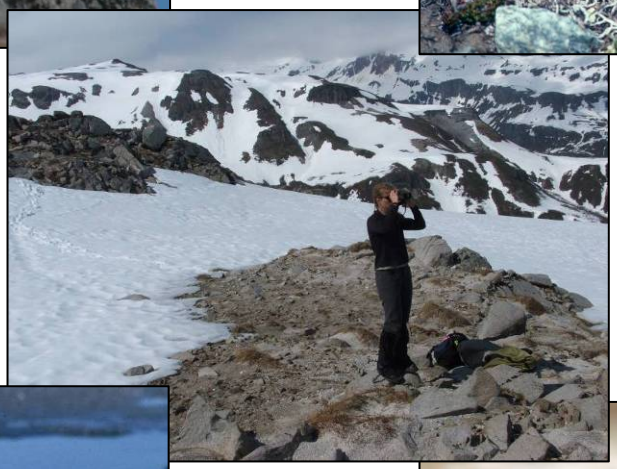
National Park Service - Southwest Alaska Network
Inventory & Monitoring Program

Inventory of Montane-nesting Birds in Katmai and Lake Clark National Parks and Preserves

Final Report



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Acronyms:

ALMS	Alaska Landbird Monitoring Program
ARCN	Arctic Network
ASC	Alaska Science Center
GIS	Geographic Information System
GPS	Global Positioning System
NED	National Elevation Dataset
NPP	National Park and Preserve
NPS	National Park Service
SWAN	Southwest Alaska Network
USGS	U. S. Geological Survey
YUCH	Yukon-Charley Rivers National Preserve

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Cover images, clockwise from top left: Rock Ptarmigan *Lagopus mutus* (USGS photo by D. Ruthrauff), nesting Surfbird *Aphriza virgata* (USGS photo by R. Gill), American Pipit *Anthus rubescens* (photo by G. McElroy, VIREO), and Wandering Tattler *Tringa incana* (USGS photo by R. Gill). Center image: Caroline Van Hemert conducts a point count survey on 30 May, 2006, in the Barrier Range mountains overlooking Kinak Bay, plot 3, Katmai National Park and Preserve (USGS photo by P. Farrell).

Abstract

As part of the National Park Service's Inventory and Monitoring Program, biologists from the U. S. Geological Survey's Alaska Science Center conducted an inventory of birds in montane regions of Katmai and Lake Clark National Parks and Preserves during 2004–2006. We used a stratified random survey design to allocate samples by ecological subsection. To survey for birds, we conducted counts at 468 points across 29, 10-km x 10-km (6.2-mi x 6.2-mi) sample plots in Katmai and 417 points across 25, 10-km x 10-km sample plots in Lake Clark. We detected 92 and 104 species in Katmai and Lake Clark, respectively, including 40 species of conservation concern. We detected three species not previously recorded in Katmai (Ring-necked Duck [*Aythya collaris*], Lesser Scaup [*Aythya affinis*], and White-tailed Ptarmigan [*Lagopus leucurus*]) and two species not previously recorded in Lake Clark (Northern Flicker [*Colaptes auratus*] and Olive-sided Flycatcher [*Contopus cooperi*]). The most commonly detected species in both parks was Golden-crowned Sparrow (*Zonotrichia atricapilla*); Fox Sparrow (*Passerella iliaca*) and American Pipit (*Anthus rubescens*) were abundant and widely-distributed as well. We defined sites as low (100–350 m), middle (351–600 m), or high (601–1,620 m) elevation based on the distribution of vegetation cover, and similarly categorized the 34 most-commonly detected species based on the mean elevation of sample points at which they were detected. High elevation (i.e., alpine) sites were characterized by high percent cover of dwarf shrub and bare ground habitat and supported species like Rock Ptarmigan (*L. mutus*), American Golden-Plover (*Pluvialis dominica*), Wandering Tattler (*Tringa incana*), Surfbird (*Aphriza virgata*), and Snow Bunting (*Plectrophenax nivalis*), all species of conservation concern. This inventory represents the first systematic survey of birds nesting in montane regions of both parks. Results from this inventory can form the foundation of subsequent monitoring efforts.

Executive Summary

The National Park Service (NPS) manages over 200,000 km^2 (77,220 mi^2) of protected lands within Alaska. In order to more effectively protect and manage these vast holdings, NPS formed four Inventory and Monitoring networks: the Arctic, Central, Southeast, and Southwest Alaska Networks. The Southwest Alaska Network (SWAN) of national parks includes five units totaling nearly 38,000 km^2 (14,670 mi^2): Alagnak Wild River Corridor, Aniakchak National Monument and Preserve, Katmai National Park and Preserve, Kenai Fjords National Park, and Lake Clark National Park and Preserve. These units encompass nearly 20% of all NPS lands within Alaska, and cover a diverse spectrum of geography and landforms in a landscape largely dominated by massive, glacier-covered mountains.

The two largest parks within SWAN are Katmai and Lake Clark National Parks and Preserves. At over 16,000 km^2 (6,175 mi^2) each, these two parks dominate the landscape not only in their geographical extent but also in their ruggedness and grandeur of terrain. This same terrain and remote setting, however, make both parks challenging sites in which to conduct biological research, often resulting in a basic lack of information on the status of biological resources within both parks. Avian resources are relatively well described for species occurring at low elevation sites, especially along the waterways and marine coasts of both parks. Information on the distribution and abundance of birds away from the coasts, however, is lacking. Consequently, the overall lack of knowledge concerning the distribution and abundance of montane-nesting birds in both parks is a management priority.

Within the framework of the NPS's Inventory and Monitoring Program, biologists from the U. S. Geological Survey's Alaska Science Center designed and implemented a repeatable, scientifically valid sampling design tailored to sample birds occurring in montane regions of Katmai and Lake Clark. Site access was predominantly via helicopter, and two-person crews spent up to two nights at sample sites. We conducted the inventory during late May–early June of 2004–2006, a period selected to maximize our ability to detect a wide range of species. Samples were allocated in proportion to the extent of ecological subsections within each park, and we conducted surveys at 468 points across 29, 10-km x 10-km (6.2-mi x 6.2 mi) sample plots in Katmai and 417 points across 25, 10-km x 10-km sample plots in Lake Clark.

We detected 92 and 104 species in Katmai and Lake Clark, respectively, including three species not previously recorded in Katmai (Ring-necked Duck [*Aythya collaris*], Lesser Scaup [*Aythya affinis*], and White-tailed Ptarmigan [*Lagopus leucurus*]) and two species not previously recorded in Lake Clark (Northern Flicker [*Colaptes auratus*] and Olive-sided Flycatcher [*Contopus cooperi*]). Results from this inventory combined with summaries of previous bird records documented the occurrence of 164 and 166 species in Katmai and Lake

Clark, respectively. We detected 40 species of conservation concern during this inventory, and based on the records of previous observers an additional 22 species of conservation concern occur in these parks. Only three species of conservation concern were detected on ≥ 15 sample plots in each park (Willow [*Lagopus lagopus*] and Rock [*L. mutus*] ptarmigan, Golden-crowned Sparrow [*Zonotrichia atricapilla*]), and the remaining 37 species had restricted distributions (detected on < 5 sample plots; e.g., Short-eared Owl [*Asio flammeus*], Olive-sided Flycatcher, Rusty Blackbird [*Euphagus carolinus*]).

In addition to documenting new species in each park, we refined the extent of the breeding range and documented the breeding status of several species. Prior to this inventory, the southern extent of the breeding range of a group of alpine shorebirds (Wandering Tattler [*Tringa incana*], Surfbird [*Aphriza virgata*], and Baird's Sandpiper [*Calidris bairdii*]) was known to extend as far south as the Turquoise Lake region of Lake Clark. Observations of breeding individuals of all three species at sites approximately 250 km (155 mi) south in Katmai greatly extended the known breeding range for these species. Additionally, previous observations of Black-bellied Plover (*Pluvialis squatarola*), American Golden-Plover (*P. dominica*), Pacific Golden-Plover (*P. fulva*), Wandering Tattler, Surfbird, Baird's Sandpiper, and American Pipit (*Anthus rubescens*) in Katmai were of migrating individuals, usually detected along the coast. We confirmed that these seven species breed in montane regions of Katmai.

The species that were most commonly detected during point counts were all passerines. Golden-crowned Sparrow (n = 668 individuals detected), Fox Sparrow (*Passerella iliaca*; n = 425), American Pipit (n = 341), and redpoll species (*Carduelis* species; n = 341) were the most commonly detected species overall. Patterns in frequency of detection of certain species varied between parks. For instance, while Golden-crowned Sparrows had the highest average occurrence (number of individuals detected / number of points surveyed) in both parks (87% and 63% in Katmai and Lake Clark, respectively), the average occurrence of Wilson's Warblers (*Wilsonia pusilla*; 49% and 26% in Katmai and Lake Clark, respectively) and Dark-eyed Juncos (*Junco hyemalis*; 12% and 37% in Katmai and Lake Clark, respectively) varied greatly between parks.

We used the Viereck classification system to characterize vegetation cover at sample points within the region's ecological subsections and to assess bird-habitat associations. We combined Viereck classifications into six ecologically meaningful categories: forest, tall shrub, low shrub, dwarf shrub, bare ground, and herbaceous habitats. To facilitate describing the distribution of birds with respect to habitat, we created three elevation categories based on the distributional patterns of vegetation cover: low (100–350 m), middle (351–600 m), and high (601–1,620 m) elevation. Similarly, the 34 most-commonly detected species were assigned to an elevation category based on the mean elevation of the sample points at which they were detected.

Low elevation regions were dominated by forest habitat, and common species detected at these sites included three species of conservation concern, Whimbrel (*Numenius phaeopus*), Varied Thrush (*Ixoreus naevius*), and Gray Jay (*Perisoreus canadensis*). Middle elevation sites contained approximately equal amounts of forest, tall, low, and dwarf shrub habitat and supported species of conservation concern like Golden-crowned Sparrow, Lapland Longspur (*Calcarius lapponicus*), and Willow Ptarmigan. The dominant vegetation cover at high elevation ("alpine") sites was dwarf shrub, and low shrub and bare ground habitat was common as well. Commonly-detected alpine species of conservation concern were Rock Ptarmigan, American Golden-Plover, Surfbird, and Snow Bunting (*Plectrophenax nivalis*).

Differences in overall distribution and average occurrence of birds between parks followed park-specific differences in the occurrence and extent of habitat cover types. Wilson's Warblers and Dark-eyed Juncos, for example, were strongly associated with tall shrub and forest habitats, respectively. Katmai contained more tall shrub habitat than Lake Clark, whereas Lake Clark contained more forest than Katmai, and this difference potentially explained the higher average occurrence of Wilson's Warblers in Katmai and Dark-eyed Juncos in Lake Clark. The distribution of habitats across the study site followed a north-south latitudinal gradient (forest to shrub and tundra) and a low-high elevation gradient (forest to tundra and bare ground).

The Kukaklek Lake region in Katmai and the highlands surrounding Twin, Turquoise, and Telaquana lakes in Lake Clark support unique, diverse avifaunas of regional importance that include many species of conservation concern. These sites contain combinations of geology, physiography, climate, and water resources that create a wide diversity of nesting and foraging sites unique to these parks. In these regions not only did we detect the greatest number of species in each park, but we also detected numerous species not detected elsewhere in either park. Given potential local (e.g., oil, gas, and mining developments) and global (e.g., global climate change) disturbances, these regions merit recognition as locally important sites of avian diversity.

This inventory represented the first systematic survey of birds in Katmai and Lake Clark, and its results form a foundation for future monitoring efforts. Given the dearth of information regarding the avifauna of Alaska in general, this inventory significantly augments our understanding of the distribution and abundance of Alaska's birds. Prior to this inventory, most records of birds within Katmai and Lake Clark were from a window of time between early summer and early fall. In order to completely document each park's avian resources, additional efforts should focus during other parts of the annual cycle. Further, because both parks support numerous individuals of species of conservation concern, species-specific studies could meaningfully augment on-going conservation efforts.

TABLE OF CONTENTS

Abstract iii
Executive Summary iv
TABLE OF CONTENTS vii
LIST OF FIGURES ix
LIST OF TABLES xi
APPENDICES xii
Introduction 1
Ecological Context 3
Background and Study Rationale 7
Objectives 8
Methods 8
Sampling Frame 8
Sample Unit Selection 9
Bird Surveys at Sample Points 9
Species List, Species of Conservation Concern 10
Data Summaries 11
Species Occurrence and Distribution 11
Associations Between Birds, Habitats, and Elevation 11
Results 13
Survey Effort and Conditions 13
Species Lists 13
Elevational Distribution of Birds 19
Frequency of Occurrence 21
Species Distribution 23
Bird-habitat Associations 27
Forest 29
Tall Shrub 29
Low Shrub 30
Dwarf Shrub 31
Bare Ground 32
Herbaceous 33
Physical and Habitat Attributes of Ecological Subsections 34
Areas of Special Importance to Montane Birds 35
Kukaklek Lake 36

Twin / Turquoise / Telaquana Lake Highlands 36
Discussion 36
Landbird Distribution and Abundance 37
Patterns of Habitat Use 38
Breeding Range and Status 39
Species of Conservation Concern 40
Potential Impacts and Conservation Threats 40
Areas of Special Importance to Montane Birds 41
Recommendations for Future Study 43
Acknowledgements 44
Literature Cited 46
Appendix 53

LIST OF FIGURES

Figure 1. Location of parks within the Southwest Alaska Network. 2
Figure 2. Ecoregions of Katmai and Lake Clark National Parks and Preserves. .4
Figure 3. Location of plots in relation to ecological subsections in Katmai National Park and Preserve. 5
Figure 4. Location of plots in relation to ecological subsections in Lake Clark National Park and Preserve. 6
Figure 5. Elevational distribution of species commonly detected during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Box plots show median (thin vertical line), mean (thick vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Number of detections is shown in parentheses for each species. 20
Figure 6. Percent cover of habitats by study area, park, and elevational category at survey points during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Box plots show median (thin vertical line), mean (thick vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Number of points surveyed in each category in parentheses. 28
Figure 7. Black spruce (*Picea mariana*) of typical forest habitat at plot 7 in Lake Clark National Park and Preserve, 16 May 2004. Lake Clark in background. 29
Figure 8. *Alnus*-dominated tall shrub habitat near Lake Clark Pass, plot 17, Lake Clark National Park and Preserve, 28 May 2004. 30
Figure 9. Open, *Betula*- and *Salix*-dominated low shrub habitat (foreground) adjacent to Telaquana Lake, plot 23, Lake Clark National Park and Preserve, 25 May 2004. Note signs of permafrost degradation including open water moat in the foreground and falling black spruce in the background. 31
Figure 10. Dwarf shrub habitat consisting primarily of expansive *Empetrum nigrum* mats adjacent to Kukaklek Lake, plot 29, Katmai National Park and Preserve, 15 May 2005. 32
Figure 11. Rock-strewn, bare ground at 1,369 m (4,500 ft) elevation between Twin and Turquoise lakes, plot 18, Lake Clark National Park and Preserve, 24 May 2004. 33
Figure 12. Herbaceous, graminoid-dominated habitat (foreground) at 790 m (2,600 ft) elevation adjacent to Kulik Lake at plot 26, Katmai National Park and Preserve, 17 May 2005. 34
Figure 13. Conditions on 3 June 2006 at plot 4 in Johnson River Valley, Lake Clark National Park and Preserve. Snowcover was nearly complete, but emergent vegetation was in leaf and birds were present and active. 35
Figure 14. Low shrub habitat (background) and dwarf shrub and herbaceous habitat (foreground) adjacent to Kukaklek Lake at plot 29, Katmai National Park and Preserve, 15 May 2005. 42

Figure 15. Dwarf shrub and herbaceous habitat at plot 16, Lake Clark National Park and Preserve, 11 June 2004. Bonanza Hills in background. 43

LIST OF TABLES

Table 1. Birds of Katmai and Lake Clark National Parks and Preserves. 'X' indicates a species detected during the inventory of montane-nesting birds 2004–2006, 'P' indicates a species recorded by previous observers, and a blank indicates that the species has not been recorded in that particular park. Species in bold are species of conservation concern (see Table 2). . 14

Table 2. Species of conservation concern recorded in Katmai and Lake Clark National Parks and Preserves. 'X' indicates a species detected during the inventory of montane-nesting birds 2004–2006, 'P' indicates a species recorded by previous observers. 18

Table 3. Occurrence of birds on 10-min point counts during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. 21

Table 4: Species occurrence by 10-km x 10-km sample plot during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. 24

APPENDICES

Appendix 1. Area of ecological subsections and sample point distribution within the sampling frame for the inventory of montane-nesting birds within Katmai and Lake Clark National Parks and Preserves, 2004–2006. 53
Appendix 2. Vegetation classification (after Viereck et al. 1992) used during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. 55
Appendix 3: Species distribution by 10-km x 10-km sample plot for birds detected during the inventory of montane-nesting birds in Katmai National Park and Preserve, 2005–2006. See Figure 3 for plot locations. 56
Appendix 4: Species distribution by 10-km x 10-km sample plot for birds detected during the inventory of montane-nesting birds in Lake Clark National Park and Preserve, 2004, 2006. See Figure 4 for plot locations…65
Appendix 5. Abundance (A), breeding status (BS), and habitat affinity of birds recorded during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Not included in this list are 33 species strongly associated with aquatic habitats (e.g., most waterfowl, loons, grebes, gulls, terns, Osprey, Bald Eagle, American Dipper). Abundance, status, and habitat associations are based on inventory results, and abundance codes refer specifically to the early-spring inventory period. A dash indicates that a species was not detected in that particular park, and species in bold are species of conservation concern (see Table 2). 73
Appendix 6. Percent occurrence of habitats at sample points in ecological subsections during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Number of points surveyed is shown in parentheses for each subsection. See Appendix 1 for key to subsection names. 76
Appendix 7. Percent cover of habitats at sample points during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Box plots show median (thin vertical line), mean (thick vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Number of detections is shown in parentheses for each species. Species ordered from top to bottom based on increasing values of mean elevation at sample points where they were detected (see Figure 5).78
Appendix 8. Snow cover, snow occurrence, and elevation of sample points in ecological subsections surveyed during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Box plots (8a, 8c) show median (thin vertical line), mean (thick vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Number of points surveyed is shown in parentheses for each subsection. See Appendix 1 for key to subsection names. 80
Appendix 9. Percent cover of habitats at sample points in ecological subsections during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Box plots show median (thin vertical line), mean (thick vertical line), quartiles (open box), and 10th and

90th percentiles of values (whiskers). Number of points surveyed is shown in parentheses for each subsection. See Appendix 1 for key to subsection names. 81
Expected Species List Source References 83
Annotated List of Mammals and Amphibians 86

Introduction

The National Park Service (NPS) manages 390 land units covering nearly 340,000 km^2 (over 130,000 mi^2) of protected lands throughout the United States and associated territories. Nearly two-thirds of these lands are distributed across 16 parks, preserves, and monuments within Alaska. In order to more effectively manage Alaska's vast holdings, NPS formed four networks based on proximity and ecological similarity: the Arctic, Central, Southeast, and Southwest Alaska Networks (National Park Service 2006a).

The Southwest Alaska Network (SWAN) of national parks includes five units totaling nearly 38,000 km^2 (14,670 mi^2; Figure 1). SWAN units encompass approximately 2% of Alaska's total land area, and nearly 20% of all NPS lands within Alaska. SWAN parks cover a diverse spectrum of geographic features and landforms, but the overall defining characteristic of this network is its impressive mountains. From the fjord-dominated landscapes of Kenai Fjords National Park in the south to the volcanically sculpted caldera of Aniakchak National Park and Monument to the west, the SWAN network sits atop a tectonic confluence that largely defines the region. The two largest parks within the SWAN unit are Katmai and Lake Clark National Parks and Preserves (NPPs). At over 16,000 km^2 (6,175 mi^2) each, these two parks dominate the landscape not only in size but also in ruggedness and grandeur of terrain. Both parks are impressive examples of a tangible geologic history; numerous active volcanoes and huge post-glacial lakes dominate the Katmai landscape, and extensive ice fields, glaciers, and moraines define the Lake Clark area (Detterman 1986, Manley and Kaufman 2002).

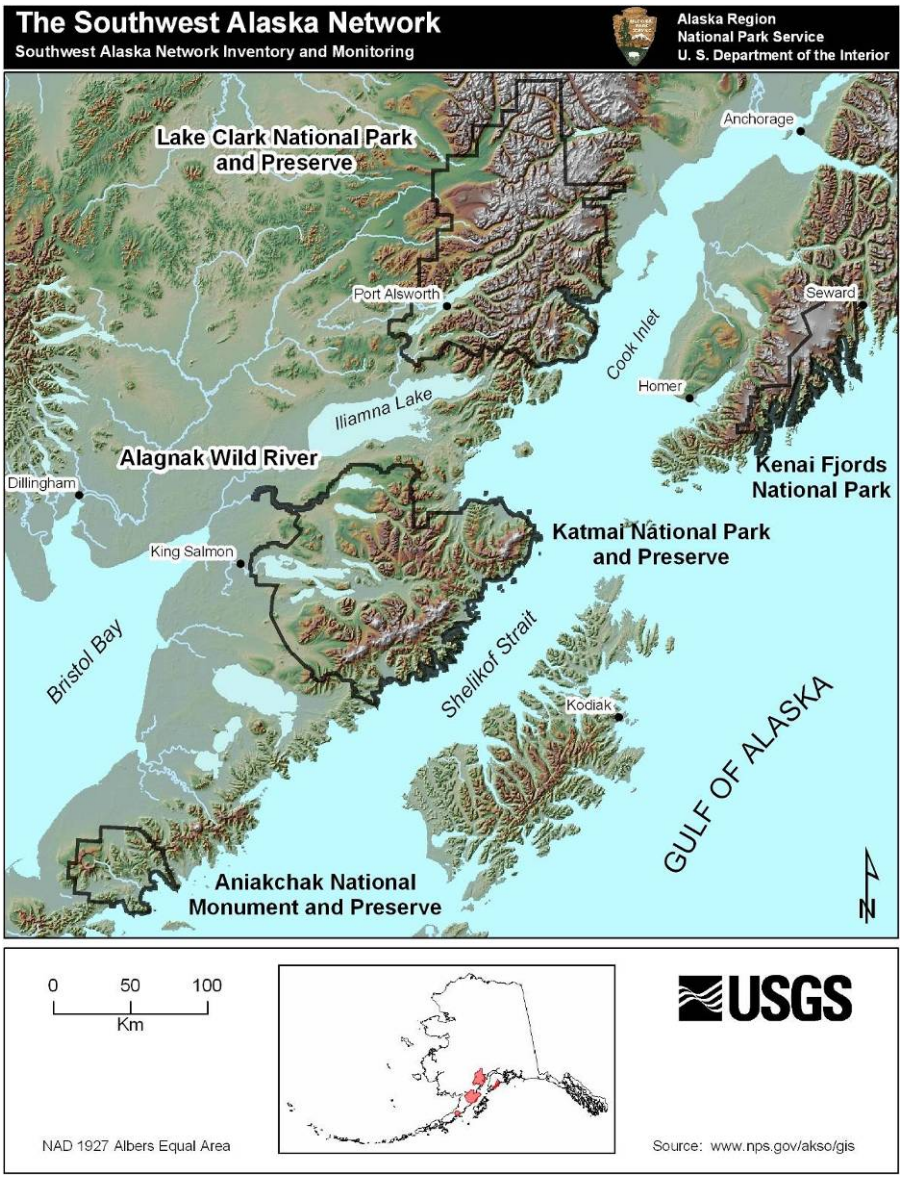

Figure 1. Location of parks within the Southwest Alaska Network.

Although geologic processes have sculpted the physiographies of the SWAN parks, the region's associated biological systems have been strongly influenced by climate and localized weather patterns. Climatic factors (e.g., temperature, precipitation, wind) interact with physical features (e.g., north-south orientation of Alaska and Aleutian mountain ranges), which together influence the biological landscape. The eastern portions of all parks are strongly influenced by a Pacific maritime climate (wet, cloudy, windy, and cool summers; wet winters), whereas the western portions are continental (Lake Clark) or transitional (Katmai and Aniakchak) and are characterized by wider temperature ranges and less precipitation. In general, these patterns produce a landcover gradient that transitions from the heavily forested woodland environment in Lake Clark to a treeless, low shrub, ericaceous-heath landscape on the Alaska Peninsula that begins in the vicinity of Katmai (Nowacki et al. 2002).

The primary mission of the NPS is to conserve unimpaired the natural and cultural resources and values of the National Park system for the enjoyment of present and future generations. To attain this mission, the Service must have credible scientific information to better manage, maintain, and protect park resources. Many parks are currently unable to achieve this mission due to a lack of basic and credible scientific knowledge about park resources.

In 2001, the SWAN initiated biological inventories of vertebrate animals and vascular plants in the network's parks to document occurrence, distribution, and where possible, relative abundance. Landbirds were ranked among the top eight priorities for biological inventories in the SWAN (Kedzie-Webb 2001). The inventories will lay the groundwork for park managers to develop effective monitoring programs, make informed management decisions concerning species or their habitats, and to educate the public.

Ecological Context

NPS mapped all Alaska park units following the ECOMAP framework (ECOMAP 1993). ECOMAP is a hierarchical system that delineates ecological boundaries at various scales. Ecoregions are large areas with similar continental patterns of climate and geology, and are composed of sections. Sections are physiographic regions with similar regional patterns of geology and climate. In turn, sections are composed of subsections, areas with a more narrowly defined geology composed of repeated association of geomorphic units (ECOMAP 1993). The NPS uses these landscape level maps as the foundation for biological inventory and monitoring programs.

Katmai and Lake Clark are the largest parks in the SWAN and also contain the most expansive ecoregions (Figure 2). The Alaska Peninsula ecoregion dominates Katmai, and consists of relatively young Pleistocene moraines that define the location and extent of Katmai's massive lakes (Shephard and Spencer 2000). Katmai's numerous active volcanoes also fall within this ecoregion, and vegetation is dominated by low shrublands interspersed with ericaceous heath and *Dryas*-lichen communities. The relatively small portion of the Bristol Bay Lowlands ecoregion within Katmai, in contrast, contains older Pleistocene drift and outwash located in the western lowlands of the park and is dominated by low and dwarf shrub communities. Approximately 120 km to the north, Lake Clark is defined by the Alaska Range, Cook Inlet Basin, and Lime Hills ecoregions (Spencer 2001). The huge mountains of the Alaska Range promote a cold, continental climate, creating a landscape largely void of vegetation. Low-lying areas within this ecoregion are characterized by shrub communities and, rarely, forests. The Cook Inlet Basin ecoregion occurs sparingly in Lake Clark, and is typified by organic soils supporting wet forests of spruce and mixed woodlands. The Lime Hills ecoregion is characterized by numerous moraines and vegetation dominated by shrub communities and, less commonly, forests and woodlands.

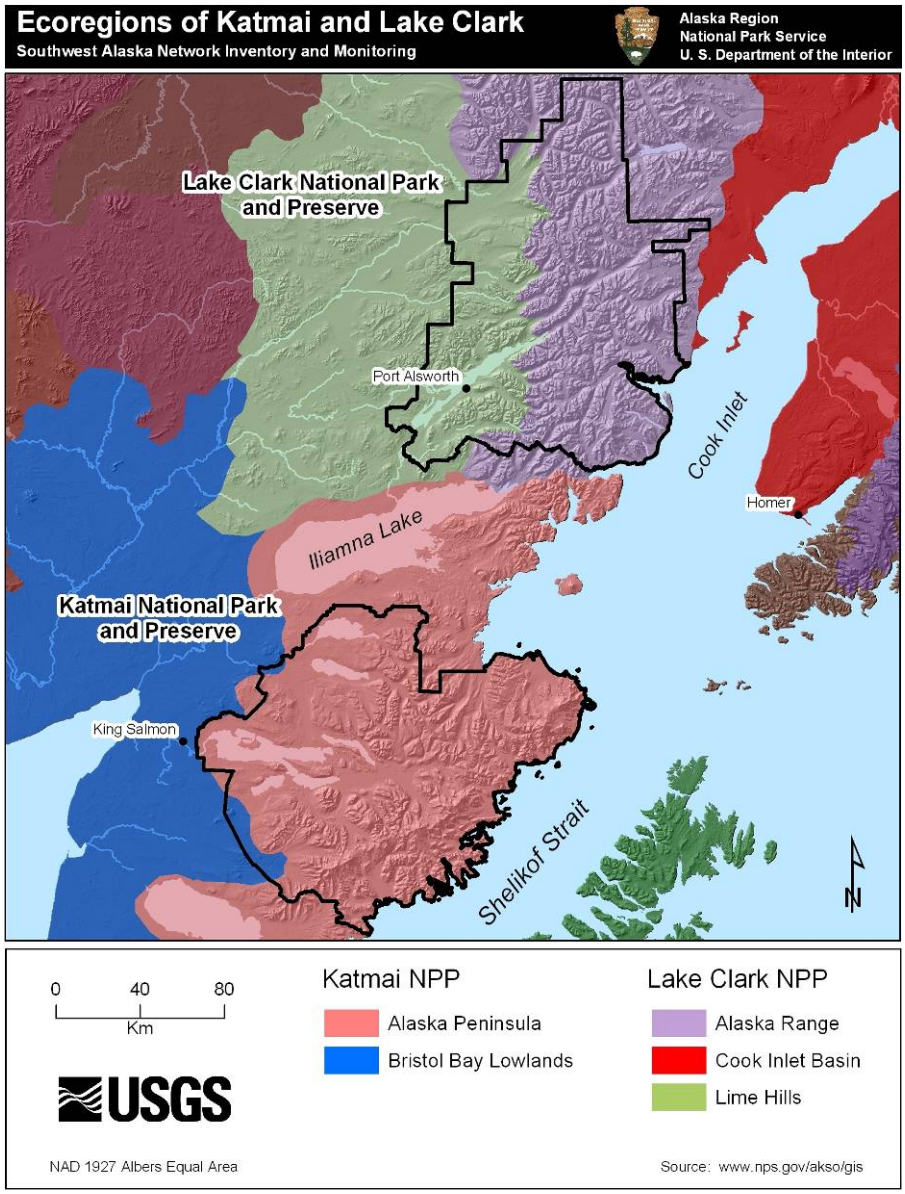

Figure 2. Ecoregions of Katmai and Lake Clark National Parks and Preserves.

The diversity of landforms in each park is reflected in the number of ecological subsections. Within Katmai, ecoregions are subdivided into three sections comprising twenty subsections (Figure 3; Shephard and Spencer 2000), and Lake Clark's ecoregions are likewise split into six sections comprising fourteen subsections (Figure 4; Spencer 2001).

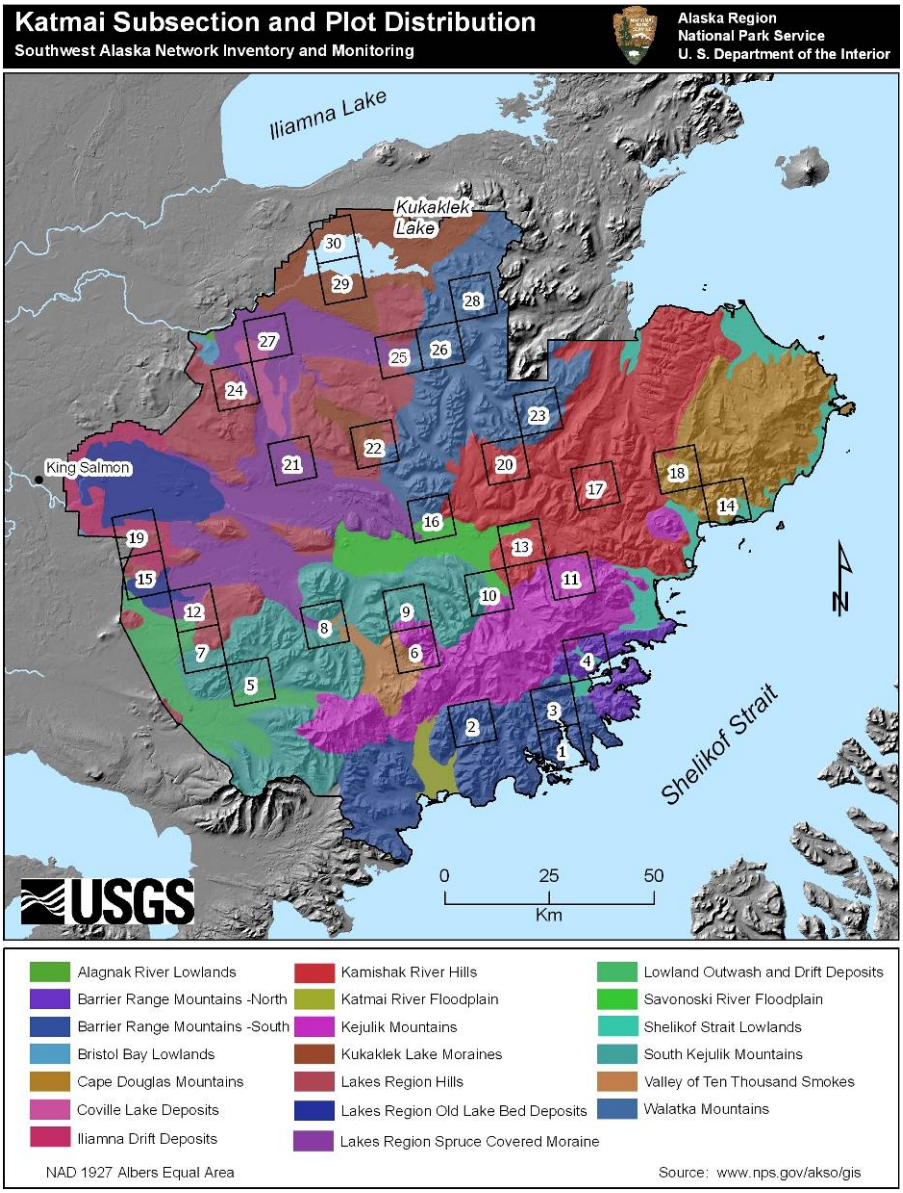

Figure 3. Location of plots in relation to ecological subsections in Katmai National Park and Preserve.

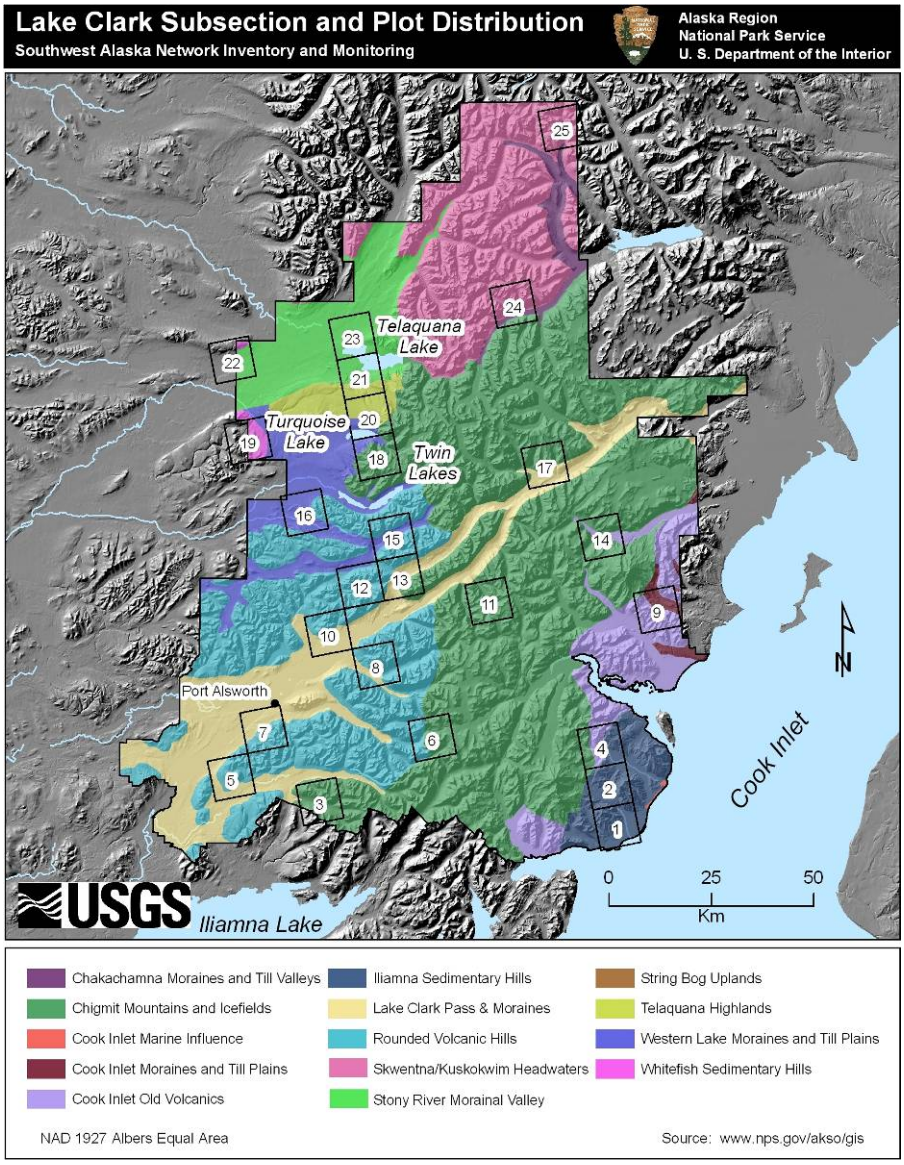

Figure 4. Location of plots in relation to ecological subsections in Lake Clark National Park and Preserve.

Despite their close proximity, regional factors including landforms, local climate, and the orientation and extent of physical barriers influence the avifaunas of each park, creating aspects unique to each. Katmai, for instance, sits at the base of the Alaska Peninsula and thus likely supports a bird community more influenced by wet, cool, maritime climates. Lake Clark, despite its substantial maritime boundary, likely supports a bird community more typical of continental areas. The Chigmit and Neacola Mountains in Lake Clark serve as a barrier to the influences of Cook Inlet, and promote the dry, warm-summer/cold-winter climate more typical of interior Alaska.

Background and Study Rationale

Compared to many regions of Alaska, the avifaunas of Katmai and Lake Clark NPPs are relatively well described. Various biological expeditions (Hine 1919, Racine and Young 1978), species-specific studies (Gill et al. 1999), general observations (Williamson and Peyton 1962, Gibson 1967, Jones and Petersen 1979), and regional surveys (Bailey and Faust 1984, Gill and Tibbitts 1999, Bennett 1996a) provide general information on birds of the region. Both parks, however, are incredibly rugged and largely free of roads and human infrastructure, and nearly all previous work was restricted to coastlines and waterways. Consequently, our understanding of the status and distribution of birds away from the shores of waterways is almost completely lacking (but see Gill et al. 1999).

Information from relatively small portions of SWAN parks (Gill et al. 1999) and elsewhere in Alaska (Tibbitts et al. 2005), however, points to the importance of montane areas as nesting habitat for particular assemblages of birds. The breeding distribution of alpine-nesting shorebird species such as American Golden-Plover (see Table 1 for all scientific names), Pacific Golden-Plover, Surfbird, Wandering Tattler, and Baird's Sandpiper is poorly known in general and for SWAN parks in particular (Senner and McCaffery 1997, Gill et al. 1999, Gill et al. 2002a, b). For one little-studied seabird, the Kittlitz's Murrelet, nearly one-quarter of the approximately 30 nests found in the North American portion of its range have come from steep scree or rocky slopes of Alaska Peninsula mountains (Day et al. 1999). Based on existing knowledge of species' distributions in Alaska, both parks also likely support significant numbers of passerine species whose populations are in decline, including Olive-sided Flycatcher and Rusty Blackbird (Rich et al. 2004). Because they breed in relatively inaccessible areas, montane-nesting birds are typically underrepresented in more traditional surveys that rely on roads, trails, and waterways to access sample areas. It is noteworthy, then, that montane-nesting birds tend to be poorly studied yet well represented on many conservation agencies' lists of species of concern.

Although Katmai and Lake Clark are isolated and largely undeveloped, tourist access is facilitated by their proximity to regional travel hubs (e.g., King Salmon, Port Alsworth, Anchorage). If visitation increases in the future, natural resources will potentially come under increased pressure. In addition, proposed economic developments outside of park borders could potentially impact the region (e.g., off-shore oil and gas exploration, mineral extraction). Maintaining the core wilderness aspects of each park while mitigating potential anthropogenic impacts is a great challenge, and informed scientific inquiry can enable effective natural resource management decisions. Comprehensive inventories are a foundation of any natural resource management program.

Objectives

The NPS Alaska Region Science Strategy states that scientific data should guide management decisions for preserving NPS core values in each park (National Park Service 2006b). In response to NPS needs for more information on their avian resources, biologists from the U. S. Geological Survey's (USGS) Alaska Science Center (ASC) conducted an inventory of the montane-nesting birds of Katmai and Lake Clark NPPs. In this study, we addressed two principal objectives:

1. Document through targeted field investigations the montane-nesting avifaunas of Katmai and Lake Clark NPPs.

2. Quantify the distribution, abundance, and habitat associations of bird species occurring in montane areas during the breeding season in Katmai and Lake Clark NPPs.

To accomplish these objectives, we:

1. Collected and summarized all existing information on the occurrence, distribution, and abundance of all bird species in Katmai and Lake Clark NPPs.

2. Implemented a repeatable, scientifically valid sampling design suited to survey birds in expansive areas with limited access.

3. Collected data on vegetation cover type and physical attributes at each sample point in order to describe avian habitat associations.

These data will serve as a basic avifaunal inventory of montane regions in these parks and can form the foundation for future monitoring efforts. Given the dearth of information regarding montane-nesting species in general, and within Katmai and Lake Clark in particular, information generated from this inventory will serve to educate the public as well as inform park managers by documenting avian resources and identifying montane areas of special importance to birds.

Methods

Sampling Frame

Our sampling frame in Katmai and Lake Clark included all non-glaciated montane regions that were accessible for sampling. We determined accessibility based on topography, specifically the steepness of the terrain, using guidelines developed during similar inventory work in the Arctic Network of National Parks (Tibbitts et al. 2005). We delineated the sampling frame in a Geographic Information System (GIS) using digital map layers and procedures that allowed polygons to be included in the frame if they were: 1) within park boundaries, 2) > 100 m (327 ft) above sea level, 3) < 50 degree slope, and 4) unglaciated. Elevation and

slope attributes were derived from the National Elevation Dataset (1:24,000 scale) and park boundary (1:63,360) and glacier coverage (1:60,000) from the NPS ECOMAP efforts (Shephard and Spencer 2000, Spencer 2001). To further delineate accessible areas, we excluded open water sections of large lakes (> 200 km^2 or 77 mi^2) by drawing a 500 m (0.31 mi) buffer strip along lake shorelines and excluding adjacent open water areas. Finally, this inventory's focus on montane regions (i.e., lands > 100 m above sea level) led us to exclude small polygons of six lowland subsections that occurred within the sampling frame (Appendix 1). After application of these procedures, the resulting sampling frame encompassed 8,921 km^2 across 15 ecological subsections in Katmai and 6,254 km^2 across 13 subsections in Lake Clark (Appendix 1).

Sample Unit Selection

To determine the location of sampling sites, we used a stratified random sampling design based on ecological subsections. We identified potential sampling units using an existing Alaska-wide GIS grid composed of 10-km x 10-km (6.2-mi x 6.2-mi) plots that has been used in other recent landbird and shorebird surveys in the state (Handel and Cady 2004, Tibbitts et al. 2005). In total, 213 and 207 plots were delineated in Katmai and Lake Clark, respectively, and most (206 in Katmai and 204 in Lake Clark) contained areas that met the criteria for inclusion in the sampling frame. We estimated that we could survey a total of 900 points across the parks given: 1) the 3-year study period, 2) 12-day-long field sessions, 3) 10 point counts per day per crew, and 4) 2–3 crews per year. We allocated these sample points proportionally to the area covered by each ecological subsection (Appendix 1). To avoid over-sampling expansive subsections at the expense of uncommon ones, we constrained the number of points allocated to each subsection to between 10 and 60. We selected sample plots by first defining all plots by their dominant subsection and then randomly selecting among them within each stratum until point allocations were fulfilled. Following this protocol, we selected 30 and 29 sample plots in Katmai and Lake Clark, respectively. In the field, sample points were located at 500-m intervals along transects placed across gradients of elevation and land cover, and we attempted to sample all subsections present within each plot. Random placement of points was somewhat constrained by plot access and ruggedness of the terrain.

Bird Surveys at Sample Points

Our target for this inventory was the population of birds present in montane regions of Katmai and Lake Clark during the early breeding season (i.e., mid-May to early-June). This period coincided with the peak courtship activity of this bird assemblage, allowing us to maximize detection rates. We conducted bird surveys at each survey point using distance sampling methodology (Buckland et al. 2001) employing protocols developed by the USGS ASC Shorebird Project (Tibbitts et al. 2005) and the Alaska Landbird Monitoring Program (ALMS, Handel and Cady 2004). To assess the timing of surveys in relation to spring arrival of birds, we replicated point transects at a sub-sample of sites two weeks

after the initial surveys in 2004. In addition to these structured surveys, we compiled comprehensive lists of species with notes on their breeding status for all birds, mammals, and amphibians encountered during the 1–3 days we were present at a plot. All crew leaders had several years of experience studying the avifauna of Alaska using similar methodologies.

We conducted two surveys at each sample point: 1) a 10-min count during which we recorded detailed information on species that typically breed at low densities (raptors, cranes, shorebirds, gulls, jaegers, owls, corvids) and, at the same time, kept a tally (number of individuals per min) of all other avian species, and 2) a subsequent 5-min count at the same point during which we collected detailed information on landbirds (ptarmigan, grouse, woodpeckers, passerines) and waterbirds (waterfowl, loons, grebes, terns).

At the start of each 10-min count, we recorded standardized data on site and survey conditions (e.g., time of day, weather, wind speed, wind direction), survey location using a GPS unit, and percent cover of all vegetation types within 50 m (dense habitats) or 150 m (open habitats) of the point. We visually classified vegetation to at least level III of the Viereck et al. (1992) system, and further classified to level IV when possible (Appendix 2).

We recorded the following information for each bird detection: elapsed time, species, number of individuals, and radial distance from the survey point. Whenever possible, we collected additional data such as behavior, vocalizations, breeding status, and microhabitat with which a bird was associated. We used laser rangefinders to measure distances to individual birds. If an individual was heard but not seen, we estimated its exact distance from the point along with an estimate of the possible range of its location (e.g., 70–120 m, 300–400 m) by measuring distance to landmarks on either side of the vocalizing bird.

Species List, Species of Conservation Concern

In order to provide proper context for our findings, we created a list of reputable sightings of birds in or immediately adjacent to each park (i.e., King Salmon, Naknek, Iliamna region, Redoubt Bay, or Tuxedni Wilderness). Source materials for this list included published journal articles, books, unpublished reports, internal NPS lists, and personal communications from qualified observers (see Appendix, Expected Species List Source References). Nomenclature used follows that of the American Ornithologists' Union (1998, 2006).

Within each park's list, we identified species of conservation concern as defined by one of five conservation organizations: Audubon Alaska (Stenhouse and Senner 2005), Partners in Flight (Rich et al. 2004), U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 2002), Alaska Shorebird Group (Alaska Shorebird Group 2000, unpublished), and Boreal Partners in Flight (Boreal Partners in Flight Working Group 1999). The criteria for inclusion on each organization's list varied, but in general species of conservation concern are those with threatened,

declining, or small populations. Partners in Flight defines species as Stewardship or Watch List species (Rich et al. 2004). Stewardship species are those with a significant proportion of their population occurring in a single region or avifaunal biome, whereas Watch List species are those species suffering severe conservation threats.

Data Summaries

Species Occurrence and Distribution

We summarized point survey data to compare the observed occurrence and distribution of bird species across parks, elevations, and habitats. We standardized detections for survey effort by calculating the average occurrence (number of individuals detected / number of point surveyed) of all species detected during 10-min counts. We summarized distribution by calculating the number of species detected at each sample plot during all point surveys (both 10- and 5-min counts) and all opportunistic detections. Given the difficulty in distinguishing between Common and Hoary redpolls, we combined observations of these species for all summaries except for each park's species list. All redpolls identified to species in the field were Common Redpolls.

Based on patterns of species occurrence and distribution, we identified one region in each park as an area of special importance to montane birds. This designation was based on overall species abundance, the proportion of the avifauna comprised by species of conservation concern, and the number of observations unique to each region. We relied on our own expert opinion to evaluate the uniqueness of potential sites compared to other sites across Alaska.

Associations Between Birds, Habitats, and Elevation

We assessed the habitat associations of birds using vegetation cover type data collected at each sample point. We combined similar vegetation cover types into 6 broad categories based on the Viereck classification system (Viereck et al. 1992). Our six cover types were essentially groupings at Viereck level I and II, and are as follows: forest, tall shrub (≥ 1.5 m tall), low shrub (1.5 m–20 cm tall), dwarf shrub (< 20 cm tall), bare ground (rocks, ash), and herbaceous (graminoids, herbs, mosses, lichens; Appendix 2). In addition, we created a cover type for snow.

Several important abiotic factors vary across elevational gradients (e.g., temperature, moisture, length of growing season), and this variation ultimately affects the distribution of vegetation types and, thus, birds. To examine the distribution of vegetation cover types and the associated bird communities, we grouped vegetation cover data and bird detections by the elevation at sample points. We defined sample points based on the observed distributional patterns of vegetation cover types as either low (100–350 m), middle (351–600 m), or high (601–1,620 m) elevation points (note: 1,620 m was the elevation of the highest sample point). We also applied these elevation categories to species

detected during bird surveys. For the purposes of this assessment, we included all species with 10 or more detections within 500 m (*n* = 13 species detected during 10-min counts) or 150 m (*n* = 21 species detected during 5-min counts). We included species within 500 m in order to enhance our ability to describe the habitat associations of this poorly-studied group of birds. Based on our observations throughout the course of the study, habitats within 150 m and 500 m of points were similar. The aforementioned 34 species were categorized according to the mean elevation of sample points at which the species were detected. We assumed that species used habitats similarly between parks, and so pooled habitat data across the two parks.

To characterize the vegetation patterns within ecological subsections, we calculated the average elevation and percent occurrence and cover of each habitat type across all survey points by subsection. To assess bird-habitat associations, we summarized the percent cover of habitat types for the same 34 species with ≥ 10 detections. We summarized the percent snowcover of points within subsections to describe the spring survey conditions. We plotted all these summaries in box plot form, wherein we displayed the mean, median, quartiles, and 10th and 90th percentiles of habitat cover, elevation, and snowcover values. Displaying data in this format allows for visual comparison of broad landscape and physiographic patterns. Finally, we combined behavioral observations (e.g., nest incubation, singing, drumming, flight displays) with patterns of occurrence, distribution, and habitat associations of species of terrestrial birds to categorize their breeding status, abundance, and general habitat affinities within the parks.

In order to focus our efforts away from lowland regions in both parks previously described by other researchers, we defined our sampling frame as montane regions in each park technically available for sampling (i.e., all unglaciated, non-lacustrine lands > 100 m above sea level and < 50 degree slope). Typically, the term 'montane' refers to mountainous regions below treeline (Merriam-Webster 1986), but we broaden the term to also include areas above treeline. Herein, we specifically refer to regions above treeline as alpine, and this meaning is in accordance with the typical usage of the word (Merriam-Webster 1986). The alpine region corresponds to the high elevation category described above. Thus, in this report the term montane broadly includes the region above treeline, herein referred to as the alpine region.

Finally, it is important to note that we do not account for incomplete and variable detection probabilities of bird species in these assessments of species distribution, occurrence, and bird-habitat relationships. Detection probability is a factor of many variables (e.g., observer experience, time of day, habitat, weather), and simple presence/absence counts do not take into account false-negative error rates (Tyre et al. 2003). We likely underestimated the number of points at which a particular species occurred, thus hindering our ability to completely describe species-specific habitat affinities (Tyre et al. 2003). It is our intention with the current summary, however, to provide a general foundation

upon which to base more detailed, species-specific habitat analyses. Subsequent analyses should model and incorporate detection probabilities in order to more accurately describe abundances and habitat affinities of birds within the study area.

Results

Survey Effort and Conditions

We conducted surveys during 16–29 May 2004, 11–25 May 2005, and 29 May–5 June 2006; we resampled three plots during 9–12 June 2004. We sampled 29 plots in Katmai (23 in 2005, six in 2006; Figure 3) and 25 plots in Lake Clark (22 in 2004, three in 2006; Figure 4). In total, we conducted surveys at 468 points in Katmai and 417 points in Lake Clark; we resampled one point in Katmai in 2005, and 36 points in Lake Clark in 2004. This sample effort of 885 unique point surveys conducted over 37 days entailed over 220 hours of survey time.

Sample plots were accessed via fixed-wing (e.g., Cessna 185, 206) and rotary aircraft (e.g., Hughes 500, Bell JetRanger 206) that staged out of Port Alsworth, King Salmon, and remote fuel caches. Straight-line distances between fueling bases and sample plots ranged between 5 and 100 km.

We surveyed fewer plots (54 vs. 59) and sample points (885 vs. 908) than originally planned, mostly due to the extra time it took to access sample points in subsections with steep terrain or thick vegetation (e. g., Skwentna/Kuskokwim Headwaters, Stony River Morainal Valley). Also, periods of inclement weather briefly interrupted surveys in all three years and helicopter mechanical problems slowed operations in 2005. Crews surveyed an average of 9.3 points/day which was slightly below our anticipated average of 10 points/day/crew. Overall, we sampled all 15 subsections within our sampling frame in Katmai and 12 of 13 subsections in Lake Clark; String Bog Uplands was not sampled (Appendix 1).

Survey conditions were generally good, although short periods of inclement weather briefly interrupted surveys in all three years. Temperatures during surveys ranged from 1°–27° C, and approximately 20% of counts were conducted during periods of active precipitation (either fog, hail, rain, or snow).

Species Lists

We detected a total of 116 individual species, including twenty-one species of waterfowl, four grouse and ptarmigan, three loons, two grebes, ten raptors, one crane, eighteen shorebirds, seven gulls, terns, and jaegers, two owls, three woodpeckers, and forty-five passerines (Table 1). We detected 92 species in Katmai and 104 species in Lake Clark (Table 1). Most species (n = 80, 69%) were recorded in both parks, but 12 species were detected in Katmai only (e.g., Greater White-fronted Goose, Lesser Scaup) and 24 in Lake Clark only (e.g., Canada Goose, Trumpeter Swan). We detected three species not previously recorded in Katmai (Ring-necked Duck, Lesser Scaup, and White-tailed

Ptarmigan), and two species not previously recorded in Lake Clark (Northern Flicker and Olive-sided Flycatcher). Our compilation of previous records of birds in each park included 182 species and yielded a list with 80% overlap between parks (Table 1).

Table 1. Birds of Katmai and Lake Clark National Parks and Preserves. 'X' indicates a species detected during the inventory of montane-nesting birds 2004–2006, 'P' indicates a species recorded by previous observers, and a blank indicates that the species has not been recorded in that particular park. Species in bold are species of conservation concern (see Table 2).

Common name	Scientific name	Katmai	Lake Clark
Waterfowl			
Greater White-fronted Goose	*Anser albifrons*	X	P
Emperor Goose	*Chen canagica*		P
Brant	*Branta bernicla*	P	P
Canada Goose	*Branta canadensis*	P	X
Trumpeter Swan	*Cygnus buccinator*		X
Tundra Swan	*Cygnus columbianus*	X	X
Gadwall	*Anas strepera*	P	
Eurasian Wigeon	*Anas penelope*		P
American Wigeon	*Anas americana*	X	X
Mallard	*Anas platyrhynchos*	X	X
Northern Shoveler	*Anas clypeata*	P	X
Northern Pintail	*Anas acuta*	X	X
Green-winged Teal	*Anas crecca*	X	X
Canvasback	*Aythya valisineria*	P	P
Redhead	*Aythya americana*		P
Ring-necked Duck	*Aythya collaris*	X	X
Greater Scaup	*Aythya marila*	X	X
Lesser Scaup	*Aythya affinis*	X	P
Steller's Eider	*Polysticta stelleri*	P	
King Eider	*Somateria spectabilis*	P	P
Common Eider	*Somateria mollissima*	P	P
Harlequin Duck	*Histrionicus histrionicus*	X	X
Surf Scoter	*Melanitta perspicillata*	P	P
White-winged Scoter	*Melanitta fusca*	P	X
Black Scoter	*Melanitta nigra*	X	X
Long-tailed Duck	*Clangula hyemalis*	X	X
Bufflehead	*Bucephala albeola*	X	P
Common Goldeneye	*Bucephala clangula*	X	X
Barrow's Goldeneye	*Bucephala islandica*	X	X
Hooded Merganser	*Lophodytes cucullatus*	P	
Common Merganser	*Mergus merganser*	X	X
Red-breasted Merganser	*Mergus serrator*	X	X
Grouse and Ptarmigan			
Spruce Grouse	*Falcipennis canadensis*	X	X
Willow Ptarmigan	*Lagopus lagopus*	X	X
Rock Ptarmigan	*Lagopus mutus*	X	X
White-tailed Ptarmigan	*Lagopus leucurus*	X	X
Loons and Grebes			
Red-throated Loon	*Gavia stellata*	X	X

Common name	Scientific name	Katmai	Lake Clark
Pacific Loon	*Gavia pacifica*	X	X
Common Loon	*Gavia immer*	X	X
Horned Grebe	*Podiceps auritus*	X	X
Red-necked Grebe	*Podiceps grisegena*	X	P
Seabirds: Procellarids, Cormorants			
Fork-tailed Storm-Petrel	*Oceanodroma furcata*	P	
Double-crested Cormorant	*Phalacrocorax auritus*	P	P
Red-faced Cormorant	*Phalacrocorax urile*	P	
Pelagic Cormorant	*Phalacrocorax pelagicus*	P	P
Raptors			
Osprey	*Pandion haliaetus*	X	P
Bald Eagle	*Haliaeetus leucocephalus*	X	X
Northern Harrier	*Circus cyaneus*	X	X
Sharp-shinned Hawk	*Accipiter striatus*	X	X
Northern Goshawk	*Accipiter gentilis*	P	X
Red-tailed Hawk	*Buteo jamaicensis*		P
Rough-legged Hawk	*Buteo lagopus*	X	X
Golden Eagle	*Aquila chrysaetos*	X	X
American Kestrel	*Falco sparverius*	P	P
Merlin	*Falco columbarius*	X	X
Gyrfalcon	*Falco rusticolus*	X	P
Peregrine Falcon	*Falco peregrinus*	X	X
Cranes			
Sandhill Crane	*Grus canadensis*	X	X
Shorebirds			
Black-bellied Plover	*Pluvialis squatarola*	X	P
American Golden-Plover	*Pluvialis dominica*	X	X
Pacific Golden-Plover	*Pluvialis fulva*	X	P
Semipalmated Plover	*Charadrius semipalmatus*	X	X
Black Oystercatcher	*Haematopus bachmani*	P	P
Spotted Sandpiper	*Actitis macularius*	X	X
Solitary Sandpiper	*Tringa solitaria*	P	X
Wandering Tattler	*Tringa incana*	X	X
Greater Yellowlegs	*Tringa melanoleuca*	X	X
Lesser Yellowlegs	*Tringa flavipes*	P	X
Whimbrel	*Numenius phaeopus*	X	X
Hudsonian Godwit	*Limosa haemastica*	X	P
Bar-tailed Godwit	*Limosa lapponica*		P
Marbled Godwit	*Limosa fedoa*	P	P
Ruddy Turnstone	*Arenaria interpres*	P	
Black Turnstone	*Arenaria melanocephala*	P	P
Surfbird	*Aphriza virgata*	X	X
Red Knot	*Calidris canutus*		P
Sanderling	*Calidris alba*		P
Semipalmated Sandpiper	*Calidris pusilla*		P
Western Sandpiper	*Calidris mauri*	P	P
Least Sandpiper	*Calidris minutilla*	X	X
Baird's Sandpiper	*Calidris bairdii*	X	X
Pectoral Sandpiper	*Calidris melanotos*	P	X
Rock Sandpiper	*Calidris ptilocnemis*	P	P
Dunlin	*Calidris alpina*	P	P
Short-billed Dowitcher	*Limnodromus griseus*	X	X
Long-billed Dowitcher	*Limnodromus scolopaceus*		P
Wilson's Snipe	*Gallinago delicata*	X	X

Common name	Scientific name	Katmai	Lake Clark
Red-necked Phalarope	*Phalaropus lobatus*	P	X
Gulls, Terns, and Jaegers			
Franklin's Gull	*Larus pipixcan*		P
Bonaparte's Gull	*Larus philadelphia*	X	X
Mew Gull	*Larus canus*	X	X
Herring Gull	*Larus argentatus*	P	X
Glaucous-winged Gull	*Larus glaucescens*	X	X
Glaucous Gull	*Larus hyperboreus*	P	P
Sabine's Gull	*Xema sabini*	P	
Black-legged Kittiwake	*Rissa tridactyla*	P	P
Aleutian Tern	*Onychoprion aleutica*	P	
Arctic Tern	*Sterna paradisaea*	X	X
Pomarine Jaeger	*Stercorarius pomarinus*		P
Parasitic Jaeger	*Stercorarius parasiticus*	X	P
Long-tailed Jaeger	*Stercorarius longicaudus*	P	X
Seabirds: Alcids			
Common Murre	*Uria aalge*	P	P
Thick-billed Murre	*Uria lomvia*	P	
Pigeon Guillemot	*Cepphus columba*	P	P
Marbled Murrelet	*Brachyramphus marmoratus*	P	P
Kittlitz's Murrelet	*Brachyramphus brevirostris*	P	P
Ancient Murrelet	*Synthliboramphus antiquus*	P	
Parakeet Auklet	*Aethia psittacula*	P	P
Rhinoceros Auklet	*Cerorhinca monocerata*	P	P
Horned Puffin	*Fratercula corniculata*	P	P
Tufted Puffin	*Fratercula cirrhata*	P	P
Pigeons			
Rock Pigeon	*Columba livia*		P
Owls			
Great Horned Owl	*Bubo virginianus*	X	X
Snowy Owl	*Bubo scandiacus*	P	
Northern Hawk Owl	*Surnia ulula*	P	P
Great Gray Owl	*Strix nebulosa*	P	P
Short-eared Owl	*Asio flammeus*	X	P
Boreal Owl	*Aegolius funereus*	P	P
Northern Saw-whet Owl	*Aegolius acadicus*	P	P
Hummingbirds, Kingfishers			
Rufous Hummingbird	*Selasphorus rufus*		P
Belted Kingfisher	*Ceryle alcyon*	P	P
Woodpeckers			
Downy Woodpecker	*Picoides pubescens*	X	P
Hairy Woodpecker	*Picoides villosus*	P	P
American Three-toed Woodpecker	*Picoides dorsalis*	X	X
Black-backed Woodpecker	*Picoides arcticus*	P	P
Northern Flicker	*Colaptes auratus*	P	X
Passerines			
Olive-sided Flycatcher	*Contopus cooperi*	P	X
Alder Flycatcher	*Empidonax alnorum*	P	X
Say's Phoebe	*Sayornis saya*		X
Northern Shrike	*Lanius excubitor*	X	X
Gray Jay	*Perisoreus canadensis*	X	X
Steller's Jay	*Cyanocitta stelleri*		P
Black-billed Magpie	*Pica hudsonia*	X	X
Northwestern Crow	*Corvus caurinus*	P	

Common name	Scientific name	Katmai	Lake Clark
Common Raven	*Corvus corax*	X	X
Horned Lark	*Eremophila alpestris*	X	X
Tree Swallow	*Tachycineta bicolor*	X	X
Violet-green Swallow	*Tachycineta thalassina*	P	X
Bank Swallow	*Riparia riparia*	X	X
Cliff Swallow	*Petrochelidon pyrrhonota*	P	P
Black-capped Chickadee	*Poecile atricapillus*	X	X
Boreal Chickadee	*Poecile hudsonica*	X	X
Red-breasted Nuthatch	*Sitta canadensis*	P	
Brown Creeper	*Certhia americana*	P	P
Winter Wren	*Troglodytes troglodytes*	P	
American Dipper	*Cinclus mexicanus*	X	X
Golden-crowned Kinglet	*Regulus satrapa*	P	X
Ruby-crowned Kinglet	*Regulus calendula*	X	X
Arctic Warbler	*Phylloscopus borealis*	P	
Northern Wheatear	*Oenanthe oenanthe*		X
Gray-cheeked Thrush	*Catharus minimus*	P	X
Swainson's Thrush	*Catharus ustulatus*	P	X
Hermit Thrush	*Catharus guttatus*	X	X
American Robin	*Turdus migratorius*	X	X
Varied Thrush	*Ixoreus naevius*	X	X
Eastern Yellow Wagtail	*Motacilla tschutschensis*		P
American Pipit	*Anthus rubescens*	X	X
Bohemian Waxwing	*Bombycilla garrulus*	P	X
Orange-crowned Warbler	*Vermivora celata*	X	X
Yellow Warbler	*Dendroica petechia*	X	X
Yellow-rumped Warbler	*Dendroica coronata*	X	X
Blackpoll Warbler	*Dendroica striata*	X	X
Northern Waterthrush	*Seiurus noveboracensis*	X	X
Wilson's Warbler	*Wilsonia pusilla*	X	X
American Tree Sparrow	*Spizella arborea*	X	X
Savannah Sparrow	*Passerculus sandwichensis*	X	X
Fox Sparrow	*Passerella iliaca*	X	X
Song Sparrow	*Melospiza melodia*	P	P
Lincoln's Sparrow	*Melospiza lincolnii*	X	X
White-crowned Sparrow	*Zonotrichia leucophrys*	X	X
Golden-crowned Sparrow	*Zonotrichia atricapilla*	X	X
Dark-eyed Junco	*Junco hyemalis*	X	X
Lapland Longspur	*Calcarius lapponicus*	X	X
Snow Bunting	*Plectrophenax nivalis*	X	X
Rusty Blackbird	*Euphagus carolinus*	P	X
Gray-crowned Rosy-Finch	*Leucosticte tephrocotis*	X	X
Pine Grosbeak	*Pinicola enucleator*	X	X
Red Crossbill	*Loxia curvirostra*	P	
White-winged Crossbill	*Loxia leucoptera*	P	X
Common Redpoll	*Carduelis flammea*	X	X
Hoary Redpoll	*Carduelis hornemanni*	P	P
Pine Siskin	*Carduelis pinus*	P	X
Total species detected during inventory:		92	104
Total species:		164	166

We detected 40 species of conservation concern, including four species of waterfowl, four grouse and ptarmigan, one loon, four raptors, eight shorebirds, one tern, one owl, and seventeen passerines (Tables 1 and 2). An additional 22 species of conservation concern have been recorded in Katmai and Lake Clark by previous observers (Tables 1 and 2); most of these species are seabirds (e.g., Red-faced Cormorant, Marbled Murrelet) or coastal migrants (e.g., Marbled Godwit, Dunlin). Seventeen species (e.g., Willow Ptarmigan, Rock Ptarmigan) appear on this list because they are considered by Partners in Flight to be the stewardship responsibility of land managers of the region (Table 2; Rich et al. 2004).

Table 2. Species of conservation concern recorded in Katmai and Lake Clark National Parks and Preserves. 'X' indicates a species detected during the inventory of montane-nesting birds 2004–2006, 'P' indicates a species recorded by previous observers.

	Conservation status determined by program[1]:				
Common name[2]	Audubon	NALCP[3]	USFWS	ASCP	LCPA
Greater White-fronted Goose	X				
Brant	P				
Trumpeter Swan	X				
Steller's Eider	P				
Common Eider	P				
King Eider	P				
Black Scoter	X				
Long-tailed Duck	X				
Spruce Grouse		X			
Willow Ptarmigan		X			
Rock Ptarmigan		X			
White-tailed Ptarmigan					X
Red-throated Loon	X		X		
Red-faced Cormorant	P		P		
Rough-legged Hawk		X			
Golden Eagle	X				
Gyrfalcon	X	X			X
Peregrine Falcon	X	X	X		
American Golden-Plover	X		X	X	
Pacific Golden-Plover	X		X		
Black Oystercatcher	P			P	
Solitary Sandpiper	X			X	
Wandering Tattler	X				
Whimbrel	X		X	X	
Hudsonian Godwit	X		X	X	
Bar-tailed Godwit	P			P	
Marbled Godwit	P		P	P	
Ruddy Turnstone	P			P	
Black Turnstone	P		P	P	
Surfbird	X		X	X	
Red Knot				P	
Sanderling				P	
Rock Sandpiper	P		P	P	

Common name[2]	Conservation status determined by program[1]:				
	Audubon	NALCP[3]	USFWS	ASCP	LCPA
Dunlin	P			P	
Short-billed Dowitcher			X	X	
Aleutian Tern	P		P		
Arctic Tern			X		
Marbled Murrelet	P		P		
Kittlitz's Murrelet	P		P		
Ancient Murrelet			P		
Great Gray Owl					P
Short-eared Owl	X	**X**			
Rufous Hummingbird					P
Olive-sided Flycatcher	X	**X**			X
Alder Flycatcher		X			
Northern Shrike		X			X
Gray Jay		X			
Northwestern Crow					P
Boreal Chickadee		X			
American Dipper					X
Gray-cheeked Thrush					X
Varied Thrush					X
Bohemian Waxwing		X			X
Blackpoll Warbler	X		X		X
Lincoln's Sparrow		X			
Golden-crowned Sparrow					X
Lapland Longspur		X			
Snow Bunting		X			
Rusty Blackbird	X	**X**			X
Pine Grosbeak		X			
White-winged Crossbill		X			X
Hoary Redpoll		P			

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

[2]See Table 1 for scientific names.

[3]Bold refers to Watch List Species (measured or suspected declines in a population and/or small size or vulnerability of a population), normal font Stewardship Species (high proportion of a species' global population occurring in the region); Rich et al. 2004.

Elevational Distribution of Birds

As defined by our elevation categories, we conducted 272 (31% of total), 268 (30%), and 345 (39%) surveys at low, middle, and high elevation sites, respectively. We classified 11, 16, and 7 species as low, middle, and high elevation species, respectively (Figure 5). Species of conservation concern associated with low elevation sites were Whimbrel, Varied Thrush, and Gray Jay, middle elevation sites Golden-crowned Sparrow, Lapland Longspur, and Willow Ptarmigan, and high elevation sites Rock Ptarmigan, Surfbird, Snow Bunting, and American Golden-Plover.

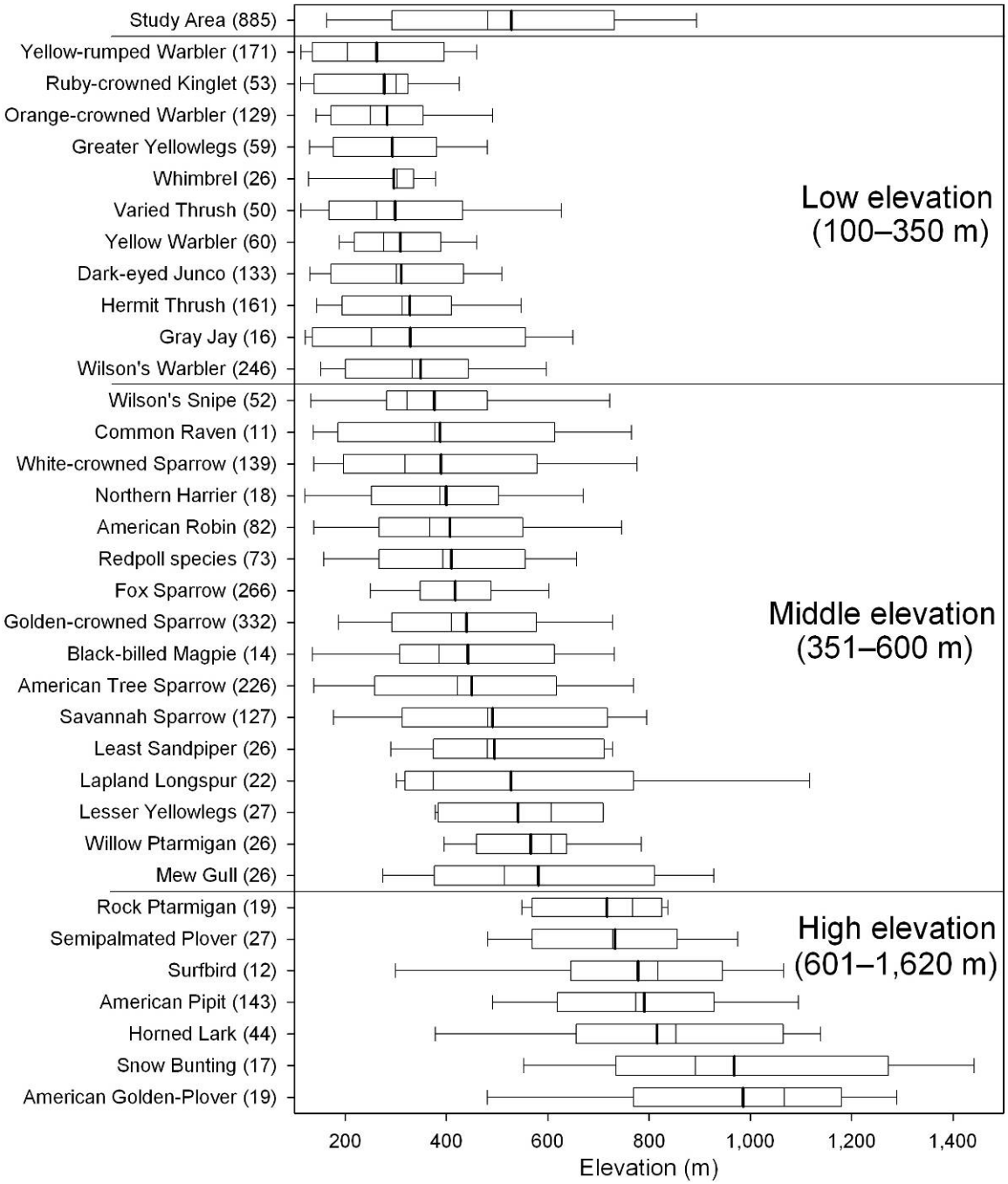

Figure 5. Elevational distribution of species commonly detected during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Box plots show median (thin vertical line), mean (thick vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Number of detections is shown in parentheses for each species.

Of the high elevation species, Rock Ptarmigan were, on average, detected at the low end of this elevational range (mean elevation at points where detected 716 ± 28.4 SE m; Figure 5) while American Golden-Plovers were typically detected at the high end (985 ± 63.6 SE m). Most high elevation species occurred over a

wide range of elevations (e.g., 1,059 m for American Golden-Plover, 997 m for Snow Bunting); the elevation range of Rock Ptarmigan, however, was comparatively narrow (362 m).

Frequency of Occurrence

Frequency of occurrence summaries are based on detections made at the 54 plots where we conducted 885 point surveys. We detected 2,986 birds of 75 species and 2,836 birds of 88 species at survey points in Katmai and Lake Clark, respectively, totaling 5,822 birds of 99 unique species (Table 3). The observed rate of detection of birds and species per point was similar between parks (Table 3). Overall we detected 6.64 (± 0.17 SE) individuals of 4.19 (± 0.08 SE) species per point (Table 3). As a group, passerines dominated the counts; the 13 most-numerous species were all passerines, totaling over two-thirds of all birds detected (Table 3). Golden-crowned Sparrow, a species most-commonly detected at middle elevation sites, was detected at one-and-one-half times the rate of any other species (0.76 birds/point; Table 3). Other commonly-detected species included Fox Sparrow (0.48 birds/point), American Pipit (0.39 birds/point), and redpoll species (0.39 birds/point; all Table 3).

Table 3. Occurrence of birds on 10-min point counts during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006.

	Katmai (*n* = 468 pts.)		Lake Clark (*n* = 417 pts.)		Overall (*n* = 885 pts.)	
Common name[1]	Number detected	Average occurrence[2]	Number detected	Average occurrence[2]	Number detected	Average occurrence[2]
Trumpeter Swan	0		40	0.096	40	0.045
Tundra Swan	6	0.013	0		6	0.007
American Wigeon	4	0.009	5	0.012	9	0.010
Mallard	15	0.032	9	0.022	24	0.027
Northern Shoveler	0		6	0.014	6	0.007
Northern Pintail	5	0.011	11	0.026	16	0.018
Green-winged Teal	3	0.006	18	0.043	21	0.024
Greater Scaup	16	0.034	50	0.120	66	0.075
Harlequin Duck	0		2	0.005	2	0.002
White-winged Scoter	0		4	0.010	4	0.005
Black Scoter	4	0.009	19	0.046	23	0.026
Long-tailed Duck	4	0.009	4	0.010	8	0.009
Bufflehead	2	0.004	0		2	0.002
Common Goldeneye	2	0.004	2	0.005	4	0.005
Barrow's Goldeneye	3	0.006	5	0.012	8	0.009
Red-breasted Merganser	4	0.009	5	0.012	9	0.010
Willow Ptarmigan	63	0.135	70	0.168	133	0.150
Rock Ptarmigan	63	0.135	35	0.084	98	0.111
White-tailed Ptarmigan	2	0.004	5	0.012	7	0.008
Pacific Loon	2	0.004	7	0.017	9	0.010
Common Loon	1	0.002	1	0.002	2	0.002
Horned Grebe	6	0.013	0		6	0.007
Red-necked Grebe	2	0.004	0		2	0.002
Osprey	1	0.002	0		1	0.001
Bald Eagle	12	0.026	7	0.017	19	0.021
Northern Harrier	22	0.047	4	0.010	26	0.029
Rough-legged Hawk	2	0.004	4	0.010	6	0.007
Golden Eagle	4	0.009	7	0.017	11	0.012

Common name[1]	Katmai (*n* = 468 pts.) Number detected	Katmai Average occurrence[2]	Lake Clark (*n* = 417 pts.) Number detected	Lake Clark Average occurrence[2]	Overall (*n* = 885 pts.) Number detected	Overall Average occurrence[2]
Merlin	7	0.015	3	0.007	10	0.011
Gyrfalcon	2	0.004	0		2	0.002
Sandhill Crane	9	0.019	1	0.002	10	0.011
Black-bellied Plover	5	0.011	0		5	0.006
American Golden-Plover	5	0.011	23	0.055	28	0.032
Pacific Golden-Plover	7	0.015	0		7	0.008
Semipalmated Plover	27	0.058	9	0.022	36	0.041
Spotted Sandpiper	1	0.002	3	0.007	4	0.005
Solitary Sandpiper	0		2	0.005	2	0.002
Wandering Tattler	0		11	0.026	11	0.012
Greater Yellowlegs	69	0.147	13	0.031	82	0.093
Lesser Yellowlegs	0		40	0.096	40	0.045
Whimbrel	34	0.073	2	0.005	36	0.041
Hudsonian Godwit	3	0.006	0		3	0.003
Surfbird	16	0.034	7	0.017	23	0.026
Least Sandpiper	26	0.056	10	0.024	36	0.041
Baird's Sandpiper	0		4	0.010	4	0.005
Short-billed Dowitcher	0		1	0.002	1	0.001
Wilson's Snipe	36	0.077	38	0.091	74	0.084
Red-necked Phalarope	0		14	0.034	14	0.016
Bonaparte's Gull	5	0.011	1	0.002	6	0.007
Mew Gull	52	0.111	45	0.108	97	0.110
Herring Gull	0		2	0.005	2	0.002
Glaucous-winged Gull	22	0.047	5	0.012	27	0.031
Arctic Tern	6	0.013	10	0.024	16	0.018
Parasitic Jaeger	2	0.004	0		2	0.002
Long-tailed Jaeger	0		1	0.002	1	0.001
Short-eared Owl	2	0.004	0		2	0.002
American Three-toed Woodpecker	4	0.009	3	0.007	7	0.008
Olive-sided Flycatcher	0		5	0.012	5	0.006
Say's Phoebe	0		2	0.005	2	0.002
Northern Shrike	1	0.002	1	0.002	2	0.002
Gray Jay	4	0.009	14	0.034	18	0.020
Black-billed Magpie	5	0.011	16	0.038	21	0.024
Common Raven	27	0.058	30	0.072	57	0.064
Horned Lark	40	0.085	43	0.103	83	0.094
Tree Swallow	18	0.038	11	0.026	29	0.033
Violet-green Swallow	0		2	0.005	2	0.002
Black-capped Chickadee	4	0.009	3	0.007	7	0.008
Boreal Chickadee	3	0.006	7	0.017	10	0.011
Golden-crowned Kinglet	0		1	0.002	1	0.001
Ruby-crowned Kinglet	7	0.015	71	0.170	78	0.088
Northern Wheatear	0		4	0.010	4	0.005
Gray-cheeked Thrush	0		14	0.034	14	0.016
Swainson's Thrush	0		5	0.012	5	0.006
Hermit Thrush	194	0.415	124	0.297	318	0.359
American Robin	136	0.291	125	0.300	261	0.295
Varied Thrush	19	0.041	80	0.192	99	0.112
American Pipit	194	0.415	147	0.353	341	0.385
Bohemian Waxwing	0		5	0.012	5	0.006
Orange-crowned Warbler	138	0.295	32	0.077	170	0.192
Yellow Warbler	24	0.051	41	0.098	65	0.073
Yellow-rumped Warbler	67	0.143	151	0.362	218	0.246
Blackpoll Warbler	0		1	0.002	1	0.001
Northern Waterthrush	2	0.004	8	0.019	10	0.011
Wilson's Warbler	227	0.485	109	0.261	336	0.380
American Tree Sparrow	153	0.327	150	0.360	303	0.342
Savannah Sparrow	112	0.239	73	0.175	185	0.209

Common name[1]	Katmai (*n* = 468 pts.) Number detected	Katmai Average occurrence[2]	Lake Clark (*n* = 417 pts.) Number detected	Lake Clark Average occurrence[2]	Overall (*n* = 885 pts.) Number detected	Overall Average occurrence[2]
Fox Sparrow	269	0.575	156	0.374	425	0.480
Lincoln's Sparrow	1	0.002	3	0.007	4	0.005
White-crowned Sparrow	106	0.226	120	0.288	226	0.255
Golden-crowned Sparrow	406	0.868	262	0.628	668	0.755
Dark-eyed Junco	54	0.115	154	0.369	208	0.235
Lapland Longspur	19	0.041	18	0.043	37	0.042
Snow Bunting	57	0.122	34	0.082	91	0.103
Rusty Blackbird	0		3	0.007	3	0.003
Gray-crowned Rosy-Finch	4	0.009	2	0.005	6	0.007
Pine Grosbeak	3	0.006	1	0.002	4	0.005
White-winged Crossbill	0		2	0.005	2	0.002
Redpoll Species	104	0.222	237	0.568	341	0.385
Pine Siskin	0		1	0.002	1	0.001
Total number of individuals:	2,986	6.42 ±0.21	2,836	6.89 ±0.26	5,822	6.64 ±0.17
Total number of species:	75	4.03±0.12	88	4.36±0.13	99	4.19±0.08

[1]See Table 1 for scientific names.
[2]Average occurrence = number of individuals detected / number of points surveyed; values for average occurrence of individuals and species by park and overall represent mean ± SE.

We detected 1,628, 2,930, and 700 individuals of low, middle, and high elevation birds, respectively (Figure 5 and Table 3). The number of detections of high elevation birds was low compared to low and middle elevation species. For example, Golden-crowned Sparrow, Fox Sparrow, redpoll species, Yellow-rumped Warbler, and Wilson's Warbler all had > 200 detections but we detected < 100 of all but one alpine-nesting species. American Pipit was the exception to this pattern, and they tied with redpoll species as the third most-commonly detected species overall (341 detections). The average occurrence of American Pipit was 0.42 and 0.35 individuals per point in Katmai and Lake Clark, respectively. For all but two species of conservation concern (Willow Ptarmigan and Golden-crowned Sparrow), we detected fewer than 100 individuals overall. We detected 34 species of conservation concern during surveys, including four alpine species: Rock Ptarmigan (*n* = 98 detected), American Golden-Plover (*n* = 28), Surfbird (*n* = 23), and Snow Bunting (*n* = 91).

We detected marked differences between parks in the average occurrence of numerous species. For instance, we detected more Ruby-crowned Kinglets, Varied Thrushes, Yellow-rumped Warblers, and Dark-eyed Juncos in Lake Clark than Katmai, while Hermit Thrushes, Wilson's Warblers, and Fox Sparrows were more frequently detected in Katmai (Table 3). The average occurrence of certain species (e.g., Wilson's Snipe, Mew Gulls, American Robins), however, was similar between parks (Table 3).

Species Distribution

Summaries of species distribution are based on all observations collected during the 1–3 day visits to the 55 plots visited during the inventory (note that crews spent 1–2 nights at plot 25 in Katmai due to inclement weather in 2005 and observations from this plot are included in species distribution summaries; crews did not, however, conduct point surveys in this plot). The distribution of species

across parks was similar to their frequency of occurrence (Tables 3, 4); commonly detected species were typically widely distributed and infrequently detected species had restricted distributions. For instance, Golden-crowned Sparrow, the most commonly-detected species overall (Table 3), tied with redpoll species as the most widely-distributed species, occurring on 54 (92%) plots (Table 4). Black-capped Chickadee, a species rarely detected during point surveys (*n* = 7), was recorded on only eight sample plots. Certain species, however, contradicted this general pattern. Golden Eagles, for instance, were observed on 20 (37%) sample plots, yet we detected only 11 individuals during point surveys.

Table 4: Species occurrence by 10-km x 10-km sample plot during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006.

	Katmai (*n* = 30 plots)		Lake Clark (*n* = 25 plots)	
Common name[1]	Number of plots:	Proportion of total plots:	Number of plots:	Proportion of total plots:
Greater White-fronted Goose	1	0.03	0	
Canada Goose	0		2	0.08
Trumpeter Swan	0		8	0.32
Tundra Swan	3	0.10	1	0.04
American Wigeon	8	0.27	6	0.24
Mallard	12	0.40	6	0.24
Northern Shoveler	0		3	0.12
Northern Pintail	7	0.23	5	0.20
Green-winged Teal	4	0.13	8	0.32
Ring-necked Duck	2	0.07	1	0.04
Greater Scaup	6	0.20	7	0.28
Lesser Scaup	1	0.03	0	
Harlequin Duck	2	0.07	4	0.16
White-winged Scoter	0		2	0.08
Black Scoter	1	0.03	1	0.04
Long-tailed Duck	4	0.13	3	0.12
Bufflehead	2	0.07	0	
Common Goldeneye	4	0.13	2	0.08
Barrow's Goldeneye	5	0.17	1	0.04
Common Merganser	2	0.07	3	0.12
Red-breasted Merganser	4	0.13	5	0.20
Spruce Grouse	3	0.10	1	0.04
Willow Ptarmigan	20	0.67	15	0.60
Rock Ptarmigan	16	0.53	15	0.60
White-tailed Ptarmigan	5	0.17	6	0.24
Red-throated Loon	1	0.03	3	0.12
Pacific Loon	4	0.13	6	0.24
Common Loon	4	0.13	3	0.12
Horned Grebe	3	0.10	2	0.08
Red-necked Grebe	2	0.07	0	
Osprey	1	0.03	0	
Bald Eagle	16	0.53	9	0.36
Northern Harrier	19	0.63	6	0.24
Sharp-shinned Hawk	1	0.03	1	0.04
Northern Goshawk	0		2	0.08

Common name[1]	Katmai (*n* = 30 plots) Number of plots:	Katmai (*n* = 30 plots) Proportion of total plots:	Lake Clark (*n* = 25 plots) Number of plots:	Lake Clark (*n* = 25 plots) Proportion of total plots:
Rough-legged Hawk	4	0.13	4	0.16
Golden Eagle	7	0.23	13	0.52
Merlin	9	0.30	10	0.40
Gyrfalcon	2	0.07	0	
Peregrine Falcon	1	0.03	2	0.08
Sandhill Crane	5	0.17	1	0.04
Black-bellied Plover	2	0.07	0	
American Golden-Plover	3	0.10	3	0.12
Pacific Golden-Plover	2	0.07	0	
Semipalmated Plover	9	0.30	5	0.20
Spotted Sandpiper	1	0.03	7	0.28
Solitary Sandpiper	0		2	0.08
Wandering Tattler	3	0.10	9	0.36
Greater Yellowlegs	17	0.57	12	0.48
Lesser Yellowlegs	0		7	0.28
Whimbrel	5	0.17	1	0.04
Hudsonian Godwit	4	0.13	0	
Surfbird	7	0.23	7	0.28
Least Sandpiper	10	0.33	8	0.32
Baird's Sandpiper	1	0.03	2	0.08
Pectoral Sandpiper	0		1	0.04
Short-billed Dowitcher	1	0.03	1	0.04
Wilson's Snipe	16	0.53	10	0.40
Red-necked Phalarope	0		5	0.20
Bonaparte's Gull	2	0.07	2	0.08
Mew Gull	10	0.33	13	0.52
Herring Gull	0		1	0.04
Glaucous-winged Gull	6	0.20	2	0.08
Arctic Tern	4	0.13	7	0.28
Parasitic Jaeger	2	0.07	0	
Long-tailed Jaeger	0		2	0.08
Great-horned Owl	1	0.03	1	0.04
Short-eared Owl	2	0.07	0	
Downy Woodpecker	1	0.03	0	
American Three-toed Woodpecker	2	0.07	3	0.12
Northern Flicker	0		2	0.08
Olive-sided Flycatcher	0		4	0.16
Alder Flycatcher	0		2	0.08
Say's Phoebe	0		2	0.08
Northern Shrike	5	0.17	2	0.08
Gray Jay	7	0.23	9	0.36
Black-billed Magpie	10	0.33	11	0.44
Common Raven	20	0.67	17	0.68
Horned Lark	13	0.43	11	0.44
Tree Swallow	10	0.33	9	0.36
Violet-green Swallow	0		3	0.12
Bank Swallow	1	0.03	2	0.08
Black-capped Chickadee	5	0.17	3	0.12
Boreal Chickadee	3	0.10	6	0.24
American Dipper	2	0.07	3	0.12
Golden-crowned Kinglet	0		2	0.08
Ruby-crowned Kinglet	4	0.13	10	0.40

Common name[1]	Katmai (*n* = 30 plots) Number of plots:	Katmai (*n* = 30 plots) Proportion of total plots:	Lake Clark (*n* = 25 plots) Number of plots:	Lake Clark (*n* = 25 plots) Proportion of total plots:
Northern Wheatear	0		2	0.08
Gray-cheeked Thrush	0		5	0.20
Swainson's Thrush	0		3	0.12
Hermit Thrush	25	0.83	23	0.92
American Robin	20	0.67	19	0.76
Varied Thrush	8	0.27	15	0.60
American Pipit	25	0.83	23	0.92
Bohemian Waxwing	0		2	0.08
Orange-crowned Warbler	22	0.73	16	0.64
Yellow Warbler	8	0.27	9	0.36
Yellow-rumped Warbler	11	0.37	14	0.56
Blackpoll Warbler	1	0.03	3	0.12
Northern Waterthrush	4	0.13	5	0.20
Wilson's Warbler	24	0.80	22	0.88
American Tree Sparrow	17	0.57	15	0.60
Savannah Sparrow	22	0.73	16	0.64
Fox Sparrow	24	0.80	19	0.76
Lincoln's Sparrow	2	0.07	6	0.24
White-crowned Sparrow	11	0.37	18	0.72
Golden-crowned Sparrow	27	0.90	23	0.92
Dark-eyed Junco	9	0.30	13	0.52
Lapland Longspur	3	0.10	6	0.24
Snow Bunting	15	0.50	7	0.28
Rusty Blackbird	0		3	0.12
Gray-crowned Rosy-Finch	3	0.10	4	0.16
Pine Grosbeak	3	0.10	3	0.12
White-winged Crossbill	0		3	0.12
Common Redpoll	12	0.40	16	0.64
Redpoll Species	27	0.90	23	0.92
Pine Siskin	0		1	0.04
Total detected during inventory:	92		104	
Total species unique to park:	12		24	

[1]See Table 1 for scientific names.

In general, we detected more species per sample plot in Lake Clark than Katmai (mean 23.5 ± 1.9 SE and 28.5 ± 2.5 SE species per plot for Katmai and Lake Clark, respectively). In Katmai, we detected the most species on plot 30 (*n* = 39 species), and plots 25 and 29 (*n* = 38 each), while in Lake Clark we detected the most species on plots 7 (*n* = 51 species) and 16 and 23 (*n* = 48 each). These Lake Clark plots were the only that we resampled, and an additional eight, thirteen, and three species were detected in plots 7, 16, and 23, respectively, during the resample period. Plot-by-plot species occurrence for Katmai and Lake Clark are presented in Appendices 3 and 4, respectively.

Differences in species occurrence between Katmai and Lake Clark revealed aspects unique to each park. In Katmai, for instance, we failed to detect many boreal forest species that were present in Lake Clark (e.g., Trumpeter Swan, Solitary Sandpiper, Lesser Yellowlegs, Olive-sided Flycatcher, Golden-crowned Kinglet, Rusty Blackbird). Of species detected only in Katmai, three were typical

of dwarf shrub tundra regions in western and northern Alaska (Gyrfalcon, Black-bellied Plover, and Pacific Golden-Plover).

We conducted point surveys at high elevation sites in 20 of 29 (69%) sample plots in Katmai and 23 of 25 (92%) sample plots in Lake Clark. Most alpine species were detected at approximately half of the plots with high elevation sites. American Pipits, however, were widely distributed among these sample plots, detected at all but one, while American Golden-Plovers were relatively restricted, detected at only six sample plots overall, in five of which we conducted surveys at high elevation sites. Most alpine species were also evenly distributed between parks, with the exception of Snow Buntings which were recorded on 50% of sample plots in Katmai but less than 30% of sample plots in Lake Clark.

We documented numerous species in areas and habitats vastly different from those described by previous observers. For example, previous records of Black-bellied Plover, American Golden-Plover, Pacific Golden-Plover, Wandering Tattler, Surfbird, Baird's Sandpiper, and American Pipit in Katmai were primarily of birds detected at lowland sites or along the coast during migration (Cahalane 1944, Cahalane 1959, Gibson 1967, Gibson 1970, Hine 1919, Savage 1996). We observed these same seven species at montane sites exhibiting behaviors indicative of breeding. Appendix 5 combines our observations of behavior with patterns of distribution, occurrence, and habitat association to describe the general abundance, breeding status, and habitat affinities of 63 and 76 species in Katmai and Lake Clark, respectively. This summary includes 34 species of conservation concern.

Bird-habitat Associations

We summarized the percent cover of the six simplified habitat types by study area, park, and elevational category (Figure 6). Overall, dwarf shrub was the most common habitat encountered on sample points, detected at nearly 50% of all points (Appendix 6), and comprised the greatest percent cover (average of 20.2% ± 0.9 SE, Figure 6). Forest habitat was the least-common habitat encountered, present at just over one-quarter of all points (Appendix 6); where present, however, it tended to cover relatively expansive areas (average of 18.3% ± 1.2 SE cover, Figure 6). Bare ground was present at approximately 30% of points (Appendix 6), but comprised the smallest percent cover overall (average of 7.7% ± 0.6 SE cover, Figure 6). Katmai contained relatively more tall shrub and bare ground habitats than Lake Clark (mean cover of tall shrub of 16.5% [± 1.3 SE] and 11.4% [± 1.1 SE] for Katmai and Lake Clark, respectively; bare ground 10.5% [± 1.0 SE] and 4.5% [± 0.6 SE] for Katmai and Lake Clark, respectively; all Figure 6), whereas Lake Clark had relatively more forest than Katmai (12.1% [± 1.3 SE] and 25.2% [± 1.9 SE] for Katmai and Lake Clark, respectively; Figure 6).

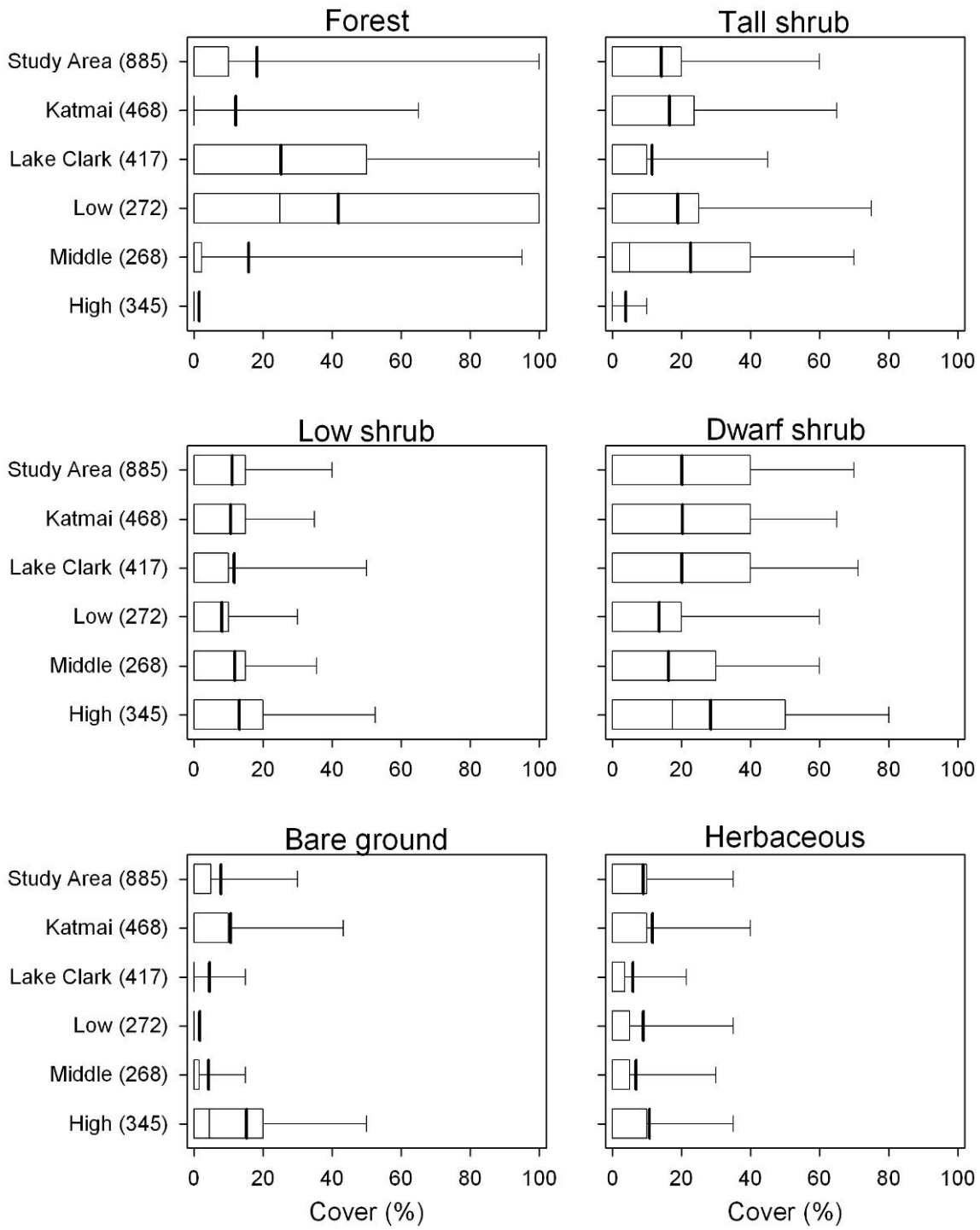

Figure 6. Percent cover of habitats by study area, park, and elevational category at survey points during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Box plots show median (thin vertical line), mean (thick vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Number of points surveyed in each category in parentheses.

To assess patterns of bird habitat use, we summarized the percent cover of vegetation at points at which the 34 most-commonly detected species were recorded (Appendix 7); species are arranged by elevation as in Figure 5.

Forest

Forest habitat was dominated by needleleaf and mixed forests composed of Black (*Picea mariana*) and White (*P. glauca*) spruce and Paper Birch (*Betula papyrifera*; Figure 7). Forest was the dominant vegetation cover at low elevation sites (mean of 41.9% [± 2.6 SE] cover), was less expansive at middle elevation sites (15.9% [± 2.0 SE]), and nearly absent at high elevation sites (1.5% [± 0.5 SE]; all Figure 6). Six species were common at points with forest cover > 45%: Gray Jay, Ruby-crowned Kinglet, Varied Thrush, Yellow-rumped Warbler, Dark-eyed Junco (all low elevation species), and White-crowned Sparrow (middle elevation species; all Appendix 7). Forest habitat essentially did not occur at alpine sites; as such, no alpine species were associated with this habitat type. Gray Jay and Varied Thrush were two species of conservation concern strongly associated with forest habitat.

Figure 7. Black spruce (*Picea mariana*) of typical forest habitat at plot 7 in Lake Clark National Park and Preserve, 16 May 2004. Lake Clark in background.

Tall Shrub

Tall shrub habitat was common at low and middle elevation sites, averaging 18.9% (± 1.9 SE) and 22.6% (± 1.8 SE) cover at these sites, respectively, but nearly absent at high elevation sites (3.8% [± 0.7 SE] cover). Tall shrub habitat was dominated by alder (*Alnus*) and, less commonly, willow (*Salix*) species (Figure 8). Tall shrub habitat was common along river drainages and steep

slopes of mountains and valleys, often in areas of recent disturbance (e.g., lateral moraines, braided river drainages), and tended to form dense, closed canopies. Middle elevation species like Northern Harrier, Fox Sparrow, and Golden-crowned Sparrow were detected at points with > 25% cover of tall shrub habitat (Appendix 7). We detected the strongest association with tall shrub habitat, however, for low elevation species like Hermit Thrush, Orange-crowned Warbler, Yellow Warbler, and Wilson's Warbler (all > 40% cover, Appendix 7).

Figure 8. *Alnus*-dominated tall shrub habitat near Lake Clark Pass, plot 17, Lake Clark National Park and Preserve, 28 May 2004.

Low Shrub

Low shrub habitat tended to occur in open areas and consisted mostly of willow, alder, and dwarf birch (*Betula*). Low shrub habitat was evenly distributed across the three elevation classes (mean of approximately 10% cover at low, middle, and high elevation sites; Figure 6). Similar to tall shrub, low shrub habitat was found along water drainages and steep terrain, but was also present in low-lying wet areas (Figure 9). Certain middle elevation species (e.g., Lesser Yellowlegs, Willow Ptarmigan, Black-billed Magpie, American Tree Sparrow, White-crowned Sparrow) were primarily associated with low shrub (Appendix 7). Despite the presence of low shrub at high elevation sites (Figure 6), alpine species did not demonstrate strong associations with this habitat (Appendix 7).

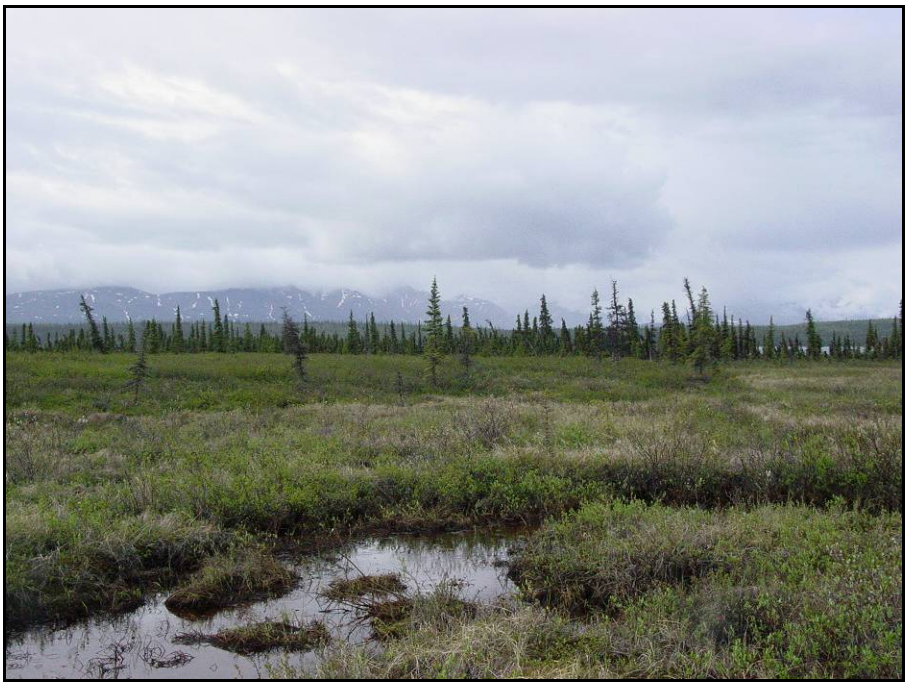

Figure 9. Open, *Betula*- and *Salix*-dominated low shrub habitat (foreground) adjacent to Telaquana Lake, plot 23, Lake Clark National Park and Preserve, 25 May 2004. Note signs of permafrost degradation including open water moat in the foreground and falling black spruce in the background.

Dwarf Shrub

Dwarf shrub habitat was the most expansive type throughout the study area (Figure 6). It comprised the largest habitat component at high elevation sites (mean of 28.5% [± 1.7 SE] cover), and was extensive at middle (16.2% [± 1.5 SE]) and low (13.6% [± 1.5 SE]) sites as well (all Figure 6). Areas supporting dwarf shrub habitat tended to be well-drained terrains dominated by dwarf birch at lower elevations and *Dryas* and various ericaceous shrubs at middle and high elevation sites (Figure 10). Most alpine species were positively associated with dwarf shrub habitat. The mean cover of dwarf shrub habitat for American Golden-Plover, Surfbird, Horned Lark, and American Pipit was ≥ 35% (Appendix 7). Whimbrel, a low elevation species, and Lapland Longspur, a middle elevation species, were also positively associated with dwarf shrub habitat (mean cover 33% and 48%, respectively; Appendix 7).

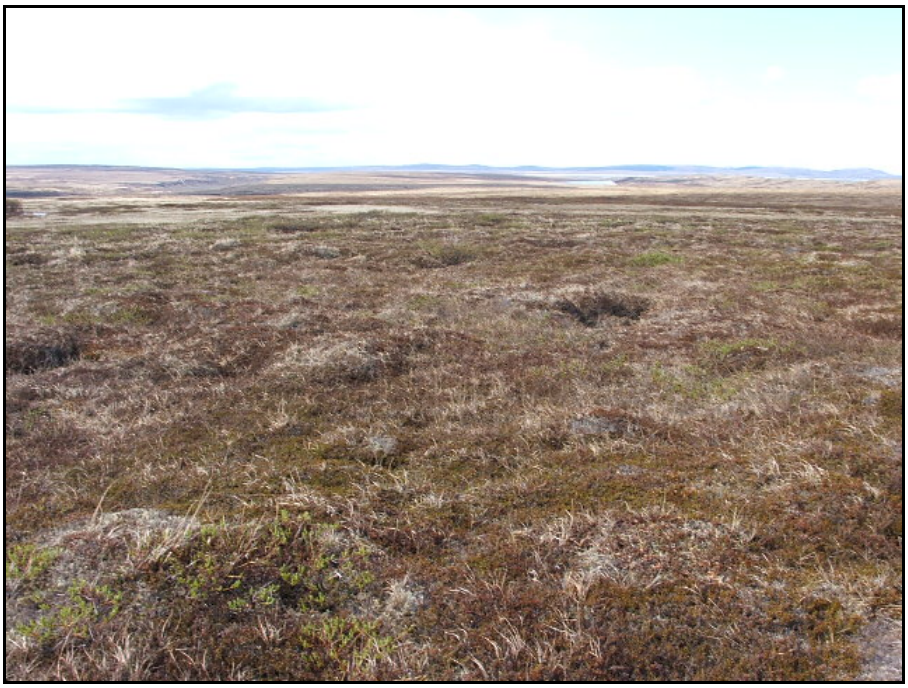

Figure 10. Dwarf shrub habitat consisting primarily of expansive *Empetrum nigrum* mats adjacent to Kukaklek Lake, plot 29, Katmai National Park and Preserve, 15 May 2005.

Bare Ground

Although limited in extent (Figure 6), we detected strong species-specific associations with bare ground habitat, especially in conjunction with dwarf shrub. Bare ground was a prominent feature at high elevation sites (mean 15.2% [± 1.3 SE] cover; Figure 6), but was essentially absent at other elevations (4.3% [± 0.7 SE] and 1.7% [± 0.5 SE] at middle and low elevations, respectively). In the volcanically active region of Katmai (e.g., Valley of Ten Thousand Smokes, Barrier Range Mountains-South), bare ground was often comprised of ash. Elsewhere, bare ground was more typically composed of rock with sparse *Dryas* cover at exposed, high-elevation sites (Figure 11). With the exception of Rock Ptarmigan, bare ground and dwarf shrub habitat occurred together at nearly 50% of all points where high elevation species were detected. Snow Buntings were strongly associated with expansive bare ground regions alone; bare ground was present at every point where this scree-nesting species was detected. No low or middle elevation species showed an association with bare ground habitat.

Figure 11. Rock-strewn, bare ground at 1,369 m (4,500 ft) elevation between Twin and Turquoise lakes, plot 18, Lake Clark National Park and Preserve, 24 May 2004.

Herbaceous

Herbaceous habitat was limited in extent but evenly distributed in all elevation classes, with mean percent cover values near 10% (Figure 6). Whimbrel (low elevation), Wilson's Snipe, Least Sandpiper, Lapland Longspur (all middle elevation), and Surfbird (high elevation) exhibited the strongest association with herbaceous habitat, all with mean cover ≥ 25% (Appendix 7). Whimbrel and Lapland Longspur, both species of conservation concern, were detected at points with a mix of herbaceous and dwarf shrub habitat types; > 70% of points where these two species were detected contained both habitat types. Herbaceous habitat was characterized by graminoids, forbs, and mosses at mesic, lower elevation sites, and sedges and lichens on well-drained xeric slopes at higher elevation sites (Figure 12).

Figure 12. Herbaceous, graminoid-dominated habitat (foreground) at 790 m (2,600 ft) elevation adjacent to Kulik Lake at plot 26, Katmai National Park and Preserve, 17 May 2005.

Physical and Habitat Attributes of Ecological Subsections

We summarized the physical and habitat attributes of the 15 subsections in Katmai and 12 subsections in Lake Clark in which we sampled (Appendices 6, 8, and 9). Locations of subsections within Katmai and Lake Clark are depicted in Figures 3 and 4, respectively. In general, the composition of habitats in subsections followed elevational gradients, with forest common at points in low elevation subsections, tall shrub in middle elevation subsections, and dwarf shrub and bare ground in higher elevation subsections.

Subsections with the greatest amount of snowcover during the inventory period were located in western sections of each park near the Shelikof Strait and Cook Inlet coasts (e.g., Cape Douglas Mountains, Cook Inlet Moraines and Till Plains; Appendix 8a). Average percent cover of snow was 18% (± 0.9 SE) and snow was present at nearly 50% of all points (Appendix 8a, 8b). Snow was present at all points in certain subsections (e.g., Barrier Range Mountains-North), and altogether absent in others (e.g., Lakes Region Spruce Covered Moraine; Appendix 8b). Despite the substantial amount of snowcover at many sites in all years, all emerged vegetation was in leaf (Figure 13). Most importantly for the purposes of this inventory, birds were present and active. High-elevation subsections did not necessarily have abundant snow cover (e.g., Telaquana Highlands; Appendix 8a, 8c), and many subsections in western regions of both parks were largely snow-free (e.g., Stony River Morainal Valley, Kukaklek Lake Moraines). Average elevation at all 885 sample sites was 529 m (± 10 SE;

Appendix 8c). The three subsections with the highest mean elevations were located in Lake Clark (Skwentna/Kuskokwim Headwaters = 1060 m ± 138.9 SE; Telaquana Highlands = 1050 m ± 35.5 SE; Chigmit Mountains and Icefields = 802 m ± 46.8 SE).

Figure 13. Conditions on 3 June 2006 at plot 4 in Johnson River Valley, Lake Clark National Park and Preserve. Snowcover was nearly complete, but emergent vegetation was in leaf and birds were present and active.

Subsections varied greatly in the variety and extent of their habitats (Appendices 6, 9), and these patterns were related to elevation. For instance, relatively low elevation subsections were dominated by forests (e.g., Lakes Region Spruce Covered Moraine, Stony River Morainal Valley), whereas relatively high elevation subsections contained expanses of dwarf shrub habitat (e.g., Telaquana Highlands, Whitefish Sedimentary Hills). One subsection, Valley of Ten Thousand Smokes, was nearly void of vegetation altogether, covered almost entirely with volcanic ash deposited by the 1912 eruption of Novarupta. Other subsections contained a mix of vegetation types that reflected the wide elevational range of sites we sampled within those subsections. For example, within Western Lake Moraines and Till Plains, we sampled 61 sites spanning nearly 1,000 m of elevation. Low shrub and dwarf shrub were the most expansive vegetation types within Western Lake Moraines and Till Plains (approximately 30% cover each), and forest, tall shrub, bare ground, and herbaceous habitats all ranged in cover from 3–15%.

Areas of Special Importance to Montane Birds

We identified the Kukaklek Lake region of Katmai (Figure 3) and the highlands surrounding Twin, Turquoise, and Telaquna lakes of Lake Clark (Figure 4) as

montane areas of special importance. We detected the greatest number of species within Katmai at plots 29 and 30, to the south and north of Kukaklek Lake, respectively, and two of Lake Clark's three most species-rich plots were located near Twin and Telaquana lakes (plots 16 and 23, respectively).

Kukaklek Lake

The Kukaklek Lake area is composed entirely of the Kukaklek Lake Moraines subsection, and ranges in elevation from approximately 210–600 m (690–2,000 ft). Snowcover averaged less than 1.5% during our inventory period (Appendix 8a), and all lakes and ponds were ice-free. In contrast to low and middle elevation sites as a whole, the dominant habitats in this area were dwarf shrub (mean cover 41.8% [± 4.0 SE]) and herbaceous (27.9% [± 4.4 SE]) habitat types. Common dwarf shrubs were Dwarf Birch (*Betula nana*) and Crowberry (*Empetrum nigrum*), and herbaceous vegetation primarily consisted of lichens (*Cladonia* species).

Fifty of the ninety-two species (54%) we detected in Katmai occurred in this region, including 13 species of conservation concern. Within Katmai, four species were detected only in this region (Black Scoter, Black-bellied Plover, Parasitic Jaeger, and Bank Swallow). In addition to these unique occurrences, most detections within Katmai of Tundra Swan, Red-breasted Merganser, Horned Grebe, Pacific Golden-Plover, Whimbrel, and Lapland Longspur occurred here.

Twin / Turquoise / Telaquana Lake Highlands

We inventoried seven plots (16, 18, 19, 20, 21, 22, and 23) primarily located within four subsections in this region (Stony River Morainal Valley, Telaquana Highlands, Western Lake Moraines and Till Plains, and Whitefish Sedimentary Hills). Elevations ranged from approximately 300–1,560 m (980–5,110 ft). Despite visiting numerous high elevation sites in the region, snow cover was minimal (mean cover 2.1% [± 0.4 SE]), likely the result of high winds having carried away snow at these open, exposed sites. Habitats were diverse, comprised primarily of dwarf shrub (mean cover 34.2% [± 3.1 SE]), low shrub (21.2% [± 2.6 SE]), and forest (18.8% [± 3.2 SE]) habitat.

Ninety-two of the 104 species (88%) we detected in Lake Clark occurred in this region, including 32 species of conservation concern. Additionally, 19 species within Lake Clark were detected only in this region, including seven species of conservation concern (Black Scoter, Long-tailed Duck, Red-throated Loon, Peregrine Falcon, American Golden-Plover, Whimbrel, and Short-billed Dowitcher). Over half of all detections of two Watch List species, Olive-sided Flycatcher and Rusty Blackbird, occurred in this region.

Discussion

This inventory represents the first systematic survey of birds within Katmai and Lake Clark and adds to a growing body of similar work conducted throughout

Alaska (Swanson and Nigro 2003, Tibbitts et al. 2005, Van Hemert et al. 2006). All of these inventories have greatly enhanced our understanding of the distribution and abundance of birds in Alaska. Results of this inventory can guide future management decisions and resource conservations strategies and can form the framework for future park- and region-wide monitoring efforts. The intrinsic value of the parks' avian resources will only increase if habitat loss and degradation continues outside park boundaries, and effective monitoring strategies will be essential components of future conservation efforts.

Landbird Distribution and Abundance

The 116 species of birds that we detected in these parks represents a substantial portion of the Alaskan avifauna (Gabrielson and Lincoln 1959, Kessel and Gibson 1978). We detected nearly 70% of the same species of bird in both parks, and our compilation of the previous records of birds in each park yielded a list with 80% overlap between parks. Such a large overlap is not unexpected given the close proximity of the parks and their similar habitats and topography.

Observations of species unique to a particular park, however, followed predictable patterns based on the availability and types of habitat. Many species unique to Katmai were coastal/pelagic seabirds (e.g., Fork-tailed Storm-Petrel, Thick-billed Murre, Red-faced Cormorant), and Katmai's long, rocky coastline simply provides more of this habitat than Lake Clark. In contrast, many birds unique to Lake Clark were vagrants or uncommon species at the edge of their range (e.g., Franklin's Gull, Rock Dove, Rufous Hummingbird). Other species unique to Lake Clark include migrant shorebirds using the Lake Clark coast's extensive mudflats (e.g., Red Knot, Sanderling, Long-billed Dowitcher); the extent of use of Katmai's coastline by migrating shorebirds is largely unknown. Patterns of species abundance mimicked those of species distribution, and were consistent with our findings that Lake Clark contained more forest habitat than Katmai whereas Katmai contained more shrub habitat than Lake Clark.

Species diversity is low at high elevation sites (Chapin and Körner 1994), and many alpine species breed at low densities (Gill et al. 2002a, Senner and McCaffery 1997, Kren and Zoerb 1997). Thus, despite conducting more point count surveys at high than either low or middle elevation sites, we detected comparatively few individuals of alpine species. In addition to the seven commonly-detected alpine species in Figure 5, five other species were characteristic of alpine regions: Wandering Tattler, Baird's Sandpiper, Say's Phoebe, Northern Wheatear, and Gray-crowned Rosy-Finch. Together these 12 species comprise the typical alpine-nesting avifauna present throughout much of Alaska (Swanson and Nigro 2003, Tibbitts et al. 2005). They also represent a vulnerable group of birds; five of the twelve are species of conservation concern.

It is important to note that it is not elevation *per se* that describes the distribution of birds across the region. More specifically, birds distribute themselves by preferred habitats which vary in distribution locally by elevation and regionally by

latitude (Pielou 1979). Elevational and latitudinal vegetation patterns are largely determined by temperature and moisture gradients (Pielou 1994, Arris and Eagleson 1989), factors which in turn define the length and intensity of the growing season. In general, the duration and intensity of the growing season decreases with both elevation and latitude (Billings 1973, Krebs 1985), promoting the growth of prostrate shrubs at the expense of trees (Sturm et al. 2001).

The mean elevation and elevational range with which species are associated tends to decrease with increasing latitude (Pielou 1979). Accordingly, the same assemblage of alpine birds were detected in similar habitats at lower elevations in the Arctic Network of National Parks (ARCN; Tibbitts et al. 2005). These sites are approximately 900 km (over 7 degrees of latitude) north of SWAN. Thus, the elevation categories by which we classified bird species is most relevant within Alaska for latitudes near those of Katmai and Lake Clark (i.e., approximately 58°–62°) and would likely move upward at lower latitudes and contract downward at higher latitudes.

In Katmai and Lake Clark, forests occupy low elevation sites, eventually giving way to tall and low shrub habitats at middle elevation sites, with dwarf shrub and herbaceous vegetation dominating at high elevation sites. At extremely high elevations (i.e., > 1,000 m [3,280 ft]), vegetation is scarce altogether, with only expanses of lichen encrusted rock and bare ground at these inhospitable sites. Given these general patterns, one can better predict habitat-specific associations. For instance, American Golden-Plovers, Surfbirds, Horned Larks, American Pipits, and Snow Buntings were all detected at points with relatively high percent cover of dwarf shrub and bare ground, and the average elevation of points at which these same alpine species were detected was at least 275 m (900 ft) higher than the overall average. In contrast, Greater Yellowlegs, Gray Jays, Orange-crowned Warblers, and Yellow Warblers were detected at locations over 200 m lower than the overall average, correlating with these species' preferences for forest and tall shrub habitats. Elevation's role in shaping and influencing habitat distribution allows us to simply characterize and predict patterns of avian distribution.

Patterns of Habitat Use

The transition from the shrub and herbaceous dominated regions of the Alaska Peninsula to the more boreal, forested regions of Lake Clark provides diverse breeding habitats for over 125 bird species. In general, avian patterns of habitat use mimicked the elevational patterns of habitat occurrence (i.e., species were commonly detected in the dominant habitats of that particular elevational category). Certain species, however, utilized habitats which were relatively uncommon within an elevational category. Whimbrel, for instance, strongly avoided the expansive forest habitats at low elevation sites and instead were detected in relatively uncommon dwarf shrub and herbaceous habitats; similarly, Lesser Yellowlegs were detected at the relatively uncommon forested sites at middle elevation sites. Clearly, elevation alone does not adequately characterize

avian habitat associations, and other variables that we did not measure would likely help to better describe patterns of avian habitat use. Subsequent analyses could incorporate detection probabilities and additional variables (e.g., proximity to water, fire history, canopy cover) to more accurately assess bird-habitat associations.

The species-specific patterns of habitat use revealed in this study are similar to those revealed in other parts of Alaska. For example, Gray Jays, Ruby-crowned Kinglets, Yellow-rumped Warblers, and Dark-eyed Juncos were primarily detected in forest habitats in Yukon-Charley Rivers National Preserve (YUCH; Swanson and Nigro 2003), ARCN (Tibbitts et al. 2005), and the upper Susitna River basin (Kessel 1998). Other similarities include the strong association of alpine species like American Golden-Plover, Surfbird, Horned Lark, Northern Wheatear, and American Pipit with sparsely vegetated habitats in YUCH and ARCN. These same species were associated with the structurally similar dwarf shrub and bare ground habitats in Katmai and Lake Clark, underscoring the importance of this habitat to high elevation species. Thus, species-specific habitat association patterns are generally consistent across broad regions of Alaska. Differences, however, highlight regional changes in species abundance. For instance, a notable difference between the bird communities of Katmai and Lake Clark and YUCH, ARCN, and the Susitna region was the frequent occurrence of Swainson's Thrush in forest habitats at the latter study sites; Swainson's Thrush are relatively uncommon in Katmai and Lake Clark.

Overall, we detected more individuals of more species at low and middle elevation sites compared to high elevation sites. Low and middle elevation sites were characterized by forest and tall shrub habitat, but high elevation sites essentially contained no forest or tall shrub habitat and were instead characterized by dwarf shrub and bare ground habitat. Habitats at low and middle elevation sites are likely more complex structurally than the sparse, prostrate vegetation found at high elevation sites. Previous research has demonstrated a positive relationship between structural complexity and avian species diversity (MacArthur et al. 1966, Recher 1969), which may explain why we detected more species at low and middle elevation sites compared to high elevation sites.

Breeding Range and Status

This inventory refined the Alaska breeding range for several alpine species. Previous work conducted in alpine regions of Lake Clark largely defined the southern breeding range of three shorebird species, Wandering Tattler, Surfbird, and Baird's Sandpiper (Bennett 1996b, Gill et al. 1999, Gill et al. 2004). Evidence of breeding, however, was lacking for these species south of the Turquoise Lake region. This inventory extended the breeding ranges of all three species approximately 250 km (155 mi) south to high-elevation sites in central Katmai. Conversely, certain alpine species were conspicuous by their absence. For example, Say's Phoebe and Northern Wheatear occurred in Lake Clark, but

despite surveying extensively at suitable sites throughout Katmai, neither species was detected.

In order to effectively manage avian resources, one must consider the breeding status of a species within a region. Potential management strategies differ, for example, for species that occur as migrants and those that occur as resident breeders. The timing (breeding vs. migration) and sample frame (high elevation vs. low elevation/coastal) of this inventory allowed us to assess the breeding status of many of the birds we detected. Conducting this inventory during the period of peak breeding display activity was an effort to maximize our ability to detect species, but it also efficiently documented the breeding status of Katmai and Lake Clark's avian resources.

Species of Conservation Concern

Our compilation of previously documented sightings includes 62 species of conservation concern (57 and 56 in Katmai and Lake Clark, respectively), of which we detected 40 during this inventory. Seventeen species within Katmai and Lake Clark are identified as Stewardship Species in the North American Landbird Conservation Plan (Rich et al. 2004). This is a biome-specific designation indicating that these particular species occur primarily in that particular biome; as such, the primary responsibility for that species' conservation falls to that region (Rich et al. 2004). All the other species identified as species of conservation concern, however, are designated because they are vulnerable to a combination of threats related to demography, population size, or distribution. Importantly, an inadequate understanding of the status and distribution within the northern part of species' ranges has been identified as a crucial gap in the conservation and management of many species (Rich et al. 2004). Compared to most other states, general life history information is lacking for much of Alaska's avifauna.

As a state, Alaska is unique in that it still supports expansive regions of relatively pristine habitat. Additionally, the majority of Alaska's bird species are migratory, and the primary conservation threats to these species typically lie outside the state. These facts often make active conservation management within the state an ineffective proposition. As stated above, however, basic life history information is lacking for many of Alaska's species of conservation concern, and efforts at Katmai and Lake Clark NPPs could meaningfully contribute to state- and nation-wide monitoring and management efforts. Land managers in Alaska can actively promote conservation by preserving habitats within Alaska while forming partnerships with land management entities in other parts of the species' range.

Potential Impacts and Conservation Threats

National Parks in Alaska tend not to suffer the impacts that affect many parks in other states. Currently, visitation rates are relatively low and human impacts moderate. Katmai and Lake Clark, however, are not immune to change. Private

inholdings and native allotments comprise 1% and 18% of total lands within Katmai and Lake Clark, respectively, and development is occurring at many of these sites. Events outside park boundaries can also have profound effects. For instance, the Bristol Bay watershed is currently the site of proposed large-scale developments (e.g., off-shore oil and gas exploration, mining). The Bristol Bay region is a globally-unique ecosystem that includes over 20 Important Bird Areas (Senner et al. 2004). Katmai and Lake Clark are intimately linked to Bristol Bay, as evidenced by the fact that major rivers from both parks drain to this ecosystem. There is widespread concern that these developments could adversely affect the region's wildlife, and the extent to which this could adversely affect montane birds is unknown and warrants serious consideration.

Global climate change is perhaps the best example of how events outside park boundaries can potentially affect resources within. Climate change may be the greatest threat to alpine-nesting birds in both parks if it results in sub-alpine and alpine habitats becoming dryer, or if alpine vegetation is replaced by non-alpine vegetation as has been predicted (ACIA 2004). Over the past 50 years, Alaska has experienced a warming climate with longer growing seasons, increased permafrost thawing, an increase in water loss due to evaporation from open water and transpiration from vegetation, and yet no substantial change in precipitation (Klein et al. 2005). Jorgenson et al. (2006) compared 1929 and 2004 photographs of alpine tundra adjacent to Turquoise Lake and documented shrinkage of tundra ponds from drying, paludification from vegetation colonizing shallow water, and replacement of sedge-dominated vegetation with dwarf shrubs.

If current climatological trends continue, it is likely that forest and tall shrub habitats will become more prevalent at higher elevations (Myeni et al. 1997, Serreze et al. 2000, ACIA 2004). Whether the habitats that currently characterize the alpine regions of both parks will likewise make an upward elevational shift is unclear, however, because much of the region's high-elevation terrain (i.e., sites > 1,000 m elevation) lacks organic soils and is currently covered by extensive glaciers. Although most glaciers throughout Alaska are rapidly receding (Arendt et al. 2002), there may be a prolonged lag between the disappearance of glaciers and the establishment of vegetation communities (Chapin et al. 1994). Thus, alpine vegetation types, and hence alpine birds, may be unable to rapidly adjust their ranges higher in elevation.

Areas of Special Importance to Montane Birds

Given the potential threats to montane regions in both parks, we identified one region in each park as an montane area of special importance. The Kukaklek Lake region in Katmai and the Twin/Turquoise/Telaquana Lake highlands in Lake Clark support unique, diverse avifaunas of regional importance that include many species of conservation concern. Both regions are characterized by extensive highlands consisting of Pleistocene-era moraines that form rolling terrain with varied physiographies (Shephard and Spencer 2000, Spencer 2001). Landscape

relief gives rise to numerous kettle ponds, snow-holding depressions, and wet hollows. Combined, the geology, elevational relief, water resources, and physiography of these areas create a wide diversity of nesting and foraging sites unique to these parks (A. Bennett, pers. comm.). Park managers can benefit montane birds by being sensitive to local (e.g. increased visitation), regional (e.g., oil or mineral exploration), and global (e.g., global climate change) issues that may negatively impact these regions. Efforts to ensure the continued integrity of these sites will substantially benefit montane birds.

The Kukaklek Lake region in Katmai contains rolling expanses of ericaceous tundra interspersed with small stands of spruce, shrub-filled draws, and numerous kettle ponds (Figure 14). This diversity of landforms and habitats serves as an intersection of ecotones; the avifauna of this area includes many species unique to both tundra and boreal ecosystems (for more, see Williamson and Peyton 1962). Kukaklek Lake's relatively high elevation (250 m [810 ft]) seems to promote more tundra-adapted, alpine species (e.g., American Golden-Plover, Wandering Tattler, Horned Lark, American Pipit), whereas its close proximity to more typical boreal habitats encourages birds more common to low-lying areas to the immediate north and south (e.g., Greater Yellowlegs, Hermit Thrush, Wilson's Warbler).

Figure 14. Low shrub habitat (background) and dwarf shrub and herbaceous habitat (foreground) adjacent to Kukaklek Lake at plot 29, Katmai National Park and Preserve, 15 May 2005.

In Lake Clark, the highlands running between Twin, Turquoise, and Telaquana lakes host an assemblage of birds unique to SWAN as a whole, and previous descriptions of birds at sites in these highlands attest to the area's diversity

(Keith 1973, Bennett 1996b, Bennett 1996c, Gill et al. 1999). To the east, glacier-carved mountains give way to valleys carpeted by spruce and broadleaf (primarily *Populus*, *Betula*) forests. Dwarf shrub and herbaceous habitats lead west, eventually giving rise to thick stands of boreal forest scattered with wetlands. This area is bound to the south by the dwarf shrub-dominated Snipe Lake/Bonanza Hills region (Figure 15), while the Stony and Mulchatna rivers drain the boreal region to the northwest. This diversity of landforms and habitats likewise promotes a diversity of bird species. The avifauna of this region is represented by a wide variety of boreal (e.g., Rusty Blackbird, Trumpeter Swan, Greater Yellowlegs), tundra (e.g., American Golden-Plover, Willow Ptarmigan), and alpine species (e.g., Surfbird, Northern Wheatear, White-tailed Ptarmigan).

Figure 15. Dwarf shrub and herbaceous habitat at plot 16, Lake Clark National Park and Preserve, 11 June 2004. Bonanza Hills in background.

Recommendations for Future Study

This inventory greatly augments our understanding of the status, abundance, and distribution of breeding birds in Katmai and Lake Clark. Results from other seasons of the year, however, are lacking. The majority of bird records for the parks cover the period from approximately late April through late August, and although this period likely encompasses the time of greatest avian abundance and diversity, accurate information on the occurrence and distribution of birds during other parts of the annual cycle would be valuable. Recording the occurrence of species using these parks during the non-breeding season (i.e., spring and fall migrants, residents during the non-breeding season) would more accurately document the parks' avian resources and enable managers to make more informed management decisions.

Both parks host numerous species of conservation concern, and focused, species-specific projects (e.g., International Rusty Blackbird Technical Working

Group; Smithsonian Migratory Bird Center 2006) in both parks could greatly facilitate coordinated conservation efforts. Additionally, participation in more broad-scale efforts, such as ALMS (Handel and Cady 2004), and in programs such as Park Flight (National Park Service 2006c) and Sister Park (National Park Service 2006d) could provide information that may help inform future management decisions and enhance the ability of parks to better address questions of conservation concern.

Globally, changes in climate are being expressed in changes in the distribution of plants and animals (Parmesan and Yohe 2003), and landscape-level changes attributable to global climate change are predicted to accelerate over the next 100 years, especially at high-latitude sites (ACIA 2004). To better predict potential changes to park landscapes in general and avian resources in particular, one must better identify the numerous factors that influence avian distribution patterns. Discrete, focused habitat selection assessments measuring likely biotic (e.g., habitat structural diversity, seasonal arthropod abundance) and abiotic (e.g., photoperiod, gradients of temperature, moisture) factors that affect bird distribution would allow park managers to better anticipate future changes to the region's avifauna.

These inventories form the basis for future monitoring programs, and park managers and biologists can define these efforts within the capabilities of the methodology (see Nichols and Williams 2006). For instance, our methodology successfully detects and describes broad-scale patterns of distribution and abundance, and could potentially function well as a tool for monitoring populations of common species. However, this methodology presents great logistical and financial challenges, and is unlikely to track the status of rare or uncommon species beyond detecting presence or absence. For instance, nearly all the alpine species in these parks occur at extremely low densities, and future monitoring may require more intensive sampling in focused areas of interest (e.g., areas of special importance to montane birds) or cooperation with other entities conducting similar work on these same species at different sites (e.g., increased participation of NPS biologists and managers with groups like Boreal Partners in Flight, Boreal Landbird Initiative, Alaska Shorebird Group).

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Appendix

Appendix 1. Area of ecological subsections and sample point distribution within the sampling frame for the inventory of montane-nesting birds within Katmai and Lake Clark National Parks and Preserves, 2004–2006.

Park	Subsection name	Subsection code	Total area of subsection (km^2)	Total area within sampling frame (km^2)[1]	Number of points allocated	Number of points surveyed[2]
Katmai	Alagnak River Lowlands	ARD	475	0	0	-
	Bristol Bay Lowlands	BBL	1,761	0	0	-
	Barrier Range Mountains-North	BRN	467	82	10	15
	Barrier Range Mountains-South	BRS	1,713	479	30	37
	Cape Douglas Mountains	CDM	1,223	369	23	34
	Coville Lake Deposits	CLD	120	51	10	14
	Iliamna Drift Deposits	IDD	287	83	10	13
	Kejulik Mountains	KEM	1,469	566	35	26
	Kukaklek Lake Moraines	KLM	1,380	825	52	47
	Katmai River Floodplain	KRF	152	0	0	-
	Kamishak River Hills	KRH	3,239	1,534	60	51
	Lowland Outwash and Drift Deposits	LOD	1,572	523	33	17
	Lakes Region Old Lake Bed Deposits	LRD	588	0	0	-
	Lakes Region Hills	LRH	1,785	1,342	60	56
	Lakes Region Spruce Covered Moraine	LRM	1,767	755	41	34
	South Kejulik Mountains	SKM	2,099	1,006	60	48
	Savonoski River Floodplain	SRF	387	65	10	6
	Shelikof Strait Lowlands	SSL	682	0	0	-
	Valley of Ten Thousand Smokes	TTS	223	175	11	15
	Walatka Mountains	WAM	2,094	1,020	60	55
		Total	23,483	8,921	505	468
Lake Clark	Cook Inlet Marine Influence	CIMI	55	0	0	-
	Cook Inlet Moraines and Till Plains	CIMT	547	60	10	11
	Cook Inlet Old Volcanics	CIOV	1,062	267	17	30
	Chigmit Mountains and Icefields	CMI	8,132	1,023	60	54
	Chakachamna Moraines and Till Valleys	CMTV	529	165	10	6

Park	Subsection name	Subsection code	Total area of subsection (km^2)	Total area within sampling frame (km^2)[1]	Number of points allocated	Number of points surveyed[2]
Lake Clark	Iliamna Sedimentary Hills	ISH	664	221	14	21
	Lake Clark Pass and Moraines	LCPM	3,006	1,048	60	64
	Rounded Volcanic Hills	RVH	3,097	998	60	77
	String Bog Uplands	SBU	147	1	10	0
	Skwentna/Kuskokwim Headwaters	SKH	5,572	413	26	9
	Stony River Morainal Valley	SRMV	3,296	952	60	35
	Telaquana Highlands	TH	274	266	17	24
	Western Lake Moraines and Till Plains	WLTP	1,474	792	49	61
	Whitefish Sedimentary Hills	WSH	651	48	10	25
		Total	28,506	6,254	403	417

[1]Sampling frame comprises all unglaciated, non-lacustrine lands > 100 m above sea level and < 50 degree slope (see Methods for details).

[2]Only first replicate of points reported here; 37 points were repeated (see Methods for details).

Appendix 2. Vegetation classification (after Viereck et al. 1992) used during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006.

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[1]	*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. Non vegetated	*A. Snow*	*1. Complete snow cover*
	B. Water	*1. Creek, river, lake, pond*
	C. Rock	*1. Scree slope, boulder field*

[1]Italicized categories were added to the classification to accommodate specific situations encountered during the inventory.

Appendix 3: Species distribution by 10-km x 10-km sample plot for birds detected during the inventory of montane-nesting birds in Katmai National Park and Preserve, 2005–2006. See Figure 3 for plot locations.

	Plot identification number													
Common name	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Greater White-fronted Goose														
Tundra Swan														
American Wigeon					X			X						
Mallard					X			X			X	X		
Northern Pintail					X		X							
Green-winged Teal					X			X						
Ring-necked Duck								X						
Greater Scaup					X			X						
Lesser Scaup							X							
Harlequin Duck					X									
Black Scoter														
Long-tailed Duck							X				X			
Bufflehead														
Common Goldeneye					X			X						
Barrow's Goldeneye							X	X						X
Common Merganser					X									
Red-breasted Merganser							X							
Spruce Grouse														
Willow Ptarmigan	X				X		X	X	X	X	X		X	
Rock Ptarmigan	X		X	X	X		X			X	X		X	X
White-tailed Ptarmigan	X	X	X											
Red-throated Loon							X							
Pacific Loon												X		
Common Loon								X						
Horned Grebe					X									
Red-necked Grebe														
Osprey														
Bald Eagle	X		X	X			X				X	X		X
Northern Harrier					X		X	X	X		X	X	X	X
Sharp-shinned Hawk								X						

	Plot identification number													
Common name	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Rough-legged Hawk	X				X									
Golden Eagle		X		X										
Merlin	X				X		X	X			X		X	
Gyrfalcon					X									
Peregrine Falcon					X									
Sandhill Crane														
Black-bellied Plover														
American Golden-Plover														
Pacific Golden-Plover							X							
Semipalmated Plover						X	X		X		X			
Spotted Sandpiper								X						
Wandering Tattler											X			X
Greater Yellowlegs					X		X	X		X		X	X	
Whimbrel												X		
Hudsonian Godwit												X		
Surfbird											X		X	
Least Sandpiper					X		X					X		
Baird's Sandpiper														
Short-billed Dowitcher					X									
Wilson's Snipe					X		X	X				X	X	X
Bonaparte's Gull								X						
Mew Gull					X		X	X				X		
Glaucous-winged Gull			X								X			
Arctic Tern					X									
Parasitic Jaeger														
Great-horned Owl														
Short-eared Owl					X									
Downy Woodpecker														
American Three-toed Woodpecker												X		
Northern Shrike								X					X	
Gray Jay								X				X		
Black-billed Magpie		X		X	X				X		X		X	
Common Raven				X	X		X	X		X	X	X	X	X

	Plot identification number													
Common name	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Horned Lark				X	X			X	X				X	X
Tree Swallow							X	X		X		X		
Bank Swallow														
Black-capped Chickadee												X	X	
Boreal Chickadee								X						
American Dipper					X					X				
Ruby-crowned Kinglet												X		
Hermit Thrush	X	X	X	X	X		X	X	X	X	X	X	X	X
American Robin	X			X	X		X	X		X		X	X	X
Varied Thrush								X		X		X	X	
American Pipit	X		X	X	X	X	X	X	X	X	X	X	X	X
Orange-crowned Warbler	X	X	X	X	X			X	X	X	X	X	X	X
Yellow Warbler	X	X	X										X	X
Yellow-rumped Warbler								X		X	X	X	X	
Blackpoll Warbler										X				
Northern Waterthrush				X						X			X	
Wilson's Warbler	X	X	X	X	X			X	X	X	X	X	X	X
American Tree Sparrow		X		X	X		X	X				X		X
Savannah Sparrow	X		X	X	X		X	X		X		X	X	X
Fox Sparrow	X	X	X	X	X		X		X	X	X	X	X	X
Lincoln's Sparrow														
White-crowned Sparrow								X	X	X		X		
Golden-crowned Sparrow	X	X	X	X	X		X	X	X	X	X	X	X	X
Dark-eyed Junco								X				X		
Lapland Longspur							X							
Snow Bunting	X	X	X			X	X		X		X			X
Gray-crowned Rosy-Finch			X	X										
Pine Grosbeak								X					X	
Redpoll Species	X	X	X	X	X		X	X	X	X	X	X	X	X
Total number of species on plot:	17	12	15	18	37	3	29	37	14	20	22	30	26	20

	Plot identification number													
Common name	15[1]	16	17	18	19	20	21	22	23	24	25	26	27	28
Greater White-fronted Goose														
Tundra Swan								X				X		
American Wigeon		X					X			X	X			
Mallard					X		X	X		X	X		X	
Northern Pintail								X		X				X
Green-winged Teal								X						
Ring-necked Duck							X							
Greater Scaup		X						X			X			
Lesser Scaup														
Harlequin Duck											X			
Black Scoter														
Long-tailed Duck											X			
Bufflehead								X						
Common Goldeneye											X		X	
Barrow's Goldeneye							X				X			
Common Merganser											X			
Red-breasted Merganser											X			
Spruce Grouse	X	X											X	
Willow Ptarmigan	X	X	X	X	X	X		X		X			X	X
Rock Ptarmigan		X	X	X		X		X				X		X
White-tailed Ptarmigan				X		X								
Red-throated Loon														
Pacific Loon											X			
Common Loon					X						X			
Horned Grebe										X				
Red-necked Grebe							X						X	
Osprey													X	
Bald Eagle	X			X		X		X		X	X		X	
Northern Harrier	X	X		X		X	X	X		X	X		X	
Sharp-shinned Hawk														
Rough-legged Hawk				X										X
Golden Eagle	X		X	X		X		X						

	Plot identification number													
Common name	15[1]	16	17	18	19	20	21	22	23	24	25	26	27	28
Merlin	X									X				X
Gyrfalcon								X						
Peregrine Falcon														
Sandhill Crane	X				X		X						X	
Black-bellied Plover														
American Golden-Plover								X				X		
Pacific Golden-Plover														
Semipalmated Plover						X		X	X		X			X
Spotted Sandpiper														
Wandering Tattler														
Greater Yellowlegs	X	X				X	X	X		X	X	X	X	
Whimbrel	X												X	
Hudsonian Godwit	R							X					X	
Surfbird						X		X			X	X	X	
Least Sandpiper						X		X		X		X		X
Baird's Sandpiper						X								
Short-billed Dowitcher														
Wilson's Snipe	X	X			X		X	X		X	X		X	
Bonaparte's Gull													X	
Mew Gull	X			X				X		X	X			
Glaucous-winged Gull					X						X			
Arctic Tern											X			
Parasitic Jaeger														
Great-horned Owl										X				
Short-eared Owl								X						
Downy Woodpecker		X												
American Three-toed Woodpecker							X							
Northern Shrike							X						X	
Gray Jay	X				X		X						X	
Black-billed Magpie			X	X		X					X			
Common Raven	X		X	X	X		X	X		X		X	X	
Horned Lark			X			X		X		X		X		X
Tree Swallow					X		X				X		X	

	Plot identification number													
Common name	15[1]	16	17	18	19	20	21	22	23	24	25	26	27	28
Bank Swallow														
Black-capped Chickadee		X		X							X			
Boreal Chickadee							X			X				
American Dipper														
Ruby-crowned Kinglet							X				X		X	
Hermit Thrush	X	X	X	X	X		X	X		X	X			X
American Robin	X	X			X		X	X		X	X		X	X
Varied Thrush		X					X			X	X			
American Pipit		X	X	X	X	X		X	X	X		X		X
Orange-crowned Warbler	X	X	X	X	X		X			X	X		X	
Yellow Warbler	X			X	X									
Yellow-rumped Warbler		X					X			X	X		X	
Blackpoll Warbler														
Northern Waterthrush													X	
Wilson's Warbler	X	X	X	X	X		X	X		X	X			X
American Tree Sparrow	X				X	X	X	X		X	X		X	
Savannah Sparrow	X		X		X	X	X	X		X	X		X	X
Fox Sparrow		X	X	X	X		X	X		X	X		X	X
Lincoln's Sparrow							X			X				
White-crowned Sparrow	X				X		X			X	X		X	
Golden-crowned Sparrow	X	X	X	X	X	X	X	X		X	X		X	X
Dark-eyed Junco	X	X					X			X	X		X	
Lapland Longspur												X		
Snow Bunting		X		X		X		X	X			X		X
Gray-crowned Rosy-Finch				X										
Pine Grosbeak											X			
Redpoll Species	X	X	X	X	X	X	X	X		X	X		X	X
Total number of species on plot:	25	22	14	21	21	19	30	33	3	31	38	11	31	17

[1] 'R' refers to species detected only during count repeated on 13 May, 2005.

[2]Plot 25 was not part of the random sample, but crews collected numerous observations during a two-day stay in 2005 necessitated by poor weather.

Common name	Plot ID 29	Plot ID 30	Number of plots on which species detected:
Greater White-fronted Goose	X		1
Tundra Swan		X	3
American Wigeon	X	X	8
Mallard	X	X	12
Northern Pintail	X	X	7
Green-winged Teal	X		4
Ring-necked Duck			2
Greater Scaup		X	6
Lesser Scaup			1
Harlequin Duck			2
Black Scoter		X	1
Long-tailed Duck	X		4
Bufflehead		X	2
Common Goldeneye			4
Barrow's Goldeneye			5
Common Merganser			2
Red-breasted Merganser	X	X	4
Spruce Grouse			3
Willow Ptarmigan	X	X	20
Rock Ptarmigan			16
White-tailed Ptarmigan			5
Red-throated Loon			1
Pacific Loon	X	X	4
Common Loon		X	4
Horned Grebe		X	3
Red-necked Grebe			2
Osprey			1
Bald Eagle	X	X	16
Northern Harrier	X	X	19
Sharp-shinned Hawk			1
Rough-legged Hawk			4
Golden Eagle			7

Common name	Plot ID 29	Plot ID 30	Number of plots on which species detected:
Merlin			9
Gyrfalcon			2
Peregrine Falcon			1
Sandhill Crane	X		5
Black-bellied Plover	X	X	2
American Golden-Plover	X		3
Pacific Golden-Plover	X		2
Semipalmated Plover			9
Spotted Sandpiper			1
Wandering Tattler	X		3
Greater Yellowlegs	X	X	17
Whimbrel	X	X	5
Hudsonian Godwit			4
Surfbird			7
Least Sandpiper	X	X	10
Baird's Sandpiper			1
Short-billed Dowitcher			1
Wilson's Snipe	X	X	16
Bonaparte's Gull			2
Mew Gull		X	10
Glaucous-winged Gull	X	X	6
Arctic Tern	X	X	4
Parasitic Jaeger	X	X	2
Great-horned Owl			1
Short-eared Owl			2
Downy Woodpecker			1
American Three-toed Woodpecker			2
Northern Shrike		X	5
Gray Jay		X	7
Black-billed Magpie			10
Common Raven	X	X	20
Horned Lark	X		13
Tree Swallow	X	X	10

Common name	Plot ID 29	Plot ID 30	Number of plots on which species detected:
Bank Swallow		X	1
Black-capped Chickadee			5
Boreal Chickadee			3
American Dipper			2
Ruby-crowned Kinglet			4
Hermit Thrush	X	X	25
American Robin	X	X	20
Varied Thrush			8
American Pipit	X	X	25
Orange-crowned Warbler	X		22
Yellow Warbler			8
Yellow-rumped Warbler		X	11
Blackpoll Warbler			1
Northern Waterthrush			4
Wilson's Warbler	X	X	24
American Tree Sparrow	X	X	17
Savannah Sparrow	X	X	22
Fox Sparrow	X	X	24
Lincoln's Sparrow			2
White-crowned Sparrow	X		11
Golden-crowned Sparrow	X	X	27
Dark-eyed Junco		X	9
Lapland Longspur	X		3
Snow Bunting			15
Gray-crowned Rosy-Finch			3
Pine Grosbeak			3
Redpoll Species	X	X	27
Total number of species on plot:	38	39	

Appendix 4: Species distribution by 10-km x 10-km sample plot for birds detected during the inventory of montane-nesting birds in Lake Clark National Park and Preserve, 2004, 2006. See Figure 4 for plot locations.

	Plot identification number													
Common name	1	2	3	4	5	6	7[1]	8	9	10	11	12	13	14
Canada Goose							R							
Trumpeter Swan								X	X	X		X	X	
Tundra Swan														
American Wigeon							R						X	
Mallard							X						X	
Northern Shoveler														
Northern Pintail														
Green-winged Teal					X								X	X
Ring-necked Duck														
Greater Scaup										X			X	
Harlequin Duck		X					X					X		
White-winged Scoter														
Black Scoter														
Long-tailed Duck														
Common Goldeneye									X				X	
Barrow's Goldeneye														
Common Merganser			X				X						X	
Red-breasted Merganser							X						X	
Spruce Grouse														
Willow Ptarmigan		X	X	X	X				X		X	X		X
Rock Ptarmigan		X		X	X					X	X	X	X	
White-tailed Ptarmigan			X	X		X					X			
Red-throated Loon														
Pacific Loon	X						X						X	
Common Loon							R							
Horned Grebe							X							
Bald Eagle	X	X		X			X							X
Northern Harrier					X		X							
Sharp-shinned Hawk														
Northern Goshawk										X				

Common name	Plot identification number													
	1	2	3	4	5	6	7[1]	8	9	10	11	12	13	14
Rough-legged Hawk						X			X					
Golden Eagle				X	X		X	X					X	X
Merlin				X			X					X	X	X
Peregrine Falcon														
Sandhill Crane								X						
American Golden-Plover														
Semipalmated Plover										X				
Spotted Sandpiper		X	X				X						X	
Solitary Sandpiper													X	
Wandering Tattler		X	X			X					X			X
Greater Yellowlegs					X		X	X		X		X	X	X
Lesser Yellowlegs					X		X							
Whimbrel														
Surfbird			X				X			X		X		
Least Sandpiper					X		X							X
Baird's Sandpiper														
Pectoral Sandpiper														
Short-billed Dowitcher														
Wilson's Snipe					X		X			X		X	X	X
Red-necked Phalarope														
Bonaparte's Gull														
Mew Gull	X			X	X		X							X
Herring Gull														
Glaucous-winged Gull	X													
Arctic Tern													X	
Long-tailed Jaeger														
Great-horned Owl													X	
American Three-toed Woodpecker								X		X		X		
Northern Flicker							R							
Olive-sided Flycatcher									X				X	
Alder Flycatcher							R							
Say's Phoebe														
Northern Shrike					X									

	Plot identification number													
Common name	1	2	3	4	5	6	7[1]	8	9	10	11	12	13	14
Gray Jay							X	X		X		X	X	
Black-billed Magpie		X	X	X	X		X	X	X			X	X	
Common Raven			X	X	X		X	X	X	X		X	X	X
Horned Lark			X		X	X								
Tree Swallow	X			X			R					X	X	
Violet-green Swallow							X							
Bank Swallow														
Black-capped Chickadee	X						X						X	
Boreal Chickadee							X	X				X		
American Dipper							X					X		
Golden-crowned Kinglet					X			X						
Ruby-crowned Kinglet					X		X	X		X			X	
Northern Wheatear														
Gray-cheeked Thrush				X	X							X		X
Swainson's Thrush							X							
Hermit Thrush	X	X	X	X	X	X	X	X	X	X	X	X	X	X
American Robin			X	X	X		X	X	X	X		X		X
Varied Thrush		X	X	X	X		X	X	X	X		X	X	
American Pipit	X	X	X	X	X	X	X		X	X	X	X	X	X
Bohemian Waxwing							X							
Orange-crowned Warbler	X	X			X		X	X	X			X	X	
Yellow Warbler	X	X		X			R		X					
Yellow-rumped Warbler			X	X	X		X	X	X	X		X	X	
Blackpoll Warbler													X	
Northern Waterthrush				X				X						
Wilson's Warbler	X	X	X	X	X	X	X	X	X		X	X	X	
American Tree Sparrow			X							X		X		X
Savannah Sparrow		X	X	X	X		X		X			X		
Fox Sparrow	X	X	X	X	X	X	X	X	X		X	X	X	X
Lincoln's Sparrow					X		X	X					X	
White-crowned Sparrow					X		X	X		X	X	X	X	X
Golden-crowned Sparrow	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dark-eyed Junco			X		X		X	X		X		X	X	

	Plot identification number													
Common name	1	2	3	4	5	6	7[1]	8	9	10	11	12	13	14
Lapland Longspur					X					X				
Snow Bunting			X			X				X				
Rusty Blackbird							R							
Gray-crowned Rosy-Finch				X					X					
Pine Grosbeak					X		X							
White-winged Crossbill							X							
Redpoll Species		X	X	X	X	X	X	X	X	X	X	X	X	X
Pine Siskin								X						
Total number of species on plot:	13	17	22	24	33	11	51	25	20	24	11	30	38	20

[1] 'R' refers to species detected only during counts repeated when plots 7, 16, and 23 revisited 9–12 June, 2004.

Common name	Plot identification number											Number of plots on which species detected:
	15	16[1]	17	18	19	20	21	22	23[1]	24	25	
Canada Goose				X								2
Trumpeter Swan		X						X	X			8
Tundra Swan		R										1
American Wigeon		X		X		X			X			6
Mallard		X			X			X	X			6
Northern Shoveler		X				X			X			3
Northern Pintail		X		X		X	X		X			5
Green-winged Teal		X		X	X	X			X			8
Ring-necked Duck		R										1
Greater Scaup		X		X	X	X		X				7
Harlequin Duck						X						4
White-winged Scoter		R							X			2
Black Scoter		X										1
Long-tailed Duck				X		X	X					3
Common Goldeneye												2
Barrow's Goldeneye		X										1
Common Merganser												3
Red-breasted Merganser				X		X			X			5
Spruce Grouse	X											1
Willow Ptarmigan	X	X	X	X	X	X	X					15
Rock Ptarmigan	X	X	X	X	X	X	X	X				15
White-tailed Ptarmigan			X	X								6
Red-throated Loon		R		X		X						3
Pacific Loon		X					X		X			6
Common Loon		R							X			3
Horned Grebe		X										2
Bald Eagle					X	X		X	X			9
Northern Harrier		R			X		X	X				6
Sharp-shinned Hawk	X											1
Northern Goshawk								X				2
Rough-legged Hawk								X	X			4

Common name	Plot identification number											Number of plots on which species detected:
	15	16[1]	17	18	19	20	21	22	23[1]	24	25	
Golden Eagle	X	R	X	X		X	X				X	13
Merlin	X		X	X		X			R			10
Peregrine Falcon				X				X				2
Sandhill Crane												1
American Golden-Plover					X	X		X				3
Semipalmated Plover				X	X	X	X					5
Spotted Sandpiper	X								X	X		7
Solitary Sandpiper								X				2
Wandering Tattler	X			X		X	X					9
Greater Yellowlegs		X		X	X	X			X			12
Lesser Yellowlegs		X		X			X	X	X			7
Whimbrel								X				1
Surfbird				X		X	X					7
Least Sandpiper		X		X	X	X			X			8
Baird's Sandpiper				X		X						2
Pectoral Sandpiper		X										1
Short-billed Dowitcher									X			1
Wilson's Snipe		X			X			X	X			10
Red-necked Phalarope		X		X	X	X	X					5
Bonaparte's Gull		X							X			2
Mew Gull		X	X	X	X	X	X	X	X			13
Herring Gull									X			1
Glaucous-winged Gull									R			2
Arctic Tern		X		X	X	X		X	X			7
Long-tailed Jaeger						X	X					2
Great-horned Owl												1
American Three-toed Woodpecker												3
Northern Flicker									X			2
Olive-sided Flycatcher								X	X			4
Alder Flycatcher		R										2
Say's Phoebe			X			X						2
Northern Shrike		R										2

Common name	Plot identification number											Number of plots on which species detected:
	15	16[1]	17	18	19	20	21	22	23[1]	24	25	
Gray Jay	X							X	X	X		9
Black-billed Magpie	X	X										11
Common Raven		X	X		X	X	X	X	X			17
Horned Lark		X	X	X	X	X	X	X			X	11
Tree Swallow		R		X					X	X		9
Violet-green Swallow				X					X			3
Bank Swallow		R							R			2
Black-capped Chickadee												3
Boreal Chickadee								X	X	X		6
American Dipper				X								3
Golden-crowned Kinglet												2
Ruby-crowned Kinglet	X				X		X	X	X			10
Northern Wheatear			X			X						2
Gray-cheeked Thrush				X								5
Swainson's Thrush									X	X		3
Hermit Thrush	X		X	X	X	X	X	X		X	X	23
American Robin	X	X	X	X	X	X	X	X	X	X		19
Varied Thrush	X						X	X	X	X		15
American Pipit	X	X	X	X	X	X	X	X	X		X	23
Bohemian Waxwing								X				2
Orange-crowned Warbler	X	X	X	X		X	X		X	X		16
Yellow Warbler		R	X			X				X		9
Yellow-rumped Warbler	X						X	X	X	X		14
Blackpoll Warbler		R							X			3
Northern Waterthrush							X	X		X		5
Wilson's Warbler	X	X	X	X		X	X	X	X	X	X	22
American Tree Sparrow	X	X	X	X	X	X	X	X	X	X	X	15
Savannah Sparrow	X	X	X	X	X	X	X	X	X			16
Fox Sparrow	X		X	X			X	X		X		19
Lincoln's Sparrow									X	X		6
White-crowned Sparrow	X	X		X	X	X	X	X	X	X	X	18
Golden-crowned Sparrow	X	X	X	X	X	X	X	X			X	23

Common name	Plot identification number											Number of plots on which species detected:
	15	16[1]	17	18	19	20	21	22	23[1]	24	25	
Dark-eyed Junco	X				X		X	X	X	X		13
Lapland Longspur		X		X		X		X				6
Snow Bunting			X	X		X					X	7
Rusty Blackbird								X	X			3
Gray-crowned Rosy-Finch	X		X									4
Pine Grosbeak										X		3
White-winged Crossbill								X		X		3
Redpoll Species	X	X	X	X	X	X	X	X	X	X		23
Pine Siskin												1
Total number of species on plot:	26	48	23	42	27	42	32	40	48	21	9	

[1] 'R' refers to species detected only during counts repeated when plots 7, 16, and 23 revisited 9–12 June, 2004.

Appendix 5. Abundance (A), breeding status (BS), and habitat affinity of birds recorded during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Not included in this list are 33 species strongly associated with aquatic habitats (e.g., most waterfowl, loons, grebes, gulls, terns, Osprey, Bald Eagle, American Dipper). Abundance, status, and habitat associations are based on inventory results, and abundance codes refer specifically to the early-spring inventory period. A dash indicates that a species was not detected in that particular park, and species in bold are species of conservation concern (see Table 2).

Abundance Codes

A = Abundant: Species occurs regularly in suitable habitats. Species widely distributed (detected on > 10 study plots per park) or locally abundant (> 35 individuals detected per park during surveys).

C = Common: Species occurs in suitable habitats, but many areas of suitable habitat unoccupied. Species distribution is discontinuous (detected on 6–10 study plots per park) or occurrence is locally common (≥ 20 individuals detected per park during surveys).

U = Uncommon: Species occurs regularly, but utilizes very little of suitable habitat. Species distribution is irregular (detected on ≤ 5 study plots per park) and overall occurrence is low (< 20 individuals detected per park during surveys).

Breeding Status Codes

CB = Confirmed Breeder: Nest discovered during inventory.

B = Breeder: Breeding activity observed during inventory (e.g., territorial display, pair-bond behavior, singing, etc).

P = Probable Breeder: Detected in suitable breeding habitat during inventory.

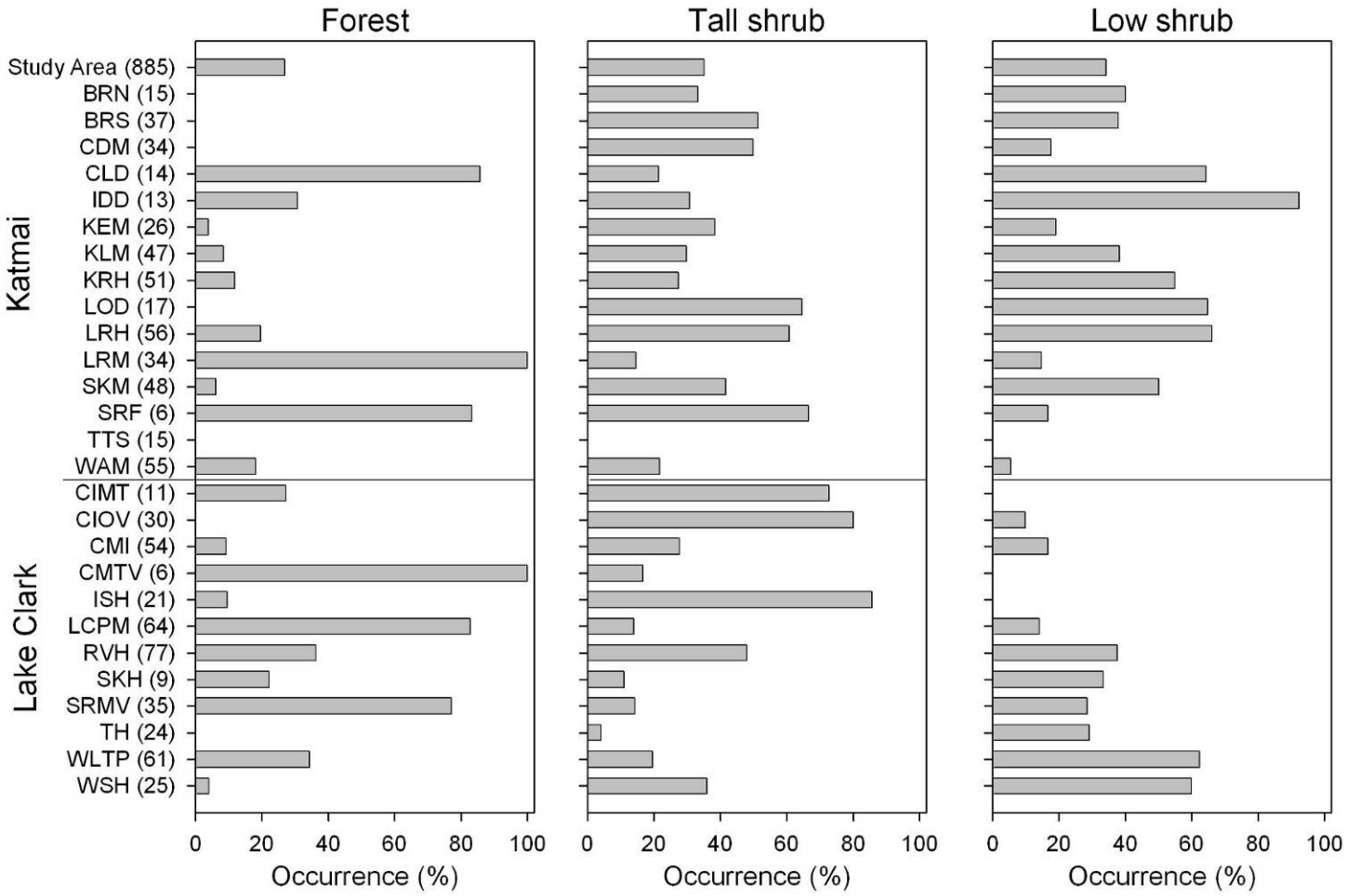
	Katmai		Lake Clark		Habitat[2]					
Common name[1]	A	BS	A	BS	F	TS	LS	DS	BG	H
Trumpeter Swan	-	-	C	B	•					•
Tundra Swan	U	CB	U	P				•		
Spruce Grouse	U	P	U	P	•					
Willow Ptarmigan	A	B	A	B			•			•
Rock Ptarmigan	A	B	A	B				•	•	•
White-tailed Ptarmigan	U	B	C	B				•		•
Northern Harrier	A	B	C	P		•	•	•		
Sharp-shinned Hawk	U	P	U	P	•	•				
Northern Goshawk	-	-	U	P	•					
Rough-legged Hawk	U	P	U	P				•		•
Golden Eagle	C	P	A	P			•	•	•	
Merlin	C	B	C	P			•	•		
Gyrfalcon	U	B	-	-			•	•		
Peregrine Falcon	U	P	U	P				•		•
Sandhill Crane	U	B	U	P			•	•		•
Black-bellied Plover	U	B	-	-				•		•
American Golden-Plover	U	B	C	B				•	•	
Pacific Golden-Plover	U	B	-	-				•		•

Common name[1]	Katmai A	Katmai BS	Lake Clark A	Lake Clark BS	Habitat[2] F	TS	LS	DS	BG	H
Semipalmated Plover	C	B	U	B				•	•	•
Spotted Sandpiper	U	P	C	B	•	•				
Solitary Sandpiper	-	-	U	B	•	•				
Wandering Tattler	U	B	C	B				•	•	
Greater Yellowlegs	A	B	A	CB	•	•	•			
Lesser Yellowlegs	-	-	A	B	•		•			
Whimbrel	C	B	U	B				•		•
Hudsonian Godwit	U	B	-	-			•	•		•
Surfbird	C	B	C	B				•	•	•
Least Sandpiper	C	B	C	B				•		•
Baird's Sandpiper	U	B	U	B				•	•	
Pectoral Sandpiper	-	-	U	P						•
Short-billed Dowitcher	U	P	U	B	•					•
Wilson's Snipe	A	B	A	B	•					•
Red-necked Phalarope	-	-	U	B				•		•
Parasitic Jaeger	U	B	-	-				•		•
Long-tailed Jaeger	-	-	U	P				•		•
Great-horned Owl	U	B	U	B	•					
Short-eared Owl	U	P	-	-				•		•
Downy Woodpecker	U	P	-	-	•	•				
American Three-toed Woodpecker	U	B	U	B	•					
Northern Flicker	-	-	U	P	•	•				
Olive-sided Flycatcher	-	-	U	B	•					
Alder Flycatcher	-	-	U	B		•	•			
Say's Phoebe	-	-	U	CB				•	•	
Northern Shrike	U	P	U	P		•	•	•		
Gray Jay	C	P	C	B	•					
Black-billed Magpie	C	B	A	B			•			
Common Raven	A	B	A	P		•	•	•		•
Horned Lark	A	B	A	B					•	•
Tree Swallow	C	B	C	P	•					
Violet-green Swallow	-	-	U	P	•	•				
Black-capped Chickadee	U	B	U	B		•	•			
Boreal Chickadee	U	B	C	B	•					
Golden-crowned Kinglet	-	-	U	P	•					
Ruby-crowned Kinglet	U	B	A	B	•					
Northern Wheatear	-	-	U	B					•	
Gray-cheeked Thrush	-	-	U	B		•	•			
Swainson's Thrush	-	-	U	B	•					
Hermit Thrush	A	CB	A	B	•	•				
American Robin	A	CB	A	CB	•					
Varied Thrush	C	B	A	B	•					
American Pipit	A	B	A	B				•	•	
Bohemian Waxwing	-	-	U	P	•	•				
Orange-crowned Warbler	A	B	A	B	•	•				
Yellow Warbler	C	B	A	B		•				
Yellow-rumped Warbler	A	B	A	B	•					
Blackpoll Warbler	U	B	U	B	•					
Northern Waterthrush	U	B	U	B	•					

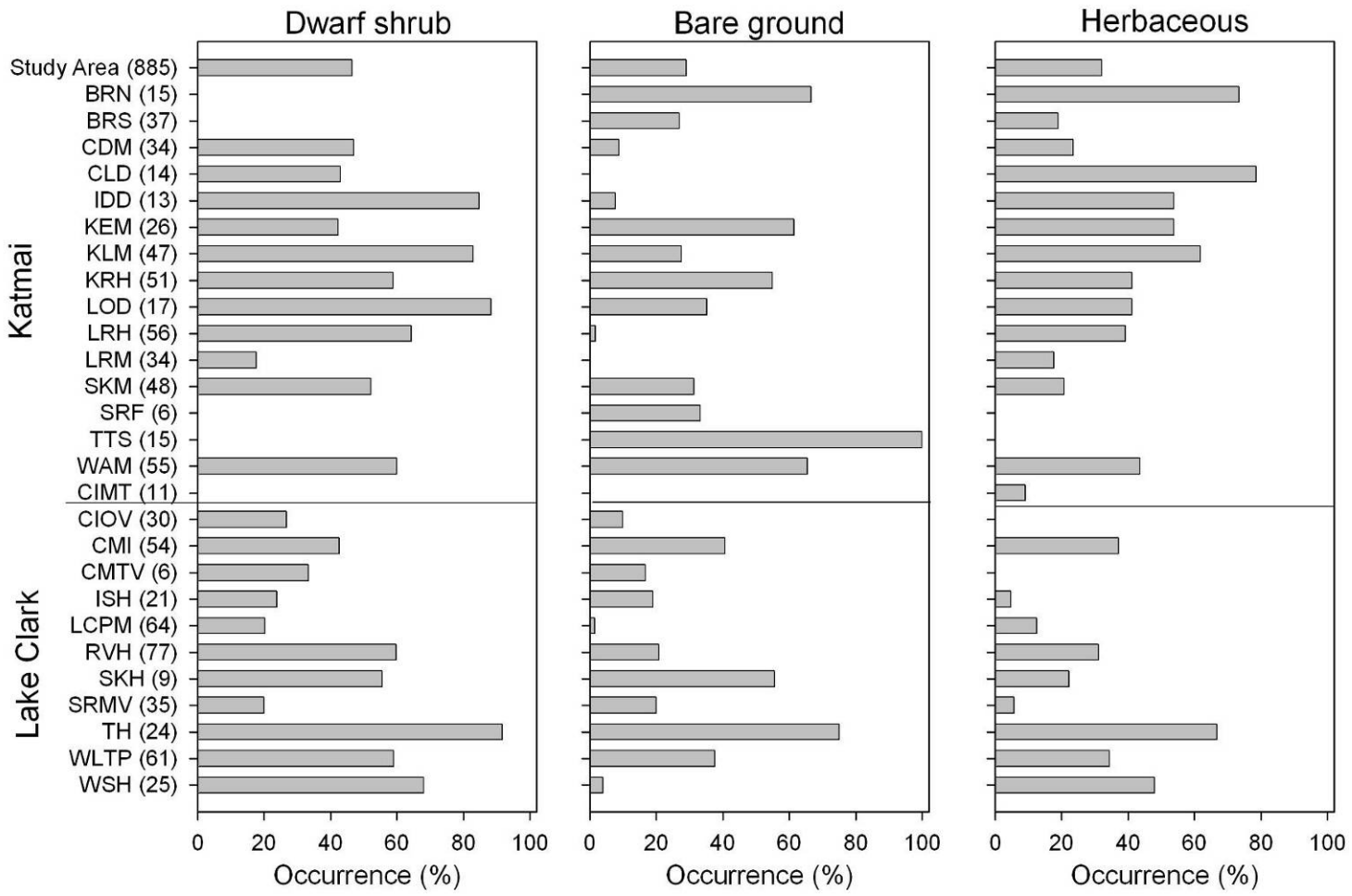
	Katmai		Lake Clark		Habitat[2]					
Common name[1]	A	BS	A	BS	F	TS	LS	DS	BG	H
Wilson's Warbler	A	B	A	B	•	•				
American Tree Sparrow	A	CB	A	B			•	•		•
Savannah Sparrow	A	B	A	CB				•		•
Fox Sparrow	A	CB	A	B		•				
Lincoln's Sparrow	U	B	C	B	•	•				
White-crowned Sparrow	A	B	A	B	•		•			
Golden-crowned Sparrow	A	CB	A	CB		•	•			
Dark-eyed Junco	A	CB	A	CB	•					
Lapland Longspur	U	B	C	B				•		•
Snow Bunting	A	B	C	B					•	
Rusty Blackbird	-	-	U	B	•					
Gray-crowned Rosy-Finch	U	B	U	B					•	
Pine Grosbeak	U	B	U	B	•					
White-winged Crossbill	-	-	U	B	•					
Redpoll Species	A	CB	A	B	•	•				
Pine Siskin	-	-	U	P	•					

[1]See Table 1 for scientific names.

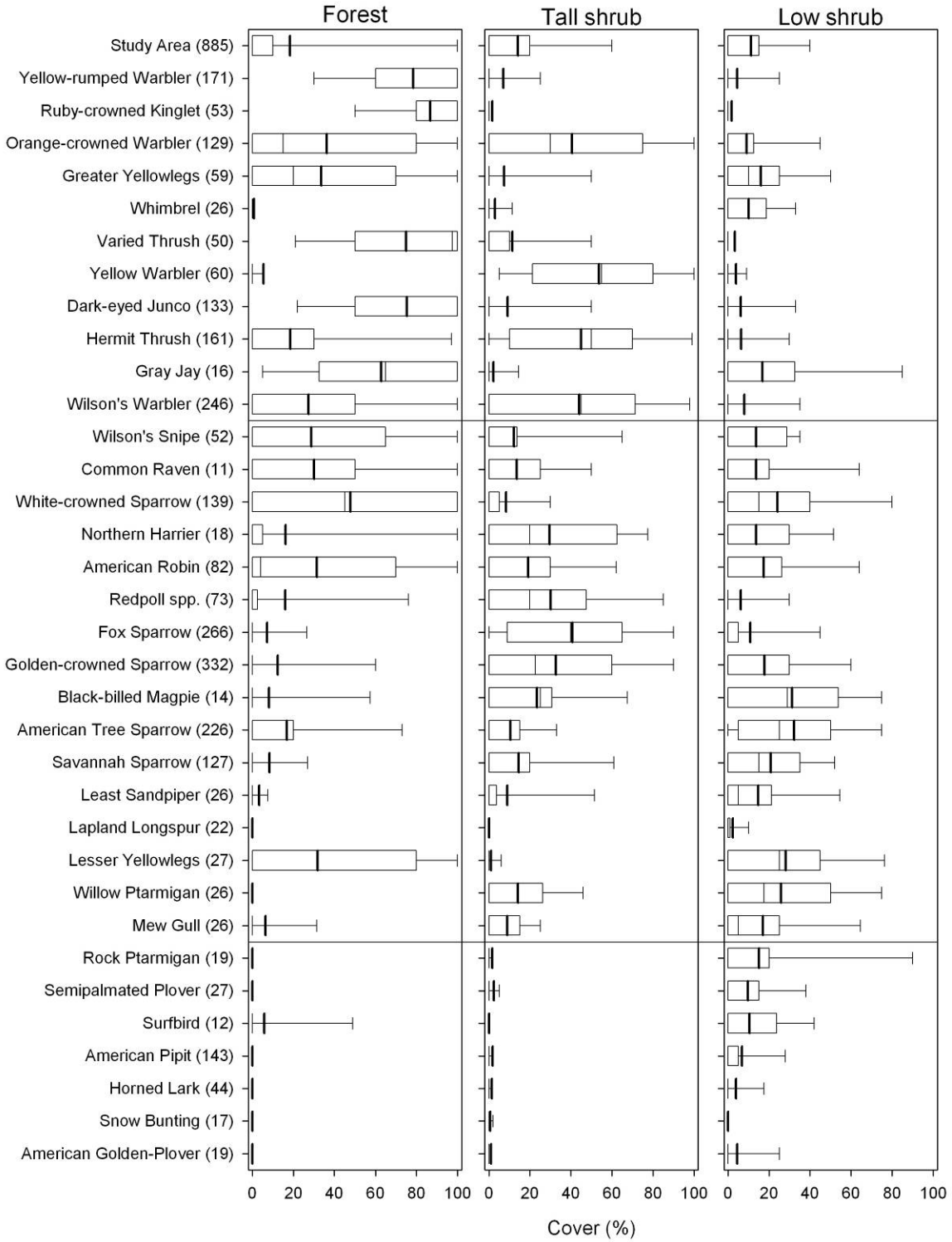
[2]F=Forest, TS=Tall Shrub, LS=Low Shrub, DS=Dwarf Shrub, BG=Bare Ground, H=Herbaceous



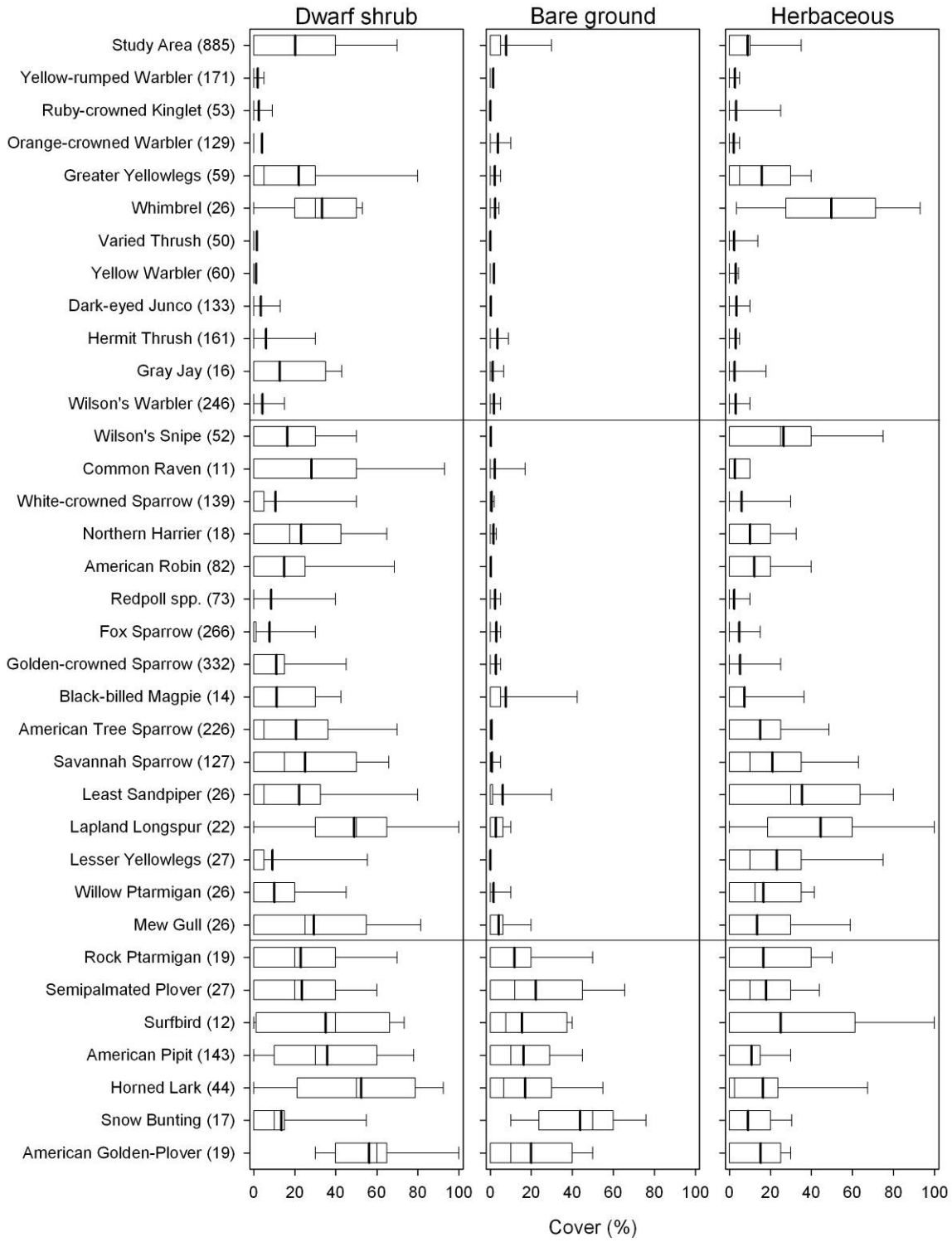
Appendix 6. Percent occurrence of habitats at sample points in ecological subsections during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Number of points surveyed is shown in parentheses for each subsection. See Appendix 1 for key to subsection names.



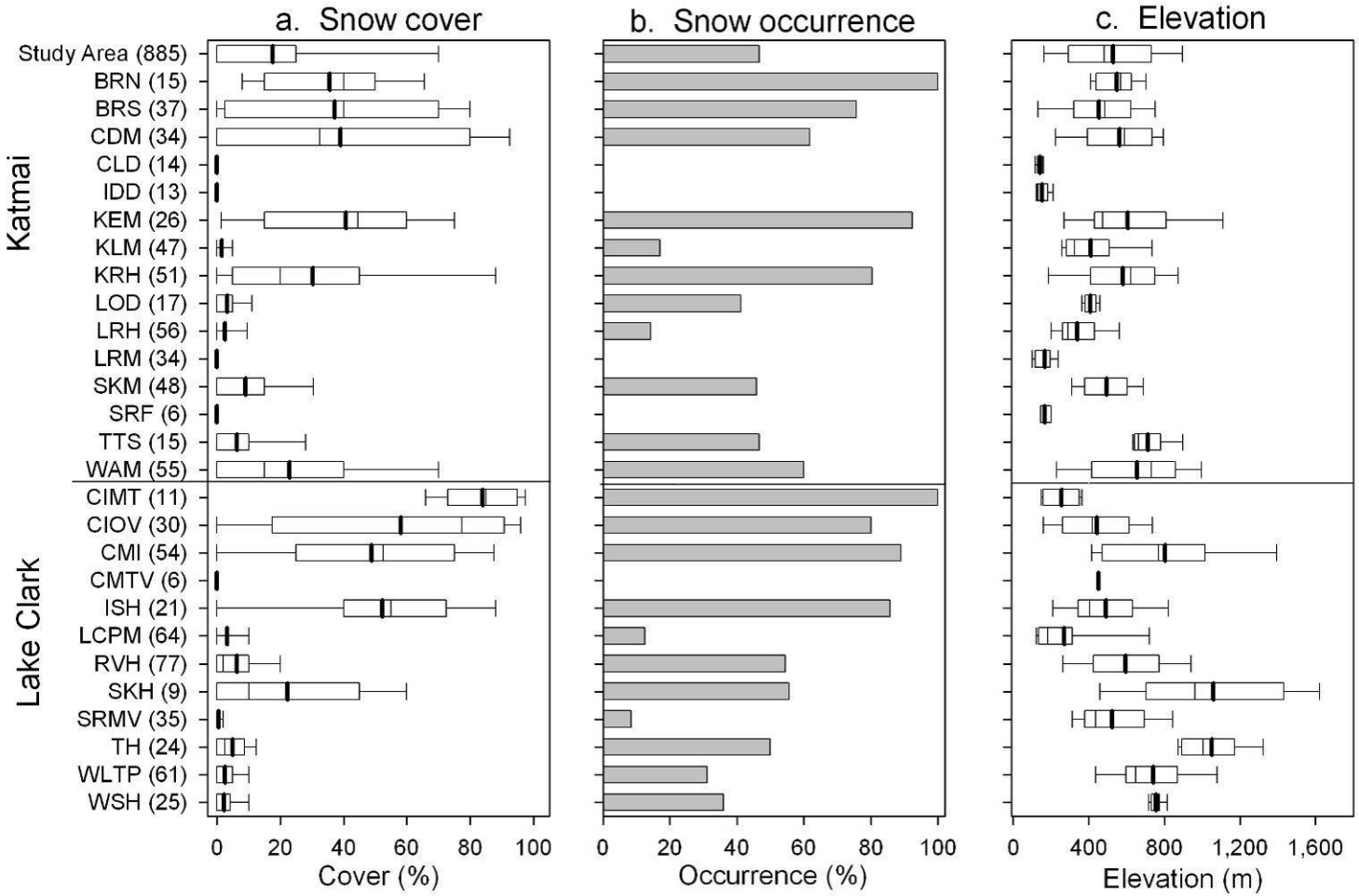
Appendix 6, continued.



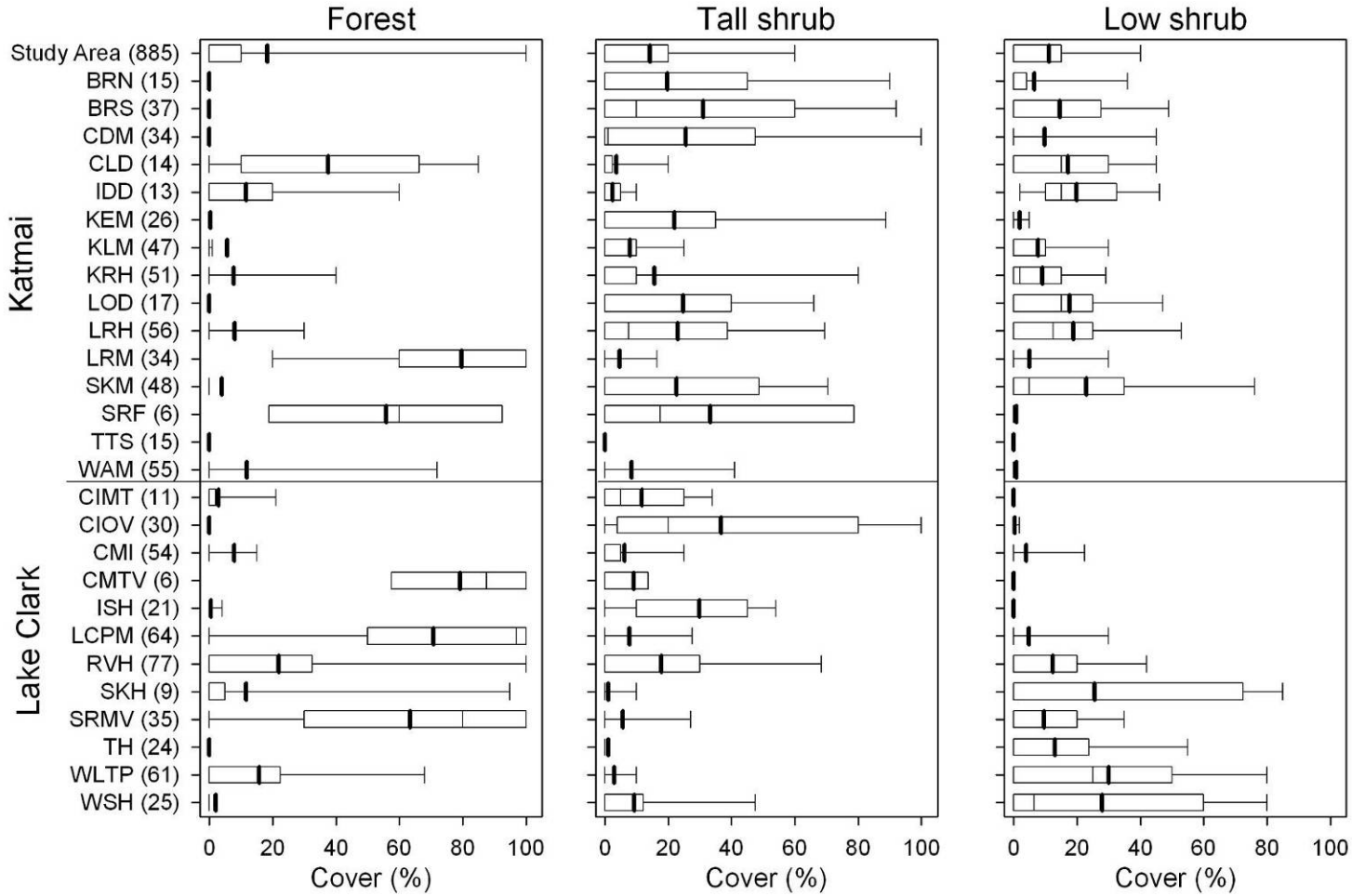
Appendix 7. Percent cover of habitats at sample points during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Box plots show median (thin vertical line), mean (thick vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Number of detections is shown in parentheses for each species. Species ordered from top to bottom based on increasing values of mean elevation at sample points where they were detected (see Figure 5).



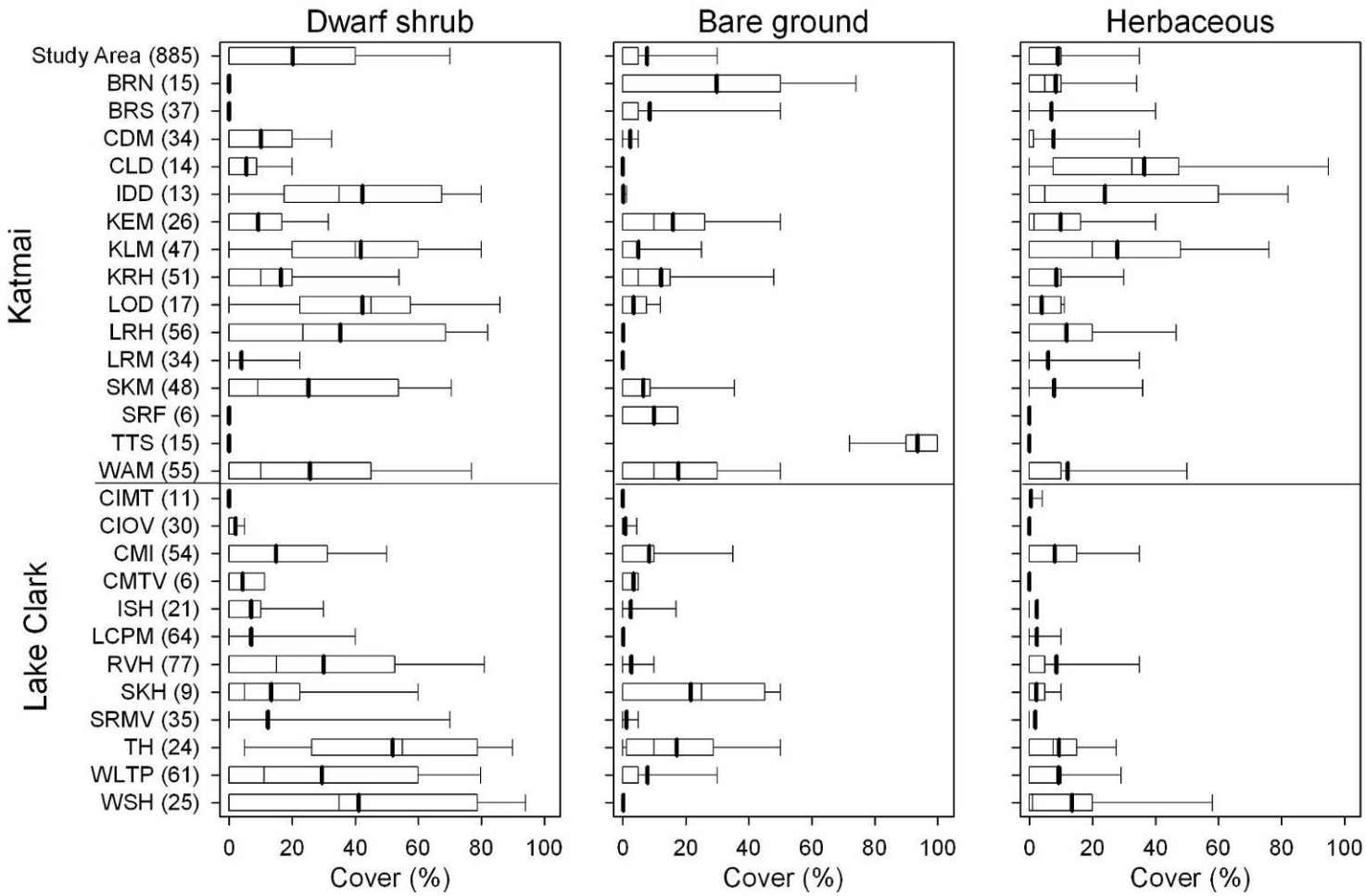
Appendix 7, continued.



Appendix 8. Snow cover, snow occurrence, and elevation of sample points in ecological subsections surveyed during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Box plots (8a, 8c) show median (thin vertical line), mean (thick vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Number of points surveyed is shown in parentheses for each subsection. See Appendix 1 for key to subsection names.



Appendix 9. Percent cover of habitats at sample points in ecological subsections during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006. Box plots show median (thin vertical line), mean (thick vertical line), quartiles (open box), and 10th and 90th percentiles of values (whiskers). Number of points surveyed is shown in parentheses for each subsection. See Appendix 1 for key to subsection names.



Appendix 9, continued.

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Annotated List of Mammals and Amphibians

Mammals and amphibians recorded during the inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves, 2004–2006.

Mammals (class *Mammalia*)[1]

Wolf (*Canis lupis*): We observed one wolf along Soluka Creek in Katmai (plot 2), and observed wolf tracks on seven additional sample plots (three in Katmai, four in Lake Clark).

Red fox (*Vulpes vulpes*): Red fox were observed on four sample plots (7 and 22 in Katmai, 5 and 15 in Lake Clark), and tracks or scat were observed on an additional six sample plots, five of which were in Katmai.

Lynx (*Lynx canadensis*): No adult lynx were encountered, but we discovered one "nest" containing four kittens on the lower slopes of Mt. Griggs in Katmai (plot 9; see photo below).

Wolverine (*Gulo gulo*): Wolverines were seen on three sample plots, all in Katmai (6, 9, 20). In addition to these animals, we observed wolverine tracks in five additional sample plots (three in Katmai, two in Lake Clark).

Black bear (*Ursus americanus*): We encountered black bears only in Lake Clark. We noted this species on five sample plots (4, 5, 7, 17, and 24) across the park.

Brown Bear (*Ursus arctos*): Brown bears were widely distributed across both parks, detected on 44 of 55 sample plots (80%). We observed animals on 18 sample plots, and saw evidence of brown bears (scat, dens, tracks) at an additional 26 plots.

Moose (*Alces alces*): Moose were widely distributed across the region. We saw moose on seven sample plots (four in Katmai, three in Lake Clark), and detected the presence of moose on an additional 30 sample plots.

Caribou (*Rangifer tarandus*): A single caribou was seen on one sample plot in Katmai (5), and we encountered tracks, trails, or scat on 12 other plots. Sites in the Neacola Mountains of Lake Clark were extensively crisscrossed with caribou trails.

Dall Sheep (*Ovis dalli*): Our observation of 4 lambs and 15 ewes in the Portage Lake valley of sample plot 13, Lake Clark, constituted our only sighting of Dall sheep. We detected evidence of sheep in one additional plot in both Katmai and Lake Clark.

Hoary Marmot (*Marmota caligata*): We had two observations of hoary marmots, both at high-elevation sites in Katmai (sample plots 3 and 22).

Arctic Ground Squirrel (*Spermophilus parryii*): Arctic ground squirrels were the most-commonly observed mammal during our work. We detected these animals on 27 sample plots in Katmai (90%), and 21 sample plots in Lake Clark (84%). Observers were especially impressed by the high densities of Arctic ground squirrels at sites throughout Lake Clark.

Red Squirrel (*Tamiasciurus hudsonicus*): We observed red squirrels on three sample plots in Katmai and nine sample plots in Lake Clark. We encountered middens at three additional sites in Katmai and one in Lake Clark.

Beaver (*Castor canadensis*): All visual observations of beaver were restricted to three sample plots in Katmai, but beaver dams and lodges were wide-spread, observed on twenty sample plots spread across both parks.

Voles, Lemmings (family *Muridae*): We were unable to determine the species of the few small rodents we observed. We saw animals or encountered freshly-exposed sub-nivean tunnels of vole or lemming species on nine sample plots in Katmai and six sample plots in Lake Clark.

Porcupine (*Erethizon dorsatum*): We observed porcupines at four sample plots in Katmai and one plot in Lake Clark, and detected their presence on five additional sample plots. One curious observation consisted of a porcupine crossing a snowfield at approximately 1,000 m elevation on the slopes of Mt. Douglas (plot 18).

Collared Pika (*Ochotona collaris*): Pika were detected only at two high-elevation sites, both in Lake Clark (plots 10 and 20).

Snowshoe Hare (*Lepus americanus*): Snowshoe hares were observed on three sample plots in Katmai (6, 8, and 21) and one in Lake Clark (23). Scat or the remains of dead showshoe hares were detected on 11 additional sample plots, all in Katmai.

Tundra Hare (*Lepus othus*): We observed the scat of tundra hares on two sample plots in Katmai (4 and 18) and one sample plot in Lake Clark (20).

Amphibians (class *Amphibia*)[2]

Wood Frogs (*Rana sylvatica*): We observed or heard wood frogs on five sample plots, three in Katmai (24, 29, and 30) and two in Lake Clark (16 and 23).

Four lynx kittens encountered in plot 9, Katmai National Park and Preserve, 26 May 2005.

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[1]Common and scientific names follow Jarrel et al. (2005). See Figures 3 and 4 for plot locations in Katmai and Lake Clark, respectively.
[2]Common and scientific names follow MacDonald (2003). See Figures 3 and 4 for plot locations in Katmai and Lake Clark, respectively.