B
Wagtails, Pipits, Waxwings				
Eastern Yellow Wagtail	b	b	b	b
American Pipit	b	b	b	b
Bohemian Waxwing[c]			b*	b*
Warblers				
Orange-crowned Warbler	b	b	b	b
Yellow Warbler		b	b	b
Yellow-rumped Warbler		b	b	b
Blackpoll Warbler[c]				b*
Northern Waterthrush				b*
Wilson's Warbler	b	b	b	b
Sparrows				
American Tree Sparrow	B	B	B	B
Savannah Sparrow	B	B	B	B
Fox Sparrow	B	B	B	B
White-crowned Sparrow	B	B	B	B
Golden-crowned Sparrow[c]		B	B	B
Dark-eyed Junco		B	B	B
Lapland Longspur[c]	B	B	B	B
Smith's Longspur[c]		b*		b*
Snow Bunting[c]	b	b	b	b
Blackbirds				
Rusty Blackbird[c]			b*	b*
Finches				
Gray-crowned Rosy-Finch	b	b	b	b
Pine Grosbeak[c]			b	b
White-winged Crossbill[c]				b*
Common Redpoll	B	B	B	B
Hoary Redpoll[c]	?	b*	?	b*
Pine Siskin				b*
Totals	**53**	**91**	**57**	**96**

a B = breeding based on observations of nests or nesting behavior; M = probable migrant based on observations of birds in passage. Upper and lower case denote levels of relative abundance or activity with upper case indicative of widespread occurrence or passage. An asterisk denotes probable breeding based on knowledge of species' range in Alaska.

b See Appendix 1 for scientific names. Phylogenetic order follows American Ornithologists' Union Check-list of North American Birds (7th Edition, 1998) and supplements.

c Species of conservation concern (Boreal Partners in Flight Working Group 1999; U.S. Fish and Wildlife Service 2002; Rich et al. 2004; Stenhouse and Senner 2005; Alaska Shorebird Group 2000, unpublished).

We also tested whether either the number of individuals or the number of species detected per point depended on time of day, since some birds exhibit diurnal patterns in singing behavior and courtship displays (e.g., Holmes and Dirks 1978; Farnsworth et al. 2002; Swanson and Nigro 2003). For the same species groups as listed above, we used generalized estimating equations to model the effect of time of day on number of detections per point (PROC GENMOD, SAS Institute 2003). Because the count data were not normally distributed, we used a negative binomial distribution with a log link function to model variance (Littell et al. 2002). To account for possible temporal and spatial correlation among points within plots, we specified the working correlation matrix as independent, exchangeable, or single-order autoregressive to match the empirical data. We assessed strength of the relationship with time of day using the Wald Chi-square statistic (Ballinger 2004). This analysis was restricted to times between 0900 and 2159 ADT, when most (97%) of the points were surveyed.

Because logistical constraints necessitated that we sample different geographic areas of the northern parks each year, any differences in detectability of species due to interannual variation in phenology could have been confounded with geographic area. To assess such potential bias, we compared the rates of cue production across years. Analysis of the number of cues detected within three or more time intervals within a count period allows one to model the probability that a bird produces a cue during the count period and is subsequently detected (Farnsworth et al. 2002). To determine if birds produced cues at different rates among years, we defined 12 groups of species based on similarity of detection cues and length of count period: 10-minute—raptors; shorebirds; jaegers and gulls; ravens and jays; 5-minute—loons and waterfowl; ptarmigan; larks and swallows; finches; thrushes; wagtails and pipits; warblers; sparrows. For each group we calculated the total number of individuals recorded within five 2-minute intervals for 10-minute counts and within three time intervals (0 to 2, 2 to 4, and 4 to 5 minutes) for 5-minute counts. We used a Chi-square test of independence to identify significant interannual differences for each group in the patterns of cues detected across time intervals. Significant differences in temporal detections of singing or flight-displaying birds would suggest that interannual differences in numbers of birds detected might be due to behavior rather than to geographic differences in densities.

Lastly, to determine if our sampling effort was adequate to detect most species over the study area and within ecological sections, we developed species-accumulation curves based on the number of species recorded compared to the cumulative number of points sampled. A curve reaching its asymptote indicated that adequate sampling had occurred, while a curve with increasing slope suggested that additional species would likely have been detected with more sampling.

Summarizing Detections

We summarized information on behavior and sex of birds recorded during point counts by species groups (e.g., proportion of shorebirds that were flying, proportion of passerines that were male). To investigate spatial patterns in occurrence and diversity, we computed plot- , section-, and subsection-level measures of relative abundance (birds per

Table 3. *Conservation status of species recorded at Cape Krusenstern National Monument, Noatak National Preserve, Kobuk Valley National Park, and Gates of the Arctic National Park and Preserve.*

	Species of concern in the region by program[a]				
Common name[b]	**USFWS**	**Audubon**	**ASCP**	**LCPA**	**NALCP**
Brant		C[c]			
Black Scoter		C			
Long-tailed Duck		C			
Spruce Grouse					S
Willow Ptarmigan					S
Rock Ptarmigan					S
Red-throated Loon	C	C			
Yellow-billed Loon	C	C			
Rough-legged Hawk					S
Golden Eagle		C			
Gyrfalcon		C		S	S
Peregrine Falcon	C	C			S
American Golden-Plover	C	C	C		
Pacific Golden-Plover	C	C			
Solitary Sandpiper		C	C		
Wandering Tattler		C			
Whimbrel	C	C	C		
Hudsonian Godwit	C	C	C		
Bar-tailed Godwit	C	C	C		
Surfbird	C	C	C		
Red Knot		C	C		
Dunlin	C	C	C		
Buff-breasted Sandpiper	C	C	C		
Short-eared Owl		C		C	C
Olive-sided Flycatcher		C		C	C
Northern Shrike				S	S
Gray Jay					S
Boreal Chickadee					S
Arctic Warbler	C				
Gray-cheeked Thrush				S	
Varied Thrush				S	
Bohemian Waxwing					S
Blackpoll Warbler	C	C		S	
Golden-crowned Sparrow				S	
Lapland Longspur					S
Smith's Longspur	C	C		C	C
Snow Bunting					S
Rusty Blackbird		C		C	C
Pine Grosbeak					S
White-winged Crossbill				S	S
Hoary Redpoll				S	S

a USFWS = U. S. Fish and Wildlife Service's Birds of Conservation Concern (U.S. Fish and Wildlife Service 2002), Audubon = Audubon Alaska Watchlist (Stenhouse and Senner 2005), ASCP = Alaska Shorebird Conservation Plan (Alaska Shorebird Group 2000, unpublished), LCPA = Landbird Conservation Plan for Alaska (Boreal Partners in Flight Working Group 1999), NALCP = North American Landbird Conservation Plan (Rich et al. 2004).

b See Appendix 1 for scientific names.

c C = species of conservation concern; S = species of stewardship responsibility. Conservation concern is based on measured or suspected declines in a population and/or small size or vulnerability of a population (but see individual programs for specific criteria). Stewardship responsibility is based on a high proportion of a species' global population occurring in the region.

point) and local species richness (species per point) as well as the more general measure of broad species richness (number of species per plot, section, or subsection). Depending on the assessment, we computed these measures for individual species or for all species combined using the following datasets: (1) all birds detected out to an unlimited distance during 10-minute counts, (2) all landbirds and waterbirds detected out to an unlimited distance during 5-minute counts, and (3) all passerines detected within 150 m of survey points during 5-minute counts.

Data from unlimited-distance counts provided the majority of information for inventory purposes (e.g., presence or absence of species, distribution). However, estimates of relative abundance and local species richness from these counts were likely biased by unequal detection probabilities of species across distances and habitats (Burnham 1981; Rostenstock et al. 2002; Thompson 2002). Therefore we used data from fixed-distance counts (i.e., all passerines within 150 m of survey points during 5-minute counts) to further interpret spatial patterns of relative occurrence and diversity (Nur et al. 1999). For some assessments (e.g., behavior summaries), we excluded birds identified as the same individuals on consecutive points. We used Kruskal-Wallis tests to compare broad patterns of species richness (species per plot) among parks.

Rarefaction Curves and Expected Species Richness

We calculated expected species richness [E(S)] for each ecological section using rarefaction, which is a statistical technique that estimates, based on the observed data, the number of species that would be expected to occur in an area with a given level of sampling (James and Rathbun 1981; Gotelli and Colwell 2001). Rarefaction models assume that (1) sampling was adequate to characterize distribution of species, (2) spatial distribution of individuals was random, (3) samples of taxonomically similar organisms were drawn from similar community types, and 4) sampling techniques were standardized (Gotelli and Colwell 2001). We calculated E(S) for each section using EstimateS 7.0 software (Colwell 2004) and considered each point count a sample of species richness (Gotelli and Colwell 2001). We then rescaled the estimates in terms of numbers of individuals rather than number of point sampled (Gotelli and Colwell 2001). We compared estimates of E(S) for all sections at the level of 50 individuals and, where sample size allowed, at levels of 100, 200, and 500 individuals.

Community Similarity

To investigate similarity in assemblages of birds between ecological sections, we used the Morisita-Horn Index, which compares the observed proportions of shared species across sites weighted for abundance, and thus is less sensitive to species richness and sample size than other similarity indices (Magurran 1988; Krebs 1999). The value incorporates both species richness and species evenness (distribution of individuals among species) and ranges from 0 to 1 (no similarity to complete similarity, respectively). The Morisita-Horn Index is calculated as:

$$C_{\mathrm{mH}} = \frac{2\sum(an_i bn_i)}{(da + db)aN \cdot bN}$$

where aN = total number of individuals of all species in section A, an_i = number of individuals in the ith species in section A, and

$$da = \frac{\sum an_i^2}{aN^{\ 2}}$$

To facilitate comparison of similarity (or, conversely, distinctness) of assemblages across sections, we created matrices based on the Morisita-Horn Index.

Species Dominance and Evenness

To assess species dominance within each ecological section, we calculated the fraction of each sample (i.e., birds per section) that was represented by the most common species. Measured this way, dominance is sensitive to sample size, e.g., if only one individual was detected in the sample, the dominance value would be 1.00.

Species evenness is a measure of the relative abundance of species within an assemblage. To assess species evenness within each ecological section, we used Hurlbert's Index of Evenness (Hurlbert 1971), which calculates the probability of an interspecific encounter (PIE), or the probability that two randomly sampled individuals from an area represent two different species. This index is unbiased by sample size, although the variance increases at small sample sizes (Magurran 1988). Values range from 0 to 1 and approach 0 as a particular species in the assemblage becomes numerically dominant. PIE is calculated as:

$$PIE = \left(\frac{N}{N-1}\right)\left(1-\sum p_i^2\right)$$

where $N =$ total number of species in the sample and $p_i =$ the proportion of species i within the assemblage.

Species Diversity

We calculated bird species diversity (a measure that incorporates both richness and evenness) for each ecological section using the Shannon Index ($H^{'}$), which is calculated as:

$$H^{'} = -\sum_{i-1}^{s} p_i \,\mathrm{h}\; p_i$$

where $s =$ total number of species, $p_i =$ proportion of species i in the assemblage, and h = the natural logarithm. For most bird communities, the Shannon Index typically ranges between 1.5 and 3.5 (Magurran 1988); diversity and evenness increase with higher values of $H^{'}$. However, interpretation of $H^{'}$ is not straightforward because the value is related to both the number of species and to their relative abundance. Thus, different values of $H^{'}$ between sections can indicate differences in species richness, species evenness, or both.

Habitat Associations

Distribution of Habitats

We used the measurements of percent cover of vegetation cover types within a circle of 150-m radius centered on each of the 1,652 survey points to describe habitat composition of the study area. Cover types were based on a modified Viereck et al. (1992) vegetation classification system and standard protocols (see Classification of Vegetation Cover Types, above). Most of the 97 cover types recorded were encountered infrequently (93% occurred on <10% of points) while a few (e.g., *Dryas* Dwarf Scrub, Mesic Graminoid Herbaceous) dominated the landscape. To allow for meaningful comparisons, we consolidated cover types into seven broad categories (hereafter habitats) based on structural and floristic characteristics (Appendix 7). Habitats were defined as (1) Ephemeral (snow and ice), (2) Forest (Viereck I forest and Viereck II dwarf tree scrub types), (3) Tall Shrub (Viereck II tall scrub types), (4) Low Shrub (Viereck II low scrub types and our scrub emerging from snow type), (5) Herbaceous (Viereck II graminoid and forb types, except those with tussocks as dominant structure), (6) Herbaceous-Tussock (Viereck II graminoid and forb types with tussocks as the dominant structure), and (7) Sparsely Vegetated (Viereck II dwarf scrub and bryoid herbaceous and our rock types). Photographs depicting the habitat cover types are presented in Appendix 8. We did not include Ephemeral in the subsequent assessments because we felt that snow and ice cover were primarily artifacts of the sampling period and not reliable predictors of habitat use by birds.

For each ecological section and the entire study area, we calculated the percent occurrence of each habitat as the number of points at which a particular habitat occurred divided by the total number of points in the area. We also computed the median and quartiles of the elevation and of the percent cover of each habitat across all points in each section and over the study area.

Bird–Habitat Associations

We examined the occurrence of species at survey points relative to the elevation and habitat cover within 150 m of the point. For each species, we calculated the median and quartile values of elevation and habitat cover for all points at which it was detected; we then qualitatively compared these values with the corresponding values for all points sampled across the study area (e.g., Northern Harriers occurred at points with higher percent cover of Herbaceous-Tussock habitat than points sampled across the study area; >75% of all detections of Surfbirds were above 700 m) to identify potential patterns of habitat selection or avoidance.

For these assessments we included species of landbirds that had been detected ≥5 times within 150 m of a survey point. We also included all species of shorebirds or potential avian predators that had been detected ≥5 times within 500 m. Because many of the latter were detected beyond the 150-m radius in which habitat data had been collected, we were less certain of the assessments of habitat associations for these species. To address this uncertainty, we recorded the specific elevation and habitat within the area immediately surrounding as many birds as possible that were standing or in flight display 150 to

500 m from the point. We then assessed the concordance between these values and the elevation and habitats within 150 m of these points; in 171 of 188 cases (91%) where habitat association of a distant bird (150 to 500 m from points) was recorded opportunistically, the corresponding point contained this habitat. Similarly, the elevation for 66 of 88 cases (74%) of distant birds fell within 20 m of the corresponding point's elevation. We felt that such strong concordance justified the inclusion of distant birds in these assessments (i.e., shorebird and avian predator-habitat associations).

Data from Bering Land Bridge National Preserve

For comparison with our inventory of the northern parks, we include survey data collected in and adjacent to Bering Land Bridge in 1988, 1989, 1991, and 2000. In conjunction with a broader study of the Bristle-thighed Curlew, we conducted 11 to 39 point counts in each of six montane areas in and adjacent to the park in plots approximately 10 km x 10 km in size (townships were the sample unit; Appendix 10). During each 10-minute point count we recorded all shorebirds and potential avian predators out to an unlimited distance and documented the presence of all other species of birds detected during the count. We also recorded weather data, habitat cover within 150 m of each survey point, and the behavior of each shorebird and potential avian predator detected. We sampled several additional montane areas with spot-checks, which were brief (one to six hour) searches on foot in prime breeding habitat of the Bristle-thighed Curlew. During spot-checks, observers recorded the presence of all shorebirds detected and, if the situation permitted, all other species.

RESULTS

Inventory

Effort

Between 2001 and 2003, birds were sampled over 67,800 km^2 of montane habitat within the parklands, which represented between 51 and 100% of the areal extent of each of the four parks (Table 1). We visited 69 of the 73 (95%) plots allocated through the sampling design, including 5 plots in Cape Krusenstern, 9 in Kobuk Valley, 21 in Gates of the Arctic, and 34 in Noatak (Fig. 6, Appendices 4 to 6). In terms of landscape features, we sampled all 14 of the ecological section level strata and 75 of 104 subsection strata (Table 1).

By design, taking into account expected patterns of avian diversity, Cape Krusenstern, Noatak, and Kobuk Valley were sampled in slightly higher proportions relative to their area and Gates of the Arctic was sampled in a relatively lower proportion (Fig. 10a). This pattern was also apparent at the level of ecological section (Fig. 10b).

Annually, we sampled between 20 and 27 plots (Fig. 6), with each crew sampling five to seven plots per year during a 1.5 to 2.5 day visit at each plot. Crews comprised 9 observers in 2001, 8 in 2002, and 10 in 2003, representing 18 different individuals over the three-year effort (but only 8 different primary observers). Over this period we conducted 1,651 10-minute point counts and 1,647 5-minute counts, encompassing 275 hours and 137 hours, respectively, of survey time.

Timing and Conditions

In 2001, we conducted surveys from 1 to 11 June, in 2002 from 30 May to 9 June, and in 2003 from 26 May to 10 June. The chronology of spring breakup was slightly ahead of normal (see Methods) over inland areas of Cape Krusenstern, Kobuk Valley, and western Noatak in 2001 and 2002, but slightly delayed in eastern Noatak and throughout Gates of the Arctic in 2003. Snow cover in 2001 and 2002 decreased from about 15 to 25% on most plots during the first week of June to <5% the following week. In 2003, we encountered considerably more snow at the start of the survey period (45 to 90%) than in previous years and experienced slower rates of snow melt, with snow cover still at 20 to 70% into the second week of June.

Air temperatures were typical for this time of year with daily minimum temperatures remaining above freezing on plots after 31 May in 2001 and 2002, and 4 June in 2003. Mean daily minimum and maximum temperatures of 2.4°C (range 0 to 6) and 15.1°C (range 11 to 21), respectively, were recorded at the village of Noatak (Fig. 5) in 2001 (http://fire.ak.blm.gov). In 2002, mean daily minimum and maximum temperatures of 4.8°C (range –2 to 13) and 15.7°C (range 8 to 22), respectively, were recorded at the village of Ambler (Fig. 5), while in 2003 mean daily minimum and maximum temperatures of 2.2°C (range –1.1 to 6.1) and 12.7°C (range 4 to 18°), respectively, were recorded at the village of Anaktuvuk Pass.

The Montane-nesting Bird Community

Number of Species

During the study we detected a total of 115 species of birds, including 53 in Cape Krusenstern, 91 in Noatak, 57 in Kobuk Valley, and 96 in Gates of the Arctic (Table 2). Among these were 46 species of landbirds (grouse, ptarmigan, woodpeckers, flycatchers, larks, swallows, chickadees, kinglets, thrushes, wagtails, pipits, waxwings, warblers, sparrows, blackbirds, and finches), 26 species of shorebirds, 19 species of potential avian predators (hawks, falcons, eagles, cranes, jaegers, gulls, owls, shrikes, jays, and ravens), and 24 species of waterbirds (waterfowl, loons, and terns). We determined that at least 106 of the 115 species (92%) were breeding in the study area, based on behavior of individuals and presence of nests or young (Table 2). Eight species (e.g., Snow Goose, Buff-breasted Sandpiper) appeared to be transients through the area presumably while en route to breeding areas to the north and east. The status of one species (Northern Flicker) was not determined.

The average number of species recorded on individual plots did not differ significantly among the four parks ($\chi^2 = 5.9$, $P = 0.12$), with the highest recorded on Cape Krusenstern (30.4 ± 2.19 SD; range = 28 to 32; $n = 5$), followed by Gates of the Arctic (25.8 ± 9.1 SD; range 15 to 50; $n = 21$), Noatak (25.6 ± 5.2 SD; range = 14 to 35; $n = 34$), and Kobuk Valley (25.4 ± 3.5 SD; range = 19 to 30; $n = 9$).

Distribution

Individual species varied markedly in the number of plots on which they were detected (Table 4), ranging from Redpoll spp. that were recorded on a high of 68 (99%) plots to 19 species (e.g., Snow Goose, Bufflehead) that were recorded on a single plot (<1%). Among shorebirds, only two species (Wilson's Snipe and American Golden Plover) were widely distributed, occurring on ≥34 plots (≥50%); four species (Whimbrel, Wandering Tattler, Surfbird, and Baird's Sandpiper) were moderately widespread, occurring on 17 to 33 plots (25% to 50%; Table 4. See also Species of Concern, below). The remaining 18 species had more restricted distributions and were detected on ≤16 plots (≤25%). Among potential avian predators (identified by superscripts in Table 4), only two species (Common Raven and Long-tailed Jaeger) were widely distributed, while another six species were moderately widespread. Eleven species had restricted distributions.

Among passerines, several species ($n = 12$) were widely distributed (Redpoll spp., White-crowned Sparrow, American Pipit, Savannah Sparrow, American Tree Sparrow, Horned Lark, American Robin, Northern Wheatear, Fox Sparrow, Lapland Longspur, Golden-crowned Sparrow, and Gray-cheeked Thrush; Table 4). Fewer species ($n = 5$) were moderately widespread (Wilson's Warbler, Bluethroat, Orange-crowned Warbler, Say's Phoebe, Gray-crowned Rosy-Finch), while most ($n = 19$) had restricted distributions (e.g., Yellow-rumped Warbler, Varied Thrush, Eastern Yellow Wagtail). Waterfowl occurred sporadically among the plots with the majority of species (23 of 24) detected on <15 plots (Table 4); Northern Pintail, the exception to the pattern, were moderately widespread (24 plots). Rock Ptarmigan were ubiquitous (49 plots) whereas Willow Ptarmigan were moderately widespread (29 plots).

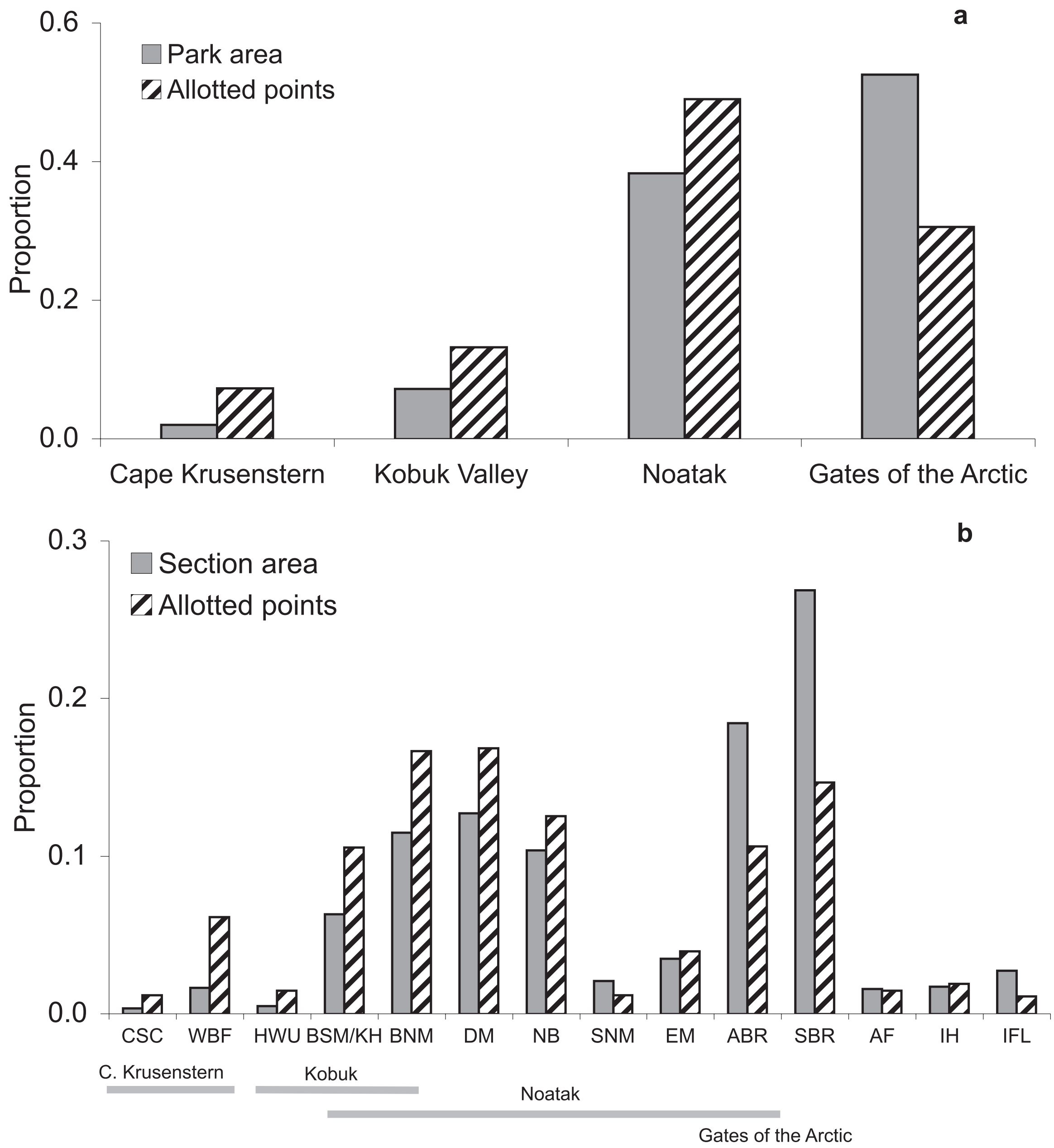

Fig. *10. Allotment of survey points (n = 1,652) relative to (a) park size and (b) area of ecological sections within parks during the inventory of montane-nesting birds, Arctic Network, Alaska, 2001–2003. Section acronyms: ABR = Arctic Brooks Range, AF = Arctic Foothills, BNM = Baird Northern Mtns., BSM/KH = Baird Southern Mtns. and Kiana Hills, CSC = Chukchi Sea Coastal Plain, DM = De Long Mtns., EM = Endicott Mtns., HWU = Hockley-Waring Uplands, IFL = Interior Forested Lowlands, IH = Interior Highlands, NB = Noatak Basin, SNM = Schwatka Northern Mtns., SBR = Subarctic Brooks Range, WBF = Western Brooks Foothills.*

Breeding ranges of the majority of species were expanded considerably by this inventory based on comparisons with information from previous surveys in the region (e.g., Irving 1960; Dean and Chesmore 1974). In Appendix 11 we present maps of the occurrence of species among plots; not included are maps for 20 species that were encountered on too few plots (<3) to establish a meaningful distribution (unless they were species of concern). That said, even the sporadic occurrence of some species provided insight into their status in the parks (Table 2). It is also important to note that species usually associated with lowlands and wetlands (e.g., waterfowl) were likely more abundant and more widely distributed than is apparent from viewing their maps of occurrence because the maps depict plots in montane areas only.

Percent of Expected Species

We documented 115 (78%) of the 147 species we had expected to encounter in montane areas of the four northern parks of the Arctic Network (Table 2, Appendix 12). Species that were missed included those whose periods of courtship display preceded (owls) or followed (Alder Flycatcher) our presence or those that are infrequent migrants (Appendix 12). Based on the NPS list of expected species, we recorded two species (Pacific Golden-Plover and Pine Siskin) that were not expected to occur in the Arctic Network (http://science.nature.nps.gov/im/apps/npspp/index.htm). Our observations also allowed us to reclassify (at the park level) several species from the "expected" to the "documented" category. These included Buff-breasted Sandpiper in Cape Krusenstern; Common Merganser, Red-tailed Hawk, Pacific Golden-Plover, and Greater Yellowlegs in Noatak; Common Merganser, Violet-green Swallow, and Bluethroat in Kobuk Valley; and Bar-tailed Godwit, Surfbird, Red Knot, Bluethroat, and Pine Siskin in Gates of the Arctic.

Species of Concern

Over a third of the species (41 of 115) detected on the inventory appear on state or national lists of birds of conservation and stewardship concern (Tables 2 and 3). Various lines of evidence (e.g., behavior, nests, young birds) indicated that 38 of these species nested in the Arctic Network (Table 2). (One other species of concern, Bristle-thighed Curlew, was found nesting in Bering Land Bridge and another species, Arctic Tern, is considered a species of concern in that park only.) Among the four northern parks, the proportion of species of concern ranged from 18% to 26% of the recorded avifauna, and the proportion of stewardship species ranged between 8% and 18% (Tables 2 and 3). Five species (Rock Ptarmigan, American Golden-Plover, Gray-cheeked Thrush, Golden-crowned Sparrow, and Lapland Longspur) were widely distributed, occurring on over 50% of the 69 plots sampled; four others (Rough-legged Hawk, Wandering Tattler, Whimbrel, and Surfbird) occurred on a third or more of the plots (Table 4, Appendix 11). However, over half the species of concern were restricted in distribution to fewer than 10% of the plots, with observations often involving single birds (Tables 4 and 5). One notable exception was the Bar-tailed Godwit (Table 5), which was recorded in numbers on all five plots in Cape Krusenstern (Table 5, Appendix 11).

Table 4. *Number of plots on which a species was recorded during the inventory of montane-nesting birds in the Arctic Network, Alaska, late May–early June 2001–2003.*

Common name[a]	Number of plots[b]	Map number[c]	Common name	Number of plots	Map number
Greater White-fronted Goose	12	1	Semipalmated Plover	10	29
Snow Goose	1		Greater Yellowlegs	1	
Brant[d]	2	2	Lesser Yellowlegs	7	30
Canada Goose	13	3	Solitary Sandpiper[d]	3	31
Tundra Swan	7	4	Wandering Tattler[d]	33	32
American Wigeon	4	5	Spotted Sandpiper	3	
Mallard	4	6	Upland Sandpiper	13	33
Northern Shoveler	1		Whimbrel[d]	29	34
Northern Pintail	24	7	Hudsonian Godwit[d]	2	35
Green-winged Teal	8	8	Bar-tailed Godwit[d]	7	36
Greater Scaup	15	9	Surfbird[d]	20	37
Harlequin Duck	1		Red Knot[d]	2	38
Surf Scoter	2		Semipalmated Sandpiper	7	39
White-winged Scoter	1		Western Sandpiper	2	
Black Scoter[d]	1	10	Least Sandpiper	11	40
Long-tailed Duck[d]	14	11	Baird's Sandpiper	19	41
Bufflehead	1		Pectoral Sandpiper	11	42
Common Merganser	5	12	Dunlin[d]	1	43
Red-breasted Merganser	4	13	Buff-breasted Sandpiper[d]	2	44
			Long-billed Dowitcher	7	45
Spruce Grouse[d]	2	14	Wilson's Snipe	57	46
Willow Ptarmigan[d]	29	15	Red-necked Phalarope	8	47
Rock Ptarmigan[d]	49	16	Red Phalarope	1	
Red-throated Loon[d]	2	17	Pomarine Jaeger[e]	2	
Pacific Loon	4	18	Parasitic Jaeger[e]	15	48
Common Loon	2		Long-tailed Jaeger[e]	44	49
Yellow-billed Loon[d]	1	19	Mew Gull[e]	31	50
			Herring Gull[e]	1	
Northern Harrier[e]	21	20	Glaucous Gull[e]	22	51
Northern Goshawk[e]	1		Arctic Tern	10	52
Red-tailed Hawk[e]	1				
Rough-legged Hawk[d, e]	22	21	Short-eared Owl[d, e]	12	53
Golden Eagle[d, e]	29	22			
Merlin[e]	18	23	Northern Flicker	1	
Gyrfalcon[d, e]	8	24			

Table 4. *(continued)*

Common name[a]	Number of plots[b]	Map number[c]	Common name	Number of plots	Map number
Peregrine Falcon[d, e]	4	25	Olive-sided Flycatcher[d]	3	54
Sandhill Crane[e]	6	26	Say's Phoebe	20	55
Black-bellied Plover	3		Northern Shrike[d, e]	5	56
American Golden-Plover[d]	53	27			
Pacific Golden-Plover[d]	1	28	Gray Jay[d, e]	13	57
			Common Raven[e]	62	58
Horned Lark	56	59	Orange-crowned Warbler	25	75
Tree Swallow	5	60	Yellow Warbler	14	76
Violet-green Swallow	4	61	Yellow-rumped Warbler	16	77
Bank Swallow	4	62	Blackpoll Warbler[d]	1	78
			Northern Waterthrush	4	79
Boreal Chickadee[d]	4	63	Wilson's Warbler	33	80
Ruby-crowned Kinglet	9	64	American Tree Sparrow	60	81
Arctic Warbler[d]	2	65	Savannah Sparrow	62	82
Bluethroat	32	66	Fox Sparrow	42	83
Northern Wheatear	42	67	White-crowned Sparrow	63	84
Townsend's Solitaire	1		Golden-crowned Sparrow[d]	40	85
Gray-cheeked Thrush[d]	39	68	Dark-eyed Junco	14	86
Swainson's Thrush	7	69	Lapland Longspur[d]	41	87
Hermit Thrush	1		Smith's Longspur[d]	6	88
American Robin	56	70	Snow Bunting[d]	12	89
Varied Thrush[d]	15	71			
			Rusty Blackbird[d]	3	90
Eastern Yellow Wagtail	15	72			
American Pipit	62	73	Gray-crowned Rosy-Finch	20	91
Bohemian Waxwing[d]	6	74	Pine Grosbeak[d]	4	92
			White-winged Crossbill[d]	4	93
			Redpoll spp.[d, f]	68	94
			Pine Siskin	1	

a See Appendix 1 for scientific names.

b Total plots sampled = 69.

c Map number corresponds to distribution map in Appendix 11.

d Species of conservation concern (Boreal Partners in Flight Working Group 1999; U.S. Fish and Wildlife Service 2002; Rich et al. 2004; Stenhouse and Senner 2005; Alaska Shorebird Group 2000, unpublished). Within the Redpoll spp. group, only Hoary Redpoll is a species of concern.

e Species considered to be a potential predator of adult birds, chicks, or eggs.

f Common Redpoll and Hoary Redpoll not distinguished in this summary.

Birds of Bering Land Bridge National Preserve

A total of 53 species were detected in or adjacent to Bering Land Bridge during previous surveys of montane-nesting birds in that region, including 20 species of conservation concern (Appendix 13). All except Brant likely breed in montane areas of the park. Forty-nine of the 53 species found in Bering Land Bridge were also found during the inventory of the four northern parks (Table 2, Appendix 13). Four species (Bristle-thighed Curlew, Rock Sandpiper, Cliff Swallow, and Lincoln's Sparrow) were recorded only at Bering Land Bridge.

Detections During Point Counts

Time of Season and Time of Day Effects

Point counts were conducted over 11 days in 2001 and 2002 and over 16 days in 2003. Three groups of species showed a significant increase in number of birds detected per point as a function of date (Fig. 11). The rate of increase was gradual for jaegers and gulls ($\chi^2_1 = 10.51$, $P = 0.001$) and for raptors ($\chi^2_1 = 4.06$, $P = 0.04$), whereas the rate of detection for loons and waterfowl increased abruptly during the last few days of the survey period ($\chi^2_1 = 13.26$, $P < 0.001$). Loons and waterfowl showed a concomitant seasonal increase in the number of species detected per point ($\chi^2_1 = 9.72$, $P = 0.002$; Fig. 11).

Almost all point counts (97%) were conducted between 0900 and 2200 hours ADT because of logistical constraints. Within this time frame, passerines were the only group to show a significant diurnal trend in detection rates (Fig. 12). Both number of individuals ($\chi^2_1 = 5.48$, $P = 0.02$) and number of species ($\chi^2_1 = 5.20$, $P = 0.02$) detected per point declined slightly during this daytime period. The few point counts done during other hours suggested that detection rates of both individuals and species peaked between 0300 and 0800 h and reached a nadir just after midnight (Fig. 12).

Detectability Across Years

For 10 of 12 species groups, the proportion of individuals detected in different time intervals during the count period did not vary among years, suggesting no interannual difference in detectability. These groups included shorebirds, jaegers and gulls, and jays and ravens detected during 10-minute counts ($\chi^2_8 = 4.33$ to 7.98, $P > 0.01$) and waterfowl, ptarmigan, and all other passerines except finches detected during 5-minute counts ($\chi^2_4 = 1.66$ to 6.56, $P > 0.1$). Temporal patterns of detections within count periods varied significantly among years for two groups: raptors ($\chi^2_8 = 16.59$, $P = 0.035$) and finches ($\chi^2_4 = 13.55$, $P = 0.009$). Most detections of both groups were visual observations of birds flying overhead. Thus, interannual differences were not related to variation in production of cues (courtship displays or songs). We concluded such differences were more likely attributable to random movements (especially of large flocks of redpolls) and not likely to be confounded with geographical patterns of distribution.

Table 5. *Detection of birds on 10-minute and subsequent 5-minute point counts during the inventory of montane-nesting birds in the Arctic Network, Alaska, late May–early June 2001–2003. Values in red indicate a species comprised >5% of all birds detected or occurred on >5% of all points surveyed.*

	10-minute counts			5-minute counts		
		Proportion among			Proportion among	
Common name[a]	Total birds detected	All birds detected (*n* = 9,225)	All points surveyed (*n* = 1,651)	Total birds detected	All birds detected (*n* = 5,992)	All points surveyed (*n* = 1,647)
Greater White-fronted Goose	42	0.005	0.008	15	0.003	0.002
Brant[b]	89	0.001	0.001	0		
Canada Goose	50	0.005	0.012	42	0.007	0.009
Goose spp.	60	0.007	0.001	55	0.009	0.001
Tundra Swan	9	0.000	0.003	7	0.001	0.002
American Wigeon	6	0.001	0.002	2	0.000	0.001
Mallard	2	0.000	0.001	0		
Northern Pintail	61	0.007	0.014	42	0.007	0.001
Green-winged Teal	12	0.001	0.003	6	0.001	0.002
Greater Scaup	95	0.010	0.012	60	0.010	0.009
Scaup spp.	34	0.004	0.002	57	0.001	0.002
Harlequin Duck	0			1	0.000	0.001
Surf Scoter	4	0.000	0.001	2	0.000	0.001
White-winged Scoter	15	0.002	0.001	15	0.003	0.001
Black Scoter[b]	2	0.000	0.001	2	0.000	0.001
Scoter spp.	0			12	0.002	0.001
Long-tailed Duck[b]	83	0.009	0.022	84	0.014	0.020
Common Merganser	6	0.001	0.002	3	0.001	0.001
Red-breasted Merganser	8	0.001	0.002	3	0.001	0.001
Duck spp.	34	0.004	0.004	69	0.012	0.005
Willow Ptarmigan[b]	222[c]	0.024	0.093	321	0.054	0.081
Rock Ptarmigan[b]	177[c]	0.019	0.086	187	0.031	0.079
Ptarmigan spp.	5	0.001	0.002	6	0.001	0.003
Red-throated Loon[b]	2	0.000	0.001	2	0.000	0.001
Pacific Loon	6	0.001	0.002	5	0.001	0.002
Common Loon	4	0.000	0.001	2	0.000	0.001
Yellow-billed Loon[b]	3	0.000	0.001	0		
Loon spp.	3	0.000	0.001	0		
Northern Harrier[d]	22	0.002	0.013		nc[e]	
Rough-legged Hawk[b, d]	22	0.002	0.013		nc	
Golden Eagle[b, d]	24	0.003	0.013		nc	
Eagle spp.[d]	1	0.000	0.001		nc	
Merlin[d]	8	0.001	0.004		nc	
Gyrfalcon[b, d]	3	0.000	0.002		nc	

Table 5. *(continued)*

	10-minute counts			5-minute counts		
		Proportion among			Proportion among	
Common name[a]	Total birds detected	All birds detected (n = 9,225)	All points surveyed (n = 1,651)	Total birds detected	All birds detected (n = 5,992)	All points surveyed (n = 1,647)
Peregrine Falcon[b, d]	3	0.000	0.002		nc	
Falcon spp.[d]	1	0.000	0.001		nc	
Raptor spp.[d]	5	0.001	0.003		nc	
Sandhill Crane[d]	7	0.001	0.003		nc	
American Golden-Plover[b]	362	0.039	0.138		nc	
Pacific Golden-Plover[b]	1	0.000	0.001		nc	
Golden-Plover spp.	3	0.000	0.002		nc	
Semipalmated Plover	14	0.002	0.007		nc	
Greater Yellowlegs	1	0.000	0.001		nc	
Lesser Yellowlegs	34	0.004	0.010		nc	
Wandering Tattler[b]	58	0.006	0.031		nc	
Spotted Sandpiper	1	0.000	0.001		nc	
Upland Sandpiper	13	0.001	0.006		nc	
Whimbrel[b]	286	0.031	0.099		nc	
Hudsonian Godwit[b]	1	0.000	0.001		nc	
Bar-tailed Godwit[b]	38	0.004	0.017		nc	
Surfbird[b]	28	0.003	0.011		nc	
Semipalmated Sandpiper	25	0.003	0.009		nc	
Western Sandpiper	9	0.000	0.003		nc	
Least Sandpiper	18	0.002	0.008		nc	
Baird's Sandpiper	33	0.004	0.015		nc	
Pectoral Sandpiper	28	0.003	0.008		nc	
Buff-breasted Sandpiper[b]	9	0.000	0.001		nc	
Long-billed Dowitcher	24	0.003	0.004		nc	
Wilson's Snipe	340	0.037	0.162		nc	
Red-necked Phalarope	22	0.002	0.004		nc	
Red Phalarope	9	0.000	0.001		nc	
Small shorebird spp.	24	0.003	0.007		nc	
Shorebird spp.	19	0.002	0.006		nc	
Pomarine Jaeger[d]	4	0.000	0.001		nc	
Parasitic Jaeger[d]	30	0.003	0.014		nc	
Long-tailed Jaeger[d]	463	0.050	0.131		nc	
Jaeger spp.[d]	8	0.001	0.004		nc	
Mew Gull[d]	69	0.007	0.025		nc	
Glaucous Gull[d]	52	0.006	0.018		nc	
Gull spp.[d]	7	0.001	0.003		nc	
Arctic Tern	25	0.003	0.008	21	0.004	0.007
Short-eared Owl[b, d]	6	0.001	0.004		nc	

Table 5. *(continued)*

	10-minute counts			5-minute counts		
		Proportion among			Proportion among	
Common name[a]	Total birds detected	All birds detected (n = 9,225)	All points surveyed (n = 1,651)	Total birds detected	All birds detected (n = 5,992)	All points surveyed (n = 1,647)
Northern Flicker	0			1	0.000	0.001
Olive-sided Flycatcher[b]	10	0.001	0.006	9	0.002	0.005
Say's Phoebe	14	0.002	0.008	9	0.002	0.005
Flycatcher spp.	0			1	0.000	0.001
Northern Shrike[b, d]	5	0.001	0.002		nc	
Gray Jay[b, d]	23	0.002	0.001		nc	
Jay spp.[d]	1	0.000	0.001		nc	
Common Raven[d]	190	0.021	0.075		nc	
Horned Lark	200	0.022	0.095	138	0.023	0.070
Tree Swallow	2	0.000	0.001	0		
Violet-green Swallow	10	0.001	0.002	19	0.003	0.003
Bank Swallow	10	0.001	0.002	5	0.001	0.001
Swallow spp.	0			1	0.000	0.001
Boreal Chickadee[b]	3	0.000	0.001	1	0.000	0.001
Chickadee spp.	2	0.000	0.001	1	0.000	0.001
Ruby-crowned Kinglet	50	0.005	0.022	38	0.006	0.019
Arctic Warbler[b]	2	0.000	0.001	2	0.000	0.001
Bluethroat	91	0.001	0.049	89	0.015	0.047
Northern Wheatear	80	0.009	0.042	58	0.001	0.031
Townsend's Solitaire	0			1	0.000	0.001
Gray-cheeked Thrush[b]	166	0.018	0.084	122	0.020	0.063
Swainson's Thrush	41	0.004	0.018	41	0.007	0.017
American Robin	416	0.045	0.197	351	0.059	0.167
Varied Thrush[b]	99	0.011	0.044	96	0.016	0.041
Eastern Yellow Wagtail	22	0.002	0.010	19	0.003	0.001
American Pipit	438	0.047	0.185	306	0.051	0.137
Bohemian Waxwing[b]	39	0.004	0.005	10	0.002	0.002
Orange-crowned Warbler	56	0.006	0.028	51	0.009	0.029
Yellow Warbler	17	0.002	0.007	15	0.003	0.008
Yellow-rumped Warbler	63	0.007	0.029	44	0.007	0.022
Northern Waterthrush	6	0.001	0.002	5	0.001	0.002

Table 5. *(continued)*

	10-minute counts			5-minute counts		
		Proportion among			Proportion among	
Common name[a]	Total birds detected	All birds detected (n = 9,225)	All points surveyed (n = 1,651)	Total birds detected	All birds detected (n = 5,992)	All points surveyed (n = 1,647)
Wilson's Warbler	79	0.009	0.040	71	0.012	0.038
Warbler spp.	1	0.000	0.001	1	0.000	0.001
American Tree Sparrow	660	0.072	0.241	643	0.107	0.236
Savannah Sparrow	661	0.072	0.279	620	0.103	0.257
Fox Sparrow	219	0.024	0.099	201	0.034	0.093
White-crowned Sparrow	404	0.044	0.185	359	0.060	0.164
Golden-crowned Sparrow[b]	325	0.035	0.134	311	0.052	0.126
Dark-eyed Junco	34	0.004	0.018	31	0.005	0.015
Lapland Longspur[b]	573	0.062	0.188	645	0.108	0.183
Smith's Longspur[b]	5	0.001	0.003	3	0.001	0.002
Snow Bunting[b]	25	0.003	0.008	17	0.003	0.008
Sparrow spp.	25	0.003	0.013	30	0.005	0.015
Rusty Blackbird[b]	1	0.000	0.001	2	0.000	0.001
Gray-crowned Rosy-Finch	24	0.003	0.010	26	0.004	0.011
Pine Grosbeak[b]	4	0.000	0.002	1	0.000	0.001
White-winged Crossbill[b]	13	0.001	0.001	1	0.000	0.001
Redpoll spp.[b, f]	883	0.096	0.279	535	0.089	0.208
Pine Siskin	2	0.000	0.001	1	0.000	0.001
Passerine spp.	37	0.004	0.008	40	0.007	0.021
No birds detected			0.074			0.143

a See Appendix 1 for scientific names.

b Species of conservation concern (Boreal Partners in Flight Working Group 1999; U.S. Fish and Wildlife Service 2002; Rich et al. 2004; Stenhouse and Senner 2005; Alaska Shorebird Group 2000, unpublished). Within the Redpoll spp. group, only Hoary Redpoll is a species of concern.

c At a few plots in 2001, only presence/absence of ptarmigan (vs. number of birds) was recorded during 10-minute counts; thus values represent minimum number of ptarmigan on counts.

d Species considered to be a potential predator of adult birds, chicks, or eggs.

e nc = this species not censused during 5-minute point counts.

f Common Redpoll and Hoary Redpoll not distinguished in this summary.

Gender and Behavior of Birds Detected

Because the inventory was timed to coincide with the early nesting period and females of most species are generally more secretive than males at this time, we expected higher rates of detection for males than females. Indeed, most individuals detected during point counts were males engaged in courtship behaviors. Among 1,191 individual shorebirds detected, we classified 42% as male (502 individuals) and 5% as female (63) based on behavior and plumage; 53% (626) were not or could not be sexed. Among 4,836 individual passerines, 75% could be classified as male (based primarily on aural detections of song) and 1% as female (by plumage); sex could not be assigned to 24%. We rarely ascertained the sex of jaegers, gulls, or raptors. About half (44%) of the waterfowl detected (224 individuals) were in pairs or mixed-sex flocks; among single birds 16% were male and 4% were female. Of the 493 individual ptarmigan detected, 90% were male and 1% were female; sex of the remaining birds was not determined.

Among the shorebirds for which we were able to determine behavior (77% of 1,191 individuals) most were involved in courtship displays (41%); considerably fewer were standing/preening/sleeping (20%), walking/feeding (19%), or flying (20%). We were able to assign behavior to an even higher proportion (91% of 4,836 individuals) of passerines, of which most were perched and courting (56%), followed by ones seen performing aerial courtship displays (14%) or flying/walking (12%). Most raptors with known behavior (91% of 82 individuals) were flying (68%) or standing/preening/sleeping (20%) while most waterfowl (87% of 108 individuals) were observed swimming (76%). Jaegers and gulls were mostly detected in flight (64%), usually when low along the ground or along rivers, while ptarmigan were mostly (62%) seen perched, particularly males, on shrubs or rock outcroppings.

Almost all birds detected (97% and 95% on 10-minute and 5-minute counts, respectively) were identified to species (or to genus, in the case of redpolls; Table 5). The majority of detections were of single birds (65% and 90% on 10-minute and 5-minute counts, respectively). Average flock size was small (2.7 ± 0.56 SE; range = 2 to 45; n = 1,959 flocks on 10-minute counts) with the larger flocks comprised mostly of waterfowl or redpolls. Most birds were detected within the first few minutes of a count. For example, 65% of all detections of shorebirds and potential avian predators occurred during the first 5 minute of 10-minute counts, and 75% of all detections of landbirds and waterbirds occurred during the first 3 minute of 5-minute counts.

Detections of the same individual on multiple points appeared to be a function of the size and behavior of the bird. Species with the highest rates of multiple detection (5 to 19% of individuals detected >1 time) were large (e.g., Glaucous Gull, Rough-legged Hawk), patrolled large home ranges (e.g., Common Raven, Long-tailed Jaeger), and/or had loud courtship displays (e.g., Wilson's Snipe, Whimbrel). In contrast, individuals of species that were small and/or had relatively small home ranges (e.g., Red-necked Phalarope, most passerines) were seldom (≤4% of individuals) detected on multiple points.

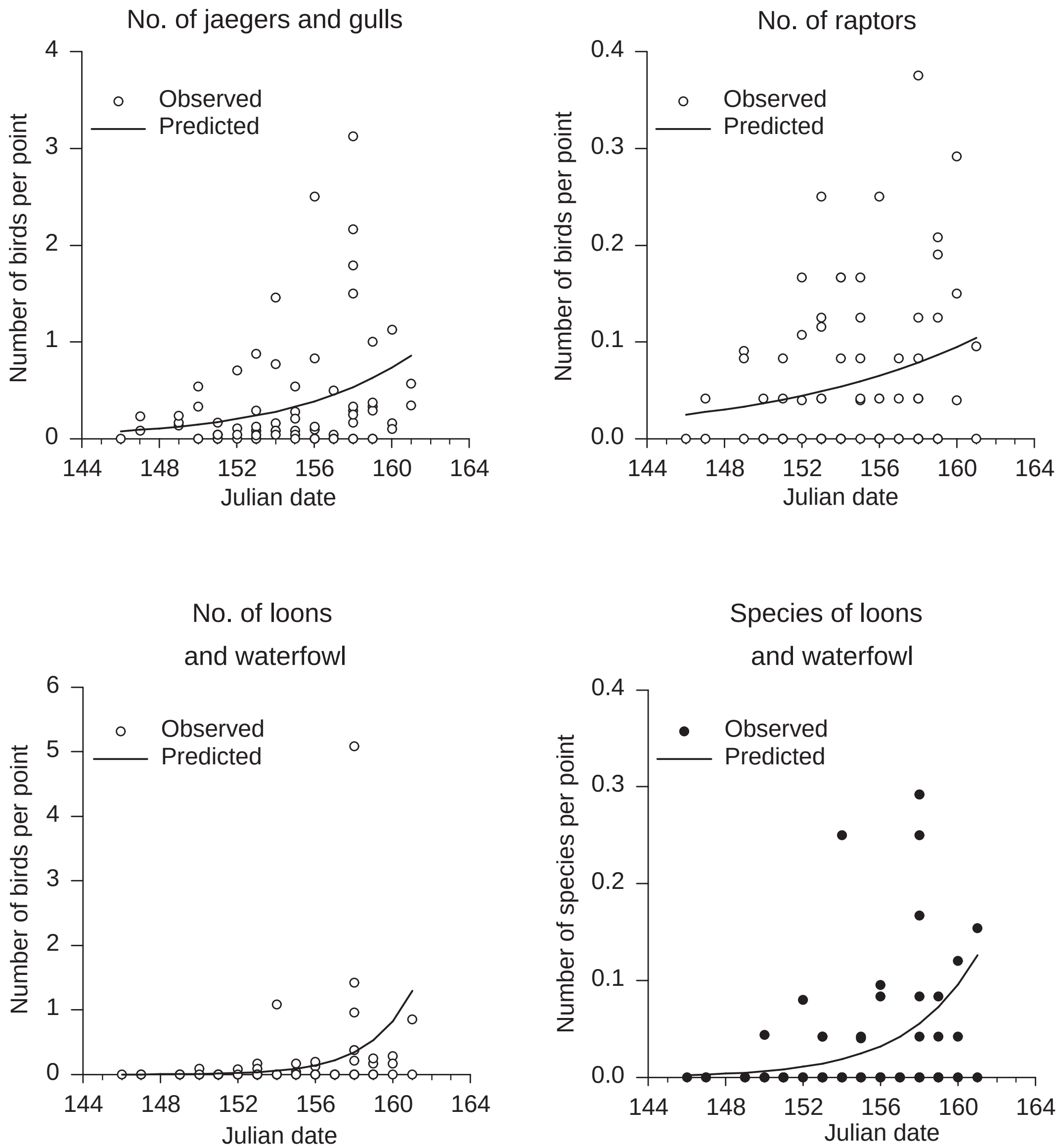

Fig. *11.* *Seasonal patterns in numbers of birds and species detected per point for different species groups across 69 survey plots in the Arctic Network, Alaska, 2001–2003. Surveys extended from 26 May–11 June (Julian dates 146–161). The solid lines show the best-fitting models for predicting detection rates by survey date; no other groups of birds had significant seasonal trends in detection rates for either numbers of birds or numbers of species.*

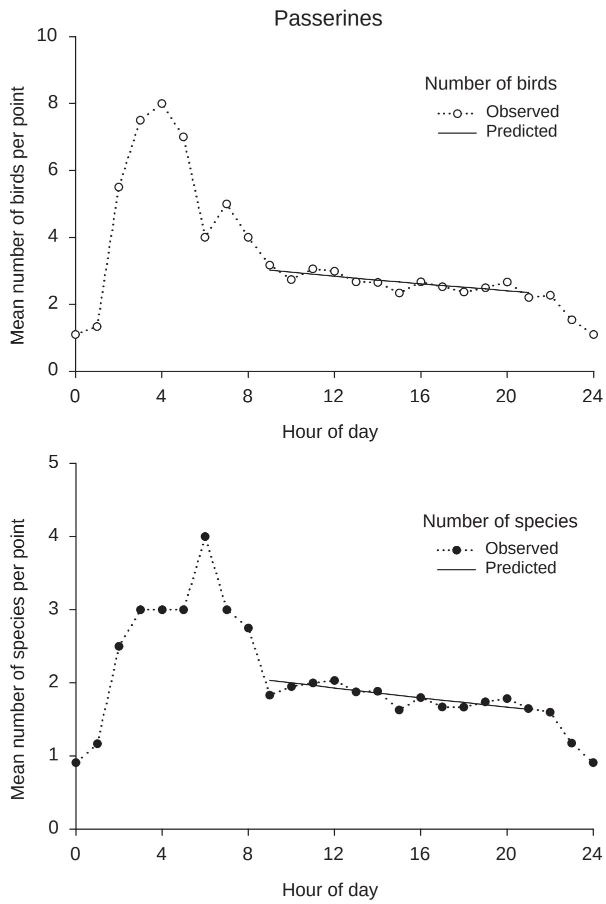

Fig. *12. Diurnal patterns in mean numbers of passerine birds (top) and species (bottom) detected per point count across 69 survey plots in the Arctic Network, Alaska, late May–early June 2001–2003. The solid lines show the best-fitting models for predicting detection rates between 0900 and 2200 h ADT, during which 97% of the point counts were conducted. Detection rates declined slightly for both number of individuals (P = 0.02) and number of species (P = 0.02) but were relatively stable compared with the early morning period. No other group of species exhibited a diurnal trend during the core survey period.*

Occurrence of Species

Frequency of Occurrence on Point Counts

We recorded a total of 9,225 detections of birds (including multiple detections of the same individuals) representing 99 species during 1,651 10-minute point counts (Table 5). These included 1,400 shorebirds of 22 species, 954 potential avian predators of 16 species, 6,192 landbirds of 41 species, and 655 waterbirds of 20 species. In addition, we counted 5,992 birds representing 60 species during the subsequent 1,647 5-minute point counts (Table 5), comprising 5,485 landbirds of 42 species and 507 waterbirds of 18 species. The majority of birds on 5-minute counts were undoubtedly the same individuals recorded during the previous 10-minute counts at the same location, but detailed information (e.g., habitat affinities and distance to point) was obtained for them only during the 5-minute counts (see Methods). A few species (Brant, Mallard, Harlequin Duck, Yellow-billed Loon, Tree Swallow, Northern Flicker, and Townsend's Solitaire) were detected during only one type of count and at very low rates (<0.001% of points surveyed; Table 5).

For most species (102 of 115), occurrence on plots was documented by a combination of point counts and incidental observations between counts or at camp (Appendix 11). Thirteen species were documented by incidental observations only: Snow Goose, Northern Shoveler, Bufflehead, Spruce Grouse, Northern Goshawk, Red-tailed Hawk, Black-bellied Plover, Solitary Sandpiper, Red Knot, Dunlin, Herring Gull, Hermit Thrush, and Blackpoll Warbler (Appendix 11).

Overall, detection rates of birds on point counts were quite low, reflecting the low breeding densities and/or low detectabilities of birds in the montane Arctic. For instance, 83% of the species were detected on only a small proportion of the counts (<4%) while no birds were detected on 7% and 14% of 10-minute and 5-minute counts, respectively (Table 5). Detection rates were particularly low for shorebirds and potential avian predators, with none detected on 51% of the 10-minute counts.

A few species dominated detections on point counts. The seven most commonly detected species on 10-minute counts accounted for 44% of all detections and each comprised ≥5% of all birds detected (Table 5). These species were primarily passerines (Long-tailed Jaeger being the exception) and included Redpoll spp. (10% of all birds, 28% of all points), Savannah Sparrow (7% and 28%), American Tree Sparrow (7% and 24%), Lapland Longspur (6% and 19%), Long-tailed Jaeger (5% and 13%), American Pipit (5% and 19%), and American Robin (5% and 20%).

Among shorebirds, the most commonly detected species were American Golden-Plover (4% of all birds on 10-minute counts, 14% of all points), Wilson's Snipe (4% and 16%), and Whimbrel (3% and 10%). Each of these species constituted >20% of all shorebirds detected, while the remaining 19 species each comprised <4% of total detections. Among potential avian predators, Long-tailed Jaeger and Common Raven (2% of birds, 8% of points) were the most numerous.

When considering the species that were sampled during both the 10-minute and the 5-minute counts (i.e., waterbirds and most landbirds), we found that species-specific measures of occurrence (i.e., proportion of a species among all birds detected and among all points surveyed) were similar between the two counts. This is likely because most detections on 10-minute counts occurred during the first five minutes of the count. For instance, Willow Ptarmigan were detected on 9% and 8% of 10-minute and 5-minute counts, respectively, and Horned Lark comprised 2.2% and 2.3% of birds detected during 10-minute and 5-minute counts, respectively (Table 5). Overall, the same 14 species were most commonly detected on both 10-minute and 5-minute counts.

Occurrence of Species by Ecological Section

Most species were associated with only a few ecological sections, with slightly less than half of the species (48/99) detected during 10-minute counts found in ≤3 sections (Tables 6, 7). Further, half of these were detected within a single section. Relatively few species (n = 16) were broadly distributed, occurring in ≥10 sections, with a single species (Redpoll spp.) recorded in all sections. It should be noted that these associations were measured with respect to species detected during point counts only and thus reflect a minimum estimate of section use by species.

Occurrence of Species in Bering Land Bridge National Preserve

Survey sites in and near Bering Land Bridge extended from the northwest to the central Seward Peninsula (Appendix 10). Several species occurred throughout the area, including two species of ptarmigan, five species of shorebirds (American and Pacific golden-plovers, Whimbrel, Western Sandpiper, and Wilson's Snipe), Long-tailed Jaeger, several thrushes (e.g., Bluethroat, Gray-cheeked Thrush), Orange-crowned and Wilson's warblers, most sparrows (e.g., American Tree Sparrow, Savannah Sparrow), and redpolls (Appendix 13). A few species were restricted to the far northwest sites (sites 1 and A; Appendix 10) including Red Knot, Pectoral Sandpiper, Rock Sandpiper, and Yellow Warbler (Appendix 13). Species found in Bering Land Bridge and not the other Arctic Network parks included Rock Sandpiper (detected at site 1), Bristle-thighed Curlew (sites 1, C, D), Cliff Swallow (sites 3 and B), and Lincoln's Sparrow (site 5; Appendices 10 and 13).

Shorebirds and potential avian predators were detected on point counts at similar rates in Bering Land Bridge as elsewhere in the Arctic Network (Tables 6, 8). For example, detection rates of American Golden-Plover ranged from 0.03 to 0.95 birds per point among sites in Bering Land Bridge (Table 8) and 0.07 to 0.89 birds per point among ecological sections in the four northern parks (Table 6). Interannual differences in detection rates of shorebirds and potential avian predators on counts at the one site in Bering Land Bridge that was revisited on two disparate dates (Site 1, Ear Mountain, Appendix 10) were almost certainly related to differences in seasonal timing of surveys; counts were conducted 17–20 June in 1988 and 3–4 June in 2000, with the earlier dates closer to the peak of courtship activity for all species. As a result, the earlier counts in 2000 yielded more species and higher detection rates than counts in 1988 (Table 8).

Relative Abundance and Diversity

Relative Abundance

Across the entire study area, observers detected an average of 5.6 ± 0.13 SE birds per 10-minute point count (Table 9). Relative abundance was lowest in the Arctic Foothills section (2.3 birds/point) and highest in Interior Forested Lowlands (12.8 birds/point) and Western Brooks Foothills (10.1 birds/point). The remaining 11 sections were more uniform with respect to bird detections, ranging from 3.9 to 7.4 birds/point. Relative abundance was more variable at the subsection level, with the lowest mean value (0.50 birds/point) recorded in Utilok Carbonate Mountains and the highest values found in Kobuk Lowlands-Tundra (22.0 birds/point), Imikneyak Mountains (15.0), and Upper Noatak Floodplain (13.3). Relative abundance of most subsections was in the 2.0 to 10.0 birds/point range.

Broad Species Richness

The rate at which we detected new species throughout the entire study area is shown in Figure 13a. The species accumulation curves for all species and for just passerines reflect an initial steep rise comprised of species that were fairly common and well-distributed and thus more easily detected, but as more points are sampled the curves become shallower, reflecting much lower rates of accumulation, representing species that were rare and/or unevenly distributed. The curves also provide a metric of the census effort needed to detect most species present on the area. For instance, after sampling 248 points (15%

of total) we had recorded only 49 species (50% of total), but with a five-fold increase in effort (1,018 points; 62% of total) we had detected 88 species (90% of total). The flattening of the curve (Fig. 13a, Point c) at around 1,358 points (82% of total 10-minute counts) corresponds to an observed species detection rate of 100%, suggesting that few additional species would have been noted with additional effort. Figure 13a affords a similar comparison for a subset of species, passerines, where 100% of the observed species were detected after conducting 403 points, or only 24% of the total point counts conducted during the inventory. The 90% detection level for passerine species (20 of 22 species) was reached after only 239 (15%) points had been sampled.

We also assessed species richness and the efficiency of our sampling effort at the level of the ecological section (Appendix 3, Table 9). The greatest number of species was recorded in De Long Mountains (58 species), Noatak Basin (56), and Baird Northern Mountains ecological sections (56). Based on the shapes of species accumulation curves when all species were considered we determined that seven sections (50%) had been sampled sufficiently to record almost all species likely to be present (Fig. 14a) and therefore met the assumptions required for comparisons of species richness and diversity based on rarefaction (see below). Similar comparisons were warranted for the passerine dataset (Fig. 15a).

Local Species Richness

At the local scale, the average number of species recorded per 10-minute point count ranged from 1.5 to 6.2 species per point among different ecological sections and was highest for sections in the west (Western Brooks Foothills, Chukchi Sea Coastal Plain) and southeast (Interior Highlands, Interior Forested Lowlands; Table 9). At the subsection level, mean local species richness ranged from 0.5 to 7.6 species per point, was generally highest in the lower elevation and forested subsections (e.g., Mulgrave Hills, Kobuk Lowlands–Tundra, Kobuk River Floodplain, Shiiliak Hills, and Upper Noatak Floodplain), and was not always directly related to richness at the section level.

Expected Species Richness (Rarefaction)

When comparing species richness across ecological sections for which we had adequate samples to construct rarefaction curves, the best estimate (i.e., based on sampling 500 individuals) revealed that expected species richness was highest in De Long Mountains and lowest in Western Brooks Foothills (Table 10, Fig. 14b). Shapes of the rarefaction curves for the different sections illustrated that the expected number of species, E(S), varied depending on sampling level; in addition, the rankings of the sections in E(S) also shifted relative to sampling level (Fig. 14b). Areas of the curves with steeply increasing slopes reflect high heterogeneity among samples, likely caused by patchy distribution of birds, and this indicates the need for higher levels of sampling to characterize the avifauna. Comparisons of the curves at higher levels of sampling (≥500 individuals) suggested that E(S) was similar for all sections except Western Brooks Foothills, which was substantially lower (Fig. 14b).

Table 6. *Mean number of birds detected in ecological sections on 10-minute point counts*

Common name[b]	Chukchi Sea Coastal Plain (19)[c]	Western Brooks Foothills (101)	Baird Southern Mtns. / Kiana Hills (174)	Baird Northern Mtns. (274)	Delong Mtns. (278)	Noatak Basin (207)	Hockley-Waring Upland (24)	Endicott Mtns. (65)	Schwatka Northern Mtns. (19)	Arctic Brooks Range (175)	Subarctic Brooks Range (242)	Interior Highlands (31)	Interior Forested Lowlands (18)	Arctic Foothills (24)	Overall (1,651)
	Section[a]														
Greater White-fronted Goose	0.37	.	.	.	.	0.16	.	.	.	.	.	.	.	0.04	0.03
Brant[d]	.	.	.	0.32	.	.	.	.	.	.	.	.	.	.	0.05
Canada Goose	0.05	0.11	.	.	0.03	0.14	.	.	.	.	.	.	.	.	0.03
Goose spp.	.	.	.	.	.	0.29	.	.	.	.	.	.	.	.	0.04
Tundra Swan	.	.	.	0.01	0.02	0.01	.	.	.	.	.	.	.	.	0.01
American Wigeon	.	.	.	0.02	.	.	.	.	.	.	.	.	.	.	0.00
Mallard	.	.	.	.	0.01	.	.	.	.	.	.	.	.	.	0.00
Northern Pintail	.	.	.	0.01	0.01	0.21	.	.	.	0.04	.	0.06	0.17	.	0.04
Green-winged Teal	.	.	.	.	.	0.04	.	.	.	.	0.02	.	.	.	0.01
Greater Scaup	.	.	.	.	0.07	0.23	.	.	.	0.14	0.01	.	.	.	0.06
Surf Scoter	.	.	.	.	.	0.02	.	.	.	.	.	.	.	.	0.00
White-winged Scoter	.	.	.	.	0.05	.	.	.	.	.	.	.	.	.	0.01
Black Scoter[d]	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	0.00
Scoter spp.	.	.	.	.	0.09	0.04	.	.	.	.	.	.	.	.	0.02
Long-tailed Duck[d]	.	.	.	.	0.04	0.34	.	.	.	.	0.01	.	.	.	0.05
Common Merganser	.	.	.	.	0.01	0.01	.	0.03	.	.	.	.	.	.	0.00
Red-breasted Merganser	.	.	.	.	.	0.04	.	.	.	.	.	.	.	.	0.00
Duck spp.	.	.	.	.	.	0.16	.	.	.	.	.	.	.	.	0.02
Willow Ptarmigan[d]	0.95[e]	1.13[e]	0.05	0.18	0.10	0.02	.	.	.	.	.	.	.	.	0.13
Rock Ptarmigan[d]	.	0.41[e]	0.11	0.19	0.12	0.00	.	0.02	0.05	0.13	0.03	.	.	.	0.11
Ptarmigan spp.	.	.	0.01	0.00	0.00	.	.	0.02	.	.	.	.	.	.	0.00
Red-throated Loon[d]	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	0.00
Pacific Loon	.	.	.	.	.	0.02	.	.	.	.	0.00	.	.	.	0.00
Common Loon	.	.	.	.	.	0.02	.	.	.	.	.	.	.	.	0.00
Yellow-billed Loon[d]	.	0.03	.	.	.	.	.	.	.	.	.	.	.	.	0.00
Loon spp.	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	0.00
Northern Harrier	0.11	0.07	0.01	0.02	0.00	0.02	.	.	.	0.01	.	.	.	.	0.01
Rough-legged Hawk[d]	.	0.09	.	0.01	0.02	0.00	.	.	.	0.01	0.02	.	.	.	0.01
Golden Eagle[d]	.	0.01	0.02	0.02	0.01	.	0.04	.	.	0.01	0.03	.	.	0.04	0.01

Table 6. *(continued)*

Common name[b]	Section[a]: Chukchi Sea Coastal Plain (19)[c]	Western Brooks Foothills (101)	Baird Southern Mtns. / Kiana Hills (174)	Baird Northern Mtns. (274)	Delong Mtns. (278)	Noatak Basin (207)	Hockley-Waring Upland (24)	Endicott Mtns. (65)	Schwatka Northern Mtns. (19)	Arctic Brooks Range (175)	Subarctic Brooks Range (242)	Interior Highlands (31)	Interior Forested Lowlands (18)	Arctic Foothills (24)	Overall (1,651)
Eagle spp.	.	.	.	.	.	0.00	.	.	.	.	.	.	.	.	0.00
Merlin	.	.	.	0.01	0.00	0.00	.	.	.	.	0.02	.	.	.	0.00
Gyrfalcon[d]	.	.	.	.	0.00	0.00	.	.	.	0.01	.	.	.	.	0.00
Peregrine Falcon[d]	.	0.02	.	0.00	.	.	.	.	.	.	.	.	.	.	0.00
Falcon spp.	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	0.00
Raptor spp.	0.05	0.02	.	.	.	0.00	.	.	.	.	0.00	.	.	.	0.00
Sandhill Crane	0.16	0.02	.	.	0.01	.	.	.	.	.	.	.	.	.	0.00
American Golden-Plover[d]	0.42	0.70	0.20	0.19	0.12	0.14	.	0.52	0.89	0.31	0.07	.	.	0.46	0.22
Pacific Golden-Plover[d]	.	.	.	0.00	.	.	.	.	.	.	.	.	.	.	0.00
Golden-Plover spp.	.	.	.	.	.	.	.	0.02	.	0.01	.	.	.	.	0.00
Semipalmated Plover	.	.	0.01	0.01	0.02	0.02	.	.	.	.	.	.	.	.	0.01
Greater Yellowlegs	.	.	.	.	0.00	.	.	.	.	.	.	.	.	.	0.00
Lesser Yellowlegs	.	.	.	.	0.01	0.11	.	.	.	0.01	.	.	0.33	.	0.02
Wandering Tattler[d]	.	.	0.02	0.03	0.08	0.02	.	.	.	0.10	0.02	0.03	.	.	0.04
Spotted Sandpiper	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	0.00
Upland Sandpiper	.	.	.	0.01	.	0.02	.	.	.	0.02	0.02	.	.	.	0.01
Whimbrel[d]	0.63	1.31	0.14	0.14	0.11	0.23	.	0.02	.	.	.	.	.	.	0.17
Hudsonian Godwit[d]	.	.	.	0.00	.	.	.	.	.	.	.	.	.	.	0.00
Bar-tailed Godwit[d]	0.21	0.34	.	.	.	.	.	.	.	.	.	.	.	.	0.02
Surfbird[d]	.	.	0.03	0.02	0.03	.	.	.	.	0.01	0.03	.	.	.	0.02
Semipalmated Sandpiper	.	0.12	0.01	0.02	.	0.02	.	.	0.05	.	.	.	.	.	0.02
Western Sandpiper	.	0.09	.	.	.	.	.	.	.	.	.	.	.	.	0.01
Least Sandpiper	.	.	.	0.02	0.00	0.05	.	.	.	0.01	.	.	.	.	0.01
Baird's Sandpiper	.	.	0.01	0.03	0.03	.	.	.	.	0.03	0.03	.	.	.	0.02
Pectoral Sandpiper	.	0.05	.	0.00	.	.	.	.	0.58	0.06	.	.	.	.	0.02
Buff-breasted Sandpiper[d]	.	0.09	.	.	.	.	.	.	.	.	.	.	.	.	0.01
Long-billed Dowitcher	.	.	.	0.04	.	0.00	.	.	.	0.06	.	.	.	.	0.01
Wilson's Snipe	0.47	0.77	0.26	0.19	0.20	0.17	0.17	0.28	0.11	0.08	0.09	.	0.33	.	0.21
Red-necked Phalarope	.	.	.	.	.	0.03	.	.	.	0.09	.	.	.	.	0.01
Red Phalarope	.	.	.	.	.	.	.	.	.	0.05	.	.	.	.	0.01
Small shorebird spp.	0.16	0.10	.	.	.	0.00	.	0.02	.	0.05	.	.	.	.	0.01

Table 6. *(continued)*

	Section[a]														
Common name[b]	Chukchi Sea Coastal Plain (19)[c]	Western Brooks Foothills (101)	Baird Southern Mtns. / Kiana Hills (174)	Baird Northern Mtns. (274)	Delong Mtns. (278)	Noatak Basin (207)	Hockley-Waring Upland (24)	Endicott Mtns. (65)	Schwatka Northern Mtns. (19)	Arctic Brooks Range (175)	Subarctic Brooks Range (242)	Interior Highlands (31)	Interior Forested Lowlands (18)	Arctic Foothills (24)	Overall (1,651)
Shorebird spp.	.	0.06	.	0.00	.	0.02	.	.	.	0.04	0.00	.	.	.	0.01
Pomarine Jaeger	.	.	.	0.01	.	.	.	.	.	.	.	.	.	.	0.00
Parasitic Jaeger	0.37	.	0.01	0.00	0.00	0.09	.	0.02	.	.	.	.	.	.	0.02
Long-tailed Jaeger	0.79	1.81	0.11	0.23	0.14	0.51	.	0.09	0.05	0.15	0.02	.	.	0.08	0.28
Jaeger spp.	.	.	.	.	.	0.02	.	0.05	0.05	.	.	.	.	.	0.00
Mew Gull	.	0.01	0.02	0.02	0.06	0.10	.	.	.	0.06	0.05	.	.	.	0.04
Glaucous Gull	.	0.08	.	0.01	0.02	0.17	.	.	.	0.01	.	.	.	.	0.03
Gull spp.	0.11	.	0.02	.	.	.	.	0.03	.	.	.	.	.	.	0.00
Arctic Tern	.	.	0.01	0.02	0.02	0.07	.	.	.	.	.	.	.	.	0.02
Short-eared Owl[d]	.	0.04	.	0.00	0.00	.	.	.	.	.	.	.	.	.	0.00
Olive-sided Flycatcher[d]	.	.	.	.	.	.	.	.	.	.	0.04	.	.	.	0.01
Say's Phoebe	.	0.01	0.01	0.01	0.01	.	.	0.02	.	0.03	0.00	.	.	.	0.01
Northern Shrike[d]	.	.	.	.	0.00	.	.	.	.	.	0.02	.	.	.	0.00
Gray Jay[d]	.	.	0.01	.	.	.	.	.	.	.	0.05	0.19	0.17	.	0.01
Jay spp.	.	.	.	.	.	.	.	.	.	.	0.00	.	.	.	0.00
Common Raven	0.42	0.50	0.11	0.06	0.06	0.11	0.42	0.06	0.05	0.11	0.05	0.29	.	0.08	0.12
Horned Lark	.	0.08	0.16	0.12	0.11	0.01	0.08	0.15	0.37	0.24	0.10	0.45	.	0.04	0.12
Tree Swallow	.	.	.	.	.	.	.	.	.	.	0.01	.	.	.	0.00
Violet-green Swallow	.	.	.	.	.	.	.	.	.	.	0.04	.	.	.	0.01
Bank Swallow	.	.	0.01	0.00	.	0.03	.	.	.	.	.	.	.	.	0.01
Boreal Chickadee[d]	.	.	0.01	.	.	.	.	.	.	.	0.00	.	.	.	0.00
Chickadee spp.	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	0.00
Ruby-crowned Kinglet	.	.	0.06	.	0.00	.	.	.	.	.	0.08	0.19	0.72	.	0.03
Arctic Warbler[d]	.	.	.	.	0.01	.	.	.	.	.	.	.	.	.	0.00
Bluethroat	0.16	0.28	0.01	0.05	0.11	0.05	.	0.05	.	.	.	.	.	.	0.06

Table 6. *(continued)*

Common name[b]	Section[a]: Chukchi Sea Coastal Plain (19)[c]	Western Brooks Foothills (101)	Baird Southern Mtns. / Kiana Hills (174)	Baird Northern Mtns. (274)	Delong Mtns. (278)	Noatak Basin (207)	Hockley-Waring Upland (24)	Endicott Mtns. (65)	Schwatka Northern Mtns. (19)	Arctic Brooks Range (175)	Subarctic Brooks Range (242)	Interior Highlands (31)	Interior Forested Lowlands (18)	Arctic Foothills (24)	Overall (1,651)
Northern Wheatear	.	0.04	0.05	0.08	0.04	.	.	0.15	.	0.08	0.04	0.06	.	.	0.05
Gray-cheeked Thrush[d]	0.11	0.07	0.11	0.13	0.06	0.06	0.42	.	.	0.04	0.10	0.65	0.67	.	0.10
Swainson's Thrush	.	.	0.01	.	.	.	.	.	.	.	0.14	0.16	0.06	.	0.02
American Robin	.	.	0.39	0.27	0.34	0.11	1.17	0.11	0.16	0.15	0.32	0.52	.	.	0.25
Varied Thrush[d]	.	.	0.26	0.03	0.03	.	0.83	.	.	.	0.04	0.16	0.17	.	0.06
Eastern Yellow Wagtail	0.05	0.01	.	0.00	.	0.09	.	.	.	.	.	.	.	.	0.01
American Pipit	.	0.07	0.55	0.27	0.22	0.02	.	0.26	0.95	0.31	0.33	0.77	.	0.08	0.27
Bohemian Waxwing[d]	.	.	0.04	.	.	.	.	.	.	.	0.02	0.03	1.39	.	0.02
Orange-crowned Warbler	.	0.03	0.04	0.02	0.04	0.01	0.04	.	.	0.01	0.08	0.03	0.11	.	0.03
Yellow Warbler	.	.	0.01	0.01	0.02	0.03	.	.	.	.	.	.	.	.	0.01
Yellow-rumped Warbler	.	.	0.07	0.01	0.01	.	0.33	.	.	.	0.10	0.32	0.28	.	0.04
Northern Waterthrush	.	.	0.02	.	.	.	.	.	.	.	.	0.03	0.11	.	0.00
Wilson's Warbler	.	.	0.12	0.11	0.02	0.03	.	.	.	.	0.03	0.19	0.22	.	0.05
Warbler spp.	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	0.00
American Tree Sparrow	0.05	0.17	0.29	0.47	0.52	0.61	.	0.22	0.05	0.42	0.41	.	.	0.17	0.40
Savannah Sparrow	0.21	0.42	0.32	0.47	0.46	0.98	.	0.26	0.21	0.15	0.17	0.03	0.22	0.25	0.40
Fox Sparrow	.	.	0.32	0.15	0.04	0.10	0.63	0.14	.	0.02	0.07	0.58	1.56	.	0.13
White-crowned Sparrow	0.05	0.07	0.23	0.21	0.33	0.23	0.50	0.11	0.11	0.23	0.24	0.77	0.67	.	0.24
Golden-crowned Sparrow[d]	.	.	0.54	0.44	0.29	0.01	.	0.03	0.11	0.07	0.04	.	0.06	.	0.20
Dark-eyed Junco	.	.	0.02	.	.	.	.	.	.	.	0.11	0.06	0.11	.	0.02
Lapland Longspur[d]	0.58	0.74	0.07	0.25	0.08	0.72	.	2.08	1.26	0.29	0.02	.	.	0.79	0.35
Smith's Longspur[d]	.	.	.	0.01	.	.	.	.	.	0.01	.	.	.	0.04	0.00
Snow Bunting[d]	.	.	.	.	0.06	.	.	.	.	0.05	.	.	.	.	0.02
Sparrow spp.	.	.	0.09	.	0.01	0.02	0.04	.	.	.	.	.	.	.	0.02
Rusty Blackbird[d]	.	.	.	.	.	.	.	.	.	.	.	0.03	.	.	0.00

Table 6. *(continued)*

	Section[a]														
Common name[b]	Chukchi Sea Coastal Plain (19)[c]	Western Brooks Foothills (101)	Baird Southern Mtns. / Kiana Hills (174)	Baird Northern Mtns. (274)	Delong Mtns. (278)	Noatak Basin (207)	Hockley-Waring Upland (24)	Endicott Mtns. (65)	Schwatka Northern Mtns. (19)	Arctic Brooks Range (175)	Subarctic Brooks Range (242)	Interior Highlands (31)	Interior Forested Lowlands (18)	Arctic Foothills (24)	Overall (1,651)
Gray-crowned Rosy-Finch	.	.	.	.	0.01	.	.	.	.	0.06	0.04	0.06	.	.	0.01
Pine Grosbeak[d]	.	.	0.01	.	.	.	0.04	.	.	.	0.01	.	.	.	0.00
White-winged Crossbill[d]	.	.	.	.	.	.	.	.	.	.	0.05	.	.	.	0.01
Redpoll spp.[d, f]	0.11	0.14	0.70	0.52	0.45	0.48	0.17	0.60	1.21	0.30	0.51	1.19	5.28	0.25	0.53
Pine Siskin	.	.	.	.	.	.	.	.	.	.	0.01	.	.	.	0.00
Passerine spp.	.	.	0.02	0.02	0.00	0.01	.	.	0.05	0.01	0.09	.	0.17	.	0.02
Total species	**22**	**35**	**47**	**56**	**58**	**56**	**13**	**23**	**16**	**40**	**48**	**24**	**19**	**12**	

a Sections ordered from west to east.

b See Appendix 1 for scientific names.

c Number of point counts.

d Species of conservation concern (Boreal Partners in Flight Working Group 1999; U.S. Fish and Wildlife Service 2002; Rich et al. 2004; Stenhouse and Senner 2005; Alaska Shorebird Group 2000, unpublished). Within the Redpoll spp. group, only Hoary Redpoll is a species of concern.

e In these sections, only presence/absence of ptarmigan (vs. number of birds) was recorded during 10-min counts; thus values represent minimum number of ptarmigan on counts.

f Common Redpoll and Hoary Redpoll not distinguished in this summary.

Table 7. *Mean number of landbirds and waterbirds detected in ecological sections on 5-min point counts*

	Section[a]														
Common name[b]	Chukchi Sea Coastal Plain (19)[c]	Western Brooks Foothills (100)	Baird Southern Mtns. / Kiana Hills (174)	Baird Northern Mtns. (273)	De Long Mtns. (278)	Noatak Basin (206)	Hockley-Waring Upland (24)	Endicott Mtns. (65)	Schwatka Northern Mtns. (19)	Arctic Brooks Range (174)	Subarctic Brooks Range (242)	Interior Highlands (31)	Interior Forested Lowlands (18)	Arctic Foothills (24)	Overall (1,647)
Greater White-fronted Goose	.	.	.	.	.	0.07	.	.	.	.	.	.	.	.	0.01
Canada Goose	.	0.04	.	.	0.01	0.17	.	.	.	.	.	.	.	.	0.03
Goose spp.	.	.	.	.	.	0.27	.	.	.	.	.	.	.	.	0.03
Tundra Swan	.	.	.	.	0.03	.	.	.	.	.	.	.	.	.	0.00
American Wigeon	.	.	.	0.01	.	.	.	.	.	.	.	.	.	.	0.00
Northern Pintail	.	.	.	.	0.02	0.16	.	.	.	.	0.01	0.06	.	.	0.03
Green-winged Teal	.	.	.	.	.	0.01	.	.	.	.	0.02	.	.	.	0.00
Greater Scaup	.	.	.	.	0.06	0.20	.	.	.	.	0.01	.	.	.	0.04
Scaup spp.	.	.	.	.	0.15	0.00	.	.	.	0.09	.	.	.	.	0.03
Harlequin Duck	.	.	.	.	.	0.00	.	.	.	.	.	.	.	.	0.00
Surf Scoter	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	0.00
White-winged Scoter	.	.	.	.	0.05	.	.	.	.	.	.	.	.	.	0.01
Black Scoter[d]	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	0.00
Scoter spp.	.	.	.	.	0.04	.	.	.	.	.	.	.	.	.	0.01
Long-tailed Duck[d]	.	.	.	.	0.03	0.35	.	.	.	.	0.01	.	.	.	0.05
Common Merganser	.	.	.	.	0.00	.	.	0.03	.	.	.	.	.	.	0.00
Red-breasted Merganser	.	.	.	.	.	0.01	.	.	.	.	.	0.03	.	.	0.00
Duck spp.	.	.	.	.	0.05	0.25	.	.	.	0.01	.	.	.	.	0.04
Willow Ptarmigan[d]	2.53	1.94	0.02	0.18	0.08	0.01	.	0.02	.	.	.	.	.	.	0.19
Rock Ptarmigan[d]	.	0.71	0.08	0.18	0.10	0.00	.	0.02	.	0.10	0.02	.	.	0.04	0.11
Ptarmigan spp.	.	0.04	.	.	0.00	0.00	.	.	.	.	.	.	.	.	0.00
Red-throated Loon[d]	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	0.00
Pacific Loon	.	.	.	.	.	0.02	.	.	.	.	0.00	.	.	.	0.00
Common Loon	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	0.00
Arctic Tern	.	.	0.01	0.00	0.01	0.07	.	.	.	.	.	.	.	.	0.01
Northern Flicker	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	0.00

Table 7. *(continued)*

	Section[a]														
Common name[b]	Chukchi Sea Coastal Plain (19)[c]	Western Brooks Foothills (100)	Baird Southern Mtns. / Kiana Hills (174)	Baird Northern Mtns. (273)	De Long Mtns. (278)	Noatak Basin (206)	Hockley-Waring Upland (24)	Endicott Mtns. (65)	Schwatka Northern Mtns. (19)	Arctic Brooks Range (174)	Subarctic Brooks Range (242)	Interior Highlands (31)	Interior Forested Lowlands (18)	Arctic Foothills (24)	Overall (1,647)
Olive-sided Flycatcher[d]	.	.	.	.	.	.	.	.	.	.	0.03	0.03	.	.	0.01
Say's Phoebe	.	0.01	0.01	0.01	.	.	.	0.02	.	0.01	0.00	.	.	.	0.01
Flycatcher spp.	.	.	.	.	.	.	.	.	.	.	0.00	.	.	.	0.00
Horned Lark	.	0.07	0.08	0.10	0.08	.	0.08	0.12	0.37	0.14	0.06	0.32	.	.	0.08
Violet-green Swallow	.	.	.	0.01	.	.	.	.	.	.	0.07	.	.	.	0.01
Bank Swallow	.	.	.	.	.	0.02	.	.	.	.	.	.	.	.	0.00
Swallow spp.	.	.	.	.	.	.	.	.	.	.	0.00	.	.	.	0.00
Boreal Chickadee[d]	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	0.00
Chickadee spp.	.	.	.	.	.	.	.	.	.	.	0.00	.	.	.	0.00
Ruby-crowned Kinglet	.	.	0.05	.	.	.	.	.	.	.	0.07	0.19	0.39	.	0.02
Arctic Warbler[d]	.	.	.	.	0.01	.	.	.	.	.	.	.	.	.	0.00
Bluethroat	0.05	0.29	0.01	0.06	0.10	0.04	.	0.06	.	0.01	.	.	.	.	0.05
Northern Wheatear	.	0.01	0.03	0.03	0.04	0.01	.	0.17	0.05	0.06	0.02	0.03	.	.	0.04
Townsend's Solitaire	.	.	.	.	.	.	.	.	.	.	0.00	.	.	.	0.00
Gray-cheeked Thrush[d]	0.05	0.06	0.07	0.09	0.03	0.05	0.21	.	.	0.03	0.08	0.61	0.56	.	0.07
Swainson's Thrush	.	.	0.01	.	.	.	.	.	.	.	0.15	0.10	.	.	0.02
American Robin	.	.	0.29	0.25	0.26	0.06	0.92	0.11	0.11	0.13	0.33	0.42	.	.	0.21
Varied Thrush[d]	.	.	0.28	0.03	0.01	.	0.67	.	.	.	0.05	0.16	0.17	.	0.06
Eastern Yellow Wagtail	0.11	.	0.01	0.00	.	0.07	.	.	.	.	.	.	.	.	0.01
American Pipit	.	0.11	0.36	0.19	0.16	0.00	0.04	0.20	0.53	0.22	0.23	0.48	.	0.04	0.19
Bohemian Waxwing[d]	.	.	0.04	.	.	.	.	.	.	.	0.01	.	0.06	.	0.01
Orange-crowned Warbler	.	0.03	0.04	0.01	0.04	0.01	.	.	.	0.02	0.07	0.03	0.06	.	0.03
Yellow Warbler	.	.	0.02	0.01	0.01	0.03	.	.	.	.	.	.	.	.	0.01
Yellow-rumped Warbler	.	.	0.05	0.01	.	.	0.08	.	.	.	0.07	0.23	0.39	.	0.03
Northern Waterthrush	.	.	0.01	.	.	.	.	.	.	.	.	0.03	0.11	.	0.00
Wilson's Warbler	.	.	0.11	0.09	0.01	0.03	.	.	.	.	0.03	0.29	0.11	.	0.04

Table 7. *(continued)*

Common name[b]	Chukchi Sea Coastal Plain (19)[c]	Western Brooks Foothills (100)	Baird Southern Mtns. / Kiana Hills (174)	Baird Northern Mtns. (273)	De Long Mtns. (278)	Noatak Basin (206)	Hockley-Waring Upland (24)	Endicott Mtns. (65)	Schwatka Northern Mtns. (19)	Arctic Brooks Range (174)	Subarctic Brooks Range (242)	Interior Highlands (31)	Interior Forested Lowlands (18)	Arctic Foothills (24)	Overall (1,647)
	Section[a]														
Warbler spp.	.	.	.	.	.	.	.	.	.	.	0.00	.	.	.	0.00
American Tree Sparrow	0.26	0.26	0.28	0.45	0.49	0.54	.	0.15	.	0.36	0.46	0.06	.	0.25	0.39
Savannah Sparrow	0.58	0.49	0.26	0.47	0.41	0.83	.	0.32	0.16	0.14	0.20	0.03	0.06	.	0.38
Fox Sparrow	0.05	0.02	0.27	0.16	0.04	0.09	0.54	0.08	.	0.01	0.06	0.52	1.61	.	0.12
White-crowned Sparrow	.	0.10	0.18	0.23	0.26	0.21	0.63	0.12	.	0.21	0.20	0.81	0.44	.	0.22
Golden-crowned Sparrow[d]	.	.	0.55	0.45	0.22	0.01	.	0.02	0.16	0.07	0.05	.	.	.	0.19
Dark-eyed Junco	.	.	.	.	.	.	.	.	.	.	0.11	0.03	0.17	.	0.02
Lapland Longspur[d]	1.32	1.11	0.07	0.30	0.06	0.69	.	1.85	1.11	0.33	0.18	.	.	0.50	0.39
Smith's Longspur[d]	.	.	.	0.01	.	.	.	.	.	0.01	.	.	.	.	0.00
Snow Bunting[d]	.	.	.	.	0.05	.	.	.	.	0.02	.	.	.	.	0.01
Sparrow spp.	.	.	0.10	.	0.01	0.03	0.04	.	.	.	0.00	.	.	.	0.02
Rusty Blackbird[d]	.	.	0.01	.	.	.	.	.	.	.	.	.	0.06	.	0.00
Gray-crowned Rosy-Finch	.	0.01	0.01	0.00	0.00	.	.	.	.	0.09	0.02	.	.	.	0.02
Pine Grosbeak[d]	.	.	.	.	.	.	.	.	.	.	0.00	.	.	.	0.00
White-winged Crossbill[d]	.	.	.	.	.	.	.	.	.	.	0.00	.	.	.	0.00
Redpoll spp.[d, e]	0.32	0.09	0.33	0.39	0.29	0.30	0.08	0.40	0.84	0.14	0.32	0.65	2.50	0.04	0.32
Pine Siskin	.	.	.	.	.	.	.	.	.	.	0.00	.	.	.	0.00
Passerine spp.	0.05	0.11	0.06	0.00	0.01	0.01	.	.	0.11	0.01	0.02	0.03	0.06	.	0.02
Total species	**9**	**18**	**31**	**27**	**30**	**34**	**9**	**16**	**9**	**21**	**35**	**21**	**14**	**5**	

a Sections ordered west to east.
b See Appendix 1 for scientific names.
c Number of point counts.
d Species of conservation concern (Boreal Partners in Flight Working Group 1999; U.S. Fish and Wildlife Service 2002; Rich et al. 2004; Stenhouse and Senner 2005). Within the Redpoll spp. group, only Hoary Redpoll is a species of concern.
e Common Redpoll and Hoary Redpoll not distinguished in this summary.

Table 8. *Mean number of shorebirds and potential avian predators detected on 10-minute point counts in Bering Land Bridge National Preserve, Alaska, late May–June 1988, 1989, and 2000*

	Survey site[a]						
	Ear Mountain	**Ear Mountain**	**Serpentine Hot Springs**	**N. Serpentine Hot Springs**	**Hannum Creek**	**Burnt River**	**West Bat**
Common name[b]	**(1988:30)[c]**	**(2000:30)**	**(1988:37)**	**(1989:28)**	**(1988:39)**	**(1989:22)**	**(1989:11)**
Northern Harrier				0.04	0.03		
Rough-legged Hawk[d]			0.03		0.03		0.09
Golden Eagle[d]					0.03		
Gyrfalcon[d]		0.07			0.03		
American Golden-Plover[d]		0.33	0.03	0.07	0.08	0.95	0.09
Pacific Golden-Plover[d]	0.13	0.10	0.22	0.29	0.18		0.18
Golden-Plover spp.				0.04	0.13		
Whimbrel[d]	0.43	0.40	0.05	0.39	0.21	0.27	1.18
Bristle-thighed Curlew[d]	0.03	1.17					
Bar-tailed Godwit[d]	0.47	0.33	0.05		0.10		
Red Knot[d]		0.20					
Western Sandpiper	0.13	0.30	0.08	0.11	0.08		0.09
Baird's Sandpiper		0.07					
Pectoral Sandpiper		0.90					
Rock Sandpiper		0.03					
Wilson's Snipe	0.53	0.60	0.11	0.50	0.26	0.27	1.18
Parasitic Jaeger	0.03			0.04			
Long-tailed Jaeger	0.20	0.30	0.05	0.29	2.05	0.45	0.27
Short-eared Owl[d]		0.03					
Common Raven	0.13		0.11	0.07	0.03		

a See Appendix 10 for locations of surveys. Sites ordered from northwest to southeast.

b See Appendix 1 for scientific names.

c Year of survey: number of point counts.

d Species of conservation concern (Boreal Partners in Flight Working Group 1999; U.S. Fish and Wildlife Service 2002; Rich et al. 2004; Stenhouse and Senner 2005; Alaska Shorebird Group 2000, unpublished).

Table 9. *Relative abundance and number of species detected in ecological sections (red) and subsections on 10-minute point counts*

Section[a]	Subsection	Number of points	Total birds	Number of birds per point[b]	Number of species[c]	Number of species per point[d]
Chukchi Sea Coastal Plain		19	126	6.6 (0.62)	23	5.0 (0.40)
	Wulik Lowlands	19	126	6.6 (0.62)	23	5.0 (0.40)
Western Brooks Foothills		101	1,018	10.1 (0.49)	35	6.2 (0.25)
	Igichuk Hills, tundra	48	420	8.8 (0.76)	28	5.2 (0.39)
	Mulgrave Hills	53	598	11.3 (0.60)	27	7.2 (0.26)
Baird Southern Mountains/ Kiana Hills		174	994	5.7 (0.29)	47	3.9 (0.17)
	Akiak Foothills	22	140	6.4 (1.17)	25	4.1 (0.57)
	Akiak Mountains	66	340	5.2 (0.46)	29	3.7 (0.29)
	Kallarichuk Hills	17	84	4.9 (0.76)	13	3.1 (0.29)
	Salmon River Hills	20	91	4.6 (0.60)	19	3.0 (0.35)
	Shiliak Hills	9	76	8.4 (1.08)	17	6.0 (0.58)
	Squirrel Mountains	20	142	7.1 (0.62)	23	4.7 (0.37)
	Tukpahlearik Mountains	20	121	6.1 (0.92)	20	4.0 (0.58)
Baird Northern Mountains		274	1,507	5.5 (0.31)	56	3.7 (0.14)
	Aklumayuak Foothills	48	225	4.7 (0.49)	29	3.3 (0.30)
	Anaktok Mountains	8	34	4.3 (1.22)	12	2.9 (0.48)
	Angayukaqsraq Mountains	20	113	5.7 (1.04)	24	3.8 (0.52)
	Asik Mountain	5	14	2.8 (1.11)	8	2.0 (0.55)
	Eli Foothills	21	112	5.3 (0.95)	20	3.9 (0.64)
	Eli Mountains	22	187	8.5 (2.06)	21	4.6 (0.53)
	Imelyak Foothillls	29	224	7.7 (0.78)	26	4.7 (0.45)
	Kikmiksot Mountains	17	60	3.5 (0.45)	18	2.9 (0.32)
	Kunyanak Mountains	23	89	3.9 (0.62)	23	3.3 (0.48)
	Nakolik Mountains	19	117	6.2 (0.71)	18	4.5 (0.44)
	Natmotirak Foothills	16	56	3.5 (0.61)	15	2.4 (0.35)
	Skajit Mountains	10	30	3.0 (0.79)	10	2.5 (0.65)
	Tututalak Mountains	36	246	6.8 (1.30)	28	4.3 (0.35)
De Long Mountains		278	1,323	4.8 (0.29)	58	3.2 (0.14)
	Anisak Mountains	21	80	3.8 (0.84)	25	2.7 (0.56)
	Avan Mountains	4	8	2.0 (1.08)	5	1.3 (0.63)
	Bastille Mountains	17	24	1.4 (0.27)	7	1.1 (0.18)
	Iggiruk Mountains	13	34	2.6 (0.57)	12	1.7 (0.31)
	Imikneyak Mountains	5	75	15.0 (8.81)	15	4.8 (0.92)
	Kaluktavik Mountains	31	198	6.4 (0.83)	25	4.1 (0.44)
	Kaluktavik Uplands	11	84	7.6 (1.41)	15	4.5 (0.68)
	Kelly Mountains	31	122	3.9 (0.67)	20	2.9 (0.43)
	Kelly Uplands	29	196	6.8 (0.67)	27	4.7 (0.46)
	Kokolik Mountains	6	21	3.5 (0.99)	12	2.8 (0.75)
	Kugururok Mountains	32	202	6.3 (0.63)	26	4.4 (0.39)
	Kugururok Uplands	7	53	7.6 (0.92)	17	5.4 (0.65)
	Misheguk Mountains	24	122	5.1 (0.85)	25	3.3 (0.40)

Table 9. *(continued)*

Section[a]	Subsection	Number of points	Total birds	Number of birds per point[b]	Number of species[c]	Number of species per point[d]
	Nimiuktuk Hills	15	63	4.2 (0.63)	16	3.3 (0.44)
	Nuka Mountains	26	37	1.4 (0.31)	11	1.1 (0.21)
	Siniktanneyak Mountain	6	4	0.7 (0.33)	3	0.5 (0.22)
Noatak Basin		207	1,528	7.4 (0.60)	56	4.0 (0.20)
	Anisak Uplands	32	174	5.4 (0.65)	24	3.5 (0.37)
	Avingyak Glaciated Uplands	21	91	4.3 (0.70)	14	2.7 (0.39)
	Avingyak Hills	22	102	4.6 (0.55)	13	3.4 (0.39)
	Iggiruk Glaciated Uplands	16	127	7.9 (1.90)	22	4.0 (0.88)
	Kavachurak Glaciated Uplands	14	139	9.9 (1.46)	22	5.6 (0.61)
	Middle Noatak Uplands	18	85	4.7 (0.70)	16	3.2 (0.42)
	Upper Noatak Basin	77	717	9.3 (1.42)	38	4.3 (0.38)
	Upper Noatak Floodplain	7	93	13.3 (1.04)	21	7.6 (0.84)
Hockley-Waring Upland		24	117	4.9 (0.58)	13	3.8 (0.38)
	Waring Mountains	24	117	4.9 (0.58)	13	3.8 (0.38)
Endicott Mountains		65	346	5.3 (0.40)	23	3.2 (0.20)
	Aniuk Mountains	20	126	6.3 (0.86)	17	3.5 (0.37)
	Ipnavik Mountains	5	26	5.2 (1.93)	9	3.0 (1.05)
	Nukatpiat Hills	33	178	5.4 (0.42)	17	3.3 (0.23)
	Nukatpiat Mountains	7	16	2.3 (1.02)	9	1.9 (0.77)
Schwatka Northern Mountains		19	120	6.3 (0.71)	17	3.8 (0.41)
	Kavachurak Mountains	19	120	6.3 (0.72)	17	3.8 (0.41)
Arctic Brooks Range		175	713	4.1 (0.31)	40	2.4 (0.13)
	Anaktuvuk Mountain Valley	10	104	10.4 (2.61)	15	3.3 (0.34)
	Chandler Mountain Valley	17	96	5.6 (0.91)	19	2.9 (0.33)
	Endicott Mountains Noncarbonate	44	116	2.6 (0.40)	18	1.8 (0.24)
	Itkillik Mountain Valley	20	76	3.8 (0.62)	21	2.7 (0.40)
	Killik Mountain Valley	10	43	4.3 (0.76)	11	3.1 (0.35)
	Nigu Mountain Valley	16	99	6.2 (0.78)	10	3.3 (0.21)
	Oyukak Carbonate Mountains	18	116	6.4 (1.14)	20	3.8 (0.54)
	Thibodeaux Noncarbonate Mountains	34	60	1.8 (0.33)	17	1.3 (0.23)
	Utikok Carbonate Mountains	6	3	0.5 (0.22)	3	0.5 (0.22)
Subarctic Brooks Range		242	933	3.9 (0.22)	48	2.7 (0.13)
	Alatna Mountain Valley	18	78	4.3 (0.75)	20	3.6 (0.63)
	Huntfork Noncarbonate Mountains	112	269	2.4 (0.19)	31	1.8 (0.13)
	John Mountain Valley	37	154	4.2 (0.53)	25	2.6 (0.28)
	Kobuk Mountain Valley	19	135	7.1 (1.03)	22	4.8 (0.47)
	Koyukuk Mountain Valley	15	44	2.9 (0.62)	12	2.0 (0.37)
	Skajit Carbonate Mountains	15	47	3.1 (0.58)	16	2.7 (0.50)

Table 9. *(continued)*

Section[a] Subsection	Number of points	Total birds	Number of birds per point[b]	Number of species[c]	Number of species per point[d]
Southern Foothills-Metanoncarbonates Range	26	206	7.9 (0.90)	25	4.8 (0.41)
Interior Highlands	31	214	6.9 (0.75)	24	4.8 (0.45)
Angayucham Mountains	31	214	6.9 (0.75)	24	4.8 (0.45)
Interior Forested Lowlands	18	230	12.8 (2.71)	19	5.2 (0.45)
Kobuk Lowlands-Forested	14	167	11.9 (2.99)	16	4.8 (0.38)
Kobuk Lowlands-Tundra	2	44	22.0 (14.00)	12	7.5 (1.50)
Kobuk River Floodplain	2	19	9.5 (4.50)	9	6.0 (3.00)
Arctic Foothills	24	56	2.3 (0.43)	12	1.5 (0.23)
Chandler Foothills	16	33	2.1 (0.54)	10	1.3 (0.28)
Chandler Lowlands	8	23	2.9 (0.72)	6	1.9 (0.35)
Totals	**1,651**	**9,225**	**5.6 (0.13)**	**99**	**3.5 (0.06)**

a Sections ordered from west to east.
b Number of birds per section or subsection/number of point counts in that section or subsection (± SE).
c Total number of species recorded during point counts in that section or subsection.
d Number of species per section or subsection/number of point counts in that section or subsection (± SE).

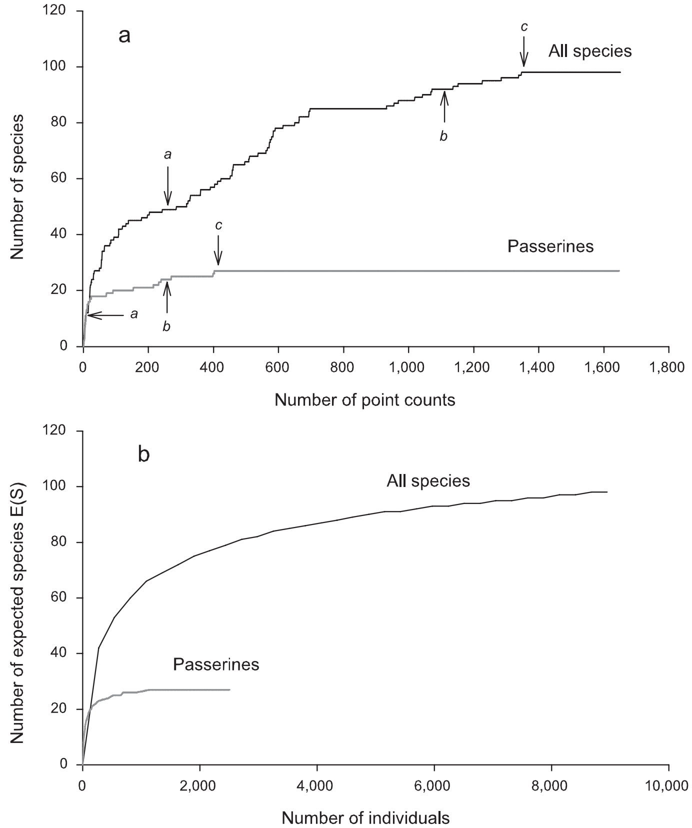

Fig. 13. *(a) Species accumulation curves and (b) rarefaction curves. Black lines (all species) represent curves from 10-minute point counts during which birds of all species were recorded out to an unlimited distance. Gray lines (passerines) represent only passerine species within 150 m of the survey point during 5-minute counts. Lower case letters on the species accumulation curves indicate the cumulative number of points that had been surveyed when observers had detected (a) 50% of the total species, (b) 90% of the species, and (c) 100% of the species. See Methods for description of rarefaction curves.*

Rarefaction curves for passerines recorded within 150 m during 5-minute counts similarly showed that E(*S*) varied with level of sampling, but the relative rankings among ecological sections were much more consistent (Table 10; Fig. 15b). Baird Southern Mountains/Kiana Hills had the highest number of expected species and Western Brooks Foothills and Noatak Basin had the lowest. Still sharply increasing rarefaction slopes from Interior Forested Lowlands and Interior Highlands suggested many more species would have been recorded in those ecological sections with higher levels of sampling (Fig. 15b).

Community Similarity

Generally, ecological sections that were in close proximity to each other and shared borders (Fig. 7) had similar communities of birds (i.e., their shared species occurred in similar proportions; Tables 11a, b). Values for the Morisita-Horn Index were high for adjacent sections (e.g., Chukchi Sea Coastal Plain:Western Brooks Foothills, $C_{mH} = 0.90$) and low for distant sections (e.g., Chukchi Sea Coastal Plain:Interior Forested Lowlands; $C_{mH} = 0.07$; Table 11a). Community similarity was not consistently related to proximity when only passerine assemblages were considered (Table 11b), suggesting that other factors such as habitat or landscape features were more influential in determining composition of passerines among sections.

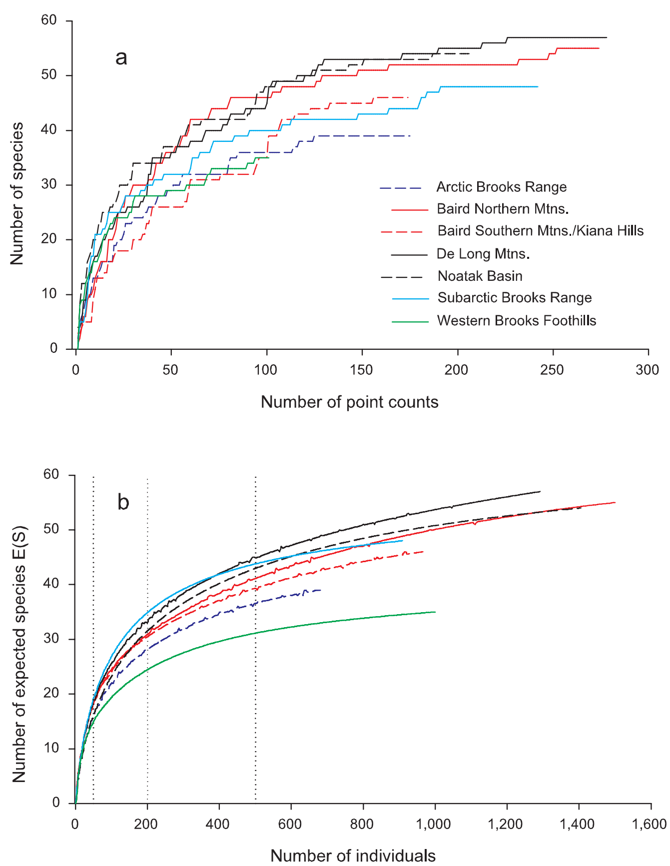

Fig. *14. (a) Species accumulation curves and (b) rarefaction curves for ecological sections based on data from 10-minute point counts. Vertical dashed lines correspond to 50, 200, and 500 individuals sampled. For example, after recording 200 individual birds in Subarctic Brooks Range (light blue line) observers would have expected to detect 35 species.*

Dominance and Evenness

Within certain ecological sections, single species clearly dominated in terms of the proportion of total numbers of birds detected during point counts. In Interior Forested Lowlands, redpolls constituted 42% of the total birds recorded out to an unlimited distance during 10-minute counts, whereas Lapland Longspurs dominated within both Endicott Mountains (40%) and Arctic Foothills (34%; Tables 6, 12). In other sections, the most dominant individual species comprised <25% of the birds detected (Table 12). Similarly, dominance values of certain passerines were very high during 5-minute counts within a 150-m radius (Tables 7, 12), with about half of all passerines detected within a section being either Lapland Longspurs (in Chukchi Sea Coastal Plain, Endicott Mountains,

Table 10. *The number of species that would be expected [E(S)] given three increasing levels of sampling (S = 50, 200, and 500 birds detected [for all species] and S = 50, 100, and 200 birds [for passerines]). To evaluate effect of sample size on spatial patterns of richness of particular assemblages of species, we present results based on (a) all species detected out to an unlimited distance during 10-minute point counts, and (b) passerine species within 150 m of the survey point during 5-minute counts. Highlighted cells indicate highest (yellow) and lowest (green) number of species that would be expected among the ecological sections at each of the sampling levels. Relative rankings among sections shifted only slightly as sample effort increased.*

	Dataset					
	All species detected during 10-minute counts			Passerines detected within 150 m during 5-minute counts		
	Sample effort			Sample effort		
Section[a]	E(50)	E(200)	E(500)	E(50)	E(100)	E(200)
Chukchi Sea Coastal Plain	16.2[b]	na[c]	na	na	na	na
Western Brooks Foothills	14.9	24.5	31.1	7.2	9.4	na
Baird Southern Mtns./ Kiana Hills	18.1	30.5	39.3	14.9	18.2	20.7
Baird Northern Mtns.	18.3	30.9	41.1	12.3	14.8	17.0
De Long Mtns.	18.4	33.5	44.9	12.9	15.9	na
Noatak Basin	16.0	31.6	43.0	8.4	11.0	13.1
Hockley-Waring Upland	10.8	na	na	na	na	na
Endicott Mtns.	11.8	18.0	na	8.6	10.7	na
Schwatka Northern Mtns.	11.4	na	na	na	na	na
Arctic Brooks Range	16.0	28.1	36.6	12.5	15.2	17.0
Subarctic Brooks Range	19.1	34.9	43.8	14.6	17.7	19.6
Interior Highlands	14.2	na	na	14.3	na	na
Interior Forested Lowlands	11.0	18.4	na	10.5	na	na
Arctic Foothills	11.2	na	na	na	na	na

a Sections ordered from west to east.

b Expected number of species based on rarefaction estimate calculated using program EstimateS (Colwell 2000).

c na = estimate not available because insufficient number of birds sampled.

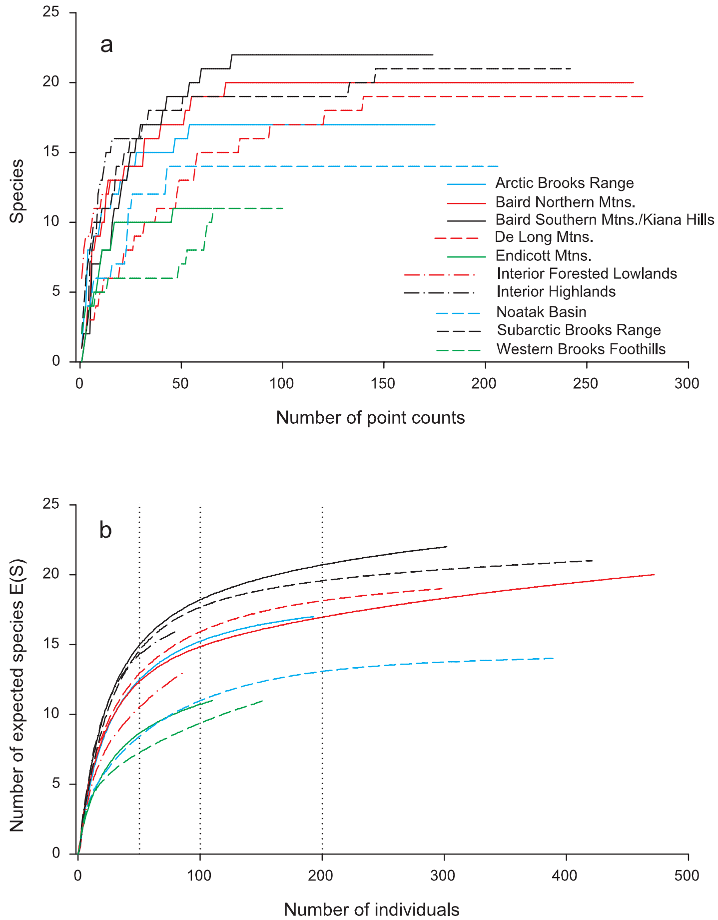

Fig. 15. *(a) Species accumulation curves and (b) rarefaction curves for passerines within ecological sections based on data from 5-minute point counts conducted during the inventory of montane-nesting birds in the Arctic Network, Alaska, late May–early June 2001–2003. Vertical dashed lines correspond to 50, 100, and 200 individuals sampled. For example, after recording 100 individual birds in Western Brooks Foothills (green dashed line) observers would have expected to detect 9 species of passerines.*

and Arctic Foothills) or redpolls (in Interior Forested Lowlands). Dominance of a single passerine was much lower in Baird Southern Mountains/Kiana Hills (Golden-crowned Sparrow) and Interior Highlands (White-crowned Sparrow), each species constituting 13% of the passerines detected in those sections.

Species evenness (i.e., the relative distribution of individuals detected among species) was generally inversely related to dominance within an ecological section (Table 12). Species evenness was high for most sections, indicating similar relative abundance of most species within sections. Values of Hurlbert's Index of evenness ranged from a low of 0.789 in Interior Forest Lowlands to a high of 0.948 in both Baird Northern Mountains and Arctic Brooks Range for all species on 10-minute counts (Table 12). The low species evenness within Interior Forested Lowlands was related to relatively higher abundance of a few species (e.g., redpolls) coupled with relatively low abundance of other species (e.g., Swainson's Thrush and Golden-crowned Sparrow; Table 6). In contrast, the high species evenness in Baird Northern Mountains and Arctic Brooks Range reflected uniformly low relative abundance of most species within these sections. Among passerines, relative abundance of species was most even in Interior Highlands (Hurlbert's Index = 0.925; Table 12) and most disparate in Arctic Foothills (0.545).

Evenness and dominance influence the rate at which species are accumulated during point counts. Ecological sections with high evenness require less sampling to record

Table 11. *Similarity matrices based on the Morisita-Horn Index comparing composition of assemblages of birds among ecological sections in the Arctic Network, Alaska, late May–early June 2001–2003. Results are presented for two datasets: (a) all species detected out to an unlimited distance during 10-minute point counts and (b) passerine species within 150 m of the survey point during 5-minute counts. Similarity indices for a particular section can be read across the row and then down the column, as outlined for Hockley-Waring Upland (HWU). The higher the index, the more similar the species assemblages are between the two sections. Highlighted cells indicate the highest (yellow) and lowest (green) similarity index for each section. For example, the bird assemblage in Hockley-Waring Upland (outlined) is most similar to that of Interior Highlands (0.59) and least similar to that of Arctic Foothills (0.04). The other green highlighted cells in the outlined region pertain to the lowest index values of other sections (e.g., BNM:HWU = 0.30; NB: HWU = 0.15, etc).*

a All species

Section[a]	CSC	WBF	BSM/ KH	BNM	DM	NB	HWU	EM	SNM	ABR	SBR	IH	IFL	AF
Chukchi Sea Coastal Plain	1.00[b]													
Western Brooks Foothills	0.90	1.00												
Baird Southern Mtns./Kiana Hills	0.28	0.32	1.00											
Baird Northern Mtns.	0.42	0.46	0.87	1.00										
De Long Mtns.	0.35	0.39	0.85	0.91	1.00									
Noatak Basin	0.52	0.53	0.52	0.72	0.73	1.00								
Hockley-Waring Upland	0.10	0.08	0.48	0.30	0.36	0.15	1.00							
Endicott Mtns.	0.40	0.36	0.33	0.40	0.32	0.53	0.11	1.00						
Schwatka Northern Mtns.	0.32	0.31	0.57	0.53	0.45	0.47	0.12	0.79	1.00					
Arctic Brooks Range	0.36	0.40	0.72	0.78	0.81	0.67	0.25	0.50	0.66	1.00				
Subarctic Brooks Range	0.15	0.17	0.83	0.76	0.85	0.54	0.44	0.29	0.52	0.78	1.00			
Interior Highlands	0.10	0.08	0.74	0.54	0.56	0.29	0.59	0.24	0.52	0.55	0.78	1.00		
Interior Forested Lowlands	0.07	0.06	0.50	0.37	0.36	0.27	0.26	0.27	0.47	0.28	0.50	0.65	1.00	
Arctic Foothills	0.43	0.40	0.33	0.44	0.35	0.59	0.04	0.94	0.80	0.55	0.30	0.19	0.23	1.00

a Sections ordered from west to east.

b Value of 1.00 indicates 100% of species are shared and they occur in the same abundance distributions (i.e., same evenness).

Table 11. *(continued)*

b Passerines only

Section[a]	CSC	WBF	BSM/ KH	BNM	DM	NB	HWU	EM	SNM	ABR	SBR	IH	IFL	AF
Chukchi Sea Coastal Plain	1.00[b]													
Western Brooks Foothills	0.96	1.00												
Baird Southern Mtns./Kiana Hills	0.26	0.28	1.00											
Baird Northern Mtns.	0.64	0.68	0.74	1.00										
De Long Mtns.	0.50	0.56	0.71	0.93	1.00									
Noatak Basin	0.91	0.93	0.41	0.81	0.73	1.00								
Hockley-Waring Upland	0.01	0.03	0.45	0.22	0.32	0.09	1.00							
Endicott Mtns.	0.85	0.83	0.14	0.42	0.26	0.63	0.06	1.00						
Schwatka Northern Mtns.	0.78	0.75	0.28	0.49	0.33	0.58	0.11	0.93	1.00					
Arctic Brooks Range	0.69	0.72	0.54	0.82	0.76	0.70	0.19	0.68	0.75	1.00				
Subarctic Brooks Range	0.47	0.49	0.63	0.78	0.81	0.58	0.38	0.36	0.42	0.81	1.00			
Interior Highlands	0.07	0.06	0.57	0.33	0.34	0.12	0.47	0.10	0.19	0.34	0.52	1.00		
Interior Forested Lowlands	0.17	0.04	0.24	0.18	0.12	0.12	0.23	0.08	0.13	0.14	0.25	0.56	1.00	
Arctic Foothills	0.67	0.64	0.19	0.48	0.42	0.58	0.00	0.64	0.52	0.64	0.50	0.05	0.00	1.00

a Sections ordered from west to east.

b Value of 1.00 indicates 100% of species are shared and they occur in the same abundance distributions (i.e., same evenness).

the majority of the species that are present; the opposite is true for sections with high dominance.

Species Diversity

After standardizing diversity measurements by sample effort across ecological sections, we found that the index of species diversity increased with additional sampling effort but that the relative rankings of sections changed only slightly (Table 13). Sampling within some sections, therefore, was insufficient for a rigorous comparison of species diversity. As sampling effort increased, the diversity index (H') for the six largest sections converged on values (3.09 to 3.18) much larger than from the smaller Western Brooks Foothills section (H' = 2.74; Table 13).

The diversity of passerine species recorded during 5-minute counts within a 150-m radius also increased as sampling effort increased, but the relative rankings of ecological sections remained remarkably consistent (Table 13). At the highest level of sampling effort, the assemblage of passerines was most diverse in the Baird Northern and Southern mountains, Arctic and Subarctic Brooks ranges, and De Long Mountains (H' = 2.37 to 2.69). Across other levels of sampling, diversity was consistently lowest in Western Brooks Foothills, Endicott Mountains, Noatak Basin, and Interior Forested Lowlands (H' = 1.52 to 1.78).

Bird–Habitat Associations

Frequency of Occurrence of Habitats at Survey Points

Most habitats were patchily distributed across the study area; only one habitat, Sparsely Vegetated, occurred within 150 m for more than half of all sample points (58%; Fig. 16). Low Shrub was also fairly ubiquitous (46% of points), while the remaining four habitats were present on less than one-third of all points. Forest occurred at the lowest overall frequency (9% of points) on the study area.

The habitats most frequently encountered at survey points varied among ecological sections (Fig. 16). Mixtures of Sparsely Vegetated, Low Shrub, and Herbaceous or Herbaceous-Tussock dominated in most sections (Western Brooks Foothills, Baird Southern Mountains/Kiana Hills, Endicott Mountains, Schwatka Northern Mountains, Arctic Brooks Range, and Arctic Foothills). Most points within Chuckchi Sea Coastal Plain and Noatak Basin also had mixtures of Low Shrub, Herbaceous, and Herbaceous-Tussock habitats, but fewer points had Sparsely Vegetated habitats. Survey points in Baird Northern and De Long mountains most frequently had mixtures of Tall and Low Shrub and Sparsely Vegetated habitats. Forests, mixed with Tall and Low Shrub habitats, occurred at most survey points in Interior Forested Lowlands and Hockley-Waring Upland. The Subarctic Brooks Range and Interior Highlands had intermediate mixtures of Forest, Tall and Low Shrub, and Sparsely Vegetated habitats.

Elevation and Percent Cover of Habitats at Survey Points

The median elevation at survey points across the study area was 537 m (Fig. 17). Ecological sections differed widely in elevation of survey points, with the median ranging from 146 m

Table 12. *Measures of dominance and evenness in assemblages of species within ecological sections during the inventory of montane-nesting birds in the Arctic Network, Alaska, late May–early June 2001–2003. To assess composition of particular assemblages across the landscape, we present data based on (a) all species detected out to an unlimited distance during 10-minute point counts and (b) passerine species within 150 m of the survey point during 5-minute counts. The dominance value for a given section is the proportion of all birds detected that belonged to the single most common species in that section. Evenness values range from 0 to 1 and approach 1 as all species within an assemblage become equally common. Highlighted cells indicate highest (yellow) and lowest (green) values within each column. For example, Interior Forested Lowlands had the highest dominance value among all sections when considering all species, with 42% of the detections in that section being Redpoll spp.; this contributed to this section's relatively low score for species evenness (0.789). In the Baird Northern Mtns. in contrast, the maximum percentage of detections by a single species was 9% (Redpoll spp.), resulting in this region's very high evenness score (0.948).*

	Dominance		Evenness[a]	
Section[b]	**All species**	**Passerines**	**All species**	**Passerines**
Chukchi Sea Coastal Plain	0.15	0.45	0.925	0.697
Western Brooks Foothills	0.18	0.39	0.911	0.739
Baird Southern Mtns./Kiana Hills	0.13	0.13	0.940	0.923
Baird Northern Mtns.	0.09	0.20	0.948	0.884
De Long Mtns.	0.11	0.21	0.944	0.883
Noatak Basin	0.14	0.36	0.938	0.768
Hockley-Waring Upland	0.24	0.26	0.870	0.830
Endicott Mtns.	0.40	0.57	0.806	0.662
Schwatka Northern Mtns.	0.20	0.43	0.869	0.786
Subarctic Brooks Range	0.14	0.19	0.941	0.918
Arctic Brooks Range	0.11	0.22	0.948	0.887
Interior Highlands	0.17	0.13	0.916	0.925
Interior Forested Lowlands	0.42	0.45	0.789	0.756
Arctic Foothills	0.34	0.55	0.827	0.545

a Evenness measured using Hurlbert's (1971) probability of interspecific encounter.

b Sections ordered from west to east.

in Chukchi Sea Coastal Plain to 991 m in Arctic Brooks Range; elevation was highest in the eastern mountain ranges (Endicott, Schwatka, Brooks ranges) and lowest in the near-coast sections, the Noatak Basin, and the Interior Forested Lowlands (Fig. 17). Generally, sections with higher median elevations also had greater variability in elevation among survey points as indicated by the breadth between 25th and 75th percentiles (interquartile range).

In general, patterns of percent cover of habitats within 150 m of the survey points were similar to their patterns of frequency of occurrence (Figs. 16 and 18). For example, the percent cover of Sparsely Vegetated habitat (median = 10%, mean = 30%) was higher than that of any other habitat type across the study area. This was followed by Herbaceous-Tussock (median = 0%, mean = 17%), Low Shrub (0%, 15%), Herbaceous (0%, 9%), Tall Shrub (0%, 6%), and Forest (0%, 5%; Fig. 18).

Percent cover of particular habitats varied extensively by ecological section (Fig. 18). For example, Forest cover was highest in Interior Forested Lowlands, Hockley-Waring Upland, and Interior Highlands, varied sporadically in Subarctic Brooks Range, and was virtually absent from the other sections. Tall Shrub cover was prevalent only in Hockley-Waring Upland and Interior Highlands but occurred sporadically in other sections. In contrast, moderate Low Shrub cover occurred consistently across all sections except Schwakta Northern Mountains, Interior Forested Lowlands, and Arctic Foothills. Cover of Herbaceous-Tussock habitat was highly variable among and within sections whereas Herbaceous cover was consistently low. Cover of Sparsely Vegetated habitats showed the highest variability, both among and within sections.

Bird–Habitat Associations

Elevation

Different suites of species could be characterized according to the range of elevations at which they occurred relative to elevations of all points sampled across the study area (Fig. 19). Among raptors, Northern Harriers and Merlins were associated with relatively lower elevations, whereas Rough-legged Hawks and Golden Eagles were observed across a broad range of elevations.

Among shorebirds, a high-elevation suite included Wandering Tattler, Surfbird, and Baird's Sandpiper, among which >75% of all detections were above 550, 700, and 800 m, respectively (Fig. 19). In contrast, Whimbrel, Bar-tailed Godwit, some sandpipers (i.e., Semipalmated, Western, and Least), and Wilson's Snipe were clearly affiliated with lower elevations in the study area, with >75% of all detections below 550 m. American Golden-Plover was more broadly distributed, with half of all birds detected between 200 m and 725 m. Jaegers, gulls, ptarmigan, and most passerines were generally found below 800 m (Fig. 19). However, a high-elevation component of the passerine avifauna was clearly present, with >75% of detections of Horned Lark, Violet-green Swallow, Northern Wheatear, American Pipit, Snow Bunting, and Gray-crowned Rosy-Finch occurring above 550 m (Fig. 19).

Table 13. *Estimates of species diversity (H') given three increasing levels of sampling (n = 50, 200, and 500 birds detected [for all species] and n = 50, 100, and 200 birds [for passerines]). To evaluate effect of sample size on spatial patterns of diversity of particular assemblages of species, we present results based on (a) all species detected out to an unlimited distance during 10-minute point counts, and (b) passerine species within 150 m of the survey point during 5-minute counts. H' varies from 0 for assemblages with only a single taxon to high values for assemblages with many taxa, each with few individuals. Highlighted cells indicate highest (yellow) and lowest (green) diversity indices among the ecological sections at each of the sampling levels. Relative rankings among sections shifted only slightly as sample effort increased.*

	Dataset					
	All species detected during 10-minute counts			Passerines detected within 150 m during 5-minute counts		
	Sample effort			Sample effort		
Section[a]	**50**	**200**	**500**	**50**	**100**	**200**
Chukchi Sea Coastal Plain	2.55[b]	na[c]	na	na	na	na
Western Brooks Foothills	2.41	2.65	2.74	1.52	1.59	na
Baird Southern Mtns./ Kiana Hills	2.65	2.97	3.09	2.47	2.61	2.69
Baird Northern Mtns.	2.67	3.01	3.13	2.18	2.30	2.37
De Long Mtns.	2.66	3.05	3.18	2.21	2.35	2.41
Noatak Basin	2.42	2.93	3.10	1.64	1.71	1.78
Hockley-Waring Upland	2.09	na	na	na	na	na
Endicott Mtns.	1.90	2.06	na	1.53	1.61	na
Schwatka Northern Mtns.	2.07	na	na	na	na	na
Arctic Brooks Range	2.48	2.93	3.10	2.21	2.35	2.40
Subarctic Brooks Range	2.61	3.02	3.18	2.36	2.54	2.67
Interior Highlands	2.41	na	na	2.48	na	na
Interior Forested Lowlands	1.80	2.10	na	1.72	na	na
Arctic Foothills	1.98	na	na	na	na	na

a Sections ordered from west to east.

b Species diversity (H') based on rarefaction estimate of the Shannon Index calculated using program EstimateS Colwell 2000).

c na = estimate not available because insufficient number of birds sampled.

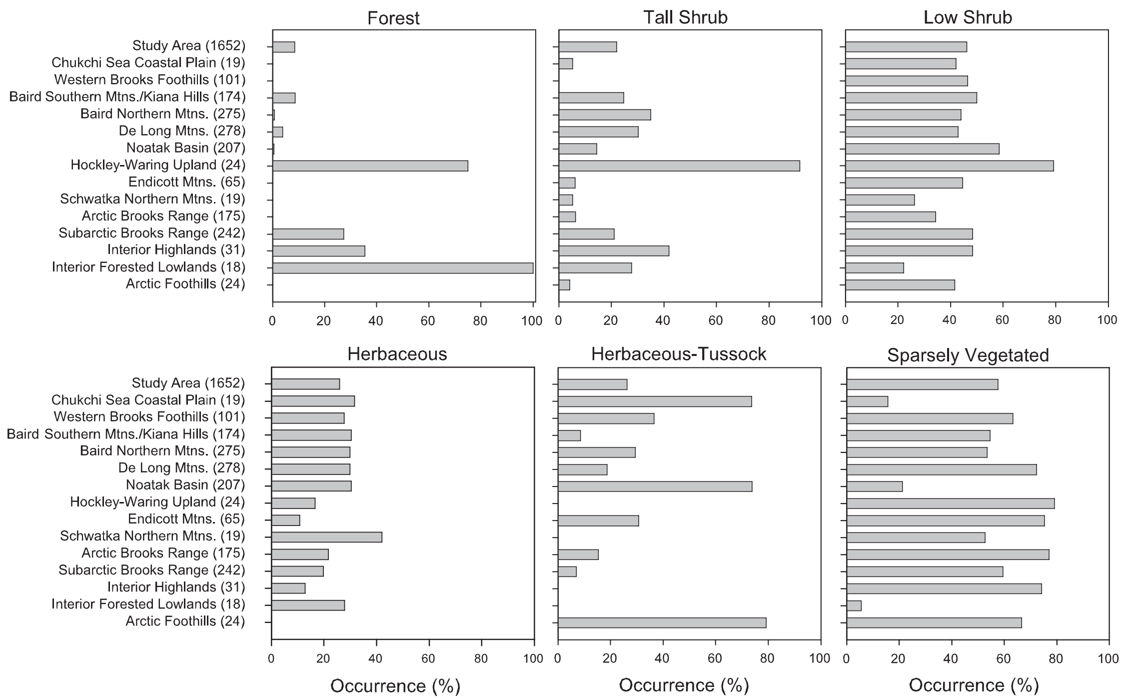

Fig. *16* *Percent occurrence of habitats within 150-m radius circle of points surveyed within the study area and each ecological section during the inventory of montane-nesting birds in the Arctic Network, Alaska, 2001–2003. Number of points surveyed in each area is shown in parentheses.*

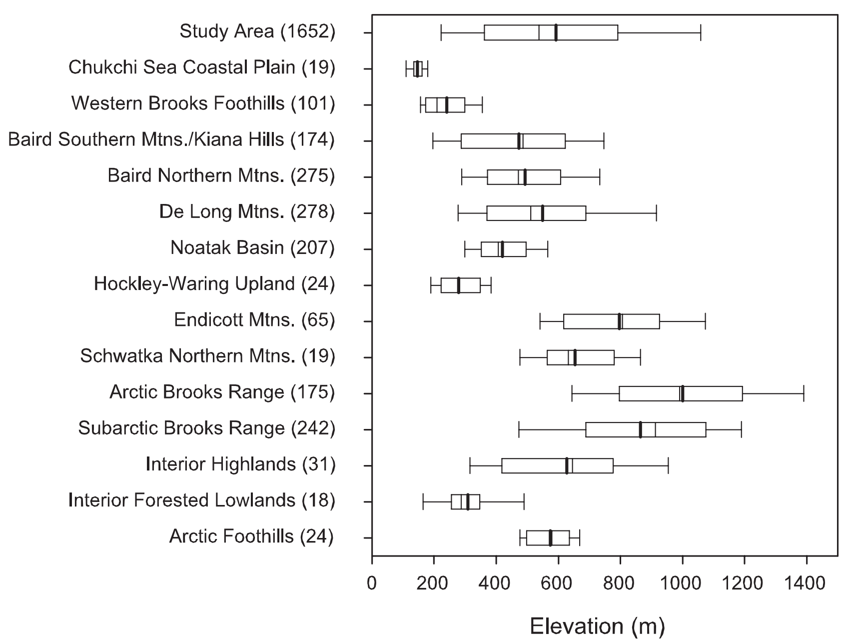

Fig. *17.* *Elevation of survey points in each ecological section during the inventory of montane-nesting birds in the Arctic Network, Alaska, 2001–2003. Box plots show median (thin vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Thick vertical line shows mean elevation. Number of points surveyed in each area is shown in parentheses.*

Habitat

Many species of birds showed strong associations with particular habitat types (Fig. 20). For example, the points at which Northern Harriers were recorded generally had higher percent cover of Herbaceous-Tussock and Low Shrub habitats than points sampled across the study area (Figs. 18 and 20), while Merlins were more strongly associated with Tall Shrub habitat. Points at which American Golden-Plovers occurred had more Herbaceous and Sparsely Vegetated habitats, whereas Whimbrel, Bar-tailed Godwits, and a whole suite of lower-elevation shorebirds were more greatly associated with Herbaceous-Tussock habitat. The high-elevation shorebirds (Wandering Tattler, Surfbird, Baird's Sandpiper) occurred at points with high percent cover of Sparsely Vegetated habitat (Fig. 20).

Willow and Rock ptarmigan were clearly associated with different habitats; Willow Ptarmigan were detected at points with higher percent cover of Herbaceous-Tussock and Low Shrub habitats, whereas Rock Ptarmigan occurred more frequently in areas with Sparsely Vegetated habitat (Fig. 21). Among passerines, there was a clear assemblage that was strongly associated with Forest habitat (e.g., Ruby-crowned Kinglet; Gray-cheeked, Swainson's, and Varied thrushes; Yellow-rumped Warbler; and Dark-eyed Junco; Fig. 21). Areas with relatively high percent cover of Tall and Low Shrub habitats were used by

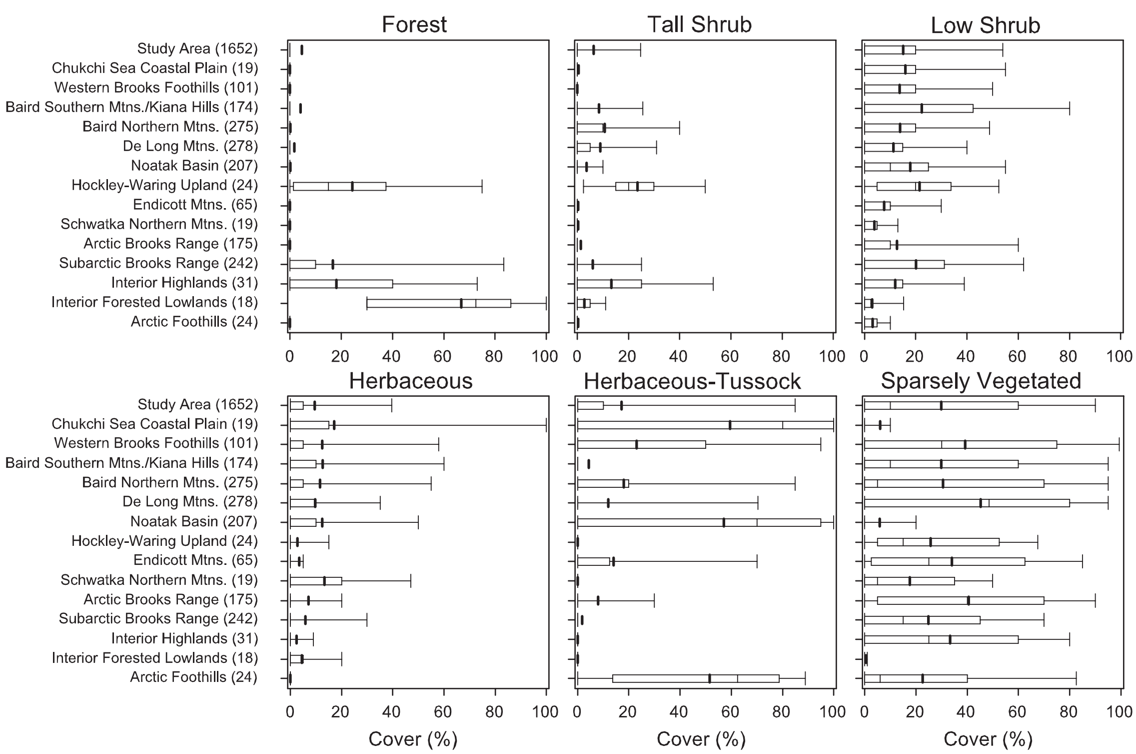

Fig. *18. Percent cover of habitats within 150-m radius circle of points surveyed within the study area and each ecological section. Box plots show median (thin vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Thick vertical line shows mean percent cover. Number of points surveyed in each area is shown in parentheses.*

some of these forest species as well as an array of warblers and sparrows. Certain species, such as Eastern Yellow Wagtail, Savannah Sparrow, and Lapland Longspur, occurred at points with relatively high percent cover of Herbaceous-Tussock habitat. The high-elevation suite of passerines (Horned Lark, Northern Wheatear, American Pipit, Snow Bunting, and Gray-crowned Rosy-Finch) occurred in areas with high percent cover of Sparsely Vegetated habitat.

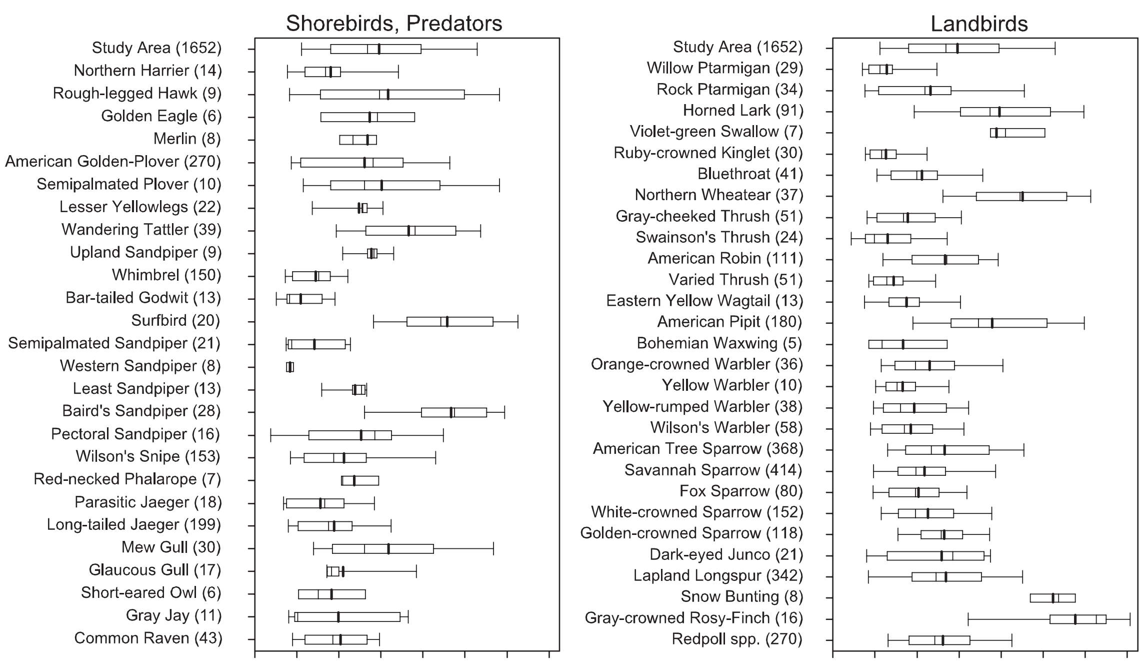

Fig. *19.* *Elevation at points where birds were detected. Box plots show median (thin vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Thick vertical line shows mean elevation. Number of detections for each species is shown in parentheses.*

DISCUSSION

The 2001–2003 inventory of birds inhabiting montane areas of Alaska's Arctic Network of National Parks was unprecedented in several respects. Foremost was the size of the study area, a complex of five parks and preserves that collectively represent about 25% of all National Park Service lands. Equally daunting was implementing a survey protocol over a vast, largely unpopulated, and roadless area that is inherently difficult to work in due to the steep mountains and glacier-carved valleys that dominate the landscape. And finally, many of the birds that nest in montane areas, the defining feature of the Arctic Network, occur in very low densities in disjunct distributions. These and other peculiar life history traits mandated special consideration in the design of the inventory.

In the end, the above challenges were met and our primary goal of documenting the occurrence of a substantial portion of the montane-nesting avifauna in the Arctic Network was achieved. In addition, we produced a comprehensive assessment of the breeding range and habitat associations for a majority of the species encountered, including 41 species of concern. But probably more importantly, we designed and tested a protocol that can be used to conduct additional inventories and to monitor the distribution, abundance, and density of birds over expansive landscapes.

In the following, we discuss several aspects of our findings and present an evaluation of the overall sampling protocol and the effectiveness of the design in meeting our objectives.

Inventory

Were the Goals Achieved?

The primary goals of the study were to (1) document the occurrence of 90% of the species of birds likely to occur in montane habitats of each park, and (2) determine the distribution and relative abundance of species of special concern in each park. We initially estimated that 147 species of birds were likely to occur in montane habitats of the Arctic Network, yet we documented the presence and delineated the distributions of only 115 species, 78% of those expected. Being able to achieve the 90% criterion during our sampling window proved unrealistic for several reasons. The main one was that the criterion represented the avifauna expected in the Arctic Network throughout the annual cycle. Thus, the expected total included not only locally breeding birds, the group we focused on, but also migrants. The critical factor in detecting either of these groups (as it relates to conducting an inventory) is understanding their timing of occurrence.

The breeding cycle for species occupying similar ecological niches is generally synchronized in the Arctic, but across groups the timing of breeding may be offset by several weeks. For instance, birds that nest at higher elevation, such as many shorebirds, raptors, and some passerines, begin nesting early because most place their nests on the ground when appropriate habitat becomes available through exposure or melt-off. On the other hand, arboreal-nesting passerine species are generally restricted to riparian habitats in

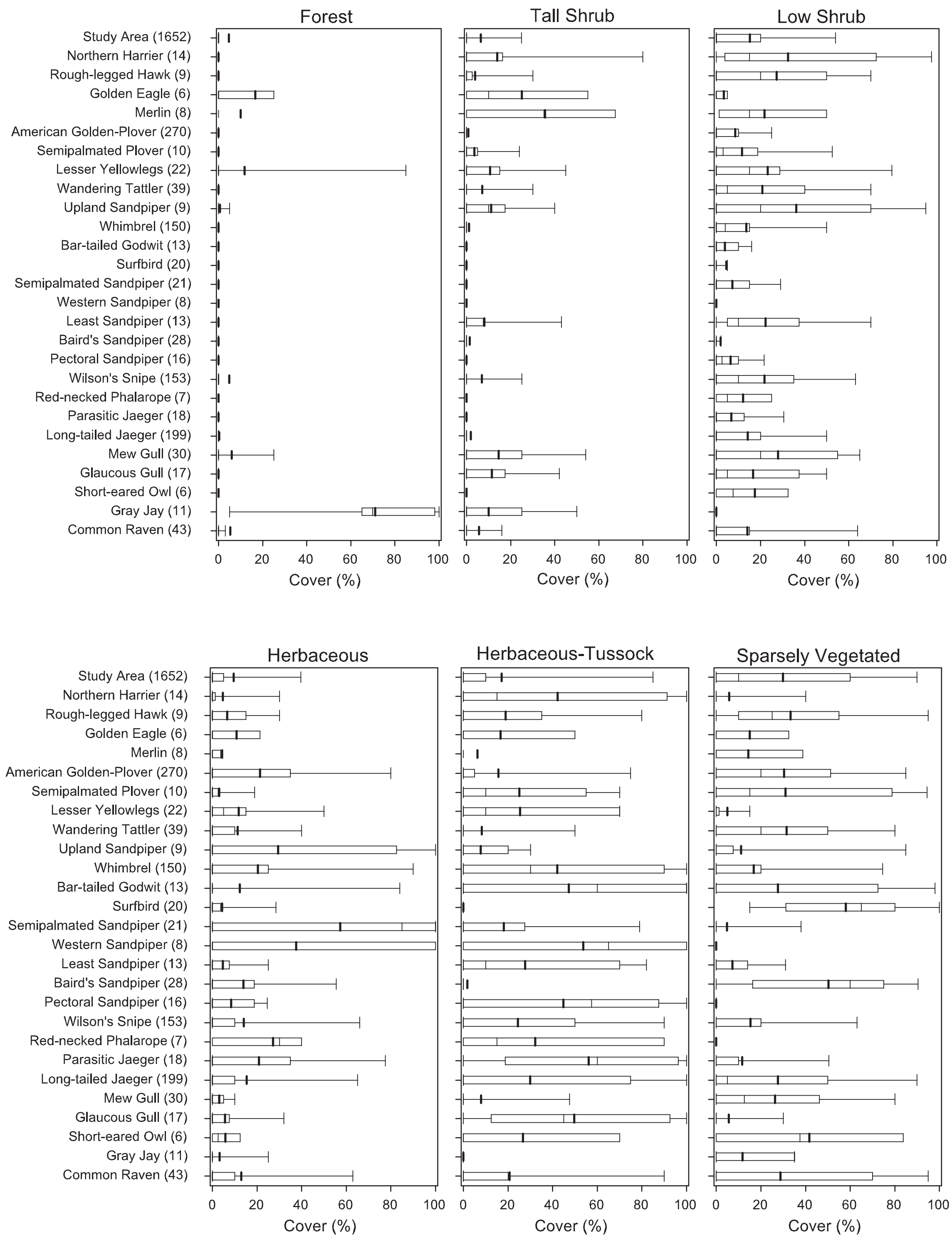

Fig. *20.* *Percent cover of habitats within 150-m radius circle at points where shorebirds and potential avian predators were surveyed. Box plots show median (thin vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Thick vertical line shows mean percent cover. Number of detections for each species is shown in parentheses.*

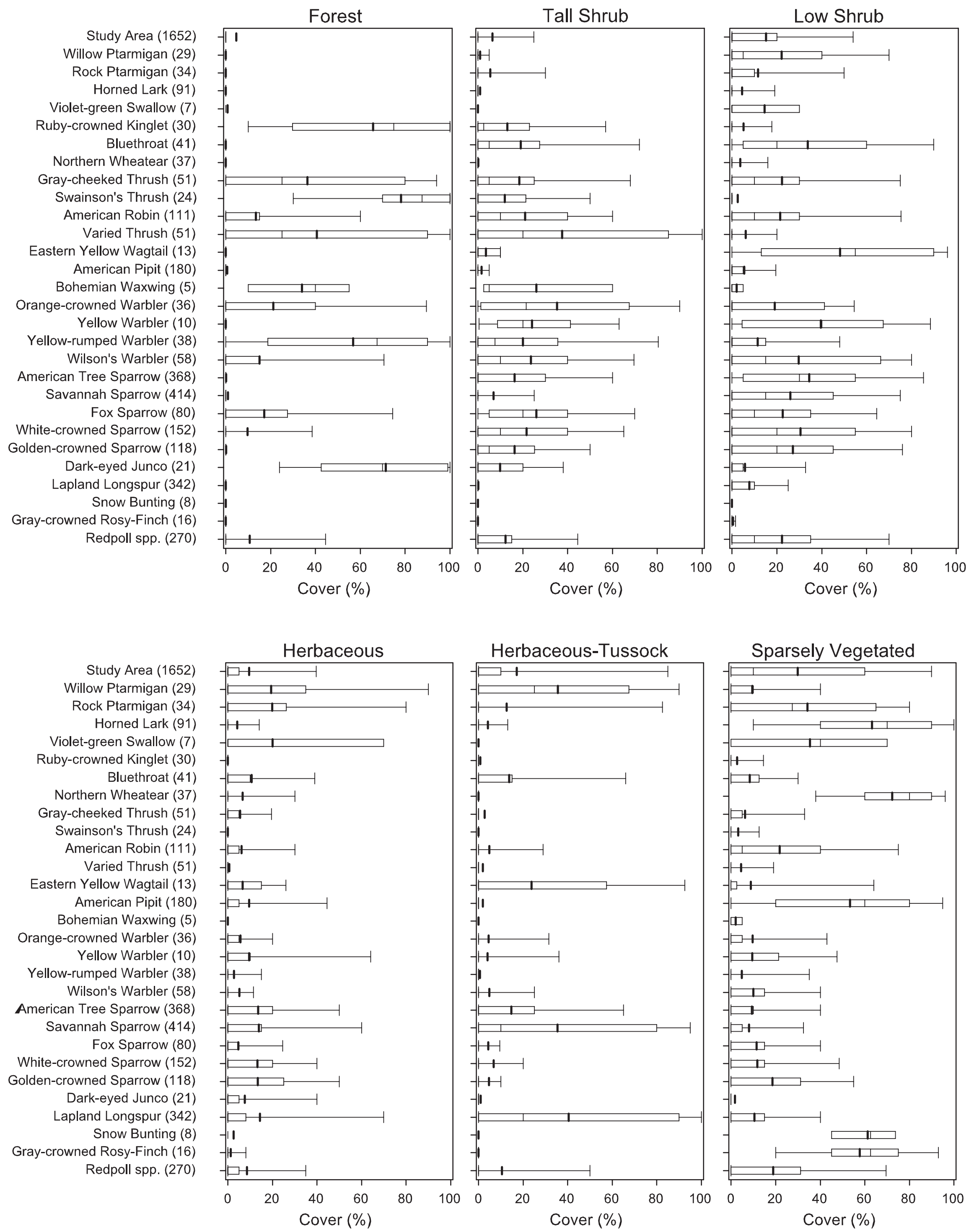

Fig. *21. Percent cover of habitats within 150-m radius circle at points where landbirds were surveyed. Box plots show median (thin vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Thick vertical line shows mean percent cover. Number of detections for each species is shown in parentheses.*

valleys and along drainages, and these areas tend to hold snow and only become available later in the season.

The timing of occurrence of species that do not breed in the area, but occur only as migrants, also varies considerably. Some species may occur only during fall and not during spring migration, some may pass through during a very short period, some migrants may not normally stop over in the area except in years with adverse conditions, and yet others may have migration routes that only peripherally reach the Arctic Network and then not annually. These patterns affect the number of species that could be detected during an inventory. Realizing this beforehand, we chose to maximize the detection of species by focusing our effort on the early breeding season, when locally breeding species are active and when many migrants are passing through. Our results clearly show that our sampling effort detected almost all species that occurred in the Arctic Network during the study period (Fig. 13b). By extending the sample period a couple of weeks earlier we would likely have detected more resident species (e.g., owls; Irving 1960) and by extending sampling a couple of weeks later we likely would have detected more species of waterfowl (Fig. 11).

Species reported by previous investigators but that we failed to detect (Appendix 12) resulted from their work spanning different time periods or focusing more intently on specific habitat types. For instance, studies that sampled across seasons and over multiple years (e.g., Grinnell 1900, Irving 1960, Swanson 1998) documented more early-nesting species (e.g., Great-horned Owl), late-arriving species (e.g., Alder Flycatcher) and infrequent migrants (e.g., Sanderling, Stilt Sandpiper). Other studies that depended on transport along river corridors (e.g., McLenegan 1887; Hines 1963) encountered more riparian-nesting species (e.g., Red-necked Grebe, Belted Kingfisher) and forest-dwellers (e.g., American Three-toed Woodpecker, Northern Hawk Owl) than we did. The two species that we documented as new to the Arctic Network (Pacific Golden-Plover and Pine Siskin) were both at the northwestern limits of their ranges (Johnson and Connors 1996; Dawson 1997). Species that we documented as new to individual parks were either very infrequent migrants (e.g., Buff-breasted Sandpiper in Cape Krusenstern), which would only be detected serendipitously, or regular breeders inhabiting areas not surveyed before (e.g., Bluethroats in upland areas of Kobuk Valley).

If a future goal is simply to document species and not assess other factors such as their distribution and habitat associations, then comparatively little additional effort would be needed beyond what we invested to reach the 90% criterion. Trained crews could be deployed to (1) target early and late nesting species, (2) focus efforts on specific habitats and ecological sections where avian diversity was highest (see Table 13), and (3) visit migration corridors such as Anaktuvuk Pass or prominent river valleys like the Killik, John, and lower Noatak during periods of peak migration, particularly during the post-breeding period.

Our other primary goal was to determine the distribution and relative abundance of species of special concern in each park. The 25 species of conservation concern occurring in the Arctic Network include 11 species of shorebirds and five species of landbirds with documented population declines or highly restricted breeding distributions. Seven of these species have significant breeding concentrations within one or more of the parks and warrant particular conservation attention: Short-eared Owl, American Golden-Plover, Wandering Tattler, Whimbrel, Bar-tailed Godwit, Surfbird, and Smith's Longspur. Although the Rusty Blackbird was encountered on only three plots, this species is likely more widespread in forested wetlands in the southern portions of the network. Bering Land Bridge hosts another species of concern not found in the other parks, Bristle-thighed Curlew; this species has an extremely restricted breeding range.

In addition to these vulnerable species, the Arctic Network also supports 16 species highlighted for conservation attention because of special stewardship responsibilities. Among these, 10 occur broadly in the Arctic Network: Willow and Rock ptarmigan, Rough-legged Hawk, Gyrfalcon, Gray-cheeked and Varied thrushes, Golden-crowned Sparrow, Lapland Longspur, Snow Bunting, and Hoary Redpoll.

We were able to compile distributional profiles for those species of concern that had relatively large population sizes and were conspicuous during early breeding (e.g., American Golden-Plover, Whimbrel, Willow and Rock ptarmigan, Gray-cheeked Thrush, and Golden-crowned Sparrow). For the remaining species, we were able to map where we detected them and document the types of habitat with which they were associated. Such information may guide future efforts for management, monitoring, and research.

Our analysis of distribution for all species suggested that patterns of occurrence across ecological sections of the four parks were most strongly influenced by elevation and latitude, whose gradients reflected changes in habitat composition. In general, Sparsely Vegetated, Herbaceous-Tussock, and Low and Tall Shrub were the most important habitats for breeding birds in the Arctic Network. Not surprisingly, differences in composition of assemblages of birds and species richness were greatest between ecological sections with the most disparate habitat composition (e.g., Chukchi Sea Coastal Plain and Interior Forested Lowlands; Table 11, Fig. 16).

A significant insight into the effectiveness of our study in defining species' distributions came from a comparison with a similar avian inventory conducted in Yukon-Charley Rivers National Preserve, the nearest NPS unit to the Arctic Network (Swanson and Nigro 2003). Despite Yukon Charley being a fraction of the size of the Arctic Network study area (10,200 vs. 67,800 km^2), 115 species were recorded from both areas. Forty-nine of these were common to both areas. Notable differences in species composition between the two areas included the more species of shorebirds (26 vs. 12) and gulls and jaegers (6 vs. 2) recorded in the Arctic Network, and more species of passerines (4 more woodpeckers, 5 more flycatchers, 3 more owls, and 2 more grouse) recorded in Yukon-Charley. Most differences were in part due to obvious differences in landscape and habitat between the two areas (e.g., more forest in Yukon-Charley), but the overall later period (5–30 June) of the Yukon-Charley inventory undoubtedly contributed to the greater diversity of passerine species recorded there.

The data from our inventory provides baseline information that can be used to monitor changes in the distribution and abundance of birds over time. There are many advantages to monitoring birds on their breeding grounds, not the least of which is that the size and distribution of a breeding population can be monitored directly instead of inferred from studies of the population at other times and places during the annual cycle. This is particularly relevant for species whose nonbreeding distributions are poorly known (e.g., Eastern Yellow Wagtail and Northern Wheatear) or for those species that are widely dispersed away from the breeding grounds (e.g., Long-tailed Jaeger, Wandering Tattler, Surfbird).

Trends in distribution and abundance of birds in the Arctic Network can be monitored through replicate point count surveys conducted at regular intervals (similar to the BBS, ALMS, and PRISM). Alternatively, the status of populations can be gauged by employing intensive study methods (e.g., mark-recapture) to monitor demographic parameters (annual survival of breeding birds, productivity). Demographic modeling can then be used to help pinpoint causes of changes in status of populations and predict the effects of any environmental perturbations (e.g., climate change) on population dynamics. Land managers and researchers can use the information gathered during our inventory to identify sites and species where such programs would be appropriate. Trends in annual phenology and floristic composition of vegetation in the region can also be monitored using estimates of percent cover of habitats at sample points. In addition, the >1,400 photographs of vegetation taken at geo-referenced survey points provide the beginnings of a standardized time-series of images of montane vegetation (Sturm et al. 2001). Such images could prove useful for monitoring the effects of global climate change, which is already affecting the distribution of habitats in the Arctic (Arctic Climate Impact Assessment 2004).

RECOMMENDATIONS

Logistics

It is unlikely that an inventory of this nature and scope will be repeated by the NPS across the Arctic Network in the near future. However, it is possible that scaled-down versions will be implemented as part of a monitoring effort. The costs for helicopters, fuel, and fuel transport represented the single largest expenditure for the inventory and accounted for 79% of all operational costs. Future efforts should not only consider the types of helicopters needed but their more efficient use. For example, if less gear is required (i.e., day trips vs. overnight visits), use of smaller, more fuel efficient and less costly helicopters such as the Robinson 44 might be considered instead of turbine-powered models such as the Hughes 500 and Bell 206. To help maximize survey time, we recommend that upon arrival at a plot, crews drop their camping gear at that day's planned campsite and then travel by helicopter to the start of a transect that, if possible, terminates at or near the camp. Additional time savings for both personnel and helicopter can be achieved by deferring visits to isolated or difficult-to-access points until transitioning between plots and having the helicopter stand by while these points are surveyed. Lastly, cost savings could be accrued by using snowmachines to cache and retrieve fuel storage containers instead of flying fuel into and out of sites.

Like Swanson and Nigro (2003), we also found it important to have several contingency plans available when coordinating logistics so that data collection could proceed regardless of changing circumstances. We likewise found that it was important that participants were comfortable working in wilderness situations so they could focus on data collection during the physically tasking two weeks of field work. In general, the efficiency of data collection increased (in terms of points per unit time) when participants were suitably familiar with the study design and data requirements so that they could quickly make appropriate decisions about alternate placement of routes and campsites.

Methodology

Point count methodology with distance estimation had both advantages and drawbacks relative to the goals of this study. Conducting surveys at fixed points allowed us to document the avifauna present relative to habitat within a prescribed distance of each point. Line transects in such steep terrain would have been unsafe and inefficient and would not have allowed ready analysis of habitat associations. Recording new species detected between survey points allowed a more complete inventory of each plot than point counts alone. Although distance estimation requires extensive training, it allows estimation of densities for those species with adequate numbers of detections, given certain assumptions are met (Buckland et al. 2004).

Many of the montane-nesting species, particularly shorebirds and raptors, had extremely low detection rates, so we were unable to obtain sufficient numbers of detections to estimate density for them. The most straightforward way to increase number of required detections (60 to 80 per species) would be to increase the number of point counts conducted per unit time or area. This could be accomplished by (1) conducting a single 10-minute count at each point rather than separate 10-minute and 5-minute counts; (2) shortening the distance (for example, to 250 m instead of 500 m) between points; (3) deploying more crews (our crews were able to conduct an average of 10 point counts per day); and (4) lengthening the seasonal sampling window. For passerines, sampling could also be concentrated during the diurnal window in which singing rates are highest (i.e., 0200– to 0800 hours ADT). However, doing so would preclude any direct comparisons with counts conducted outside this window, when detection rates are significantly lower but very stable. An alternative would be to conduct counts throughout the entire daylight period and model the effect of time of day as a covariate. All of these alternatives have their pros and cons and whichever methods are chosen should depend ultimately on the goals of the study.

Additional Analyses

To fully use the data collected during the inventory, several additional analyses can be performed. First, the density of birds by ecoregion can be estimated for those species (several passerines, a few shorebirds, jaegers, and ptarmigan) with sufficient detections (60 to 80) by using program DISTANCE (Thomas et al. 2003) to model detection probabilities. The ability to estimate density for the remainder of the species will increase as species-specific distance information is added to an Alaska-wide database populated by and maintained at the USGS-ASC (Handel and Cady 2004). Second, logistic regression models can be developed to predict occurrence of species based on habitat classes and landscape characteristics (e.g., elevation, slope). And third, resource selection probability functions can be estimated using those variables for which information is available on network-wide GIS (e.g., elevation, slope) by comparing points used by each species with a randomly selected sample of points available in the study area. Additional analyses could ensue following standardization of available digital land cover maps (Markon and Wesser 1998; Helt et al. 2000) to enable habitat variables to be assessed on a network-wide basis. Finally, power analyses can be conducted using the results from this study to design efficient and cost-effective monitoring plans for species or groups of species targeted by the Arctic Network's Monitoring Program.

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APPENDIX 1
COMMON AND SCIENTIFIC NAMES OF BIRDS REFERENCED IN THIS REPORT

Names and phylogenetic sequence follow *The A.O.U. Checklist of North American Birds* (7th ed., 1998) and supplements. Differences between the nomenclatures of A.O.U. and the Integrated Taxonomic Information System (ITIS 2004) are footnoted.

Common name	Scientific name
Waterfowl	
Greater White-fronted Goose	*Anser albifrons*
Snow Goose	*Chen caerulescens*
Brant	*Branta bernicla*
Canada Goose	*B. canadensis*
Tundra Swan	*Cygnus columbianus*
American Wigeon	*Anas americana*
Mallard	*A. platyrhynchos*
Northern Shoveler	*A. clypeata*
Northern Pintail	*A. acuta*
Green-winged Teal	*A. crecca*
Greater Scaup	*Aythya marila*
Harlequin Duck	*Histrionicus histrionicus*
Surf Scoter	*Melanitta perspicillata*
White-winged Scoter	*M. fusca*
Black Scoter	*M. nigra*
Long-tailed Duck[b]	*Clangula hyemalis*
Bufflehead	*Bucephala albeola*
Common Merganser	*Mergus merganser*
Red-breasted Merganser	*M. serrator*
Grouse and Ptarmigan	
Spruce Grouse	*Falcipennis canadensis*
Willow Ptarmigan	*Lagopus lagopus*
Rock Ptarmigan	*L. mutus*
Loons and Grebes	
Red-throated Loon	*Gavia stellata*
Pacific Loon	*G. pacifica*
Common Loon	*G. immer*
Yellow-billed Loon	*G. adamsii*
Red-necked Grebe	*Podiceps grisegena*
Hawks, Falcons, Cranes	
Northern Harrier	*Circus cyaneus*
Northern Goshawk	*Accipiter gentilis*
Red-tailed Hawk	*Buteo jamaicensis*
Rough-legged Hawk	*B. lagopus*
Golden Eagle	*Aquila chrysaetos*
Merlin	*Falco columbarius*
Gyrfalcon	*F. rusticolus*
Peregrine Falcon	*F. peregrinus*
Sandhill Crane	*Grus canadensis*
Shorebirds, cont.	
American Golden-Plover	*P. dominica*
Pacific Golden-Plover	*P. fulva*
Semipalmated Plover	*Charadrius semipalmatus*
Greater Yellowlegs	*Tringa melanoleuca*
Lesser Yellowlegs	*T. flavipes*
Solitary Sandpiper	*T. solitaria*
Wandering Tattler	*Heteroscelus incanus*
Spotted Sandpiper[a]	*Actitis macularius*
Upland Sandpiper	*Bartramia longicauda*
Whimbrel	*Numenius phaeopus*
Bristle-thighed Curlew	*N. tahitiensis*
Hudsonian Godwit	*Limosa haemastica*
Bar-tailed Godwit	*L. lapponica*
Surfbird	*Aphriza virgata*
Great Knot	*Calidris tenuirostris*
Red Knot	*C. canutus*
Semipalmated Sandpiper	*C. pusilla*
Western Sandpiper	*C. mauri*
Least Sandpiper	*C. minutilla*
Baird's Sandpiper	*C. bairdii*
Pectoral Sandpiper	*C. melanotos*
Rock Sandpiper	*C. ptilocnemis*
Dunlin	*C. alpina*
Buff-breasted Sandpiper	*Tryngites subruficollis*
Long-billed Dowitcher	*Limnodromous scolopaceus*
Wilson's Snipe[c]	*Gallinago delicata*
Red-necked Phalarope	*Phalaropus lobatus*
Red Phalarope[d]	*P. fulicarius*
Jaegers, Gulls, and Terns	
Pomarine Jaeger	*Stercorarius pomarinus*
Parasitic Jaeger	*S. parasiticus*
Long-tailed Jaeger	*S. longicaudus*
Mew Gull	*Larus canus*
Herring Gull	*L. argentatus*
Glaucous Gull	*L. hyperboreus*
Arctic Tern	*Sterna paradisaea*
Owls	
Great Horned Owl	*Bubo virginianus*
Northern Hawk Owl	*Surnia ulula*
Short-eared Owl	*Asio flammeus*

Common name	Scientific name
Shorebirds	
Black-bellied Plover	*Pluvialis squatarola*
Woodpeckers	
American Three-Toed Woodpecker[e]	*Picoides dorsalis*
Northern Flicker	*Colaptes auratus*
Flycatchers	
Olive-sided Flycatcher	*Contopus cooperi*
Alder Flycatcher	*Empidonax alnorum*
Say's Phoebe	*Sayornis saya*
Shrikes	
Northern Shrike	*Lanius excubitor*
Jays and Ravens	
Gray Jay	*Perisoreus canadensis*
Common Raven	*Corvus corax*
Larks and Swallows	
Horned Lark	*Eremophila alpestris*
Tree Swallow	*Tachycineta bicolor*
Violet-green Swallow	*T. thalassina*
Bank Swallow	*Riparia riparia*
Cliff Swallow[g]	*Petrochelidon pyrrhonota*
Chickadees	
Boreal Chickadee[h]	*Poecile hudsonica*
Kinglets and Thrushes	
Ruby-crowned Kinglet	*Regulus calendula*
Arctic Warbler	*Phylloscopus borealis*
Bluethroat	*Luscinia svecica*
Northern Wheatear	*Oenanthe oenanthe*
Townsend's Solitaire	*Myadestes townsendi*
Gray-cheeked Thrush	*Catharus minimus*
Swainson's Thrush	*C. ustulatus*
Hermit Thrush	*C. guttatus*
American Robin	*Turdus migratorius*
Varied Thrush	*Ixoreus naevius*
Kingfishers	
Belted Kingfisher	*Ceryle alcyon*
Wagtails, Pipits, Waxwings	
Eastern Yellow Wagtail[f]	*Motacilla tschutschensis*
American Pipit	*Anthus rubescens*
Bohemian Waxwing	*Bombycilla garrulus*
Warblers	
Orange-crowned Warbler	*Vermivora celata*
Yellow Warbler	*Dendroica petechia*
Yellow-rumped Warbler	*D. coronata*
Blackpoll Warbler	*D. striata*
Northern Waterthrush	*Seiurus noveboracensis*
Wilson's Warbler	*Wilsonia pusilla*
Sparrows	
American Tree Sparrow	*Spizella arborea*
Savannah Sparrow	*Passerculus sandwichensis*
Fox Sparrow	*Passerella iliaca*
Lincoln's Sparrow	*Melospiza lincolnii*
White-crowned Sparrow	*Zonotrichia leucophrys*
Golden-crowned Sparrow	*Z. atricapilla*
Dark-eyed Junco	*Junco hyemalis*
Lapland Longspur	*Calcarius lapponicus*
Smith's Longspur	*C. pictus*
Snow Bunting	*Plectrophenax nivalis*
Blackbirds	
Rusty Blackbird	*Euphagus carolinus*
Finches	
Gray-crowned Rosy-Finch[i]	*Leucosticte tephrocotis*
Pine Grosbeak	*Pinicola enucleator*
White-winged Crossbill	*Loxia leucoptera*
Common Redpoll	*Carduelis flammea*
Hoary Redpoll	*C. hornemanni*
Pine Siskin	*C. pinus*

a Scientific name in ITIS = *Actitis macularia*
b Common name in ITIS = Oldsquaw
c Common (scientific name) in ITIS = Common Snipe (*Gallinago gallinago*)
d Scientific name in ITIS = *P. fulicaria*
e Common (scientific name) in ITIS = Three-toed Woodpecker (*Picoides tridactylus*)
f Common (scientific name) in ITIS = Yellow Wagtail (*Motacilla flava*)
g Scientific name in ITIS = *Hirundo pyrrhonota*
h Scientific name in ITIS = *Poecile hudsonicus*
i Common name in ITIS = Rosy Finch

APPENDIX 2
NUMBER OF PLOTS ALLOCATED FOR SAMPLING WITHIN EACH GROUP OF ECOLOGICAL SECTIONS SURVEYED

These are shown relative to the percent of the entire study area and of each individual park that each section comprises.

				Percent (%) of area[a]				
Section/subsection	Sub-section code	Sub-section group[b]	Number of plots allocated	All parks combined	Cape Krusen-stern	Noatak	Kobuk Valley	Gates of the Arctic
Chukchi Sea Coastal Plain								
Wulik Lowland	WUL		1	0.2	12.7			
Western Brooks Foothills								
Igichuk Hills, tundra	IHT		2	0.6	30.7			
Mulgrave Hills	MLH		2	1.1	56.6			
Baird Southern Mtns./ Kiana Hills[c]								
Shiliak Hills	SHH	A	1	0.1		0.3		
Squirrel Mountains	SQM	A		0.4		1.0		
Akiak Foothills	AFH		1	1.6			22.5	
Kallarichuk Hills	KLH	B	1	0.5			7.4	
Salmon River Hills	SRH	B		0.5			7.3	
Akiak Mountains	AKM		3	2.7		0.1	38.0	
Jade Mountains	JDM	C	1	0.0			0.6	
Tukpahlearik Mountains	TKM	C		0.4		0.1	5.1	
Baird Northern Mountains								
Asik Mountain	ASM	D		0.1		0.2		
Eli Mountains	ELM	D	1	0.5		1.2		
Kikmiksot Mountains	KIM	D		0.3		0.8		
Tututalak Mountains	TUM	E	2	2.7		6.9		
Agashashok Mountains	AAM	F		0.4		1.1		
Anaktok Mountains	ATM	F	2	0.2		0.2	1.9	
Nakolik Mountains	NAM	F		0.5		1.2		
Kunyanak Mountains	KYM	G		0.8		1.4	3.9	
Natmotirak Mountains	NTM	G	2	0.7		1.6	1.0	
Skajit Mountains	SKM	G		0.2		0.3	0.5	
Eli Foothills	ELH		1	0.5		1.4		
Aklumayuak Foothills	AKH		2	2.2		5.6	0.5	
Natmotirak Foothills	NTH		2	1.1		2.6	0.7	
Imelyak Foothillls	IMH		1	1.2		3.2		
Angayukaqsraq Mountains	AYM		1	0.3		0.1	3.8	

				Percent (%) of area[a]				
Section/subsection	Sub-section code	Sub-section group[b]	Number of plots allocated	All parks combined	Cape Krusen-stern	Noatak	Kobuk Valley	Gates of the Arctic
De Long Mountains								
Ikalukrok Mountains	IKM	H	2	0.0		0.1		
Kelly Mountains	KEM	H		1.5		3.8		
Kokolik Mountains	KOM	H		0.3		0.8		
Sivukat Mountains	SIM	H		0.1		0.3		
Avan Mountains	AVM	I	1	0.6		1.5		
Kugururok Mountains	KUM	I		0.8		2.0		
Bastille Mountains	BAM		1	0.9		2.3		
Misheguk Mountains	MIM		1	1.1		2.7		
Imikneyak Mountains	IMM	J	1	0.6		1.6		
Kaluktavik Mountains	KLM	J		0.6		1.6		
Iggiruk Mountains	IGM		1	0.7		1.9		
Anisak Mountains	ANM		1	1.1		2.9		
Nuka Mountains	NUM	K	1	0.7		1.9		
Siniktanneyak Mountain	SNM	K		0.3		0.8		
Kelly Uplands	KEU		1	0.7		1.9		
Kaluktavik Uplands	KLU		1	1.4		3.6		
Kugururok Uplands	KUU	L	1	0.8		2.1		
Nimiuktuk Hills	NIH	L		0.6		1.4		
Noatak Basin								
Avingyak Hills	AGH	M	1	0.5		1.2		
Cutler Hills	CUH	M		0.1		0.3		
Aklumayuak Glaciated Uplands	AKU	N	1	0.5		1.2		
Avingyak Glaciated Uplands	AGU	N		0.4		0.9		
Kavachurak Glaciated Uplands	KGU		1	1.1		2.4		0.4
Middle Noatak Uplands	MNU		1	0.9		2.2		
Anisak Uplands	ANU		1	0.7		1.7		
Iggiruk Glaciated Uplands	IGU		1	1.6		4.1		
Upper Noatak Basin North	UNB		2	2.0		5.3		
Upper Noatak Basin South	UNB	O	2	2.1		5.4	0.1	
Upper Noatak Floodplain	UNF	O		0.7		1.6		0.1
Hockley-Waring Upland								
Waring Mountains	WRM		1	0.5			6.7	

				Percent (%) of area[a]				
Section/subsection	Sub-section code	Sub-section group[b]	Number of plots allocated	All parks combined	Cape Krusen-stern	Noatak	Kobuk Valley	Gates of the Arctic
Endicott Mountains								
Aniuk Mountains	AIM	P	2	2.0		5.1		
Ipnavik Mountains	IPM	P		0.3		0.7		
Nukatpiat Hills	NPH	P	1	0.6		0.6		0.6
Nukatpiat Mountains	NPM	P	1	0.7		1.0		0.6
Schwatka Northern Mountains								
Kavachurak Foothills	KVH	Q	1	0.7		1.2		0.4
Kavachurak Mountains	KVM	Q		1.4		2.1		1.2
Arctic Brooks Range								
Anaktuvuk Mountain Valley	ANV	R	8[e]	0.4				0.8
Chandler Mountain Valley	CMV	R		0.4				0.7
Endicott Mountains Noncarbonate	EMN	R		7.9				15.1
Etivluk Mountain Valley	EMVd	R		0.2				0.5
Itkillik Mountain Valley	IMV	R		0.3				0.6
Killik Mountain Valley	KIV	R		2.6				4.9
Nigu Mountain Valley[f]	NGU	R		0.8		0.6		1.0
Noatak Mountain Valley	NMV	R		1.0				2.0
Oyukak Carbonate Mountains	OCM	R		0.9				1.7
Thibodeaux Noncarbonate Mountains	TNM	R		2.1				4.1
Upper Noatak Floodplain	UNF	R		0.1				0.2
Utikok Carbonate Mountains	UCM	R		2.0				3.9
Subarctic Brooks Range								
Alatna Mountain Valley	AMV	S	13[g]	1.7				3.3
Arrigetch Peaks Granitics	APG	S		2.2				4.2
Blind Pass Mountains	BPM	S		0.0				0.1
Huntfork Noncarbonate Mountains	HFN	S		12.4				23.8
John Mountain Valley	JMV	S		2.5				4.8
Kobuk Mountain Valley	KMV	S		0.6				1.1
Koyukuk Mountain Valley	KOV	S		2.5				4.8
Mount Doonerak Mountains	MDM	S		1.1				2.0
Shulakpachak Noncarbonate Mountains	GSNMh	S		0.4				0.8
Skajit Carbonate Mountains	SCM	S		1.2				2.2
Southern Foothills-Metanoncarbonates	SFM	S		2.6				5.0
Ulaneak Mountains	ULM	S		0.3				0.6

Section/subsection	Sub-section code	Sub-section group[b]	Number of plots allocated	Percent (%) of area[a] All parks combined	Cape Krusen-stern	Noatak	Kobuk Valley	Gates of the Arctic
Interior Highlands								
Angayucham Mountains	GANM[h]	T		1.0				2.0
Jack White Range	JWR	T	1	0.0				0.0
Lockwood Hills	LOH	T		0.7				1.3
Interior Forested Lowlands								
Klikhtentotzna Creek Lowlands	KCL	U		0.1				0.1
Kobuk Lowlands-Forested	KLF	U		1.6				3.0
Kobuk Lowlands-Tundra	KLT	U		0.2				0.4
Kobuk River Floodplain	KRF	U	1	0.2				0.3
Koyukuk Lowlands	KOL	U		0.4				0.8
Koyukuk River Floodplain	KOF	U		0.2				0.3
Norutak Lake Lowlands	NLL	U		0.1				0.2
Arctic Foothills								
Anaktuvuk Foothills	ANF	V		0.0				0.0
Chandler Foothills	CHF	V		0.3				0.6
Chandler Glaciated Lowlands	CGL	V		0.1				0.2
Chandler Lowlands	CHL	V		0.3				0.6
Etivluk Foothills	EIF	V	1	0.2				0.3
Etivluk Lowlands	EIL	V		0.1				0.2
Itkillik Glaciated Lowlands	IGL	V		0.1				0.2
Killik Foothills	KIF	V		0.0				0.0
Killik Glaciated Lowlands	KGL	V		0.2				0.4
Killik Lowlands	KIL	V		0.2				0.4

a Percent of the study area and of individual parks comprised by each subsection; only parklands ≥100 m ASL included.

b Like letters denote subsections grouped by physiographic attributes for plot allocation (see text).

c These two sections combined into one stratum.

d Code for Etivluk Mountain Valley was EMV in digital layers and EIM in subsection report (Boggs and Michaelson 2001); we used EMV.

e One plot not sampled due to dangerous snow conditions.

f Labelled Nigu Glaciated Uplands in Noatak (Jorgenson et al. 2002) and Nigu Mountain Valley in Gates of the Arctic (Boggs and Michaelson 2001).

g Three plots not sampled due to dangerous snow conditions.

h These subsection codes in Gates of the Arctic conflict with codes in Noatak; we preface the Gates of the Arctic subsections with a "G".

APPENDIX 3
AREA OF ECOLOGICAL SECTIONS AND SUBSECTIONS COMPRISING THE SAMPLE UNIVERSE

Section/subsection	Area (km²) by park[a]			
	Cape Krusenstern	Noatak	Kobuk Valley	Gates of the Arctic
Chukchi Sea Coastal Plain (153)[b]				
Wulik Lowland	153			
Western Brooks Foothills (1,056)				
Igichuk Hills, tundra	371			
Mulgrave Hills	685			
Baird Southern Mtns./Kiana Hills (3,952)				
Akiak Foothills			1,007	
Akiak Mountains		14	1,698	
Jade Mountains			26	
Kallarichuk Hills			329	
Salmon River Hills			327	
Shiliak Hills		68		
Squirrel Mountains		239		
Tukpahlearik Mountains		17	229	
Baird Northern Mtns. (7,399)				
Agashashok Mountains		263		
Aklumayuak Foothills		1,375	20	
Anaktok Mountains		62	84	
Angayukaqsraq Mountains		13	171	
Asik Mountain		61		
Eli Foothills		334		
Eli Mountains		308		
Imelyak Foothills		780		
Kikmiksot Mountains		191		
Kunyanak Mountains		357	173	
Nakolik Mountains		298		
Natmotirak Foothills		653	32	
Natmotirak Mountains		388	45	
Skajit Mountains		79	22	
Tututalak Mountains		1,692		
De Long Mtns. (8,204)				
Anisak Mountains		707		
Avan Mountains		360		
Bastille Mountains		580		
Iggiruk Mountains		473		

Section/subsection	Area (km²) by park[a] Cape Krusenstern	Noatak	Kobuk Valley	Gates of the Arctic
Ikalukrok Mountains		26		
Imikneyak Mountains		405		
Kaluktavik Mountains		390		
Kaluktavik Uplands		894		
Kelly Mountains		926		
Kelly Uplands		475		
Kokolik Mountains		198		
Kugururok Mountains		487		
Kugururok Uplands		520		
Misheguk Mountains		669		
Nimiuktuk Hills		357		
Nuka Mountains		465		
Siniktanneyak Mountain		206		
Sivukat Mountains		68		
Noatak Basin (6,535)				
Aklumayuak Glaciated Uplands		307		
Anisak Uplands		427		
Avingyak Glaciated Uplands		231		
Avingyak Hills		297		
Cutler Hills		67		
Iggiruk Glaciated Uplands		1,006		
Kavachurak Glaciated Uplands		588		138
Middle Noatak Uplands		542		
Upper Noatak Basin		2,627	3	
Upper Noatak Floodplain		405		36
Hockley-Waring Upland (299)				
Waring Mountains			299	
Endicott Mtns. (2,239)				
Aniuk Mountains		1,261		
Ipnavik Mountains		175		
Nukatpiat Hills		139		212
Nukatpiat Mountains		258		195
Schwatka Northern Mtns. (804)				
Kavachurak Foothills		296		131
Kavachurak Mountains		508		400
Arctic Brooks Range (11,968)				
Anaktuvuk Mountain Valley				269
Chandler Mountain Valley				243
Endicott Mountains Noncarbonate				5,029

Section/subsection	Area (km²) by park[a] Cape Krusenstern	Noatak	Kobuk Valley	Gates of the Arctic
Etivluk Mountain Valley				152
Itkillik Mountain Valley				189
Killik Mountain Valley				1,639
Nigu Mountain Valleyc		153		344
Noatak Mountain Valley				661
Oyukak Carbonate Mountains				580
Thibodeaux Noncarbonate Mountains				1,368
Upper Noatak Floodplain				52
Utikok Carbonate Mountains				1,290
Subarctic Brooks Range (17,577)				
Alatna Mountain Valley				1,087
Arrigetch Peaks Granitics				1,412
Blind Pass Mountains				18
Huntfork Noncarbonate Mountains				7,923
John Mountain Valley				1,613
Kobuk Mountian Valley				362
Koyukuk Mountain Valley				1,598
Mount Doonerak Mountains				674
Shulakpachak Noncarbonate Mtns.				272
Skajit Carbonate Mountains				743
Southern Foothills-Metanoncarbonates Range				1,665
Ulaneak Mountains				211
Interior Highlands (1,098)				
Angayucham Mountains				655
Jack White Range				9
Lockwood Hills				435
Interior Forested Lowlands (1,746)				
Klikhtentotzna Creek Lowlands				48
Kobuk Lowlands, Forested				1,005
Kobuk Lowlands, Tundra				149
Kobuk River Floodplain				99
Koyukuk Lowlands				265
Koyukuk River Floodplain				99
Norutak Lake Lowlands				82
Arctic Foothills (1,005)				
Anaktuvuk Foothills				14
Chandler Foothills				204
Chandler Glaciated Lowlands				61

Section/subsection	Area (km²) by park[a] Cape Krusenstern	Noatak	Kobuk Valley	Gates of the Arctic
Chandler Lowlands				215
Etivluk Foothills				104
Etivluk Lowlands				69
Itkillik Glaciated Lowlands				54
Killik Foothills				10
Killik Glaciated Lowlands				138
Killik Lowlands				137
Totals	**1,209**	**24,679**	**4,464**	**33,348**

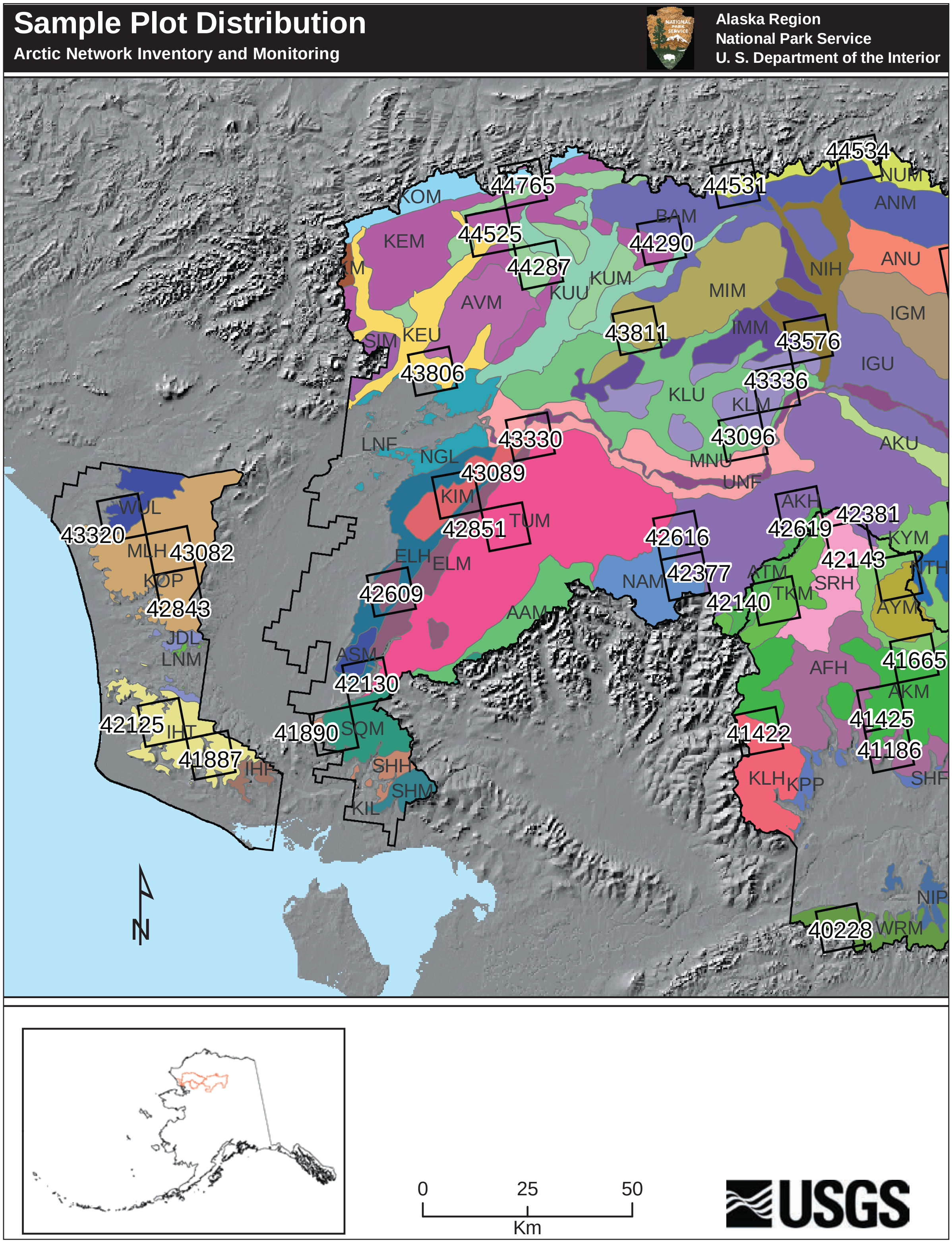
a Estimated area (km²) of subsections within the sample universe derived from digital maps by Boggs and Michaelson (2001), Swanson (2001a, b), and Jorgenson et al. (2002); excluded from the sample universe are lands within park boundaries <100 m ASL derived using digital elevation model (DEM) of USGS.

b Estimated area (km²) of sections within the sample universe.

c This subsection labelled Nigu Glaciated Uplands in Noatak (Jorgenson et al. 2002) and Nigu Mountain Valley in Gates of the Arctic (Boggs and Michaelson 2001).

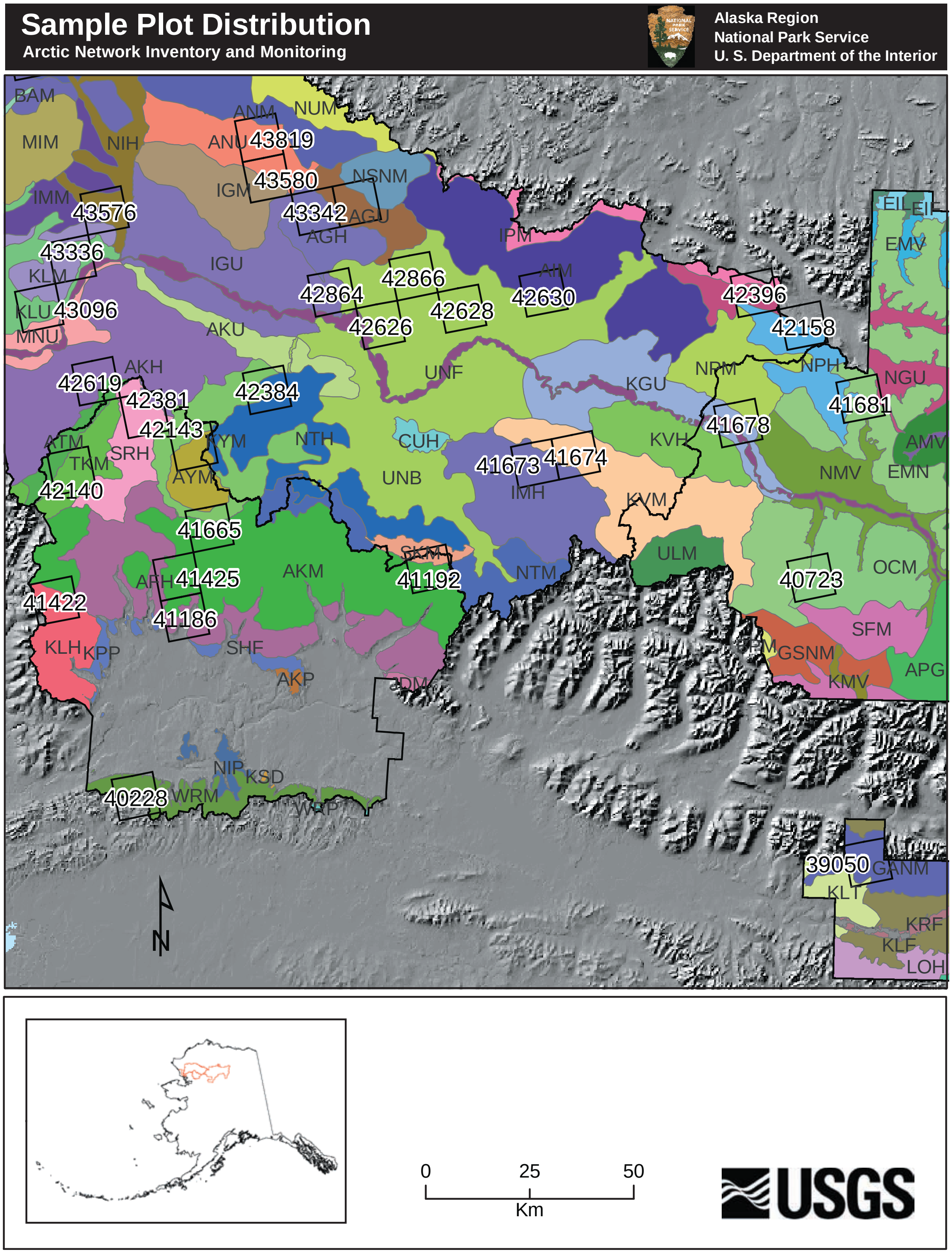
APPENDIX 4
LOCATION OF PLOTS IN RELATION TO ECOLOGICAL SUBSECTIONS IN THE WESTERN PORTION OF THE ARCTIC NETWORK, ALASKA

Numbers correspond to plot identification number in archival database. See Appendix 2 for key to subsections.



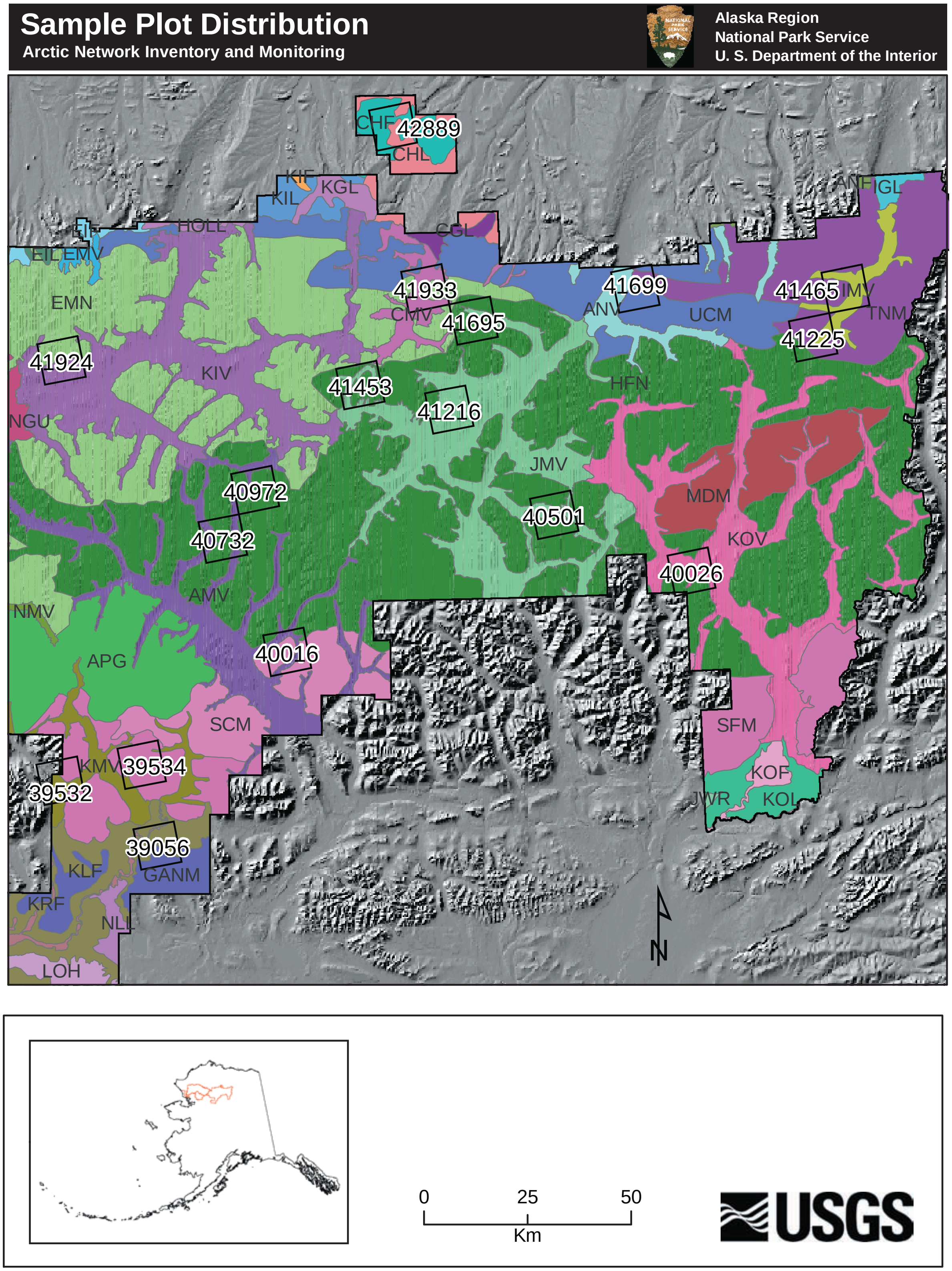
APPENDIX 5
LOCATION OF PLOTS IN RELATION TO ECOLOGICAL SUBSECTIONS IN THE CENTRAL PORTION OF THE ARCTIC NETWORK, ALASKA

Numbers correspond to plot identification number in archival database. See Appendix 2 for key to subsections.



APPENDIX 6
LOCATION OF PLOTS IN RELATION TO ECOLOGICAL SUBSECTIONS IN THE EASTERN PORTION OF THE ARCTIC NETWORK, ALASKA

Numbers correspond to plot identification number in archival database. See Appendix 2 for key to subsections.



APPENDIX 7
VEGETATION CLASSIFICATION (AFTER VIERECK ET AL. 1992) USED DURING THE MONTANE-NESTING BIRD INVENTORY OF THE ARCTIC NETWORK

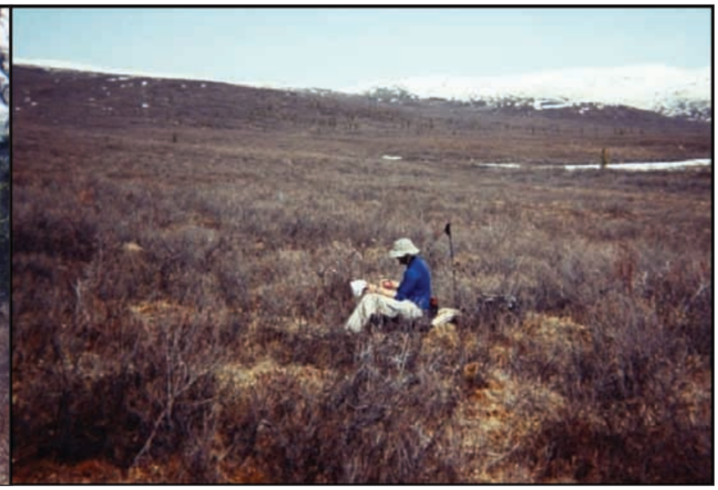
Level I	Level II	Level III
I. Forest	A. Needleleaf (conifer) forest	1. Closed needleleaf forest 2. Open needleleaf forest 3. Needleleaf woodland
	B. Broadleaf forest	1. Closed broadleaf forest 2. Open broadleaf forest 3. Broadleaf woodland
	C. Mixed forest	1. Closed mixed forest 2. Open mixed forest 3. Mixed woodland
II. Scrub	A. Dwarf tree scrub	1. Closed dwarf tree scrub 2. Open dwarf tree scrub 3. Dwarf tree scrub woodland
	B. Tall scrub	1. Closed tall scrub 2. Open tall scrub
	C. Low scrub	1. Closed low scrub 2. Open low scrub
	D. Dwarf scrub	1. Dryas dwarf scrub 2. Ericaceous dwarf scrub 3. *Willow dwarf scrub* 4. *Birch dwarf scrub*
	E. Scrub emerging from snow[a]	*1. Shrub branches poking through snow*
III. Herbaceous	A. Graminoid herbaceous	1. Dry graminoid herbaceous 2. Mesic graminoid herbaceous 3. Wet graminoid herbaceous
	B. Forb herbaceous	1. Dry forb herbaceous 2. Mesic forb herbaceous 3. Wet forb herbaceous
	C. Bryoid herbaceous	1. Bryophyte (mosses) 2. Lichens
	D. Aquatic herbaceous	1. Freshwater aquatic herbaceous 2. Brackish water aquatic herbaceous 3. Marine aquatic herbaceous
IV. Nonvegetated	*A. Snow*	*1. Complete snow cover*
	B. Water	*1. Creek, river, lake, pond*
	C. Rock	*2. Scree slope, boulder field*

a Italicized categories were added to the classification to accommodate specific situations encountered during the inventory.

APPENDIX 8
REPRESENTATIVE IMAGES OF THE SIX HABITAT COVER TYPES DESCRIBED

USGS photos by T. Van Pelt and R. Gill.

Forest



Low Shrub

Low Shrub foreground, Forest in valley

Tall Shrub

Herbaceous

Herbaceous-Tussock

Sparsely Vegetated

Sparsely Vegetated

APPENDIX 9
ANNOTATED LIST OF MAMMALS RECORDED

Wolf (*Canis lupis*)—Signs of wolves were noted on seven plots[a], all in Gates of the Arctic. The lone sighting of animals was of a group of three on plot 41695[a] on 2 June 2003.

Red fox (*Vulpes vulpes*)—This species was noted on 12 of 65 plots (18%), occurring on seven plots in Noatak, three in Cape Krusenstern, and on single plots in Kobuk Valley and Gates of the Arctic.

River otter (*Lontra canadensis*)—Tracks of this species were noted on plot 40723 in Gates of the Arctic.

Wolverine (*Gulo gulo*)—Wolverines were seen on five different plots during the study, one in Kobuk Valley (41186), two in Noatak (42630, 44534), and two (40016, 42889) in Gates of the Arctic.

Marten (*Martes americana*)—Evidence (tracks) of this species was noted only in Gates of the Arctic (plot 39056).

Least weasel (*Mustela nivalis*) or ermine *(M. erminea*)—Scat of either a least weasel or ermine was noted on plot 39056 in Gates of the Arctic.

Black bear (*Ursus americanus*)—This species was positively identified only once, from plot 39532 in Gates of the Arctic. It is likely that some of the scat attributed to brown bear, especially in forested areas along riparian corridors, was from black bears that are reportedly common throughout Noatak, Kobuk Valley, and Gates of the Arctic parks.

Brown bear (*U. arctos*)—We recorded evidence of brown bears on 40 of the 65 plots (62%) for which observations of mammals were noted. This species was seen about equally in all parks during all years of the study.

Moose (*Alces alces*)—Moose were recorded on just over half (36 of 65) of the plots and were found about equally among all four parks. The occurrence of moose in Cape Krusenstern is a recent event—having happened within the past 50 years—with numbers there and the three other northern Arctic Network parks having steadily increased over the ensuing period.

Caribou (*Rangifer tarandus*)—This was the most frequently detected mammal throughout the study area and study period, with animals recorded on 54 of 65 plots (83%). Caribou in this region belong to the western arctic herd that winters south of the parks and migrates in May and early June to calving areas northwest and summer range north of Gates of the Arctic. Most of the migration had passed before we arrived each year, but several groups of 25 to 100 animals were still present in each park in early June.

Muskox (*Ovibos moschatus*)—Muskox were recorded on three plots. Herds of 15 and between 25 and 30 animals were seen on Mt. Noak in Cape Krusenstern (plot 41887) and two animals (plot 41678) and droppings (plot 41681) were noted in the eastern Noatak Basin of Gates of the Arctic.

Dall's sheep (*Ovis dalli*)—Dall's sheep were recorded on 20 of 65 plots (31%) with observations confined to plots in Noatak (4) and Gates of the Arctic (16). In Noatak, animals were only noted in the extreme western Baird Mountains while in Gates of the Arctic they were observed in two montane areas, the Schwatka and Endicott ranges. The largest single group we observed was comprised of 30 animals.

Alaska marmot (*Marmota broweri*)—Animals were seen (6) or heard (2) on 6 of 65 plots (9%) during the study, including on four plots in Noatak (41890, 42609, 42851, 47377) and two in Gates of the Arctic (41465, 42889).

Arctic ground squirrel (*Spermophilus parryii*)—Arctic ground squirrels were the second most frequently seen mammal during the study, occurring on 47 of 65 plots (72%). They were recorded annually from all four parks and found from almost tide line in Cape Krusenstern to beyond the vegetation zone in the mountains of Noatak and Gates of the Arctic.

Red squirrel (*Tamiasciurus hudsonicus*)—This species was detected once in Kobuk Valley (plot 41186) and on four plots in Gates of the Arctic (39050, 39532, 39534, 40501).

Beaver (*Castor canadensis*)—Beaver dams, lodges, or fresh cuttings were recorded from only five plots (8%) during the study—two in Kobuk Valley (41422, 42140) and three in Gates of the Arctic (39050, 39532, 40732).

Voles and lemmings. Since the task at hand was an inventory of birds, we spent comparatively little time assessing the not uncommon small brown things scurrying at our feet, and thus many observations of small mammals were not to species. At the family level (Muridae), we recorded animals on about half of the plots (49%). Voles were recorded on 31% (n = 20) of the plots with observations spread about equally among the three years and parks. Northern red-backed (*Clethrionomys rutilus*) and tundra (*Microtus oeconomu*) voles were each identified on three plots while a single singing vole (*Microtus miurus*) was identified on plot 39532. Lemmings were only identified from Gates of the Arctic, where they were noted on 8 of the 27 (30%) plots surveyed in that park. Only brown lemmings *Lemmus trimucronatus* were identified to species and on only two plots. Collared lemmings (*Dicrostonyx groenlandicus*) have been recorded in all northern Arctic Network parks while northern bog lemmings (*Synaptomys borealis*) have been recorded only in Noatak and Gates of the Arctic.

Porcupine (*Erethizon dorsatum*)—Evidence of porcupines was recorded from 11 plots, 1 in western Noatak, 1 in extreme south Kobuk Valley, and 9 in Gates of the Arctic.

Snowshoe hare (*Lepus americanus*)—This species was recorded on nine (14%) plots: one in Cape Krusenstern, three in Noatak, two in Kobuk Valley, and three in Gates of the Arctic. During the three-year study period a single animal was seen—being eaten by a red fox. All other detections were either of droppings or tracks.

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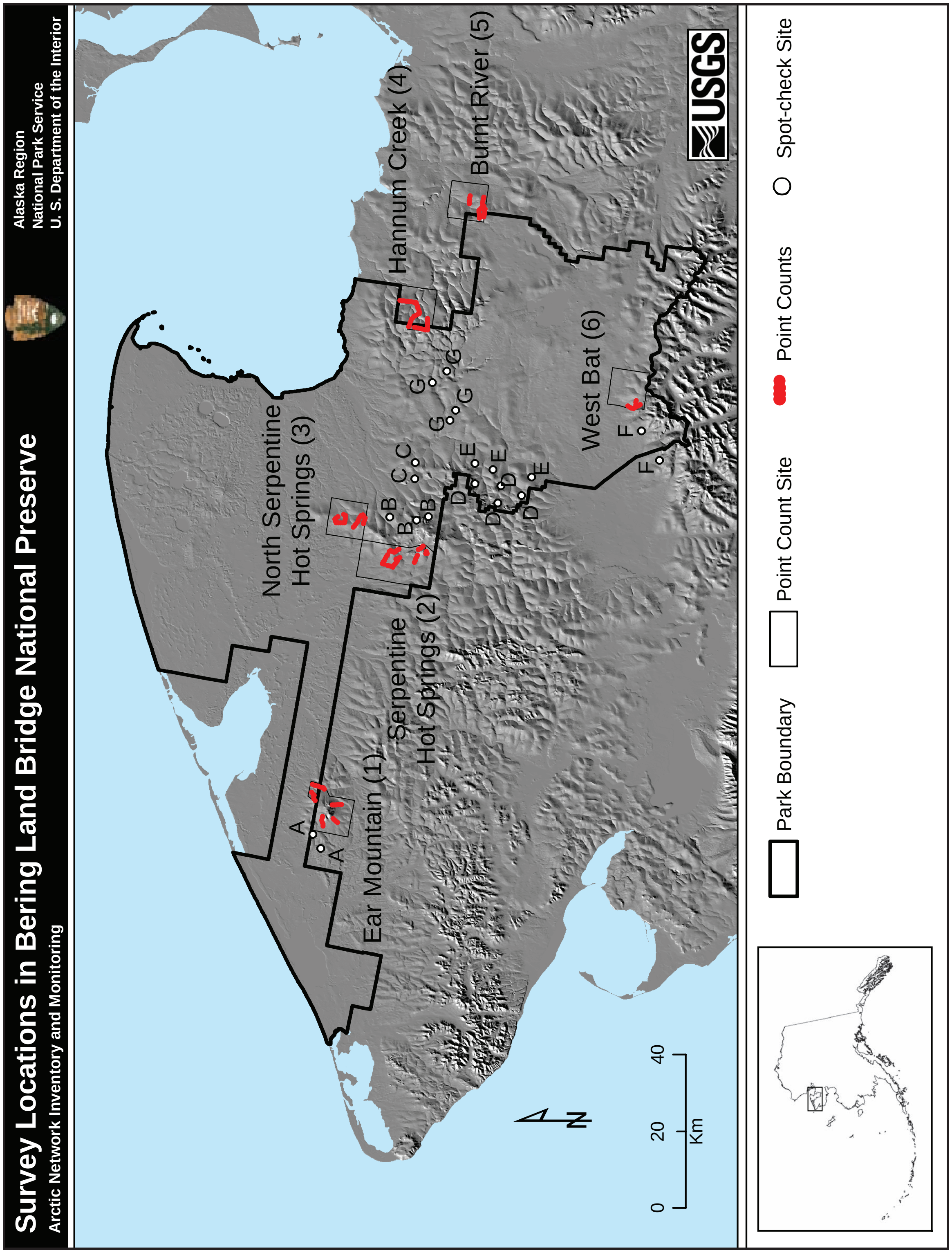
a Observations of mammals were made on 65 of 69 plots surveyed during the inventory. English and scientific names follow Jarrel et al. (2001). Locations of plots depicted in Appendices 4–6.

APPENDIX 10
LOCATIONS OF SURVEYS OF MONTANE-NESTING BIRDS IN AND ADJACENT TO BERING LAND BRIDGE NATIONAL PRESERVE, ALASKA, LATE MAY TO JUNE 1988, 1989, 1991, AND 2000

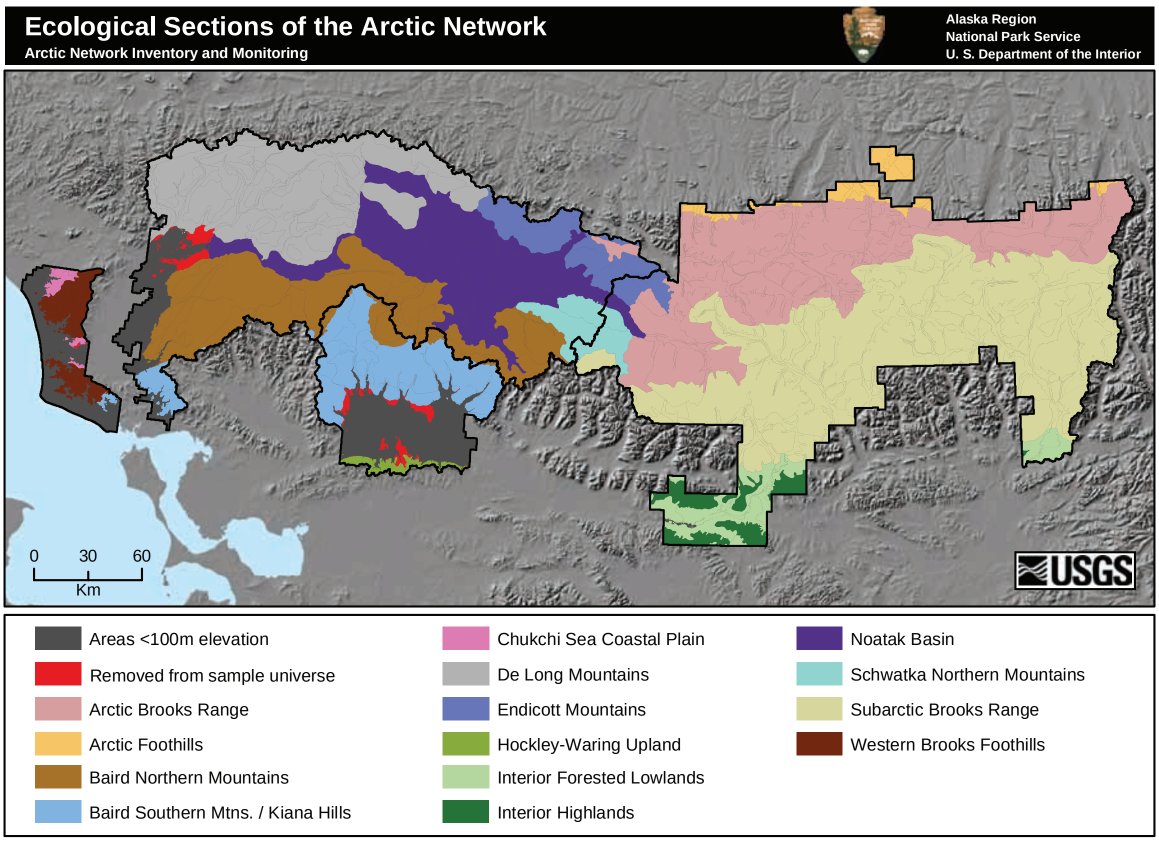
Numbers and letters refer to site names listed in Table 8 and Appendix 12.

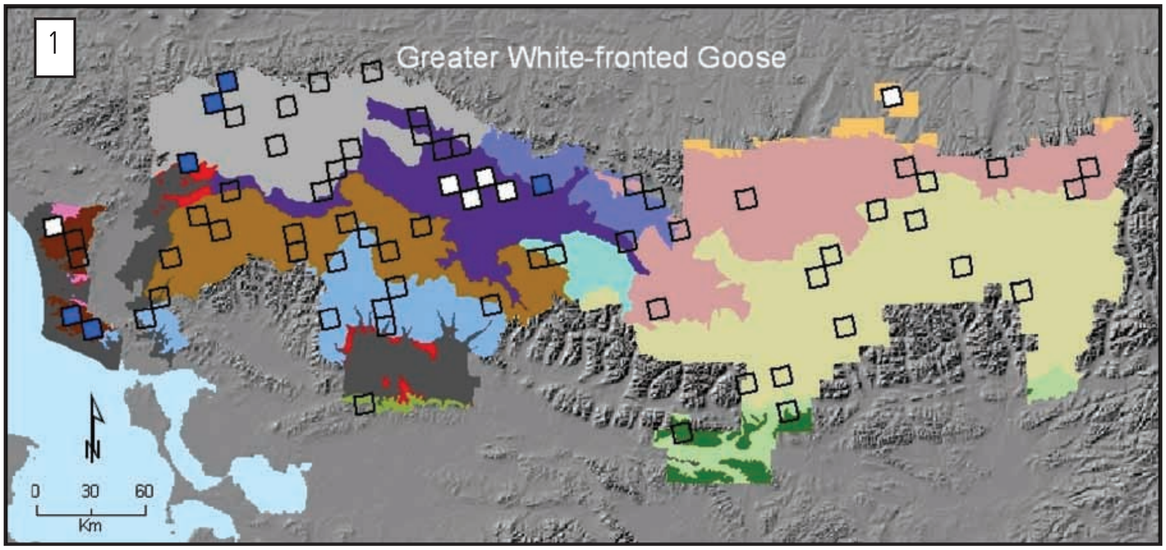


APPENDIX 11
DISTRIBUTION OF BIRDS BY ECOLOGICAL SECTION

Only species detected on three or more plots and those of conservation concern are depicted (see Tables 2 and 3). Numbers on maps correspond to those in Table 4. Species detected on point counts are shown by solid white squares, those detected on a plot but not during a point count by solid blue squares, and those not detected on plot by clear squares.

Key to Ecological Sections

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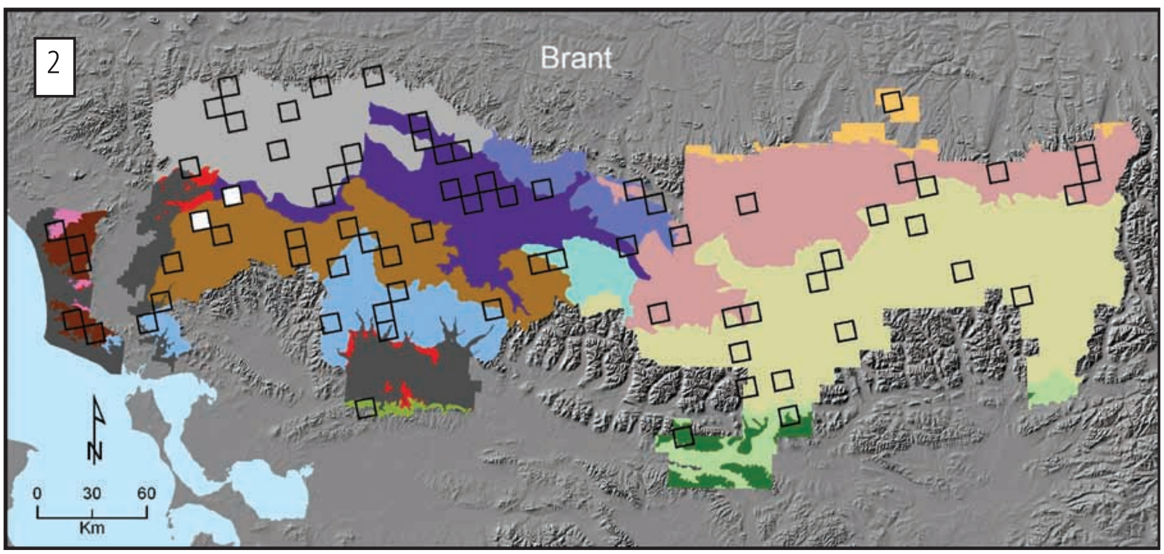
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Brant
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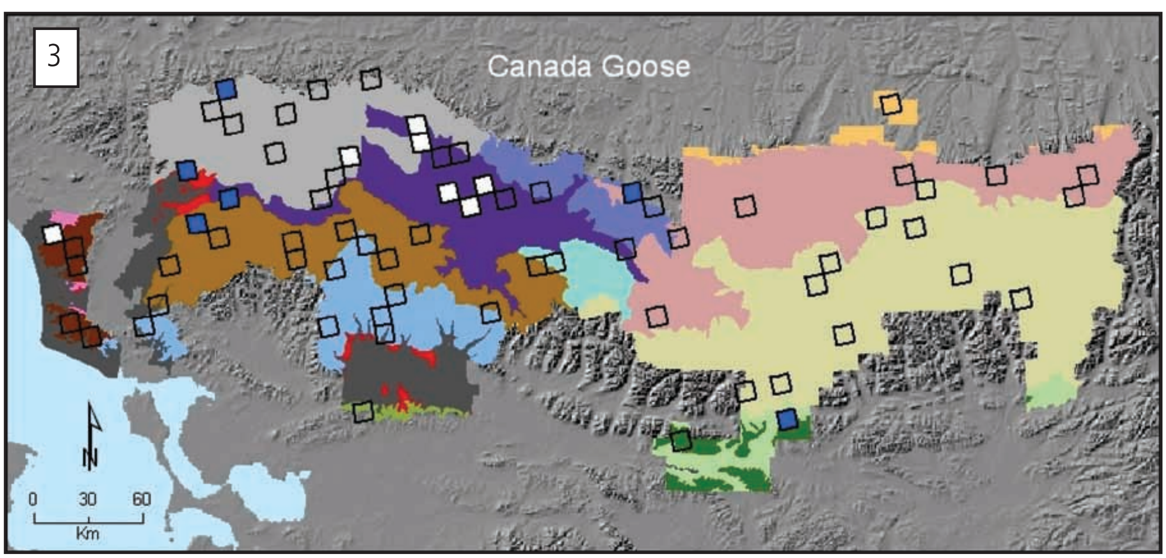
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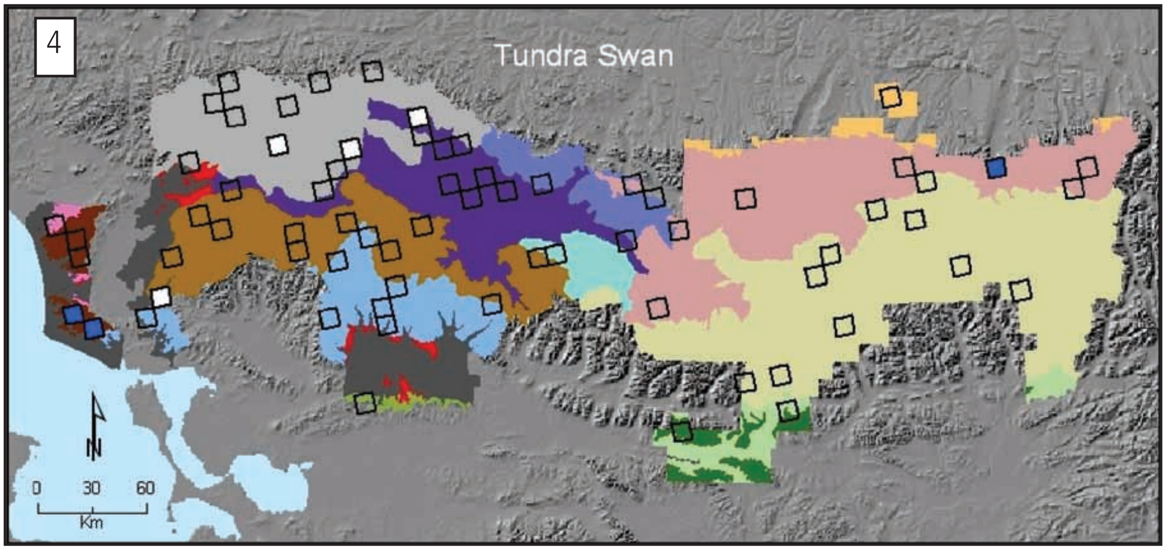
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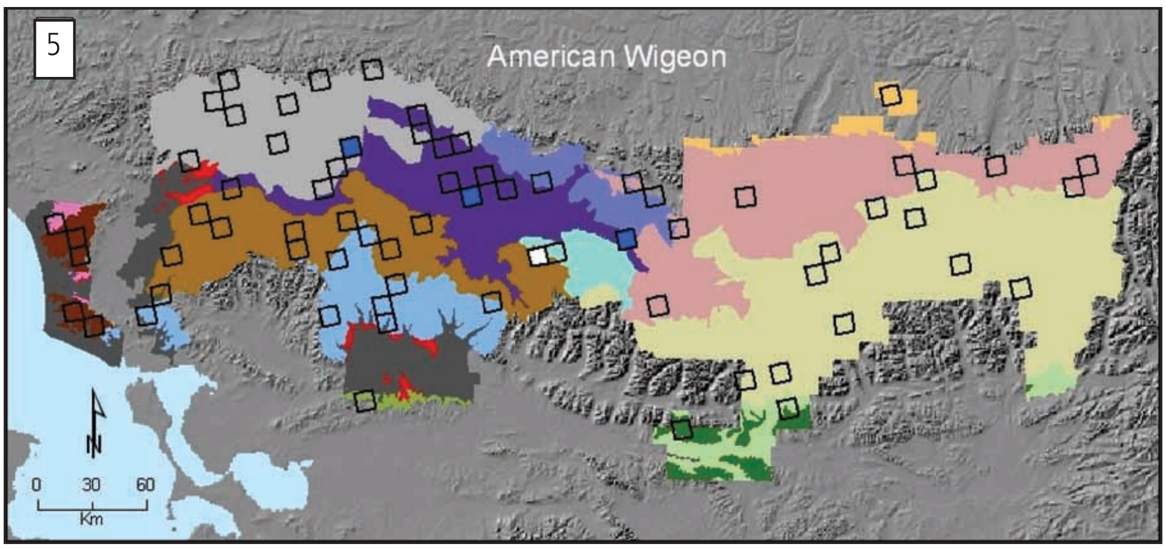
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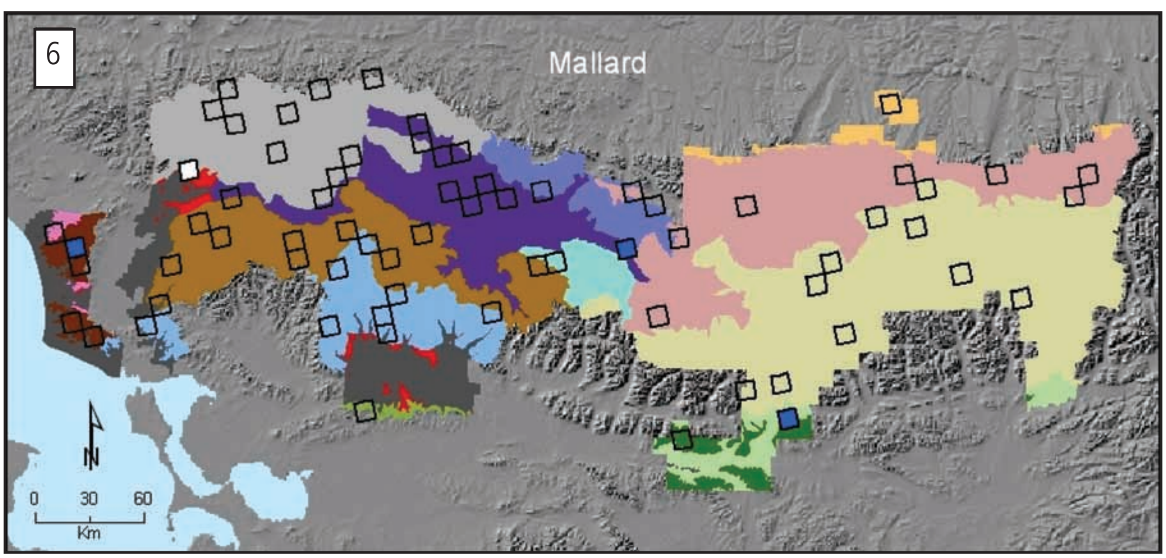
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Mallard
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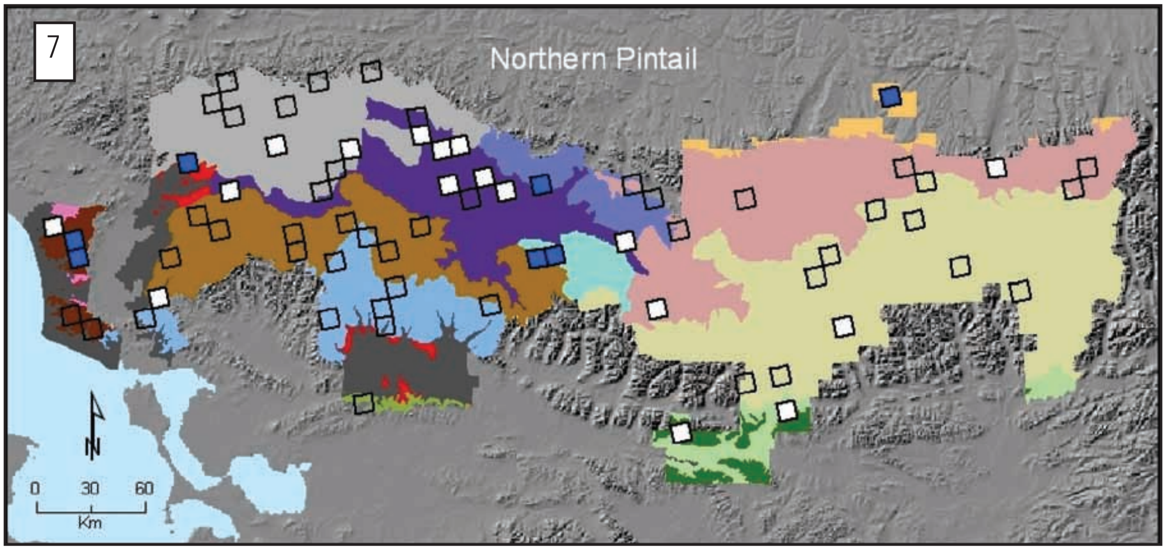
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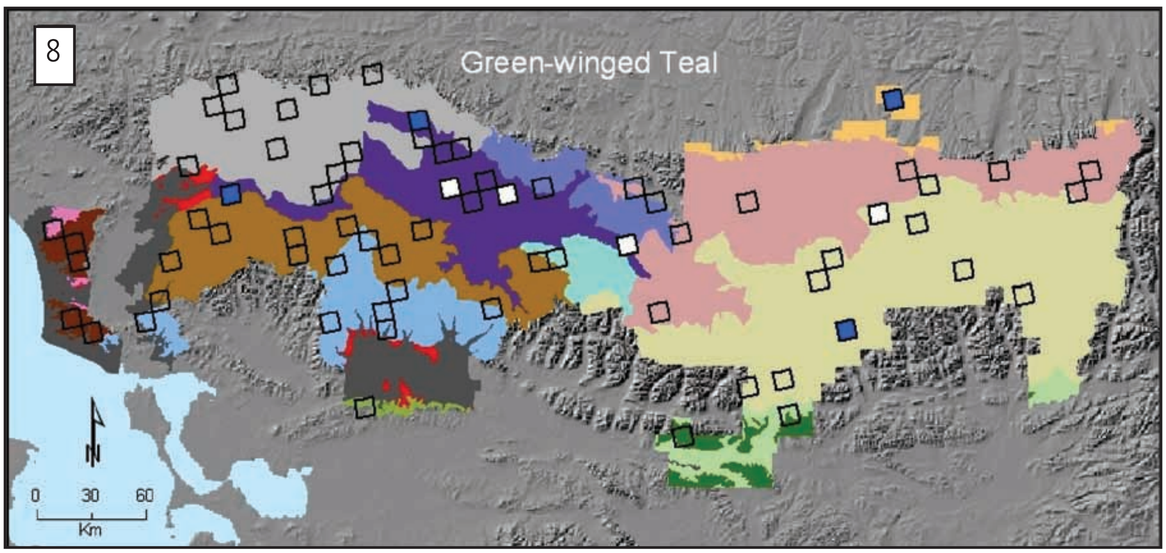
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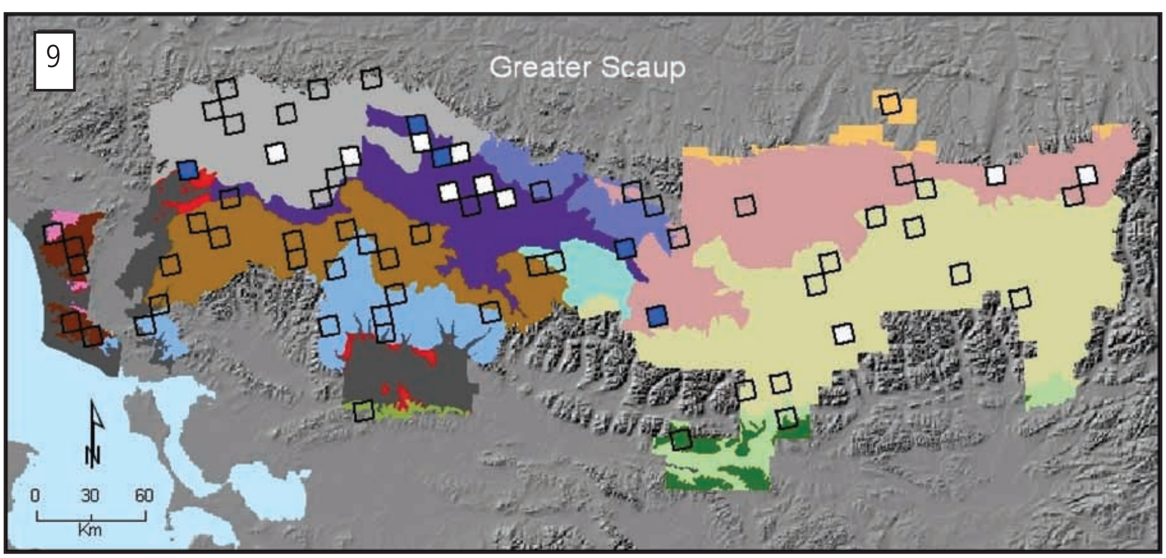
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Greater Scaup
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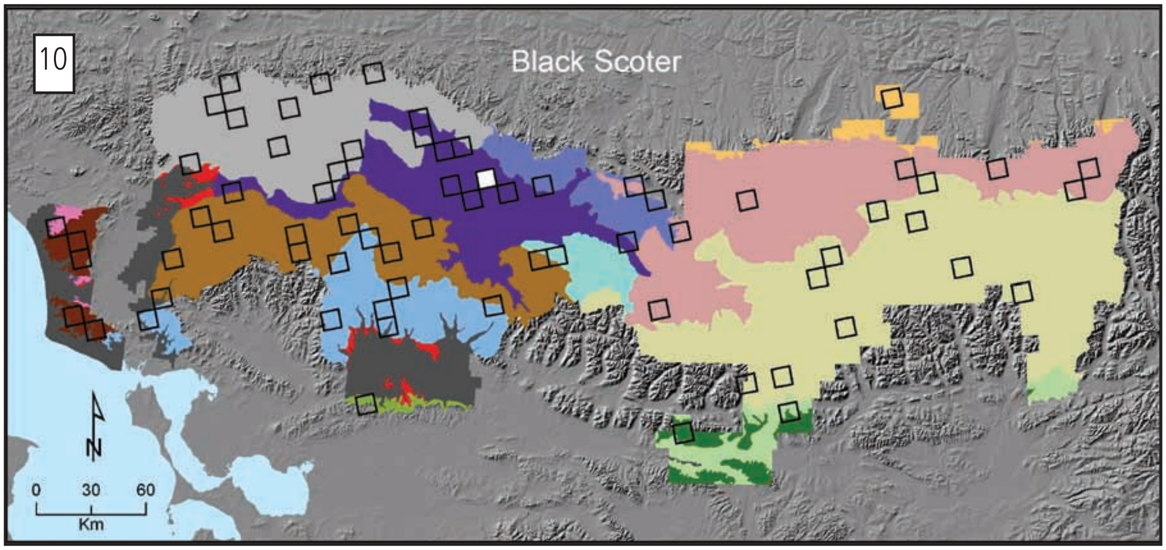
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Black Scoter
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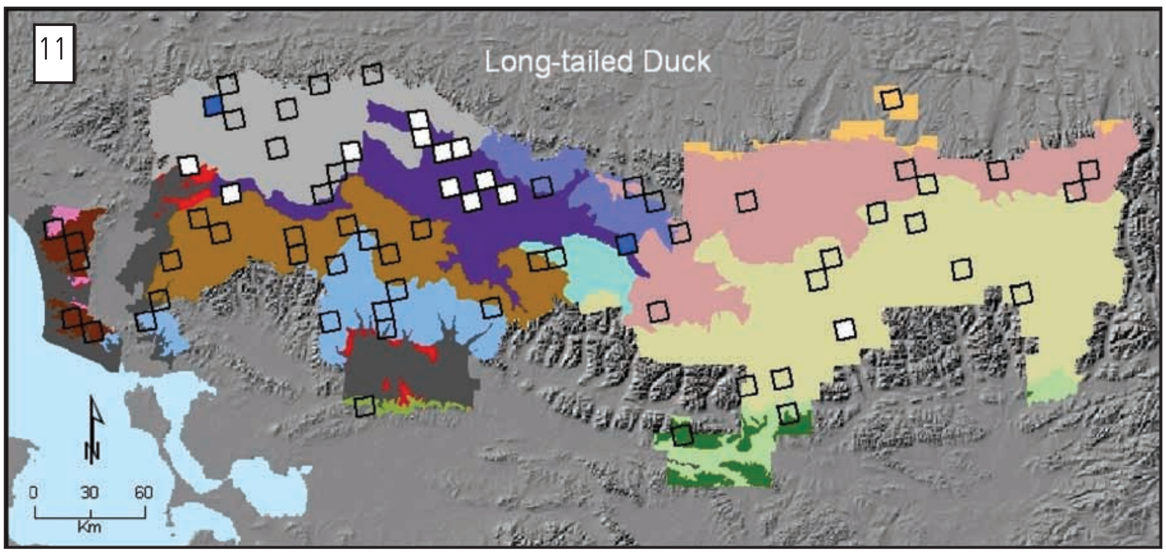
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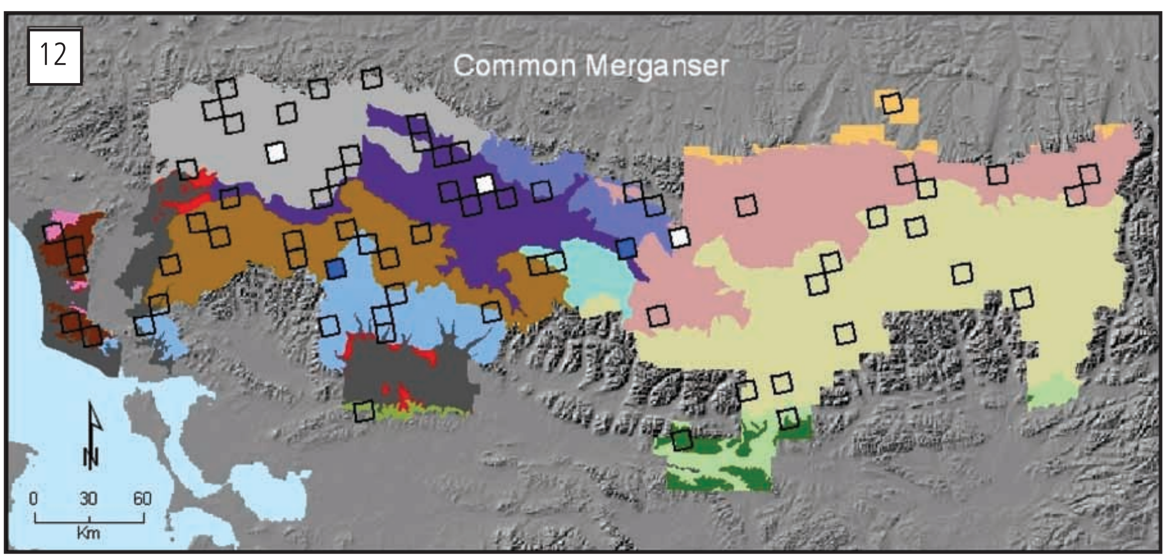
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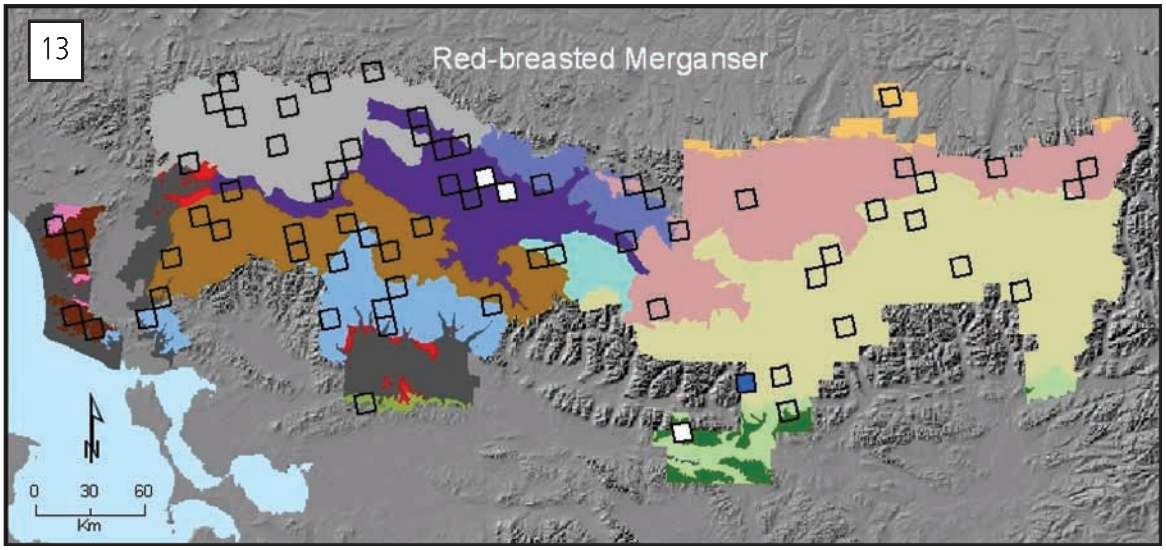
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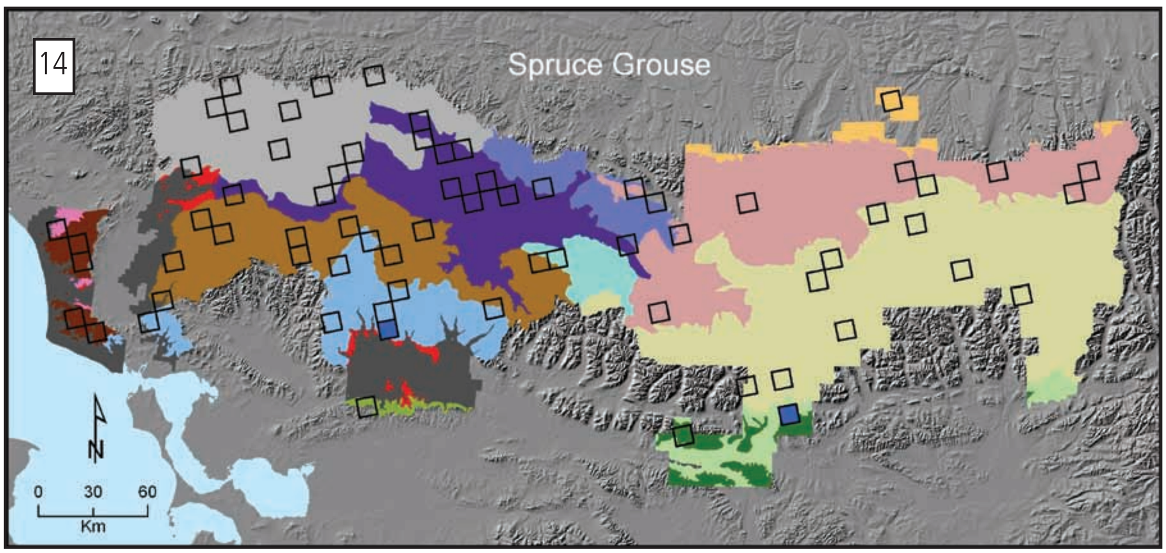
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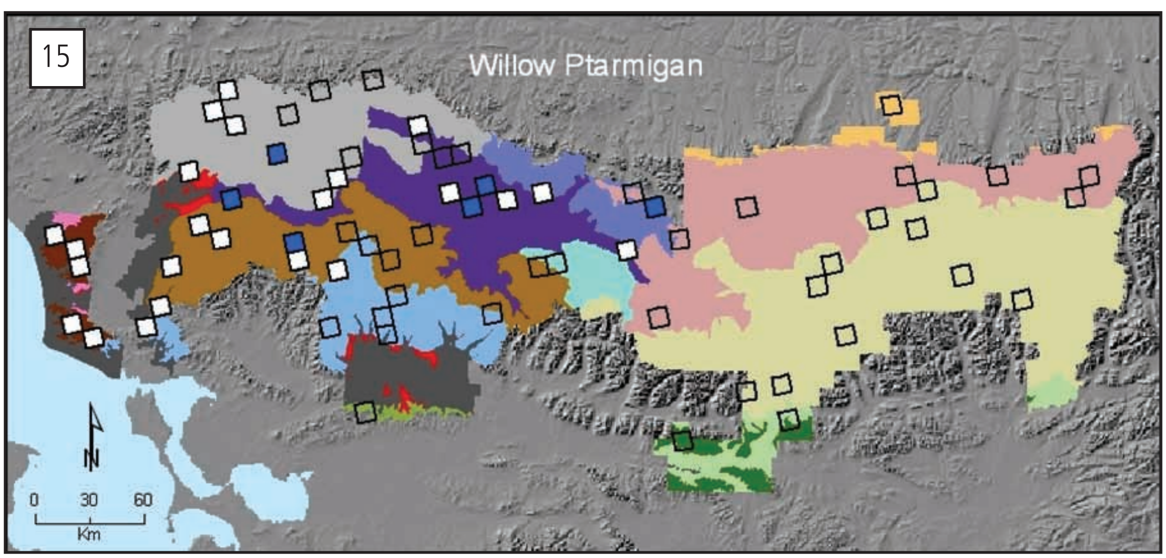
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Willow Ptarmigan
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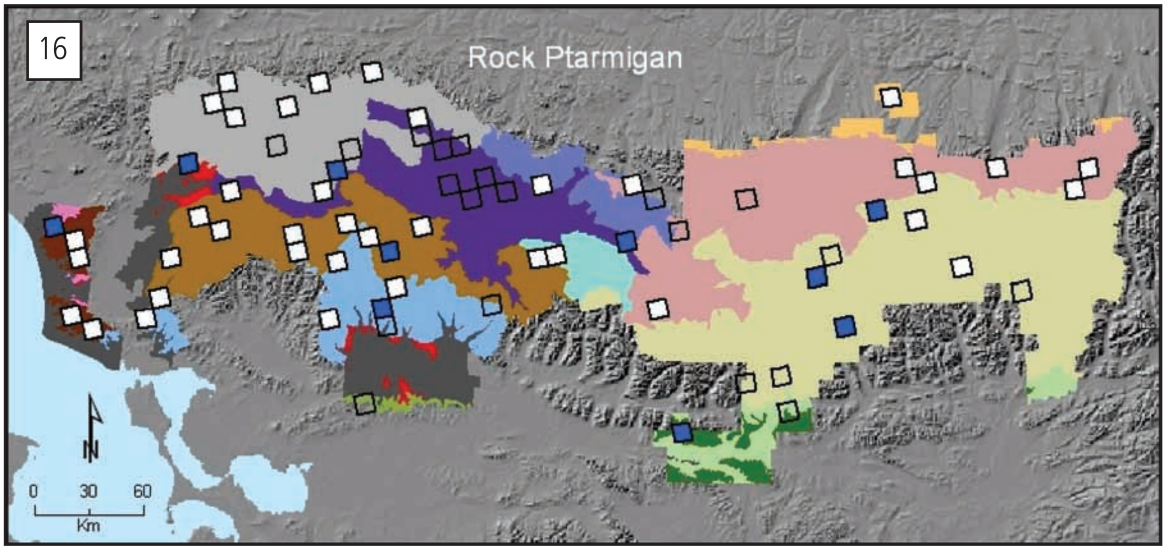
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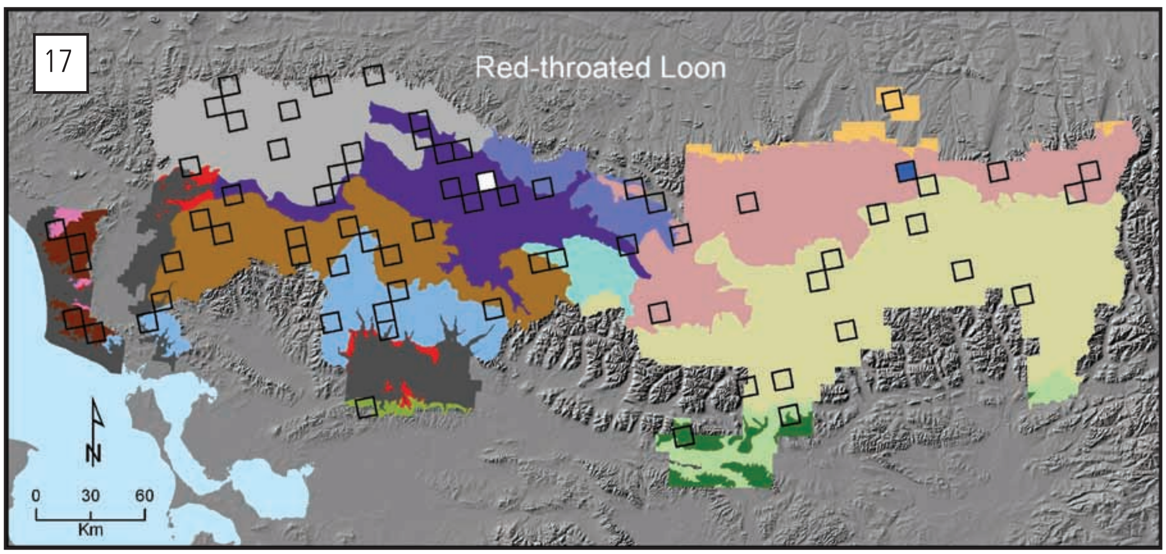
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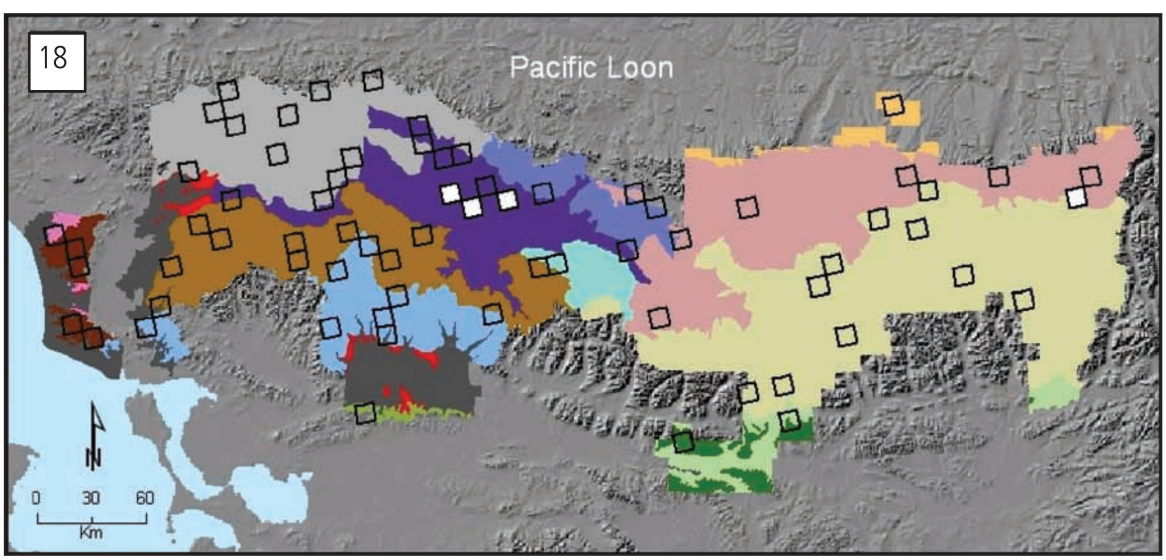
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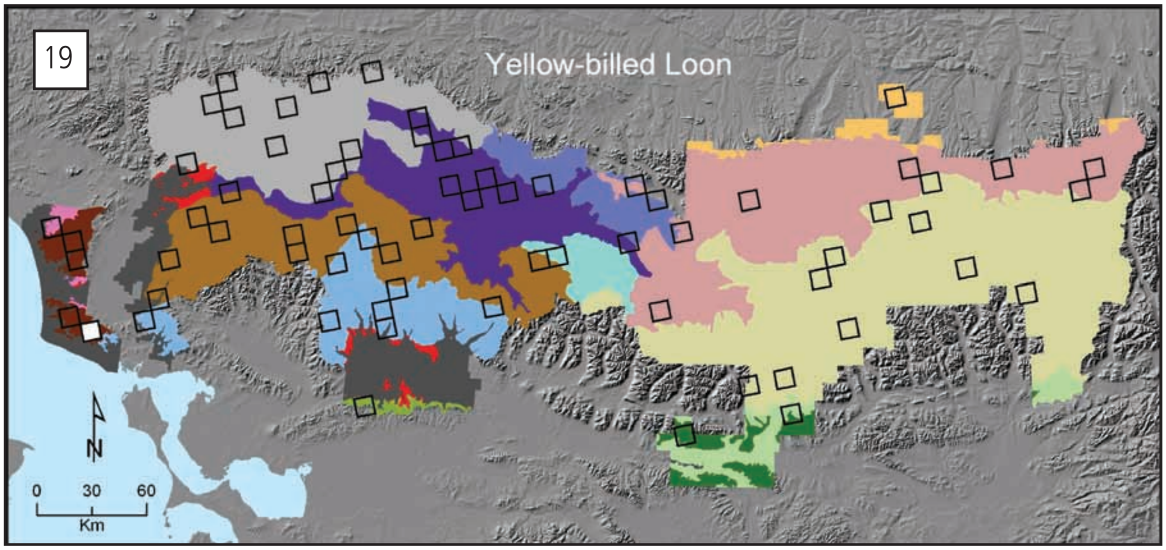
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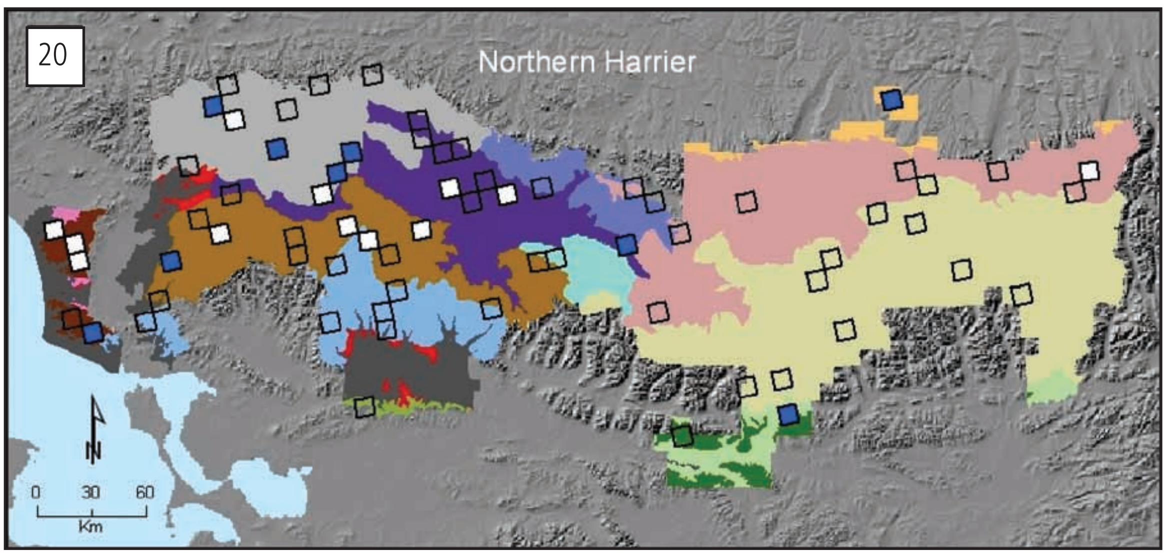
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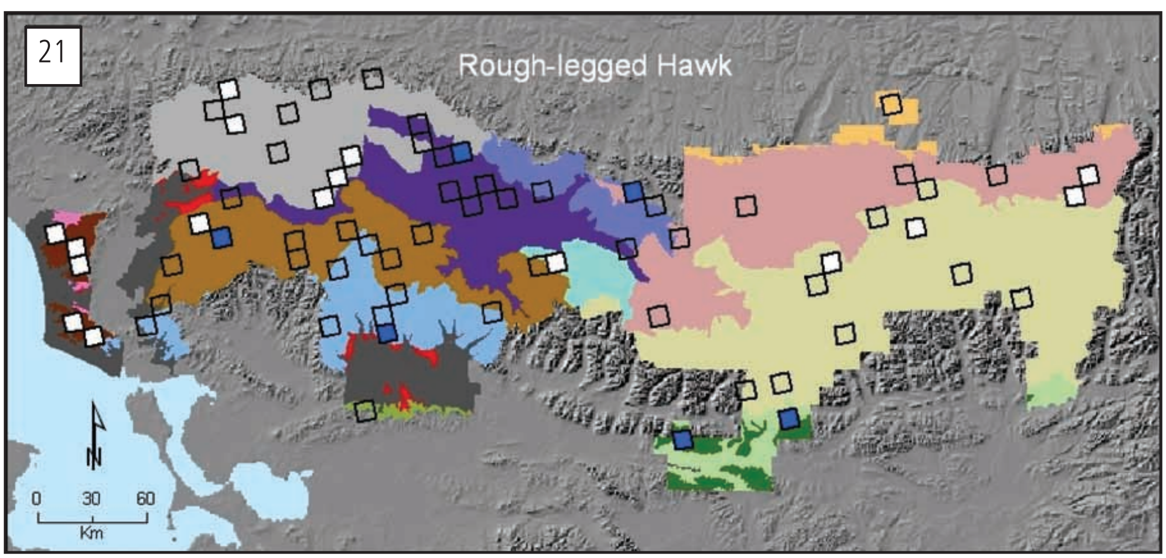
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Rough-legged Hawk
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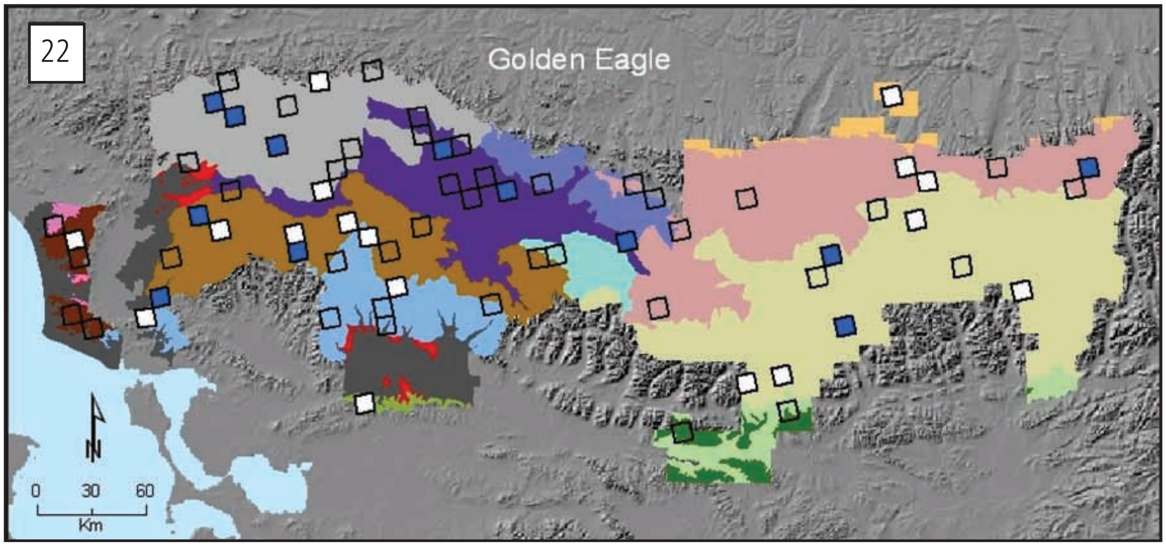
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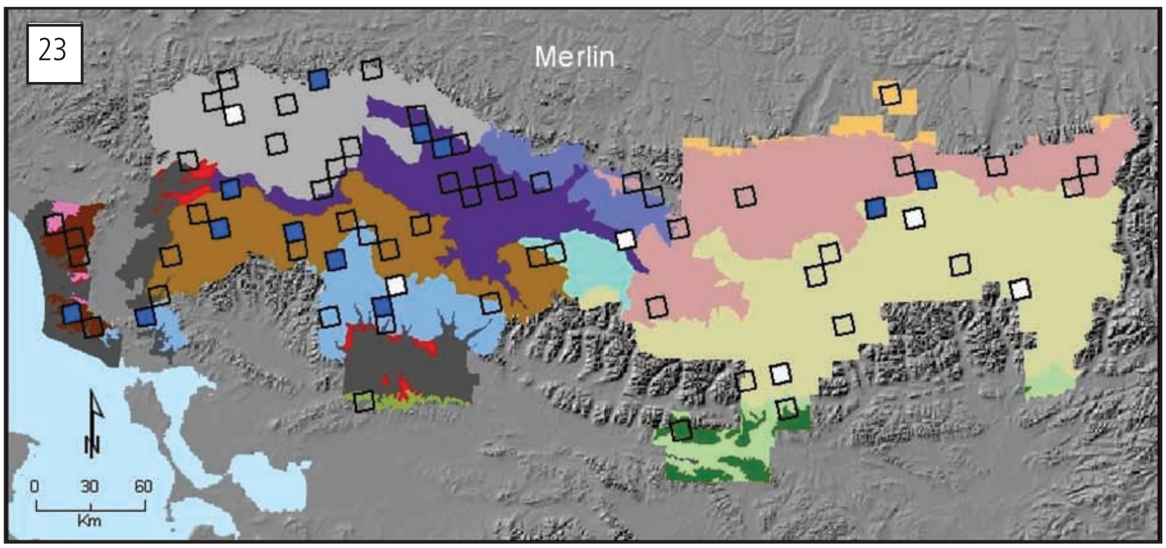
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Merlin
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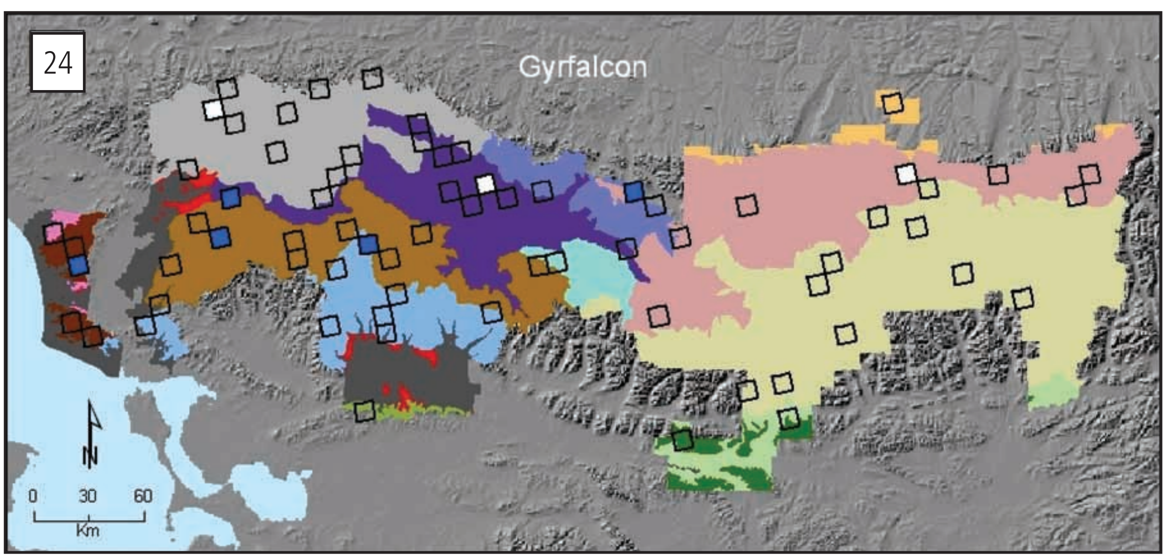
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Gyrfalcon
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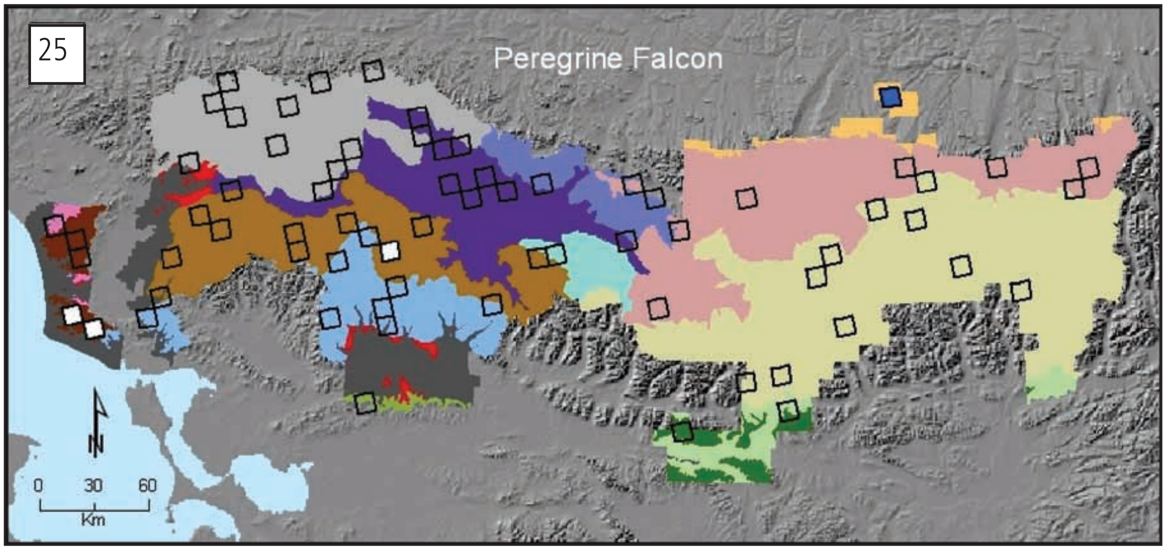
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Peregrine Falcon
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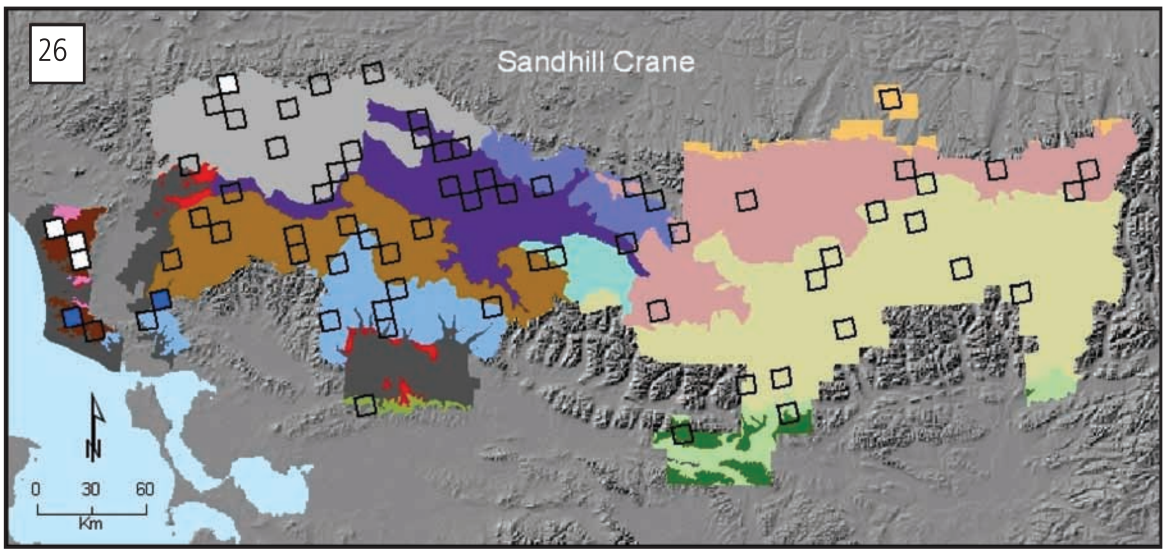
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Sandhill Crane
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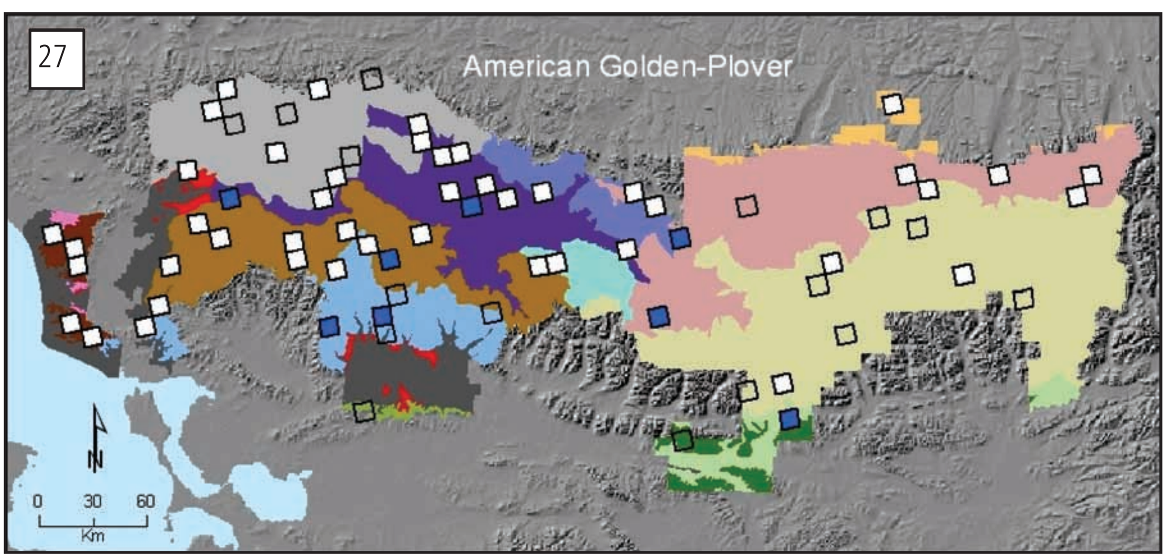
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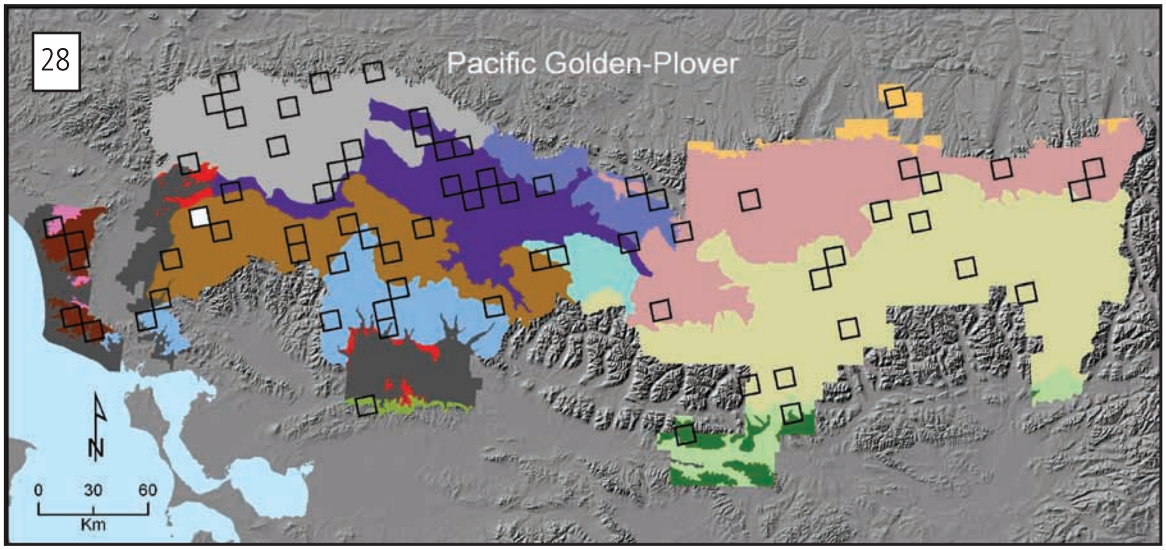
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Pacific Golden-Plover
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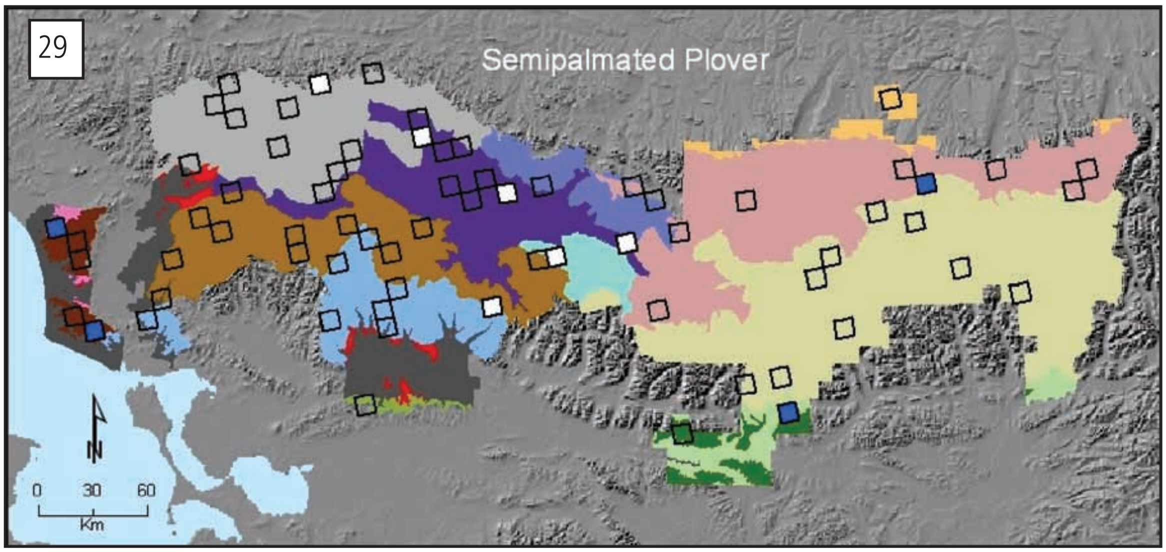
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Semipalmated Plover
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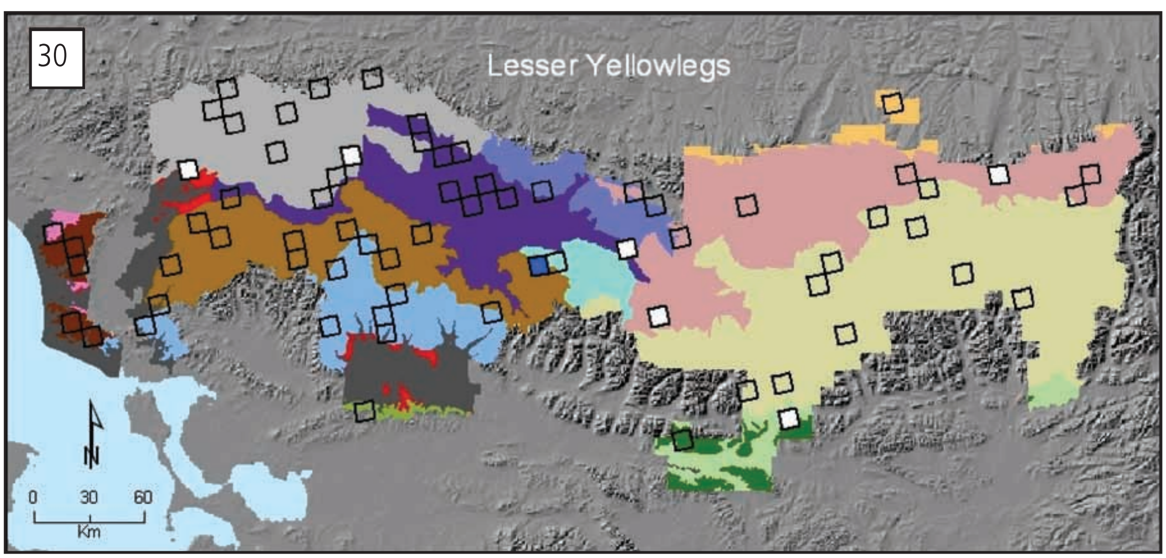
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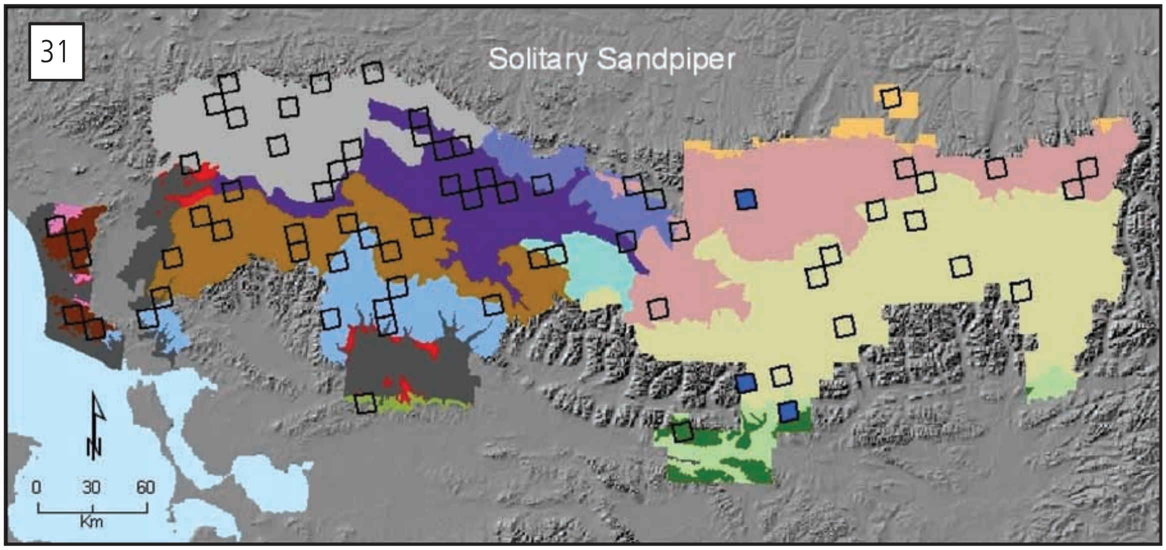
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Solitary Sandpiper
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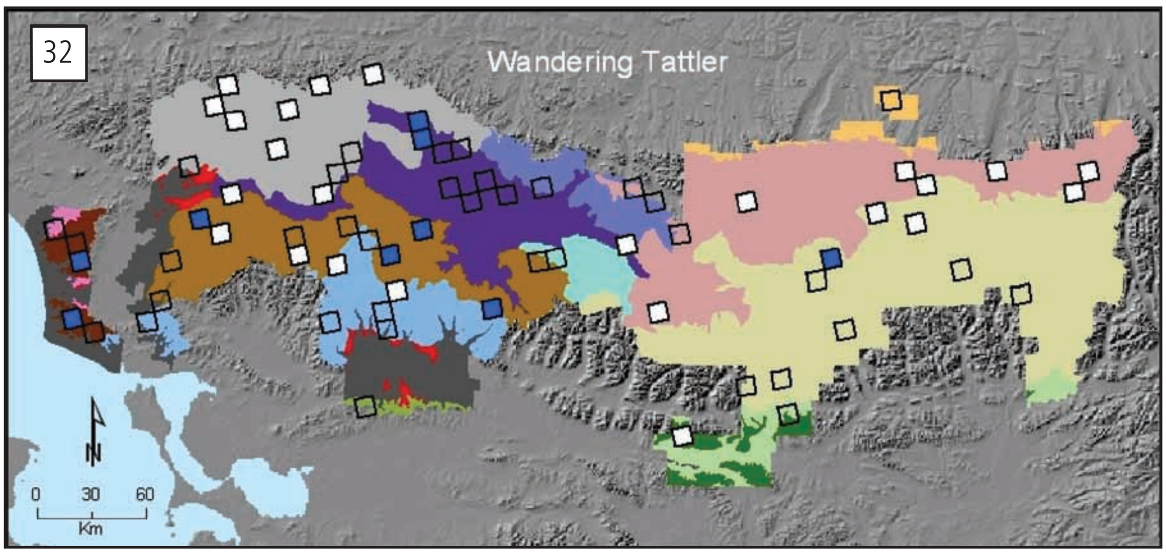
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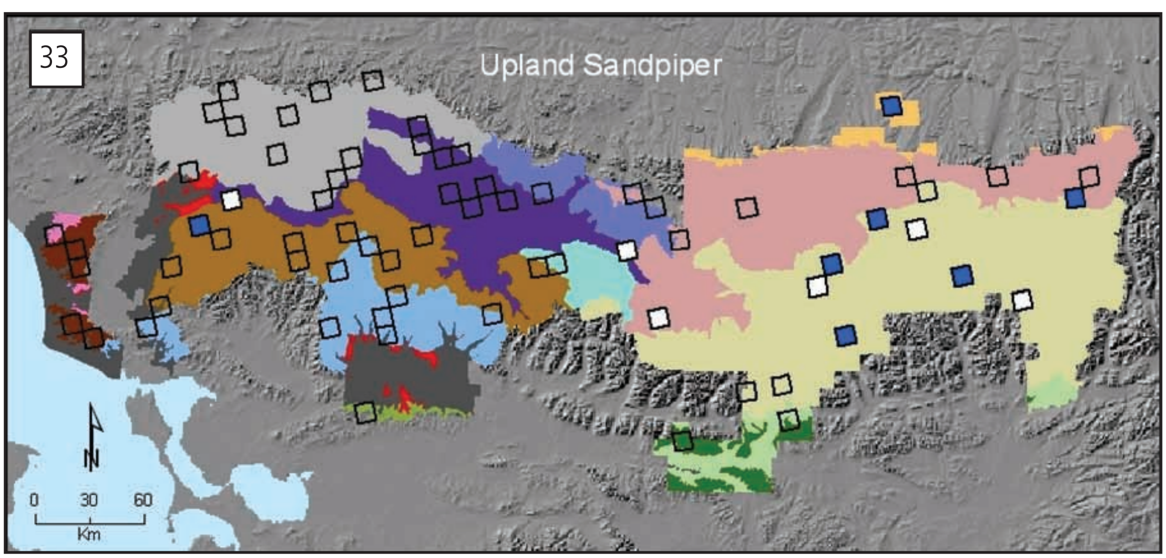
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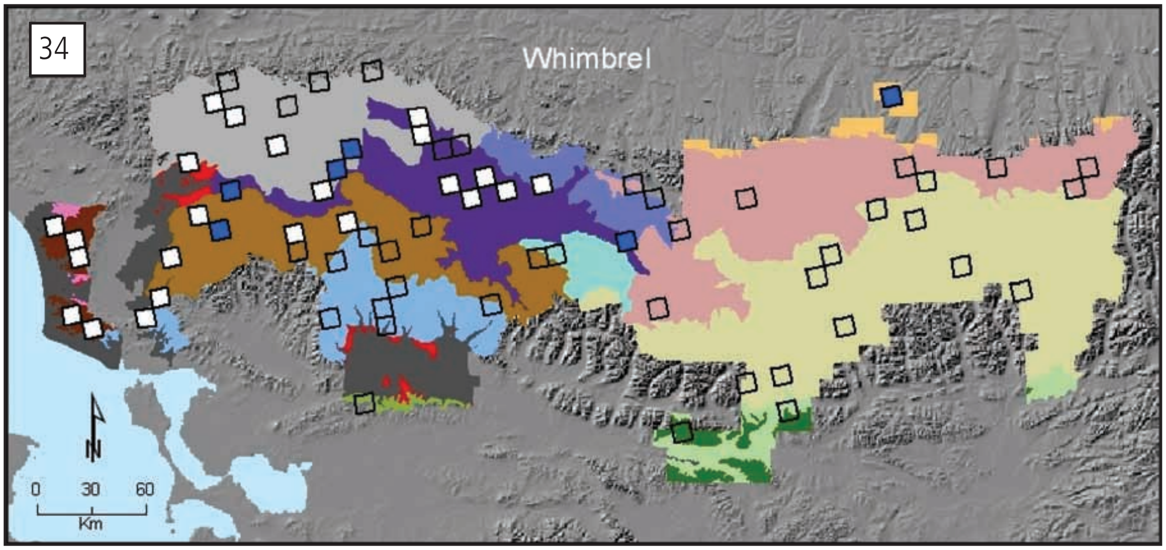
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Whimbrel
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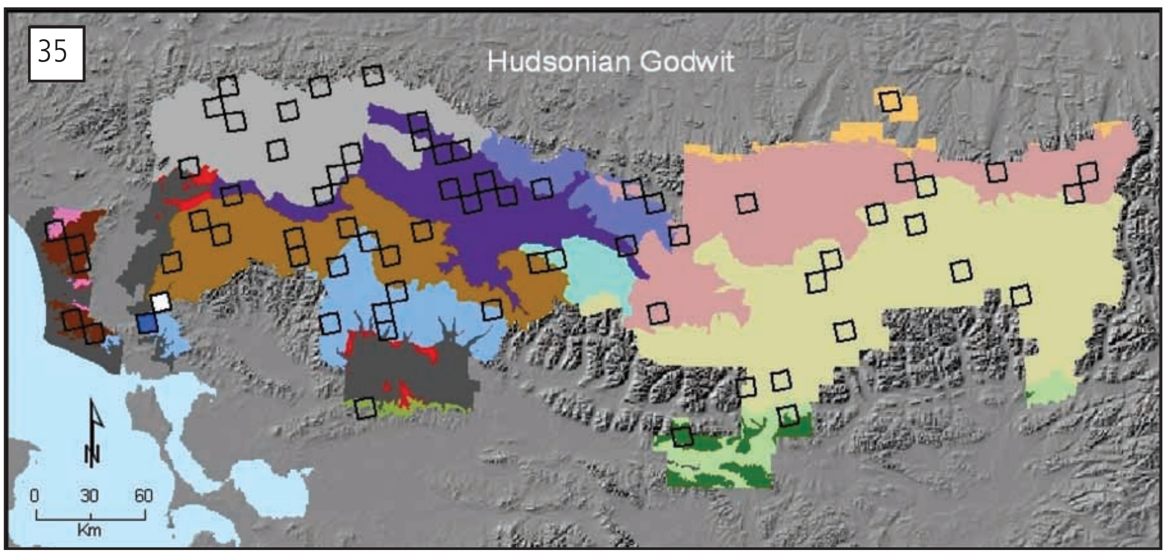
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Hudsonian Godwit
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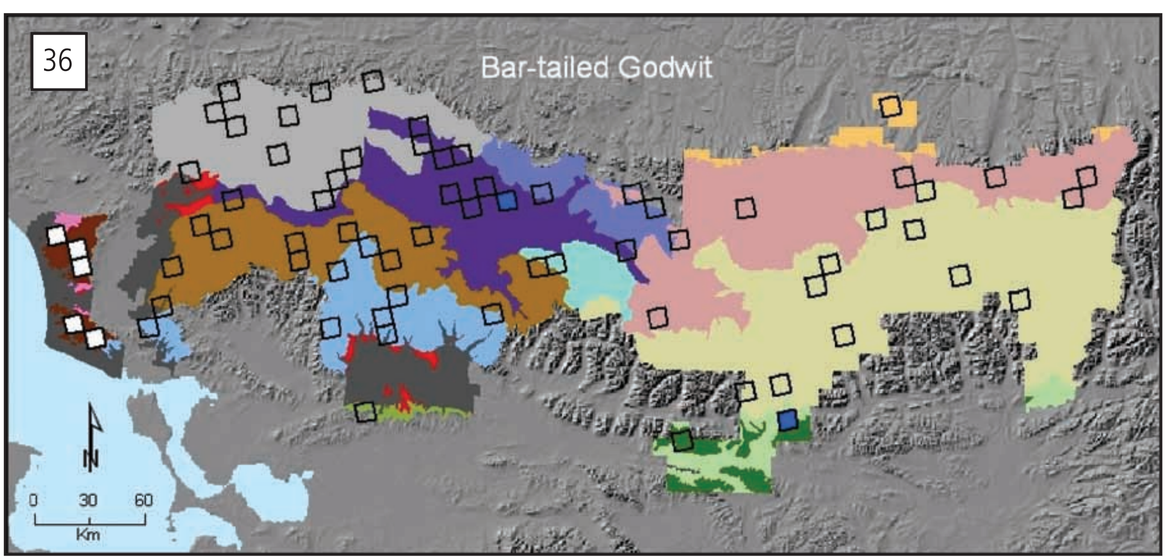
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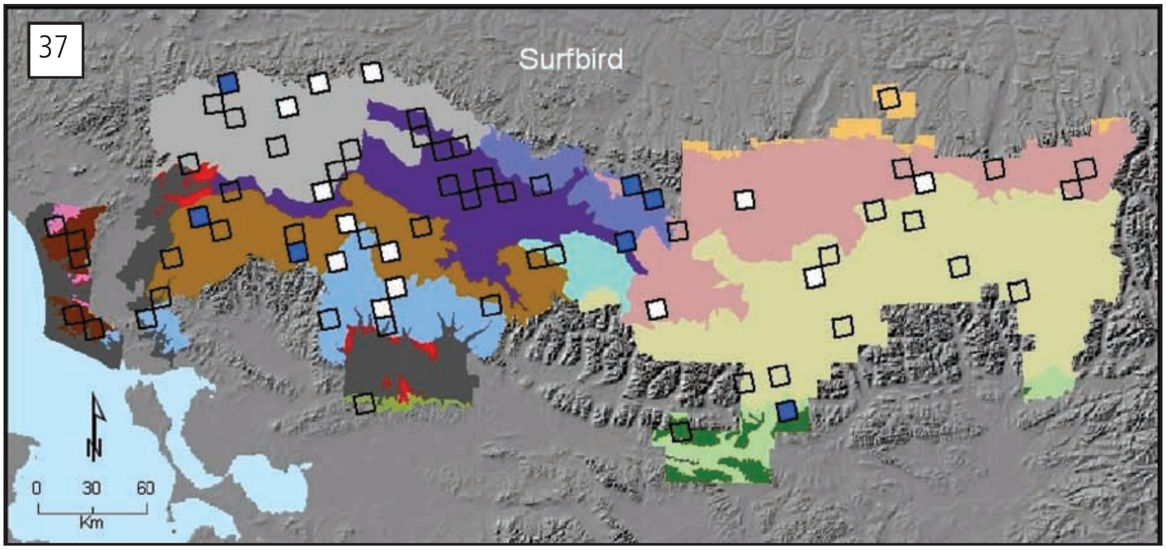
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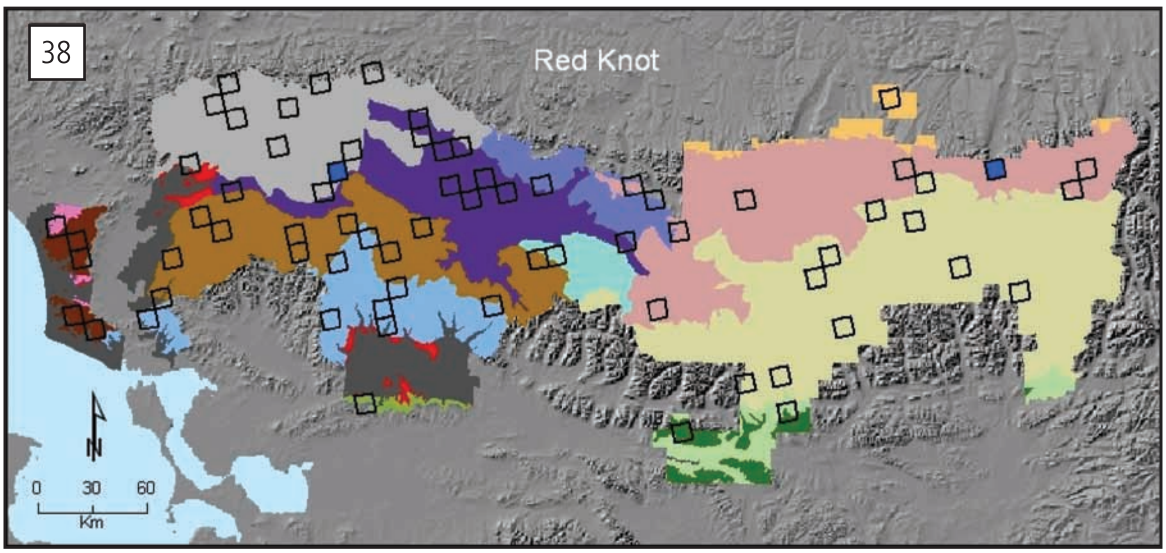
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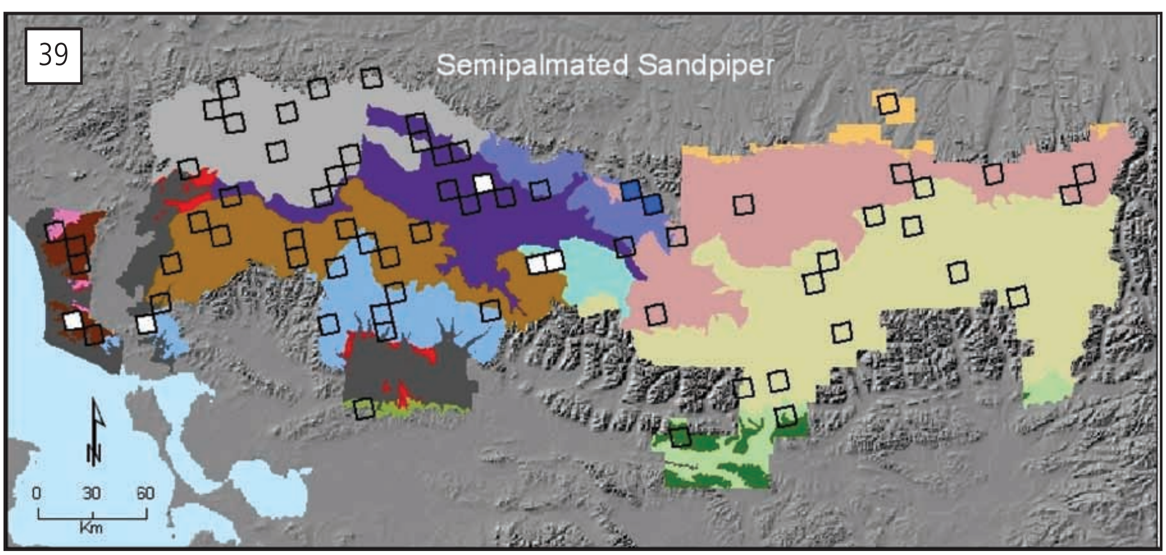
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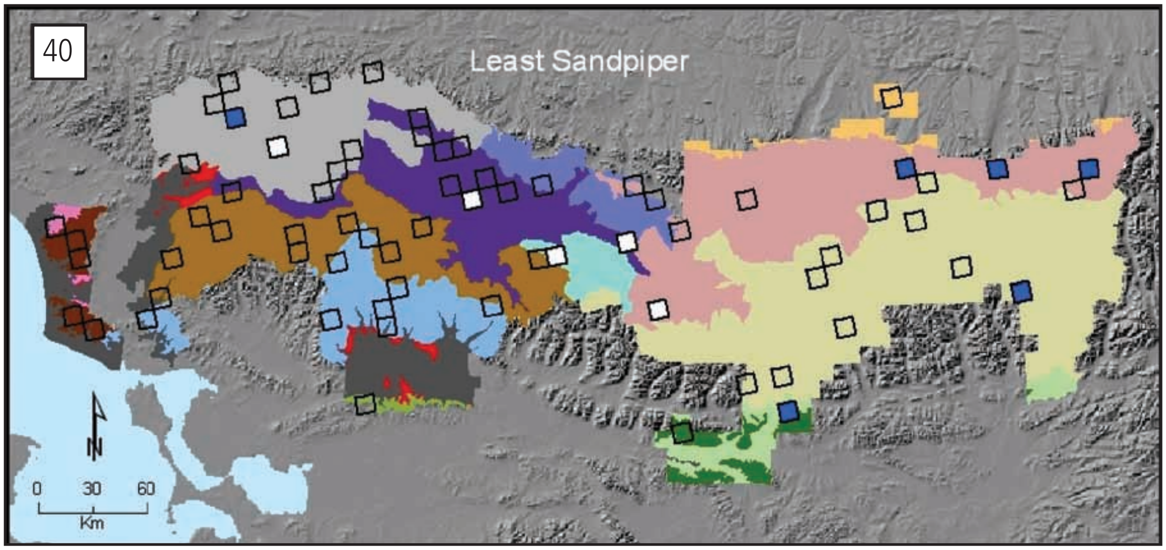
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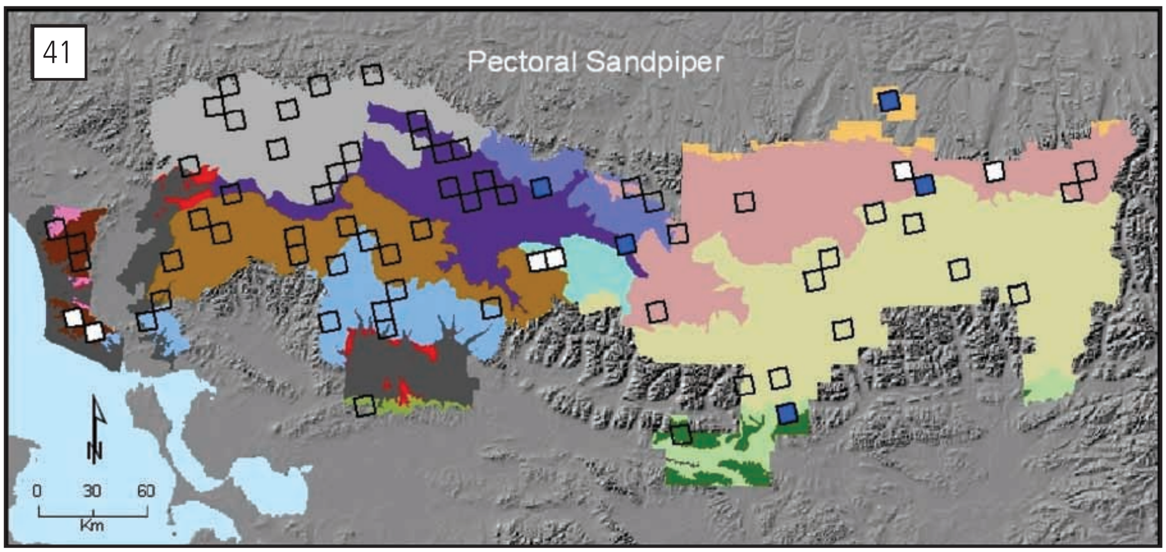
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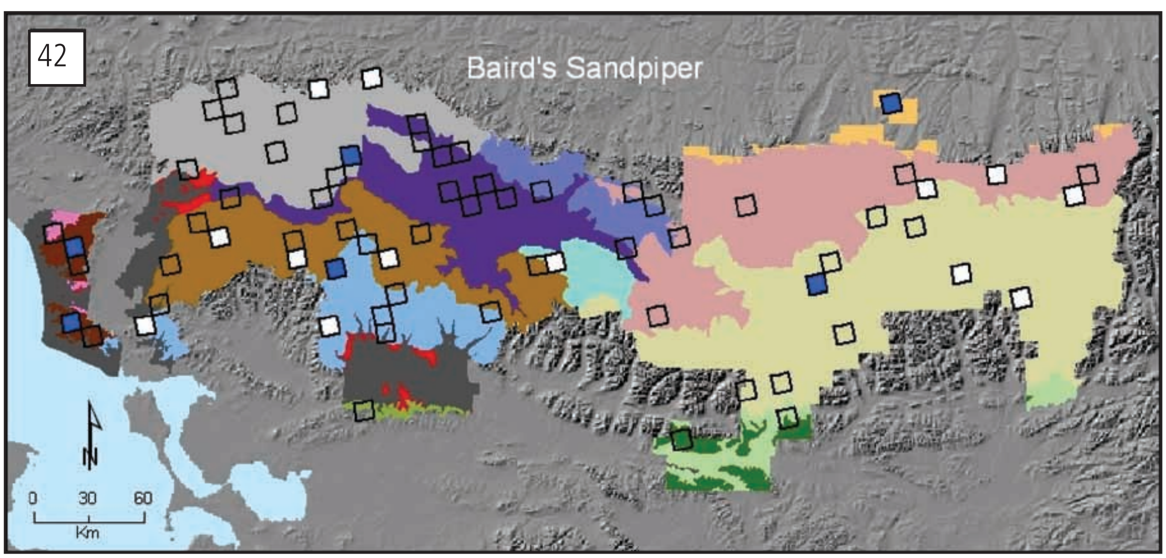
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Baird's Sandpiper
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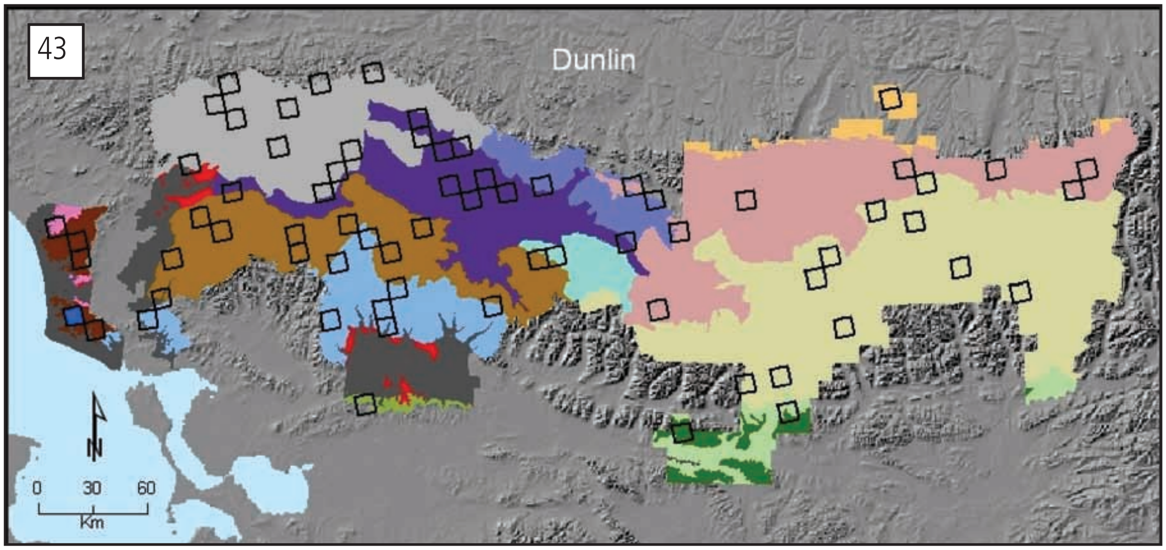
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Dunlin
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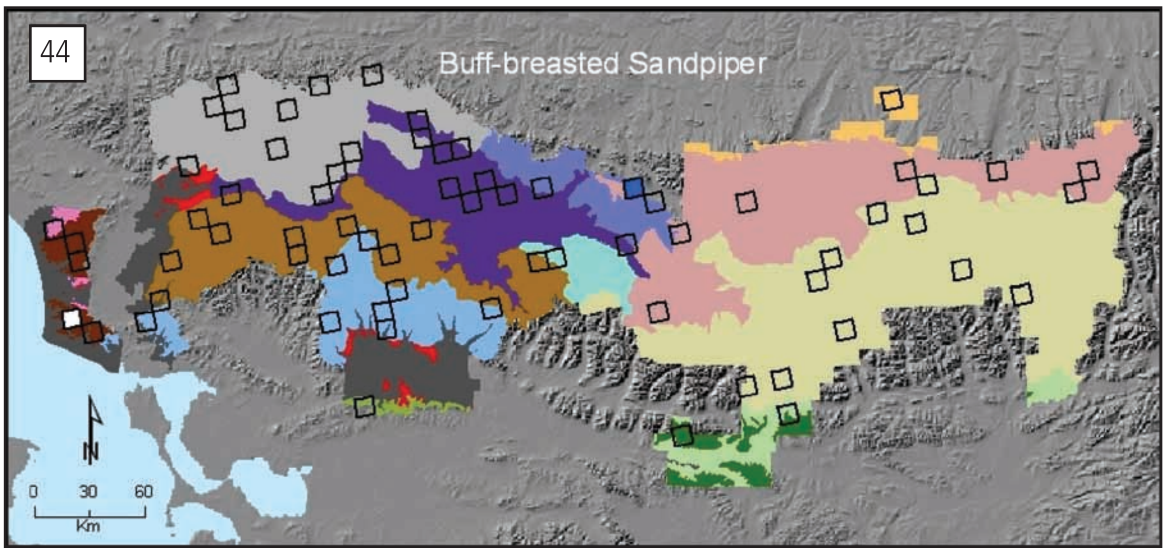
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Buff-breasted Sandpiper
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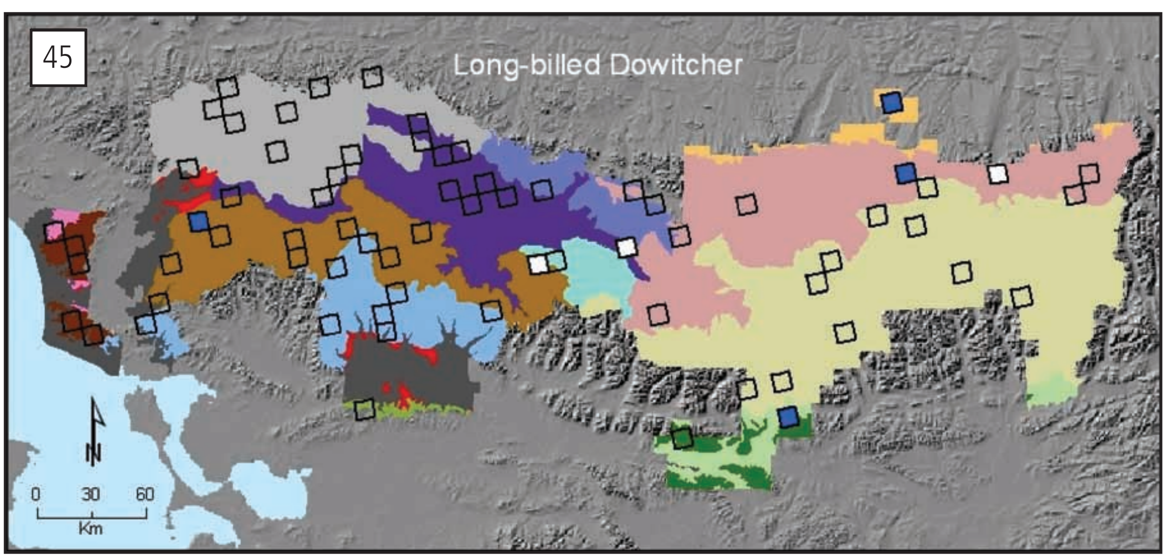
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Long-billed Dowitcher
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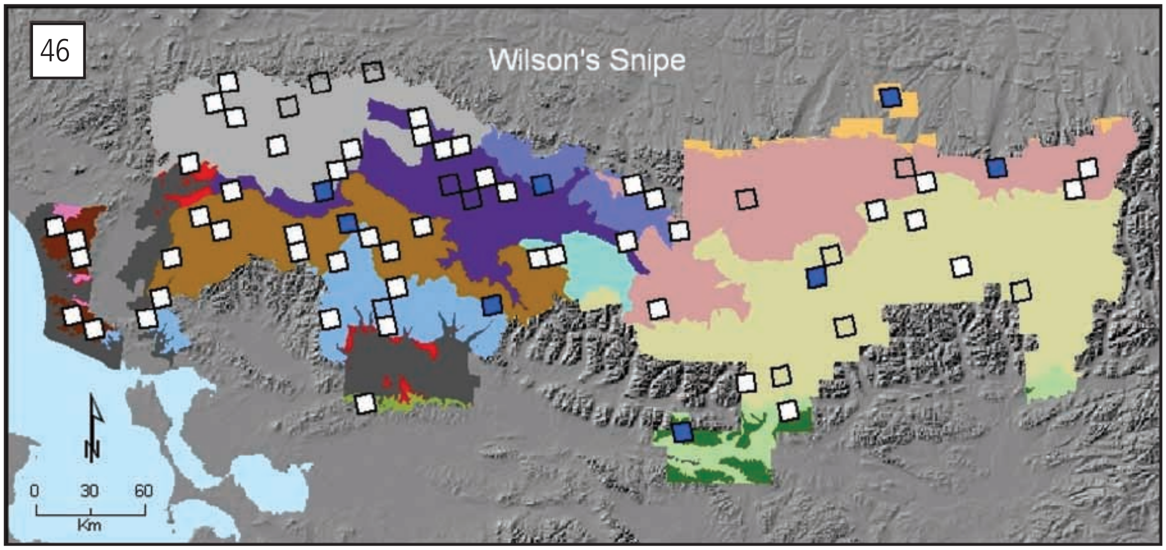
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Wilson's Snipe
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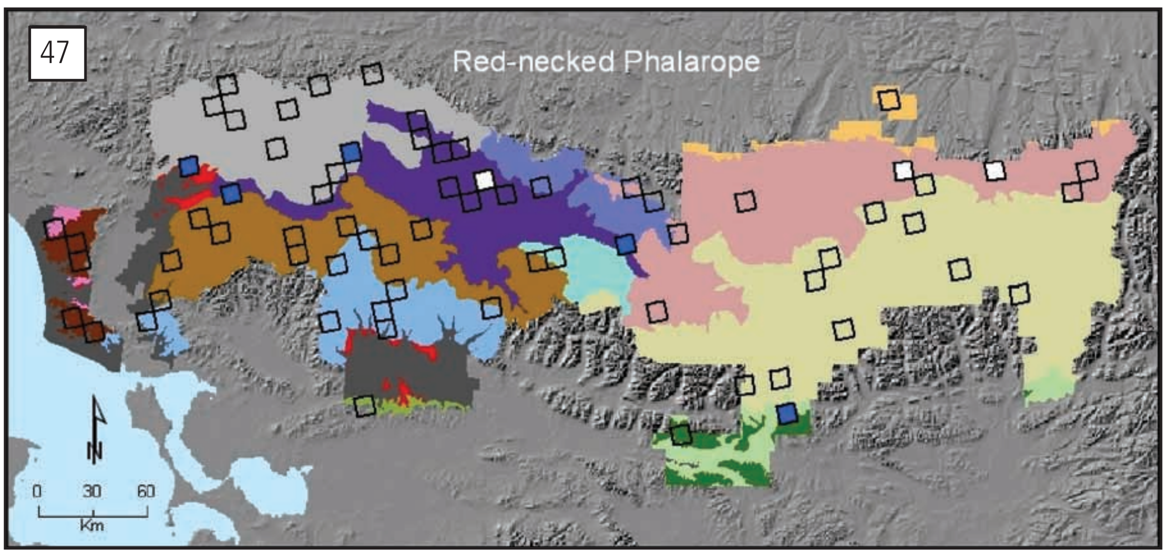
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Red-necked Phalarope
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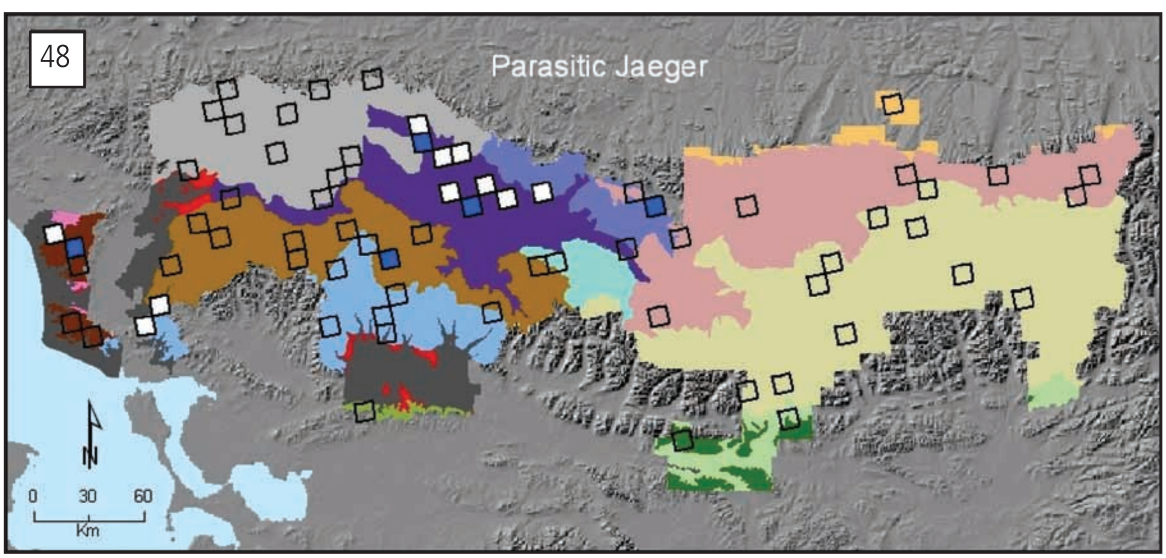
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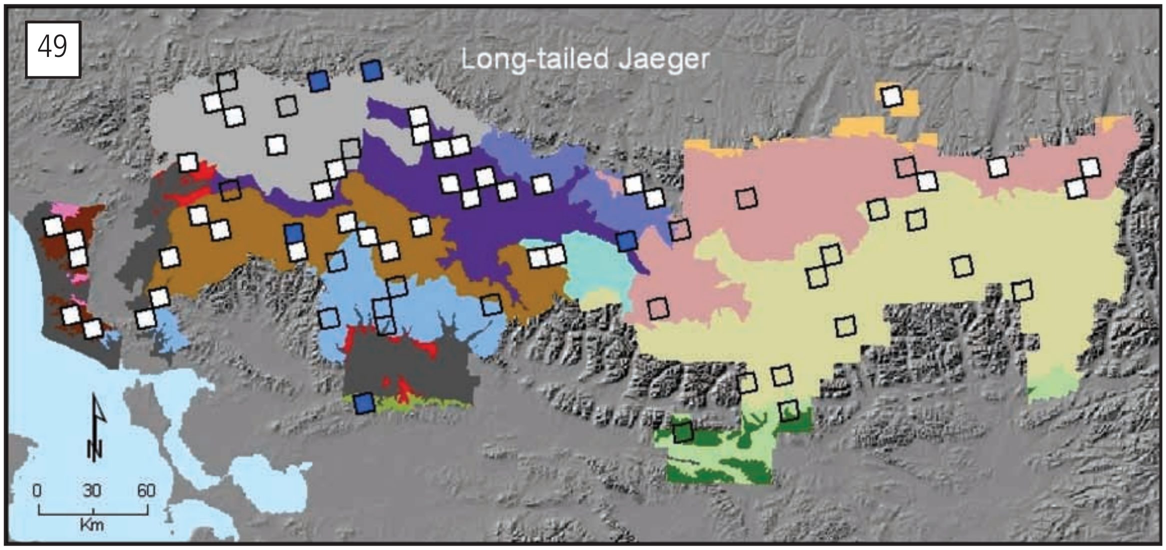
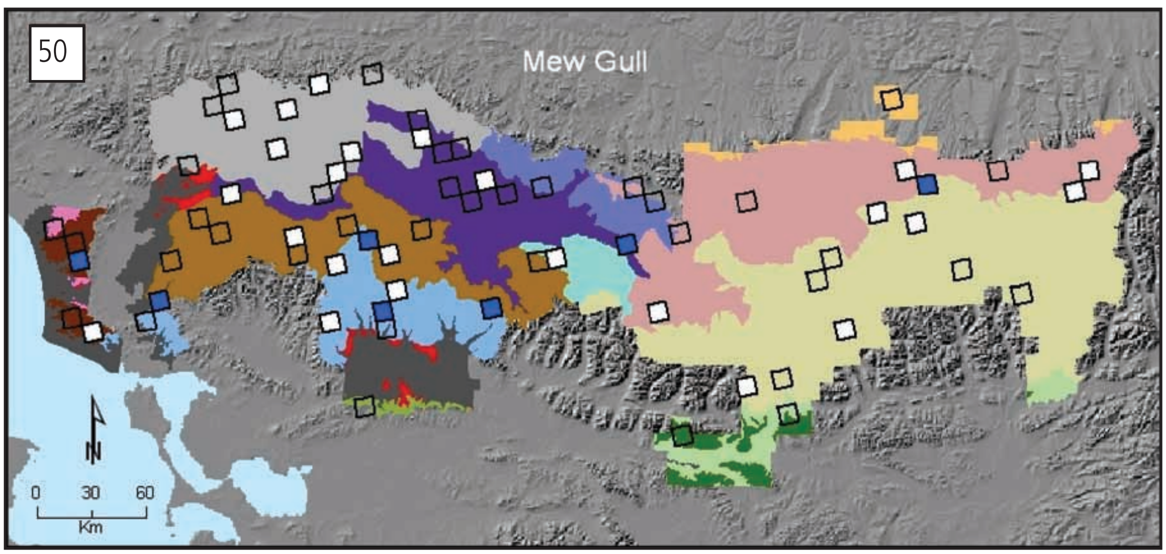
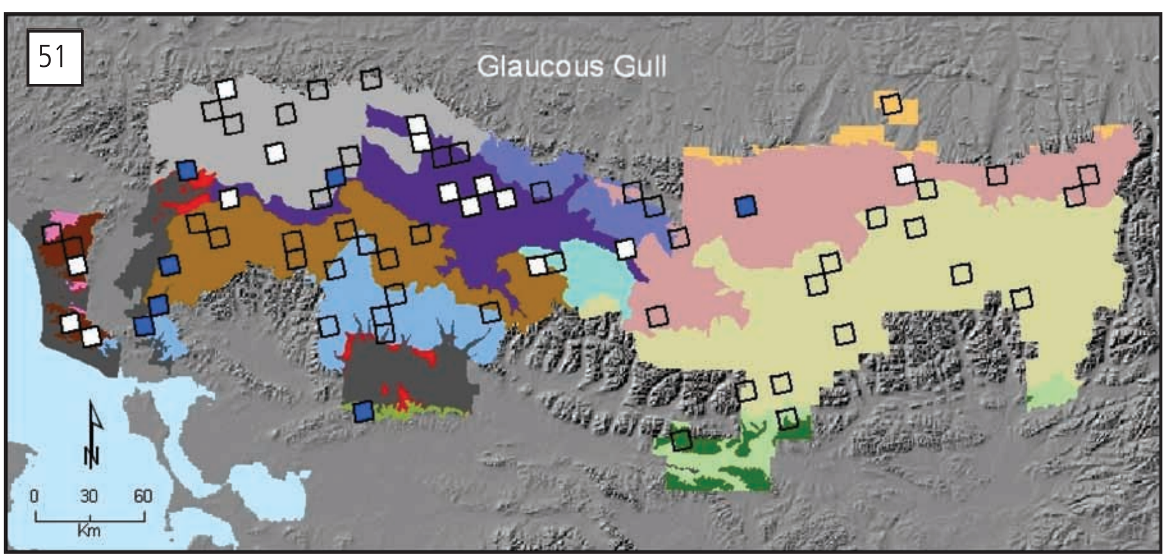
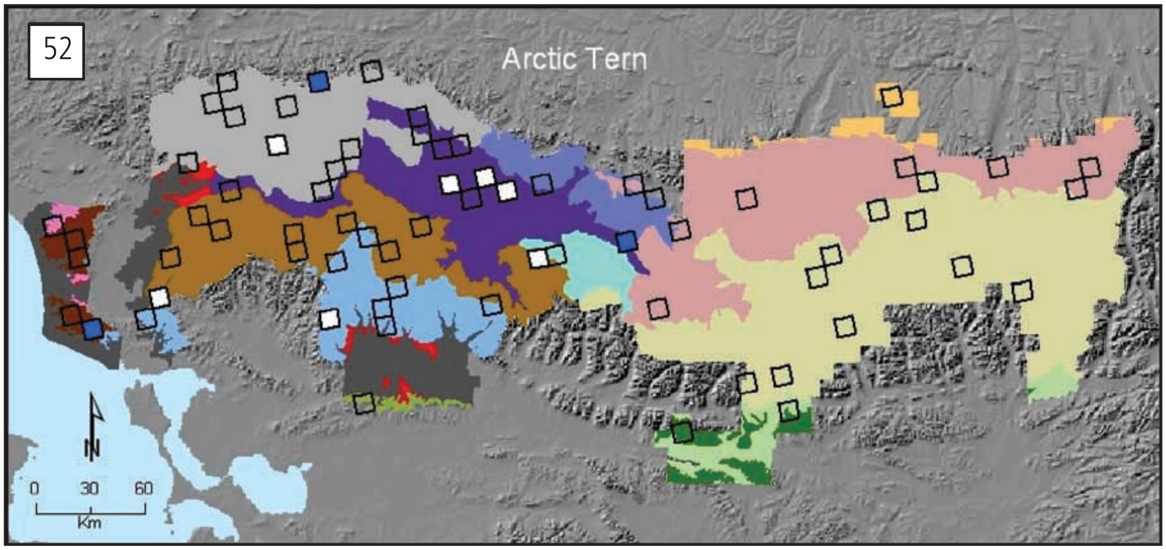
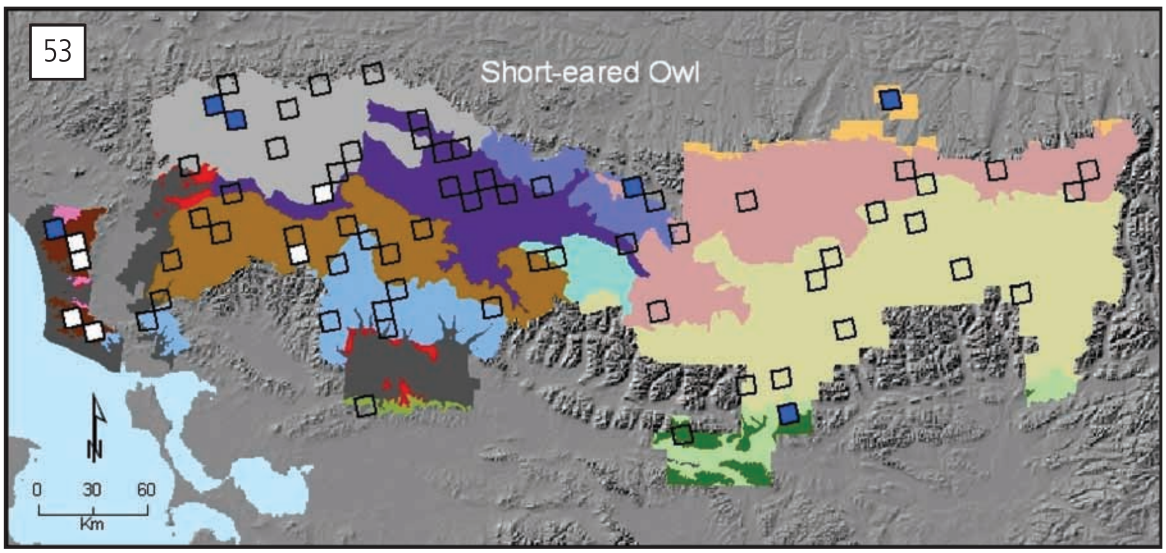
Parasitic Jaeger
0 30 60
Km

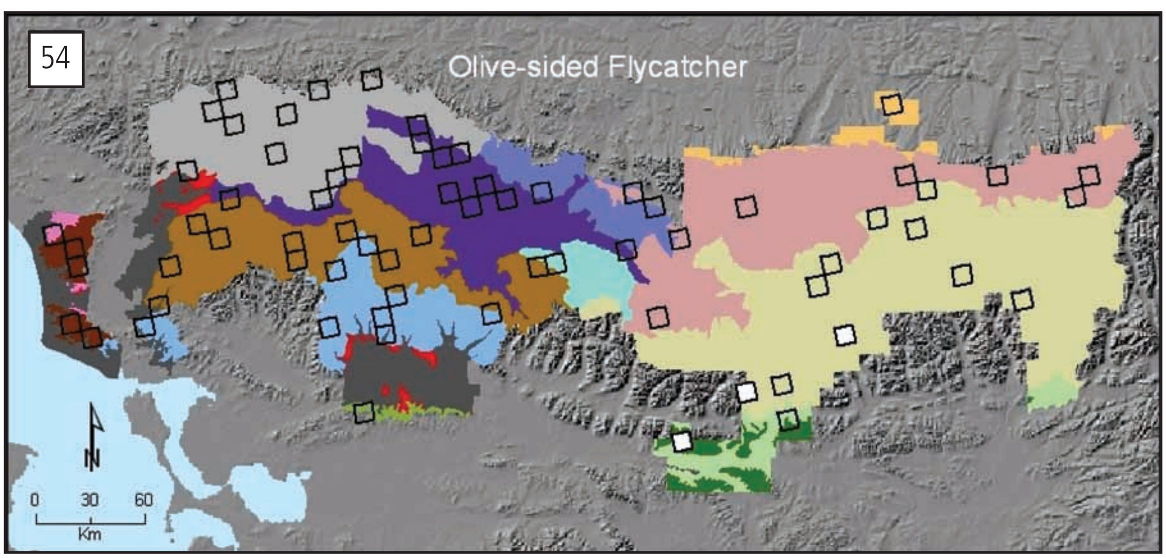

49
Long-tailed Jaeger
0 30 60
Km

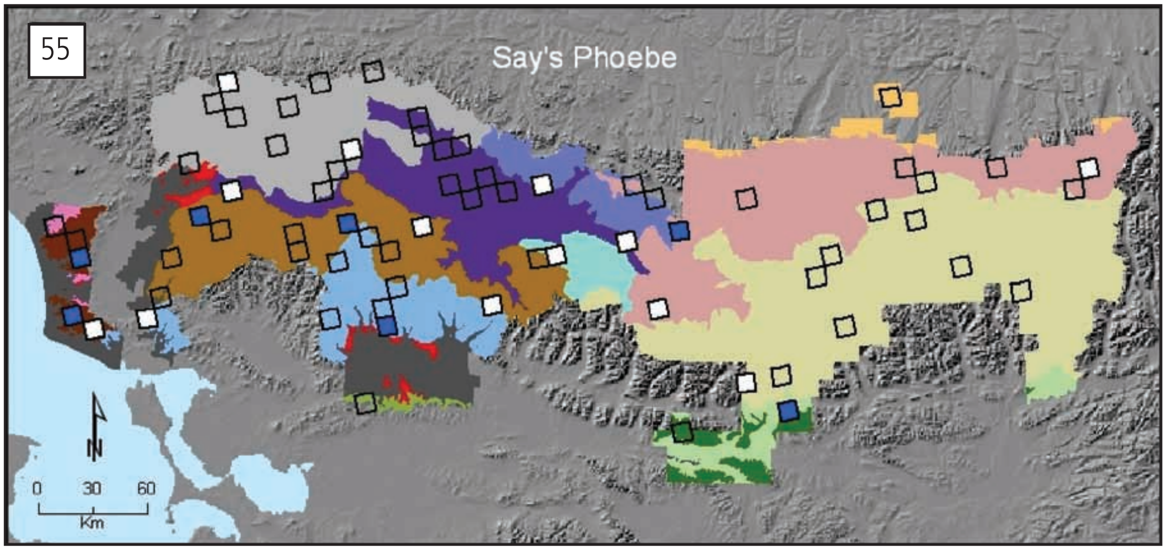

50
Mew Gull
0 30 60
Km

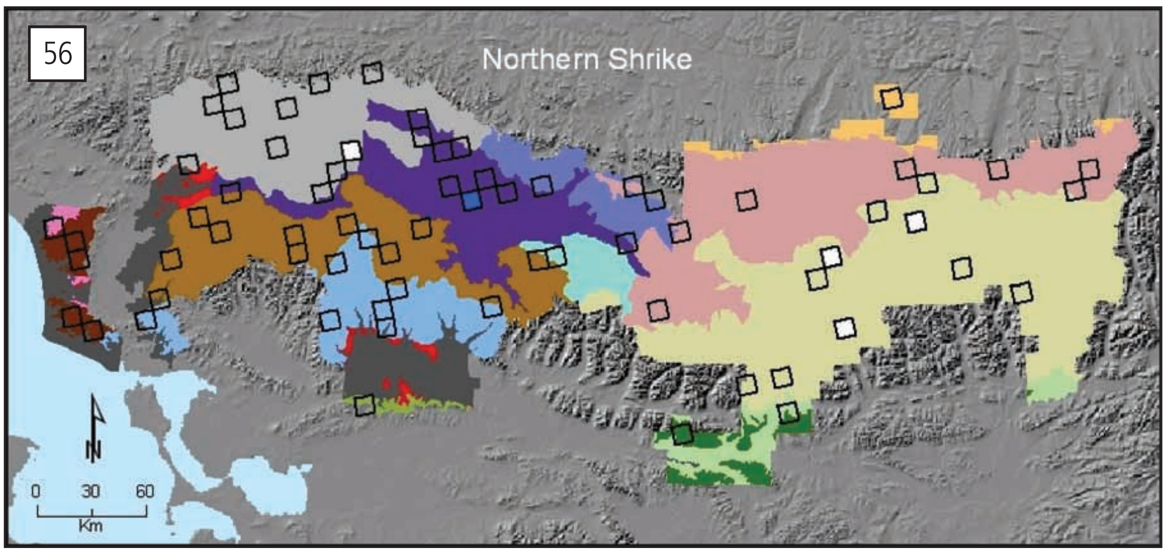

51
Glaucous Gull
0 30 60
Km

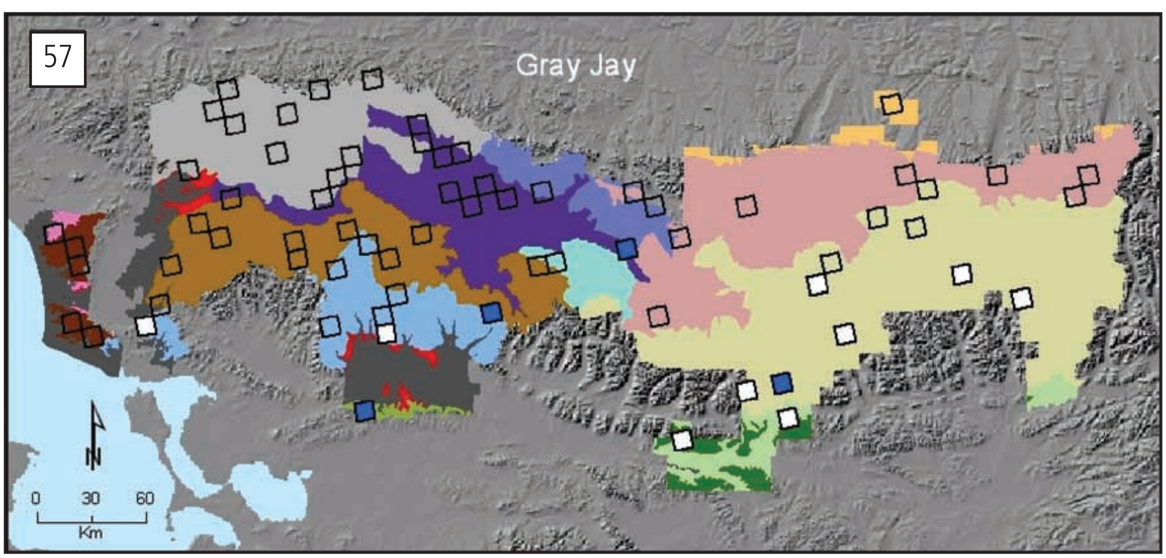

52
Arctic Tern
0 30 60
Km

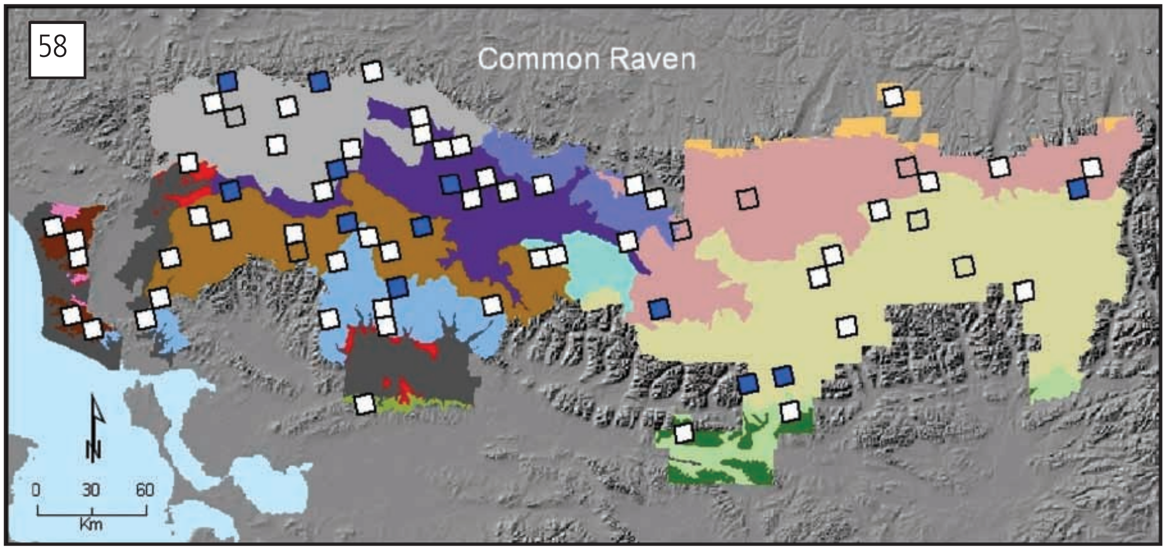

53
Short-eared Owl
0 30 60
Km

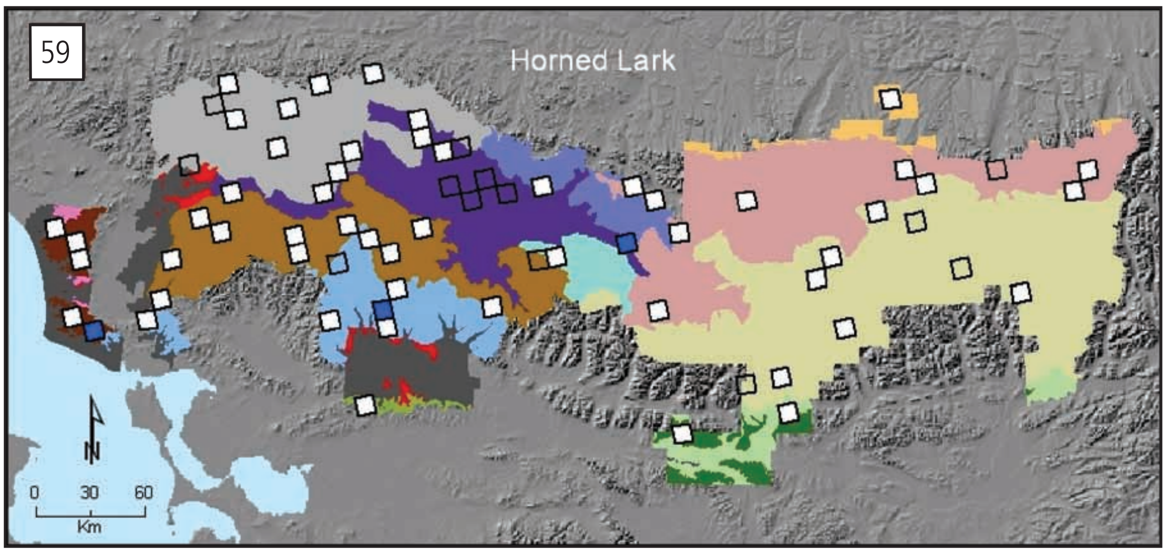

54
Olive-sided Flycatcher
0 30 60
Km

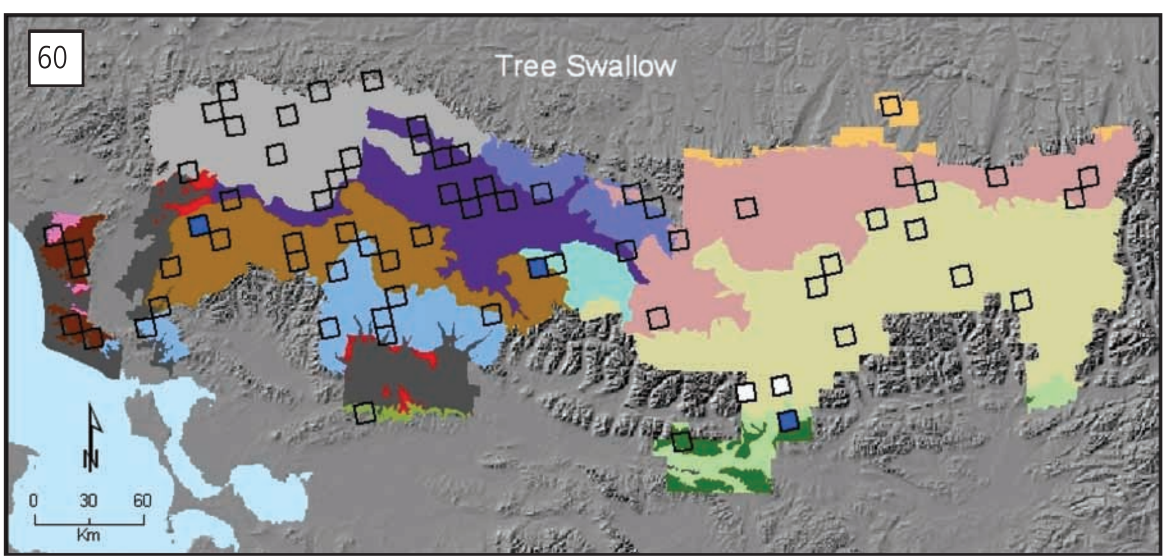

55
Say's Phoebe
0 30 60
Km

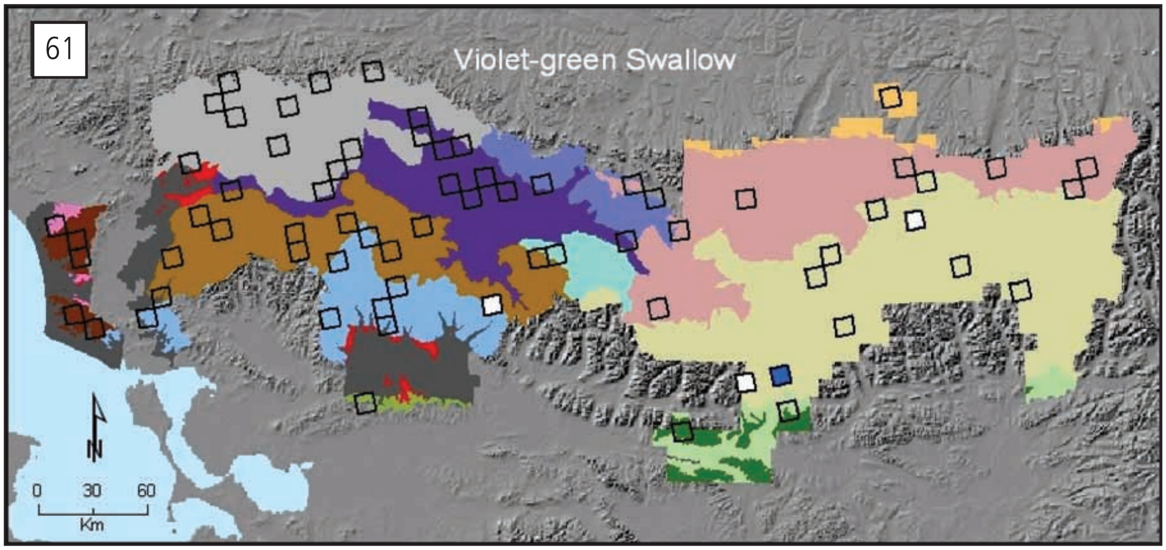

56
Northern Shrike
0 30 60
Km

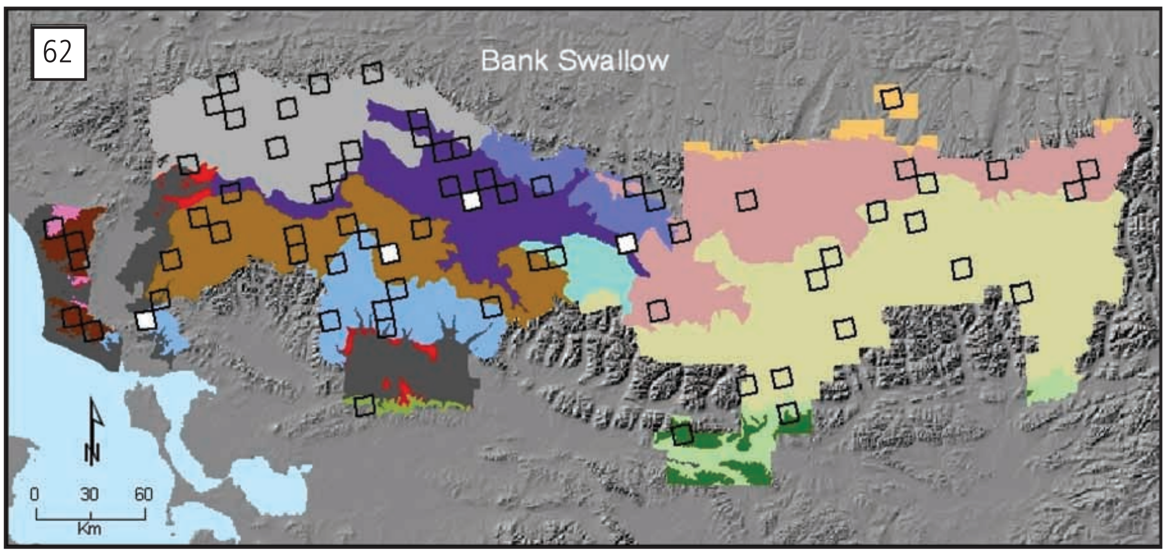

57
Gray Jay
0 30 60
Km

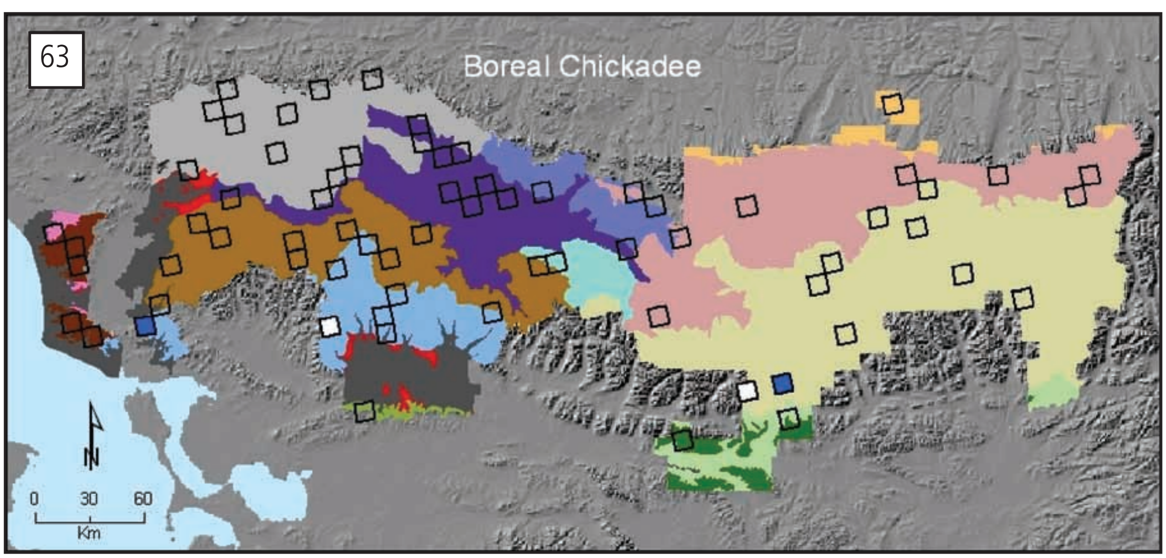

58
Common Raven
0 30 60
Km

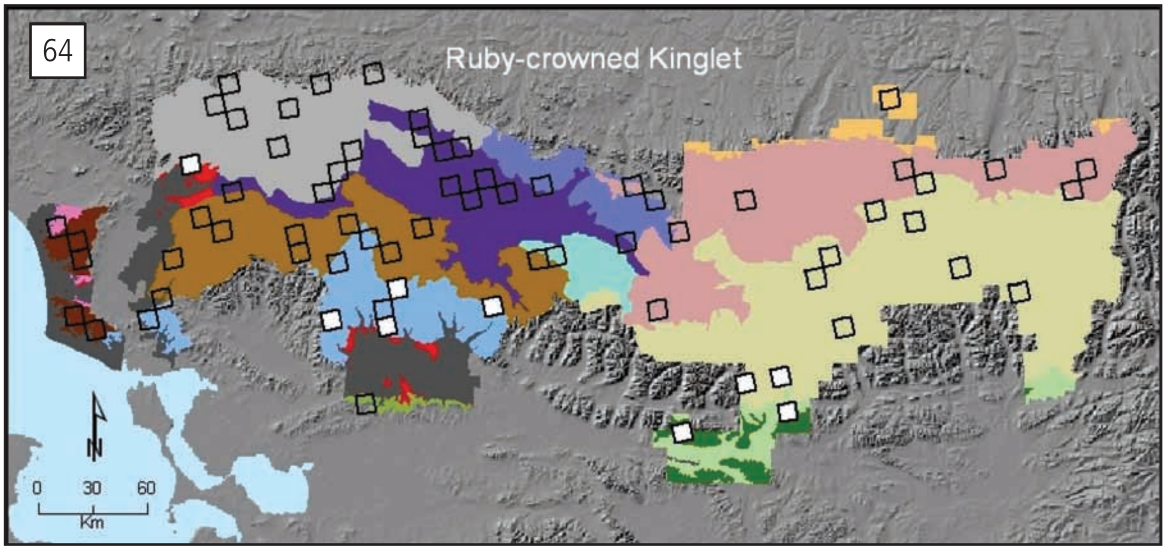

59
Horned Lark
0 30 60
Km

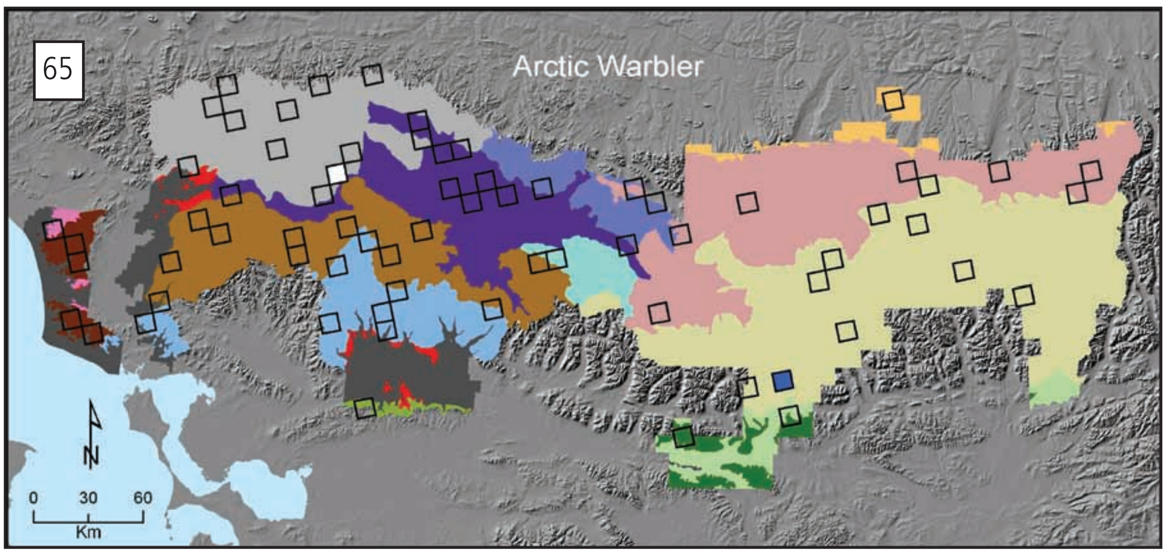

60
Tree Swallow
0 30 60
Km

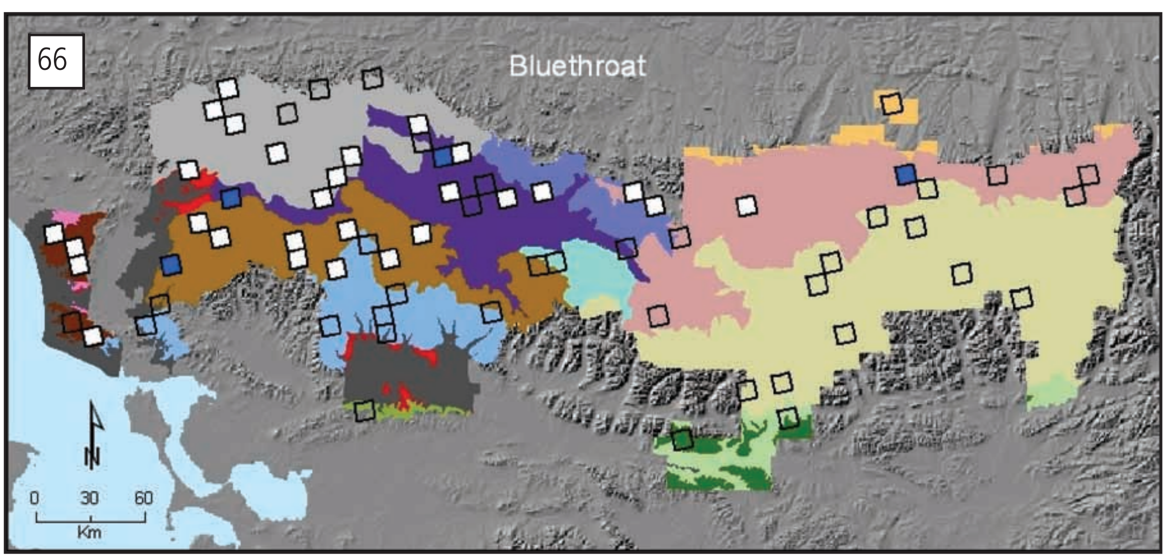

61
Violet-green Swallow
0 30 60
Km

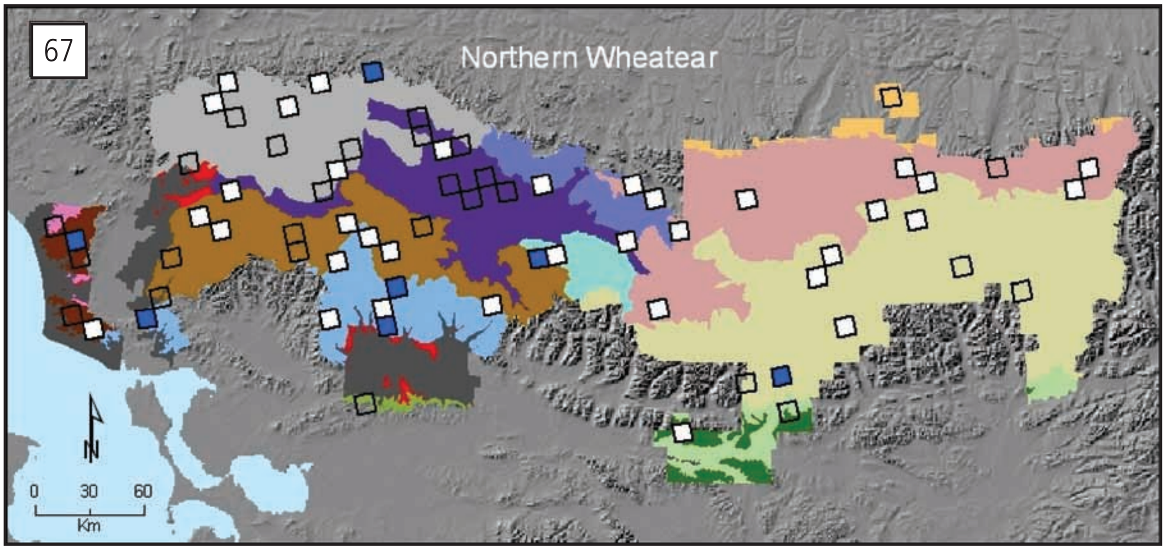

62
Bank Swallow
0 30 60
Km

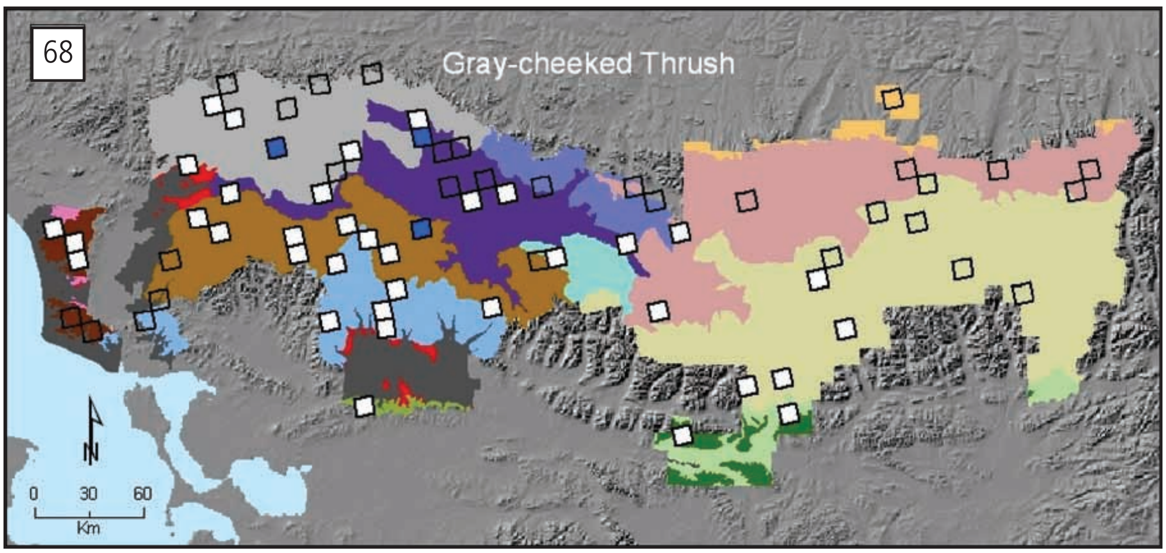

63
Boreal Chickadee
0 30 60
Km

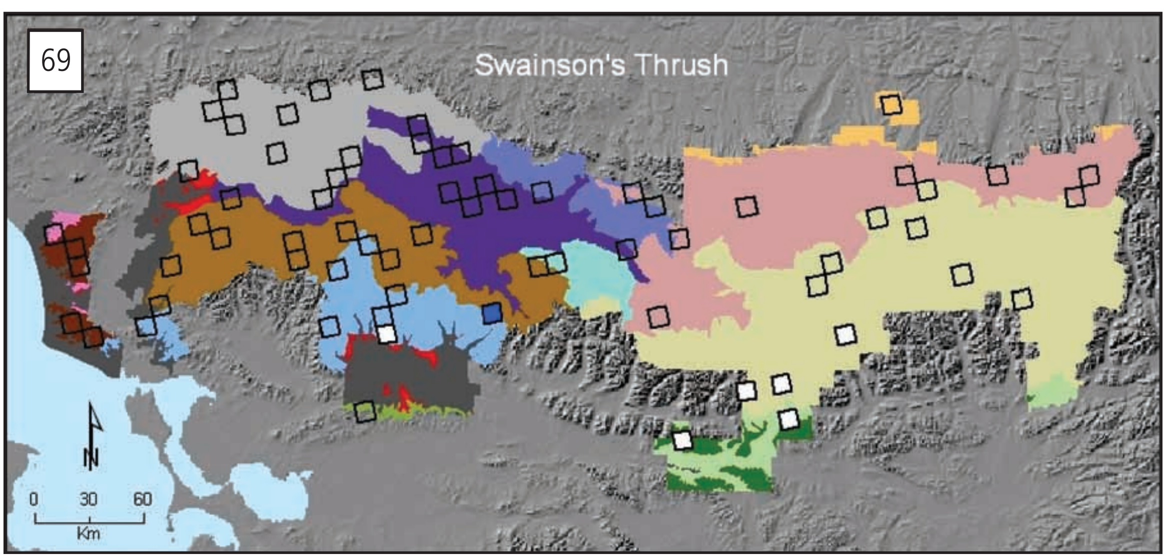

64
Ruby-crowned Kinglet
0 30 60
Km

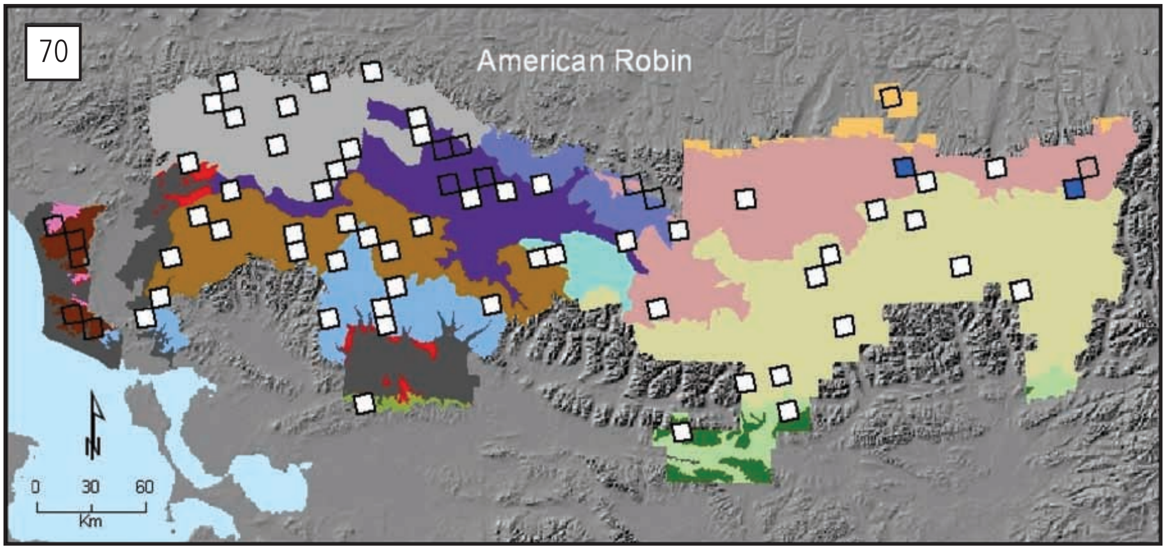

65
Arctic Warbler
0 30 60
Km

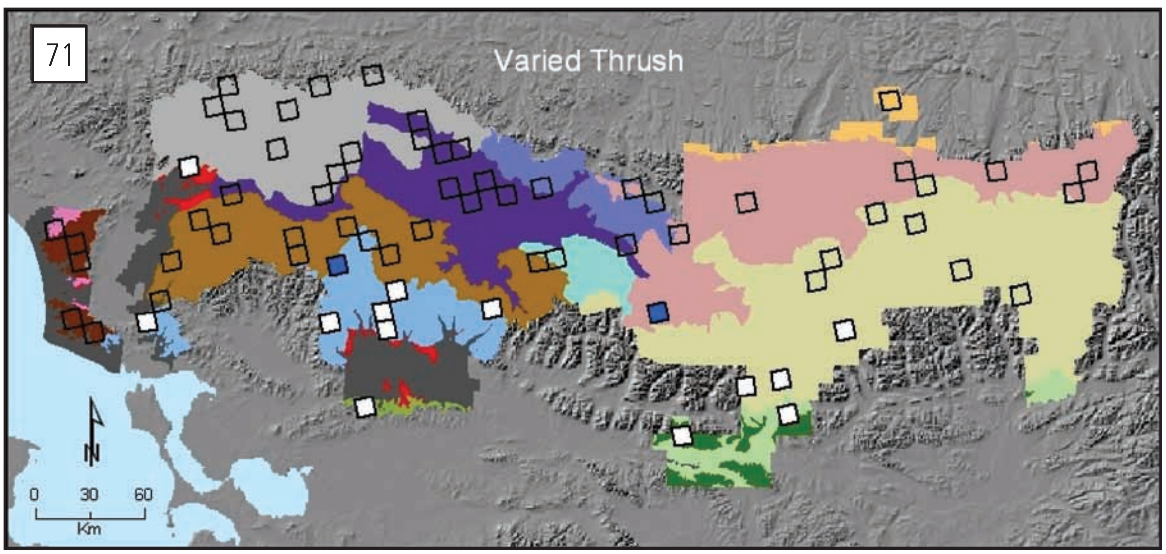

66
Bluethroat
0 30 60
Km

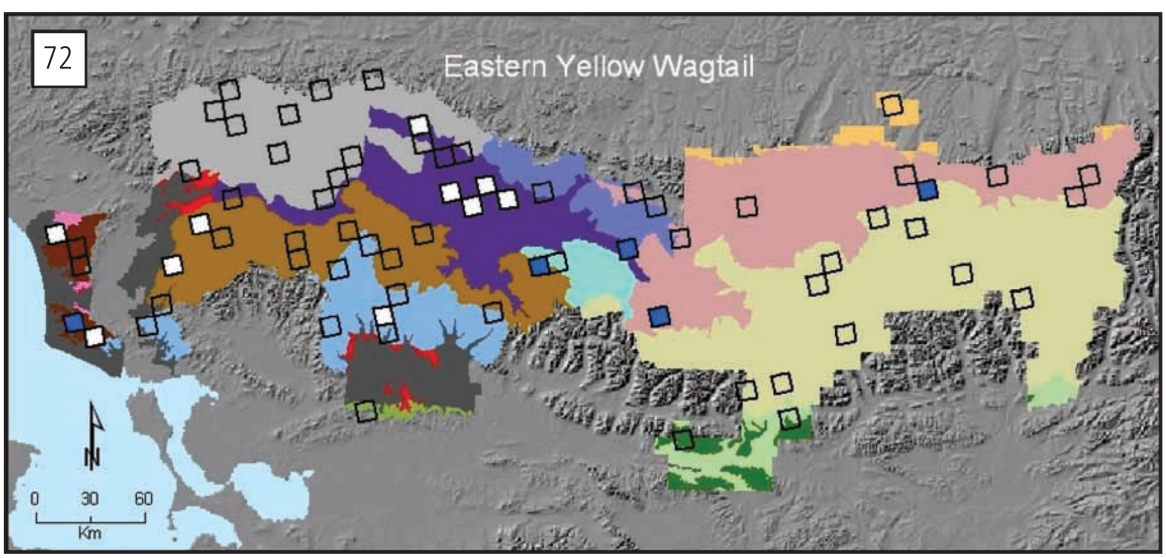

67
Northern Wheatear
0 30 60
Km

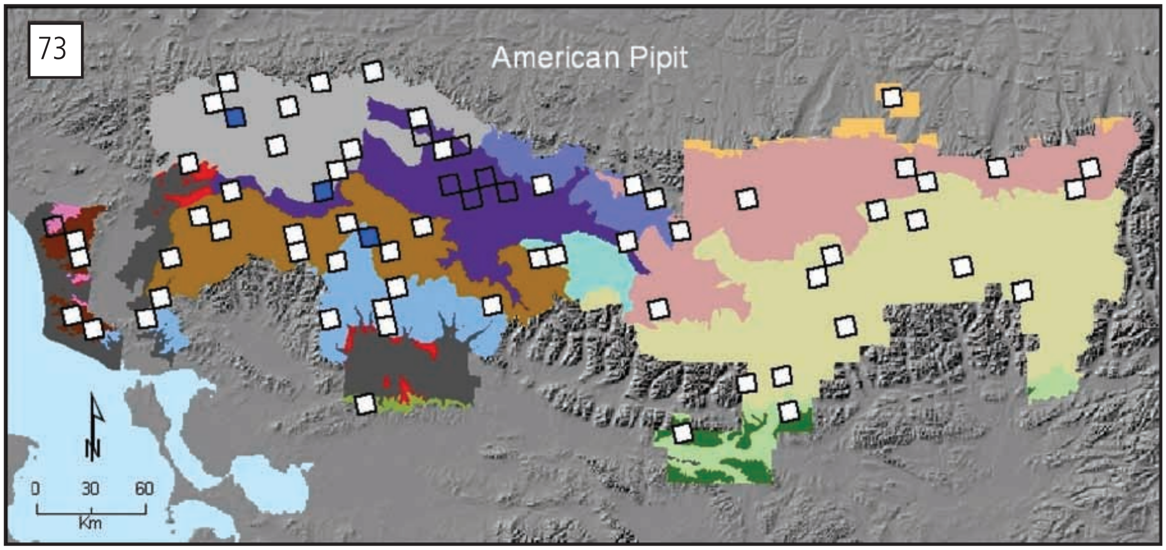

68
Gray-cheeked Thrush
0 30 60
Km

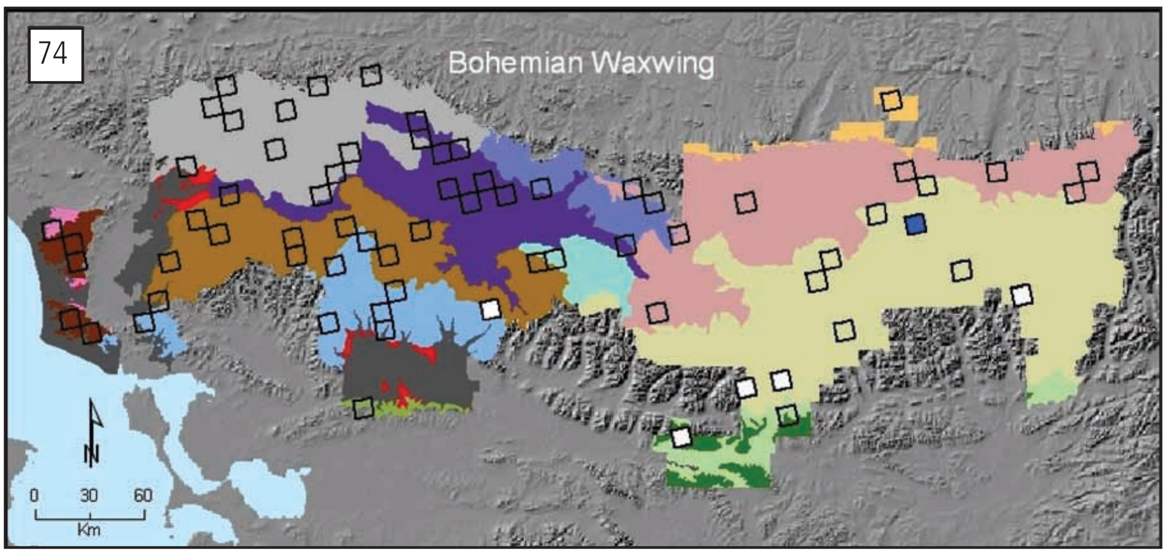

69
Swainson's Thrush
0 30 60
Km

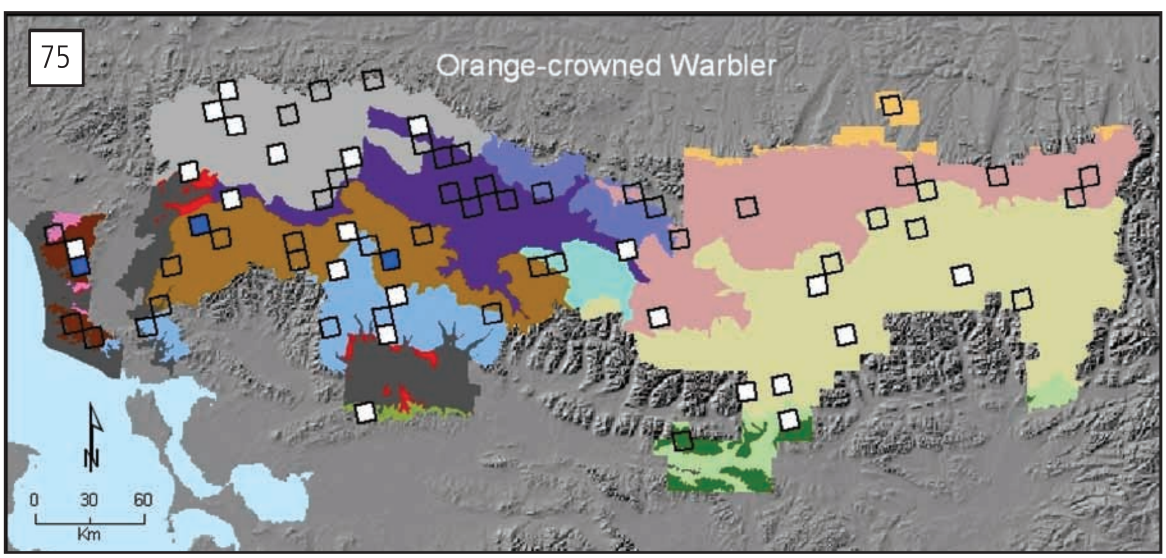

70
American Robin
0 30 60
Km

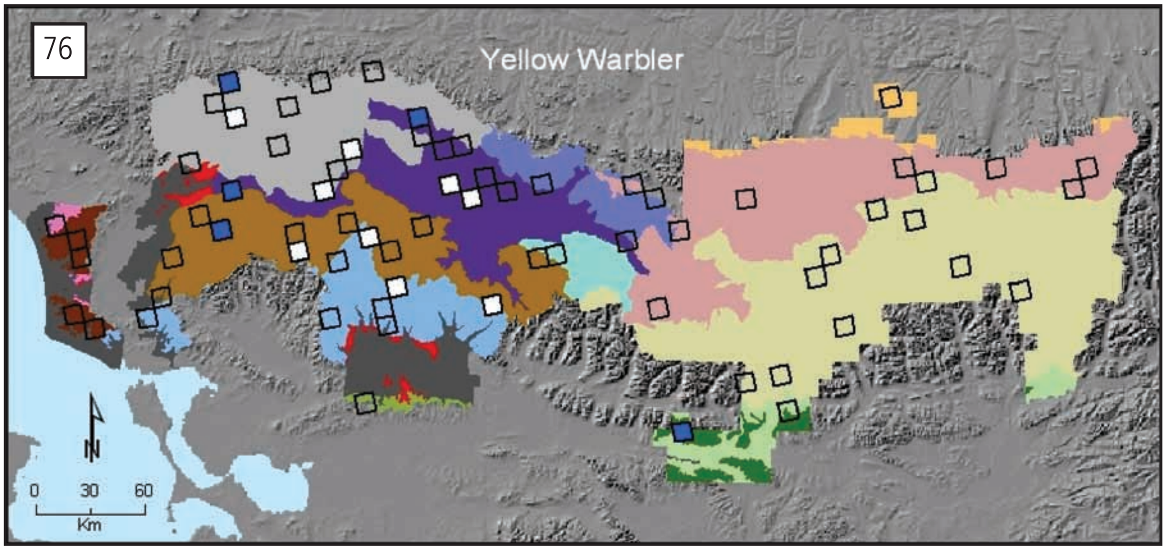

71
Varied Thrush
0 30 60
Km

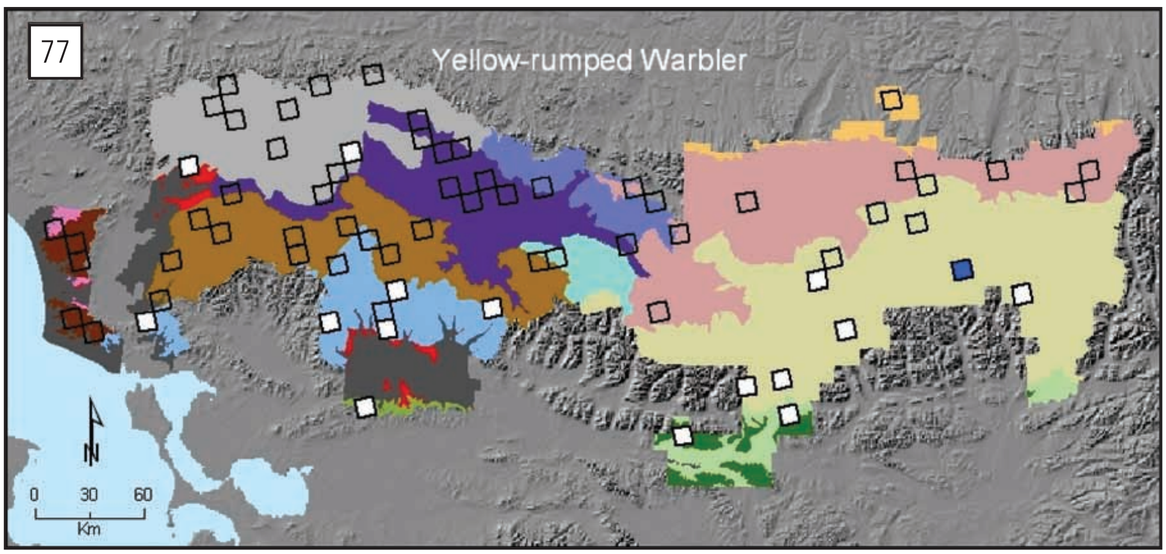

72
Eastern Yellow Wagtail
0 30 60
Km

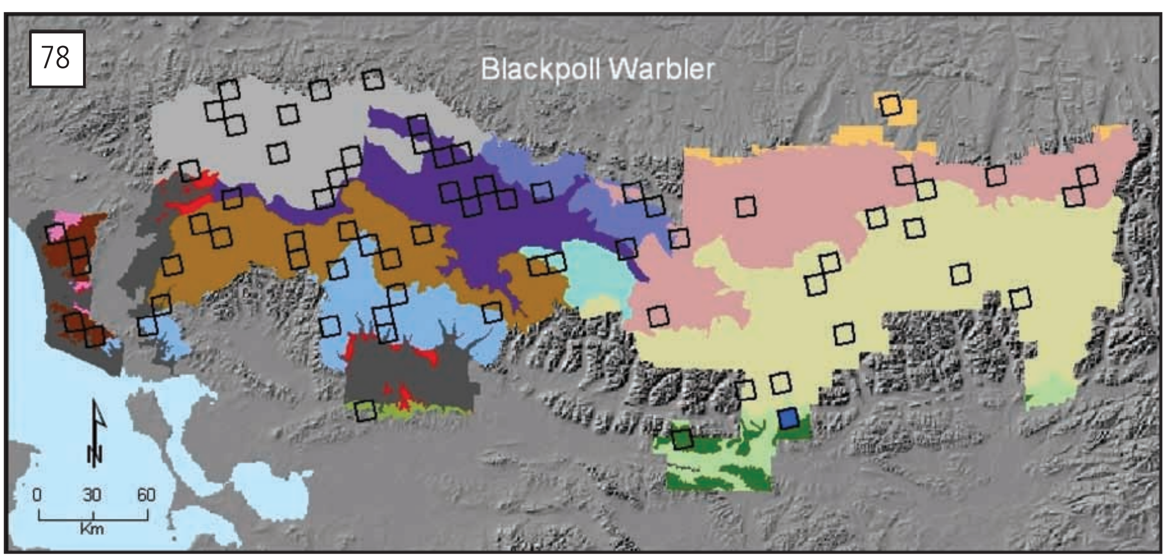

73
American Pipit
0 30 60
Km

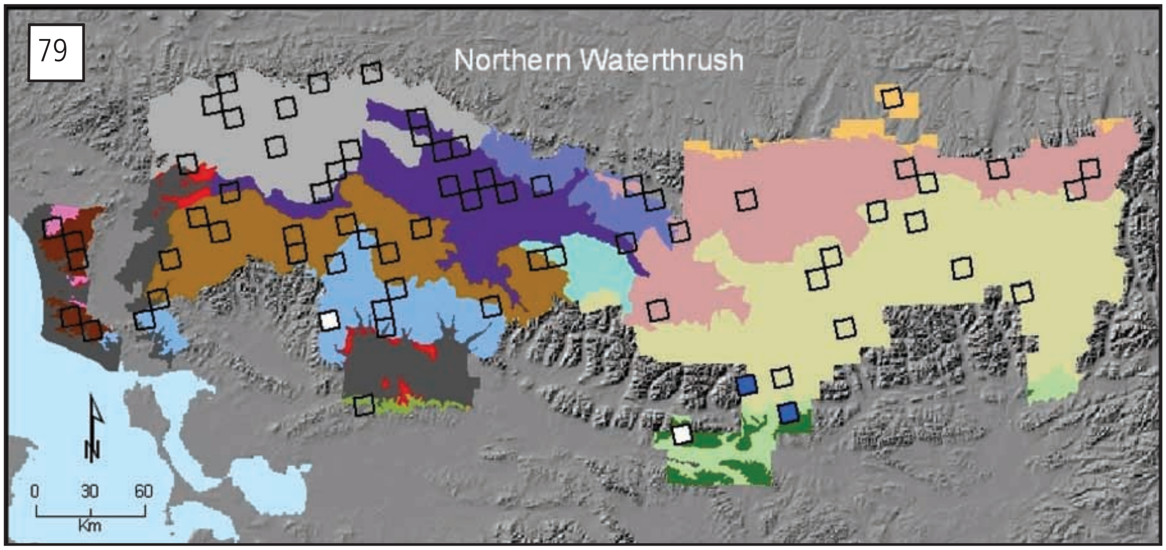

74
Bohemian Waxwing
0 30 60
Km

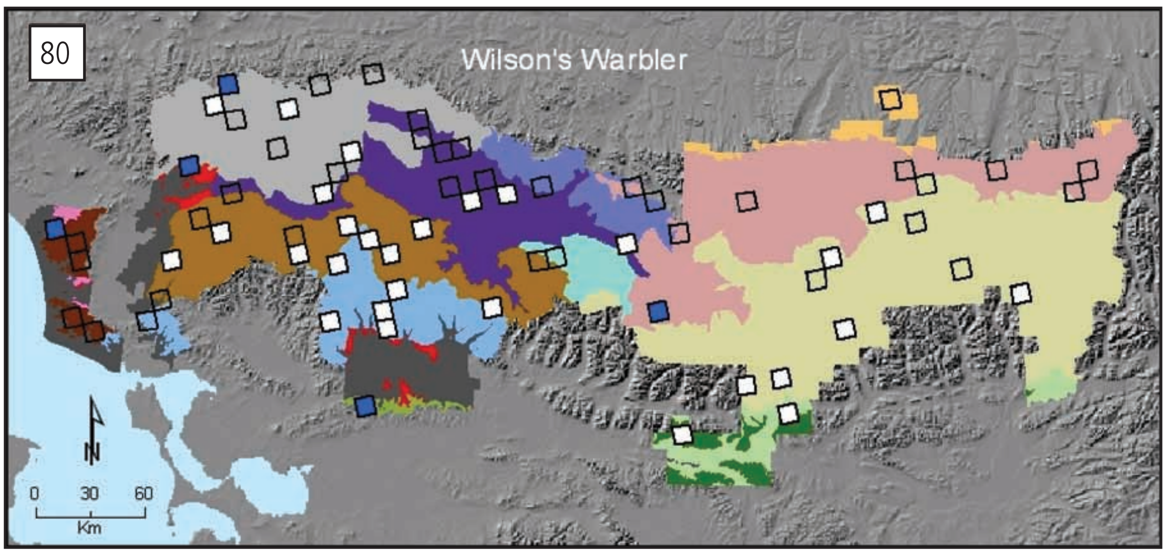

75
Orange-crowned Warbler
0 30 60
Km

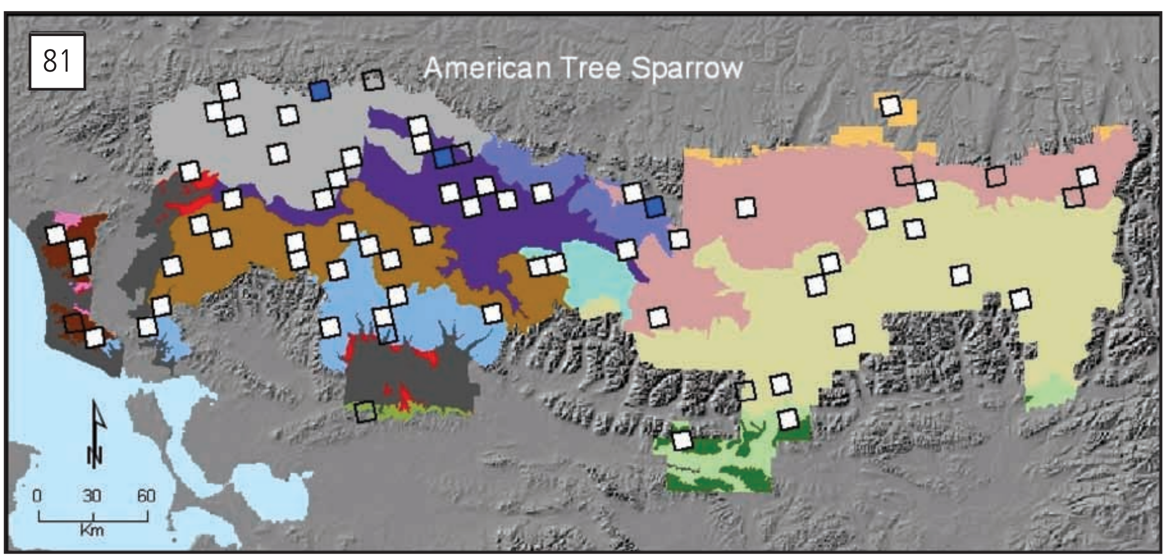

76
Yellow Warbler
0 30 60
Km

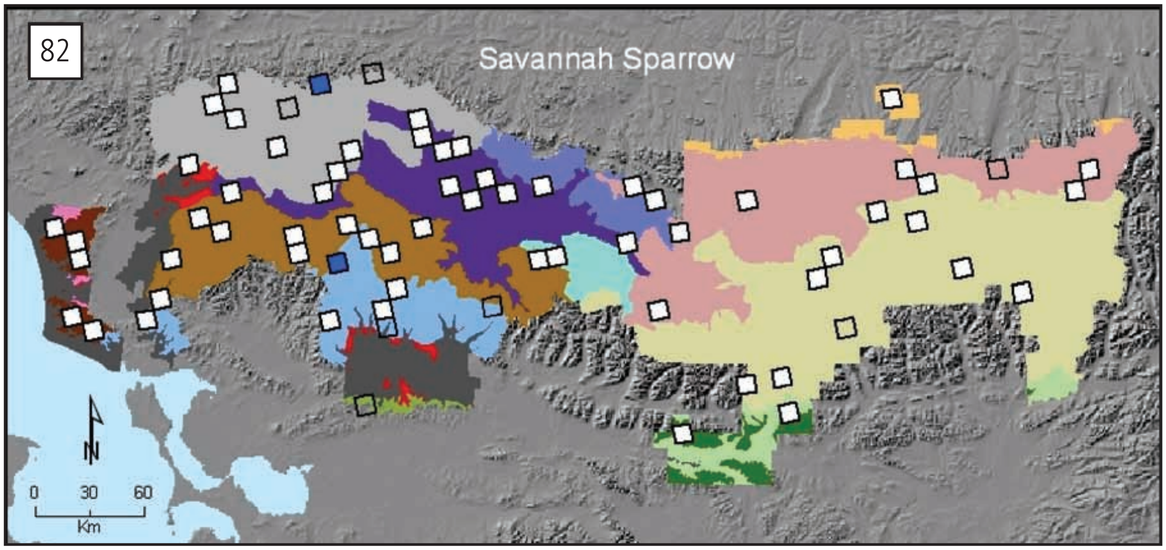

77
Yellow-rumped Warbler
0 30 60
Km

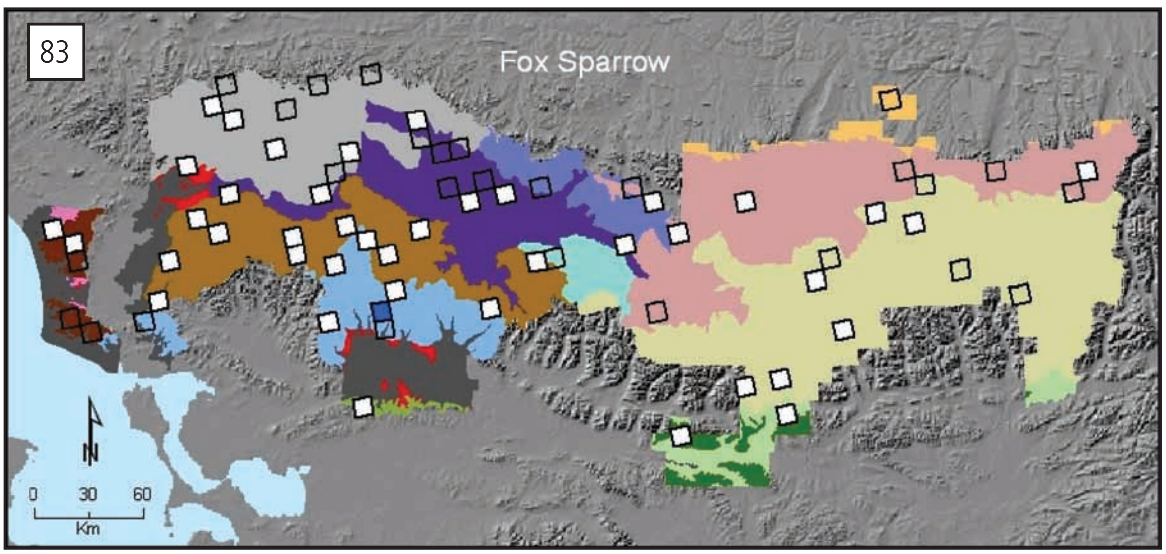

78
Blackpoll Warbler
0 30 60
Km

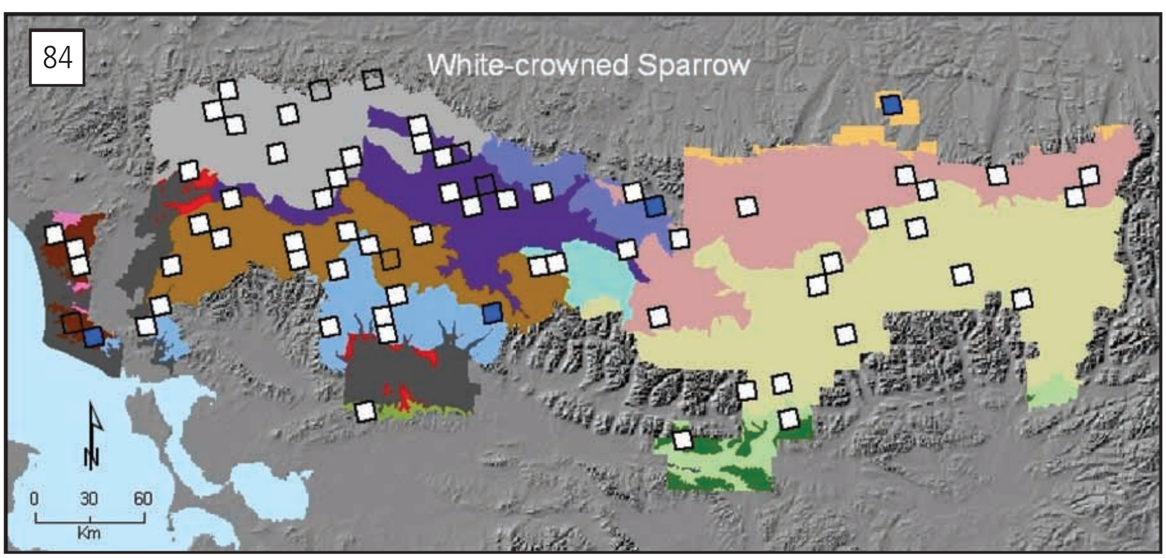

79
Northern Waterthrush
0 30 60
Km

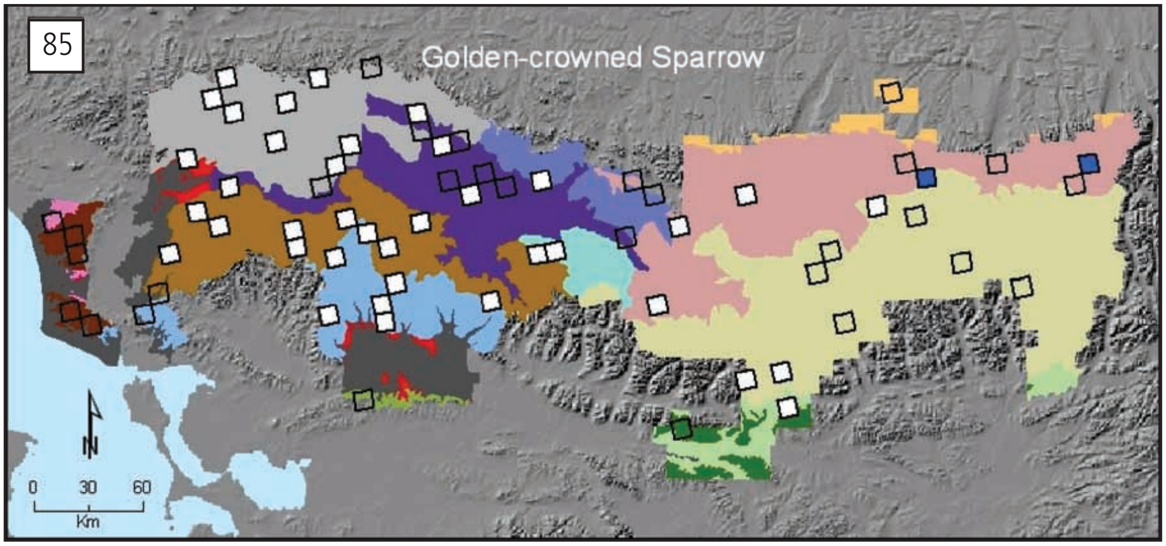

80
Wilson's Warbler
0 30 60
Km

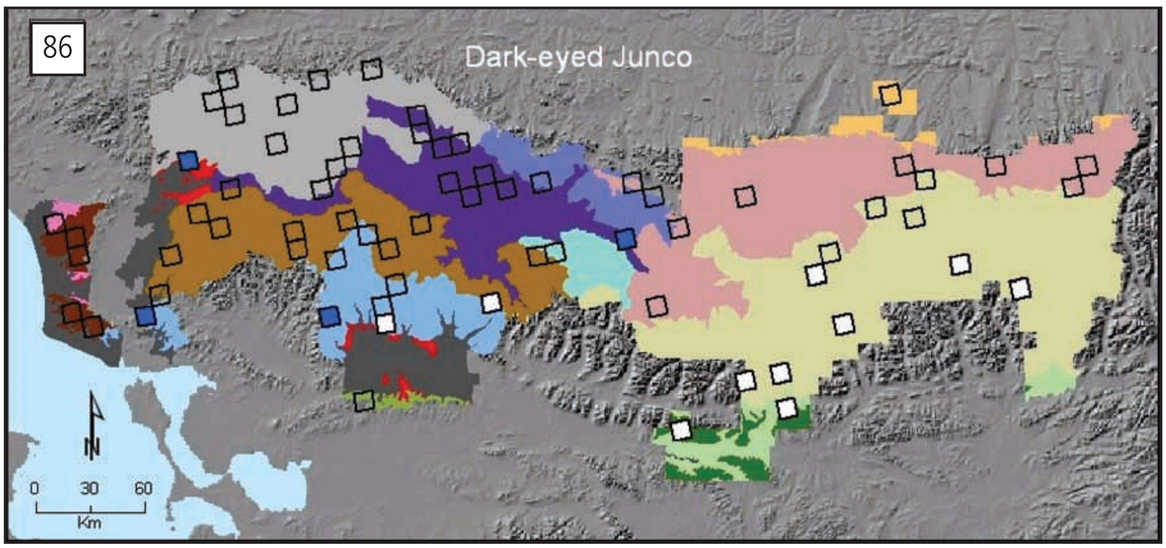

81
American Tree Sparrow
0 30 60
Km

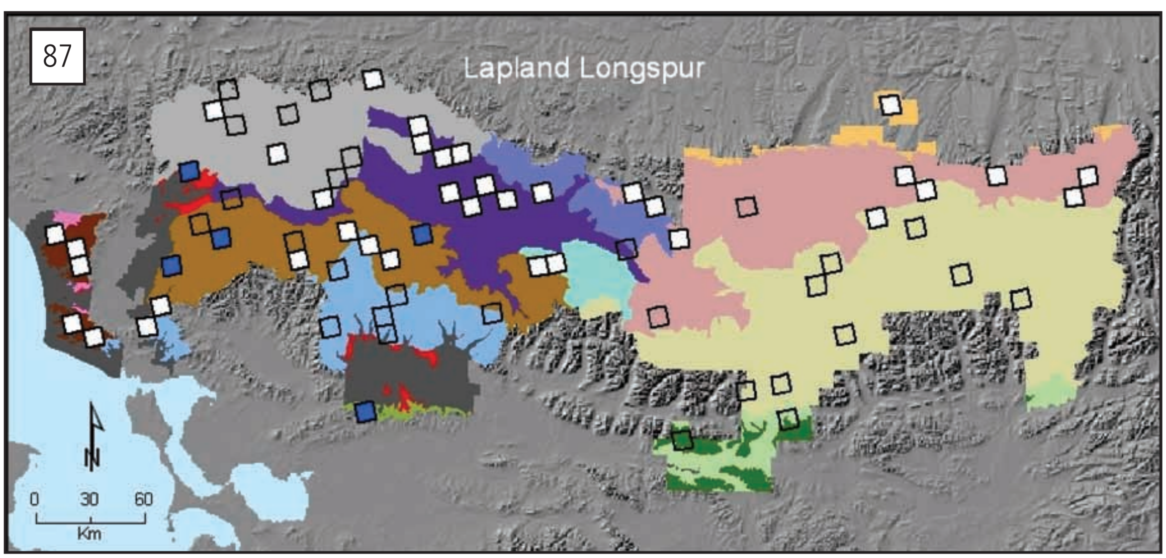

82
Savannah Sparrow
0 30 60
Km

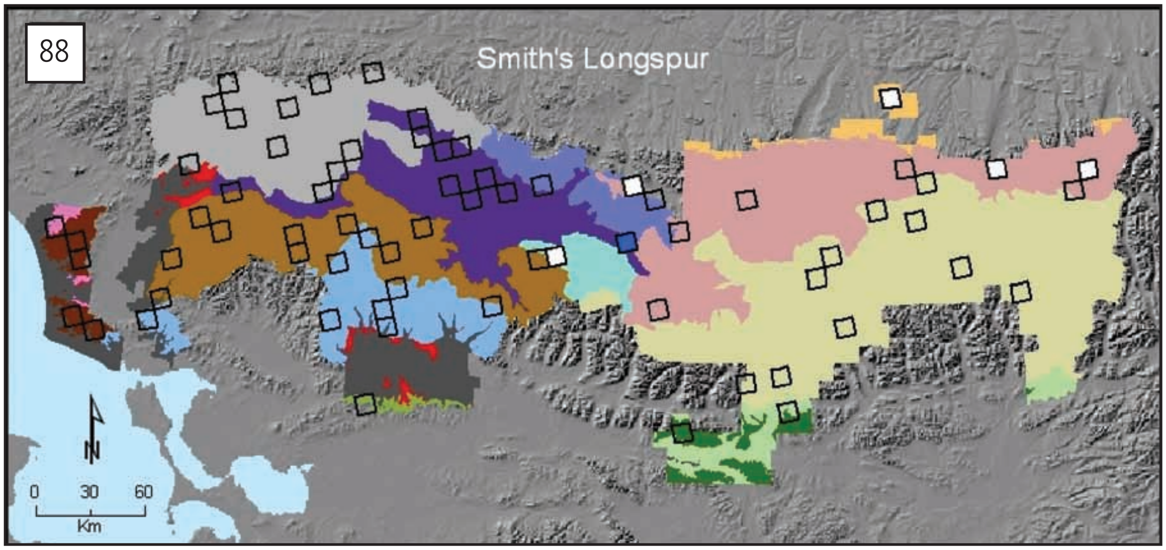

83
Fox Sparrow
0 30 60
Km

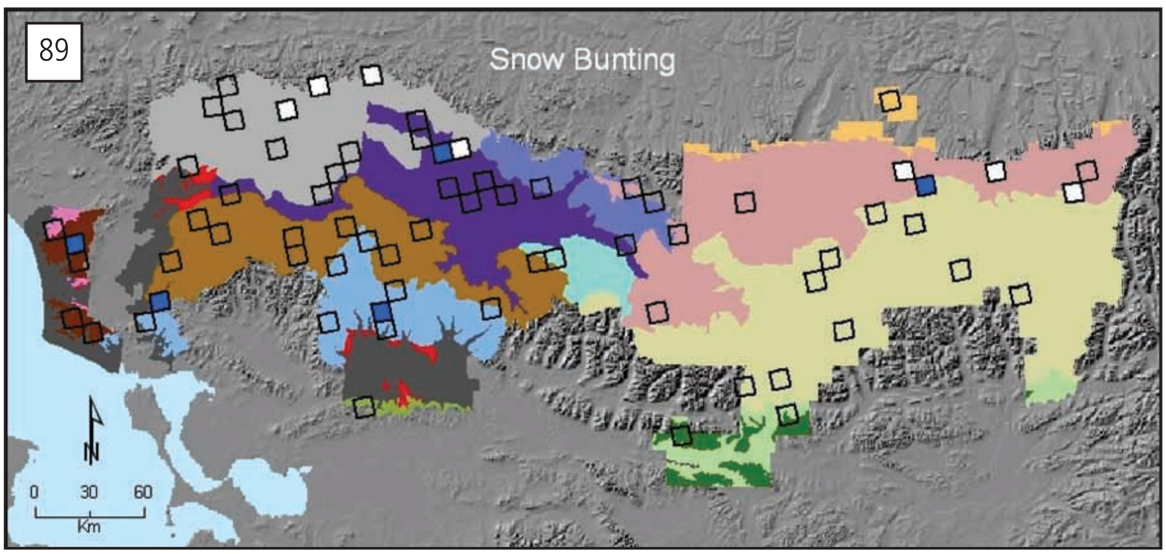

84
White-crowned Sparrow
0 30 60
Km

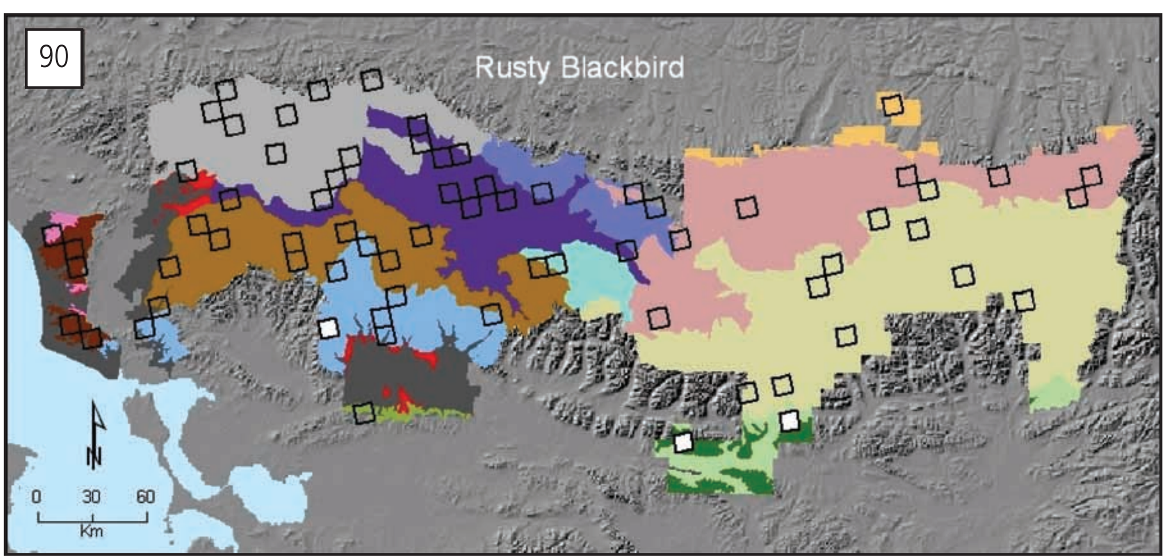

85
Golden-crowned Sparrow
0 30 60
Km

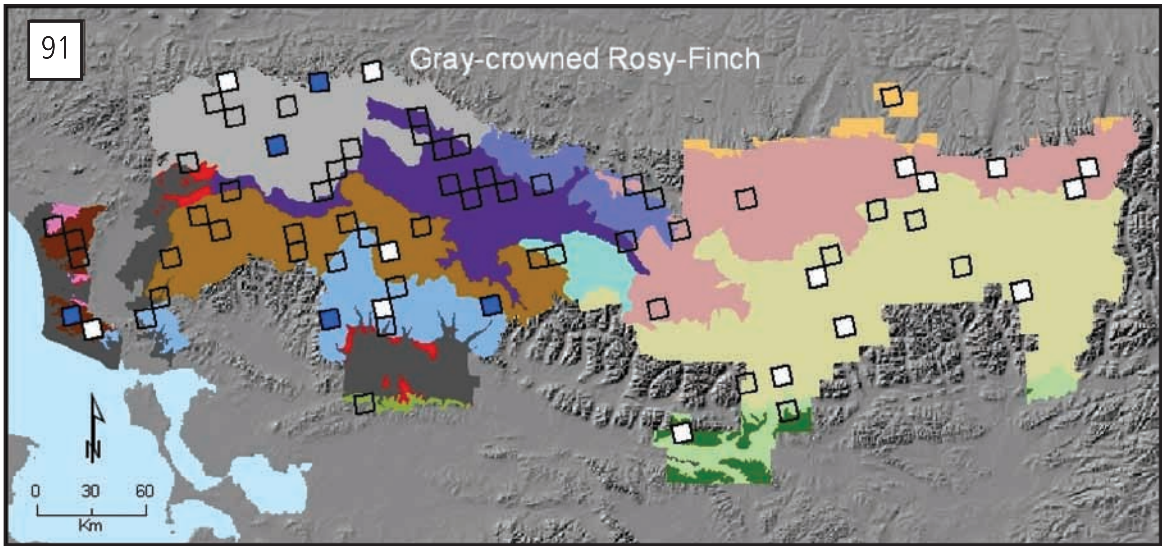

86
Dark-eyed Junco
0 30 60
Km

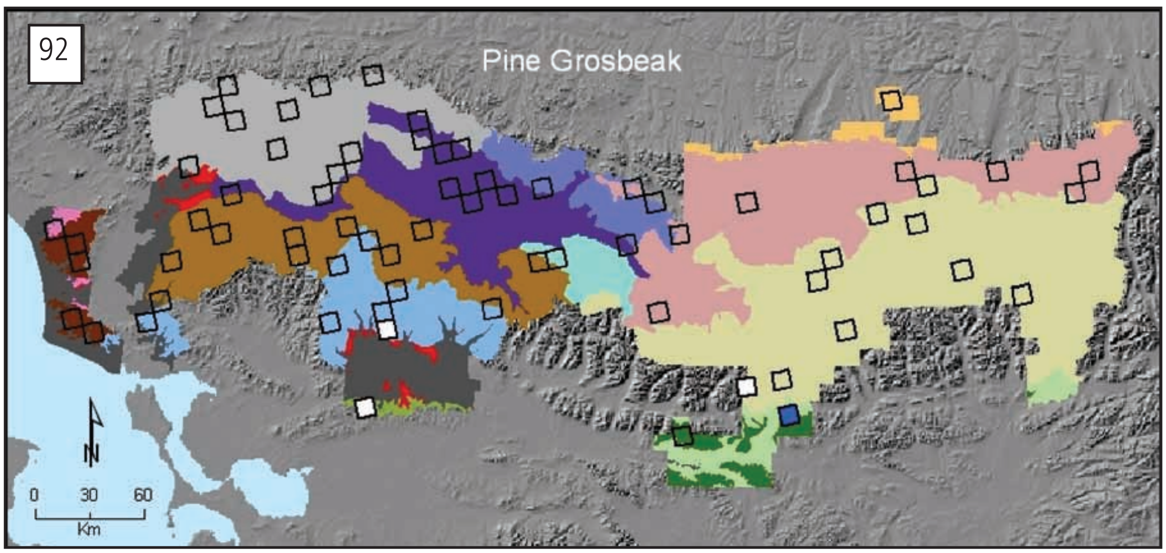

87
Lapland Longspur
0 30 60
Km

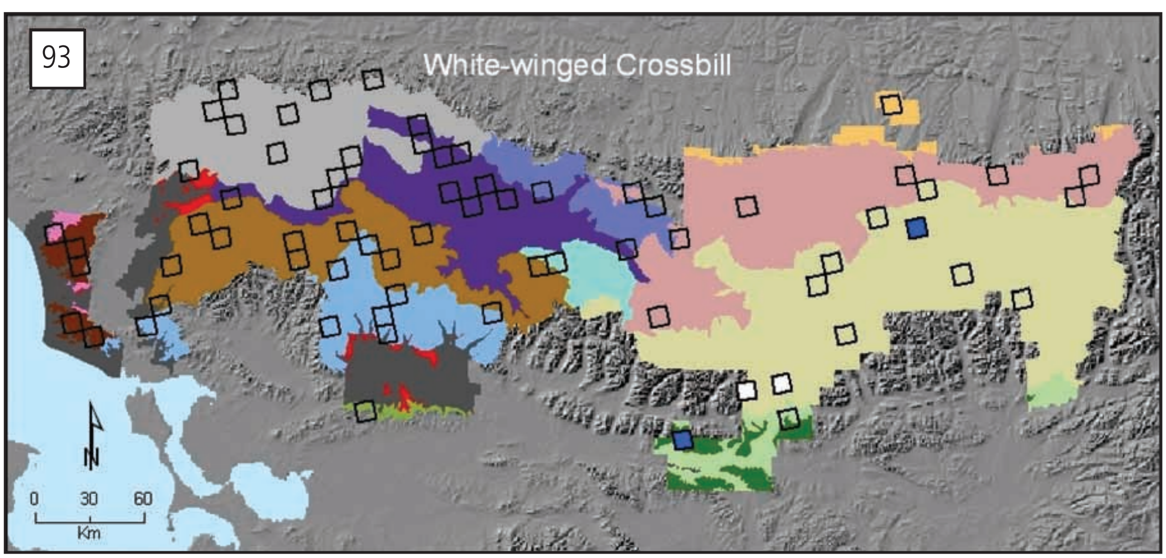

88
Smith's Longspur
0 30 60
Km

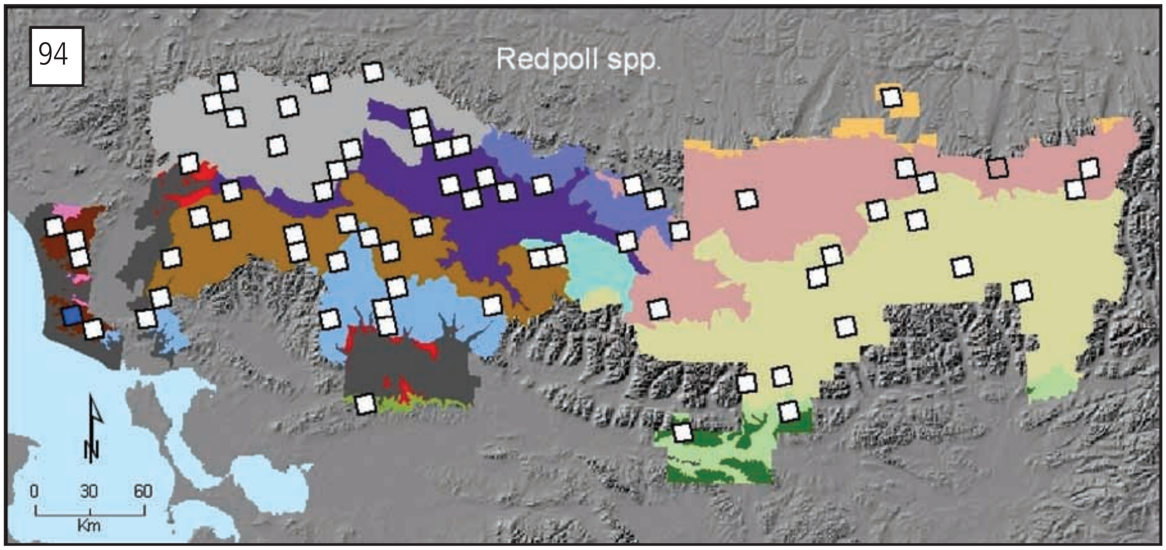

89
Snow Bunting
0 30 60
Km


90
Rusty Blackbird
0 30 60
Km


91
Gray-crowned Rosy-Finch
0 30 60
Km


92
Pine Grosbeak
0 30 60
Km


93
White-winged Crossbill
0 30 60
Km


94
Redpoll spp.
0 30 60
Km

APPENDIX 12
COMMON AND SCIENTIFIC NAMES OF BIRDS EXPECTED TO OCCUR IN THE FOUR NORTHERN PARKS OF THE ARCTIC NETWORK BUT NOT DETECTED DURING THE INVENTORY OF MONTANE-NESTING BIRDS IN 2001–2003

Expectation of occurrence was based on information from previous surveys in the region and general knowledge of species' distributions in Alaska.

Common name	Scientific name	Likely status in the Arctic Network
Waterfowl		
Canvasback	*Aythya valisineria*	lowland-nesting
Lesser Scaup	*A. affinis*	lowland-nesting
Common Goldeneye	*Bucephala clangula*	rare breeder?
Grebes		
Horned Grebe	*Podiceps auritus*	lowland-nesting
Red-necked Grebe	*P. grisegena*	lowland-nesting
Osprey, Hawks, Falcons		
Osprey	*Pandion haliaetus*	lowland-nesting
Bald Eagle	*Haliaeetus leucocephalus*	lowland-nesting
Sharp-shinned Hawk	*Accipiter striatus*	?
American Kestrel	*Falco sparverius*	lowland-nesting
Shorebirds		
Bristle-thighed Curlew	*Numenius tahitiensis*	post-breeder on coast; detected in Bering Land Bridge
RuddyTurnstone	*Arenaria interpres*	migrant
BlackTurnstone	*A. melanocephala*	rare breeder?
Sanderling	*Calidris alba*	migrant
Rock Sandpiper	*C. ptilocnemis*	rare breeder?
Gulls		
Bonaparte's Gull	*Larus philadelphia*	lowland-nesting
Glaucous-winged Gull	*L. glaucescens*	lowland-nesting
Owls		
Great Horned Owl	*Bubo virginianus*	early nesting
Snowy Owl	*B. scandiaca*	early nesting
Northern Hawk Owl	*Surnia ulula*	early nesting
Great Gray Owl	*Strix nebulosa*	early nesting
Boreal Owl	*Aegolius funereus*	early nesting
Kingfishers		
Belted Kingfisher	*Ceryle alcyon*	riparian-nesting
Woodpeckers		
Hairy Woodpecker	*Picoides villosus*	early nesting
American Three-toed Woodpecker	*P. dorsalis*	early nesting

Common name	Scientific name	Likely status in the Arctic Network
Flycatchers		
Western Wood-Pewee	*Contopus sordidulus*	late nesting
Alder Flycatcher	*Empidonax alnorum*	late nesting
Swallows		
Cliff Swallow	*Petrochelidon pyrrhonota*	detected in Bering Land Bridge
Chickadees		
Black-capped Chickadee	*Poecile atricapillus*	early nesting
Gray-headed Chickadee	*P. cincta*	early nesting
Nuthatches		
Red-breasted Nuthatch	*Sitta canadensis*	early nesting
Dippers		
American Dipper	*Cinclus mexicanus*	riparian-nesting
Sparrows		
Lincoln's Sparrow	*Melospiza lincolnii*	patchy distribution; detected in Bering Land Bridge

APPENDIX 13
SPECIES RECORDED DURING SURVEYS OF MONTANE-NESTING BIRDS IN AND ADJACENT TO BERING LAND BRIDGE NATIONAL PRESERVE, ALASKA, LATE MAY–JUNE 1988, 1989, 1991, AND 2000

	Point count surveys[a]						Spot-check surveys[a]						
Common name[b]	1	2	3	4	5	6	A[c]	B	C	D[c]	E	F	G
Brant[d]											x		
Canada Goose	x		x					x					
Northern Pintail	x				x						x		
Willow Ptarmigan[d]	x	x	x		x	x			x		x	x	
Rock Ptarmigan[d]	x	x	x	x	x	x		x	x			x	
Northern Harrier			x	x				x	x			x	
Rough-legged Hawk[d]		x		x		x		x	x		x		x
Golden Eagle[d]				x					x		x		
Gyrfalcon[d]	x			x									
Sandhill Crane	x		x										
American Golden-Plover[d]	x	x	x	x	x	x		x	x	x	x	x	x
Pacific Golden-Plover[d]	x	x	x	x		x							
Golden-Plover spp			x	x									
Whimbrel[d]	x	x	x	x	x	x	x	x	x		x	x	x
Bristle-thighed Curlew[d]	x						x		x	x			x
Bar-tailed Godwit[d]	x	x		x			x	x	x				
Red Knot[d]	x												
Western Sandpiper	x	x	x	x		x	x		x		x	x	
Baird's Sandpiper	x								x				
Pectoral Sandpiper	x						x						
Rock Sandpiper	x												
Wilson's Snipe	x	x	x	x	x	x	x	x	x	x	x	x	
Pomarine Jaeger											x		
Parasitic Jaeger	x		x						x				
Long-tailed Jaeger	x	x	x	x	x	x		x	x		x	x	x
Mew Gull													x
Arctic Tern[d]	x												
Short-eared Owl[d]	x								x				
Say's Phoebe	x												
Gray Jay			x										
Common Raven	x	x	x	x				x	x		x		

Common name[b]	Point count surveys[a] 1	2	3	4	5	6	Spot-check surveys[a] A[c]	B	C	D[c]	E	F	G
Horned Lark	x	x		x	x								x
Tree Swallow									x				
Cliff Swallow		x						x					
Arctic Warbler[d]	x			x									
Bluethroat	x		x	x	x	x		x	x		x	x	x
Northern Wheatear	x		x	x	x			x				x	
Gray-cheeked Thrush[d]	x	x		x		x					x	x	
American Robin		x		x							x	x	
Eastern Yellow Wagtail	x		x								x	x	
American Pipit	x	x	x	x	x								
Orange-crowned Warbler		x		x					x		x		
Yellow Warbler													
Wilson's Warbler		x		x	x						x		
American Tree Sparrow	x	x	x	x	x			x	x		x	x	
Savannah Sparrow	x	x	x	x	x	x		x	x		x		
Fox Sparrow	x	x	x	x	x			x	x		x		
Lincoln's Sparrow				x									
White-crowned Sparrow	x	x		x	x				x		x		
Golden-crowned Sparrow[d]	x	x	x	x	x								
Lapland Longspur[d]	x	x	x	x	x	x		x	x		x	x	x
Snow Bunting[d]		x	x										
Common Redpoll			x						x				
Hoary Redpoll[d]	x	x	x	x		x		x	x		x	x	
Redpoll spp.[e]	x	x	x	x	x	x							

a See Appendix 10 for location of surveys. Numbers correspond to: 1 = Ear Mountain, 2 = Serpentine Hot Springs, 3 = North Serpentine Hot Springs, 4 = Hannum Creek, 5 = Burnt River, and 6 = West Bat.

b See Appendix 1 for scientific names.

c Only shorebirds censused at these sites.

d Species of conservation concern (Boreal Partners in Flight Working Group 1999; U.S. Fish and Wildlife Service 2002; Rich et al. 2004; Stenhouse and Senner 2005; Alaska Shorebird Group 2000, unpublished).

e Common Redpoll and Hoary Redpoll not distinguished.