

U.S. Fish and Wildlife Service

# Wildlife Resources of the Nushagak and Kvichak River Watersheds, Alaska, Final Report

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**Anchorage Fish and Wildlife Field Office  
Anchorage, Alaska  
April 2013**

## **ACKNOWLEDGEMENTS**

This report is the result of the work of many people and all those who contributed are listed in Appendix 1. If we have forgotten to acknowledge anyone we sincerely apologize. Kirsti Sanchez and Greg Aull, who were 2011 summer hires in the Anchorage Fish and Wildlife Field Office (AFWFO), completed much of the initial literature review and prepared initial drafts of some of the species accounts. Colleen Matt, Ken Whitten, Chuck Schwartz, Lowell Suring, and Tom Rothe agreed to assist with the project under small contracts by reviewing and improving species accounts for brown bear, caribou, moose, bald eagle, and waterfowl, respectively. U.S. Fish and Wildlife Service (USFWS) Alaska Peninsula-Becharof National Wildlife Refuge (NWR) Biologist Susan Savage prepared the shorebird species account, and USFWS AFWFO biologist Maureen de Zeeuw prepared the landbird account and the initial draft of the bald eagle account; and they collaborated on the species list. Marcus Geist of The Nature Conservancy provided GIS support including maps, watershed area calculations and land cover information and analysis. Numerous Federal and State agency wildlife biologists generously gave time and effort to review and improve sections of the report. Of special note are United States Geological Survey (USGS) biologist Layne Adams, National Park Service (NPS) biologists Buck Mangipane and Grant Hilderbrand, retired NPS biologist Page Spencer, and USFWS biologists Andy Aderman (Togiak NWR) and Dom Watts (Alaska Peninsula-Becharof NWR) who provided significant reviews, edits, information and insight based on their considerable scientific expertise and knowledge. Heather Dean of the Environmental Protection Agency and Rich Harris of the University of Montana provided thorough and impressive editing of the initial and external review drafts of the report, respectively. Their attention to detail made this a far more consistent, precise, and readable report. Finally, this project would not have been possible without the support and encouragement from Ann Rappoport, long-time AFWFO Field Supervisor, now retired.

This document should be cited as:

Brna, Philip J. and Verbrugge, Lori A. (Eds.) 2013. Wildlife resources of the Nushagak and Kvichak River watersheds, Alaska. Final Report. Anchorage Fish and Wildlife Field Office, U.S. Fish and Wildlife Service, Anchorage Alaska. 177 pp.

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# EXECUTIVE SUMMARY

## ***Background***

At the request of the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS) has prepared this report which summarizes known information related to brown bear (*Ursus arctos*), moose (*Alces alces gigas*), caribou (*Rangifer tarandus*), wolf (*Canis lupus*), waterfowl, bald eagle (*Haliaeetus leucocephalus*), shorebirds, and landbirds in the Bristol Bay region of Alaska, with a focus on the Nushagak and Kvichak watersheds. These species were selected for review because of their importance to ecosystem function, their direct link to salmon, or their importance to local and Alaska residents. EPA is conducting a watershed assessment in the Nushagak and Kvichak watersheds in response to requests from various organizations under the authority of the Clean Water Act, and has requested assistance from the USFWS, as the agency with responsibilities and expertise for the nation's fish and wildlife resources. This report is a small portion of the larger EPA effort which includes evaluation of fish resources of the region, hydrology, and an ecological risk assessment related to potential effects of large scale mineral development on fish, wildlife, water quality, and humans. In addition to being part of the EPA Bristol Bay Watershed Assessment, the information in this report will be useful for Statewide or regional land use planning, completion of environmental documentation for permitting of development projects, or activities related to Landscape Conservation Cooperatives in Alaska. An initial draft of this report was released as an appendix to the first public review draft of the EPA assessment. This final report is being released as a stand-alone USFWS report.

In this report, we describe, to the extent that existing data allow, habitat use, food habits, behavior, interspecies interactions, productivity and survival, populations, subpopulations, genetics, human use and interactions, and management for wildlife with a focus on the Nushagak and Kvichak watersheds. We describe the relationships of these wildlife species (brown bear, moose, caribou, wolf, and bald eagle) or species guilds (waterfowl, shorebirds and landbirds) with salmon. We describe the dependence of wildlife on marine derived nutrients (MDN) transported to these watersheds by salmon, and the role of wildlife in distributing MDN through the ecosystem to the extent this information is available.

About 40 current or retired biologists and scientists from USFWS, National Park Service, Bureau of Land Management, U.S. Geological Survey, U.S. Forest Service, and Alaska Department of Fish and Game were involved with preparation and review of this report. Collectively, these biologists and scientists have significant experience with research and management of wildlife in Alaska and many have extensive experience in the Nushagak and Kvichak watersheds.

## ***The Importance of Marine-Derived Nutrients to Bristol Bay***

One of the most important ecological functions of salmon is to transfer large quantities of nutrients from the marine environment into terrestrial and freshwater ecosystems within the watersheds where adults return to spawn. Marine-derived nutrients (MDN), in combination with other ecosystem features such as suitable spawning habitat and oceanic carrying capacity, are essential for the survival and growth of the next generation of salmon, and also greatly benefit other fish and wildlife species. Herbivores benefit from increased vegetative growth in riparian areas stimulated by MDN, whereas carnivores and scavengers directly consume migrating salmon or their carcasses. In both aquatic and terrestrial ecosystems, MDN are also integrated into the base of food chains, and productivity is enhanced among species at higher trophic levels. It is likely that southwest Alaska and the Nushagak and Kvichak watersheds support large populations of wildlife both because habitat in the region is almost totally intact and because of the presence of millions of salmon annually spawning, rearing, and migrating to the sea and back. In addition to the lack of significant anthropogenic watershed disturbances, the introduction of millions of pounds of MDN from salmon annually makes Bristol Bay relatively unique.

Brown bears within the Nushagak and Kvichak watersheds depend on salmon for food and survival. Accumulation of fat reserves is important for successful hibernation and for female reproductive success. Wolves also consume salmon seasonally when available, and this marine-derived source of food is a major component of the lifetime total diet of wolves in areas where the two species co-exist. Brown bears and wolves play an important role in distributing MDN from streams to the terrestrial environment, both by transporting salmon carcasses prior to consumption and through excretion of wastes rich in salmon nutrients. Both brown bears and wolves have been documented travelling long distances to feed on salmon.

The large influx of nutrients to riverine and terrestrial systems from salmon also benefits waterfowl, both directly as sources of prey and carrion, and indirectly as nutrient drivers of aquatic systems. Of the 24 duck species that regularly occur in Bristol Bay, at least 11 are known to prey on salmon eggs, parr, or smolts, or to scavenge on carcasses. Of these, greater (*Aythya marila*) and lesser (*A. affinis*) scaup, harlequin duck (*Histrionicus histrionicus*), bufflehead (*Bucephala albeola*), common (*B. clangula*), and Barrow's goldeneyes (*B. islandica*), and common (*Mergus merganser*) and red-breasted (*M. serrator*) mergansers exhibit directed foraging on salmon. Mallards feed more on salmon than do other dabbling ducks because they are distributed across a diversity of summer habitats in spawning areas, and they are the principal wintering dabbling duck on the North Pacific coast where fall-winter salmon runs occur. Fish predators, such as mergansers, feed extensively on salmon fry and smolts. Ducks of other species may prey on smolts opportunistically. Salmon eggs are a seasonally rich food source for harlequin ducks, goldeneyes and scaups, species that frequent rivers and streams, and probably for other opportunistic ducks as well. Dabbling ducks (mallard, green-winged teal), diving ducks,

and sea ducks that inhabit spawning waters probably all scavenge easy protein-rich meals from salmon carcasses when opportunity arises.

Spawned-out salmon carcasses provide an ideal food resource for bald eagles. Variation in regional salmon abundance affects bald eagle population size, distribution, breeding, and behavior. In one studied population, annual salmon availability in spring was a strong determinant of whether adult bald eagles laid eggs, and also influenced the timing of egg-laying. As with other salmon consumers, bald eagles affect the ecosystems within their range by distributing MDNs in their excretions.

Direct or indirect interactions between shorebirds and salmon are not well-documented. Some shorebird species are observed to consume dead salmon and salmon eggs. No studies have yet estimated the contribution of salmon to the energetics of shorebird populations; however, the abundance of invertebrates in the intertidal zone is very likely due in part to MDN from salmon that die on the coast and in the rivers feeding Bristol Bay. Shorebirds play a role in introducing MDNs into the terrestrial system, especially during the migratory period, but this has not been quantified. Some of the longest migrations known for birds involve shorebird species (e.g., bar-tailed godwit (*Limosa lapponica*)) that use Bristol Bay intertidal areas in autumn. Such flights are possible not only due to the extreme abundance of intertidal invertebrates (polychaetes, crustaceans, gastropods, and bivalves) in the region, but also because the adjacent uplands are usually rich in fruits of ericaceous plants or tubers that birds such as plovers, whimbrels (*Numenius phaeopus*), and godwits, regularly feed on. Some species (e.g., whimbrel, Hudsonian godwit (*Limosa haemastica*), and black and ruddy turnstones (*Arenaria melanocephala*, *A. interpres*)) feed on herring roe, carrion (including salmon carcasses), and salmon eggs. Many shorebirds make use of freshwater invertebrates; small fish may be consumed by yellowlegs and phalaropes.

Landbirds also benefit from salmon carcasses when available. Aquatic invertebrate larvae feed on salmon carcasses, overwinter in the soil, and emerge in the spring as adults. These invertebrate adults become prey for a variety of landbird species in the spring, and serve as an important seasonal subsidy during a period when terrestrial invertebrate biomass is low. Salmon also benefit landbirds by increasing plant productivity due to MDN inputs, potentially resulting in an abundance of berries and seeds for avian consumption. Some birds, such as the American dipper (*Cinclus mexicanus*), consume salmon eggs, fry, and small bits of carcasses when available.

MDNs carried upstream by spawning salmon have implications for nutrient flow into riparian habitats, and are thought to enhance growth and productivity therein. Although it is plausible that MDNs contribute to increased plant productivity and thus benefit moose and caribou, evidence of this direct link was not located in the scientific literature.

In summary, MDN from salmon cycle throughout the ecosystem of watersheds that have healthy salmon runs, benefitting wildlife, increasing vegetation productivity, and promoting the production of periphyton, aquatic macroinvertebrates, resident freshwater fish, and juvenile salmon. This nutrient cycling depends on interactions with terrestrial wildlife species, that distribute MDN throughout the terrestrial environment both by transporting salmon carcasses and excreting of feces and urine. The loss of either salmon or key wildlife species may result in significant changes to the productivity, diversity and physical structure of the ecosystem, via mechanisms that extend beyond simple “food chain” interactions.

# CONTENTS

ACKNOWLEDGEMENTS .....	i
EXECUTIVE SUMMARY .....	ii
Background .....	ii
The Importance of Marine-Derived Nutrients to Bristol Bay .....	iii
LIST of FIGURES .....	x
LIST of TABLES.....	x
INTRODUCTION .....	1
METHODOLOGY .....	3
Geographic Scope of USFWS Evaluation .....	3
Selection of Wildlife Species for Characterization.....	4
The Characterization Process.....	5
CHARACTERIZATION OF WILDLIFE .....	6
Overview.....	6
Alaska- .....	6
Southwest Alaska Region- .....	6
The Importance of Marine-Derived Nutrients to Bristol Bay Watershed Ecosystems .....	7
Overview of Land Cover and Habitat Types .....	10
BROWN BEARS.....	13
Introduction.....	13
Habitat.....	13
Food Habits.....	14
Behavior.....	15
Interspecies Interactions.....	17
Mortality, Productivity, and Survivorship .....	18
Population .....	20
Human Use/Interaction/Management .....	21
Sport Hunting for Brown Bears .....	21
Game Management Unit 9-.....	21
Game Management Unit 17-.....	22
Subsistence Hunting for Brown Bears-.....	22
Bear Viewing-.....	23
Other Bear-Human Interactions .....	23

Local Residents and Bear-Human Conflicts-.....	23
Other Recreational Users and Bear-Human Conflicts- .....	23
<b>MOOSE</b> .....	25
Introduction.....	25
Habitat.....	25
Winter Habitat- .....	28
Food Habits.....	29
Behavior.....	32
Movements and Home Ranges- .....	32
Sexual Segregation and Grouping Behaviors- .....	35
Mating and Maternal Behaviors- .....	36
Activity Budgets- .....	38
Interspecies Interactions.....	39
Mortality, Productivity, and Survivorship .....	41
Population, Subpopulations, and Genetics.....	44
Human Use (Subsistence, Recreation)/Interaction/Management) .....	45
<b>BARREN GROUND CARIBOU</b> .....	48
Introduction.....	48
Population History of Caribou in the Upper Bristol Bay Region .....	48
Habitat.....	49
Seasonal Preference- .....	49
Food Habits.....	50
Spring-.....	50
Summer-.....	50
Fall- .....	50
Winter- .....	50
Behavior.....	50
Seasonal Range Use and Migrations- .....	50
Response to Disturbance-.....	52
Interspecies Interactions.....	52
Mortality, Productivity, Survivorship .....	53
Mortality- .....	53
Breeding-.....	53

Human Use/Interaction/Management .....	53
WOLF .....	56
Introduction.....	56
Habitat.....	56
Food Habits.....	57
Diet- .....	57
Salmon as a Food Source.....	58
Dispersal of Marine-Derived Nutrients (MDNs) by Wolves-.....	59
Behavior.....	59
Wolf Packs-.....	59
Range-.....	60
Dispersal (Emigration)-.....	61
Seasonal Movements- .....	61
Interspecies Interactions; Response to Change in Salmon Populations/ Distribution .....	62
Mortality, Productivity, and Survivorship .....	63
Population Estimates.....	65
Human Use/Interaction/Management .....	66
WATERFOWL.....	68
Introduction.....	68
Regional Overview- .....	68
History of Waterfowl Surveys- .....	69
Waterfowl Resources and Seasonal Occurrence.....	71
Estuaries and Inner Bristol Bay- .....	71
Bristol Bay Lowlands- .....	75
Inland Tundra/Taiga- .....	79
Nutrients, Trophic Relations and Foods .....	80
Nutrients and Habitat Productivity- .....	80
Food Habits-.....	81
Importance of Marine-Derived Nutrients (Salmon and Herring) to Waterfowl- .....	84
Populations, Subpopulations, and Genetics .....	86
Swans-.....	86
Geese- .....	86
Dabbling and Diving Ducks- .....	87

Sea Ducks- .....	87
Human Use.....	88
Nonconsumptive Uses- .....	88
Recreational Harvest-.....	88
Subsistence Harvest- .....	89
BALD EAGLES .....	92
Introduction.....	92
Habitat.....	92
Food Habits.....	94
Diet- .....	94
Significance of MDNs- .....	96
Foraging Methods-.....	96
Behavior.....	97
Territoriality-.....	97
Flocking- .....	98
Migration and Local Movements-.....	98
Interspecies Interactions.....	99
Breeding, Productivity, Survival, and Mortality .....	99
Breeding-.....	99
Productivity and Survival- .....	100
Mortality- .....	101
Population, Distribution, and Abundance .....	103
Human Use.....	105
SHOREBIRDS.....	106
Introduction.....	106
Habitat.....	109
Food Habits.....	111
Behavior (Movements) .....	111
Interspecies Interactions.....	113
Breeding, Productivity, and Survivorship.....	114
Population, Subpopulations, and Genetics.....	116
Human Use and Threats.....	116
LANDBIRDS.....	118

Introduction.....	118
Habitat.....	118
Species Diversity .....	119
Food Habits.....	120
Interspecies Interactions.....	120
APPENDIX A: LIST OF AUTHORS AND REVIEWERS .....	122
APPENDIX B: SOUTHWEST ALASKA TERRESTRIAL VERTEBRATE SPECIES.....	124
APPENDIX C: LITERATURE CITED.....	133

## LIST of FIGURES

Figure 1. Nushagak and Kvichak River watersheds and inner Bristol Bay.....	2
Figure 2. National Land Cover Dataset, land cover types for the Nushagak River watershed and Kvichak River watershed.....	11
Figure 3. Nushagak and Kvichak River watersheds and associated Alaska Department of Fish and Game, game management units. ....	22

## LIST of TABLES

Table 1. Size of sub-basins (sq. mi.) within the Nushagak and Kvichak River watersheds and percent of watershed or sub-basin within each National Land Cover Database land cover type.	12
Table 2. Mean (range) home range size (km <sup>2</sup> ) for selected moose populations in Alaska.....	35
Table 3. Moose activity budgets in winter <sup>1</sup> and spring/summer <sup>2</sup> in Denali National Park and Preserve (averages) .....	38
Table 4. Subsistence statistics for moose harvest in GMUs 9B, 17B, and 17C. ....	47
Table 5. Estimated population size and harvest of the Mulchatna caribou herd, 1991-2008. ....	54
Table 6. Average territory sizes (km <sup>2</sup> ) of wolf packs in Alaska*.....	61
Table 7. Wolf harvests in GMUs 9, 10 and 17 reported to Alaska Dept. of Fish and Game. ....	67
Table 8. Average abundance indices and densities of species/groups recorded in late May on the Alaska Yukon Waterfowl Breeding Population Survey, Bristol Bay Lowlands (Stratum 8).....	76
Table 9. General food habits and consumption of fish by duck species of Bristol Bay. ....	82
Table 10. Reported survival of bald eagle nestlings in Alaska.....	102
Table 11. Summary of surveys for bald eagle nests in the Bristol Bay study area.....	104
Table 12. Shorebirds found in the Bristol Bay Watershed. ....	108

## INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is conducting a watershed assessment in the Nushagak and Kvichak River watersheds of Bristol Bay, Alaska in response to requests from nine Tribal Governments and other interests. The tribes have requested that EPA take action to protect the Bristol Bay watershed from the adverse impacts of potential large-scale hard rock mining projects using EPA's statutory authority, including Section 404(c) of the Clean Water Act (CWA). Section 404(c) allows EPA to prohibit or restrict discharges of dredged or fill material into waters of the United States, including wetlands, when it determines that such discharges would have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas. EPA has also received requests from two tribes and other interests to refrain from taking advance action and to wait for specific permit applications for mining projects to be reviewed by the U.S. Army Corps of Engineers (Corps) pursuant to Section 404 of the CWA and the National Environmental Policy Act (NEPA). EPA is conducting the Bristol Bay Watershed Assessment (BBWA) under its Clean Water Act Section 104(a) authority, which directs them to: *"...conduct and promote the coordination and acceleration of, research, investigations, experiments, training, demonstrations, surveys, and studies relating to the causes, effects, extent, prevention, reduction, and elimination of pollution."*

EPA has requested that the U.S. Fish and Wildlife Service (USFWS) provide assistance in conducting the BBWA. The mission of the USFWS is to work with others to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. The USFWS works to protect a healthy environment for people, fish and wildlife, and helps Americans conserve and enjoy the outdoors and our living treasures. The USFWS has responsibility for fish and wildlife resources, with specific emphasis on migratory birds, endangered plants and animals, certain marine mammals, and freshwater and anadromous fish. USFWS expects that this report will be useful to EPA in completing the BBWA, but it should also provide a comprehensive summary of wildlife information for others interested in southwest Alaska. These uses might include: completion of environmental documentation for oil and gas leasing or any development project; activities related to the Western Alaska Landscape Conservation Cooperative; activities of the Southwest Alaska Salmon Habitat Partnership; or any land use planning effort. An initial draft of this report was released as an appendix to the first public review draft of the EPA assessment. This final report is being released as a stand-alone USFWS report.

The Bristol Bay watershed is comprised of six major drainages: the Togiak, Nushagak, Kvichak River, Naknek, Egegik, and Ugashik Rivers. The Kvichak and Nushagak River watersheds are the principal Bristol Bay drainages that have lands open to large-scale development. Much of the rest of the region is within National Parks or National Wildlife Refuges, and is protected from such

development. EPA's analysis therefore, focuses on the Nushagak and Kvichak watersheds (Figure 1).

The objectives of the BBWA process are to build a common understanding of the fish and wildlife resources of Bristol Bay and of the potential impacts to those resources from large-scale development, and to identify possible options for protecting these resources. The assessment represents is an integration of several types of evaluations. The first component is an assessment of the resources themselves, also called a characterization by EPA, that synthesizes current conditions within the Nushagak and Kvichak watersheds and compares these resources to other regional or reference areas. Its focus is determining if the resources in question-- the wildlife of the Nushagak and Kvichak watersheds, represent an exceptional resource that might be worthy of special protection. For exceptional resources, the characterization identifies the environmental factors contributing to the extraordinary nature of the resource, i.e., what must be protected to retain exceptional status. The second component of the evaluation is a predictive risk assessment, devoted to estimating the effects of reasonably foreseeable large-scale development in the area on wildlife. It is organized on the established EPA frameworks for ecological and cumulative risk assessments. Both the potential development scenarios and the results of the predictive risk assessment include inherent uncertainties and cumulative risks.

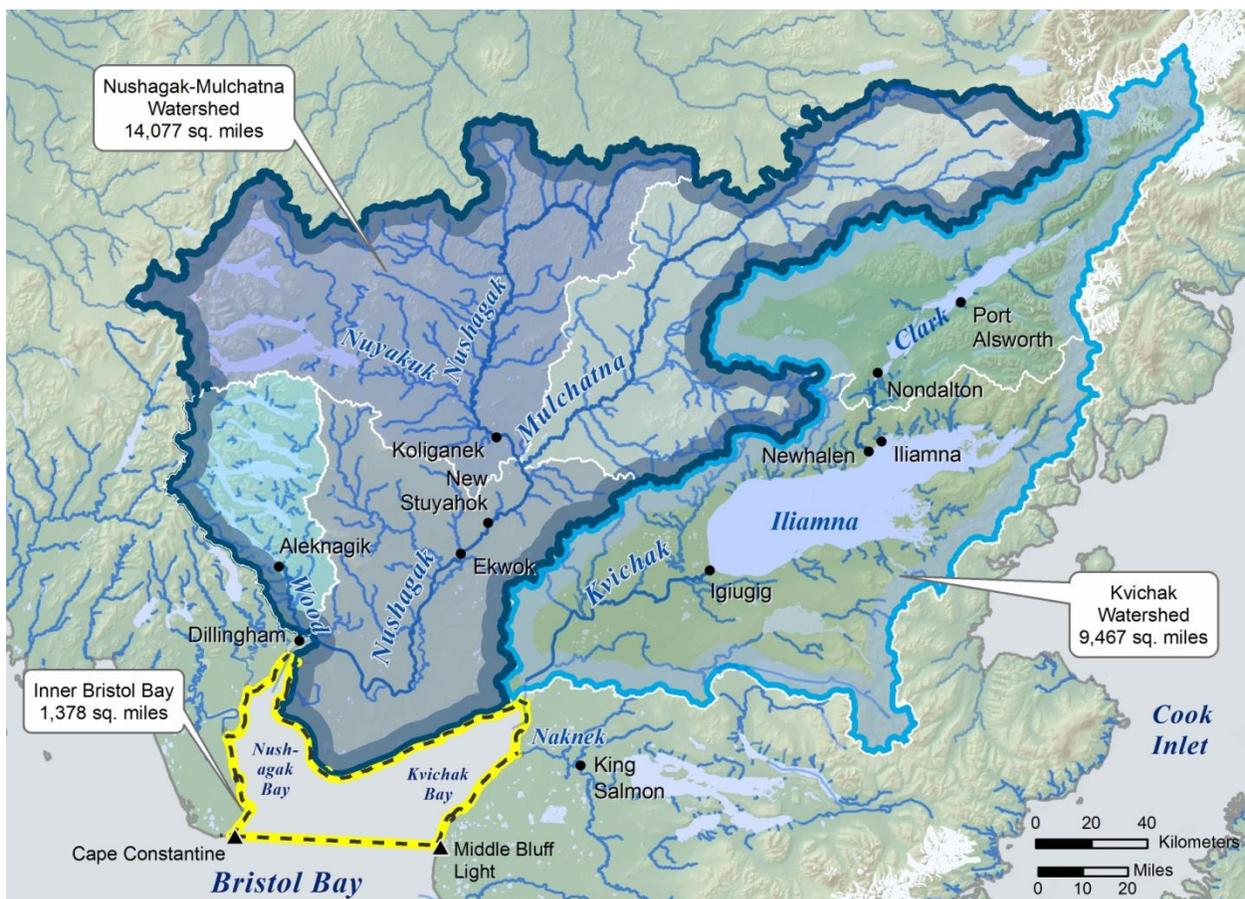


Figure 1. Nushagak and Kvichak River watersheds and inner Bristol Bay.

## **METHODOLOGY**

There are two phases of the EPA BBWA: characterization and predictive risk assessment. Characterization consists of a review and documentation of relevant literature, as well as interviews with knowledgeable agency staff and other experts on the ecological and economic significance of the fish and wildlife resources in the Nushagak and Kvichak watersheds. Characterization describes the level of current scientific knowledge of Bristol Bay's fish and wildlife resources and determines the ecological and economic significance of Bristol Bay fish and wildlife resources locally and around the North Pacific Ocean.

Predictive risk assessment is the review and documentation of relevant literature, as well as interviews with knowledgeable agency staff and other experts on the risks, threats, and stressors associated with current and foreseeable human activity on the health, productivity, ecological integrity, and long-term sustainability of fish and wildlife resources of Bristol Bay. It includes review and documentation of mitigation practices used to abate threats and risks to fish and wildlife resources.

Based on the scope of the BBWA, USFWS has formulated three objectives for this report:

1. Describe significant, representative wildlife species in Bristol Bay and their importance to humans;
2. Describe the importance of marine derived nutrients to these wildlife species; and
3. Describe the role of these wildlife species in distributing marine derived nutrients throughout the ecosystem.

This report does not describe potential impacts of large-scale development, such as mining, on wildlife.

### ***Geographic Scope of USFWS Evaluation***

The primary geographic scope of the BBWA, and therefore this report, is the Nushagak and Kvichak watersheds. In addition to terrestrial mammals, the USFWS is characterizing migratory birds, many of which use marine waters during some portion of the year. Therefore, we needed to determine the extent of freshwater influence from these river systems in the Bristol Bay marine environment. Data on the hydrography of the Bay are limited; however, an evaluation based on salinity differences, drift cards, and fluorescent dye (Straty, 1977), indicates that the net seaward flow of lighter and less saline river runoff water from the Kvichak River, and the adjacent Naknek River to the south, moves in a counterclockwise direction along the northwest side of inner Bristol Bay, where it mixes with water from the Nushagak River. Data indicate that the mixture of Kvichak and Naknek River water remains detectable as far as Cape Constantine. On the southeast side of the bay, there is more uncertainty. However, water from the Egegik River does not appear to travel much further north than Middle Bluff Light. North of Middle Bluff Light, freshwater immediately along the shoreline is probably mostly from the Naknek River, but by around 8 km off shore, waters from the Naknek and Kvichak Rivers become mixed. Therefore, to facilitate

evaluation of migratory birds in marine waters, we define the area of freshwater influence as the area north of a line drawn from Cape Constantine east to Middle Bluff Light. We call this area Inner Bristol Bay for purposes of this report. This area is marked with the yellow dashed line on Figure 1.

### ***Selection of Wildlife Species for Characterization***

EPA asked USFWS for assistance in evaluating wildlife species that can be directly linked to salmon, due either to their direct dependence on salmon for survival (food), or to their role in distributing marine derived nutrients throughout freshwater aquatic or terrestrial ecosystems. The large number of species in the Nushagak and Kvichak watersheds made it impractical to characterize every species. Additionally, staff resources available to the USFWS and time constraints imposed by the EPA BBWA prevented collection of new wildlife data; thus our analysis is based primarily on existing data.

The first step was to identify a subset of wildlife species that represented major components of biodiversity in the region. Initially, the USFWS decided to use portions of an approach developed by The Nature Conservancy for ecoregional planning (Groves et al., 2000). This process was modified for use by the Mat-Su Salmon Habitat Partnership to develop a Strategic Habitat Action Plan, and also by The Nature Conservancy in preparing the Alaska Peninsula and Bristol Bay Basin Ecoregional Assessment (The Nature Conservancy in Alaska, 2004). A simplified version was also used by the Southwest Alaska Salmon Habitat Partnership to develop a Strategic Habitat Conservation Action Plan. The USFWS is a member of both fish habitat partnerships, and USFWS biologists were also involved with the Ecoregional Assessment, so were familiar with ecoregional planning concepts.

As described by Groves et al. (2000), ecoregional planning is a complex, step-by-step approach with the goal of selecting and designing networks of areas of high biodiversity significance (conservation sites) that will conserve the diversity of species, communities, and ecological systems in an ecoregion. Since this differed from our objectives, we used selected portions of the approach to help identify wildlife species targets. Using individual species-level targets facilitates identification of threats and development of strategies and actions to abate those threats.

We selected key wildlife species based largely on professional judgment, as well as consultation with EPA and members of the BBWA Intergovernmental Technical Team. Key species either regulate energy flow and nutrient dynamics, or they are ecosystem engineers that modulate habitat structure (Davic, 2003). We defined key species as those that we know, have a direct link to salmon, or are of special interest to local or Alaska residents. Additionally, migratory birds and bald eagles were considered key species because the USFWS has direct statutory authority for them under the Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act.

The term “key species”, as we use it, should not be confused with the term “keystone species” which are those (e.g., beaver (*Castor canadensis*), bison (*Bison bison*), prairie dog (*Cynomys* spp.)), whose impact on a community or ecological system is disproportionately large given their abundance and biomass (Paine, 1995). Keystone species have spatial, compositional and functional requirements that may encompass those of other species in the region and they may play a critical role in maintaining the structure of an ecological community. They affect other organisms within the ecosystem and partly determine the types and number of other species in the community. Their removal may initiate changes in ecosystem structure and lead to a loss of diversity. Keystone species may also be wide-ranging and depend on vast areas for survival. These species include top-level predators as well as migratory mammals, anadromous fish and birds (The Nature Conservancy in Alaska, 2004). Keystone species may regulate local species diversity in lower trophic levels (Davic, 2003).

The key species we selected for inclusion in our evaluation are :

- brown bear;
- moose;
- barren ground caribou;
- wolf;
- waterfowl (as a guild);
- bald eagle;
- shorebirds (as a guild); and
- landbirds (as a guild).

We also considered including species listed under the Endangered Species Act and seabirds, but a preliminary assessment revealed there were no known breeding or otherwise significant occurrences of either species listed as threatened or endangered, or significant assemblages of seabirds in the Nushagak and Kvichak watersheds or Inner Bristol Bay.

### ***The Characterization Process***

Staff from the Anchorage Fish and Wildlife Field Office (AFWFO) prepared initial drafts of all but two of the species accounts. The waterfowl species account was developed by a contractor, and the shorebird account was drafted by a USFWS National Wildlife Refuge biologist. Species accounts were based on a suggested outline provided by AFWFO. We circulated for review and comment initial draft species accounts to numerous experts from the USFWS, other federal and State agencies, and other knowledgeable individuals, many of whom are retired federal or State wildlife biologists. The USFWS then obtained assistance from expert wildlife biologists to revise the draft species accounts on brown bear, caribou, moose, and bald eagles. Finally, we circulated the revised draft species accounts for review and comment. A list of authors and reviewers for each species account is provided in Appendix 1. All completed species accounts are incorporated in this report.

Species accounts were largely developed using available published information, but in some instances we used unpublished information from species experts. Our preference was to use data specific to the Nushagak and Kvichak watersheds. However, we also used relevant information from other regions of Alaska or other parts North America.

## **CHARACTERIZATION OF WILDLIFE**

### ***Overview***

***Alaska-*** Many Alaskans depend on the State's diverse wildlife resources<sup>1</sup> for food and enjoyment. Traditional subsistence harvest and personal use, sport and guided hunting, as well as nonconsumptive uses, such as wildlife viewing, are all critical components of the Alaska economy and lifestyle (ADFG, 2006). According to the Alaska Department of Fish and Game (ADFG), the value of game species such as moose, caribou, and deer are well understood by most Alaskans (ADFG, 2006). Historically, species not taken for subsistence, sport, or commercial use, were perceived as having little direct economic value. However, the contribution of nongame species to Alaska's economy is substantial, although difficult to quantify. According to ADFG, basic biological information on life history, population levels, and other parameters is lacking for many species, but the majority of Alaska's wildlife resources are considered healthy.

***Southwest Alaska Region-*** Southwest Alaska, including the Nushagak and Kvichak watersheds, possesses intact, naturally functioning terrestrial ecosystems that still support naturally occurring species, including large carnivores. Such ecosystems, with undiminished biodiversity, are becoming extremely rare globally. Interactions among large terrestrial herbivores and their predators are an intrinsic property of intact functioning ecosystems and are a flagship ecological feature of southwest Alaska (Bennett et al., 2006; Jarrell et al., 2004; Nushagak-Mulchatna Watershed Council, 2007).

Based on a compilation of vertebrate species lists for Togiak National Wildlife Refuge (NWR) (USFWS, 2009b), Alaska Peninsula and Becharof NWR Bird List (USFWS, 2010b), and southwest Alaska national parks (Cook and MacDonald, 2005), Southwest Alaska supports 192 species of birds and 41 species of terrestrial mammals (Appendix 2). There is no comprehensive species list available for the Nushagak and Kvichak watersheds, but it is reasonable to assume that species in these watersheds are nearly identical to those in the larger region.

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<sup>1</sup> ADFG includes fish, reptiles, amphibians, and marine mammals (including whales) in the definition of wildlife in the Comprehensive Wildlife Strategy. Of the 1,073 vertebrate species known to occur in Alaska, there are 469 species of birds and 64 species of terrestrial mammals (ADFG 2006; Jarrell et al 2004).

Of all the species described in this report, caribou, moose and waterfowl are probably the most important to local residents for subsistence use. These also provide significant recreational hunting opportunities for both nonlocal resident and nonresident hunters. Other species which provide subsistence food for local residents include black bear (*Ursus americanus*), beaver, ptarmigan (*Lagopus* spp.), and porcupine (*Erethizon dorsatum*). River otter (*Lontra canadensis*), red fox (*Vulpes vulpes*), marten (*Martes americana*), and wolverine (*Gulo gulo*) are also important in the region. We have not identified any of these other wildlife species as key species for purposes of this report.

### ***The Importance of Marine-Derived Nutrients to Bristol Bay Watershed Ecosystems***

One of the most important ecological functions of salmon is to transfer large quantities of nutrients from the marine environment into terrestrial and inland aquatic ecosystems where adults return to spawn. Pacific salmon spend most of their lives feeding and growing at sea before returning to spawn and die in natal streams or lakes, and approximately 95 to 99% of the carbon, nitrogen, and phosphorus in an adult salmon's body is derived from the marine environment (Larkin and Slaney, 1997; Schindler et al., 2005). For oligotrophic Lake Iliamna, the annual nitrogen pool associated with the annual spawning migration is similar in volume to the dissolved nitrogen pool in the lake, indicating the importance of adult salmon to the lake's nitrogen budget (Kline et al., 1993). MDN, in combination with other ecosystem features such as availability of suitable spawning habitat and oceanic carrying capacity (Schindler et al., 2005), are essential for the survival and growth of the next generation of salmon, and also greatly benefit a number of other fish and wildlife species.

For brown bears within the Nushagak and Kvichak watersheds, the annual salmon runs provide an excellent source of lipids. In several Alaskan brown bear populations, lipids obtained through the consumption of salmon contributed approximately 80% of the mass gained by bears prior to winter hibernation (Hilderbrand et al., 1999c). Accumulation of fat reserves is important for successful hibernation and for female reproduction (Farley and Robbins, 1995; Hilderbrand et al., 1999c).

Wolves also consume salmon seasonally when available, and this can be a major component of the lifetime total diet of wolves in areas where the two species co-exist (Adams et al., 2010; Darimont et al., 2003; Szepanski et al., 1999). Salmon consumption is not limited to wolves living in coastal areas; some Pacific salmon spawning grounds are hundreds of miles inland. A study in Interior Alaska documented seasonal salmon consumption among wolves who lived more than 1,200 river miles (1,931 km) from the coast (Adams et al., 2010).

Both brown bears and wolves play an important role in distributing MDN from streams to the terrestrial environment, both by transporting salmon carcasses prior to consumption and through excretion of wastes rich in salmon nutrients (Darimont et al., 2003; Helfield and Naiman, 2006; Holtgrieve, 2009).

We found no research on MDN links involving salmon and moose or caribou. We believe that, although MDN transported to the Nushagak and Kvichak watersheds by salmon may be detectable in tissues of these species, especially those feeding in riparian areas (e.g. moose), this does not necessarily imply a nutritional benefit. A direct benefit to these herbivores would require that salmon have a strong fertilizing effect on vegetation, which in turn produces additional forage and, herbivores would also have to be forage limited (L. Adams (USGS), pers. comm., 1/4/12). However, anecdotal reports of both deer and moose feeding directly on salmon carcasses have been documented (G. Hilderbrand (NPS), pers. comm., (1/4/12).

For waterfowl, salmon function both as sources of prey and carrion, as well as transporters of nutrients into aquatic systems. The large influx of nutrients to riverine and terrestrial systems strongly benefits waterfowl (Holtgrieve, 2009; Willson et al., 1998; Willson and Halupka, 1995). Of the 24 duck species that regularly occur in Bristol Bay, at least eleven are known to prey on salmon eggs, parr, and smolts, or to scavenge on carcasses (Table 9). Of these, greater and lesser scaups, harlequin ducks, buffleheads, common and Barrow's goldeneyes, and common and red-breasted mergansers forage directly on salmon. Among dabbling ducks, mallards feed the most on salmon because they are distributed across a diversity of summer habitats in spawning areas, and because they are the principal wintering dabbling duck on the North Pacific coast where fall or winter salmon runs occur. Fish predators like mergansers feed extensively on salmon fry and smolts (Munro and Clemens, 1932; Munro and Clemens, 1937; Munro and Clemens, 1939; Salyer and Lagler, 1940; White, 1957; Wood, 1987a). Other duck species may prey on smolts incidentally. Salmon eggs are a seasonally rich food source for harlequin ducks, goldeneyes, and scaup that frequent rivers and streams (Cottam, 1939; Dzinbal and Jarvis, 1984; Munro, 1923) and probably opportunistically for other ducks. Species including dabbling ducks (e.g. mallards, green-winged teals), diving ducks, and sea ducks that inhabit spawning waters probably opportunistically scavenge salmon carcasses to obtain protein-rich meals.

Spawned-out salmon carcasses which accumulate on stream banks, river bars, lake shores, and tidal flats, provide an ideal food source to bald eagles (Armstrong, 2010). Salmon carcasses may provide food to eagles after the spawning season, because many carcasses become frozen into river ice during the winter and thus are available for consumption by eagles the following spring (Hansen et al., 1984). The abundance of salmon affects bald eagle population size, distribution, breeding and behavior (Armstrong, 2010). In one studied population, salmon availability in spring was tightly correlated with whether adult bald eagles laid eggs in a given year, and also influenced the timing of egg-laying (Hansen et al., 1984). As with other salmon carcass consumers, bald eagles affect the ecosystems in which they live by distributing MDNs in their excretions (Gende et al., 2002).

Neither direct nor indirect interactions between shorebirds and salmon have been well-documented. Some shorebirds have been observed to consume dead salmon and salmon eggs, but

it is unlikely they have an impact on salmon populations. No studies yet quantified the contribution of salmon to the energetics of shorebird populations; however, the abundance of invertebrates in the intertidal zone is very likely due in part to MDN from salmon that die on the coast as well as in the rivers feeding Bristol Bay. Shorebirds play a role in distributing MDNs within the terrestrial system, especially during the migratory period, but this has not been quantified. Although they feed in the intertidal zone, shorebirds frequently roost in the terrestrial zone where they deposit their waste. In spring, shorebirds require food resources not only to fuel their migration, but, for some species, to assure they arrive on the breeding grounds with sufficient energy reserves to initiate nesting and egg production (Klaassen et al., 2006; Yohannes et al., 2010). Some of the longest bird migrations known involve shorebird species (e.g., bar-tailed godwit) that use the intertidal areas of Bristol Bay in autumn (Battley et al., 2011; Gill et al., 2009). Such flights are possible not only due to the abundance of intertidal invertebrates (polychaetes, crustaceans, gastropods, and bivalves) in the region, but also because the adjacent uplands are usually rich in fruits of ericaceous plants or tubers on which birds such as plovers, whimbrels, and godwits, regularly feed (Elphick and Klima, 2002; Johnson and Connors, 1996; Paulson, 1995; Skeel and Mallory, 1996). Some shorebirds (e.g., whimbrel, Hudsonian godwit, black and ruddy turnstones) feed on herring roe, carrion, including salmon carcasses, and salmon eggs (Elphick and Tibbitts, 1998; Gill et al., 2002; Handel and Gill, 2001; Nettleship, 2000; Norton et al., 1990). Many shorebirds make use of freshwater invertebrates; small fish may be consumed by yellowlegs (Elphick and Tibbitts, 1998) and phalaropes (Rubega et al., 2000).

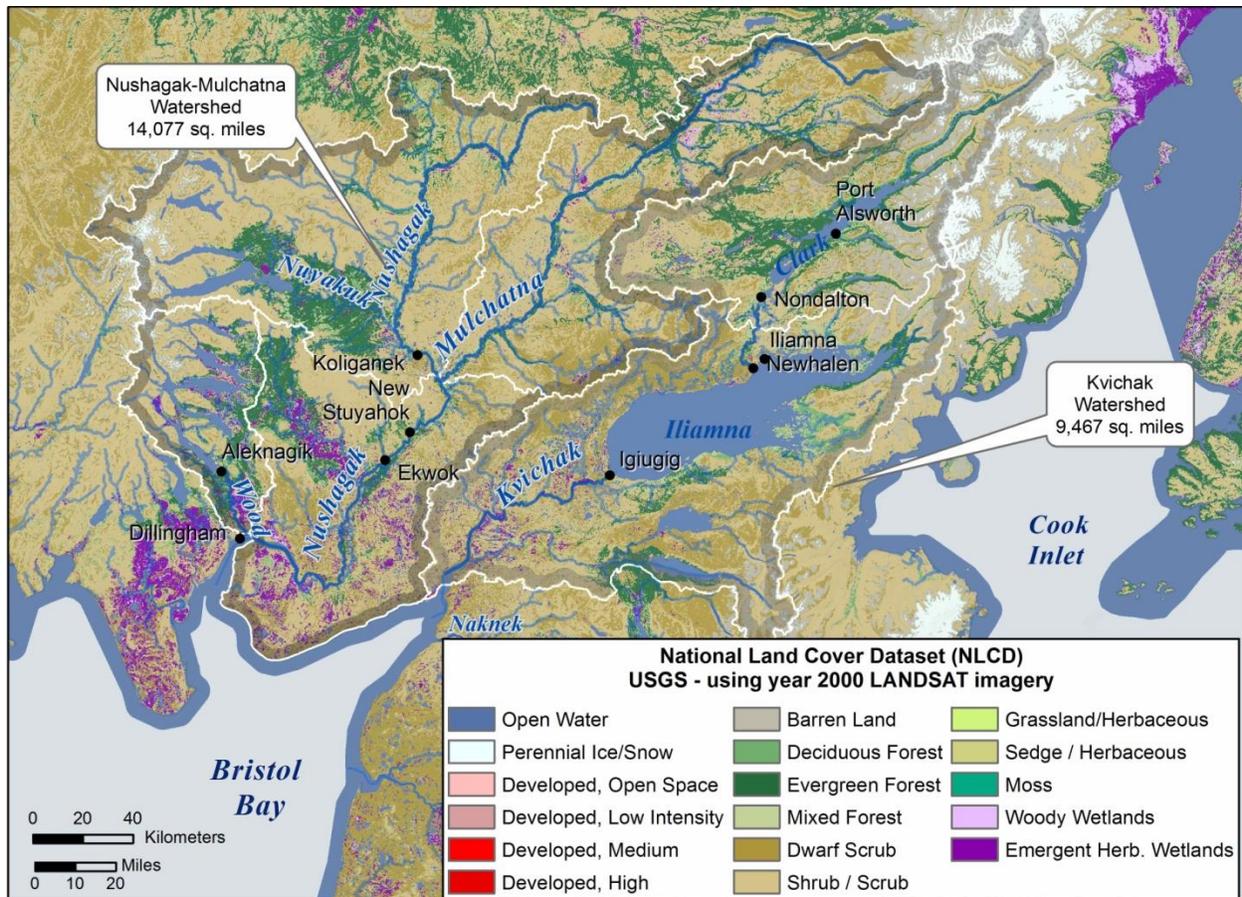
Landbirds also benefit from salmon carcasses when available. Aquatic invertebrate larvae feed on salmon carcasses (Wipfli et al., 1999), overwinter in the soil, and emerge in the spring as adults. These invertebrate adults become aerial prey for a variety of landbirds in the spring, and serve as an important seasonal subsidy during a period when terrestrial invertebrate biomass is low (Nakano and Murakami, 2001). Salmon also benefit landbirds by increasing plant productivity due to MDN inputs (Helfield and Naiman, 2001), potentially resulting in an abundance of berries and seeds for avian consumption (Christie and Reimchen, 2008). Some birds, such as the American Dipper, consume salmon eggs, fry, and small bits of carcasses directly when available. In one study of dippers, consumption of salmon fry was related to higher fledgling mass and lower reduction of brood size (Obermeyer et al., 2006).

In summary, MDN from adult salmon cycle throughout the ecosystem of watersheds with healthy salmon runs, benefitting wildlife, increasing vegetation productivity, and promoting the production of periphyton, aquatic macroinvertebrates, resident freshwater fish, and juvenile salmon (Helfield and Naiman, 2006). This nutrient cycling is in turn dependent on interactions with wildlife, which distribute MDN into the terrestrial environment through both transport of carcasses and excretion of wastes. The loss of either salmon or key wildlife species may result in significant changes to the productivity, diversity and physical structure of the ecosystem, via mechanisms that extend beyond simple “food chain” interactions (Helfield and Naiman, 2006).

## ***Overview of Land Cover and Habitat Types***

We use the National Land Cover Database 2001 (NLCD) as a surrogate for a wildlife habitat-type map. The NLCD is a Landsat-derived, map at the 30-meter spatial resolution scale that illustrates land cover for the United States, including Alaska (Homer et al., 2004) (<http://alaska.usgs.gov/science/geography/nlcd.html>). The NLCD dataset is a fairly broad-level characterization, and is the only dataset that covers the entire Nushagak and Kvichak watersheds. The NLCD describes 19 land cover types within Alaska: open water; perennial ice/ snow; developed, open space; developed, low intensity; developed, medium intensity; developed, high intensity; barren land; deciduous forest; evergreen forest; mixed forest; dwarf scrub; shrub/scrub; grassland/herbaceous; sedge/herbaceous; moss; pasture/hay; cultivated crops; woody wetlands; and emergent herbaceous wetlands (Selkowitz and Stehman, 2011; Talbot, 2010).

Figure 2 shows the land cover types present in the Nushagak and Kvichak watersheds. The NLCD does not describe wetlands in great detail and wetlands likely extend into other land cover types not specifically identified as such (e.g., sedge/herbaceous land cover, which may include wet tussock tundra, and evergreen forest, which may include wet black spruce bogs). Table 1 shows the total size of each watershed and sub-watershed, as well as the percentage of each NLCD land cover type in each.



**Figure 2. National Land Cover Dataset, land cover types for the Nushagak River watershed and Kvichak River watershed.**

Currently, there exists only a single statewide ecosystem map for Alaska (Nowacki et al., 2001). This map describes 32 ecoregional landscapes, but it is very coarse and not intended to provide specific habitat classifications for wildlife. This ecosystem map does not provide sufficient detail to be used for habitat type classification as part of this project.

**Table 1. Size of sub-basins (sq. mi.) within the Nushagak and Kvichak River watersheds and percent of watershed or sub-basin within each National Land Cover Database land cover type.**

	Kvichak River Watershed			Nushagak River Watershed					Total
	Lake Clark Sub-basin	Lake Iliamna Sub-basin	Sub-total	Mulchatna River Sub-basin	Upper Nushagak River Sub-basin	Lower Nushagak River Sub-basin	Wood River Sub-basin	Sub-total	
<b>Size (sq. mi.)</b>	3,532	5,935	9,467	4,291	5,026	3,386	1,367	14,077	23,537
<b>Land Cover Type</b>	<b>Percent of Watershed</b>								
<b>Open-Water</b>	5.96	23.89	17.20	2.31	5.34	5.36	14.28	5.29	
<b>Perennial Ice &amp; Snow</b>	6.51	0.38	2.67	0.39	1.61	0.00	1.32	0.82	
<b>Developed, Low Intensity</b>	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	
<b>Barren Land</b>	23.55	5.88	12.47	4.61	3.31	0.09	.36	2.94	
<b>Deciduous Forest</b>	2.92	2.79	2.84	1.94	3.63	2.15	4.36	2.83	
<b>Evergreen Forest</b>	15.51	5.34	9.13	10.04	11.86	9.63	13.81	10.96	
<b>Mixed Forrest</b>	4.45	3.20	3.67	2.30	5.08	2.99	5.47	3.77	
<b>Dwarf Scrub</b>	10.85	22.57	18.19	24.50	12.77	20.06	5.26	17.24	
<b>Shrub Scrub</b>	28.27	31.79	30.66	51.08	54.97	44.86	44.12	50.23	
<b>Sedge Herbaceous</b>	0.01	1.67	1.05	0.48	0.37	3.86	0.13	1.22	
<b>Moss</b>	0.01	0.02	0.01	0.00	0.02	0.09	0.34	0.06	
<b>Woody Wetlands</b>	0.64	0.19	0.36	1.28	0.16	0.74	1.24	0.75	
<b>Emergent Herbaceous</b>	0.81	2.28	1.73	1.53	1.05	10.17	6.32	3.90	

# **BROWN BEARS**

## ***Introduction***

This section characterizes brown bears that spend most of their lives in the Nushagak and Kvichak watersheds. Some of the general information comes from decades of research on this species in its entire cosmopolitan ranges. We note where information varies from that available for the Nushagak and Kvichak watersheds. Because of their interconnected home ranges and close genetic relationships, brown bear habitat selection and behavior show a great degree of overlap wherever they occur (Schwartz et al., 2003).

We use the term “brown bears” to refer to all North American bears of the classification *Ursus arctos*, although bears in interior parts of North America traditionally have been referred to as grizzly bears and those on the coast, in salmon-rich areas, as brown bears.

## ***Habitat***

Brown bears are wide-ranging animals that, use many different plant and animal communities throughout the course of a year. Habitat is defined here as the location or environment where an organism is most likely to be found. Habitats provide the food, water, and cover that a species needs to survive. Biologists generally use the term “home range” to describe the area that an animal uses to carry out the normal activities of securing food, mating, and caring for young. Brown bears are generally solitary, food-maximizing individuals whose home ranges vary with the availability of their seasonal foods. When food is abundant, as during salmon runs, home ranges of female bears may be smaller than at other times because of their ability to obtain sufficient energy to meet their nutritional needs. Conversely, home ranges may increase in order to take advantage of more widely dispersed food resources (McLoughlin et al., 1999).

On the Alaska Peninsula, brown bears emerge from their dens between early April and early June. Males tend to emerge before females. Females with cubs of the year are often the last to leave the den (Miller, 1990). Brown bears often spend June to mid-August in lowland and coastal areas, although some bears in the Nushagak and Kvichak watersheds probably do not include coastal plains within their home ranges. A study conducted on Admiralty Island, found that brown bears did not necessarily use rich coastal habitats as part of their home ranges, although reasons for these differential patterns of habitat selection are not known (Schoen et al., 1986).

Brown bears typically spend July through mid-September near streams that support salmon runs (Schoen et al., 1986). The Nushagak and Kvichak watersheds contain at least 8,286 linear miles (13,335 linear kilometers) of anadromous fish habitat, not including lakes (Johnson and Blanche, 2011). As salmon begin to appear in the streams, bears move closer to them, sometimes congregating where shallow streams make preying on fish more efficient (Aumiller and Matt, 1994). Studies of bear predation on salmon in a series of streams in the Wood River system

demonstrated that the probability of a fish being killed by a bear increases with decreasing stream size (Quinn et al., 2001).

Brown bears move to higher elevations in the fall, presumably to feed on berries and other food items (Collins et al., 2005). Some bears continue to feed on fish until October, especially in shallow streams where dead and dying sockeye salmon wash out of lakes after spawning (Fortin et al., 2007).

Brown bears typically dig their dens at higher elevations within their home ranges (Van Daele et al., 1990), on 20- to 50-degree slopes between 300 and 1,600 meters in elevation. The mean date for den entrance is October 14, and most bears have entered their dens by early November. Brown bears spent an average of 201 days in winter dens in the Nelchina area in south-central Alaska, (Miller, 1990).

### ***Food Habits***

Brown bears on the Alaska Peninsula travel within their home ranges to exploit seasonally available food sources (Glenn and Miller, 1980). During late summer and fall, bears gain weight rapidly and store it primarily as fat. Peak body mass generally occurs in fall, just prior to hibernation (Hilderbrand et al., 2000). Bears must maximize weight gain prior to hibernation because they metabolize only fat and muscle during that time and must rely on those stored energy reserves for reproduction and survival.

Following den emergence in spring, bears commonly graze on early season herbaceous vegetation, such as cow parsnip (*Heracleum lanatum*), horsetails (*Equisetaceae*), lupine (*Lupinus spp.*), false hellebore (*Veratrum viride*) and grasses (Gramineae) (ADFG, 1985). They also search for and scavenge winter-killed carrion, as well as moose and caribou calves (Glenn and Miller, 1980). Bears with access to salt marshes commonly graze on sedges (*Carex spp.*), grasses (e.g., *Elymus spp.*), sea-coast angelica (*Angelica lucida*), and forbs (e.g., *Plantago spp.* and *Triglochin spp.*). Brown bears are also known to dig for soft-shelled clams (*Mya arenaria*) and Pacific razor clams (*Siliqua patula*) on intertidal beaches (Smith and Partridge, 2004). Bears on the coast may also scavenge for dead marine life (Glenn and Miller, 1980).

In July through October, brown bears move to streams to take advantage of the predictable runs of salmon. The Nushagak and Kvichak Rivers support five species of Pacific salmon (*Oncorhynchus spp.*) (Salomone et al., 2011). The abundance of salmon in the Nushagak and Kvichak watersheds makes them prime habitat for brown bears because salmon are an excellent source of lipids.

Lipids obtained through the consumption of salmon account for approximately 80% of the mass gained by bears (Hilderbrand et al., 1999b). More than other factors, the accumulation of fat determines whether brown bears will hibernate successfully, or in the case of females, produce cubs (Farley and Robbins, 1995). In addition, bigger, fatter adult females produce faster growing

cubs that survive better than do cubs produced by smaller, leaner females (Ramsay and Stirling, 1988). Larger, fatter males also receive an advantage from their size. Dominance in males is necessary to win breeding opportunities and defend estrus females, and larger males tend to compete better for these opportunities than smaller males (Robbins et al., 2007).

The availability, age, and spawning status of salmon all played significant roles in consumption choices made by brown bears in Bristol Bay and Southeastern Alaska. (Gende et al., 2004). When salmon were abundant, bears preferentially ate fish parts with higher caloric content, such as roe and brains. In addition, bears consumed sexually mature (or ripe) fish before fish that had spawned-out. Some bears were even observed catching and releasing fish that had spawned-out and consuming only ripe fish with higher energy content (Gende et al., 2004).

Brown bears are also known to feed extensively on wild fruits, including crowberry (*Empetrum nigrum*), lowbush cranberry (*Vaccinium vitis-idaea*), and bog blueberry (*Vaccinium uliginosum*) (Fortin et al., 2007; Rode et al., 2006a; Rode et al., 2006b). The simultaneous ingestion of salmon and berries appears to increase growth rate of bears, over that attained by ingesting one or the other alone (Robbins et al., 2007).

Fall foraging is especially important for brown bears. In the fall, brown bears seek out available meat sources including salmon, ungulates, and rodents, as well as berries, in order to store as much fat as possible. The more efficiently bears forage, the more vital lipids they can store, thereby improving their ability to survive and reproduce (Robbins et al., 2007).

## **Behavior**

Brown bears have generalist life history strategies, extended periods of maternal care, and omnivorous diets. Generalists thrive in a wide variety of environmental conditions and use a variety of food resources. Brown bears must travel long distances in their six months of activity to procure the abundance and variety of food needed to flourish.

Movement patterns that define home ranges are influenced by important food resources, breeding, reproductive status, individual dominance status, security, and human disturbance (Schwartz et al., 2003). The larger ranges of adult males overlap several females (Schwartz et al., 2003). Female brown bears are generally faithful to their home ranges. Sub-adult females tend to stay close to or within the home range of their mothers. Sub-adult males tend to disperse longer distances (Glenn and Miller, 1980). Brown bears searching for alternative foods outside their usual home ranges, as well as dispersing bears, often run into more conflicts with humans (increasing human-caused bear mortality) than bears staying within their home ranges (Schwartz et al., 2003).

Differences in home range size between study areas are attributed to differences in habitat quality and distribution (McLoughlin et al., 2000). That brown bear home ranges respond to habitat quality is illustrated by the difference in home range size in various study areas. For example, in

the Nelchina River basin of south-central Alaska, adult female home ranges averaged 408 km<sup>2</sup> (158 mi<sup>2</sup>), whereas those of adult males averaged 769 km<sup>2</sup> (297 mi<sup>2</sup>) (Ballard et al., 1982). In contrast, Collins et al. (2005) estimated home range size for adult females as 356 km<sup>2</sup> (137 mi<sup>2</sup>) in the southwest Kuskokwim Mountains, west of the Nushagak watershed. On the relatively productive Alaska Peninsula, Glenn and Miller (1980) found an average seasonal range of 293 km<sup>2</sup> (113 mi<sup>2</sup>) for adult females (n=30) and 262 km<sup>2</sup> (101 mi<sup>2</sup>) for adult males (n=4), although the small sample size for adult males cautions against comparing these directly. Glenn and Miller (1980) pointed out that other data contradicted the apparent finding of smaller male than female seasonal ranges, e.g., the cumulative 6-year movements of 13 adult males were greater than those of 49 females. In addition, they found that seasonal range movement of subadult males (744 km<sup>2</sup>) (287 mi<sup>2</sup>) was three times that of subadult females (249 km<sup>2</sup>) (96 mi<sup>2</sup>).

Brown bears hibernate in dens during winter, and rely on stored energy reserves for survival. During hibernation, bears can go up to seven months without eating, drinking, defecating, or urinating (Schwartz et al., 2003). Generally, brown bears seek out remote, isolated areas and sites that will accumulate enough snow to insulate them from cold winter temperatures, often on steep slopes. Bears may prefer steeper slopes for denning sites, due to reduced potential for disturbance (Goldstein et al., 2010).

Female brown bears enter estrus beginning in late spring and, depending upon male availability, may continue breeding into August. However because males are rarely limiting in a population, most breeding occurs in May and June. After the eggs are fertilized development proceeds to the blastocyst stage and then halts. Embryo implantation is delayed until hibernation begins. It is possible for a litter to have multiple sires. Female brown bears that have successfully bred and have implanted embryos have an obligate denning requirement because the newborns are completely helpless at birth and remain so for several months. Most births occur in January and February after 6-8 weeks of gestation. All maternal care from fetal development through the first four months of lactation occur in the den and all nutrient reserves for the developing young are drawn from maternal body stores accumulated the previous summer/fall. Litters can vary from one to four cubs; however, twins are the most common (Schwartz et al., 2003).

Brown bears in the Nushagak and Kvichak watersheds interact with humans around residences, recreational sites, and in the backcountry. The behavior of bears during these interactions depends on many variables (Herrero et al., 2005). Brown bears that have received food or garbage while near humans or their habitations can become food-conditioned. Food-conditioning is a form of operant conditioning in which bears learn to associate sources of food with humans or their infrastructure (Matt, 2010). Food-conditioned bears are more likely to encounter humans in an aggressive manner, perhaps because they assertively seek foods where humans are found. Preventing access to anthropogenic foods keeps bears from being positively rewarded for close association with people (Herrero, 2002).

Habituation describes behavior that is different from food-conditioning (Aumiller and Matt, 1994; Herrero, 2002). A habituated bear is one that, through repeated exposure to a neutral situation, such as a person observing it from a close distance learns to mute its reaction, thus conserving energy. Consequently, habituation often is assumed to have occurred when bears tolerate people at close distances. Habituation is not an all-or-none response and may vary widely among individual bears. Some bears become habituated to certain human artifacts such as roads and other structures (Follman and Hechtel, 1990).

Most brown bear attacks are associated with defensive behavior, such as females protecting cubs or incidents involving protection of a food cache such as an ungulate carcass (Herrero, 2002; Herrero and Higgins, 1999; Herrero and Higgins, 2003). Whether a bear charges or attacks a human in a defensive manner is dependent on many factors in the immediate environment, as well as the prior experience and individual behavior of both the human and the bear (Herrero et al., 2005). Historical records strongly suggest that brown bears have not been important predators on people, although rare incidences of predation have occurred (Herrero, 2002).

### ***Interspecies Interactions***

Pacific salmon (*Oncorhynchus* spp.) and brown bears meet the basic criteria of “keystone species.” The loss of either species would result in significant changes in the productivity, diversity and physical structure of their communities, far beyond just their “food chain” interactions. By both consuming and transporting partially consumed salmon, brown bears distribute MDNs via decaying salmon carcasses and through excretion of wastes rich in salmon nutrients (Helfield and Naiman, 2006).

Pacific salmon spend most of their lives feeding and growing at sea before returning to spawn and die in their natal streams. Approximately 99% of the carbon, nitrogen, and phosphorus in their bodies when they return to freshwater is from the marine environment (Hilderbrand et al., 1999c). These nutrients are transported inland when salmon return to their natal streams to spawn. For example, sockeye salmon (*O. nerka*) are estimated to import approximately 12,700 kg (27,940 lbs) of phosphorus and 101,000 kg (222,200 lbs) of nitrogen into to the Wood River system each year (Holtgrieve, 2009).

Nitrogen, phosphorus, and carbon are among the most important MDNs. These nutrients cycle through the ecosystem, benefitting other forms of wildlife and vegetation, promoting the production of periphyton (e.g., algae), aquatic macroinvertebrates, resident freshwater fish, and juvenile salmon (Helfield and Naiman, 2006). Insects that benefit directly from decaying salmon include stoneflies (*Plecoptera* spp.), caddis flies (*Trichoptera* spp.), mayflies (*Ephemeroptera* spp.), midges (*Diptera* spp.: Chironmids (*Chironomidae* spp.), blackflies (*Diptera: Simuliidae*), and carrion beetles (*Coleoptera: Silphidae*) (Helfield, 2001).

As salmon enter freshwater streams in late July and throughout August, brown bears become hyperphagic (consume abnormally large quantities of food) as they store energy for winter by consuming salmon which contain protein and fat (Hilderbrand et al., 1999b). On the Kenai Peninsula, each female brown bears is estimated to consume 1,003 kg (2,207 lbs) (SD = 489 kg) of salmon each year and transport approximately 37.3 kg (82 lbs) of MDNs to terrestrial ecosystems (Hilderbrand et al., 2004; Hilderbrand et al., 1999a).

In one study, brown bears delivered 83 to 84% of marine-derived nitrogen found in white spruce trees near two Kenai Peninsula creeks (Hilderbrand et al., 1999a). In addition, Helfield and Naiman (2006) found Sitka spruce growth rates to be three times greater near salmon spawning sites than in areas lacking spawning sites. Other studies also show that “bears feeding on salmon increased soil ammonium concentrations three-fold and nitrous oxide (NO<sub>3</sub>) flux by 32 fold” (Holtgrieve, 2009).

The level of MDNs by brown bears transport shows the significance of salmon abundance in areas with brown bears. These levels suggest that loss of either population would change the nitrogen budget “and, by extension, the productivity and structure of the riparian forest” (Helfield and Naiman, 2006). The potential loss of this nitrogen source would also greatly affect other organisms throughout the food chain and ecosystem (Helfield, 2001).

### ***Mortality, Productivity, and Survivorship***

Brown bears have a low reproductive rate due to their relatively late age of first reproduction, small litter size, and long interval between litters. This low reproductive rate makes them particularly susceptible to impacts from humans (Schwartz et al., 2003). On the Alaska Peninsula, mean age at first reproduction for female brown bears was 4.4 years (Miller and Sellers, 1992). The youngest female upon emerging from her den with cubs in the late spring would thus be 5.4 years old. If cubs are raised until the typical age of weaning (2.4 years), the female’s age at second breeding likely would not occur until she was 7.4 years (Schwartz et al., 2003). Therefore, during the first ten years of her life, a female brown bear is capable of producing only two litters.

Age at first reproduction, litter size and inter-litter intervals vary among individuals and populations. Females are capable of breeding in the same spring that they wean their cubs; however, they do not always wean them at 2.4 years and may keep them until they are 3.4 years. Interval between litters was 3 to 6 years (Schwartz et al., 2003). A ten-year study in southwest Alaska, documented considerable variation in reproductive intervals (Kovach et al., 2006). Compared with other Alaska studies, this population had among the highest rates of offspring production, yet the lowest number of female offspring weaned per year.

Adult female brown bears that eat meat (mostly salmon) in the fall gain approximately 80% fat mass (Hilderbrand et al., 1999b). Deposited fat during winter dormancy was a better predictor of cub production than lean body mass (Farley and Robbins, 1995). Although late summer and fall

salmon are a critical resource on their own, it is likely the availability of both fall berries and salmon together enable brown bears to accumulate body reserves important for reproduction and hibernation (Hilderbrand et al., 1998; Robbins et al., 2007). Despite the fact that productivity would logically be higher in populations with access to salmon in the fall, Kovach et al. (2006) found that, in southwest Alaska, females had only slightly higher productivity (measured as female cubs/weaned/adult female/yr) than the figures reported for Yellowstone National Park and the Selkirk Mountains, where salmon are not present.

The age and sex structure of brown bear populations is dynamic. Many variables, such as habitat conditions, time of year of observations, and hunting make generalizations difficult. However, in one study of a hunted population on Kodiak Island, the population structure of brown bears was 26% cubs, 22% yearlings, 27% sub-adults, and 25% adults (Troyer and Hensel, 1964). The number of cubs born varies from year to year, and the proportion of cubs in any brown bear population is a function of both reproductive rate and early mortality. Cub survival rates, based on observation of den emergence from the first year to the second year, were estimated for two areas on the Alaska Peninsula. At Black Lake, cub survival was an estimated 57%, while cub survival in Katmai National Park was an estimated 34% (Miller et al., 2003).

Survival of adult males varies among populations, but is generally lower in hunted populations. In the middle Susitna River basin study area in south-central Alaska, Miller et al. (2003) estimated annual survival of adult males at 82% in 1985. Ten years later, in 1995, Miller et al. estimated only 71% annual survival for adult males, due to increased hunting pressure. Female survival rates are generally higher than males. In the middle Susitna study, Miller et al. (2003) estimated 90% annual survival for adult females in both 1985 and 1995. In their study of female survivorship in a hunted population in the southwest Kuskokwim Mountains, midway between Dillingham and Bethel, Alaska, Kovach et al. (2006) found mean annual survival estimates of 90.1 to 97.2% for radio collared females aged five years or older.

Because of the difficulty of observing them, causes of natural mortality are poorly known for brown bears. Although adult males are known to kill juveniles, and adults kill other adults, there are insufficient data to fully assess the effects of predation on younger bears by adult bears (Schwartz et al., 2003). Brown bears are exposed to more dangers during some life stages than others. Cubs are particularly vulnerable during their first year of life. In the middle Susitna study, survival for cubs of the year was estimated at 67% (Miller et al., 2003). Kovach et al. (2006) reported survival rates of 48.2 to 61.7% for cubs of the year. In the Kuskokwim Mountains study, Kovach et al. (2006) estimated survival rates of 71.3 to 83.8% for one- and two-year-old offspring, combined.

Dispersing sub-adults may be forced to choose marginal home ranges or areas near human habitation where mortality risks are high (Servheen, 1996). Brown bears can harbor parasites and diseases that may contribute to mortality, and starvation has also been reported. However, there

are no reported cases of parasites or diseases causing major die-offs within populations (Schwartz et al., 2003).

In most brown bear populations, human-caused mortality is higher than natural mortality among adults. The rate of human-caused mortality varies greatly in Alaska, where contact between bears and humans is a function of human population density, activities of both species, and hunting regulations. Servheen (1996) lists the following categories of human-caused mortality, in order of increasing frequency: direct human/bear confrontations (hikers, backpackers, photographers, hunters, etc.); attraction of grizzly bears to improperly stored food and garbage associated with human habitations and other sources: careless livestock husbandry, including the failure to properly dispose of dead livestock; inadequate protection of livestock; loss of bear habitat; and hunting, both lawful and illegal.

### ***Population***

Brown bear population abundance is usually expressed in terms of density. Two methods for estimating bear population density, capture-mark-recapture (when applied to an assumed area), and aerial line-transect survey, have been used recently in Alaska. Both methods have been applied in early spring, prior to leaf growth on deciduous shrubs and trees.

Alaskan brown bear populations vary in density depending on the availability and distribution of food (Miller et al., 1997; Schwartz et al., 2003), achieving highest densities where bears have access to multiple runs of Pacific salmon (Hilderbrand et al., 1999c; Miller et al., 1997). Based on a modified capture-mark-recapture method, Miller et al. (1997) estimated the density of all ages of brown bears along the Pacific Coast of the Alaska Peninsula at 551 bears per 1,000 km<sup>2</sup>, the highest documented anywhere in North America. In contrast, brown bears on Alaska's north slope have the lowest estimated density at only 3.9 bears of all ages/1,000 km<sup>2</sup> (Reynolds, 1976).

Population density estimates for the Nushagak and Kvichak watersheds are not currently available, but recent aerial distance sampling surveys in portions of the watersheds and in nearby watersheds provide some data. Using the double observer aerial line-transect method, brown bear density in the Lake Clark National Park and Preserve portion of the Kvichak watershed was estimated at 39 bears/1000 km<sup>2</sup> (E. Becker (ADFG), pers. comm.). Recent aerial line transects in the remainder of the inland Kvichak watershed estimated 47.7 bears of all ages/1000 km<sup>2</sup> (Becker, 2010). In the nearby northern Bristol Bay area (Togiak NWR and Bureau of Land Management Goodnews Block), an area including both coastal and inland habitats, brown bear population density was estimated as 40.4 bears/1,000 km<sup>2</sup> (Walsh et al., 2010).

As expected, spring surveys that include coastal habitat have higher population density estimates than those with only inland habitats. Researchers using the ADFG aerial line-transect double-count survey method as in the above studies, estimated brown bear density at 124 bears/1,000 km<sup>2</sup> in Katmai National Park (GMU 9C), in an area that included both coastal and inland brown bear

habitat. Along the coast of Lake Clark National Park and Preserve (NPP) (GMU 9A), brown bear density was estimated at 150 bears/1,000 km<sup>2</sup> (Olson and Putera, 2007).

When inferring the geographic distribution of brown bears from density estimates, it should be noted that brown bears can move long distances. Bears that are counted in coastal areas in the spring may move inland and upstream in the summer and fall to take advantage of pre- and post-spawning salmon. It is common to see brown bears in interior Lake Clark NPP feeding on post-spawning salmon in September and October, and less commonly, in December (B. Mangipane (NPS), pers. comm., 9/27/11).

### ***Human Use/Interaction/Management***

In the Nushagak and Kvichak watersheds, humans value bears for sport hunting, subsistence hunting, and for viewing. Humans and bears interact in many other situations, including both residents and non-residents visiting the area for purposes other than seeking encounters with brown bears.

#### ***Sport Hunting for Brown Bears***

***Game Management Unit 9-*** The Alaska Board of Game has placed a high priority on maintaining a quality hunting experience for the large brown bears of the Alaska Peninsula in Game Management Unit (GMU) 9, which includes the Kvichak watershed (Figure 3). Due to the ease of access using aircraft and the high quality of bear trophies in the unit, an active guiding industry for the area developed during the 1960s. Non-resident sport hunters are required to use a guide for brown bear hunting throughout Alaska, and to have their harvest inspected and sealed by ADFG. The ADFG management program strives to maintain stable guide and client numbers over time. As of 2007, approximately 75% of the GMU 9 brown bear harvest came from guided hunts (ADFG, 2009).

The current brown bear management objective for GMU 9 is to maintain a high bear density with a sex and age structure that will sustain a harvest composed of 60% males, with 50 males aged eight years or older taken during the combined fall and spring seasons. In GMU 9, in the 2007 Regulatory Year (July 1, 2006 through June 30, 2007), results reported to ADFG revealed a harvest of 621 bears (72% male and 28% female).

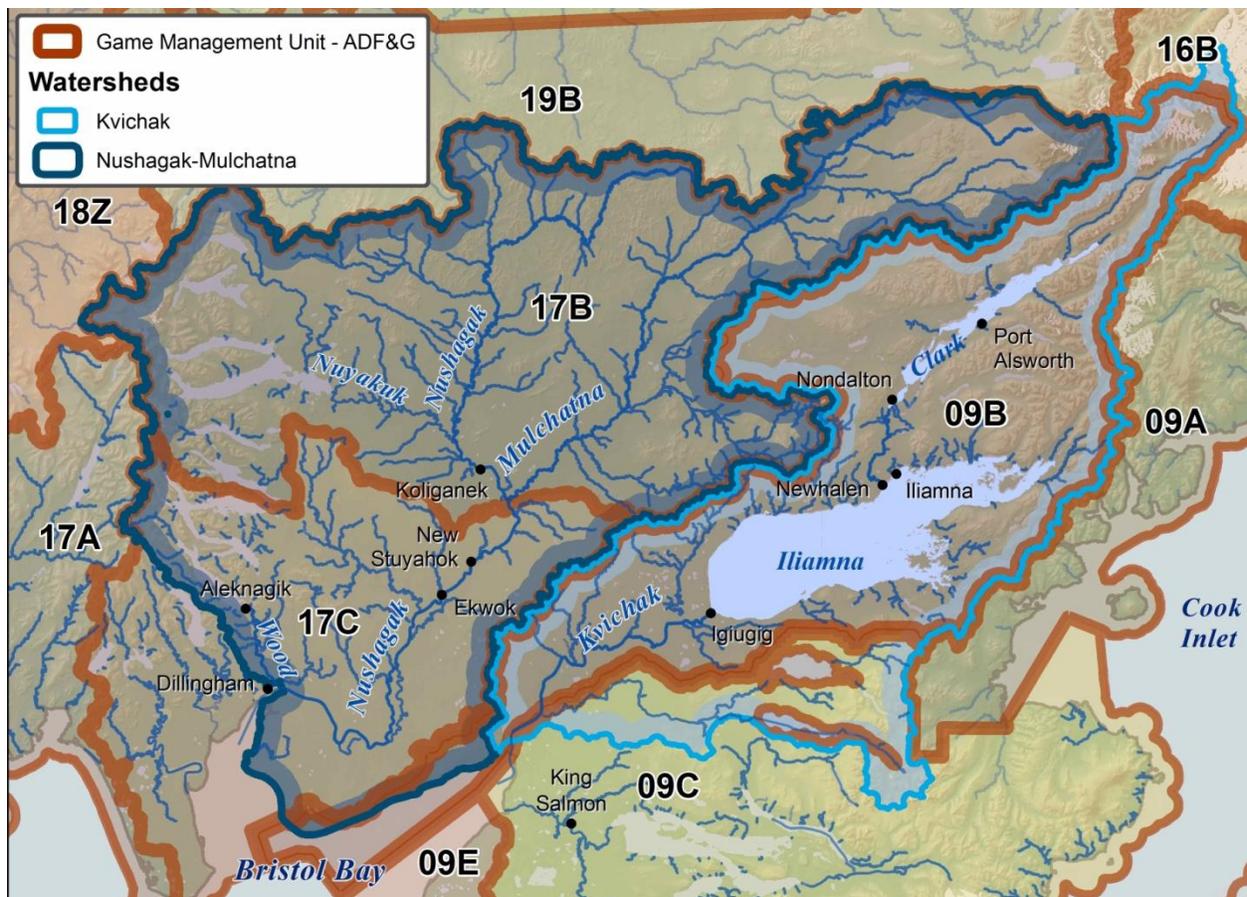


Figure 3. Nushagak and Kvichak River watersheds and associated Alaska Department of Fish and Game, game management units.

**Game Management Unit 17-** In GMU 17, which includes the most of the Nushagak River watershed, brown bears are neither as abundant nor, usually, as large as those found on the Alaska Peninsula. GMU 17 has not received much hunting pressure in the past. However, interest in hunting brown bears in many parts of Alaska is increasing, and bear hunting in GMU 17 has increased substantially since the mid-1990s. As of 2007, the brown bear population objective for GMU 17 was to maintain a brown bear population that will sustain an annual harvest of 50 bears composed of at least 50% males (ADFG, 2009).

**Subsistence Hunting for Brown Bears-**

On non-federal lands in GMUs 9b and 17, subsistence brown bear hunters must obtain a subsistence registration permit for bears to be taken for food. In addition to requiring a registration permit, the subsistence brown bear hunting regulations establish a hunting season of September 1 to May 31, limit take to one bear/regulatory year, and prohibit take of cubs and females with cubs (ADFG, 2011a). Salvage of the hide and skull is optional and the hide and skull need not be sealed, unless they are removed from the Western Alaska Brown Bear Management Area, in which case they must be sealed by an ADFG representative and their trophy value destroyed. All edible meat must be salvaged for human consumption. On federal lands within GMUs 9 and 17,

residents must consult the Federal Subsistence Management Program Regulations (available at <http://alaska.fws.gov/asm/law.cfm?law=2&wildyr=2010>). Federal and State subsistence hunting regulations differ. For example, on federal lands in GMU 9B, there is a federal registration permit harvest quota of 4 females or 10 bears and the season closes as soon as the first quota is reached.

### **Bear Viewing-**

The Kvichak watershed contains specific destinations for recreational visitors to view brown bears. Lodges on Lake Clark, Kukakluk Lake, Nonvianuk Lake, and Battle Lake offer brown bear viewing in addition to fishing expeditions. Several guides and air taxis take brown bear viewers to Funnel Creek and Moraine Creek on day trips.

The 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation reported that 491,000 Alaskan residents and non-residents participated in wildlife watching as a primary activity (USFWS and US Department of Commerce Census Bureau, 2006). Bear viewing is now the leading recreational activity in Lake Clark NPP. Bear viewing altered spatiotemporal food resource use by brown bears; however, total resource use declined only when bears were exposed to 24-hour daily human activity. Energy expenditure, indexed as daily travel distances, was significantly higher when bears responded by altering spatial rather than temporal resource use. However, body weight and composition were unaffected as bears shifted their foraging to other locations or times (Rode et al., 2007; Tollefson et al., 2005).

### **Other Bear-Human Interactions**

**Local Residents and Bear-Human Conflicts-** In both GMU 9 and 17, both legally harvested bears and non-hunting mortalities are reported annually. Villages with open landfills attract bears during the spring, summer, and fall. Residential garbage, dog food, and fish drying racks also lure bears close to humans. Local residents commonly kill bears in defense of life and property near villages and fishing sites. Although reporting rates seem to have improved in recent years, most non-hunting mortalities of bears are reported either indirectly or not at all; as such, any conclusions based solely on harvest data or reported non-hunting mortalities should be viewed with caution (ADFG, 2009).

During the 2007 regulatory year, ADFG received 17 reports of bears killed by people in defense of life and property in GMU 9; however, wildlife managers estimated that the number of unreported brown bear killings in the unit might be over 50 when considering unreported data. During the same period in GMU 17, ADFG received 5 reports of defense of life and property mortalities; however wildlife managers assumed there were more unreported brown bear killings (ADFG, 2009).

**Other Recreational Users and Bear-Human Conflicts-** Park managers analyzed 171 bear-human incidents over 24 years in Lake Clark NPP. They found that brown bears received food as a result

of encounters with humans in 46% on the incidents, and that bears were killed in 23% of the incidents (Wilder et al., 2007). Managers were concerned about the large number of food-conditioning incidents, given that food-conditioned bears are responsible for the majority of human injuries from bears in national parks (Herrero, 2002; Wilder et al., 2007). Food-conditioned bears have been found to be 3 to 4 times more likely to be killed by humans than non-food conditioned bears (Mattson et al., 1992). Wilder et. al. (2007) also noted that casual bear photographers at private recreational cabins at Telequana Lake, may have contributed to the high number of bear-human incidents because “individuals repeatedly fed bears in this area to facilitate photography.”

# MOOSE

## *Introduction*

Moose, the largest member of the deer family (*Cervidae*), have a circumpolar distribution in the northern hemisphere (ADFG, 2011d; Telfer and Kelsall, 1984), occupying a broad band of boreal forest dominated by spruce, fir, or pine trees. Fire is a major force that shapes these vegetative communities (Odum, 1983; Telfer and Kelsall, 1984). Moose occur in northern forests of North America, Europe, Russia, and China (Karns, 2007). The association between moose and the northern boreal forest is unique, as there are no counterparts in the southern hemisphere (Shelford, 1963). There are four recognized subspecies of moose in North America (Hundertmark et al., 2003; Peterson, 1952; Peterson, 1955); the one found in the study area (Nushagak and Kvichak watersheds) is the Alaska-Yukon subspecies (*Alces alces gigas*) (Miller, 1899). This subspecies is often referred to as the “tundra moose,” since it is often found in and near tundra areas (Bubenik, 2007). However, it also inhabits the boreal forest, low elevation riparian and delta habitats, and mixed deciduous forest areas. The Alaska-Yukon subspecies is generally larger than the other subspecies in body size and antler development. In Alaska, moose are found in suitable habitats throughout the mainland portion of the State, except on the northernmost coastal plain (LeResche et al., 1974), ranging from the Stikine River in southeast Alaska to the Colville River on the Arctic Slope (ADFG, 2011d). Moose are ruminants, with a four-chambered stomach, and are classified as browsers based on their foraging strategy (Hofmann, 1973). Moose consume mainly tree and shrub leaves and woody twigs during winter (Renecker and Schwartz, 2007). Due to their large body size and the volume of vegetation consumed, moose play an important role in plant productivity and nutrient cycling in ecosystems where they occur (Molvar et al., 1993).

Here we characterize moose that inhabit the Nushagak and Kvichak watersheds, but we provide substantial information accumulated from decades of research on this species from across North America. Since moose are a generalist species, much of this information is relevant to moose in the Nushagak and Kvichak areas. We borrow heavily from the work of a distinguished group of moose biologists, which provides a near complete summary of moose biology and management (Franzmann and Schwartz, 1998; Franzmann and Schwartz, 2007) and have attempted to cite them when appropriate. We also relied on a separate, condensed version of these data with more recent updates (Bowyer et al., 2003).

## *Habitat*

Both stable and transitory habitats are important in the evolution of moose (Geist, 1971). Permanent habitats are those that persist through time without alteration in character or condition, such as riparian willow/poplar communities and high-elevation shrub/scrub communities that do not succeed to different kinds of vegetation (Peek, 2007). Telfer (1984) characterized the full range of moose habitats as consisting of boreal forest, mixed forest, large delta floodplains, tundra subalpine shrubs, and stream valley/riparian zones. According to Peek (2007), boreal forest habitats are considered fire-controlled, and likely represent the primary environments in which

moose evolved (Kelsall and Telfer, 1974; Peterson, 1955). As noted by Peek (2007), delta floodplains are expected to have the highest density of moose, followed by shrub/shrub habitats, boreal forests, mixed forests, and stream valley/riparian zones. A study in the Copper River Delta supported the finding that large deltas and floodplains are the most productive of these five major habitat types for moose (MacCracken et al., 1997b). Boreal forest habitats are the least stable through time, whereas stream valley/riparian zones are the most stable. In Alaska and the Northwest Territories, climax tundra and subalpine shrub communities at higher latitudes and elevations are more stable in time and space than are alluvial and riverine habitats (Viereck and Dyrness, 1980).

Transitory habitats of moose include boreal forests where fire creates successional shrub communities that provide extensive forage. Geist (1971) hypothesized that islands of permanent habitat found along water courses and deltas and in the high elevation dwarf shrub communities serve as refugia where moose populations persist and from which they disperse into transient habitats created by fire. The frequency of fire in boreal forests is considered sufficient to promote adaptations favoring dispersal of yearling moose to newly created habitats (Peek, 2007). The dominant land cover types in the study area consist of high elevation dwarf shrub, shrub/scrub and tundra habitats, with lower elevation boreal forests (deciduous, evergreen and mixed) and riparian habitats (woody wetlands) along water courses (Table 1). All of these cover classes represent high-quality moose habitat.

Habitat selection by moose is influenced by availability of food, predator avoidance, and snow depth (Dussault et al., 2005). Peek (2007) advanced the view that moose select habitat primarily on the basis of the most abundant and highest quality forage. Because these resources are unequally distributed in space and time, moose habitat may be considered as a series of patches of different types and sizes, with the value of each patch varying through the year. However, the total year-round value of a diverse habitat should be emphasized even if each part is only critical at one season or another. Further, sufficient size of both overall habitat, and possibly each patch of any given habitat, must be accessible to make an area suitable for occupation by moose. As a corollary, if a certain critically important community, such as shrub/scrub vegetation type, is unavailable in sufficient quantity, then the ability of an overall habitat to support moose may be reduced, even if it contains a highly diverse set of other plant communities.

The typical annual pattern of moose habitat selection includes open upland and aquatic areas that provide the best forage in early summer, followed by more closed canopy areas that provide the best forage as summer progresses and plant quality changes. In autumn, after the rut and into winter, moose intensify use of open areas with the highest biomass of dormant shrubs which contain the remaining major source of palatable forage. Closed canopy areas are used in late winter when forage is naturally at its lowest value and quantity for the year. The nature of the cover used at this time will provide the best protection available from wind and cold, and may range from tall shrub communities to tall closed canopy conifer stands (Peek, 2007). Metabolic

activity in moose generally corresponds to this pattern, being highest in summer and lowest in winter (Regelin et al., 1985). Alaskan moose generally do not use areas > 1,220 m in elevation (Ballard et al., 1991). Also, in Alaska, because forage quantity and quality (nutritional value) in summer and winter can differ by orders of magnitude, winter habitat availability is often the ultimate limit on moose abundance (Stephenson et al., 2006). Spatial heterogeneity of habitat on a relatively small scale ( $\leq 34 \text{ km}^2$ ) ( $13 \text{ mi}^2$ ) enhances habitat quality for moose (Maier et al., 2005), probably because it enables moose to respond to rapidly changing conditions such as weather (Stephenson et al., 2006).

Moose benefit from early successional stages of vegetation that provide woody browse (Schwartz, 1992). A disturbance regime that provides persistent shrub communities, distributed in a diverse mosaic on the landscape, is essential to high moose density (Stephenson et al., 2006). In Alaska, this disturbance can be provided by fire (LeResche et al., 1974; Maier et al., 2005), glacial outwash, and earthquakes (Stephenson et al., 2006). On the Kenai Peninsula, forest succession following fire provided the most abundant forage for moose 20 years post-burn (Bangs et al., 1985; Schwartz and Franzmann, 1989; Spencer and Chatelaine, 1953; Weixelman et al., 1998). Schwartz and Franzmann (1989) reported that, after a fire in 1969, moose abundance peaked about 15 years later, when browse plants reached maximum productivity. The moose increase was attributed to high production and low mortality, with some initial shifting of home ranges from adjacent high-density populations. Where fire had been absent for 25 years, moose densities on the Kenai Peninsula were sufficiently high to cause the forage base to shift from a multispecies complex to a much less diverse community dominated primarily by white birch (Oldemeyer et al., 1977). In the boreal forest, the optimum successional stages for moose are 11-30 years after burning (Kelsall et al., 1977).

In Game Management Unit (GMU) 17 in northern Bristol Bay, moose habitat is enhanced primarily by the scouring of gravel bars and low-lying riparian areas by ice and water during the spring thaw (Woolington, 2008). Willows and other plants quickly regenerate after bank scouring and subsequent deposit of river silt (Woolington, 2004). This disturbance mechanism is particularly important for the Nushagak and Mulchatna Rivers and for the lower reaches of the major tributaries to those rivers (Woolington, 2008). Major river systems with large riparian zones, such as the Nushagak and Mulchatna Rivers, contain alluvial habitats that support an abundant moose population, because they feature an abundance of nutritious food, primarily in the form of regenerating willow stands. Deciduous shrubs proliferate in these areas because of the annual influx of nutrients from waterways, sufficient soil moisture, and changing river channels. Lightning-caused wildfires also occur occasionally in GMU 17 (Woolington, 2008), and provide disturbance that enhances moose habitat. Moose habitat has not been formally assessed for GMUs 17B and 17C. Much of GMU 17 is wet or alpine tundra, and moose are located mostly along the riparian areas (Woolington, 2008).

In interior Alaska, female moose density was highest close to towns, at moderate elevations, in areas with greatest amounts of riparian habitat, and in areas where fire had occurred 11 to 30 years earlier (Maier et al., 2005). Moose avoided non-vegetated areas. Female moose preferred areas with patch plentiful diversity, indicating their need for habitat with both food and concealment. Maier et al., (2005) postulated that moose preferred to be near towns either because human disturbance of vegetation provided high-quality food, or because predators such as wolves and grizzly bears tend to avoid human-inhabited areas.

On the Copper River Delta, tall open alder-willow and low sweetgale-willow habitats were used most by moose, and use of tall closed alder-willow habitat was intermediate (MacCracken et al., 1997b). Aquatic and woodland spruce habitats were used the least by Copper River Delta moose. Aquatic plants were used seasonally during the period from April through August, and were used primarily for foraging by both sexes (MacCracken et al., 1993).

In northwest Alaska during March and April, moose used (quantified by percent of time) stands of felt-leaf willow (*Salix alaxensis* 85.0%), followed by other willow (*Salix*) (6.4%), riparian areas (3.9%), gravel bars (2.5%), and upland areas (1.3%) (Gillingham and Klein, 1992).

**Winter Habitat-** The influence of snow on moose habitat use patterns has received considerable attention. Heavy snow during severe winters can be a limiting factor for moose populations. Deep snow can reduce browse availability by burying it, and travelling through deep snow requires increased energy expenditure (Ballard et al., 1991). Snow characteristics that have ecological significance for moose include temperature, density, hardness, and depth (Peek, 1986). Because the temperature of snow fluctuates less than ambient temperatures (and never falls as low as the air temperature), snow provides insulation for moose against temperature extremes (Peek, 2007). Density and hardness influence the ability of an animal to travel across or through the snowpack. Under some conditions, snow density can be sufficient to support the mass of a wolf but not a moose. Under these circumstances wolf predation on moose tends to be high (Ballard and Van Ballenberghe, 2007). For other cervids (mule deer (*Odocoileus hemionus*) and elk), energy expenditure while moving through snow increases exponentially with increasing snowpack maturation through the winter. Hardness and density affect sinking depth, and snow level at front knee height has been suggested as a threshold parameter (Parker et al., 1984). Applying the same principals and relationship to moose, snow depth beyond 50-60 cm (20-24 in) would result in a relatively large increase in energy expenditure for movement (MacCracken et al., 1997a). Snow depths of 70–100 cm (28-39 in) have been shown to limit the travel of moose (Des Meules, 1964; Kelsall, 1969; Kelsall and Prescott, 1971). When snow depths approach 97 cm (38 in), moose have been confined to areas where forest canopies are dense (Kelsall and Prescott, 1971).

The distribution of snow within the forest influences moose habitat use patterns. Snow depth is nearly always greater in open areas until late winter, when snow exposed directly to the sun melts more rapidly than snow protected by tree canopies. Snow falling on tree branches of fine-needled

conifers, such as spruce, tends to be retained in the canopy and produces a lower snow depth immediately beneath the tree canopy in areas called tree wells (Pruitt, 1959). This snow tends to produce a hard dense surface when it falls from the tree branches to the ground, which provides more support for moose traveling beneath the canopy (Peek, 2007). In some geographic locations with deep winter snow, mature coniferous forests can provide zones of shallow snow accumulation that benefit moose survival (Balsom et al., 1996). In deep snow habitats where conifers are absent, such as in shrub/scrub tundra or riparian communities, moose use the best available microsites produced by combinations of shrub canopies and topography that reduce snow depths. However, the principal adaptation is simply to reduce energy expenditure (Peek, 2007).

Severe winters have been associated with high rates of starvation among moose calves (Ballard et al., 1991). In Quebec, females with calves preferred habitats providing protection from predators, whereas solitary adult females preferred habitats with moderate food abundance, moderate protection from predators, and substantial shelter against deep snow (Dussault et al., 2005). In Denali National Park and Preserve (DNPP) during the severe winter of 1986, large males were the only moose able to remain in the Jenny Creek unit, which had a higher forage biomass but deeper snow than other units (Miquelle et al., 1992). Moose are very tolerant of cold temperatures, but are susceptible to heat stress. The upper critical temperature range for moose during winter is -5 to 0°C; in summer upper thermal limits are 14 to 20°C (Renecker and Hudson, 1986).

### ***Food Habits***

Moose eat mainly leaves, twigs and bark of woody plants (Schwartz, 1992; Van Ballenberghe et al., 1989). Renecker and Schwartz (2007) reviewed the diets of moose, listing more than 221 plant genera/species, with willow (*Salix*), birch (*Betula*), and alder (*Alnus*) predominating across North America. Daily use patterns of time and space explain how moose satisfy hunger, remain fit, avoid thermal stress, maintain security from predators, and reproduce. Because many of an individual moose's life cycle needs interact daily, tradeoffs often occur, because most requirements are more critical at certain times than at others. The day-to-day needs of moose for food and thermoregulation are most often preempted in favor of other activities that accommodate reproduction. However, the survival instinct is satisfied most on a daily basis by optimizing food consumption while minimizing risk and effort. In this regard, a basic constraint for most moose is that food is abundant but of low quality (Renecker and Schwartz, 2007).

Moose are ruminants, with a four-chambered stomach. In ruminants, browse, forbs, and grass are held in the large-chambered rumen until adequate nutrients are extracted from fibrous materials and plant particles are small enough to pass through to the omasum and abomasum. Based on feeding habits, specialization and design of the digestive anatomy, ruminants are classified into three main groups (Hofmann, 1973): browsers that eat mainly shrubs and trees; grazers that eat mainly grass; and mixed or intermediate feeders that eat a mixture of grass, forbs, and browse. The moose is a browser and has been classified as a seasonally adaptive concentrate selector

(Hofmann, 1989). Concentrate selectors have a relatively small ruminoreticular chamber and must search for high-quality foods that will pass rapidly through the digestive system. Moose select plant species and parts (twigs and foliage) high in cell-soluble sugars that ferment rapidly in the rumen. They generally avoid plants that are fibrous and require extensive breakdown in size before passage from the rumen. Moose have a relatively narrow muzzle, prehensile lips, and a tongue that allow them to select high-quality plant parts (Renecker and Schwartz, 2007). Moose ferment mostly the soluble components of their food, and propel digesta rapidly through their digestive system (Schwartz, 1992). Their digestive efficiency is regulated by forage selection, rumination, gut morphology, and mechanisms controlling the rate of passage of food (Schwartz, 1992). Moose can ingest and process high-quality foods more rapidly, (e.g., aquatic plants eaten in summer), because both passage and digestion rates are increased (McArt et al., 2009).

Plant species distributed within the range of moose respond to seasonality by growing during the short summers and entering a state of dormancy during the long winters. Plant nutrient quality varies seasonally. Plants begin their growth phase in early spring, long before actual green-up occurs. In general, spring and summer foods are 1.5 to 3 times more nutritious than winter foods, depending on which constituent is examined (Schwartz and Renecker, 2007). Summer diets contain excess digestible energy and protein, whereas winter diets generally are insufficient to meet maintenance requirements (Renecker and Hudson, 1989; Schwartz et al., 1988; Schwartz et al., 1987). Moose feeding habits and diets vary seasonally as a result of a complex interaction of internal physiological regulators and the external environment. There is an annual cycle of food selection and intake, fat metabolism, metabolic rate, and body mass dynamics that is not driven simply by food quality and availability (Schwartz, 1992). The gastrocentric hypothesis predicts that large male moose will eat large amounts of low quality, fibrous foods, while smaller-bodied females will consume smaller amounts of higher-quality forage to meet the demands of reproduction and lactation (Oehlers et al., 2011). Both sexes reduce food consumption and metabolic rates in winter when they operate at a net energy deficit by mobilizing fat reserves (Miquelle et al., 1992; Schwartz, 1992).

Protein and energy are considered the major limiting nutrients within the environment (Schwartz, 1992). Summer protein intake is critical for lactating female moose (McArt et al., 2009). Tannins have a negative influence on forage quality, because they reduce the amount of protein available (Robbins et al., 1987). In two areas of Alaska, browse quality differences were consistent with observed differences in moose reproductive success (McArt et al., 2009). In recent years, the productivity of DNPP moose has been significantly higher than that of moose in the Nelchina Basin. A study of browse quality in the two areas found that, on average, nitrogen levels were 9% lower and tannin levels 15% higher in the Nelchina Basin than in DNPP, resulting in a digestible protein differential of 23%. McArt et al. (2009) concluded that the Nelchina moose population was nitrogen-limited. In both systems, browse quality declined significantly as summer progressed, with nitrogen levels decreasing and tannin levels increasing in all species of browse studied. In

comparison with early-summer forage, digestible protein had decreased by an average of 35% by mid-summer and 70% by late summer (McArt et al., 2009).

High-quality summer forage, particularly near wetlands, allows nursing cows to regain body condition and calves to grow so they can better escape predators and survive their first winter (ADFG, 2011d). During the spring-summer period, moose feed in aquatic habitats. In the Copper River Delta, aquatic habitats produced about four times more forage than terrestrial habitats, and the forage was more digestible (MacCracken et al., 1993). Although some researchers have linked summer consumption of aquatic plants by moose to a craving for sodium (Jordan, 1987), data from the Copper River Delta did not support this hypothesis. Rather, these data suggested that moose selecting aquatic forage were switching from an energy-maximizing to a time-minimizing strategy (MacCracken et al., 1993) because aquatic plants were high in water content. Although a moose can fill its rumen quickly, the relative quantity of dry matter consumed is less than when eating the same amount of terrestrial vegetation, such as leaves.

Moose also select bark as part of their diet seasonally, although it forms a relatively small part of the diet. Bark stripping occurs mostly in winter, when there are fewer twigs available due to snow cover (MacCracken et al., 1997b). In DNPP, female moose also stripped bark in aspen-spruce forests in May and June, coincident with birth and lactation (Miquelle and Van Ballenberghe, 1989). Moose also avoid certain plant species because of low palatability due to their chemical defenses, such as black cottonwood (*Populus balsamifera trichocarpa*) on the Kenai Peninsula (Weixelman et al., 1998) and white spruce (*Picea glauca*) both on the Kenai and in other parts of Alaska (Weixelman et al., 1998).

In the Copper River Delta, moose consumed three different diets that varied among winter, spring/early summer, and late summer/fall (MacCracken et al., 1997b). Willow dominated all three diets; the differences were related to the amounts of sweetgale (*Myrica gale*), marsh five-finger (*Potentilla palustris*) and graminoids in the diet. Winter diets included sweetgale and alder (*Alnus* spp.), which are both nitrogen-fixers, leading to relatively higher protein content. Spring/early summer diets were most diverse, due to the increased use of emergent aquatic plants such as marsh five-finger. Late summer/fall diets were least diverse, consisting almost entirely of willow leaves and twigs (MacCracken et al., 1997b).

Moose diets in DNPP were also found to vary by season. In summer, seven species of willow constituted 81.5% of the diet (Van Ballenberghe et al., 1989), and diamond-leaf willow (*Salix planifolia*) was eaten more than any other plant species (45.7%). Willow constituted 94% of DNPP moose diets in winter (Risenhoover, 1989).

Moose can influence the composition and productivity of the terrestrial plant community through browsing (Bedard et al., 1978). In DNPP, moose initiated positive feedback loops in their environment through browsing (Molvar et al., 1993). Willows exhibited a growth response to

moose herbivory; specifically, leaf area was significantly greater at a site with high moose density than at a site with low moose density. Annual biomass productivity per growing point on willow stems increased with increasing browsing intensity on the plant as a whole because of release from apical dominance. Moose also increase nutrient cycling rates because their urine and feces transfer nutrients to soil. The organic content of soil can also be enhanced by moose, in turn benefitting microbiota such as decomposers (Molvar et al., 1993). In interior Alaska, twigs re-growing from two-year old willow stems that had been browsed by moose had larger diameters than those that had not been browsed in the previous year (Bowyer and Neville, 2003). Browsing on felt-leaf willow had no effect on nitrogen content, digestibility, or tannin content, indicating that the willow had no tannin-mediated inducible defense system in response to herbivory (Bowyer and Neville, 2003).

MDNs carried upstream by spawning salmon have implications for nutrient flow into riparian habitats, and are thought to enhance growth and productivity therein (Quinn et al., 2009). Although it is plausible that MDNs contribute to increased plant productivity and thus benefit moose, evidence of this direct impact was not located in the scientific literature.

Moose density is often associated with food abundance (Eastman and Ritcey, 1987; Joyal, 1987; Oldemeyer and Regelin, 1987; Schwartz and Franzmann, 1989; Thompson and Euler, 1987). As reviewed by Renecker and Schwartz (2007), forage biomass varies with successional stage of forests. In Newfoundland, available woody biomass increased from about 200 kg/ha (179 lbs/ac) in two-year-old clear cuts to more than 2,000 kg/ha (1,786 lbs/ac) at 8 years, at which time it peaked and subsequently declined gradually (Parker and Morton, 1978). On the Kenai Peninsula, important browse species peaked about 15 years after fire (Spencer and Hakala, 1964). Oldemeyer and Reglin estimated the biomass of important browse species in successional stands on the Kenai NWR; browse production measured at 3, 10, 30, and 90 years post-burn was 37, 1,399, 397, and 4 kg/ha (33,1,249, 354, and 3.6 lb/ac), respectively (Oldemeyer and Regelin, 1987).

## ***Behavior***

**Movements and Home Ranges-** The ways in which moose use their environment both spatially and temporally are of great interest to resource managers (Hundertmark, 2007). The dynamics of animal movements and distribution in space and time are integral to behavioral, ecological, genetic, and population processes. Thus, the attributes of the space occupied by individual animals, both annually and seasonally (home ranges), patterns of movement within home ranges, establishment of new home ranges by young moose, and colonization of new habitats (dispersal) and movements between seasonal ranges (migration) must all be considered in comprehensive management programs.

Moose home range sizes vary with the sex and age of the animal, season, habitat quality, and weather. Two studies from Alaska generated the largest estimates of home range size, although one of these (Grauvogel, 1984) included migratory locations in the estimate of seasonal ranges,

which can increase home range size significantly (Hundertmark, 2007). Moose in south-central and northwest Alaska (Ballard et al., 1991) had mean seasonal ranges  $> 92 \text{ km}^2$  ( $36 \text{ mi}^2$ ). With the exception of home ranges of non-migratory adults in the later study, total home range sizes exceeded  $259 \text{ km}^2$  ( $100 \text{ mi}^2$ ). In contrast, estimates of annual ranges for moose in northwest Minnesota were  $\leq 3.6 \text{ km}^2$  ( $1.4 \text{ mi}^2$ ) (Phillips et al., 1973).

Seasonal ranges, when they exist, represent partitioning of the environment based on behavioral and energetic constraints. Migratory moose (those that use separate winter and summer ranges) use distinct seasonal ranges because they attempt to optimize their nutrient intake on summer range, but conditions on these ranges may preclude occupation during some or all winters. Moose that remain on the same range during winter and summer are termed non-migratory, and remain because environmental conditions permit it. A third seasonal range, associated with mating, occurs in autumn, but many investigators define this as part of the summer range (Hundertmark, 2007). Breeding areas for tundra moose are typically in open habitats where visibility is good. This is likely for behavioral purposes so bulls and cows can see each other as they display. It may also afford some protection from predators.

In several moose populations studied in Alaska, some individuals were non-migratory residents whereas others migrated seasonally. In the Copper River Delta, 8 of 15 collared females were migratory, whereas 2 of 5 collared males were migratory (MacCracken et al., 1997b). Moose in the study area exhibited greater fidelity to summer range than to winter range (MacCracken et al., 1997a). Winter severity influenced yearly winter migratory behavior in the Copper River Delta (Stephenson et al., 2006). Moose populations in south-central Alaska (GMU 13, consisting of the Nelchina and upper Susitna basins) also included both migratory and non-migratory individuals (Ballard et al., 1991). Migratory moose exhibited three seasonal periods of movement – autumn migration to wintering areas, spring migrations to calving areas or summer feeding grounds, and early fall migrations to rutting areas (Ballard et al., 1991). In the Togiak River drainage of the northern Bristol Bay area (GMU 17A), some collared moose were resident whereas others migrated seasonally (Woolington, 2008). During a population estimation survey in February 1995, 29 moose were documented moving westward from the upper Sunshine Valley in GMU 17C (the lower Nushagak watershed) into GMU 17A (Woolington, 2008).

Cows with new-born calves restrict their movements for the first few weeks, after which they gradually expanded their home range to approximate home range size of other adults (LeResche, 1974). In one study, cow-calf pairs had smaller summer home ranges than did other moose, and calf movements increased exponentially with age during the first six weeks of life (Ballard et al., 1980).

When comparing among the sexes, males are almost always found to occupy larger annual home ranges. In south-central Alaska, males had significantly larger home ranges than did females (Ballard et al., 1991). In northwestern Alberta researchers found no difference between the sexes,

but noted the tendency for bulls to occupy larger winter and spring home ranges (Lynch and Morgantini, 1984).

In several Alaskan moose population, the timing of seasonal migration has been observed to vary significantly among individuals. In the Nelchina Basin (GMU 13), individual moose movements varied by month both in the initiation and the duration of winter migration (Van Ballenberghe, 1977). Snow depth was an important factor that influenced winter migratory behavior in that population. Cows with calves tended to migrate to wintering grounds earlier than did males and cows without calves (Van Ballenberghe, 1977). During spring, the initiation of migration varied substantially between individuals, but all migrated quickly once they started moving (Van Ballenberghe, 1977). Individual moose in GMU 13 initiated migration to wintering areas, ranging from mid-August to mid-February (Ballard et al., 1991). Dates of spring migration ranged from March through mid-July; during some years, moose remained on the winter range for calving. Subsequent movement to the summer range in mid-summer seemed related to plant development (Ballard et al., 1991).

Moose in various areas within Alaska migrated differing distances seasonally and had varied annual home range sizes (Ballard et al., 1991; Gillingham and Klein, 1992; MacCracken et al., 1997b) (Table 2). Moose on the Seward Peninsula of northwest Alaska migrated up to 80 km (49.7 mi) seasonally (Gillingham and Klein, 1992). In south-central Alaska, the distance between winter and summer ranges of migratory moose averaged 48 km (29.8 mi), and varied from 16 to 93 km (9.9 to 57.8 mi) (Ballard et al., 1991).

Moose use of seasonal home ranges varies little from year to year (Ballard et al., 1991). In south-central Alaska GMU 13, only one of 101 radio-collared female adults dispersed from their home range during a 10-yr study period (Ballard et al., 1991). During the fall of 1978, that female moved 177 km (110 mi) from her previous location (Ballard et al., 1991).

In the northern Bristol Bay region, some moose collared in GMU 17A beginning in 2000 have moved westward within GMU 17A and into the southern part of GMU 18 (Woolington, 2008). This is thought to be part of a continued westward expansion into previously unpopulated moose habitat (Woolington, 2008).

**Table 2. Mean (range) home range size (km<sup>2</sup>) for selected moose populations in Alaska.**

Study area	Migratory status	Age/Sex	Mean home range size (km <sup>2</sup> )			Reference
			Total	Winter	Summer	
Kenai Peninsula	M	Adult/M	137 (56–185)			(Bangs et al., 1984)
	N	Adult/M	52 (34–64)			
	N	Adult/F	127 (25–440)	63 (13–184)	36 (2–152)	(Bangs and Bailey, 1980)
Seward Peninsula	M	Adult	938 (236–1,932)	311 (36–1,393)	324(41–1,323)	(Grauvogel, 1984)
	N	Adult	218 (91–350)	98 (36–223)	93 (44–150)	
	I	Adult	339 (205–593)	122 (21–334)	210 (60–559)	
South-central	N	F	290 (111–787)	113 (10–430)	103 (23–456)	(Ballard et al., 1991)
	M	F	427 (274–580)	147 (15–375)	263 (60–622)	
Southeast	N	Adult/F	28 (9–51)	11 (3–30)	14 (2–30)	(Doerr, 1983)

Migratory status: M = migratory, N= nonmigratory, and I = intermediate. Data from Hundertmark (2007).

***Sexual Segregation and Grouping Behaviors-*** Bowyer et al. (2003) provide a succinct discussion of sexual segregation in moose, and we paraphrase it here. Sexual segregation is the differential use of space by the sexes outside the mating season (Barboza and Bowyer, 2000) and often includes differential use of habitats and forage. Sexual segregation is especially pronounced in moose and plays a crucial role in their ecology (Bowyer et al., 2001; Miller and Litvatitis, 1992; Miquelle et al., 1992). In Alaska, male and female moose select habitats differently, leading to their spatial segregation throughout most of the year (Oehlers et al., 2011). Adult males select habitats with greater forage abundance and females select areas with more concealment cover during winter (Bowyer et al., 2001; Miquelle et al., 1992), whereas, cows with calves select denser cover and are more secretive than other age groups (Peek, 2007). Females with calves remained solitary and preferred forested habitats, which provided better cover from predators. Miquelle et al. (1992) found that spatial segregation was most extreme during a deep-snow winter, when only large males could access forage at higher-elevation Jenny Creek due to their larger body size. Such differences in habitat use between the sexes have implications for surveying of moose populations, because it can affect the accuracy of sex and age ratio information obtained by direct observation (Bowyer et al., 2002; Peek, 2007; Peterson, 1955; Pimlott, 1959).

The effect of habitat enhancement on sexual segregation was studied in interior Alaska after willow stands had been mechanically crushed (Bowyer et al., 2001). During winters following the treatment, males occurred predominantly on the more open, disturbed area. Adult females and young resolved the tradeoff between foraging on a greater abundance of food in the disturbed area and a reduced risk of predation in the mature stand by using older stands of untreated willow, where dense vegetation offered substantial concealment from wolves (Bowyer et al., 2001).

The way in which moose, either individually or in groups, partition their habitats and associate with other moose can be informative in determining needs of various segments of the population (Hundertmark, 2007). Moose have been referred to as “quasi-solitary,” and large groups are uncommon (Houston, 1968). The tendency of moose to lead a solitary life or to occur in groups depends on their age, sex, and reproductive status, and varies by season. Molvar and Bowyer (1994) note that Alaskan moose are more gregarious than moose from Eurasia and suggest that the formation of social groups is a recently evolved adaptation in response to a relative abundance of predators and to relatively open terrain. In DNPP, larger groups ventured farther from cover but were less efficient at foraging due to inter-individual aggression (Molvar and Bowyer, 1994).

Cows with calves are consistently the most solitary members of the population, probably because of predator avoidance (Hauge and Keith, 1981; Hundertmark, 2007; Miquelle et al., 1992). Alaskan female moose with calves are nearly always solitary at the time of birth (Miquelle et al., 1992; Molvar and Bowyer, 1994). Females without calves are more likely than males to be solitary during early summer, but they become more gregarious as summer progresses (Miquelle et al., 1992). In DNPP, during the summer, females without calves were seen alone only 23% of the time (Miquelle et al., 1992). During June-August, male moose in DNPP were consistently gregarious (Miquelle et al., 1992). When in a group, small males were more likely than large males to be in a group that included females at all times except the rut and post-rut (Miquelle et al., 1992).

In south-central Alaska GMU 13, calves separated from their mothers at an average age of 14 months (Ballard et al., 1991). In that study, 33% of yearlings and a single 2-year old moose were observed in 1 to 6 temporary re-associations with their mothers after their original dispersal. Calves were more likely to re-associate with their mother if she was not caring for a new calf (Ballard et al., 1991).

**Mating and Maternal Behaviors-** Moose in North America display two general patterns of mating behavior. In the taiga of Canada, moose have a serial mating system, in which bulls search for cows in heat by traveling widely while calling and thrashing their antlers (Bubenik, 2007). The bull digs shallow pit holes in which he urinates, but they are located randomly and seldom in the same spot in successive years. For all the cows to be bred during the 3-week mating season, the serial mating strategy requires the presence of a relatively high number of bulls. For moose living in tundra habitats, Bubenik (2007) concluded that due to differences in climatic conditions of the periglacial tundra, the tactic of serial mating was replaced by communal or harem mating. Among tundra moose, a prime bull settles in a mating area of about 10 km<sup>2</sup> (3.9 mi<sup>2</sup>) toward the end of August. Rutting areas are used traditionally (Bubenik, 2007). In early September, bulls begin scent-urinating on trails and in pit holes. Two prime-aged bulls may share a harem when it contains 8 or more cows. During the 8 to 10 days of breeding in the harem, a tundra bull probably can fertilize as many or more cows as a taiga bull does during the entire 3-week rut because the

tundra bull can mate with each female in his harem without traveling long distances to locate a new female.

Many mammals have evolved seasonal reproductive patterns that ensure adaptation to predictable annual changes in the environment. Moose exhibit marked seasonal changes in reproductive behavior that reflect adaptations to yearly fluctuations in food availability and that ensure favorable conditions for rearing young (Schwartz, 2007). Thus, moose breed only during autumn. Breeding in the fall ensures that calves are born in spring when forage is high in nutrient quality and that cows have a high probability of producing enough milk to successfully raise their calves. Day length may provide the clue to annual timing of the breeding season. The breeding season for moose is relatively short. Because it is difficult to determine the exact date of breeding under natural conditions, few studies provide detailed information. Researchers with the most robust data sets have concluded that moose exhibit a very well-defined breeding season, as judged by conception dates and the spread of observed breeding (Crichton, 1992; Schwartz and Hundertmark, 1993; Thomson, 1991). The mean date of breeding in British Columbia ranged from October 5 to 10, with a standard deviation of 5 days (Thomson, 1991). The mean breeding date in Manitoba was September 29, and 93% of females were bred by October 12 (Crichton, 1992). The mean breeding date in Alaska was October 5, with a range from September 28 to October 12. Annual variation in breeding dates in all studies was minor, suggesting that photoperiod, rather than weather influenced rut timing. Synchrony of the rut has also been observed in DNPP. Over a 12-year interval, rutting consistently occurred during the brief period from September 24 through October 5 (Van Ballenberghe and Miquelle, 1993).

Moose cows across North America give birth during a relatively short period. The peak birthing period occurs from about May 15 through June 7 (Schwartz, 2007). In DNPP, timing of birth in moose was consistent from year to year, despite variation in climate between years (Bowyer et al., 1998). Birth timing exhibited “extreme synchrony” and Bowyer et al. (1998) hypothesized that moose were tracking long-term patterns of climate to time reproduction. Hence, there is concern that moose will be vulnerable to climate change independent of changes to vegetation (Bowyer et al., 1998).

In DNPP, the primary drivers influencing birth site selection were microclimate, forage abundance and quality, and risk of predation (Bowyer et al., 1999). Birth sites were not re-used, and some females appeared to behave unpredictably shortly before giving birth, perhaps in an attempt to thwart predators (Bowyer et al., 1999). Proximity to human development did not influence birth site selection. Moose preferred birth sites with abundant willow, high visibility (to detect predators), and a southeasterly exposure that would be warmer and drier (Bowyer et al., 1999). Bark stripping was common around birth sites, because females seldom travelled more than 100 m (328 feet) from their young and hence rapidly depleted the birth site’s forage (Bowyer et al., 1999).

**Activity Budgets-** Moose spend most of their active time foraging. Seasonal rates of forage intake tend to follow the cyclic nature of energy metabolism in moose (Regelin et al., 1985), with higher rates of activity and intake in spring and summer and reduced rates during winter. Activity budgets tend to follow a similar pattern. Activity budgets have been studied for DNPP moose during winter (Risenhoover, 1986) and spring/summer (Van Ballenberghe and Miquelle, 1990). DNPP moose exhibited low activity levels from January through April, when they were active, on average, only 27.3% of the time (6.5 h/d) (Risenhoover, 1986). Behaviors associated with resting and foraging comprised 99.3% of DNPP moose winter activity budgets. In contrast, Miquelle et al. (1992) found that during winter in DNPP, small males spent some of their active time engaged in social behavior. In both winter and early spring in DNPP, moose exhibited a polyphasic pattern, alternating between foraging and bedding, with about six cycles per 24 hours (Risenhoover, 1986).

Following their relative inactivity in winter, DNPP moose increased their metabolic rate in April, as evidenced by the onset of antler development in males and increased mobility of cows (Risenhoover, 1986). Activity increased during May to a peak in early June, then began to decline until mid-August (Van Ballenberghe and Miquelle, 1990). DNPP moose were active 12.8 h/d at the peak, and activity declined to 9 h/d by late summer (Van Ballenberghe and Miquelle, 1990). In summer DNPP moose spent about equal amounts of time feeding, resting and ruminating during each 24-h period (Van Ballenberghe and Miquelle, 1990). The differences between winter (Risenhoover, 1986) and spring/summer (Van Ballenberghe and Miquelle, 1990) activity budgets in DNPP, are summarized in Table 3.

**Table 3. Moose activity budgets in winter<sup>1</sup> and spring/summer<sup>2</sup> in Denali National Park and Preserve (averages)**

<b><u>Activity Parameter</u></b>	<b><u>Winter</u></b>	<b><u>Spring/Summer</u></b>
Total active time/day (hr)	6.5	10.1
Total resting time/day (hr)	17.5	13.9
# Activity bouts/day	5.7	8.2
Duration of activity bouts (min)	68	73
Duration of resting bouts (min)	178	97
Foraging time/day (hr)	4.9	7.5
Rumination time/day (hr)	11.7	6.7

1= "Winter" is January through April; data from Risenhoover 1986

2="Spring/Summer" is 1 May through 15 August; data from Van Ballenberghe and Miquelle (1990)

On the Seward Peninsula of northwestern Alaska, moose winter activity budgets were 43.2% feeding, 42.8% bedding, 8.4% walking, 4.4% standing, and 1.2% other (Gillingham and Klein, 1992). Walking time was far greater than reported during winter in DNPP (where it was < 1%) (Risenhoover, 1986). Gillingham and Klein (1992) attributed this difference to moose on the Seward Peninsula using the Kuzitrin River as a feeding and movement corridor during winter. The

use of a narrow, linear feature, such as a river bottom, requires moose to travel farther up and down the river to obtain food, as opposed to feeding in a large, non-linear area. At least 2 other differences between moose in DNPP and the Seward Peninsula are notable. First, DNPP is characterized by an abundance of predators (wolves and bears), whereas no predators use the Seward Peninsula in winter (Gillingham and Klein, 1992). Second, moose activity on the Seward Peninsula was highly synchronized during mid-afternoon in late April, presumably due to heat stress (Gillingham and Klein, 1992). In contrast, there was no significant correlation between mean daily temperature and daily activity level in DNPP during winter (Risenhoover, 1986).

On the Copper River Delta, the duration of inactive periods of moose was shortest on the west delta, which had the highest estimates of forage abundance and quality among the 3 areas studied (MacCracken et al., 1997a). This suggests that the relative duration of inactive bouts might be useful as an index of habitat quality for moose.

### ***Interspecies Interactions***

Boer (2007) provided an excellent review of the interspecific relationships between moose and other species. Interspecific interactions between moose and other species take on one or more of the following general forms: competition, parasite-mediated competition, predation, and commensalism (Boer, 2007). Due to the diversity of habitats, species combinations, and abundance of sympatric species throughout the moose range, a variety of competitive mechanisms operate. Of the interspecific interactions possible, competition most obviously influences moose habitat use and distribution (Boer, 2007). Throughout their North American range, moose compete with an array of other ungulate species. However, in the Nushagak and Kvichak watersheds, caribou are the only other ungulate species abundant enough to compete with moose. Direct competition between moose and caribou appears limited and insignificant (Davis and Franzmann, 1979). Food preferences of moose and caribou coincide to some degree, but the diet of caribou appears to be more specialized. In winter, caribou consume forbs and deciduous vegetation and lichens (Darby and Pruitt, 1984; Servheen and Lyon, 1989). Moose primarily consume browse, but also use forbs and deciduous vegetation during summer (Dodds, 1960; Eastman and Ritcey, 1987).

As reviewed by Boer (2007), in multi-prey systems, moose and caribou populations may influence each other indirectly. Increasing moose numbers in western and central portions of DNPP have resulted from increased availability of caribou as alternate prey for wolves (Singer and Dalle-Molle, 1985). In the eastern section of DNPP, migrating caribou were available as prey for only a brief period of time, and therefore, were not a particularly important factor of the area's prey base; moose populations have declined. Moose are the primary prey of wolves in other areas of Alaska as well (Gasaway et al., 1983), although other authors have attributed an increase in moose numbers in northern Alaska to a preference by wolves for caribou (Coady, 1980).

Interspecific population dynamics have been studied in several areas of Alaska with multiple predator and prey species. These relationships can be quite complex and can vary based on both abiotic and biotic factors within the ecosystem. None of the interspecies studies reviewed here were conducted in the Nushagak and Kvichak watersheds.

In Alaskan ecosystems with multiple predators, bears were responsible for more moose calf kills than were wolves. Black bears can be significant predators of moose calves (Franzmann et al., 1980). Of 47 radio-collared neonatal calves on the Kenai Peninsula, black bears killed 34%, whereas brown bears and wolves each killed 6% (Franzmann et al., 1980). In the western Interior, near McGrath, black bears were also the dominant source of predation mortality of calves during 6 out of 7 years studied; wolves and brown bears were secondary predators in that system (Keech et al., 2011). In contrast, brown bears were the primary predators of moose calves in a south-central Alaska study, causing 73% of calf mortality (Ballard et al., 1991). Brown bears were also the primary predator in east-central Alaska (GMU 20E), where 79-82% of radio-collared moose calves died by the age of eleven months (Gasaway et al., 1992). In that study, 52% of moose calves were killed by brown bears, 12-15% of calves by wolves, and 3% by black bears.

Several studies have compared the causes of calf mortality in the nutritionally unproductive 1947 burn and in the productive high-quality habitat of the 1969 burn on the Kenai Peninsula, Alaska (Franzmann and Schwartz, 1986; Schwartz and Franzmann, 1989; Schwartz and Franzmann, 1991). Black bears killed 34 and 35% of the calves, respectively, whereas wolves and brown bears killed 5 and 13%, respectively. Total calf mortality from all causes ranged from 51-55%. Moose densities were 4 times greater in the 1969 burn area ( $370/100 \text{ km}^2$ ) ( $9.6/\text{mi}^2$ ) and the population was increasing, whereas the population in the 1947 burn was about  $100/100 \text{ km}^2$  ( $2.6/\text{mi}^2$ ) and declining. The investigators concluded that habitat quality had a significant impact on reproductive rate and population growth. The moose population in high-quality habitat (1969 fire area) was capable of sustaining this level of predation and continued to grow, whereas the population in poor habitat (1947 fire area) was not.

Wolves appeared to select for moose calves in some areas and seasons in Alaska, but not in others. In south-central Alaska, moose calves were taken in proportion to their abundance during May through October (Ballard et al., 1987). In contrast, during November through April wolves preyed on moose calves selectively. During those winter months, calves were only 12-20% of the moose population, but they comprised 40% of kills by wolves (Ballard et al., 1987). During autumn in northwest Alaska, wolves did not display selectivity for moose calves, which were killed in proportion to their abundance in the population (Ballard et al., 1997). On the Kenai Peninsula, wolves killed mostly moose calves (47%), yearlings, and older adults (Peterson et al., 1984). Half of moose adults killed by wolves during that study were >12 years old. Wolf predation on moose calves was highest during the winter with deepest snow, and calves killed after 1 January were commonly malnourished, with bone marrow fat content  $\leq 10\%$ .

In east-central Alaska (GMU 20E), predation was the primary cause of non-hunting deaths for yearling and adult moose (Gasaway et al., 1992). Of 46 non-hunting moose deaths during 1981-1987, 89% were killed by brown bears or wolves, 9% died from antler wounds or locked antlers, and 2% drowned. Peterson et al. (1984) examined the incidence of debilitating conditions among 109 wolf-killed adult moose on the Kenai Peninsula. They found that 20 had moderate or severe periodontitis, 14 had arthritis, 1 had a broken leg, and 1 had a leg wedged between trees. Of 40 wolf-killed adult moose assessed for bone marrow fat content, 4 had levels  $\leq 20\%$ , indicating severe malnutrition (Peterson et al., 1984).

Wolves in various regions in Alaska displayed different relative preferences for moose and caribou as prey. In south-central Alaska, moose were the primary prey of wolves, constituting 38% of observed kills, whereas caribou were the second most important prey at 21% (Ballard et al., 1987). In northwest Alaska, caribou were the preferred prey of wolves (Ballard et al., 1997). In January through April 1988, when caribou were abundant, 92% of observed ungulates killed by wolves were caribou. In contrast, in 1989 and 1990 when caribou were less abundant, they constituted 11% and 48% of observed ungulate kills, respectively (Ballard et al., 1997).

Estimated kill rates for wolf packs on the Kenai Peninsula varied from 1 moose every 3.1 days to 1 moose every 21.4 days (Peterson et al., 1984). The average kill interval in winter for Kenai wolf packs with more than 2 members was 4.7 days. In 38 wolf-moose encounters observed on the Kenai Peninsula, wolves succeeded in killing only 2 moose (Peterson et al., 1984).

Ballard et al. (1997) speculated that the recent occurrence of moose (since the 1940s) in northwest Alaska has altered the historical migratory patterns of wolves in that area. There is evidence that wolves in northwest Alaska formerly migrated with the caribou herds, but now they do so only when alternate prey (moose) numbers are insufficient.

### ***Mortality, Productivity, and Survivorship***

Understanding the dynamics of a population requires knowledge of how many individuals it contains, how fast it is increasing or decreasing, its rate of production of young, and its rate of loss through mortality (Van Ballenberghe and Ballard, 2007). Moose populations increase by the addition of calves born to the population each year and decrease by the loss of animals. Moose die from a variety of causes including hunting, predation, starvation, accident, drowning, vehicle collision, parasites, and disease. Mortalities are generally divided into two major categories: human-caused or natural. Moose populations are adaptable to artificially disturbed habitats, and therefore are often found in close proximity to roads, major highways, and railways, but this association can cause significant mortality (Child, 2007). In populated areas of Alaska, large numbers of moose are killed each year by collisions with motor vehicles and trains (Bowyer et al., 2003; Child, 2007). During 1963-1990, 3,054 moose were killed on the Alaska Railroad, with losses ranging from 7 to 725 annually (Modafferi, 1991). In the severe winter of 1989-1990, deep snow caused many moose to travel on roads and railroads and fatalities exceeded the previous

record by more than 100 animals. That winter, in the Willow-Talkeetna area, the number of railroad kills represented a 70% loss from the resident population (Schwartz and Bartley, 1991). Other sources of mortality include sport and subsistence hunting and poaching (Woolington, 2004).

Prime-aged moose tend to have very high rates of survival because they are not as vulnerable to natural causes of mortality as younger (calves) or older age classes. Survival rates are generally estimated by radio collaring individuals and following them for some period of time (Van Ballenberghe and Ballard, 2007). Ballard et al. (1991) provided data on mean annual survival rates from a sample of radio-collared adult female moose during a 10-year period. From 25 to 80 moose per year were followed in a study area where hunting of cows was prohibited. Annual survival rates were estimated at 94.8%. Data from yearling females spanned 4 years with 2 to 22 individuals per year collared, and annual survival rates averaged 95.1%. Annual survival of yearling and adult males averaged 75.4 and 90.9% respectively, with hunting the major mortality factor. On the Kenai Peninsula, researchers followed 51 radio-collared females for 6 years, reporting a 92% annual survival rate (Bangs et al., 1989). Survival of cows aged 1 to 5 years was estimated at 97% and 84% for females aged 16 to 21 years. Hunting was not a significant cause of mortality of the study population. As reported by Van Ballenberghe and Ballard (2007), various other studies using radio-collared moose have reported annual survival rates of adults ranging from 75 to 94%, depending upon the extent of human hunting. In general, starvation and wolf predation during severe winters causes the greatest mortality in older age classes (Ballard et al., 1991; Bowyer et al., 2003); moose weakened from starvation are particularly vulnerable to wolf predation. Bull moose occasionally wound each other during the rut and die from these wounds (ADFG, 2011d).

As reviewed by Van Ballenberghe and Ballard (2007), hunting is a major limiting factor of many moose populations throughout the world, and can reduce moose population density (Crete et al., 1981). In Quebec, where natural mortality apparently was low, harvest rates as high as 25% were reported (Crete, 1987). Moose harvest rates ranging from 2 to 17% have also been reported for various other parts of North America (Crete, 1987). In some European environments, where severe winters, predation and nutritional stress are absent, moose harvest as high as 50% of the winter population is sustainable (Cederlund and Sand, 1991). In concert with other factors, including severe winters, high harvest rates have contributed to moose population declines in Alaska (Gasaway et al., 1983). In addition, hunting can significantly reduce the number of bulls, perhaps sufficiently to reduce the level of first-estrus conception (Bishop and Rausch, 1974). When, due to heavy hunting pressure, there are fewer than ten bulls per 100 cows, some cows simply may not encounter a bull early in the mating season. Breeding early in the mating season means the rut, and therefore calving would be synchronous. A cow mating late in the breeding season will calve later calving in the spring. Most North American moose populations harvested at this rate would decline sharply. In nearly all areas where hunting is legal, harvest is managed under sustainable

principals, so hunting mortality seldom results in unintended population declines (Timmerman and Buss, 2007).

Both hunter numbers and moose harvest have increased in the Nushagak and Kvichak watersheds in recent decades. Responding to a 4-fold increase in moose hunters in GMU 17 from 1983 to 2006 (from 293 to 1,182), reported moose harvest tripled (from 127 to 380). In GMU 17B (the upper Nushagak watershed), the reported harvests for the past 5 years that data were available, varied from 113 to 183, with a mean annual harvest of 149 moose. In GMU 17C (the Togiak watershed), the 5-year mean annual harvest was 224, with a range of 193 to 251 (Woolington, 2008). Legal moose in GMUs 17B and 17C for Alaska residents are those with spike-fork antlers, antler spreads of no less than 50 inches (127 cm) or at with at least 3 brow tines on one antler. The largest antlers reported exceeded 69 inches (175 cm).

Juvenile moose tend to have lower survival rates than adults. Calves are typically the most vulnerable age class. Calf moose mortality can be divided into two general time periods when mortality is highest: from birth to about 6 months of age, and from about 6 months to 1 year of age (Van Ballenberghe and Ballard, 2007). These periods correspond roughly to particular vulnerabilities, specifically, to bear and wolf predation in the first period and hunting (in some areas), wolf predation, and winter starvation in the second period. According to Van Ballenberghe and Ballard (2007), neonatal mortality varies greatly, depending on several factors, most notably the extent of predation. Several studies of radio-collared moose calves have documented that predators may account for up to 79% of newborn deaths and that survival during the first eight weeks of life may be as low as 17% (Ballard et al., 1981; Ballard et al., 1991; Franzmann et al., 1980; Gasaway et al., 1992; Larsen et al., 1989; Osborne et al., 1991). Further losses during the first year of life may reduce annual survival to as low as 10% (Van Ballenberghe and Ballard, 2007). In south-central Alaska, Ballard et al. (1991) observed that brown bears caused the majority of natural death of calves younger than 5 months of age, whereas, on the Kenai Peninsula, Franzmann et al. (1980) documented that black bears were the greatest cause of moose calf mortality.

Moose breed in late September to early October (Van Ballenberghe and Miquelle, 1993) and adult females give birth to 1 or 2 calves in late May–early June each year (Peterson, 1955; Schwartz, 2007; Testa et al., 2000), and litters of 3 are rare (Coady, 1982). Production of moose calves is the result of a complex chain of biological processes including estrus cycles, rutting behavior, fertilization, gestation, pre-partum events and birth (Boer, 1992; Schwartz, 2007; Van Ballenberghe and Ballard, 2007). Fecundity, or productivity of individual moose, is related to sexual maturation and a broad array of ecological factors affecting food supply, forage quality, and weather that affect the physiological status of females. These factors influence ovulation, pregnancy rates, litter size, and fetal sex ratios. Ultimately, fecundity and subsequent survival of young determines recruitment rates and population trends.

Studies of reproductive tracts have shown that female moose do not ovulate in their first year of life and thus do not produce calves as yearlings. Cows may or may not breed in their second year, depending on body mass (Saether, 1987). Most cows are sexually mature at around 28 months of age and females continue to breed to the end of their life (~18 years) (ADFG, 2011d; Schwartz, 2007). Twinning rates were shown to be strongly correlated with body condition of female moose (as influenced by habitat quality) in several diverse moose populations (Franzmann and Schwartz, 1985). In an area known to contain abundant high-quality food resources on the Kenai Peninsula, up to 70% of cows with calves had twins the subsequent year. This contrasts to other populations, in which twinning rates as low as 5% were reported (Houston, 1968; Markgren, 1969; Pimlott, 1959), but some of the estimates may have considered post-natal mortality. Twinning rates exceeding 40-50% are uncommon for moose populations strongly limited by nutrition. Twinning frequency is a good indicator of cow health condition and habitat quality (Dodge et al., 2004). Calves that survive predation in the summer are weaned in August, but will remain with their mother until the next calf is born the following spring (Schwartz, 2007), or for an additional year if no new calf is born (Testa, 2004).

### ***Population, Subpopulations, and Genetics***

The number of animals in a population (abundance), is only useful when the geographic boundaries of an area are well defined, because that allows biologists to estimate density (the number of individuals per unit area), which is a more useful parameter. Gasaway et al. (1992) compared moose population densities over very large areas (>2000 km<sup>2</sup>) (772 mi<sup>2</sup>) of generally continuous habitat across a broad area of Alaska and the Yukon Territories. They noted that smaller sites exhibited high variability in prey and predator densities and in habitat quality, making realistic comparisons more difficult. They focused their comparisons on the post-hunt, early winter season, thereby enhancing comparability. The mean density of moose from 20 populations was estimated at 0.15/km<sup>2</sup> (0.39/mi<sup>2</sup>) (range 0.045–0.417/km<sup>2</sup>) (0.017–0.16/mi<sup>2</sup>) in areas where predation was thought to be a major limiting factor of moose. Densities of 16 other populations in the same area, where predation was not limiting, averaged 0.66 moose/km<sup>2</sup> (1/7/mi<sup>2</sup>) (Van Ballenberghe and Ballard, 2007). Ballard et al. (1991) provided 29 moose density estimates from Alaska, including some populations studied by Gasaway et al. (1992); they ranged from 0.05 to 1.24/ km<sup>2</sup> (0.13–3.2/mi<sup>2</sup>).

ADFG estimated the total population of moose in Alaska to be 175,000–200,000 animals (ADFG, 2011d). The 2004 population estimate for the study area of the Nushagak and Kvichak watersheds was 8,100 to 9,500 moose (Butler, 2004; Woolington, 2004). This estimate was based on population data from ADFG GMUs 17B, 17C, 9B and less than half the area of GMU 9C, outside the Katmai National Park (Figure 3).

Moose are relatively new inhabitants in the Bristol Bay area, possibly having migrated into the area from middle Kuskokwim River drainages during the last century (Woolington, 2004). Moose were either not present or were rare in the northern Bristol Bay area until the turn of the twentieth

century, and even then the moose population did not increase until three decades ago (Butler, 2004; Woolington, 2004). Suspected reasons for low moose populations in the Bristol Bay region are heavy hunting pressure, particularly on female moose in the western part, and bear predation in the eastern part (Butler, 2004; Woolington, 2004). Over the last 25 years, managed harvesting, predator control, an increase in caribou herds as an alternative predator food source, and consecutive mild winters have led to an increase and expansion of the moose population westward (Butler, 2004; Woolington, 2004).

The largest moose population in the study area is in the Nushagak drainage; the upper watershed (GMU 17B) has an estimated 2,800-3,500 moose, and the lower drainage (GMU 17C) has an estimated 2,900-3,600 moose (ADFG, 2011d). These moose comprise about 73% of the total population in the Nushagak and Kvichak watersheds. The Nushagak drainage has large, healthy areas of riparian habitat, a major component of which is felt-leaf willow, a preferred browse species (Bartz and Naiman, 2005). The number of moose in the Kvichak watershed was estimated at 2,000 in GMU 9B, and less than 400 moose in the portion of GMU 9C outside Katmai National Park (Butler, 2008).

Fall trend counts have provided notoriously unreliable data on moose populations in GMU 17 (Woolington, 2008). Suitable survey conditions, including complete snow coverage, light winds, and moose presence on winter range rarely occurs before antler drop. Regular population estimation surveys of portions of the unit during late winter provide the best population information; unfortunately they do not provide reliable information on sex and age composition.

Moose population estimates in the northern Bristol Bay area are produced by a statistical model, which uses harvest ticket data from sport and subsistence hunters (Butler, 2004; Woolington, 2004). The ADFG, Division of Subsistence suspects there is a considerable unreported subsistence harvest as well as illegal harvest occurring in some regions of Alaska (ADFG, 2011d). Illegal harvest of moose in Unit 17 was probably more of a problem in the past than during recent years. Unit residents formerly pursued moose with snow machines during the winter and spring, when both male and female moose were taken. Attitudes have changed following considerable efforts by State and federal management agencies, working with local communities to help hunters see the benefits of reducing illegal moose kills. It is now common to see moose near local villages throughout the winter (Woolington, 2008).

### ***Human Use (Subsistence, Recreation)/Interaction/Management***

In Alaska 7,400 moose were harvested in 2007. Residents harvested 6,750 moose and 685 were taken by non-resident hunters (ADFG, 2011d). The harvest of 7,400 moose yields approximately 3.5 million pounds (1,587,573 kg) of meat.

Harvest records from ADFG for 1983 to 2002 indicate that GMUs 9 and 17 provided 7% of the total moose harvest in Alaska (BLM 2007). According to ADFG, Division of Subsistence

(<http://www.adfg.alaska.gov/sb/CSIS/>), local subsistence hunters from King Salmon, Naknek, and South Naknek harvested 19 moose in GMU 9B in 2007; total meat harvested was estimated at 10,206 pounds (4,629 kg). In unit 17B, local residents from Igugig, Koliganek, and New Stuyahok harvested 88 moose in 2005 (the most recent year with available data); total meat harvested was estimated at 48,208 pounds (21,867 kg). Residents from Naknek and South Naknek harvested 4 moose from unit 17C with a total of 5,357 pounds (2,430 kg) of meat. In total, subsistence moose meat accounted for 63,771 pounds (28,987 kg) with an average of 128 pounds (158 kg) harvested per household (Table 4).

Moose are an important subsistence food species for residents in the area served by the Bristol Bay Area Health Corporation (Ballew et al., 2004). In a survey on traditional food consumption conducted in 2002, 86% of respondents reported consumption of moose meat within the past year, at a median per capita consumption rate of 5lb/yr (2.3 kg/yr) (Ballew et al., 2004). Moose was the third greatest subsistence source of meat to residents of that region; residents reported eating more salmon and caribou than moose. Subsistence statistics (Table 4) also suggest that, on average, a high percentage of individuals from villages in the area (38%) attempted to harvest a moose, with about 20% succeeding. Additionally, about 24% of individuals reported sharing their moose with others, while 44% received meat from others.

In addition to being a source of subsistence meat, moose also contributed to the local economy, through jobs created as a result of non-resident hunters seeking a remote fly-in or boat-in experience to take a trophy moose.

**Table 4. Subsistence statistics for moose harvest in GMUs 9B, 17B, and 17C.**

GMU	Community name	Study year	Respondents using moose (%)	Respondents attempting harvest (%)	Moose successfully harvested (%)	Respondents sharing meat (%)	Respondents receiving meat (%)	Reported harvest (#)	Estimated harvest (#)	Reported harvest (lbs)	Estimated harvest (lbs)	Mean harvest/household (lbs)
09B	King Salmon	2007	33	31	10	10	24	5	9	2,700	4,849	55
09B	Naknek	2007	48	23	5	5	47	4	10	2,160	5,357	29
09B	South Naknek	2007	29	24	0	0	29	0	0	0	0	0
17B	Igiugig	2005	100	50	42	75	67	6	6	3,240	3,510	270
17B	Koliganek	2005	86	68	50	54	46	16	24	8,640	12,960	309
17B	New Stuyahok	2005	94	65	51	43	65	30	58	16,200	31,738	331
17C	Naknek	2007	48	23	5	5	47	4	10	2,160	5,357	29
17C	South Naknek	2007	29	24	0	0	29	0	0	0	0	0
Total										35100	63771	
Mean			58	38	20	24	44					128

(Data are from 2005 or 2007 and represent the most recent information available.)

(<http://www.adfg.alaska.gov/sb/CSIS/>)

# BARREN GROUND CARIBOU

## ***Introduction***

Alaska is currently home to 31 herds of wild caribou (*Rangifer tarandus granti*), with a combined population of approximately 760,000. Caribou herds are defined by their traditional and predictable use of calving areas, each of which are separate and distinct from the calving grounds of other herds (Skoog, 1968). Use of other seasonal ranges is variable and less traditional. Caribou from different herds may overlap on seasonal ranges other than calving areas (Cameron et al., 1986). Historically, most caribou herds have fluctuated widely in numbers and in use of range (Skoog, 1968).

Adult bull caribou in southwestern Alaska usually weigh between 350 and 450 lbs (159 to 182 kg); females weigh between 175 and 225 lbs (80 to 120 kg) (ADFG, 1985). Body weight can vary with environmental and nutritional conditions (Cameron, 1994; Valkenburg et al., 2003). Caribou are the only members of the deer family in which both males and females grow antlers. Bulls begin to shed the velvet on their antlers between late August and early September, marking the start of breeding season. The largest bulls begin shedding their antlers in late October, with smaller bulls losing their antlers later in the winter. Females shed velvet in September (Skoog, 1968). Pregnant females usually keep their antlers until the calving season in the spring, whereas non-pregnant females lose their antlers about a month before calving begins. Some females never grow antlers (Whitten, 1995). Caribou populations throughout the Bristol Bay region have declined recently and body weights and antler sizes are now relatively low. In the past the area produced large-bodied animals with record book antlers (Valkenburg et al., 2003).

## ***Population History of Caribou in the Upper Bristol Bay Region***

Historical accounts from the early 1800s indicate that caribou were plentiful in the Bristol Bay region. There may have been a large herd that ranged from Bristol Bay across the Kuskokwim and Yukon deltas all the way to Norton Sound. By the late 1800s caribou throughout this area had declined dramatically. Caribou numbers may have increased in the early 1930s, but were declining again by the late 1930s. Domestic reindeer were brought to the Bristol Bay region in the early 1900s, but by the 1940s, reindeer herds were widely neglected and either died out or were assimilated into wild caribou populations (Skoog, 1968; Woolington, 2009a). Caribou in the Nushagak drainage remained relatively scarce into the 1970s, at about 10,000-15,000 animals (Woolington, 2009a).

Over the past thirty years, caribou herds in southwest Alaska have continued to undergo significant changes in abundance. The Nushagak and Kvichak drainage basins are now used primarily by caribou from the Mulchatna herd. The Mulchatna herd grew rapidly during the

1980s and 1990s, from a population of about 18,600 animals in 1981 to a peak of approximately 200,000 in 1997. By 1999 the Mulchatna herd had declined to 175,000 and it continued to decline, to approximately 30,000 in 2008 (Valkenburg et al., 2003; Woolington, 2009a). As the Mulchatna herd grew, it overlapped with and eventually assimilated the much smaller Kilbuck (or Qavilnguut) herd that formerly ranged infrequently into the western part of the Nushagak drainage. By the late 1990s the Kilbuck herd had ceased to function as a distinct population (Woolington, 2009a).

The Northern Alaska Peninsula herd recovered from a population low of about 2,000 in the late 1940s to about 20,000 in 1984. The population remained at about 15,000 to 19,000 through 1993, but has since declined steadily to about 2,000 to 2,500 today (Butler, 2009a). For the most part, caribou of the Northern Alaska Peninsula herd remain well south of the Kvichak drainage. However, from 1986 to 2000 many caribou from the Northern Alaska Peninsula herd wintered in the Kvichak drainage, south of Lake Iliamna (Butler, 2009a). In the late 1980s and early 1990s, the Kvichak drainage was also used by far more (up to 50,000) Mulchatna caribou (Woolington, 2009a). The two herds always returned to their traditional calving and summer ranges and remained distinct (Butler, 2009a; Hinkes et al., 2005; Woolington, 2009a).

The Nushagak Peninsula herd is a small population that was established in 1988 when caribou from the Northern Alaska Peninsula herd were translocated to the Nushagak Peninsula south of the Nushagak River delta, on the west side of upper Bristol Bay. The Nushagak Peninsula had been unoccupied by caribou for approximately 100 years (Hotchkiss, 1989; Paul, 2009). The Nushagak Peninsula herd grew rapidly after its introduction, from 146 caribou to over 1,000 caribou in 1994. Growth continued at a slower rate to about 1,400 caribou in 1997. Population density peaked at approximately 1.2 caribou/km<sup>2</sup> (3.1/mi<sup>2</sup>). During the next decade, calf recruitment and adult female survival decreased and the population declined to 546 caribou in 2006 (Aderman, 2009). The population remained at about 550 caribou until 2009 and then increased to 801 in 2011 (Aderman and Lowe, 2011).

## ***Habitat***

***Seasonal Preference-*** Spring calving grounds tend to be in open tundra areas or high and rugged mountains. Predator densities are often lower in such areas, but large caribou herds can also calve at high densities in sparsely forested terrain, where their sheer numbers and synchronized timing of births can swamp the effects of predators (ADFG, 1985; Skoog, 1968).

During summer (mid-June to mid-August), caribou feed in open tundra, mountain, or sparsely forested areas. To avoid harassment from mosquitoes and other insects, caribou often gather on windswept ridges, glaciers, lingering snow drifts, gravel bars, elevated terrain, cinder patches, and beaches. Caribou near the coast may also avoid insects by standing head down and motionless on mudflats (ADFG, 1985; Skoog, 1968).

In winter caribou often feed in forested areas, especially where there are spruce-lichen associations. In addition to forested areas, caribou can also be found along ridge tops, on frozen lakes and in bogs during winter (ADFG, 1985; Skoog, 1968).

## **Food Habits**

**Spring-** From mid-April to mid-June, caribou usually eat catkins of willow (*Salix alaxensis*, *S. planifolia*, *S. pulchra*, and *S. glauca*), as well as grasses and sedges (*Carex bigelowii*, *C. membranacea*, *C. podocarpa*, and *Eriophorum vaginatum*). They also consume fruticose lichens, resin birch (*Betula glandulosa*), dwarf birch (*B. nana*), and horsetails (*Equisetum* spp.) (ADFG, 1985; Skoog, 1968).

**Summer-** From mid-June to mid-August, caribou typically consume willow leaves, resin birch, and dwarf birch, as well as sedges and grasses, especially grasses from the genera *Alopecurus*, *Arctagrostis*, *Dupontia*, *Festuca*, *Poa*, *Puccinellia*, *Calamagrostis*, and *Hierochloe*. They also eat horsetails, legumes (*Astragalus umbellatus*, *Lupinus arcticus*, *Hedysarum alpinum*, and *Oxytropis nigrescens*), and forbs such as *Gentiana glauca*, *Swertia perennis*, *Sedum roseum*, *Antennaria monocephala*, *Artemisia arctica*, *Epilobium latifolia*, *Pedicularis* spp., *Petasites frigidus*, *Polygonum bistorta*, *Rumex arcticus*, and *Saxifraga* spp. (ADFG, 1985; Skoog, 1968).

**Fall-** Caribou feed on grasses, sedges, and lichens throughout the fall. They also feed on willow and water sedge (*Carex aquatilis*), if they are available (ADFG, 1985). Caribou also feed on mushrooms, when available (Skoog, 1968).

**Winter-** Caribou winter diets consist primarily of lichens (especially *Cladonia* spp. and *Cetraria* spp.), with smaller amounts of sedges and grasses, as well as horsetails, and the tips and buds of willows and dwarf shrubs (e.g., *Vaccinium uliginosum*). They may consume vegetation in muskrat (*Ondatra zibethicus*) pushups during winter, as well as aquatic vegetation in poorly drained coastal plains (ADFG, 1985; Skoog, 1968).

## **Behavior**

**Seasonal Range Use and Migrations-** Some caribou herds travel long distances between summer and winter ranges, to find adequate sources of food and bear their calves in areas relatively free of predators (Bergerud, 1996; Griffith et al., 2002; Skoog, 1968; Whitten et al., 1992). Physical features on the landscape influence caribou migration routes. Caribou must make their way around open seawater, large lakes, swift rivers, rivers with floating ice, rocky regions in high mountains, volcanic cinder patches, glaciers, and burned areas. Features such as frozen lakes and rivers, as well as ridge tops, eskers, streambeds, and hard-surfaced snow drifts aid caribou during winter migration (ADFG, 1985). Since the 1980s, calving areas, other seasonal

ranges, and migration routes of the Mulchatna herd have varied widely. The Mulchatna herd has ranged extensively throughout most of the Nushagak and Kvichak watersheds, but caribou from this herd also spend much of their time to the north in the Kuskokwim River drainage (Woolington, 2009a).

In contrast to most other migratory caribou herds, the Mulchatna herd does not use the same traditional calving ground each year, although its calving areas have remained distinct from those of any other herds. The Mulchatna herd calved in the Bonanza Hills area of the upper Mulchatna River watershed during the 1980s. In 1992, calving shifted west to the Mosquito River drainage in the upper Mulchatna watershed. From 1994 to 1999 calving generally occurred in the upper Nushagak River watershed. From 2000 to 2002 calving was split between the lower Nushagak watershed and the South Fork of the Hoholitna River, in the Kuskokwim drainage. In 2003 and from 2005 to 2008, calving occurred near Kemuk Mountain in the Nushagak drainage, as well as near the South Fork of the Hoholitna in the Kuskokwim drainage. In 2004, calving was widespread, from Dillingham in the Nushagak watershed, north to the Holitna and Hoholitna Rivers in the Kuskokwim drainage (Woolington, 2009a).

The Mulchatna herd often ranges widely across the Nushagak drainage during summer and fall, but also frequently uses areas to the north and west, in the Kuskokwim Mountains. During the 1980s much of the Mulchatna herd wintered north and west of Lake Iliamna, in the Kvichak drainage. In the 1990s most wintering shifted to the Kuskokwim Mountains. For the past decade part of the herd has wintered in the Nushagak and Mulchatna watersheds while part of the herd has wintered in the Kuskokwim watershed. In 2006-07 and 2007-08, up to 20,000 Mulchatna caribou wintered in the lower Nushagak and Kvichak valleys, with some going as far south as the Naknek valley in 2006-07 (Woolington, 2009a).

Mulchatna caribou are often widely dispersed during movements between seasonal ranges. In accordance with the highly variable locations of seasonal ranges, migration routes tend to vary from year to year (Woolington, 2009a).

Historically, the Northern Alaska Peninsula herd has spent most of its time in the Naknek drainage and in areas south of it, far removed from the Kvichak and Nushagak watersheds. From about 1986 through 2000 however, many caribou from the Northern Alaska Peninsula herd wintered in the Kvichak drainage, south of Lake Iliamna. But since 2001, only a single radio-collared caribou from this herd has wintered north of the Naknek River (Butler, 2009a).

Like many small caribou herds, the Nushagak Peninsula herd is sedentary and spends the entire year on the Nushagak Peninsula, although a few caribou from this herd have made short forays (< 20 km and for < 1 month) off the Peninsula (Aderman and Woolington, 2001). No overlap

between the Nushagak Peninsula herd and much larger migratory Mulchatna herd has yet been documented.

***Response to Disturbance-*** Industrial activities impact caribou by hindering or altering their movements or displacing them from preferred habitats. Barren-ground caribou on the North Slope of Alaska have avoided development such as exploration wells (Fancy, 1983) and linear developments such as roads and pipelines (Dau and Cameron, 1986) by distances of 2 to 5 km. Establishment of extensive, densely packed development with interconnecting road networks, high levels of traffic, aircraft activity, and ongoing construction or production activity around the Prudhoe Bay oilfields has resulted in general displacement of caribou from some areas (Griffith et al., 2002). Avoidance and displacement are most prevalent among females with young calves (Cameron and Whitten, 1980; Cameron et al., 1979; Griffith et al., 2002). Similarly, woodland caribou in Canada typically avoided areas near mining sites by 1 to 5 km (Weir et al., 2007). Mining activities had the highest impact on caribou during calving season. Larger groups and females with young typically avoided mining sites more often than smaller groups and caribou without young (Weir et al., 2007). Weir et al. (2007) identified corridors such as roads and seismic lines as the greatest development impact on caribou because they increase the chance of encounters with humans and predators. The large Red Dog Mine in northwestern Alaska has had only limited and localized effects on caribou movements and distribution, in part because the mine occupies only a tiny fraction of the Western Arctic Caribou herd's otherwise pristine range. Mine operators and workers have implemented policies to minimize conflicts between traffic and caribou along the road from the mine to the port site (Dau, 2009). In Norway movement patterns and range use by wild reindeer have been disrupted by combinations of highways and railroads, as well as by large hydroelectric developments (Nellemann et al., 2001; Nellemann et al., 2003). Impacts of development tend to be less when they occur on non-critical seasonal range, in areas or at times when caribou are at low density relative to available range, or when similar habitats are available nearby (Griffith et al., 2002).

### ***Interspecies Interactions***

The interrelationships of wolves, caribou, and moose populations have been studied extensively in Alaska (Gasaway et al., 1983; Mech et al., 1998; National Research Council, 1997). In large areas of interior Alaska, moose tend to persist for long time periods at low densities, with population size regulated by high rates of predation by wolves and bears (Gasaway et al., 1992). In contrast, caribou are able to periodically escape regulation by predators and at least temporarily achieve high densities (Davis and Valkenburg, 1991; Valkenburg, 2001). Caribou population dynamics in the Nushagak and Kvichak watersheds are consistent with this large pattern. Predation by wolves does not appear to be a major factor in regulating the Mulchatna herd, possibly due to rabies outbreaks that periodically reduce the wolf population (Valkenburg et al., 2003; Woolington, 2009a). Large, migratory caribou herds, such as the Mulchatna herd, may also avoid predation by moving seasonally to areas with few resident predators, or by using

seasonal ranges erratically and unpredictably. Wolves in the Nushagak and Kvichak drainages are not known to follow migratory caribou (Woolington, 2009a).

### ***Mortality, Productivity, Survivorship***

***Mortality-*** Caribou populations are influenced by the availability and quality of forage plants, predation, weather, climate, disease, and hunting (Valkenburg, 2001). Winter severity, accidents, and insect harassment can also affect caribou numbers (Hinkes et al., 2005). The Mulchatna herd's rapid growth from 1980 to 1995 indicated that predation pressure was not a limiting factor at that time. During its continued decline from 1997 to the present, this herd has been strongly limited by nutrition. Poor nutrition has also been associated with high levels of bacterial pneumonia, hoof rot (*Spherophorous necrophorous*), and high parasite loads (Valkenburg et al., 2003; Woolington, 2009a).

Predation by wolves and bears was thought to be limiting caribou calf survival and recruitment in the Northern Alaska Peninsula herd, but lowered productivity due to nutritional stress was also a problem (Butler, 2009a). In the Nushagak Peninsula Herd nutrition appears to be the ultimate factor in population size, but proximate factors such as predation, disease and dispersal are inextricably linked (Aderman and Lowe, 2012). Depletion of lichens on winter range may have contributed to poor nutrition in southwestern Alaska herds (Valkenburg et al., 2003).

Caribou population size is a direct function of calf production and survival. Production is strongly influenced by nutritional conditions. Survival is strongly influenced by predation and nutrition. The causes of calf recruitment and population size are well known, but applying them in correct proportion to an individual caribou herd is very difficult, and often only speculative, due to the lack of data (P. Walsh (USFWS), pers. comm., 7/3/12).

***Breeding-*** Rutting occurs during fall migration and on wintering grounds. Females usually breed at 28 months of age, but age at first breeding can vary from 16 to 41 months, depending on condition (Hinkes and Van Daele, 1996). Females in good nutritional condition have an 80% or higher probability of pregnancy, but pregnancy rates may drop dramatically when cows are in poor condition, due to severe weather effects on grazing, or in some cases, due to overgrazing of range associated with high densities. Gestation lengths are typically 225-235 days. Calving occurs in late May or early June; females usually produce a single calf (Skoog, 1968). Birth rates in the Mulchatna, Northern Alaska Peninsula, and Nushagak Peninsula herds began to decline after these herds reached peak population levels (Valkenburg et al., 2003).

### ***Human Use/Interaction/Management***

Nearly all caribou harvested in the Nushagak and Kvichak watersheds are from the Mulchatna herd. Caribou are an important subsistence food resource for residents in the area served by the

Bristol Bay Area Health Corporation (Ballew et al., 2004). In a survey on traditional food consumption conducted in 2002, 88% of respondents from the region reported having consumed caribou meat within the previous year (Ballew et al., 2004). Caribou was second only to salmon as a subsistence source of meat for residents of the region. Caribou are also harvested by non-local residents who fly into the area to hunt. Harvest levels for all hunters are highly dependent on caribou distribution during the fall and winter, as well as on weather and snow cover conditions that affect hunter access to caribou (Woolington, 2009a). Harvest is also generally correlated with population size, with historically high harvests occurring when caribou have been most abundant. Reported harvest of Mulchatna herd caribou from 1991-99 (including Mulchatna caribou taken in areas outside the Nushagak and Kvichak drainages) varied from 1,573 to 4,770 (Table 5) (Woolington, 2009a). Estimates of total harvest from the Mulchatna herd during this period were roughly double the reported numbers (3,770 to 9,770) (Valkenburg et al., 2003). However, harvest probably never exceeded 5% of the annual population, and did not limit herd growth, range expansion, or cause a population decline (Woolington, 2009a). As the Mulchatna herd declined after 1999, reported harvest steadily dropped to a low of 767 in 2007-08 (Table 5). Lower harvests reflect generally reduced availability of caribou (Woolington, 2009a). Also, long hunting seasons, high bag limits (5 caribou/yr), and same-day-airborne hunting, all of which were allowed during the 1990s and early 2000s, have since been replaced by more restrictive regulations.

**Table 5. Estimated population size and harvest of the Mulchatna caribou herd, 1991-2008.**

<u>Regulatory Year</u>	<u>Estimated Herd Size</u>	<u>Reported Harvest</u>
1991-1992	90,000	1,573
1992-1993	115,000	1,602
1993-1994	150,000	2,804
1994-1995	180,000	3,301
1995-1996	190,000	4,449
1996-1997	200,000	2,366
1997-1998	N/A	2,704
1998-1999	N/A	4,770
1999-2000	175,000	4,467
2000-2001	N/A	4,096
2001-2002	N/A	3,830
2002-2003	147,000	2,537
2003-2004	N/A	3,182
2004-2005	85,000	2,236
2005-2006	N/A	2,175
2006-2007	45,000	921
2007-2008	N/A	767
2008-2009	30,000	N/A

(Woolington, 2009a)

Hunting of Nushagak Peninsula caribou is managed under regulations set by the Federal Subsistence Board. From 1995 to 2011, 673 caribou were reported harvested from this herd. Reported harvests were < 12.3% of the population annually during this period (Aderman and Lowe, 2011), but there may have been additional unreported harvest (Valkenburg et al., 2003). Factors other than hunting (e.g., depletion of lichens on winter range) may have been involved in the decline of the Nushagak Peninsula Herd after 1999 (Valkenburg et al., 2003). Nevertheless, it was clear that the herd could no longer support the high levels of harvest seen during the 1990s. Harvest quotas were reduced and the herd is now increasing again.

With the Northern Alaska Peninsula herd now at low population levels, the herd no longer extends as far north as the Kvichak drainage. Overall harvest of the herd is greatly restricted, and none occurs in the Nushagak and Kvichak watersheds.

# WOLF

## ***Introduction***

The gray wolf (*Canis lupus*) is the largest wild extant canid (Paquet and Carbyn, 2003). The historic distribution of wolves once covered most of North America, but as the contiguous United States were settled during the past 250 years, wolves were widely persecuted due to their tendency to prey on livestock and pets (Mech, 1995). By the 1970s, wolf populations in the contiguous United States were decimated, which led to their protection under the Endangered Species Act. The gray wolf is currently listed as “endangered” in most of the Lower 48 states, except in Minnesota, Michigan, Wisconsin, and portions of adjacent states. In the northern Rocky Mountain states of Idaho and Montana (as well as eastern Oregon and Washington where the species was recently de-listed as “recovered,” and as “nonessential experimental” in Wyoming and portions of Arizona and New Mexico (USFWS, 2011).

([http://www.fws.gov/midwest/wolf/delisting/pdf/FR\\_grwoWGLDelist28Dec2011.pdf](http://www.fws.gov/midwest/wolf/delisting/pdf/FR_grwoWGLDelist28Dec2011.pdf))

## ***Habitat***

Wolves are habitat generalists and their home ranges can encompass a variety of diverse habitats (Mech, 1970; Mladenoff et al., 1995; Paquet and Carbyn, 2003). Historically, gray wolves were distributed throughout the northern hemisphere in every habitat where large ungulates were found (Mech, 1995). Prey abundance and availability strongly influence habitat use by wolves (Paquet and Carbyn, 2003). Male and female wolves do not differ in habitat selection, and the pack maintains their territory throughout the year.

Wolf pups are born, protected, fed, and raised in natal and secondary den sites, a series of rendezvous sites, and surrounding areas (Paquet and Carbyn, 2003). Dens provide shelter and are often located in a hole, rock crevice, hollow log, overturned stump, abandoned beaver lodge, or expanded mammal burrow (Paquet and Carbyn, 2003). Rendezvous sites are areas where pups are left while pack members forage (Theberge, 1969).

A misperception, common in years past, was that wolves needed wilderness to survive. More recent studies have shown that wolves do not need wilderness, but they do require adequate prey and a relatively low rate of mortality caused by humans (Mech, 1995; Mladenoff et al., 1999). The presence of roads has a complex impact on habitat selection by wolves. Roads benefit wolves by easing their travel and access to prey, but conversely roads are associated with human contact and increased wolf mortality through either intentional or accidental killing (Houle et al., 2010; Mladenoff et al., 1999). Near the Kenai NWR in Alaska, wolves preferred a gated pipeline road, presumably because it offered an easy travel corridor with little human use (Thurber et al., 1994). In that study, wolf absence from human-settled areas and heavily

travelled roads seemed to be caused by wolf behavioral avoidance rather than direct human-caused mortality of wolves in those areas.

## ***Food Habits***

***Diet-*** Wolves are obligate carnivores whose use of prey depends largely on the availability and vulnerability of ungulates (Weaver, 1994). Dietary habits such as preferred prey species and prey switching tactics vary substantially among wolf packs in different locations, in response to local ecological relationships.

Wolves can exhibit flexible diets, and shift to non-ungulate prey species when ungulate prey are scarce (Forbes and Theberge, 1996) or to take advantage of seasonally abundant, nutritious alternate prey species such as salmon (Darimont et al., 2008). Some wolf packs require multiple prey species during the summer, in order to meet the high energetic demands of reproduction (Paquet and Carbyn, 2003). Availability of alternate prey species is also important for wolf packs in northwestern Alaska that rely on migratory caribou that move seasonally to calving grounds where they are inaccessible to wolves (Ballard et al., 1997).

In Algonquin Park, Ontario, beavers and snowshoe hares (*Lepus americanus*) are important to the winter diet of wolves, as are scavenged moose carcasses (Forbes and Theberge, 1992; Forbes and Theberge, 1996). Other animals such as lemmings, voles, muskrat, and a variety of birds (especially waterfowl) and their eggs also supplement the wolf diet (Kuyt et al., 1981), while fish and berries are consumed seasonally, where available (Darimont and Paquet, 2000; Kohira and Rexstad, 1995).

Coastal wolves also consume marine mammal carcasses, mussels, crabs, and even barnacles (Darimont and Paquet, 2000). The Ilnik wolf pack on the Alaska Peninsula was found to preferentially use coastal habitat along Bristol Bay, where it was frequently observed consuming marine mammal carcasses that had washed ashore (Watts et al., 2010). In winter when Bristol Bay was frozen, the pack was documented using offshore sea ice, and wolves killed sea otters (*Enhydra lutris kenyoni*) near the coastline when the otters were trapped above the sea ice (Watts et al., 2010).

Wolves on the Kenai Peninsula of Alaska were found to rely heavily on moose during the summer (Peterson et al., 1984). Moose comprised an estimated 97% of ingested prey biomass in summer, which was largely scavenged from old kills; only 16% of moose carcasses found in association with wolves in summer were fresh kills. In contrast, 80% of moose consumed during the winter were fresh wolf-kills (Peterson et al., 1984). Kenai Peninsula wolves also ate snowshoe hares and beavers during the summer, and minor quantities of small rodents, birds, vegetation and other prey (Peterson et al., 1984). Scats from wolves in south-central Alaska confirmed reliance on moose; beavers and snowshoe hares were also commonly consumed

(Ballard et al., 1987). Wolves in south-central Alaska also consumed caribou, muskrat, squirrels, voles, vegetation, and a variety of other dietary items (Ballard et al., 1987).

**Salmon as a Food Source<sup>2</sup>** - Preying on salmon may have considerable adaptive value for wolves regardless of ungulate density. Foraging theory predicts an advantage to avoiding dangerous ungulate prey in favor of less dangerous alternatives such as salmon (Stephens and Krebs, 1986). Salmon also offers superior nutritive value; in one study pink salmon contained more than four times as much energy per 100 g of meat than raw black-tailed deer (*O.h. columbianus*) (Darimont et al., 2008). Behavioral observations suggest that wolves may have a broad history of seasonal consumption of salmon in areas where the two species co-exist (Darimont et al., 2003).

Wolves have often been observed consuming only the head of salmon rather than the entire fish (Darimont et al., 2003). There are several possible explanations for this behavior. Wolves may be consuming only the most energetically valuable part of the prey item, or they may be targeting specific micronutrients such as omega-3 fatty acids (Gende et al., 2001). Wolves may also be selecting head tissue to minimize their exposure to parasites such as *Neorickettsia helminthoeca*, which can infect salmon and be fatal to canids (Darimont et al., 2003).

Wolf packs that use salmon seasonally can reap benefits during the fall and winter seasons. Consumption of salmon in the fall may improve pup survivorship during weaning (Person, 2001). Winter snow can preserve salmon carcasses buried underneath, enabling use by wolves and other scavengers for the rest of the winter (Carnes 2004). Carnes (2004) compared scats from different packs in the Copper and Bering River deltas, and noted increased consumption of salmon in winter; he hypothesized this might be related to unavailability of moose in those areas.

Several studies throughout Alaska have examined the importance of salmon. In the Copper and Bering River Deltas, late summer rendezvous sites for wolves were typically located alongside shallow spots in spawning areas or at bends where gravel bars extended out into streams (Carnes 2004). Researchers at these areas observed wolves, especially pups, waiting for spent salmon carcasses to float by (Carnes 2004). In southeast Alaska, marine protein comprised 18% of the lifetime total diet of Alexander Archipelago wolves; most of the marine contribution was likely salmon, although other marine organisms were probably also consumed (Szepanski et al., 1999). In southwest Alaska's Togiak NWR, wolves have been observed delivering intact salmon

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<sup>2</sup> Ongoing research in LCNPP and the Alaska Peninsula and Becharof NWRs is providing new information on the relationship of wolves to salmon. The results of this research have not yet been analyzed or published, but preliminary results show that wolves rely on salmon, when available, for a significant portion of their diets. This information is cited as a personal communication in this section.

carcasses to their pups at rendezvous sites (Walsh, 2011). Similar foraging behavior has been observed among wolves on the Alaska Peninsula (GMUs 9C and 9E, extending from the Naknek River drainage through Port Moller), where wolves often transport captured salmon to den or rendezvous sites (D. Watts (USFWS), pers. comm., 8/23/11).

Salmon are not a food resource only for coastal wolves. Some Pacific salmon migrate long distances inland, returning to spawning grounds that may be hundreds of miles from the ocean (Quinn, 2004). A study in DNPP, documented substantial seasonal salmon consumption among these wolves who lived more than 1,200 river km (746 river mi) from the coast (Adams et al., 2010). DNPP wolves with territories where salmon were seasonally abundant and ungulates occurred at low densities ate the most salmon; salmon averaged 17% of their total long-term diet (Adams et al., 2010). Preliminary data from LCNPP indicates that wolves use salmon from the time they enter streams, through the fall, and then again after late-winter ice out (B. Mangipane (NPS), pers. comm., 9/27/11).

**Dispersal of Marine-Derived Nutrients (MDNs) by Wolves-** The influences of salmon on terrestrial systems are largely dependent on predators that remove salmon from streams, consume a portion, and leave the remains behind (Hilderbrand et al., 1999a; Reimchen, 2000). Abandoned salmon carcasses contribute to ecosystem processes when scavenging, decomposition, and fecal-urinary deposition provide MDNs to terrestrial systems that are typically nitrogen- and phosphorus-limited (Ben-David et al., 1998; Hilderbrand et al., 1999a; Reimchen, 2000; Willson et al., 1998).

Wolf behavior further influences the distribution pattern of MDNs within terrestrial ecosystems because wolves often transport salmon some distance rather than consuming it in the stream or immediate vicinity. In British Columbia wolves were observed consuming salmon on grass next to the river 70% of the time (Darimont et al., 2003). However, in LCNPP, preliminary data indicate that wolves move considerable distances over several days to feed on salmon. In 2009, in LCNPP, an individual wolf was documented travelling up to 64 km (40 mi) from a den site to feed on salmon and carry ingested remains back to feed pups through regurgitation. In 2010 and 2011, the same individual travelled up to 24 km (15 mi) and 40 km (25 mi) to feed on salmon (B. Mangipane (NPS), pers. comm., 9/27/11). In LCNPP wolves have been observed feeding on fish carcasses frozen into lake ice, and the backbones and heads left from human subsistence fishing (B. Mangipane (NPS), pers. comm., 9/27/11; P. Spencer (NPS/retired, pers. comm., 8/31/11).

## ***Behavior***

**Wolf Packs-** Gray wolves are territorial and social carnivores that typically live in packs of about 6-8 animals (although packs may include >20 wolves (Mech and Boitani, 2003)). Wolf packs typically consist of a single breeding pair, pups of the year, and their older siblings (Mech and Boitani, 2003). Mating occurs during late January to March and gestation is approximately 63

days. Most commonly each pack produces only a single litter of pups; pups are born in dens, usually during late April to May. Multiple litters, although rare, have been observed within some packs in Alaska (Ballard et al., 1987; Meier et al., 1995). Litter sizes range from 1 to 12 pups but more commonly number 4 to 6 (Fuller et al., 2003). Dens in coastal temperate rainforests are located within the root wads of living or dead trees (Person and Russell, 2009). In boreal forest or tundra, dens are located in sandy areas or gravel eskers (Ballard and Dau, 1983; McLoughlin et al., 2004). Wolves and their pups occupy dens from late April to early July, and then move to rendezvous sites where sequestered pups are fed by pack members until September or early October when they are sufficiently large to move with the pack (Mech et al., 1998; Packard, 2003; Person and Russell, 2009). Pup mortality during summer is affected strongly by availability of food (Fuller et al., 2003). Wolves usually remain within their natal packs until they reach sexual maturity at 22 to 24 months. At that age, some may disperse from their packs to find mates and establish their own packs. However, researchers reported dispersers ranging in age from 10 months to 5 years (Mech and Boitani, 2003). Abundant prey may induce some wolves to defer dispersal until they are older, allowing packs to increase in size (Fuller et al., 2003; Mech and Boitani, 2003). Dispersing wolves may travel hundreds of kilometers and traverse very difficult terrain before settling (Mech and Boitani, 2003); dispersing wolves may cross large bodies of water. For example, in southeastern Alaska, dispersing wolves were documented swimming 3 to 4 km (1.9-2.5 mi) in open ocean to move between islands (Person and Russell, 2008).

**Range-** Resident wolf packs occupy extensive territories that they attempt to defend from other wolves. Wolf territories tend to be smaller in summer, when packs remain closer to dens and home sites (Mech, 1977), and larger in winter, when packs resume nomadic travelling as pups mature. In south-central Alaska, the average distance between dens of neighboring packs was 45 km (28 mi) (Ballard et al., 1987).

Territories of wolf packs tend to be much larger in Alaska than in the continental US, due to the relatively low density of prey in Alaska. Territory and pack sizes are largely influenced by availability of prey (Mech and Boitani, 2003). In Alaska, ungulates such as moose, caribou, and Sitka black-tailed deer (*O. h. sitkensis*) are the most important prey (Gasaway et al., 1992; Kohira and Rexstad, 1997). In general, wolf territory size is inversely related to the density of available prey (Fuller et al., 2003). As with wolves generally, average territory sizes of Alaskan wolf packs were consistently larger in winter than in summer (Table 6) (Adams et al., 2008; Ballard et al., 1997; Ballard et al., 1998; Ballard et al., 1987; Burch et al., 2005; Peterson et al., 1984). Wolves in north-central Minnesota had smaller winter territory size ( $\bar{X} = 116 \text{ km}^2$ ) and higher density (39/1,000  $\text{km}^2$  in mid-winter) than any of these Alaska packs, because of an abundant white-tailed deer (*O. virginianus*) population (Fuller, 1989). Preliminary analysis of recent data from LCNPP indicates annual territory sizes from 1,155  $\text{km}^2$  to over 5,000  $\text{km}^2$ . One

pack in this study had territory sizes of 2,214 km<sup>2</sup>, 2,189 km<sup>2</sup>, and 1,834 km<sup>2</sup> in 2009, 2010 and 2011, respectively (B. Mangipane (NPS), pers. comm., 9/27/11).

**Table 6. Average territory sizes (km<sup>2</sup>) of wolf packs in Alaska\*.**

<u>Region</u>	<u>Summer</u>	<u>Winter</u>	<u>Annual</u>	<u>Reference</u>
Northwest	621	1,372	1,868	Ballard et al., 1997
Denali National Park	--	--	871	Burch et al., 2005
Central Brooks Range	--	--	358–2,315 <sup>a</sup>	Adams et al., 2008
Kenai Peninsula	--	--	466-864 <sup>b</sup>	Peterson et al., 1984
South-central	--	--	1,644	Ballard et al., 1987

a - Range of territory sizes estimated for wolf packs over the four-yr study period

b - Range of average annual territory sizes during study period

-- not determined

\* This table does not include data from an ongoing study in LCNPP.

**Dispersal (Emigration)**- Several studies in Alaska have documented emigration as a vital factor influencing the population dynamics of wolves (Adams et al., 2008; Ballard et al., 1997; Ballard et al., 1987; Peterson et al., 1984). Individuals may leave a pack and strike out on their own in response to low prey densities (Messier, 1985). High rates of infectious disease (Ballard et al., 1997), social stress within the pack, or a lack of opportunity to achieve the high social status needed to successfully breed (Peterson et al., 1984) may also cause wolves to disperse to new territories.

Dispersal is a key mechanism that wolves use to colonize new habitats. Dispersing wolves experience a high rate of mortality, but when successful, they are able to establish a new pack (Peterson et al., 1984), or join an existing pack (B. Mangipane (NPS), pers. comm., 9/27/11). Successful colonization of new territory requires both a vacancy of suitable habitat and bonding with a mate (Rothman and Mech, 1979).

**Seasonal Movements**- Wolves in south-central Alaska do not follow migratory movements of moose or caribou outside their territories, but do follow elevational movements of moose within their territories (Ballard et al., 1987). In most years, wolf packs in northwestern Alaska did not follow migratory caribou from the Western Arctic herd, but rather, switched to moose for prey during the winter and maintained year-round resident territories (Ballard et al., 1997). However, in years when moose densities were low, up to 17% of radio-collared wolf packs in northwest Alaska followed migratory caribou and then returned to their original territory for denning (Ballard et al., 1997).

In Bristol Bay, there is no evidence that wolf packs follow the Mulchatna caribou herd, although wolves are occasionally seen with the herd as it moves throughout the region (Woolington, 2009b). However, recent information in LCNPP shows that individual wolves (in most cases, lone yearling wolves) followed caribou herds for all or a portion of the year (B. Mangipane (NPS), pers. comm., 9/27/11). Packs are more likely to have established territories and take advantage of caribou when they move through those territories.

Daily distances traveled within a pack's territory range from a few kilometers up to 200 km (123 miles) (Mech, 1970). On Ellesmere Island, Northwest Territories, mean travel speed of wolves during summer on barren ground was 8.7 km/hr (5.4 mi/hr) for normal travel and 10.0 km/hr (6.2 mi/hr) when returning to a den (Mech, 1994). In south-central Alaska, a wolf pack followed for 15 days in the spring moved an average of 24 km (14.9 mi) per day (Burkholder, 1959). In LCNPP, all packs and age classes of wolves have been documented travelling up to 34 km (21 mi) in 15 hours (B. Mangipane (NPS), pers. comm., 9/27/11).

Wolves are good swimmers; coastal wolves are particularly adept at swimming and are able to swim distances as far as 13 km (8 mi) between islands (Darimont and Paquet, 2002). However, wolves may be unwilling to swim in pursuit of large ungulates. On the Kenai Peninsula, wolves ceased pursuit of moose that entered ponds or lakes and swam away from shore (Peterson et al., 1984). However, as soon as waterbodies freeze, wolves travel across them freely (P. Spencer (NPS/retired), pers. comm., 8/31/11).

### ***Interspecies Interactions; Response to Change in Salmon Populations/ Distribution***

Salmon are important seasonal prey for wolves in coastal regions and along major river systems (Adams et al., 2010; Kohira and Rextstad, 1997), to the extent that, in some coastal areas, salmon may seasonally decouple the dependence of wolves on ungulate prey (Darimont et al., 2008). In DNPP, salmon were found to be a particularly important food item for wolves in areas with low ungulate density but high salmon abundance (Adams et al., 2010). The availability of salmon had a strong impact on abundance of wolves in the northwestern flats area of DNPP; wolves were only 17% less abundant in that area compared to the rest of the study area even though ungulate densities were 78% lower. The higher wolf population density facilitated by the availability of salmon was thought to result in increased overall predation pressure on ungulates in that system (Adams et al., 2010). Moose were the predominant ungulate in the northwestern flats but occurred at densities approaching the lowest in North America (Gasaway et al., 1992), and appeared to be limited by predation rather than nutritional constraints (Adams et al., 2010).

Under some circumstances, predation by wolves may limit or regulate ungulate populations, sometimes suppressing their numbers at very low densities (top-down forcing) (Gasaway et al.,

1992). In other cases, ungulate populations are influenced mostly by carrying capacity of habitat regardless of wolf predation (bottom-up effects) (Ballard et al., 2001). The relative importance of top-down and bottom-up factors can change over time depending on habitat changes, weather conditions, and anthropomorphic disturbances (Bowyer et al., 2005).

The interrelationships of wolves, caribou and moose populations have been characterized in several ecosystems. Alterations in moose densities can have a major influence on caribou populations, through their effect on wolf predation rates. In southeastern British Columbia, wolf population numbers can be suppressed due to a lack of available food in winter, when moose numbers are low, particularly when caribou over-winter in areas inaccessible to wolves (Seip, 1992). Elevated moose densities may cause a concomitant rise in wolf numbers. If moose numbers later decline, wolves in the area will turn to caribou as an alternative food source, potentially affecting the caribou population. Industrial development can exacerbate this effect by increasing wolves' access to caribou via the creation of new linear corridors, such as roads and pipelines (James et al., 2004). These interrelationships may not be applicable to the southwest Alaska ecosystem, where caribou occupy tundra habitats in contrast to the low-density woodland caribou herds from the Canadian studies. In LCNPP, when the Mulchatna caribou herd was at high numbers, wolves fed on caribou and moose numbers were high. When the herd size declined, wolves fed more on moose and moose numbers declined by 50 percent (B. Mangipane (NPS), pers. comm., 9/27/11).

Wolves are coursing predators that actively pursue prey rather than passively ambushing them (Mech, 1970; Mech et al., 1998). Consequently, in much of Alaska they typically select open or sparsely forested habitats that enable detection and pursuit of prey. Deep snow that hinders movement of ungulate prey or restricts them to small, forested patches often facilitates predation by wolves (Mech and Peterson, 2003). For large ungulate prey such as moose, wolves often focus predation on calves, which tend to be the most vulnerable. In interior Alaska, wolves are most effective hunting in flat or rolling terrain covered with sparse boreal forest or tundra. In coastal rainforests, prey tend to be most vulnerable by wolves in open muskeg heaths at low elevations (Farmer et al., 2006).

### ***Mortality, Productivity, and Survivorship***

Annual mortality in unexploited wolf populations in Alaska and Yukon ranges from 16 to 27% and is linked strongly to prey abundance (Fuller et al., 2003). Causes of mortality include accidents (Mech, 1977), disease (Ballard et al., 1987; Woolington, 2009b), and intra- and inter-pack strife (Ballard et al., 1987). Starvation and disease often co-occur, but the nature of that relationship has not been fully established (Paquet and Carbyn, 2003). When wolves attempt to take down large prey, such as moose or caribou, they risk injury or death (Mech, 1970; Paquet and Carbyn, 2003).

Where wolves are hunted and trapped, human exploitation often produces the overwhelming majority of mortalities (Fuller et al., 2003; Paquet and Carbyn, 2003; Person and Russell, 2008; Woolington, 2009b). Human-related causes of wolf mortality include legal hunting for sport, subsistence or predation control (Ballard et al., 1997; Ballard et al., 1987; Woolington, 2009b). In a heavily exploited population in south-central Alaska, average annual mortality was 45%, of which most (36%) was human caused (Ballard et al., 1987). Human-caused mortality can be compensatory with respect to other sources of natural mortality (Fuller et al., 2003). Resident pack members usually have higher survival than nonresident dispersing wolves because dispersers may be traveling through unfamiliar or unsuitable terrain, and are subject to attacks by resident wolves (Fuller et al., 2003).

Wolves can live for up to 13 years in the wild (Mech, 1988).

Wolves have prolific reproductive potential (Ballard et al., 1987; Boertje and Stephenson, 1992), and pups generally experience high survival rates through their first autumn (Adams et al., 2008; Ballard et al., 1987). For populations to remain roughly constant over time, these pulsed increases in pack size each year are compensated for by a combination of mortality and emigration (Adams et al., 2008). The relative contribution of emigration, natural mortality, and human-caused mortality in wolf packs varies substantially throughout Alaska.

In the central Brooks Range in northern Alaska during 1987-91, the resident wolf population increased by 5%/yr while experiencing a 12% annual harvest rate (Adams et al., 2008). Harvest and natural causes were each responsible for half the annual mortality in radio-collared wolves. Causes of natural deaths that could be distinguished included being killed by other wolves ( $n=6$ ), avalanche ( $n=1$ ), and old age ( $n=1$ ) (Adams et al., 2008). Pups constituted about half the wolf population each autumn, and emigration rates from the study areas were 47% for yearlings and 27% for 2-year-olds.

In northwest Alaska during 1987-92, annual survival averaged 55.2% for radio-collared wolves (Ballard et al., 1997). Hunting was responsible for 69% of known mortalities. Rabies caused 21% of mortalities during the period 1989-91. Twenty-one wolves (25%) dispersed from their original territory during the study, with the highest dispersal rates occurring during a rabies outbreak.

In the Nelchina and upper Susitna basins in GMU 13 of south-central Alaska during 1975-82, wolf populations were highest at the beginning of the study period and declined each year from aircraft-assisted ground shooting and state-managed wolf control (Ballard et al., 1987). Litter sizes in this wolf population ranged from 2-9 pups ( $\bar{X} = 6$ ). Natural mortality accounted for only 20% of total wolf mortality. The population was estimated to be capable of sustaining a mortality rate of 50% before experiencing a population decline. Human harvests in excess of 40% of

autumn wolf numbers caused population declines. Control practices were effective at reducing wolf numbers, but when wolf control ceased the population rebounded quickly.

Wolves recolonized the Kenai Peninsula by natural immigration in the 1960s after being absent since the early 1900s. Wolf density in the winter of 1976-77 was 11 wolves/1,000 km<sup>2</sup>; density increased to 16/1,000 km<sup>2</sup> in 1978-79, dropped to 11-12 in 1980-81, and increased to 18-19 /1,000 km<sup>2</sup> in 1981-82 (Peterson et al., 1984). Annual survival among radio-collared wolves declined during each year of the study, from 100% in 1976-77 to 44% in 1980-81. Harvest was responsible for the majority of mortality. Reported harvest averaged 30% annually, and annual mortality of radio-collared wolves was 32%. Dispersal was found to play a key role in wolf population dynamics; dispersing wolves were highly vulnerable to harvest (the annual survival rate for dispersing adults was only 38%, compared to 73% for resident adults), but those dispersers who survived to reproduce were critical to maintaining populations (Peterson et al., 1984).

Seventeen wolves were radio collared in LCNPP during 2009-11, of which 8 died: 3 were harvested, 2 died in intra-specific fights, 1 drowned, and 2 died from unknown causes. Overall annual survival was 75%, 63%, and 75% during the 3 years. Of 5 dispersing wolves in LCNPP, survival was estimated at 60%, but this is likely biased high (B. Mangipane (NPS), pers. comm., 9/27/11).

### ***Population Estimates***

There are estimated to be 7,000 to 11,000 gray wolves in Alaska. The highest densities occur on the islands associated with the southeastern panhandle where black-tailed deer are the principle prey and the lowest densities occur in mountainous areas where prey consists mostly of Dall sheep (*Ovis dalli*) or mountain goats (*Oreamos americanus*) (Fuller et al., 2003; Person et al., 1996). Two genetically distinct wolf populations are recognized within Alaska; those occupying the coastal zone of southeastern Alaska, and those inhabiting the remainder of the state (Weckworth et al., 2005). During 2000 to 2009, 1,200-1,600 wolves, about 14-16% of the estimated population, were reported harvested annually in Alaska. It is estimated that wolf populations can usually sustain 30 to 40% total annual mortality (Fuller et al., 2003).

Wolf population numbers have not been well studied in the Nushagak and Kvichak watersheds. Better regional wolf population estimates, gathered using scientifically rigorous methods, are needed to improve understanding of wolf populations in the study area. Wolf populations are highly dynamic, so population estimates must be conducted on a relatively frequent basis. Additionally, wolf population numbers in this area are difficult to obtain due to vegetative cover and inconsistent snow conditions. Dense vegetation and sparse or inconsistent snow make sighting of wolves from the air difficult.

No population estimates of wolves have been conducted in the Nushagak watershed (GMUs 17B and 17C; Figure 3) (Woolington, 2009b). ADFG impressions of wolf population status in GMU 17 (the Nushagak and Togiak watersheds, west to Cape Newenham) are based on observations of wolves and tracks, reports from the public, bounty records from 1962 through 1971, mandatory sealing records beginning in 1972, and an annual trapper questionnaire program initiated in 1988 (Woolington, 2009b). Based on these data, ADFG biologists conclude that wolf density in GMU 17 peaked from 1974 to 1977 and then declined sharply by 1980. Wolf densities seemed to increase again until 1989, at which point a rabies outbreak affected canid populations in GMU 17. Wolf populations began to increase again in 1992, and wolves are now thought to be “abundant” throughout GMU 17 (Woolington, 2009b). Woolington (2009) provided current wolf population estimates for GMU 17, but these were considered too speculative to rely on for this assessment and are not presented here.

GMU 9, which includes the Kvichak watershed, extends from LCNPP to False Pass. Wolf population estimates for the region are available, but they should be used with caution for several reasons. ADFG has grouped GMUs 9 and 10 (the Aleutian Islands) for statistical purposes, so those wolf population estimates include lands outside the study area. Also, wolf population dynamics have been studied only informally in the region, and only limited descriptions of methods and results are available (Butler, 2009b). Methods included monitoring 10 wolf packs using radio-collar tracking, inferring trends through observations made during other fieldwork, reviewing reports from hunters and guides, and collecting responses to annual trapper questionnaires. Using these data, ADFG estimated a total population of 350 to 550 wolves in GMUs 9 and 10 (Butler, 2009b). Wolf densities in GMU 9 and 10 are considered low to moderate, but wolf numbers in GMU 9 appear to have increased since the 1990s despite a decline in caribou populations. Possible explanations for this increase in wolves include an abundance of alternate prey such as marine mammal carcasses, salmon, or snowshoe hares; a population rebound following a high period of mortality from a rabies outbreak; or immigration of wolves from surrounding areas (Butler, 2009b). Data are not available to evaluate these hypotheses. Estimated wolf densities in GMU 9E (the Alaska Peninsula south to Port Moller) and the southwestern portion of GMU 9C (the Naknek watershed outside Katmai NPP) are 6-7 wolves/1,000 km<sup>2</sup> (D. Watts (USFWS), pers. comm., 8/23/11).

### ***Human Use/Interaction/Management***

Reporting of wolves harvested in Alaska is mandatory, but reporting compliance is suspected to be weak in some areas (Ballard et al., 1997). The degree of reporting compliance within the Nushagak and Kvichak watersheds is unknown. The reported wolf harvests in GMUs 9, 10 and 17 for 2003-08 are summarized in Table 7.

**Table 7. Wolf harvests in GMUs 9, 10 and 17 reported to Alaska Dept. of Fish and Game.**

<b>Year</b>	<b>GMU 9 and 10<sup>a</sup></b>	<b>GMU 17<sup>b</sup></b>
2003-04	119	141
2004-05	64	60
2005-06	120	62
2006-07	85	79
2007-08	110	73

a= Butler 2009; b=Woolington 2009

Annual harvest of wolves in Alaska varies widely due to fur prices, hunter access to wolf habitat, predator control policies and practices, and population changes in response to prey populations. Hunter access is influenced by winter travel conditions (Woolington, 2009b), including snow depth and fuel prices. Wolves in the Bristol Bay area are typically hunted and trapped by local residents, but are also harvested opportunistically by non-residents primarily hunting other species.

Trappers from southwestern Alaska indicated that wolves were the 4th most important species they targeted, behind river otters, beavers, and red foxes (in that order) (ADFG, 2010). State trapping regulations do not distinguish among different uses (e.g. “subsistence,” “recreational,” or “commercial”) (ADFG, 2011b). Most rural Alaska communities are supported by a mixed subsistence-cash economy (Wolfe, 1991). Trapping is one of many traditional subsistence activities that can provide a modest income for participants. Some harvested furs are sold to dealers, but others are used locally. Furs are often made into hand-crafted items, which are more valuable than the raw pelts (Wolfe, 1991). Items commonly crafted with furs include mitts, coats, boots, fur ruffs, and slippers. In some rural areas, households use most of their harvested wolf pelts locally for ruffs, hats, and lining for winter gear, because imported materials are considered inferior (Wolfe, 1991).

# **WATERFOWL**

## ***Introduction***

This section provides a characterization of waterfowl resources (Anatidae) in the Nushagak and Kvichak watersheds. The waterfowl family includes swans, geese, and ducks (dabbling, diving, and sea). This overview is not a comprehensive account of the status, ecology, and life history of all species of waterfowl that regularly occur in the Bristol Bay region. Rather, this section briefly summarizes the prominent species, general habitat associations and their seasonal occurrence by subregion, highlights primary ecological relationships between waterfowl and sources of nutrients, particularly salmon, that support habitats and food resources, and describes human values and uses of waterfowl from Bristol Bay.

Waterfowl information in this report has been organized by geographic subregions (estuaries and inner bay, lowlands and inland tundra/taiga) that reflect substantial differences in species composition, seasonal use patterns, ecological settings, and extent of available biological information. Information in this report is primarily constrained to the Nushagak and Kvichak watersheds.

## **Regional Overview-**

Thirty-four species of waterfowl regularly use the Bristol Bay region (Appendix 2). The diverse wetlands and other aquatic habitats of the region include boreal forest and taiga lakes and ponds inland near Lake Clark, river basin wetlands and lakes along the Mulchatna, Nushagak and Kvichak valleys, tundra ponds and lakes of the lowlands, and coastal tide flats and estuaries. The diversity and extent of wetlands and waters of the region provides habitat for breeding, spring, summer, and fall migrants, and wintering waterfowl.

The Bristol Bay region is positioned as a major northern spring staging area for waterfowl that breed in western and northern Alaska, Russia, and Arctic Canada. Located at the southern extent of Bering Sea ice, the rich estuaries of Bristol Bay provide food and resting areas for migrants heading north in spring (King, 1982). Spring aggregations include swans, geese and ducks arriving from Mexico and the western U.S., sea ducks from the Pacific coast of North America (Baja Mexico, British Columbia, southeast and Gulf Coast of Alaska), and emperor geese (*Chen canagica*) and sea ducks from the Aleutian Islands.

During summer, the estuaries of Bristol Bay and Kuskokwim Bay to the north serve as traditional molting areas for large numbers of scoters (*Melanitta* spp.) that gather from the Bering Sea and western Arctic regions. These shallows provide food-rich and secure habitats at a time when these birds are nutritionally stressed and flightless. Molting occurs from July through

September, with specific timing varying between sub-adults and adults, as well as between males and females.

Bristol Bay is also an important fall staging area for waterfowl migrating south from northern and local breeding areas. Fall migration tends to be faster and more direct to staging areas than spring migration. From mid-August through early October, ducks, Canada (*Branta canadensis*) and greater white-fronted (*Anser albifrons*) geese move overland through the passes of the Alaska Range to the coastal marshes of Cook Inlet (Redoubt Bay, Trading Bay, Susitna Flats, and Palmer Hay Flats). Large numbers of ducks and geese fly to the rich lagoons and coastal tundra on the north side of the Alaska Peninsula west to Izembek Lagoon. Canada, cackling (*Branta hutchinsii*) and white-fronted geese; brant (*Branta bernicla*); and most dabbling ducks depart by early November, heading either eastward along Alaska's south coast or directly across the Gulf of Alaska to points between British Columbia and Mexico. Most dabbling and diving ducks from western Alaska fly to wintering areas within the Pacific Flyway west of the Rocky Mountains, but some greater scaup (*Aythya marila*) and other species cross the continent to the Gulf of Mexico and Atlantic Coast (King, 1973; King and Lensink, 1971). Some sea ducks, an increasing number of Pacific brant (Ward et al., 2009), and even a small population of tundra swans (*Cygnus columbianus*) winter along the Alaska Peninsula, whereas emperor geese and other sea ducks fly to the Aleutian Islands.

### **History of Waterfowl Surveys-**

Most of the quantitative data on waterfowl numbers and distribution in the greater Bristol Bay region are derived from surveys conducted over different circumscribed survey areas. Although surveys provide discrete datasets, it is important to note that the distributions and habitat use patterns of waterfowl in the Nushagak and Kvichak watersheds are continuous with habitats west of the Nushagak Peninsula and down the Alaska Peninsula to Izembek Lagoon. Information summarized in this report focuses primarily, on the inner bay, lowlands, and inland subregions of the Nushagak and Kvichak watersheds.

Osgood (1904) provided a detailed and extensive description of habitats and wildlife of the Bristol Bay region from his 1902 reconnaissance survey, mostly by canoe, starting from Cook Inlet and travelling to Iliamna Lake and Lake Clark, then up the Chulitna River and down the Kaktuli, Mulchatna, and Nushagak Rivers to Bristol Bay. His trip continued by schooner to Egegik, over the Alaska Peninsula at Becharof Lake, and then by rowboat to Cold Bay. Hurley (1931a, 1931b, 1931c; 1932) recorded observations of birds in the Bristol Bay region. Murie (1959) summarized the environment, habitats, and wildlife of the Aleutian Islands and Alaska Peninsula, with some coverage of Kvichak and Nushagak Bays, from his 1936-37 boat-based expedition. Both Osgood and Murie provided species accounts of waterfowl, reviewing records of earlier observers. Gabrielson (1944) compiled general records of birds on his extensive trip of summer 1940, including travel up the Kvichak River, across Iliamna Lake and portage to Cook

Inlet. Hine (1919) and Cahalane (1944) described birds of the nearby Katmai region. Gabrielson and Lincoln (1959) provided the most thorough compilation of bird records of their day in *The Birds of Alaska*, including information on migration patterns, ecological zones, and detailed species accounts. Gill et al. (1981) described the waterfowl and other birds of the north-central Alaska Peninsula.

Quantitative surveys of Bristol Bay waterfowl were established in the 1950s to monitor ducks and geese on prime lowland nesting habitats as part of the annual North American breeding population survey (Hodges et al., 1996). Interest in oil and gas exploration and other resource development stimulated more extensive surveys of waterfowl in coastal areas (Bartonek and Gibson, 1972; King and McKnight, 1969). The Coastal Zone Management Act of 1972 provided funding to states to synthesize information and establish cooperative wildlife resource inventories in coastal areas (Timm, 1977). In 1974, the Outer Continental Shelf Environmental Assessment Program (OCSEAP) stimulated many surveys and research projects related to waterfowl in the Gulf of Alaska, Bering Sea, and Beaufort Sea. This program greatly expanded the amount of information on waterfowl and other birds in Bristol Bay (Arneson, 1980). Information on waterfowl and other wildlife resources in the region has been reviewed broadly by USFWS (1976), Timm (1977), and USFWS (1983).

The longest-term and most consistent waterfowl surveys in the Bristol Bay region are part of the Alaska-Yukon Waterfowl Breeding Population Survey (AYWBPS), flown annually by USFWS since 1957 as part of the North American duck survey program (Mallek and Groves, 2011). This survey was designed to index breeding dabbling ducks during the early egg-laying period (late May) to provide data on annual status and long term trends. Bristol Bay (Stratum 8 in this statewide survey) is composed of 11 transects in 23 segments, sampling an area of 25,641 km<sup>2</sup> (9,900 mi<sup>2</sup>) usually flown in late May.

During 1989-97, USFWS conducted a series of experimental expanded surveys of major tundra waterfowl areas to assess means of providing more reliable annual estimates of abundance (Conant et al., 2007). The expanded waterfowl surveys flown by Platte and Butler (1995) over the Bristol Bay region in 1993 and 1994 covered a much broader area (49,890 km<sup>2</sup>) than the traditional AYWBPS, extending west to Togiak Bay and the Togiak River drainage, covering more a northerly band from Wood-Tikchik Lakes eastward to Port Alsworth, and southwest on the Alaska Peninsula to include Port Heiden and the Seal Islands. The data from this experimental survey reflect a much wider range of habitats and duck densities than the traditional AYWBPS survey (Conant et al., 2007).

Coastline and estuarine waterfowl surveys of Bristol Bay, focusing on emperor geese, have been conducted annually in spring (1981-2011) (Dau and Mallek, 2011) and fall (1980-2011) (Mallek

and Dau, 2011). Steller's eider (*Polysticta stelleri*) have been the focus of Bristol Bay surveys conducted since 1992 (Larned and Bollinger, 2011).

## ***Waterfowl Resources and Seasonal Occurrence***

### **Estuaries and Inner Bristol Bay-**

Bristol Bay estuaries and nearshore waters are important to waterfowl year round, during spring and fall migration, summer molting, and as winter range for some species. King and McKnight (1969) made the first attempt to estimate the number of birds in Bristol Bay during October, flying transects from the high tide line offshore to 12 miles (19.3 km). Their survey covered over 20,700 km<sup>2</sup> of coast from Cape Constantine south and west to Unimak Island, and included transect lines in outer Kvichak and Nushagak Bays.

During the early 1970s, Bristol Bay became a focal area of the OCSEAP studies, including offshore transect surveys of birds from Kvichak Bay south along the Alaska Peninsula (Bartonek and Gibson, 1972; USFWS, 1976). Most of the survey coverage was over the outer bay beyond the BBWA area, but it provided insights to the seasonal use of Bristol Bay nearshore waters.

An additional 33 coastal bird surveys were flown for OCSEAP between October 1975 and August 1978 (Arneson, 1980). These surveys from the Gulf of Alaska through the Aleutian Islands were designed to assess seasonal bird densities and distributions in littoral/nearshore waters, describe coastal habitats, and document migration. The North-Bristol Bay region was surveyed in spring (May) by fixed-wing aircraft, helicopter, and boats. Sections 1-6 of the study area covered the coast of Kvichak Bay to Cape Constantine within the BBWA study area.

Habitats- The estuaries and nearshore waters of Bristol Bay provide diverse aquatic habitats for waterfowl and other waterbirds (Michel et al., 1982; Selkregg, 1976). To document seasonal usage by birds, Arneson (1980) classified over 30 types of coastal habitats, ranging from intertidal flats and salt marshes to open waters. He found about 80% of waterbirds on protected delta habitats and exposed inshore waters. Dabbling ducks and geese preferred mudflats and delta habitats; diving ducks and sea ducks were found mostly in exposed inshore and bay waters. A large proportion of Nushagak and Kvichak Bays has water depths of < 10 m (Schamber et al., 2010), which provides very accessible benthic habitats for diving and sea ducks that feed largely on invertebrates.

Geese- Most of the Pacific (black) brant population and the world population of emperor geese migrate through the greater Bristol Bay and Alaska Peninsula regions during spring and fall. Pacific brant breed mostly on the Yukon-Kuskokwim (Y-K) Delta, and also along the Arctic Coasts of Alaska, northeast Russia, and Canada (Pacific Flyway Council, 2002; Reed et al., 1998). During April, Bristol Bay and the Alaska Peninsula serve as staging areas for birds assessing snowmelt and Bering Sea ice conditions. Chagvan and Nanvak Bays near Cape

Newenham hold about 50,000 brant during spring, but only small numbers of brant use Nushagak or Kvichak Bays. From late August through mid-September, most brant leave breeding areas and move south along western Alaska directly to the Alaska Peninsula and eventually to Izembek Lagoon where the entire population stages until early November. Most brant depart the Peninsula *en masse* across the Pacific to wintering grounds located from British Columbia to California, but most settle in the large bays of Baja California, Mexico (Dau, 1992; Pacific Flyway Council, 2002). Since the mid-1970s, milder conditions have allowed up to one-third of Pacific brant to winter along the western end of the Alaska Peninsula (Ward et al., 2009).

Emperor geese breed almost entirely on the coastal zone of the Y-K Delta, with a few in Russia (Pacific Flyway Council, 2006; Petersen et al., 1994). They winter from the outer Alaska Peninsula westward into the Aleutian Islands. Like brant, emperor geese migrate in spring and fall through the greater Bristol Bay area and eastern Bering Sea coast. They stage and migrate mainly through bays to the west of the Nushagak Peninsula, but a few emperor geese occur in inner Bristol Bay. During fall, large numbers of emperor geese cross Bristol Bay to the large lagoons on the northern Alaska Peninsula, particularly the Seal Islands, Nelson Lagoon, and Izembek Lagoon (Petersen et al., 1994).

Ducks- The nearshore waters of Bristol Bay host a large variety of ducks, including most of the common dabbling and diving duck species. According to spring surveys conducted in 1976-77, these ducks used an array of habitats from intertidal marshes to offshore waters. Diving duck densities were 10/km<sup>2</sup> to 100/km<sup>2</sup> along the north side of Kvichak Bay and around Nushagak Bay (Arneson, 1980). Estimated density of all birds in Kvichak Bay was 259 birds/km<sup>2</sup>, most of which were shorebirds, dabbling ducks (81/km<sup>2</sup>), and diving ducks on tide flats. In south and east Nushagak Bay, high densities (171/km<sup>2</sup>) of scaup (*Aythya spp.*) were concentrated along Flounder Flats, mixed with flocks of black scoters (*Melanitta americana*).

Deeper, more open waters were used by diving ducks and sea ducks. Relatively high densities of sea ducks (26/km<sup>2</sup>) were recorded during surveys on the east side of the Nushagak Peninsula (Arneson, 1980), composed of 10% long-tailed ducks (*Clangula hyemalis*) and 12% harlequin ducks. The majority of ducks in exposed waters and areas out to > 10 m deep were greater scaup, scoters, and eiders (see below). During spring and fall, smaller numbers of long-tailed ducks, harlequin ducks, and goldeneyes occurred in the inner Bay. Recently, up to 48,000 long-tailed ducks have been recorded in greater Bristol Bay during April (Larned and Bollinger, 2011) on their way inland or northward for breeding; few long-tails occur during fall (Mallek and Dau, 2011). Harlequin ducks used the bay before and after breeding inland and on their way west to winter in the Aleutian Islands. Mallek and Dau (2011) counted 3,300 harlequin ducks along the coasts of Bristol Bay and Alaska Peninsula during spring 2010, but they also referenced a peak count of 6,114 birds in 1992 (USFWS, 1976).

Scoters- Bristol Bay, and especially Kvichak Bay, is an important staging and molting area for black, surf (*Melanitta perspicillata*), and white-winged (*M. fusca*) scoters in spring through fall. Early surveys often did not accurately record scoters by species, but over the past ten years focused surveys have produced species-specific estimates, especially for black scoters.

Spring OCSEAP surveys along pelagic transects tallied over 253,000 scoters in May 1972 and 216,000 scoters in April 1973 (USFWS, 1976). Arneson (1980) estimated that black scoters comprised 97% of all scoters counted during spring surveys in 1976 and 1977. More recent spring estimates also have documented large number of scoters in the inner bay, including up to 45,000 black scoters (Larned, 2008).

Scoters gather in Bristol Bay during the wing molt from July through September. OCSEAP surveys counted 180,000 in July 1973 (C.D. Dau (USFWS), pers. comm., 1/5/12). A high proportion of 77 satellite-marked black scoters from several wintering areas gathered in northeast Bristol Bay where they spent an average of 15-20 days from June through September (Schamber et al., 2010).

Although lacking data on geographic distribution, King and McKnight (1969) documented about 181,000 scoters during October staging, including approximately 140,000 black scoters. On the more pelagic OCSEAP surveys, over 285,000 scoters were estimated in the outer bay during October 1974 (USFWS, 1976). Larned and Tiplady (1998) found about 20,000 black scoters in the bay during late September. Few scoters are thought to winter in upper Bristol Bay (Bellrose, 1980; Schamber et al., 2010); most probably disperse westward along the Alaska Peninsula.

Satellite telemetry indicates that black scoters from widely separate wintering areas in British Columbia, Kodiak, and Dutch Harbor all used Bristol Bay from spring through fall (Bowman et al., 2007). Analysis of cumulative satellite locations throughout the year indicates that black scoters mostly use specific areas of shallow (< 3 m) waters along the north side of Kvichak Bay, western Nushagak Bay, and Egegik Bay to the south (Schamber et al., 2010).

King Eiders- King eiders (*Somateria spectabilis*) in North America breed across the North Slope of Alaska and Arctic Canada, but inner Bristol Bay waters are also important to king eiders as both a wintering area and as a major spring staging area (Suydam, 2000). OCSEAP spring surveys estimated that about 280,000 king eiders were in outer Bristol Bay in May 1972, and over 1.8 million were found in April 1973 (USFWS, 1976). Arneson (1980) estimated eider composition was about 45% king, 36% common (*S. mollissima*), and 19% Steller's during spring coastal surveys in 1976 and 1977.

In the late 1990s, king eiders marked with satellite tags were used to guide aerial-based investigators to document specific staging and molting areas (Larned and Tiplady, 1998). During

April 2008 surveys for Steller's eiders, Larned (2008) estimated over 570,000 king eiders in Kvichak Bay; an average of 194,000 king eiders were estimated from these surveys during 2000-09 (Larned and Bollinger, 2011).

Bristol Bay has been documented as one of the few important areas for king eiders to molt; other areas include the northeast Russian coast and St. Lawrence Island (Phillips et al., 2006). Based on satellite tracking, molting king eiders arrive in Bristol Bay from Alaska's North Slope (Phillips et al., 2006) and Arctic Canada (Dickson et al., 2001). Timing and duration of molting varies by sex and age of birds, generally extending from August to October.

Smaller numbers of king eiders have been recorded in the bay; as many as 20,000 were estimated in late September (Larned and Tiplady, 1998). Southwestern Alaska, especially inner Bristol Bay, is considered one of three main wintering areas of king eiders breeding in western North America, though these birds may move considerably within the region between October and April (Opper et al., 2008).

Schamber et al. (2010) assessed the distribution of king eiders in Bristol Bay from year-round locations of satellite-marked birds. Across seasons, king eiders used most of the inner bay between the Nushagak Peninsula and Egegik Bay (averaging 10.6 km offshore), including areas with water depths of > 20 m, but they particularly frequented defined areas off Etolin Point, Half Moon Bay, and Egegik Bay where water depths were < 10 m.

*Steller's Eiders*- Bristol Bay coastal waters host Steller's eiders mostly in spring and fall, but the species is not thought to breed in the region. The historical breeding range of Steller's eiders in Alaska extends from the Y-K Delta into northwest Alaska and the western North Slope (Fredrickson, 2001). Along with a large number that breed west to the central Siberian coast, the Alaska birds are part of a Pacific (Russia-Alaska) population that probably numbers between 130,000 (Hodges and Eldridge, 2001; USFWS, 1999) and 150,000 (Fredrickson, 2001). Although historical data were not quantified, the number of Steller's eiders breeding in Alaska declined sometime between the 1940s and 1960s, especially on the Y-K Delta (Kertell, 1991). Based on estimates that there may have been fewer than 3,000 birds breeding over a substantially reduced range in Alaska during the 1990s, the USFWS listed the Alaska-breeding component of the population as threatened under the Endangered Species Act in 1997 (USFWS, 2002).

The primary wintering grounds for the Pacific population extends from the central Alaska Peninsula westward into the Aleutian Islands (Fredrickson, 2001). Thus, most birds transit Bristol Bay in spring and fall. Surveys have been conducted to assess the Pacific population during spring migration (April-early May) since 1992, including survey sections between Cape Constantine and the Naknek River (Larned and Bollinger, 2011). In general, Steller's eiders staging during spring were concentrated along the Alaska Peninsula, south of Egegik and west of

the Nushagak Peninsula; very few birds used inner Bristol Bay. Coastal surveys of emperor geese flown in late April indicate similarly low occurrence of Steller's eiders in Nushagak and Kvichak Bays (C.D. Dau (USFWS), pers. comm., 1/5/12) (Dau and Mallek, 2011).

After breeding on more northerly nesting areas, a large proportion of Pacific Steller's eiders begin to return to southwest Alaska in late June, in advance of the wing molt (Petersen, 1981). Few of these birds use inner Bristol Bay; instead they concentrate in the lagoons along the Alaska Peninsula (C.D. Dau (USFWS), pers. comm., 1/5/12) (Mallek and Dau, 2011). Molt migration progresses by sex and age class; the period of molting extends from late July for subadults to October for adult females (Petersen, 1981). Birds continue to arrive during fall staging, mainly in Nelson Lagoon and Izembek Lagoon, before moving westward to winter in the Aleutian Islands.

### **Bristol Bay Lowlands-**

**Habitats-** The Bristol Bay lowlands are characterized by old glacial deposits with moraine lakes and ponds, glacial outwash and riverine deposits along floodplains, and mixed marine deposits near the mouths of the Nushagak and Kvichak Rivers. Landcover is mostly moist and wet tundra between Nushagak and Kvichak Bays as well as, a broad region of the upper Mulchatna drainage. Tundra merges into lowland spruce-hardwood forest between the lower Nushagak River and the Wood-Tikchik Lakes, and in the Kvichak Valley to Iliamna Lake (Selkregg, 1976). This subregion has a wide diversity of freshwater lakes and ponds, as well as numerous floodplain wetlands.

Stratum 8 of the AYWBPS is generally defined to include the "lowlands," including the area southwest of Iliamna Lake to the Nushagak Peninsula and extending southwest from Naknek River to Cinder River. Table 8 provides the average indices and densities of 30 groups (32 species) of waterfowl recorded on aerial surveys flown annually in late May.

**Swans-** Tundra swans are the most common swan species in the Bristol Bay region. These tundra swans comprise 10-15% of the Western Population which breeds from Kotzebue Sound to the outer Alaska Peninsula, and winters from British Columbia to central California (Ely et al., 1997; Pacific Flyway Council, 2001). The most recent 10-year average index count of swans from Bristol Bay (AYWBPS Stratum 8) was 15,400 (0.6 swans/km<sup>2</sup>). Tundra swans arrive as early as mid-March and numbers peak in late April (Wilk, 1988). The majority of swans move north to the Y-K Delta region, but those that breed in Bristol Bay initiate nesting in early May, and young hatch in early- to mid-June. Because Bristol Bay has an earlier spring thaw, the phenology of local breeding swans is 2-4 weeks earlier than those nesting on the Y-K Delta and northern Alaska. Wilk (1988) provides indications that earlier nesting in Bristol Bay supports larger average brood sizes and higher productivity.

**Table 8. Average abundance indices and densities of species/groups recorded in late May on the Alaska Yukon Waterfowl Breeding Population Survey, Bristol Bay Lowlands (Stratum 8)**

<b>Species/Group</b>	<b>Long-term Average 1957-2011</b>	<b>Average Index 2002-2011</b>	<b>10-Yr Average Birds/km<sup>2</sup></b>
Mallard	33,100	68,100	2.68
Gadwall	1,400	2,000	0.08
American Wigeon	25,200	55,300	2.16
Green-winged Teal	30,600	71,800	2.80
Blue-winged Teal	0	200	0.01
Northern Shoveler	13,300	33,500	1.30
Northern Pintail	57,300	82,100	3.20
Redhead	0	0	0.00
Canvasback	200	200	0.01
Scaup (Lesser, Greater)	79,800	94,000	3.67
Ring-necked Duck	400	0	0.00
Goldeneye (Common, Barrow's)	4,200	1,600	0.06
Bufflehead	500	300	0.01
Long-tailed Duck	13,700	5,200	0.20
Unidentified Eider	900	500	0.02
Common Eider	0	100	0.00
Spectacled Eider	0	0	0.00
Steller's Eider	0	0	0.00
King Eider	0	0	0.00
Unidentified Scoter	79,400	36,800	1.43
Surf Scoter	n/a <sup>a</sup>	400	0.01
White-winged Scoter	n/a <sup>a</sup>	2,300	0.09
Black Scoter	n/a <sup>a</sup>	37,600	1.47
Merganser (Common, Red-breasted)	2,700	5,300	0.21
<b>TOTAL DUCKS</b>	<b>346,500</b>	<b>497,000</b>	<b>19.38</b>
White-fronted Goose	5,100	5,300	0.21
Canada/Cackling Goose	2,400	2,300	0.09
Emperor Goose	0	0	0.00
(Pacific ) Brant	0	100	0.00
<b>TOTAL GEESE</b>	<b>7,600</b>	<b>7,700</b>	<b>0.30</b>
Swan (Tundra, Trumpeter)	12,100	15,400	0.60
Sandhill Crane	3,300	5,300	0.20

<sup>a</sup> Scoters have been recorded by species only since 1993.

Geese- Long-term average index counts of geese in the region available from the AYWBPS have been relatively stable over the past 30 years (Table 8), averaging 7,700 geese (0.3/km<sup>2</sup>) during 2002-11, with greater white-fronted geese over twice as abundant as Canada geese (Mallek and Groves, 2011). Platte and Butler (1995) tallied 4,255 geese (0.09 geese/km<sup>2</sup>) over a survey area farther inland, and estimated composition as 55% white-front and 45% Canada geese. White-fronted geese in Bristol Bay currently comprise only a small portion of the Pacific Flyway population which breeds mostly on the Y-K Delta and numbers over 600,000. During the late 1970s and early 1980s, when Pacific white-fronted geese were overharvested and declined more than 80% (Pacific Flyway Council, 2003; Pamplin, 1986), those in Bristol Bay made up about 15% of the population.

White-fronted geese from Bristol Bay are slightly larger in size than most Pacific Flyway white-fronts from the Y-K Delta (Ely et al., 2005; Orthmeyer et al., 1995) although they are not considered taxonomically separate. White-fronted geese using Bristol Bay also migrate south earlier than others in fall, passing through the Klamath Basin of Oregon and California in September, and overflying the Sacramento Valley where most Pacific white-fronted geese winter. Bristol Bay birds press further south to winter in the northern highlands of Mexico (Ely and Takekawa, 1996).

The Canada/cackling geese that breed in the Bristol Bay region include Taverner's cackling geese (*Branta hutchinsii taverneri*) and lesser Canada geese (*Branta canadensis parvipes*), the former found closer to the coast. Taverner's geese breed extensively along the western and northern coastal regions of Alaska, and lesser Canada geese are found throughout Interior Alaska and Yukon Territory. However, the breeding ranges of these two populations have not been delineated and there are no reliable population indices (Pacific Flyway Council, 1994). In fall, most lesser Canada geese migrate through Cook Inlet and along the Alaska coast to winter from British Columbia into Washington and Oregon whereas Taverner's geese staging on the western Alaska Peninsula make a direct migration across the Gulf of Alaska to wintering areas. During winter, most Taverner's and lesser Canada geese form large aggregations with over 250,000 other white-cheeked ("Canada") geese in southwest Washington and western Oregon. They also are found in the upper Columbia River Basin and east of the Cascade Mountains. Intermingling of populations precludes accurate winter inventories.

The smallest subspecies of cackling geese (*B. h. minima*) migrates through the region while flying to and from the Y-K Delta coast where they breed. Cackling geese are counted annually on their breeding grounds, with survey results indicating substantial increases from a low of <30,000 in 1984 to 150,000-200,000 since 1997. During fall, nearly all of cackling geese have historically staged along the Alaska Peninsula, near Pilot Point and Cinder River (Sedinger and Bollinger, 1987). Since recovery from a major population decline caused by overharvest through the early 1980s (Pamplin, 1986), fall staging of cackling geese has occurred over a more

dispersed area westward along the Alaska Peninsula (Gill et al., 1997) from which they migrate across the Gulf of Alaska. Prior to the 1980s, cackling geese wintered in Central California, but now the majority winter in the Willamette Valley of western Oregon and near the Lower Columbia River in southwest Washington (Pacific Flyway Council, 1999).

Brant and emperor geese move through Bristol Bay coastal habitats in spring and fall (see Estuaries and Inner Bristol Bay), but the lowlands are not considered a breeding area. Lesser snow geese (*Chen caerulescens*) are occasionally seen in Bristol Bay during migration to and from Wrangel Island in Russia.

Ducks- Beginning in 1995, indices of duck abundance as measured by the AYWBPS have generally been higher than long-term averages. The most recent ten-year average is about 497,000 ducks (19.4 ducks/km<sup>2</sup>) (Table 8). The most abundant species were greater and lesser scaup (*Aythya marila* and *A. affinis*; 3.7/km<sup>2</sup>), northern pintail (*Anas acuta*; 3.2/km<sup>2</sup>), green-winged teal (*A. crecca*; 2.8/km<sup>2</sup>), mallard (*A. platyrhynchos*; 2.7/km<sup>2</sup>), and American wigeon (*A. americana*; 2.2/km<sup>2</sup>).

In their expanded survey area, Platte and Butler (1995) estimated averages of 355,200 ducks (7.12/km<sup>2</sup>). Duck species composition was similar to the AYWBPS, with the highest average densities estimated as scaup (1.9/km<sup>2</sup>), northern pintail (1.1/km<sup>2</sup>), green-winged teal (1.0/km<sup>2</sup>), and mallard (0.9/km<sup>2</sup>). Gadwall (*A. strepera*), wigeon, and shoveler (*A. clypeata*) were more prevalent south along the Alaska Peninsula, but at lower densities. High to medium densities of scaup were recorded west of Iliamna Lake near the upper Kvichak and Alagnak Rivers.

Scaup- Greater and lesser scaup cannot be differentiated during aerial surveys, but most of the scaup breeding in tundra regions are assumed to be greater scaup (Hodges et al., 1996). The relatively high densities of scaup in the Bristol Bay lowlands recorded on the AYWBPS and expanded surveys suggest that this region hosts a substantial portion of the breeding greater scaup in all of North America. About 80% of greater scaup migrate across the continent in fall, stopping in the Great Lakes, and wintering along the northeast Atlantic Coast (Kessel et al., 2002). Others winter from south-central Alaska down the Pacific Coast.

Black scoters- Bristol Bay is recognized as one of the most important breeding areas for the western (Pacific) population of black scoters that occupies Alaska and western Canada. The Pacific population may number 200,000-400,000 birds (Bordage and Savard, 1995). The AYWBPS does not provide reliable indices for breeding scoters because it is flown before nest initiation, which is later (June) than other ducks, and because scoters are also found in taiga and boreal habitats outside areas traditionally surveyed. Scoters have also not been identified to species level during AYWBPS surveys.

Through the Sea Duck Joint Venture, USFWS began conducting additional aerial surveys designed for scoters in Alaska in 2007 to improve population estimates (Stehn et al., 2010; Stehn et al., 2006), particularly for black scoters that have shown historic declines (Bordage and Savard, 1995). These new surveys have produced recent estimates of 173,000 black scoters across all western Alaska tundra breeding areas (Stehn et al., 2010). Bristol Bay is an important breeding area, containing 46,100 black scoters (0.92/km<sup>2</sup>), about 15% of all ducks identified within the expanded survey area (Platte and Butler, 1995). Densities were highest in a band from western Kvichak Bay to Lake Iliamna, and also along the western Alaska Peninsula between Egegik and Ugashik Bays.

### **Inland Tundra/Taiga-**

**Habitats-** The inland subregion of Bristol Bay is underlain by glacial deposits that are interspersed with bedrock formations in the upper Kvichak and Mulchatna drainages. Bedrock dominates in the montane areas south and east of Lake Clark. Vegetation communities are transitional from moist tundra to the west to tall shrub habitats and upland spruce hardwood forest; alpine tundra rises into the Aleutian Range (Selkregg, 1976). The subregion has abundant aquatic habitats from alpine and glacial lakes to wet tundra wetlands and floodplain basins along rivers.

Williamson and Peyton (1962) reviewed the characteristics and historical ecological classifications of the Iliamna Lake region. They concurred with previous observers that the region's dominant feature is transitional communities where the interior/arctic, southcentral coast forest, and western tundra ecotypes meet. They indicated that neither the dissected Aleutian Range to the east nor the open plateaus to the west served as barriers for avifauna. Williamson and Peyton (1962) described 12 ecological formations (habitat types) and their associated bird species. They recorded strong associations of 15 waterfowl species to open lakes and ponds, secondary preferences for streams and rivers by most species, and use of freshwater marshes by dabbling ducks.

Williamson and Peyton (1962) also included information on waterfowl distribution and abundance. Additional aerial survey coverage was provided by Platte and Butler (1995), and a few observations in montane habitats by Ruthrauff et al. (2007).

**Swans-** Trumpeter swans (*Cygnus buccinator*) are found in the eastern portion of the Bristol Bay region associated with the forested and taiga habitats typical of the boreal zone. This area abuts the temperate coastal forest and coastal marshes that are occupied by trumpeter swans in Cook Inlet. As their name suggests, tundra swans are primarily birds of open tundra. They have an extensive breeding distribution from the Alaska Peninsula and Bristol Bay coast inland to the Iliamna Lake and Lake Clark regions. The Pacific Coast Population of trumpeter swans has been increasing, including breeders on the Kenai Peninsula, Cook Inlet lowlands, and the upper

Kuskokwim valley. There is increasing evidence that trumpeter swans are expanding their range westward into tundra swan habitats (Pacific Flyway Council, 2008).

Geese- Lesser Canada geese (*B. c. parvipes*) are found throughout southcentral Alaska and interior portions of southwest Alaska. Although survey data and descriptions of geese are not readily available, some Taverner's cackling geese (*B. h. taverneri*) may also breed in the inland subregion. The ranges of these morphologically-similar, medium-sized geese have not been delineated. Canada/cackling geese are listed as common in LCNP (National Park Service, 2011) and in the Kvichak River valley. Greater white-fronted and snow geese travel during spring and fall migrations to and from Cook Inlet, and brant have also occasionally been recorded.

Ducks- Dabbling ducks are present in only moderate densities in the inland subregion, with mallards, northern pintail, and green-winged teal most common. Aerial surveys suggested the presence of pockets of spring duck habitat near the head of the Kvichak River and the upper portions of the Chulitna and Mulchatna drainages (Platte and Butler, 1995). American wigeon and northern shovelers were less abundant. Scaups and black scoters associated with boreal habitats also occurred in the same general areas, with densities as high as  $>8$  birds/km<sup>2</sup>. Among sea duck species, long-tailed duck, surf scoter, white-winged scoter, common goldeneye, Barrow's goldeneye, red-breasted merganser, and common merganser were distributed more sparsely and at low densities. Harlequin ducks were found in low densities throughout the Bristol Bay region. The occupied clear, high-gradient streams during the breeding season. Harlequins are difficult to detect on aerial surveys due to the habitat they use, and thus are often underestimated.

### ***Nutrients, Trophic Relations and Foods***

For waterfowl, body condition, reproductive success, and survival are dependent on the quantity and quality of foods available throughout their annual cycle. Waterfowl typically experience the greatest energetic demands before and during migrations, during the pre-breeding period when resources are needed for egg-laying, incubation, and territory defense, and during summer molt when feather replacement taxes reserves. Although stored reserves (body fat and protein) may be used during migration and incubation, waterfowl require habitats that have abundant food resources and they must be able to efficiently exploit specific foods. Thus, they must also be mobile to optimize seasonal foraging strategies.

### ***Nutrients and Habitat Productivity-***

In Alaska, the most productive waterfowl habitats are those that have dynamic nutrient systems that produce seasonally rich plant and animal foods for birds. For example, the mixing of marine nutrients from upwellings and terrestrial nutrients from rivers and streams enrich the productivity of coastal estuaries and lagoons. Large river deltas (e.g., Stikine, Copper, Yukon-Kuskokwim, Colville) exemplify the complex interfaces of marine and terrestrial nutrients in a matrix of low-

lying depositional wetlands, and they support high densities of breeding waterfowl. The estuaries and nearshore waters of Nushagak and Kvichak Bays are enriched by such nutrient mixing (Straty, 1977), particularly in coastal marshes used by swans, geese, and dabbling ducks, and also feature abundant benthic invertebrates used by diving and sea ducks.

The productivity of waterfowl habitats of inland-interior regions are also based on dynamic nutrient systems primarily associated with river basin wetlands and floodplains. Within the extensive watersheds of large rivers, nutrient flux (largely nitrogen and phosphorus) is driven by stream erosion, in-stream transport, and by seasonal flooding. In forested areas, mosaic patterns of wild fires can provide sources of nutrients for wetlands (Bayley et al., 1992). In the Bristol Bay region, Selkregg (1976) noted a long history of wild fires in the Mulchatna Valley; upland spruce-hardwood forests are found in the upper drainages of the Mulchatna and Nushagak Rivers. Seasonal nutrient inputs refresh and subsidize primary productivity and the development of aquatic invertebrates in floodplains and large wetland basins (Heglund, 1992). In the Nushagak and Kvichak River systems, the large biomass of sockeye and other salmon provides a significant source of imported nutrients throughout these watersheds (see below).

### **Food Habits-**

The waterfowl of Bristol Bay exhibit a wide diversity of foraging strategies and food habits; some species are specialists and some are generalists, but nearly all adapt seasonally to different foods. Among swans, geese and ducks during the breeding season, some species defend territories that are selected to provide food supplies sufficient for nesting adults and growing young; others adapt more mobile strategies to take advantage of temporarily abundant foods. During non-breeding periods (migration, molt and winter) waterfowl often aggregate and exhibit fidelity to habitats and sites with reliable food resources.

Swans and geese are primarily vegetarians, although adults and young feed opportunistically on insects, aquatic invertebrates, and other animals especially during breeding and brood-rearing season. Both trumpeter and tundra swans feed on submergent and emergent vegetation year-round. The development of cygnets to fledging often extends into fall when their freshwater habitats begin to freeze. At this time, they may move to aquatic beds in flowing waters and coastal shallows prior to migrating (Limpert and Earnst, 1994.; Mitchell and Eichholz, 2010).

Geese primarily graze on vegetation, although adults and goslings feed opportunistically on insects and invertebrates. Canada, cackling, and white-fronted geese consume shoots and stems of graminoids common in moist and wet tundra breeding habitats. In coastal areas, broods are often brought to wetland basins, tide flats, and salt marshes where foods are abundant. During fall staging, Canada and white-fronted geese often frequent uplands to feed on berries. Canada geese, emperor geese, and brant are associated with coastal habitats, where they rely on salt

marsh vegetation, eelgrass (*Zostera marina*) beds in estuaries, and some marine algae (Petersen et al., 1994; Reed et al., 1998).

The three tribes of ducks that use Bristol Bay have very diverse foods habits (Table 9). Dabbling ducks (Anatini) are generally omnivorous, feeding on seeds and aquatic invertebrates, and focusing on high protein foods prior to breeding. Diving ducks (Aythyini) are also omnivorous, but they feed in more open waters for benthic invertebrates, and they focus on animal foods during staging and wintering in coastal waters. Sea ducks (Mergini) consume mostly animal foods year-round, feeding on freshwater benthic invertebrates during breeding, and on a wide variety of marine invertebrates during staging and wintering on saltwater.

**Table 9. General food habits and consumption of fish by duck species of Bristol Bay.**

<b>Common Name</b>	<b>General Food Habits</b>	<b>Consumption of Fish</b>
<b>Dabbling Ducks</b>		
Gadwall	Primarily plant foods with some invertebrates during pre-breeding	Unknown
American Wigeon	Strongly vegetarian with some invertebrates during pre-breeding	Spring herring eggs on the Oregon coast (Bayer, 1980)
Mallard	Omnivorous, mostly plant seeds and invertebrates, increasing animal foods during pre-breeding	Incidental fish; fall and winter use of salmon eggs and flesh in spawning lakes and coastal waters (Gleason, 2007; Munro, 1943)
Northern Shoveler	Small invertebrates and seeds strained at the surface	Trace of fish in winter
Northern Pintail	Omnivorous, mostly grain and plant seeds with more invertebrates during pre-breeding	Unknown
Green-winged Teal	Omnivorous, mostly plant seeds and invertebrates, increasing animal foods during pre-breeding	Use of salmon eggs and salmon flesh in spawning streams (Gabrielson and Lincoln, 1959)
<b>Diving Ducks</b>		
Canvasback	Omnivorous, mostly plant buds, tubers, root stock and invertebrates, increasing animal foods in pre-breeding	Incidental small fish (Cottam, 1939); alewife fingerlings on fall migration in New York. Spring herring eggs on the Oregon coast (Bayer, 1980). Salmon flesh on the Washington coast (Dawson and Bowles, 1909)
Redhead	Omnivorous, mostly plant leaves and stems, invertebrates; increasing animal foods during pre-breeding	Spring herring eggs on the Oregon coast (Bayer, 1980). Largemouth bass eggs in freshwater (Jarvis and Noyes, 1986). Incidental small fish (Cottam, 1939)
Ring-necked Duck	Omnivorous, mostly plant seeds and invertebrates; increasing animal foods during pre-breeding	Incidental small fish (Cottam, 1939)
Greater Scaup	Omnivorous with varied local and seasonal focus on mollusks,	Incidental small fish (Cottam, 1939); fall and winter use of salmon eggs and

<b>Common Name</b>	<b>General Food Habits</b>	<b>Consumption of Fish</b>
	crustaceans, insects	flesh in coastal streams and lakes (Munro, 1941). Spring herring eggs (Bayer, 1980; Munro, 1941)
Lesser Scaup	Omnivorous with tendency toward animal foods, insects, mollusks, crustaceans	Light use of 8 species of fish and salmon eggs (Cottam, 1939); 3 species of fish during fall in Minnesota (Afton et al 1991); winter scavenging flesh of shad and sunfish (Christopher and Hill, 1988); Spring herring eggs on the Oregon coast (Bayer, 1980)
<b>Sea Ducks</b>		
Steller's Eider	Mostly animal foods; insect larvae in freshwater; crustaceans, mollusks, other invertebrates in saltwater	Low occurrence of small fish, probably incidental to benthic feeding (Cottam, 1939).
King Eider	Mostly insects and crustaceans with some plant foods on freshwater; mollusks, crustaceans and diverse marine invertebrates in saltwater.	Spring use of lumpfish eggs in Norway; small amounts of sculpins and fish eggs in Alaska during winter (Cottam, 1939)
Common Eider (Pacific)	Mostly animal foods, mollusks, crustaceans, and benthic marine invertebrates	Spring use of herring eggs (Cantin et al., 1974); scarce use of sculpins and sculpin roe in winter (Cottam, 1939)
Harlequin Duck	Foods almost entirely animal, freshwater invertebrates during nesting; diverse mollusks, crustaceans and other marine invertebrates during most of the year	Herring eggs in spring (Munro and Clemens, 1931; Vermeer, 1983); salmon and Dolly Varden eggs and fry; (Kistchinski, 1968); high use of salmon roe in streams in late summer (Dzinbal and Jarvis, 1984); salmon carcasses in streams and estuaries (Vermeer and Levings, 1977)
Surf Scoter	Mostly animal foods, insects and clams on freshwater; mollusks, crustaceans and other invertebrates in saltwater	Use of fish minor, but more than white-winged or black scoters. Herring eggs in spring (Bayer, 1980; Vermeer, 1981)
White-winged Scoter	Mostly animal foods; insects, clams and some plant material on freshwater; mollusks, crustaceans and other invertebrates in saltwater	Minor use of fish on fresh and saltwater; coastal herring eggs in spring (Bayer, 1980; Cottam, 1939; Munro and Clemens, 1931)
Black Scoter	Mostly animal foods; insects,, crustaceans and some plant foods on freshwater; mollusks and crustaceans in saltwater	Some use of freshwater fish eggs (Bengtson, 1971). Spring herring eggs (Bayer, 1980; Munro and Clemens, 1931)
Long-tailed Duck	Mostly animal foods; insects, crustaceans and some plant foods on freshwater; mollusks and crustaceans in saltwater	Some use of freshwater fish (Peterson and Ellarson, 1977). Herring eggs in spring (Munro and Clemens, 1931) and some bottom fish in saltwater in winter (Cottam, 1939; Sanger and Jones, 1984)
Bufflehead	Mostly animal foods with some plant material seasonally; insects and crustaceans on freshwater; crustaceans and mollusks in saltwater	Minor use of fish on freshwater; salmon eggs in coastal streams; fall and winter use of small fish; herring eggs in spring (Bayer, 1980; Munro, 1942;

Common Name	General Food Habits	Consumption of Fish
		Vermeer, 1982)
Common Goldeneye	Mostly animal foods; insects, mollusks and crustaceans on freshwater; crustaceans and mollusks in saltwater	Diverse small fish and roe in freshwaters and saltwater (Cottam, 1939; Jones and Drobney, 1986); salmon eggs and flesh on coastal lakes and rivers (Taverner, 1934); herring eggs in spring (Munro and Clemens, 1931; Vermeer, 1982)
Barrow's Goldeneye	Mostly animal foods; insects, mollusks and crustaceans in freshwater; crustaceans and mollusks in saltwater	Herring eggs in spring (Munro and Clemens, 1931; Vermeer, 1982); small numbers of sculpins taken; salmon eggs and parr on freshwater (Fitzner and Gray, 1994; Munro, 1923); salmon flesh (Cottam, 1939)
Common Merganser	Primarily small fish, also insects, mollusks, crustaceans, and small vertebrates	Very diverse fish prey. Salmon are most important in some regions (Munro and Clemens, 1932; Munro and Clemens, 1937; Salyer and Lagler, 1940)
Red-breasted Merganser	Primarily small fish, also insects, mollusks, crustaceans, and small vertebrates	Diverse fish prey. Salmon are important in some regions (Munro and Clemens, 1939; White, 1957). Also take herring and roe

Information obtained primarily from species accounts in the Birds of North America (A. Poole, Ed.).

Cornell Lab of Ornithology, Ithaca, NY. Retrieved from the Birds of North America Online: <http://bna.birds.cornell.edu/bna/>

### **Importance of Marine-Derived Nutrients (Salmon and Herring) to Waterfowl-**

Waterfowl benefit from salmon both as direct sources of prey and carrion, and as indirect nutrient drivers of aquatic systems (i.e., supporting invertebrate prey species and riverine plant communities). Roughly 30-40 million salmon spawn annually in the Kvichak and Nushagak systems (Hilborn et al., 2003; Ruggerone et al., 2010), importing perhaps 20 million kg (44 million pounds) of nutrients to the watersheds. The fate of these nutrients (primarily nitrogen and phosphorus) is divided among the breakdown of carcasses (Cederholm et al., 1989; Cederholm et al., 1999) and deposition in drainages, the outmigration of smolts (Crawford, 2001; Moore and Schindler, 2004), and discharge into estuaries. This large influx of nutrients (providing a net gain to riverine and terrestrial systems) strongly affects many plants and animals, including waterfowl (Gende et al., 2002; Holtgrieve, 2009; Willson et al., 1998; Willson and Halupka, 1995).

Of the 24 duck species that regularly occur in Bristol Bay, at least 11 species are known to prey on salmon eggs, parr, smolts, and scavenge on flesh of spent carcasses (Table 9). Of these, greater and lesser scaup, harlequin duck, bufflehead, common and Barrow's goldeneyes, and common and red-breasted mergansers forage directly on salmon. Among dabbling ducks, mallards feed most on salmon because they are distributed across a diversity of summer habitats

in spawning areas, and they are the principal wintering dabbling duck on the North Pacific coast where fall-winter salmon runs occur.

From early May through June, salmon smolts emigrate from Bristol Bay rivers, providing abundant prey (325 million smolt in the Kvichak) (Crawford, 2001) for fish predators such as mergansers (Munro and Clemens, 1932; Munro and Clemens, 1937; Munro and Clemens, 1939; Salyer and Lagler, 1940; White, 1957; Wood, 1987a; Wood, 1987b). Other duck species may prey on smolts incidentally.

From late June through early September, salmon eggs are readily available on and downstream from spawning beds. These eggs are a seasonally rich food source for harlequin ducks, goldeneyes, and scaup that frequent rivers and streams (Cottam, 1939; Dzinbal and Jarvis, 1984; Munro, 1923) and probably opportunistically for other ducks.

From mid-July through September, salmon carcasses are abundant in streams, rivers and spawning lakes. Though the scientific literature is scarce on this subject, species varying from dabbling ducks (mallard, green-winged teal) and diving ducks to sea ducks that inhabit spawning waters opportunistically scavenge easy protein-rich meals (Table 9).

Harlequin ducks offer an example of a waterfowl species that use salmon in all life stages. Harlequins breed in high gradient streams in the upper reaches of drainages (Robertson and Goudie, 1999), and they forage in portions of rivers and streams occupied by salmon. In the Kolyma Highlands in Russia, harlequins occupied stream reaches where red and pink salmon spawned, and they fed on Dolly Varden (*Salvelinus malma*) and salmon fry (Kistchinski, 1968). Dzinbal and Jarvis (1984) demonstrated that harlequins breeding in the short streams of northern Prince William Sound depended heavily on the dislodged eggs of pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon in the lower stream reaches from the first week of July to early August. In their study, the drifting biomass of salmon eggs exceeded the biomass of invertebrates in late July and early August. Harlequin ducks also scavenged from salmon carcasses from August through September (Vermeer and Levings, 1977). Winter diets did not include notable occurrence of fish (Fischer and Griffin, 2000; Vermeer, 1983).

Spring spawning of Pacific herring (*Clupea pallasii*) along Alaska coasts provides abundant food for waterfowl and many other waterbirds in need of energy during migration. Sea ducks follow the progressive spawning northward (Lok et al., 2008). Although the waters of inner Bristol Bay are turbid and not conducive to herring spawning, small concentrations may be found. The region's center of herring activity is the Togiak district west of Cape Constantine from Kulukak Bay to Cape Pierce (ADFG, 2011c). Sixteen of Bristol Bay's duck species feed on herring and herring roe during spring (Table 9; (Bayer, 1980; Lok et al., 2011; Lok et al., 2008; Munro and Clemens, 1931; Vermeer, 1983)).

## ***Populations, Subpopulations, and Genetics***

Designating subspecies, populations, and subpopulations of waterfowl has progressed through increased research on genetic diversity and relatedness, a long history of morphological measurements, and evaluation of cohesiveness, philopatry, and annual distributions of birds from traditional banding and marking studies. Overall, few population units below the species level have been established for swans, geese, and ducks, probably because their extensive migrations and mobility across broad ranges provide genetic homogeneity. The American Ornithologist's Union (AOU) no longer recognizes subspecies (American Ornithologists' Union, 2011) because of the difficulty in differentiating valid subunits and the dynamic nature of evolving groups.

In some cases, subspecies and populations have been defined when genetic, morphological, and observational data support designations that are practical for population management; these remain provisional in terms of formal taxonomy. Population units also have been designated for purposes of monitoring biodiversity by programs such as the Alaska Natural Heritage program (Alaska Natural Heritage Program, 2011), but under varying scientific standards that may be less rigorous than taxonomic determinations. Following is a summary of current understanding of population structuring in the principal waterfowl species of Bristol Bay.

### **Swans-**

Few distinctions have been made among trumpeter or tundra swans across their ranges. Trumpeter swans in Alaska are part of the Pacific Coast Population (PCP) that constitutes over 80% of the species in North America. Recent genetic studies (Oyler-McCance et al., 2007) indicate that PCP birds are distinguishable from Rocky Mountain Population (RMP) trumpeters that range from Yukon Territory south to Wyoming and Utah, but that within Alaska trumpeters are fairly homogenous through the Interior and Cook Inlet. Copper River Delta breeders were somewhat unique because of their geographic isolation. Samples were taken from Susitna Basin and the Kenai Peninsula, but not from the eastern Bristol Bay region. Based on banding and marking studies, tundra swans in southwest Alaska are affiliated with the Western Population (WP) found wintering west of the Rocky Mountains (Pacific Flyway Council, 2001). The small non-migratory group on the end of the Alaska Peninsula is considered part of the WP, not a separate entity.

### **Geese-**

The taxonomy of Canada geese has long been debated, but the recent specific separation of cackling geese (*B. hutchinsii*) from Canada geese (*B. canadensis*) is based on extensive genetic studies (Paxinos et al., 2002; Scribner et al., 2003) that support divergence of three small subspecies (*hutchinsii*) from three larger subspecies (*canadensis*) during the last glacial period. The coastal Taverner's (cackling) goose and inland lesser (Canada) goose breeding in the Bristol Bay region, as well as the migrant Cackling (cackling) goose that passes through, have been

managed somewhat separately for over 60 years. The extensive historical banding information and genetic evidence, warrants recognition of these populations among six white-cheeked goose populations in Alaska.

White fronted geese breeding in Bristol Bay differ slightly in morphology and migration patterns from other Pacific white-fronted geese nesting on the Y-K Delta, but the differences do not rise to the level of taxonomic significance, nor can they practically be managed separately (Ely et al., 2005; Orthmeyer et al., 1995; Pacific Flyway Council, 2003).

### **Dabbling and Diving Ducks-**

Historically, there has been little to support delineation of distinct populations among species of dabbling ducks (tribe *Anatini*) and diving ducks (tribe *Aythiini*), largely because of their extensive mobility and exchanges across flyways. No population structure has been suggested among these ducks for the Pacific Flyway or Bristol Bay, although extensive genetics studies have not been conducted.

### **Sea Ducks-**

Over the past 10 years, declining trends in most sea duck species (tribe *Mergini*) and the listing of spectacled and Steller's eiders under the ESA have prompted research into the structure and diversity of sea duck populations. In general, sea ducks are known to be quite philopatric to breeding, molting and wintering areas, suggesting the potential for discrete population units. In addition, sea ducks from broad breeding ranges aggregate in winter, making winter a critical period of social and genetic interchange. These unique characteristics are important for understanding the biology of sea ducks and adopting effective management regimes.

The biology and population dynamics of harlequin ducks are not well understood. They breed in the upper high-gradient drainages of Bristol Bay, and occur in the upper bay, Alaska Peninsula, and Cook Inlet during the non-breeding season. Although these birds are generally segregated by river drainages during breeding and demonstrate fidelity to wintering areas (Esler et al., 2000), dispersal occurs across regions (Cooke et al., 2000). No evidence has been found to genetically distinguish harlequins wintering in Prince William Sound, Kodiak, and Katmai areas (Lanctot et al., 1999 ). This suggests that gene flow likely has occurred across broad areas and regionally discrete populations have not developed.

In a study of genetic structure among king eiders, samples were analyzed from breeding areas from northeast Russia east to Greenland, and wintering areas on the Pacific and Atlantic sides of North America (Pearce et al., 2004). Little genetic structuring across the range was found, indicating that historical or current mobility among regions has not produced discrete populations, particularly in western North America. This includes the aggregations of molting and wintering birds in Bristol Bay.

The population structure of Steller's eiders has been an important research topic for assessing the status and prospects of the threatened Alaska-breeding component, particularly the small group breeding near Barrow. In a genetic study that compared samples from breeding and wintering areas of the Atlantic population (Russia-Norway) and the Pacific population (Russia-Alaska), some differentiation was found between the two greater populations, but no sign of subpopulation structure was detected (Pearce et al., 2005). Similar to the situation with king eiders, genetic differentiation could develop in the future if natural or anthropogenic factors produce isolation of breeding groups.

### ***Human Use***

Bristol Bay waterfowl provide viewing, educational and research values, and harvest opportunities to people in Alaska, Russia, Canada, the western U.S., and Mexico. As described above, Bristol Bay is uniquely positioned to host a great diversity of waterfowl that breed, winter, or pass through the region. This includes birds associated with Arctic breeding grounds, the Aleutian Islands, the exceptionally productive tundra habitats of western Alaska, and birds that winter as far south as Mexico and as far east as Chesapeake Bay. Although most of the common waterfowl species of North America occur in the region, species such as swans, emperor geese, and eiders are especially appreciated for their aesthetic, scientific and cultural values. The richness and abundance of waterfowl from the region supports significant subsistence and recreational harvests that are important economically and traditionally throughout western North America.

### **Nonconsumptive Uses-**

Birds that breed in or pass through Bristol Bay are subjects of wildlife viewing opportunities throughout their annual cycles, from Alaska to Mexico. During spring and fall migration, and during winter, Bristol Bay birds stop at many local, state, and federal parks and wildlife areas featuring viewing and interpretive facilities. For some species, special community events revolve around the occurrence of migrating birds. For example, there are brant festivals in British Columbia, Puget Sound, and northern California, and brant are an attraction with whale watchers in Baja California. Such events and numerous local viewing programs are also common for swans, aggregations of geese, and sandhill cranes that breed in the Bristol Bay lowlands.

### **Recreational Harvest-**

Because Bristol Bay is an important breeding and staging area for ducks and geese, birds produced in or supported by the region comprise a notable contribution to fall and winter harvests in the Pacific Flyway from Alaska to Mexico. Waterfowl harvest data have been collected by USFWS in Alaska since the early 1960s through a national mail questionnaire survey (MQS) of federal duck stamp buyers. Species composition of the harvest was estimated from duck wings and goose tails from a Parts Collection Survey (PCS). From 1971 through

1997, ADFG also conducted a mail questionnaire survey of hunters. Since 1998, waterfowl harvests have been estimated by the USFWS through the national Harvest Information Program (HIP), based on a sample of all registered migratory bird hunters. The objective of all these surveys was to produce reliable estimates of duck and goose harvests at the statewide level.

There are no reliable estimates of fall duck and goose harvests in the Bristol Bay region. Although the ADFG survey and federal MQS surveys collected harvest data by regions, the hunter sampling rates were not sufficient to provide more than a general sense of harvest across the state. Bristol Bay was only part of a large sampling region termed “Alaska Peninsula” that extended west to Unimak Pass in which ADFG data indicate that 4,000-5,000 ducks and 2,000 geese were harvested annually. Through the 1990s, this amounted to roughly 5% of Alaska’s fall duck harvest and 20-25% of the goose harvest. There are no recent regional harvest data.

Beyond southwest Alaska, birds that use Bristol Bay for some part of their life cycle contribute an unknown portion of fall harvests in south-central and southeast Alaska, which typically represent 60-70% of the statewide duck total (~70,000) and 30-40% of the statewide goose harvest (~6,100) (USFWS, 2010a). There is no practical way to estimate the proportion of ducks and geese from Bristol Bay harvested in the western states or other jurisdictions. Waterfowl banding has not been sufficient in the Bristol Bay region to undertake analysis of harvest derivation for the Pacific Flyway.

Since 2001, a fall tundra swan season has been open in GMU 17, with registration permits required. The unit includes the Togiak, Wood, and Nushagak drainages inland to Lake Clark. On average, fewer than 60 permits have been issued annually, and reported harvest has been less than 10 swans per year (ADFG, unpubl. data). A small number of tundra swans harvested in Montana, Utah, and Nevada originated in Bristol Bay.

### **Subsistence Harvest-**

Harvest of waterfowl and other birds has been an important component of Bristol Bay’s traditional subsistence culture and economy. Although spring and summer hunting occurred historically and continues, it has been largely illegal since passage of the Migratory Bird Treaty Act of 1918. Beginning September 1, fall and winter hunting has been allowed under federal and state regulations. The US Senate ratified Protocols that amended the migratory bird treaties with Canada and Mexico in 1997. These Protocols authorized the USFWS to open a legal, regulated spring and summer subsistence season for migratory birds in Alaska during 2003 for the first time in over 80 years. The Alaska Migratory Bird Co-Management Council (AMBCC) was formed, composed of USFWS, ADFG, and 12 regional representatives, which established a body of subsistence hunting regulations and undertook the vital task of assessing spring and summer subsistence harvests to meet intentions of the amended treaties.

During the 1980s, ADFG worked with federal agencies, Alaska Native regional organizations, and village governments to conduct subsistence harvest surveys of 151 rural communities in Alaska. These surveys characterized the levels and nature of migratory bird subsistence harvest in Alaska, including Bristol Bay (Wolfe et al., 1990). In response to an intensive goose conservation program on the Y-K Delta, cooperative village harvest surveys were initiated across the region and eventually expanded to Bristol Bay villages that harvested the same goose populations (Wong and Wentworth, 1999). These surveys, begun in 1995, gathered harvest data by subregions, including Togiak, Dillingham, Iliamna, and villages in the Nushagak drainage and on the Alaska Peninsula.

In a review of historical and recent harvest information, the AMBCC found the available data to be insufficient to address management needs. Therefore, it designed a comprehensive statewide survey protocol (Alaska Migratory Bird Co-Management Council, 2003) that included Bristol Bay communities on a rotating basis. Statewide subsistence harvest surveys were implemented annually from 2004 to 2009, although they were not fully funded and implemented to full performance standards.

In general, the majority of seasonal harvest of migratory birds in the Bristol Bay region occurs in spring, with a few species taken in summer, and increased hunting during fall migration and winter (Wolfe et al., 1990). The importance of the spring harvest reflects the abundance of birds during spring migration as well as the traditional need for fresh meat after winter supplies have been depleted. For the Bristol Bay/Iliamna region (not including Alaska Peninsula), Wolfe et al. (1990) estimated annual harvests in the late 1980s of about 8,800 ducks, nearly 2,000 geese, 100 swans, and 1,100 waterfowl eggs. About 70% of households used birds; waterfowl provided 3.4 lbs. (1.5 kg) of meat per capita.

Conservation concerns in the late 1980s prompted a statewide assessment of harvests for Pacific brant, emperor geese, and eider species (Wolfe and Paige, 1995). This study characterized harvest of these species in the early 1990s and presented harvest estimates by regions (including North Bristol Bay, South Bristol Bay, and Lake Iliamna-Nushagak) and some communities from ADFG and USFWS surveys during 1983-94. Harvest estimates for Bristol Bay subregions provided relative comparisons with other parts of the state, but also reflected the seasonal availability of species within the region.

Brant harvest was highest (~300) in the North Bristol Bay area where spring staging was concurrent with seal hunting (Schichnes and Chythlook, 1988), but was low in South Bristol Bay because most brant bypassed that part of the Alaska Peninsula. Brant were rare inland in the Iliamna-Nushagak region. Emperor geese, which are closely tied to the coast in transit to and from the Aleutian Islands, provided harvest in North (~300) and South (~200) Bristol Bay, but were rare inland. Because of diminished numbers, all hunting of emperor geese was closed in

1986. Eiders were harvested primarily in North Bristol Bay (~850) where king eiders are abundant during spring and molt in Nushagak and Kvichak Bay, and common eiders stage during migrations. Eider harvest was low in South Bristol Bay where king and common eiders are more transient. Only common eiders (~250) were recorded for the Iliamna-Nushagak region, probably representing either inland migrants from lower Cook Inlet or resulting from inland-dwelling residents hunting in coastal areas.

Harvest data from 1995-2005 were collected by subregion, including Dillingham, Nushagak River and Iliamna subregions (Wentworth, 2007; Wong and Wentworth, 1999). Estimated annual harvests included ~10,000 ducks (mostly dabbling ducks, with ~600 scoters, 100-200 eiders, and up to 190 harlequin ducks); 2,500-2,900 geese (up to 1,000 white-fronted geese, 800 Canada/cackling, 180-230 brant); up to 300 tundra swans; as well as < 500 waterfowl eggs.

As part of the statewide AMBCC harvest survey program, Bristol Bay communities were sampled during 2004-08, including within the Southwest Bristol Bay Subregion from Togiak south to Port Heiden, covering King Salmon and 20 villages in the Nushagak and Kvichak drainages, and the Dillingham Subregion, sampled every other year. Recent harvest estimates and seasonality of species harvests were reported by Naves (2010a, b). Approximate 5-year average harvests for the villages were: ducks: 10,200 (including 600 scoters and 1,600 eiders); geese: 5,200 (including 2,700 Canada geese, 1,300 white-fronted geese, and 1,100 brant); swans: 270; and waterfowl eggs: 800. Dillingham was surveyed on a rotational schedule (2005, 2007, 2008); results indicated estimated harvests of 1,000-5,000 ducks, 500-800 geese, up to 50 swans, and less than 100 waterfowl eggs (Naves, 2010a; Naves, 2010b).

It is difficult to characterize subsistence harvest of waterfowl precisely in the Nushagak and Kvichak watersheds and the greater Bristol Bay region because of subregional differences in the geographic diversity and seasonal availability of waterfowl species and other wildlife resources, as well as differences in cultural preferences and practices (Wright et al., 1985). In addition, local and regional harvests of migratory birds vary considerably annually because of variations in bird abundance, timing, rates, and patterns of migrations, and seasonal hunting conditions (Wolfe et al., 1990). Assessments of changes or potential changes to subsistence uses of migratory birds will rely on updated status information of their populations, review of data from the AMBCC community harvest survey program (Naves, 2010b), and compilation of historic and current harvest data for subregions and communities (Behnke, 1982; Fall et al., 2006; Fall et al., 1986; Schichnes and Chythlook, 1988; Schichnes and Chythlook, 1991).

# BALD EAGLES

## *Introduction*

Bald eagles are distributed across North America, but are most abundant in Alaska, where approximately half of the world population occurs. During the first half of the 20<sup>th</sup> century in Alaska, the abundance of bald eagles and their attraction to human food sources made them easy prey for bounty hunters (Hodges and Robards, 1982). Since even before the end of the bounty days, however, they have been valued by Americans for their stately appearance, and especially for their intrinsic association with wilderness (King, 2010). Bald eagles and their nests receive extra protection above and beyond that afforded to other migratory birds by the Migratory Bird Treaty Act (16 U.S.C. §§ 703–712). The Bald and Golden Eagle Protection Act (16 U.S.C. 668-668c), enacted in 1940 and amended several times since then, established federal responsibility for the protection of bald and golden eagles and requires consultation with the USFWS to ensure activities do not adversely affect bald eagle populations. The Act prohibits "taking" bald eagles, including their parts, nests, or eggs without a permit issued by the Secretary of the Interior,. It provides criminal penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any bald eagle ... [or any golden eagle], alive or dead, or any part, nest, or egg thereof."

A large apex predator as well as an opportunistic scavenger, the bald eagle is a key species of most of the regional food webs across coastal Alaska, from the Aleutians to the Southeast. Bald eagles were proposed as a management indicator species (MIS) for all National Forest lands in Alaska (Sidle and Suring, 1986) and selected as a MIS for the Tongass National Forest (USFS, 2008). They are also included as a “vital sign”<sup>3</sup> for long-term monitoring in southwestern Alaska national parks (Bennett et al., 2006). This chapter provides a characterization of bald eagles in the Nushagak and Kvichak watersheds, with particular emphasis on their ecological relationships with MDNs.

## *Habitat*

Bald eagles are well-known for their association with water. Most nests in the Pacific Northwest are within 1.6 kilometers (1 mile) of large waterbodies (Anthony et al., 1982) and in Alaska they are almost always found within 200 meters of a stream, lake, or ocean shoreline (Hodges and Robards, 1982; Stalmaster, 1987) (M. Swaim (USFWS), pers. comm. 8/18/11). In the Bristol Bay watershed they inhabit the spruce and mixed spruce/broadleaf forests along major rivers,

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<sup>3</sup> Defined as “a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.”

streams, and lakes of the Bristol Bay Lowlands, upper Alaska Peninsula, and Lime Hills ecoregions (ADFG, 2006), as well as coastal areas of Bristol Bay.

Throughout most of their range, bald eagles nest in forested habitat associated with riparian and beach areas (Buehler, 2000; Stalmaster, 1987). The significance of shoreline nest sites appears to be strongly related to the foraging opportunities these areas provide (Armstrong, 2010). Commonly used foraging areas are open sites where prey or carrion can be seen and accessed by these large birds. These sites are often areas that provide prey aggregations, accessible to many bald eagles at once. In Alaska, these areas include lakes, rivers, oceans, and their shorelines, beaches, and bars (Stalmaster, 1987). On the Kenai NWR, nests were located near clear, relatively shallow streams with spring and fall fish runs (Bangs et al., 1982a). While bald eagle nest sites are associated with water, they tend to be negatively associated with lands impacted by timber harvest and other human uses (Anthony and Isaacs, 1989; Livingston et al., 1990).

In Alaska, where suitable trees are present, bald eagles build their enormous nests near the tops of live trees, typically in one of the tallest of the stand (Bangs et al., 1982a; Ritchie, 1982; Stalmaster, 1987). Where large trees are absent, bald eagles nest on ridges, hillsides, small islets, or sea stacks (Suring, 2010) (S. Savage (USFWS), pers. comm., 9/14/11). Around Lake Clark and its drainages, most nests are reported to be in balsam poplar and spruce trees (Wright, 2010). Monitoring in LCNPP beginning in 1992 has identified black cottonwood as the predominant substrate for coastal nests; interior nests were roughly equally divided between cottonwood and spruce (from Witter and Mangipane 2011, in preparation). Of the 165 known bald eagle nest sites on Togiak NWR, most (~86%) are in balsam poplar trees; 8% are in spruce and 6% are located on the ground (M. Swaim (USFWS), pers. comm., 8/18/11).

On Kodiak NWR, two-thirds of bald eagle nest sites are located in trees (Zwiefelhofer, 2007). In the Bristol Bay area, at least one ground nest has been documented (on an islet in Tikchik Lake) (Wright, 2010) and one on an islet in Katmai NPP (S. Savage (USFWS), pers. comm., 9/14/11). In interior LCNPP, at least two ground nests have been documented on Flat Island, although each was occupied for only a single year (one was successful, the other failed). Two coastal ground nests near Tuxedni Bay in LCNPP have been documented during multiple years. A third coastal ground nest was found near Difficult Creek in 2011 and was successful that year (L. Witter (NPS), pers. comm., 12/15/11).

In addition to nest platforms, bald eagles need perches. In Alaska, bald eagles commonly perch in large spruce or cottonwood trees, often with a good view of foraging waters. Bald eagles often perch during 90% of daylight hours (Stalmaster and Gessaman, 1984); perches provide for resting/loafing, foraging/hunting, feeding, look-outs/sentry posts, displaying (related to territoriality), and thermal regulation (heating or cooling) (Stalmaster, 1987).

Within the Nushagak and Kvichak watersheds, the extent of communal roosting is not well-known. Generally breeding bald eagles roost on their nest tree, or on other large trees within their territory. Non-breeding bald eagles often retire to communal roosts at night, usually in large spruce or cottonwoods trees. These communal roosts may be near a foraging area, but are not as closely associated with shorelines as are perches and nest trees (Stalmaster, 1987). Non-breeding bald eagles also regularly feed, rest, and roost along gravel bars and gravel shorelines (Hansen et al., 1984). On the Naknek River in March and April, communal roosts are located on hillsides with shrubs and some balsam poplars (S. Savage (USFWS), pers. comm., 9/14/11), often on south-facing slopes that overlook the river.

Primary characteristics of winter habitat are abundant, readily available food supplies in conjunction with one or more suitable night roost sites. The majority of wintering bald eagles are found near open water, where they feed on fish, marine invertebrates, and waterfowl and seabirds, often taking dead, crippled, or otherwise vulnerable animals (Buehler, 2000). Over-wintering on the breeding grounds may provide a competitive edge in territory selection and with early initiation of nesting (Ritchie and Ambrose, 1987).

The proportion of bald eagles that over-winter in the Nushagak and Kvichak watersheds has not been quantified, and potential links between over-wintering and open water or winter prey accessibility remain to be studied. Ritchie and Ambrose (1987) reported that records of bald eagles over-wintering in northern boreal forests are rare, and that one reason is that water bodies are frozen. They observed bald eagles in winter along the Tanana River in Interior Alaska, where open water probably provides access to spawning salmon and waterfowl. Bald eagles often congregate along the ice/open water interface on the Naknek River, where wintering common mergansers and common goldeneyes are often found. Christmas bird counts during 1986-2010 in the King Salmon/Naknek area reported from none to 48 adult bald eagles (average 18) (S. Savage (USFWS), pers. comm., 9/14/11). Some over-wintering occurs in Dillingham and the surrounding area, but in much lower densities than found in summer. Some of those over-wintering eagles obtain human garbage at the city dump (M. Swaim (USFWS), pers. comm., 8/18/11).

## ***Food Habits***

***Diet-*** Bald eagles eat primarily fish (Armstrong, 2010). They do, however, have a variable diet that can include birds, mammals, and crustaceans, and, as noted above, even human garbage (Anthony et al., 1999; Knight and Knight, 1983) (also see Stalmaster 1987 and Armstrong 2010 for summaries).

Food habits vary spatially according to specific prey availability and abundance at the site. Bald eagles nesting near, and foraging at, seabird colonies during the summer may take primarily bird prey (DeGange and Nelson, 1982). In the Pacific Northwest, diet varied among sites, with the

number of bird prey items found under nests generally exceeding fish items (Knight et al., 1990).<sup>4</sup> Birds likely also out-number fish as prey at some sites on Togiak NWR, including Cape Peirce and Cape Newenham, which support high densities of breeding seabirds (M. Swaim (USFWS), pers. comm., 8/18/11).

Bald eagle diets also vary temporally, depending on prey availability and abundance. Nesting bald eagles rely primarily on the availability of salmon resources (Hansen, 1987). Inland bald eagles whose nests are close to spawning streams have higher nesting success than those with more distant nests (Gerrard et al., 1975). During late winter and early spring, when salmon resources are scarce, coastal bald eagles often shift their diet to birds (Isleib, 2010; Wright and Schempf, 2010). In one study, birds averaged nearly 20% of stomach contents by volume over the course of a year, but could constitute up to 86% of stomach contents during the colder months (Imler and Kalmbach, 1955). In other areas, mammalian prey may be used in winter because it is equally or more available, than avian prey. For example, on the Kenai NWR, bald eagles may seasonally shift from a diet of primarily fish to snowshoe hares or mammalian carrion (Bangs et al., 1982a).

Specific information on variability of bald eagle diets in the Nushagak and Kvichak watersheds is not available. Eagles in the Bristol Bay watershed area eat all five species of Pacific salmon (S. Savage (USFWS), pers. comm., 9/14/11). Bald eagles wintering along the Naknek River have been observed to take small fish, which may include eulachon (*Thaleichthys pacificus*) (S. Savage (USFWS), pers. comm., 9/14/11). Pacific herring (*Clupea pallasii*) may also be an important resource for bald eagles in the Togiak area. In early spring, S. Savage of the USFWS has also observed bald eagles catching large rainbow trout (*Oncorhynchus mykiss*). Bald eagles in Bristol Bay may also scavenge dead marine mammals (S. Savage (USFWS), pers. comm., 9/14/11).

Independent of prey availability, energy requirements may also influence prey selection. During the breeding season, many bald eagles choose large fish over small fish (Jenkins and Jackman, 1994). Diets of nesting bald eagles are much more variable than those of non-breeders (Hansen et al., 1984; Hansen et al., 1986). Non-breeders are able to range further for preferred food items (e.g., in late fall birds may leave the Chilkat Valley in southeast Alaska to go to British Columbia and Washington, where salmon may still be available). Feeding of young is, as Stalmaster (1987) says, “an enormous chore” and breeders may exploit a variety of food resources within their home range.

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<sup>4</sup> Note that fish and other soft-boned or bodied prey may be commonly under-counted by both stomach-content and under-nest methods (Ritchie 1982, Knight et al. 1990).

**Significance of MDNs-** Fresh salmon and salmon carcasses provide an ideal food resource for bald eagles, because they are large fish that become available in large numbers when they enter shallow water to spawn. Shallow water increases the likelihood that living fish will be available to bald eagles because the limited depth of water brings fish closer to the surface (Livingston et al., 1990). Returning salmon die after spawning in natal streams, providing a significant seasonal pulse of MDNs, including nitrogen and phosphorous, to the generally oligotrophic streams and lakes of northern Pacific watersheds (Hilderbrand et al., 2004; Naiman et al., 2002b; Willson et al., 1998). Spawmed-out salmon carcasses accumulate on stream banks, river bars, lake and ocean shores, and tidal flats (Armstrong, 2010). Although spawmed-out salmon are low in fat and considered a relatively low-energy food source (Christie and Reimchen, 2005), their large size, availability, sheer numbers, and other factors (including cold air temperatures that can increase the efficiency of digestion of some prey (Stalmaster and Gessaman, 1982)), contribute to their value. Salmon are approximately 79% edible flesh, compared with 71% for hares and 68% for ducks (Stalmaster, 1981). Although metabolizable energy is lower for salmon than for hares or ducks, their greater size means that a bald eagle would require only 57 salmon/year, compared with 87 hares or 135 ducks (Stalmaster, 1981; Stalmaster and Gessaman, 1982).

Armstrong (2010) reported that several studies have shown correlations between bald eagle abundance and the abundance of spawmed-out salmon. Simply put, bald eagles in southeast Alaska, the Kenai NWR, and many other parts of their range likely depend on salmon (Armstrong, 2010; Bangs et al., 1982b). However, the nature of the bald eagle-salmon relationship is complex (Hansen et al., 1986). Fluctuations in salmon abundance from year to year (and other bald eagle food sources) apparently causes bald eagles to be limited by food availability (Stalmaster and Gessaman, 1984). Salmon abundance affects not only bald eagle abundance and distribution, but also their breeding and behavior. Bald eagles, in turn, affect the riparian ecosystem and other areas they inhabit by distributing MDNs in their excretions (Gende et al., 2002).

Bald eagles in Alaska also congregate to feed on other species of anadromous and shallow-water spawning fish, particularly Dolly Varden (*Salvelinus malma*), Pacific herring, and eulachon (Armstrong, 2010). Armstrong (2010) also summarized the importance of Pacific sand lance (*Ammodytes hexapterus*) to bald eagles and other marine-associated birds and mammals.

**Foraging Methods-** Bald eagles are opportunistic foragers that exhibit complex social feeding behaviors. They use a variety of methods to obtain food, including active hunting and killing, scavenging of carcasses, and theft (pirating or kleptoparasitizing) from other eagles or other species (Stalmaster, 1987). They locate their prey by sight. Bald eagles may search for prey themselves, follow other birds, or even follow mammals to a concentrated food source (Harmata, 1984; Knight and Knight, 1983; McClelland et al., 1982). Bald eagles will not only steal fish or

force other predators away from fish, but they will also exploit fish injured or driven to the surface by others, and scavenge crippled or dead fish or fish parts left by other predators, such as humans or bears (Armstrong, 2010). Bald eagles in the Chilkat Valley of southeast Alaska typically competed amongst themselves for salmon (Hansen et al., 1984). Dominance in bald eagles may be based on several conditions that often include age and size (Garcelon, 1990; Stalmaster, 1987).

Salmon returning to spawning streams are a relatively easy prey for bald eagles, because the fish are found either in shallow waters, swimming or floating near the surface, or washed up or stranded on streambanks (McClelland and McClelland, 1986). Besides their size, abundance, and availability in shallow water, other unique aspects of salmon life history may contribute to their importance to bald eagles. For example, large numbers may be frozen into river ice in the winter, becoming available as food sources again in spring (Hansen et al., 1984). Brown bears pull salmon from holes too deep for eagles to access, often transporting and discarding portions of carcasses to other locations, where eagles then scavenge them (Armstrong, 2010). Brown bears often eat only the brains and eggs of salmon, leaving a significant proportion of the flesh for other animals including bald eagles.

According to Stalmaster (1987), bald eagles generally appear to prefer stealing food to scavenging, and prefer scavenging to hunting. Hansen et al. (1984) observed higher frequencies of stealing than scavenging of salmon carcasses in the Chilkat Valley in southeast Alaska, even though the cost and benefits of both may be equal. However, others have found that when food is scarce, bald eagles will choose scavenging over stealing if both methods are available (Knight and Skagen, 1988). During seasons of food scarcity, eagle feeding strategy may switch to one of more active hunting, particularly of large gulls and waterfowl, and some eagles may steal ducks from hunters or scavenge in garbage dumps (Wright and Schempf, 2010).

## ***Behavior***

**Territoriality-** Breeding bald eagles occupy and defend territories during the nesting period (Mahaffy and Frenzel, 1987). A territory includes the active nest, and may include one or more inactive nests which the eagles may maintain even when not in use for nesting in a given year (Hansen et al., 1984). They maintain the same territory year after year, using the same nest or an alternate nest within the same territory (Steidl et al., 1997).

The defended territory contains not only the nest trees, but also favored perches and roost(s). Territories have been reported to vary from 0.2–4.2 km<sup>2</sup> (0.08-1.6 mi<sup>2</sup>) (Garrett et al., 1993), according to site and other parameters (Stalmaster et al., 1985). Territories are located within larger home ranges. Bald eagles, unlike many other birds, do not necessarily use a territory to monopolize food, but commonly range out of their territory to obtain food communally at a site where it is abundant (Stalmaster, 1987).

Not all territories are occupied in any given year, and not all occupants will attempt to reproduce (Stalmaster, 1987). During the non-breeding season or if not breeding, bald eagles generally do not defend territories (Armstrong, 2010), although a pair may remain close to their nest or return to their territory regularly over the winter (Gende, 2010). The territory (and pair bond) is usually maintained for life (Jenkins and Jackman, 1993). Information is not currently available on characteristics of bald eagle territories (e.g., size, use patterns, average number of nests, variability according to habitat type, etc.) in the Nushagak or Kvichak watersheds.

**Flocking-** Bald eagles will often forage in large flocks (both scavenging and stealing) when a food resource is concentrated, (Stalmaster, 1987) as can occur when carrion is present. They will also hunt in large flocks when there are large aggregations of forage fish such as eulachon or sandlance (Stalmaster, 1987; Stalmaster and Gessaman, 1984; Willson and Armstrong, 1998).

In the winter, when food availability is limited (e.g., by iced-over rivers or limited daylight), bald eagles aggregate in large flocks and become very aggressive, often pirating food from other birds. Once a food source draws bald eagles to a site, their presence will attract additional birds.

At night, non-breeding and wintering bald eagles may congregate in communal roost areas (Hansen et al., 1980), which may be reused for several years. Roosts are often located where eagles are protected from the wind by vegetation or terrain, providing a favorable thermal environment. Using these protected sites helps minimize the energy stress encountered by wintering birds. Communal roosting may also assist bald eagles in finding food. However, the use of communal roosts is poorly documented in Alaska (USFWS, 2009a).

**Migration and Local Movements-** The extent to which bald eagles are migratory varies with breeding site, the severity of its climate (particularly in winter), whether the individual is adult or sub-adult, and year-round food availability (Buehler, 2000). Bald eagles breeding in coastal Alaska typically remain in the vicinity of their nest sites year-round. For example, the southeast Alaska adult population is mostly non-migratory (Sidle et al., 1986). Aleutian Island adults are also generally residents (Sherrod et al., 1976). Wintering grounds for migratory Alaska bald eagles are not well understood, but it is suspected that Interior bald eagles winter in the Intermountain West and Pacific Northwest (Ritchie and Ambrose, 1996).

Diurnal and tidal cycles affect the daily activity patterns of fish, but can also enhance or inhibit hunting conditions for bald eagles (Hansen et al., 1986). Variations in these daily patterns lead to local movements of bald eagles.

Although bald eagles in southeast Alaska are non-migratory, individual eagles will leave their territories to visit foraging areas for several days at a time (Kralovec, 1994). Eagle pairs in Southeast Alaska also return to their breeding territory periodically over the course of the winter.

Among eagles in the Bristol Bay watershed, local movement patterns, the extent of over-wintering and migration, and how each may vary with age, food availability, or other factors are poorly understood. At least some adults and sub-adults over-winter in Bristol Bay (Wright, 2010).

### ***Interspecies Interactions***

Prey availability has a strong influence on bald eagle reproduction, habitat use and territorial behavior in Alaska. Hansen et al. (1984) suggested that salmon availability in spring largely determines if and when adult bald eagles will lay eggs in a given year, although this has not been studied specifically in the Bristol Bay watershed. Bald eagles preferentially select nest sites near stable food supplies (e.g., salmon in the Chilkat Valley). Salmon availability during the nesting period regulates the survival rate of offspring. Although breeding adults in the Chilkat Valley commonly defended feeding territories, they did not do so when salmon became overabundant (Hansen et al., 1984). Fall and winter habitat use in the Chilkat Valley was also correlated with salmon availability, which is also likely the case in Bristol Bay.

Bald eagles defend vulnerable young against predators (Stinson et al., 2001). However, they are less aggressive with other species than they are with other eagles, with whom antagonistic interactions regularly occur during feeding and territory defense. One exception are ospreys (*Pandion haliaetus*), which bald eagles commonly prevent from nesting nearby (Stalmaster, 1987), although this behavior has not been investigated in the Bristol Bay area. Great horned owls (*Bubo virginianus*), which nest earlier than bald eagles, and osprey, which nest later, each may occupy bald eagle nests in southwest Alaska (S. Savage (USFWS), pers. comm., 9/14/11).

### ***Breeding, Productivity, Survival, and Mortality***

***Breeding-*** As with other birds, the timing of bald eagle nesting varies by latitude; in Alaska it begins with courtship and nest building as early as February and ends when the young fledge in late August-early September. In the Bristol Bay watershed, initiation may not occur until mid- to late March (S. Savage (USFWS), pers. comm., 9/14/11). The young are attended by the adults near the nest for several weeks after fledging (Buehler, 2000).

Whether or not bald eagle pairs breed in a given year and how early they may initiate nesting in a given year appear to be related to food availability (Hansen, 1987), particularly in spring (Hansen et al., 1984). These studies suggest that there may be a natural long-term population cycle, at least in southeast Alaska's Chilkat Valley, resulting from a saturated breeding habitat

and surplus of non-breeders, who then compete for food and cause productivity to decline. The decline may result in lower recruitment into the non-breeding population, leading to lower competition, and ultimately increased productivity. Annual occupancy rates at known nest sites within Togiak NWR varied from 45-88% between 1986 and 2006 (M. Swaim (USFWS), pers. comm., 8/18/11). The lowest occupancy rate occurred in 2006, when spring break-up was particularly late. Occupancy rates, relationships with food availability and seasonal variability, and other details of bald eagle breeding are not well understood for the Nushagak and Kvichak watersheds.

Even well-established nesting bald eagles are highly sensitive to disturbance, particularly during the phases of early courtship and territory establishment, incubation, and the first two weeks after hatching (Buehler, 2000). Bald eagles require a constant level of nest attendance during incubation and brooding. Bald eagles in newly established territories are highly sensitive to disturbance and prone to abandon nest sites during the courtship and nest-building stage (Gende et al., 1998). Occasionally, a pair will establish and maintain a territory in urban or semi-urban areas where some, usually predictable disturbance already occurs (D. Zwiefelhofer (USFWS/retired), pers. comm., 8/19/11) .

Female bald eagles are larger than males (Buehler, 2000). Both sexes incubate eggs, brood young, and deliver prey to chicks, sharing the duties more than many other raptor species, although females still undertake these tasks a greater percentage of the time than males (Cain, 1985).

**Productivity and Survival-** Productivity varies among sites according to prey abundance and availability, habitat quality, weather, breeding-season length, nesting density, and human disturbance (Gende et al., 1997; Hansen, 1987; Savage, 1997; Steidl et al., 1997). Metrics of annual productivity include number and percentage of occupied nests, successful nests, and young produced. Some local information about bald eagle productivity in the Bristol Bay area can be gleaned from National Park Service nest surveys in Lake Clark and Katmai NPPs. Average nest success (percentage of occupied nests that produced at least one young) for interior LCNPP was about 55% between 1992 and 2009, falling to 48% in 2010 (Mangipane, 2010). Nest success for the Naknek Lake and major associated drainage areas of Katmai NPP varied from 31 to 65% in the years 1992-97, although sample sizes were relatively small (Savage, 1997).

In Alaska, most egg-laying begins in mid- to late April (S. Savage (USFWS), pers. comm., 9/14/11; M. Swaim (USFWS), pers. comm., 8/18/11). Clutch sizes are 1-3 eggs. Successful pairs usually raise 1 or 2 young, or rarely, 3 young (Table 9). Bald eaglets make their first unsteady flights about 10 to 12 weeks after hatching, and fledge within a few days after their first flight. However, young birds usually remain in the vicinity of the nest for several weeks after

fledging, and rely on their parents for food until they disperse from the nesting territory, approximately six weeks later. The entire breeding cycle, from initial activity at a nest through the period of fledgling dependency, is about 6 months (Buehler, 2000).

The number of bald eagle young produced in the Nushagak and Kvichak watersheds is unknown. In Alaska, bald eagles may produce roughly 4,200 fledglings annually, although this varies considerably yearly (Schempf, 1989). Within Alaska, both inter-annual and site-specific variability in productivity can be substantial (Schempf, 1989), although neither has been comprehensively studied for the Nushagak and Kvichak watersheds. Productivity appears to be most commonly related to site-specific habitat features and prey (fish) availability in early spring during egg-laying and incubation (Anthony, 2001; Gende et al., 1997; Steidl et al., 1997). Availability of fish increases survivorship of bald eagle offspring, and therefore can cause bald eagle productivity to fluctuate widely (Hansen et al., 1984). Variability in food availability appears to be the cause of variability in fledging rates in southeast Alaska (Hansen, 1987). Productivity can be affected by human disturbance, as well (Fraser and Anthony, 2010; Stalmaster, 1987).

**Mortality-** Full-grown bald eagles have few natural enemies, and the most frequently reported causes of premature adult bald eagle mortality are human-related (Franson et al., 1995; Harmata et al., 1999; Stalmaster, 1987). Shooting, electrocution, trapping, and collisions cause about two-thirds of reported deaths. Bald eagles also die from ingesting pesticides and contaminated carrion used for predator control. Historically, bald eagles experience decreased reproduction and survival from both a wide range of pesticides and environmental contaminants (Buehler, 2000). Poisoning from a wide variety of sources accounted for 16% of all deaths in bald eagles necropsied between 1963 and 1994 at the National Wildlife Health Center (Franson et al., 1995).

Top-level predators are especially vulnerable to many contaminants, and can be viewed as sentinel species for contaminated areas (Holl and Cairns, 1995; Welch, 1994). Bald eagle eggs in the Aleutian Islands, for example, contained elevated levels of organochlorine pesticides, with concentrations of these contaminants and mercury significantly higher in eggs from Kiska Island than in eggs from the other islands (Anthony et al., 1999). In contrast, polychlorinated biphenyl (PCB) concentrations were higher in eggs from Adak, Amchitka, and Kiska islands than in those from Tanaga Island. The most likely source of these contaminants in bald eagles was their diets, which were spatially and temporally variable. A similar study found that contaminant concentrations in Aleutian bald eagle eggs were influenced more by point sources of contaminants and geographic location than by the trophic status of eagles among the different islands (Anthony et al., 2007).

Mean cadmium, chromium, mercury, and selenium concentrations in bald eagle tissues from Adak Island were consistent with levels observed in other avian studies, and were below toxic

thresholds (Stout and Trust, 2002). However, elevated concentrations of chromium and mercury in some individuals may warrant concern. Furthermore, although mean PCB and *p,p'*-dichlorodiphenyldichloroethylene (DDE) concentrations were below acute toxic thresholds, they were surprisingly high, given Adak Island's remote location.

**Table 10. Reported survival of bald eagle nestlings in Alaska.**

Site and year(s)	Average number of young raised to near <sup>a</sup> fledging per successful nest	Source
Interior LCNPP (1992–2011)	1.00–1.87 <sup>b</sup>	Witter and Mangipane (2011, in preparation)
Coastal LCNPP(1992–2011)	1.09–1.82 <sup>b</sup>	Witter and Mangipane (2011, in preparation)
Pacific Coast of the Alaska Peninsula (1989–1995)	1.55–1.71	(Dewhurst, 1996)
Port Moller (1976)	1.90 <sup>b</sup>	R. Gill, unpublished data reported in Wright (2010)
Togiak NWR (1986–1988)	0.95–1.90	L Hotchkiss and D. Campbell, unpublished data, as reported in Wright (2010)
Togiak NWR (1986–2006)	1.33–2.00 <sup>b</sup>	M. Swaim, pers. comm.
Togiak NWR (2006)	1.72	(MacDonald, 2006)
Togiak NWR (1999–2005)	1.62	(MacDonald, 2006)
Katmai NPP (1976–1979)	1.2–1.8 <sup>b</sup>	W. Toyer, unpublished data reported in Wright (2010)
Katmai NPP (1992-1993)	1.45–1.67	(Savage, 1993)
Kodiak NWR (1963 and 2002)	1.66	(Zwiefelhofer, 2007)
Petersburg area (1967–1969)	1.50–1.65	(Corr, 1974)
Gulkana River (1989–1994)	1.29–1.65	(Steidl et al., 1997)

Site and year(s)	Average number of young raised to near <sup>a</sup> fledging per successful nest	Source
Copper River (1989–1994)	1.34–1.64	(Steidl et al., 1997)
Chilkat Valley (1979–1983)	1.32	(Hansen et al., 1984)
Prince of Wales Island (1991–1993)	1.10	(Anthony, 2001)

<sup>a</sup> Nests are normally surveyed just before fledging to assess success; it is assumed that nests are successful if young are observed because once young fledge and leave the nest it is impossible to determine if they survived.

<sup>b</sup> Successful nests with three young have been reported in Lake Clark and Katmai NPPs and Port Moller (L. Witter (NPS), pers. comm., 12/15/11; and as reported in Wright [2010]). Also, 3% of nests on Togiak NWR between 1986 and 2006 had three young (M. Swaim (USFWS), pers. comm., 8/18/11).

Non-human causes of mortality include starvation, fights with other bald eagles, and incidental diseases and infections (Stalmaster, 1987). When food is limited, mortality rates are probably higher among sub-adult than adult bald eagles (Stalmaster and Gessaman, 1984). Other causes of mortality include loss of eggs and nestlings to spring storms, parental desertion of the nest, and predation by gulls, black bears, and other predators (Stalmaster, 1987). Although eggs tend to have a higher mortality rate than nestlings, nestlings also kill each other in fights, die from starvation when more aggressive nest mates receive the majority of feedings from parents, or fall from nest trees.

### ***Population, Distribution, and Abundance***

Bald eagles are one of the most abundant raptors in Alaska, with a population estimated at >58,000 (Hodges, 2011). Most Alaskan bald eagles occur in the vicinity of the southern coast (from Dixon Entrance to Bristol Bay) and secondarily along interior rivers and lakes (Schempf, 1989). An estimated 2,775 adult bald eagles were present along the Alaska Peninsula Gulf Coast in 2005 (Savage and Hodges, 2006).

Surveys of nests and calculations of nest densities and occupancy rates are commonly conducted, although nesting rates display considerable temporal and spatial variability. Nesting density is considered to be generally correlated with food availability (Dzus and Gerrard, 1993), and density of breeding bald eagles in Saskatchewan was found to be correlated with mean April temperatures (Leighton et al., 1979). Nest densities among inland river areas of southeast Alaska were highly variable among sites and years, and were correlated with food abundance and weather conditions (Hodges, 1979). In contrast, nests in the Susitna watershed were thought to be more uniformly distributed (Ritchie and Ambrose, 1996). For Interior Alaska populations,

Ritchie and Ambrose (1996) surmised that densities were greatest adjacent to coastal areas and where weather is somewhat milder and prey more seasonally accessible and diverse.

Bald eagle nesting densities in southeast Alaska varied from 0.33-0.50 (or higher on Admiralty Island) active nests/km of coastline and 0.25-0.38 active nests/km of river (Hansen et al., 1984; Hodges, 1979; Robards and King, 1966). Along the Gulkana River, 0.01-0.08 active nests/km were documented (Byrne et al., 1983). Population and nesting density was also high on Kodiak NWR, where almost 1,000 nests were located within an area of about 8,000 km<sup>2</sup> (3,077 mi<sup>2</sup>) in 2002 (Zwiefelhofer, 2007).

A comprehensive survey has not been published for bald eagles or their nests in the Bristol Bay watershed. Available data indicates that nest density may be almost as high in portions of the region as anywhere excluding the highest known densities in southeast Alaska and Kodiak. The USFWS Bald Eagle Nest Database has accumulated approximately 230 nest records for the study area (Table 10). However, 61 of those records are from the 1970s and 1980s, and those nests may not have persisted on the landscape. The remaining 169 records were collected between 2003 and 2006. A fixed-wing survey of adult bald eagles was conducted by the USFWS in 2006 along main-stem portions of some Alaskan rivers which documented 50 bald eagle nests along portions of the Nushagak, Mulchatna, and Kvichak Rivers. Of those, 24 were identified as active. Database records for 2004 and 2005 are from a project contractor survey (not flown for the USFWS Database) that was conducted along the north side of Lake Iliamna. The 2004 and 2005 surveys recorded 75 total nests in this area (S. Lewis (USFWS), pers. comm., 8/11/11). This appears to be a relatively high nesting density, although we do not know which or how many of those nests were active, nor the density of active territories. In 2003 3 nests were recorded (1 active and 1 empty nest in the lower Nushagak drainage and 1 of unknown status on an islet off the north shore of Iliamna Lake).

**Table 11. Summary of surveys for bald eagle nests in the Bristol Bay study area.**

Survey	Survey dates and results	
USFWS bald eagle nest surveys (recorded in USFWS bald eagle nest database)	1970–1990	2003–2006
	61 nest records	169 nest records
Nushagak and Mulchatna Rivers survey by USFWS	2006	
	50 nest records (24 active)	
North side of Lake Iliamna survey by contractor	2004–2005	
	75 nest records	

Some site-specific surveys conducted in portions of southwest Alaska have reported numbers of individual bald eagles. For example, summer activity surveys for Katmai NPP identified between 50 and 87 individuals in the Naknek Lake drainage between 1991 and 1997 (Savage, 1997). Although systematic efforts have not been made to identify fall bald eagle congregation sites in the Bristol Bay area (Wright, 2010), congregation sites are known to exist in surrounding areas (e.g., Port Moller, Savonoski River), and are believed to be related to late-spawning sockeye salmon, fall runs of coho salmon, and fall-staging waterfowl. Although bald eagle densities are greatest overall in southeast Alaska, salmon also appear to be a major driving force for the Bristol Bay watershed population of bald eagles, so some comparisons may be inferred. In the Chilkat Valley, fall and winter bald eagle densities in habitats adjacent to foraging areas may be ten times those of the same habitats (e.g., gravel bars, cottonwood stands) located far from food sources (Hansen et al., 1984).

### ***Human Use***

Bald eagles have been important to Native Americans historically, and continue to be important at present. Bald eagle parts have been of particular importance for rituals and many other spiritually related uses (Stalmaster, 1987). The Bald and Golden Eagle Protection Act exempts Native Americans from the prohibition against purposeful take, although a permit is required.

Non-Native Americans have not used bald eagles historically in similar ways. However, human-caused mortality, both direct and indirect, remains the largest single category of mortality. During the years in which bounties were in force (1917-1952), no fewer than 128,000 bald eagles, and probably many more, were taken in Alaska. Bald (and golden) eagles are now protected by law in the United States, and only a small number of permits are issued for indirect take (incidental to an otherwise lawful activity). Take is authorized only when it is consistent with the goal of maintaining stable or increasing bald eagle populations.

Despite legal protection, illegal direct take still occurs, most commonly when bald eagles are shot, trapped, or poisoned based on a belief that the birds prey on human-valued resources. Unpermitted indirect take probably remains the greatest source of bald eagle mortality. Leading causes of indirect take include pesticides, entanglement in fishing or trapping gear, collisions with power lines or buildings, ingestion of poisoned prey, plastics or lead shot, and disturbance or loss of nesting habitat (Buehler, 2000).

# SHOREBIRDS

## *Introduction*

Shorebirds are a diverse group, with species occurring on all continents and in all habitats ranging from sea level to the highest mountains. They are generally associated with water, particularly intertidal and estuarine environments, and thus are fairly visible to humans. Due to their broad geographic distributions, their seasonal migrations are remarkable, regularly spanning continents and frequently hemispheres. Several species engage in long, nonstop flight, but most rely on a series of sites where they stop to “refuel” for subsequent legs of their migrations. Alaska intertidal areas, particularly Bristol Bay estuaries, serve two functions for shorebirds. First, during late summer through autumn, the majority of the shorebird populations that nest in western Alaska move to the benthic-rich intertidal communities of Bristol Bay, where ample food supports them while they complete their molt and fatten for autumn migrations. Winter destinations include sites throughout north, central and south America, the central Pacific islands, and Australasia. Second, during spring, hundreds of thousands of shorebirds migrate to their western Alaska breeding grounds from staging grounds on the Copper River Delta and estuaries of Cook Inlet, passing through a broad lowland corridor (the Lake Iliamna corridor) at the base of the Alaska Peninsula, linking Kamishak Bay in lower Cook Inlet to upper Bristol Bay. In most years, the migration through this corridor is direct, but in years with late spring or adverse weather conditions, birds stop in large numbers at Bristol Bay estuaries until conditions improve farther west (Gibson, 1967; Gill and Handel, 1981; Gill and Tibbitts, 1999). Two major estuaries in the area, Nushagak and Kvichak bays, have been recognized as Western Hemisphere Shorebird Reserve Network sites (Western Hemisphere Shorebird Reserve Network, 2011).

Thirty of 41 (> 70%) of the shorebird species or subspecies that regularly occur in Alaska each year can be found in the Bristol Bay watershed (Alaska Shorebird Group, 2008); 21 of these 30 regularly nest there (Table 12). Shorebird populations worldwide are showing steady declines (Stroud et al., 2006), with causes most often attributed to loss or alteration of habitats and environmental contamination. Fourteen species that regularly occur in the Bristol Bay watershed have been ranked by the Alaska Shorebird Working Group (2008) as being of high conservation concern.

The Bristol Bay region has had a long history of studies that reported in part on shorebirds. Several of these studies date to the late 19<sup>th</sup> and early 20<sup>th</sup> centuries, but few shorebird-specific studies emanated from this region until the initiation of the Outer Continental Shelf Environmental Assessment Program (OCSEAP) in coastal Alaska in the early 1970s (Arneson, 1978; Gill et al., 1977; Gill et al., 1978). At that time, there was also increased interest in declining populations of waterfowl throughout Alaska, and considerable information on shorebirds was collected in conjunction with waterfowl studies, such as annual spring and fall

emperor goose aerial surveys (Mallek and Dau, 2011). There have also been multiple studies detailing shorebird activities during the breeding season and migration in the adjacent Kilbuck and Ahklun Mountains, and coastal areas from Kuskokwim Bay to Togiak (Petersen et al., 1991). Breeding activities of several shorebird species in the Iliamna Lake area have also been reviewed (Williamson and Peyton, 1962).

In recent years, avian surveys have been conducted by the National Park Service in LCNPP and Katmai NPP (montane surveys have included the upper Nushagak and Kvichak drainages) (Ruthrauff et al., 2007); by the USFWS (targeting lowland areas of the northern Alaska Peninsula) (Savage and Tibbitts, In prep); by the Pacific Shorebird Migration Project (including satellite tracking of godwits (*Limosa* spp.), bristle-thighed curlew (*Numenius tahitiensis*), and whimbrel (*N. phaeopus*)) (Gill et al., 2009); using color banding (whimbrels) (L. Tibbitts (USGS), pers. comm., 9/11); and using radio tracking and attachment of geo-locators (plovers (*Charadriidae*)) (Johnson et al., 2004; Johnson et al., 2001; Johnson et al., 2011; Johnson et al., 2008). These surveys have enhanced understanding of the importance of this region to various stages of shorebird life history. Information for upper Bristol Bay during the early spring remains deficient, but information for nearby Egegik (Fernandez et al., 2010) and Nanvak bays (Fernandez et al., 2010; Petersen et al., 1991) are relevant to this characterization. The paucity of information for the early spring stems in part from the winter-like conditions that frequently persist in the Bristol Bay region until early May, affecting, if not the birds' use of the area, then at least the ability of biologists to access it.

The Bristol Bay/Alaska Peninsula lagoon system, of which the Nushagak and Kvichak River deltas are part, is one of the most important migratory shorebird stop-over areas in the state. Probably only the Copper River Delta and the Yukon-Kuskokwim Delta are likely more important (Gill and Handel, 1990; Isleib and Kessel, 1973; Senner, 1979). The entire set of lagoons supports thousands of individuals, representing numerous shorebird species, which undertake post-breeding migrations to the Pacific coast of North America and across the Pacific Ocean to Australia, Southeastern Asia, and Oceania. For species that migrate directly across the ocean to Hawaii or other South Pacific islands (e.g. bar-tailed godwit (*Limosa lapponica*), ruddy turnstone (*Arenaria interpres*)), these lagoons provide the last stopover before their long overwater flights. Western sandpiper (*Calidris mauri*), dunlin (*C. alpina*), and long-billed dowitcher (*Limnodromus scolopaceus*) use the peninsula's lagoons to replenish energy reserves before departing non-stop for British Columbia and points south. The lagoons of Bristol Bay are also used by shorebirds as they migrate north in spring, providing an essential refueling location that enables species not only to succeed in reaching their breeding grounds, but also to begin breeding shortly thereafter. The relative importance of each lagoon/delta, including the deltas of the Bristol Bay region, is likely to vary annually and by species, and the loss of any one site may have a devastating effect on a species' ability to successfully migrate, and consequently add another factor to already declining populations.

**Table 12. Shorebirds found in the Bristol Bay Watershed.**

<b>Species</b>	<b>Scientific name</b>	<b>Breeding<sup>1</sup></b>	<b>Current Trend<sup>2</sup></b>	<b>Conservation Priority<sup>3</sup></b>
Black-bellied Plover	<i>Pluvialis squatarola</i>	Yes	Declining	3
American Golden-Plover	<i>Pluvialis dominica</i>	Yes	Declining	4
Pacific Golden-Plover	<i>Pluvialis fulva</i>	Yes	Declining	3
Semipalmated Plover	<i>Charadrius semipalmatus</i>	Yes	Stationary	2
Spotted Sandpiper	<i>Actitis macularius</i>	Yes	Stationary	2
Wandering Tattler	<i>Tringa incana</i>	Yes	Stationary	3
Greater Yellowlegs	<i>Tringa melanoleuca</i>	Yes	Stationary	3
Lesser Yellowlegs	<i>Tringa flavipes</i>	Yes	Declining	4
Whimbrel	<i>Numenius phaeopus</i>	Yes	Declining?	4
Bristle-thighed Curlew	<i>Numenius tahitiensis</i>		Stationary	5
Hudsonian Godwit	<i>Limosa haemastica</i>	Yes	Stationary	4
Bar-tailed Godwit	<i>Limosa lapponica</i>	Yes	Declining	4
Marbled Godwit	<i>Limosa fedoa</i>		Unknown	4
Ruddy Turnstone	<i>Arenaria interpres</i>		Unknown	3
Black Turnstone	<i>Arenaria melanocephala</i>	Yes	Stationary	4
Surfbird	<i>Aphriza virgata</i>	Yes	Declining	4
Red Knot	<i>Calidris canutus</i>		Declining	4
Sanderling	<i>Calidris alba</i>		Declining	4
Semipalmated Sandpiper	<i>Calidris pusilla</i>		Declining	3
Western Sandpiper	<i>Calidris mauri</i>	Yes	Declining?	4
Least Sandpiper	<i>Calidris minutilla</i>	Yes	Declining	3
Baird's Sandpiper	<i>Calidris bairdii</i>		Stationary	2
Pectoral Sandpiper	<i>Calidris melanotos</i>	Yes	Declining	2
Sharp-tailed Sandpiper	<i>Calidris acuminata</i>		Stationary	2
Rock Sandpiper	<i>Calidris ptilocnemis</i>	Yes	Stationary	4 or 3
Dunlin	<i>Calidris alpina</i>	Yes	Declining	4
Short-billed Dowitcher	<i>Limnodromus griseus</i>	Yes	Declining	4
Long-billed Dowitcher	<i>Limnodromus scolopaceus</i>		Stationary	3
Wilson's Snipe	<i>Gallinago delicata</i>	Yes	Declining	3
Red-necked Phalarope	<i>Phalaropus lobatus</i>	Yes	Declining	3

<sup>1</sup> Breeding status of “Yes” requires a record of breeding evidence (nest, eggs, or recently fledged young on or within 150 km of the Bristol Bay Watershed.

<sup>2</sup> Current trends were reproduced from Morrison et al. 2006, Table 1: Estimates, Current trend.

<sup>3</sup> Conservation Status scores were reproduced from Alaska Shorebird Plan 2008, Table 2, Conservation Category. Species in Categories 4-5 are of high concern and in category 2-3 are of low to moderate concern.

## **Habitat**

The geomorphology of upper Bristol Bay is shaped by the interaction between the shallow basin of the Bay and the twice-daily tidal fluctuation in excess of 10 m (33 ft). These features interact with the numerous river deltas, including the Nushagak, Kvichak, and Naknek, to form an expansive intertidal zone dominated by unvegetated sand and mudflats. The intertidal zone also includes vegetated substrate at Nushagak Bay. These intertidal areas, the Bristol Bay estuary itself, and other nearby river mouths with extensive mudflats along the Alaska Peninsula constitute the estuarine portions of the region. Approximately 530 km<sup>2</sup> (205 mi<sup>2</sup>) of intertidal habitat is found at Kvichak Bay and 400 km<sup>2</sup> (154 mi<sup>2</sup>) at Nushagak Bay (Gill et al.; Western Hemisphere Shorebird Reserve Network, 2011). In winter, substantial shore ice forms along the coast and sea ice moves through the area with the tides. The supralittoral (splash) zone varies from gradually sloping unvegetated or sparsely vegetated shore, to sandy and morainal bluffs up to 20 m (66 ft) high. Beyond the shore zone, the region is characterized by a mosaic of wetland and tundra habitats, punctuated with low and tall shrub communities, located primarily along drainages. At higher elevations are spruce, mixed spruce, birch or cottonwood forests that give way to ericaceous dwarf shrub or sparsely vegetated substrates in the alpine zone.

Shorebirds inhabit the Bristol Bay watershed primarily during two phases of their annual life cycle: migration and breeding. During each phase they make use of geographically distinct parts of the watershed. Shorebirds use the expansive intertidal and adjacent supralittoral areas during both spring and fall migrations. In spring, the mouths of major rivers including the Naknek, Kvichak and Nushagak, are often the first areas to become ice-free, and provide critical feeding habitat in the littoral zone (Gill and Handel, 1981). Shorebirds actively forage in the intertidal zone, often moving toward the declining water level as the tide drops. During high tide and at night, birds move into the adjacent supralittoral zone to continue foraging or to roost. Although information for these specific bays is sparse for the spring period, we can make inference from observations in nearby areas.

Beginning in late April and through mid-May, shorebirds migrating from wintering areas begin arriving in the Bristol Bay region (defined in Gill and Handel, 1981 as the western tip of Unimak Island north to Cape Newenham). The predominant shorebird species using region include: bar-tailed godwit (several thousand), western sandpiper (a few thousand), rock sandpiper (*C. ptilocnemis*; a few thousand), dunlin (a few thousand), black-bellied plover (*Pluvialis squatarola*; hundreds to thousands), Pacific golden-plover (*P. fulva*; several hundred), black turnstone (*Arenaria melanocephala*; several hundred), red-necked phalarope (*Phalaropus lobatus*; several hundred), Hudsonian godwit (*Limosa haemastica*; a few hundred), and short-billed dowitcher (*Limnodromus griseus*; a few hundred) (Gill and Handel, 1981). Other species are found in lesser numbers.

Beginning in mid- to late June, shorebirds that did not nest successfully, or successful post-nesting birds return to the Bristol Bay region in larger numbers than migrated through in early spring and remain for protracted periods along the intertidal zone. This general shift between terrestrial breeding habitats and the littoral zone has been documented throughout the region (Gill and Handel, 1981; Gill and Handel, 1990; Gill et al., 1977; Gill et al., 1978) and Alaska (Connors, 1978; Taylor et al., 2011). Shorebirds also make use of the supralittoral zone and terrestrial habitats near the coast during high tides and at night for feeding and for roosting (Gill and Handel, 1981; Gill et al., 1981). Initially, most birds present in the region are those nesting locally, but as the season progresses, populations swell with birds moving into the region from nesting areas in western and northern Alaska and as far away as eastern Russia (Gill et al., 1994). By early August it is not uncommon to find hundreds of thousands of shorebirds on intertidal areas of upper Bristol Bay.

Species composition and abundance in fall is similar to the spring migration except for additional species and increased numbers: bar-tailed godwit (thousands to ten thousands), dunlin (several ten thousands), red-necked phalarope (several ten thousands), and red phalarope (several ten thousands), western sandpiper (a few ten thousands), rock sandpiper (a few ten thousands), short-billed dowitcher (a few ten thousands), black-bellied plover (a few thousands), Pacific golden-plover (a few thousands), whimbrel (a few thousands), ruddy turnstones (a few thousands), black turnstones (a few thousands), sanderlings (a few thousands), long-billed dowitcher (a few thousands), greater yellowlegs (hundreds to thousands), semipalmated plover (several hundreds), and Hudsonian godwit (a few hundreds) (Gill and Handel, 1981; MacDonald, 2000; MacDonald and Wachtel, 1999). Populations awaiting storms to help carry them to Australasia and the west coast of North America may extend their period of use into October (e.g., dunlin) (Gill et al., 1978) or early November (e.g., bar-tailed godwit) (Gill et al., 2009).

Shorebirds breeding in the Bristol Bay watershed use various habitats in the terrestrial areas of the watershed, from the supralittoral zone (Gill and Handel, 1981; Gill et al., 1981) to elevations of 1,300 m (4264 ft) (Ruthrauff et al., 2007), based on their species' preferences. Many species (e.g., greater yellowlegs, dunlin, Wilson's snipe (*Gallinago delicata*), and short-billed dowitcher) prefer mesic to wet herbaceous vegetation, whereas many of the plovers or montane breeders (e.g., American golden-plover (*Pluvialis dominica*), semipalmated plover, surfbird (*Aphriza virgata*), rock sandpiper), prefer dwarf shrub/lichen vegetation or even barren areas for nest sites. Several species are highly dependent on lake or river shores (e.g., spotted sandpiper (*Actitis macularius*), wandering tattler (*Tringa incana*)) (Petersen et al., 1991). A few species (semipalmated plover, marbled godwit (*Limosa fedoa*), black turnstone, dunlin, and short-billed dowitcher) prefer the coastal fringe (Gill and Handel, 1981; Gill et al., 2004). All of these shorebirds may feed in marine intertidal zones during breeding, depending on their proximity or their preference for feeding in these environments.

## ***Food Habits***

The shorebird group derives its name from the fact that many species spend migration, and often winter, associated with shore environments. In many cases, these are marine shores. Food is likely the most important factor controlling the movements of shorebirds throughout the Bristol Bay region. Use of Nushagak and Kvichak Bays during shorebird migration is undisputed. In spring, shorebirds need to acquire critical food resources, not only to fuel their migration, but also, for some species, to assure that they arrive on the breeding grounds with sufficient reserves to initiate nesting and egg production (Klaassen et al., 2006; Yohannes et al., 2010). Beginning in mid-summer and continuing into early autumn, a few Alaska shorebird species must again find food-rich areas to support the process of partial or complete molt and, for all but a few species, to fuel extended migration. Indeed, some of the longest migrations known to birds involve shorebird species (bar-tailed godwit) that use Bristol Bay intertidal areas in autumn (Battley et al., 2011; Gill et al., 2009). Such flights are possible not only because of the extreme abundance of intertidal invertebrates (polychaetes, crustaceans, gastropods, and bivalves) in the region, but also because the adjacent uplands are usually rich in fruits of ericaceous plants or tubers that species such as plovers, whimbrels, and godwits, regularly feed on (Elphick and Klima, 2002; Johnson and Connors, 1996; Paulson, 1995; Skeel and Mallory, 1996). For species such as bar-tailed godwit and sharp-tailed sandpiper, individuals can gain up to 6% of their lean body mass per day while feeding prior to migration (Gill et al., 2005; Lindstrom et al., 2011). Other species acquire their fuel at a different trophic level. Rock sandpipers, for example, often eat the gonads of tide-stranded jellyfish medusae, whereas whimbrels, Hudsonian godwits, and black and ruddy turnstones feed on herring roe, carrion and salmon eggs (Elphick and Tibbitts, 1998; Gill et al., 2002; Handel and Gill, 2001; Nettleship, 2000; Norton et al., 1990). During the breeding season, terrestrial and freshwater environments provide the bulk of the food sources, and a wide variety of animal and vegetable resources are consumed. Most shorebird species make use of terrestrial invertebrates or their larvae or eggs, and many make use of freshwater invertebrates; small fish may be consumed by yellowlegs (Elphick and Tibbitts, 1998) and phalaropes (Rubega et al., 2000). Detailed summaries for each species are found in *The Birds of North America* (Cornell Lab of Ornithology, 2011).

Shorebirds play a role in distributing MDNs into the terrestrial system, especially during the migratory period, but this has not been quantified. They frequently feed in the intertidal zone but roost in the terrestrial zone where wastes are frequently deposited. In addition, they are prey items for many larger predators that subsequently cycle these nutrients into the terrestrial system.

## ***Behavior (Movements)***

Shorebirds move at multiple temporal and spatial scales that are usually associated with specific phases of their annual cycle, but within each, there can also be movements driven by more random events such as weather and opportunistic feeding. The most obvious movements are

associated with migration, a phenomenon that occurs twice a year in most shorebirds. Spring migration in Alaska is an end to a process that began months earlier and often in a different continent, and is driven by the pending nesting season and the need for birds to establish territories and produce young. Spring migration is characterized as rapid and direct (Gill and Handel, 1981), with little use made of intertidal areas once birds leave penultimate staging sites such as the Copper River Delta (Isleib, 1979; Iverson et al., 1996; Senner, 1979).

Spring conditions in Bristol Bay vary greatly from year to year. Shore-bound and riverine ice can vary considerably in both magnitude and timing of melt depending on the severity of the winter, amount of snow cover, and the onset of spring conditions. No formal measure of shore ice is currently conducted in this region; however remote sensors such as MODIS (Moderate Resolution Imaging Spectroradiometer) could be used to describe and monitor spring conditions (Spencer, 2006). Informal observations indicate that breakup may begin as early as late March, or be delayed until early May. Ice conditions may change within a week, or may linger for 4-6 weeks. Shorebirds make use of the Bristol Bay tidal flats as they become ice-free, typically beginning in mid- to late April and peaking in early May; the length of their stay depends in part on conditions in the nearby breeding grounds or further north on their migratory route.

Spring shorebird surveys have been limited in this area and most information comes from surveys targeting other taxa. This limitation should be borne in mind when interpreting peak numbers for spring single aerial surveys along the margins of the two bays that range from approximately 7,000 to 10,600 small to medium shorebirds (Arneson, 1978; King and Dau, 1992). Arneson (1978) conducted several surveys in one spring, noting that spring shorebird densities can change dramatically over a short time span. Although spring migration is abbreviated, variation in migration timing by sex is known for some species with males generally arriving earlier (Senner et al., 1981).

Once established on the breeding grounds, most shorebirds exhibit territorial behavior. Movements are driven by the need to defend territories, attract mates, establish and defend nests and young, feeding, and the need to find shelter from weather and predators. Once young fledge, or when nesting attempts fail, many species move to coastal habitats; such movements may be driven by deteriorating food supplies on the nesting grounds, or by increased availability of food in littoral habitats (Gill and Handel, 1981).

Shorebirds return to the coastal zone beginning in mid-June, with some remaining until early November. Summer and fall food resources in Bristol Bay are diverse and abundant, as evidenced by the diversity and numbers of shorebirds, waterfowl, and seabirds that are attracted to the area during this time (Gill et al., 1981). A clearly attractive attribute of Bristol Bay is the short distance birds must move between various components of its large system of interconnected mudflats and bays, all containing concentrated food resources. In the context of

post-breeding shorebird use, Nushagak and Kvichak Bays cannot be separated from the greater Bristol Bay/Alaska Peninsula complex. Rich food resources are in demand, because adult birds are recovering from the energetic stress of breeding, and are beginning the energy-demanding molt. Ground and aerial surveys conducted in Nushagak Bay (MacDonald, 2000; MacDonald and Wachtel, 1999) and other Alaska Peninsula lagoons (Gill et al., 1977; Gill et al., 1978) provide insight on the seasonality, and duration of use by at least 25 shorebird species. The magnitude of shorebird use has been captured on single-day aerial surveys in the latter part of the fall season; for these two bays, high counts range from 20,000 to 67,000 (Gill and King, 1980; Gill and Sarvis, 1999; Mallek and Dau, 2004). Late summer and fall shorebird use is likely greater than spring use because of the addition of juveniles in the population, longer residence times, different pathways of migrants during different times of the year, or different use patterns of individual species.

The autumn migration is broken into phases based on species, age, sex, and individual breeding success. Species-specific use patterns have been reported for Nelson Lagoon, on the central Alaska Peninsula (Gill and Jorgensen, 1979) and patterns for other species common to the Bristol Bay watershed are reported from studies on the Yukon Delta (Gill and Handel, 1981; Gill and Handel, 1990). In general, black turnstones, western sandpipers and short-billed dowitchers move through the area earliest; black-bellied plovers arrive later, and rock sandpipers, dunlin, and sanderlings may arrive at similar or later dates but remain longer into the fall. Failed breeders move to the coastal zone sooner than successful breeders (Gill et al., 1983; Handel and Dau, 1988). On the Y-K Delta, Gill and Handel (1990) observed three age-based patterns of intertidal use through the late summer. In the most common pattern, (exemplified by western sandpipers) adults arrived first, followed by a period in which adults and juveniles occurred together, and finally juveniles appeared alone. In the second pattern (bar-tailed godwits, dunlin, and rock sandpipers), adults appeared first, followed by a long period of use by both adults and juveniles. The third pattern was demonstrated by plovers, in which only juveniles used the intertidal zone in late summer. In addition, some species demonstrated a sex-specific pattern: female western sandpipers departed before males (Gill and Jorgensen, 1979), but in pectoral sandpipers (*Calidris melanotos*), males depart before females (Pitelka, 1959). The specific migration patterns demonstrated by individual shorebirds with regard to micro- and macro-habitat use and timing, will become clearer in the future as researchers continue to deploy satellite transmitters and geo-locators.

### ***Interspecies Interactions***

Shorebirds act as an intermediate link in the food web between primary producers (berries, seeds, and tubers of plants), consumers (invertebrates and small fish), and predators. Especially during migration, when birds are concentrated, their effect on invertebrate populations in feeding areas can be extensive (Jensen and Kristensen, 1990; Quammen, 1984; Sanchez et al., 2006; Wilson, 1989). The response of the invertebrate prey varies with time of year, substrate, presence of other

predators, presence of other prey, and age. Any negative effect on prey abundance is assumed to be short-term however, because these areas are revisited by shorebirds on the next tide and the next season on a daily and annual schedule. Shorebirds may also compete intra-specifically or inter-specifically for resources during migration, as demonstrated by inter-specific aggressive interactions (Burger et al., 1979).

Shorebird adults, young, and eggs provide food for a wide variety of predatory birds, including jaegers, gulls, raptors, owls, corvids, and shrikes. Avian predation has long been hypothesized to be the dominant force in shorebird flocking behavior (Lack, 1954); the relationship between the benefits (predator avoidance) and costs (feeding competition) of flocking has been explored (Stinson, 1980). Nocturnal avian predators alter shorebird use of feeding and roosting areas (Piersma et al., 2006). The increase in raptor populations following the removal of DDT appears to be altering how much time shorebirds spend in marine intertidal areas; this threat of danger may be forcing shorebirds into a trade-off between good food locations and the potential of being eaten (Ydenberg et al., 2004). In the Bristol Bay ecosystem potential mammalian predators of shorebirds, particularly eggs and chicks, include canids (especially foxes), lynx (*Lynx canadensis*), weasels (including otter), and some rodents. Shorebirds may play a role as prey in multi-species predator-prey cycles known throughout the Arctic (Underhill et al., 1993).

Direct and indirect interactions between shorebirds and salmon are not well-documented. Some shorebird species have been observed consuming dead salmon and salmon eggs, but it is unlikely that shorebirds have an impact on salmon populations. No studies have been conducted to estimate the contribution of salmon to the energetics of shorebird populations. However, the abundance of invertebrates in the intertidal zone is very likely due in part to nutrients from salmon that die on the coast and in the rivers feeding Bristol Bay.

### ***Breeding, Productivity, and Survivorship***

Based on information from studies in and adjacent to the Bristol Bay watershed, approximately 21 shorebird species are known to breed in this area. Most shorebird species form monogamous pairs, with both sexes defending breeding territories and incubating eggs; however, spotted sandpipers and red-necked phalaropes will engage in polyandry if conditions are favorable. Individuals, and especially males, commonly demonstrate site fidelity to breeding territories. Nesting begins in early to mid-May in the Bristol Bay area (Petersen et al., 1991). Territorial defense is usually strongest during the early part of the breeding season and lessens as chicks hatch (Lanctot et al., 2000). Except solitary sandpipers (*Tringa solitaria*), all shorebirds nesting in the Bristol Bay watershed nest on the ground. Shorebirds usually produce four eggs/ clutch. After a nest is depredated or lost due to environmental factors, re-nesting may be attempted in some species, but generally the season is long enough for only one complete nesting cycle (laying, incubation, and brood-rearing). Incubation may take from 18-28 days, depending on species. Chicks can move to forage in habitats outside of the nesting territories within a few days

of hatching. Adults generally brood young for several days or more until they are thermally independent, and provide defense against predators for two to three weeks. The time from hatch to fledging is from 17-45 days, depending on species. Individual breeding behaviors are discussed at length in the species accounts of the *Birds of North America* (Cornell Lab of Ornithology, 2011).

Although Alaska is known as a nursery ground for shorebirds, the Bristol Bay watershed has not been inventoried for breeding shorebird distribution or abundance. Studies from montane areas in adjacent Katmai and Lake Clark NPPs, the Kilbuck and Ahklun Mountains, and from lowlands of the northern Alaska Peninsula provide some basis for understanding the distribution of breeding species, but cannot be used to estimate breeding densities. For montane areas in Katmai and Lake Clark, the most common species found during the breeding season (in May) were semipalmated plover, spotted sandpiper, wandering tattler, greater and lesser (*Tringa flavipes*) yellowlegs, surfbird, least sandpiper (*Calidris minutilla*), and Wilson's snipe (Gill and Sarvis, 1999; Ruthrauff et al., 2007). Ruthrauff et al. (2007) extended the breeding range of several alpine shorebirds (wandering tattler, surfbird, and Baird's sandpiper (*C. bairdii*)) and confirmed these and another three species (black-bellied plover, American golden-plover, Pacific golden-plover), previously only known as migrants, to be breeders in Katmai. In the area west of the Bristol Bay watershed, Petersen et al. (1991) found black-bellied plover, semipalmated plover, spotted sandpiper, greater yellowlegs, western sandpiper, rock sandpiper, dunlin, Wilson's snipe, and red-necked phalarope to be the most common breeding shorebirds. For lowland areas of the northern Alaska Peninsula, the most common shorebird species found during May were greater yellowlegs, least sandpiper, dunlin, short-billed dowitcher, Wilson's snipe, and red-necked phalarope (Savage and Tibbitts, In prep). Other species that breed in the area include whimbrel and Hudsonian godwit (Ruthrauff et al., 2007).

Shorebird productivity, survivorship, and mortality are affected by many factors that vary by species, region and annual conditions. These parameters are not known specifically for the Bristol Bay watershed, and may not be known at all for many shorebird species. Productivity may be affected by life history (e.g., age at first reproduction, annual participation in breeding), seasonal abundance of food resources, weather, flooding, predation, and other forms of disturbance. Productivity in birds is measured in various ways, including proportion of eggs hatched, proportion of successful nests, and proportion of young fledged. Shorebird pairs may produce, at most, four chicks per season. Most small and medium-sized birds, including shorebirds, suffer from high mortality during their first weeks and months of life. Some species may experience complete reproductive failure in a region during some years.

Survival may be affected by food availability, weather, predation, and human-caused mortality (e.g., collisions with buildings, domestic cat predation, and contaminated or otherwise degraded habitats). Human disturbance and habitat degradation are significantly greater along the

migratory paths and wintering grounds of most shorebirds than on the breeding grounds. Once birds reach adult age and have successfully navigated their first migration, survival is generally higher. The U.S. Geological Survey's Bird Banding Lab maintains longevity records for banded birds (USGS Bird Banding Lab, 2011). These records indicate that smaller shorebird species live from 6-12 years, whereas some medium to large species have been recorded as living up to 21 (Pacific golden-plover) or even 23 years (bristle-thighed curlew). The average age for most populations is much lower and is not known for most shorebird species.

### ***Population, Subpopulations, and Genetics***

Shorebird populations throughout North America have been experiencing declines (Alaska Shorebird Group, 2008). Although accurate population data are lacking for most shorebirds, of the 30 regularly occurring shorebird species in the Bristol Bay watershed, 17 are suspected to be declining and 11 are thought to be stable; information is insufficient to make a determination for 2 species (Morrison et al., 2006). No species using the Bristol Bay watershed is known to be increasing in abundance.

Subspecies are recognized for 2 species of shorebirds found in the Bristol Bay watershed, especially during the migratory period. Of the 2 subspecies of dunlin that breed in Alaska, *Calidris alpina pacifica* subspecies is more likely than *C.a. arctica* to be the subspecies that migrates through Bristol Bay. Subspecies status for this species is still under investigation (Warnock and Gill, 1996). Four or 5 subspecies of rock sandpiper are found in Alaska; the most likely subspecies using the Bristol Bay watershed for breeding is *Calidris ptilocnemis tschuktschorum*; *C. p. couesi*, or *C. p. ptilocnemis* may also use the area during migration (Gill et al., 2002).

### ***Human Use and Threats***

Shorebirds have been and continue to be used for food by humans. During the latter 19<sup>th</sup> and early 20<sup>th</sup> century, shorebirds were harvested commercially along with waterfowl for human consumption. The overhunting of shorebirds and waterfowl and the killing of birds for the fashion industry in part led to the development of the Migratory Bird Treaty Act of 1918. In North America, shorebirds are protected under its provisions. Shorebirds may still be hunted under regulations formulated for each US state. In Alaska, Wilson's snipe may be harvested during the fall migratory bird season (September 1 to December 16 in the Bristol Bay area). Sixteen shorebird species common to Bristol Bay during some part of their life cycle may be harvested during the Alaska Subsistence Spring/Summer Migratory Bird season (April 1 to June 14 and July 16 to August 31). A harvest survey is conducted in parts of southwest Alaska, with various areas assessed during alternating years. However, participation in the survey is voluntary and the reports likely represent minimum harvest levels (Naves, 2011). During the 2009 survey (which included the Y-K Delta Region), 1,688 shorebirds and 1,835 shorebird eggs were

reported harvested (Naves, 2011). In general, godwits, whimbrels and curlews are targeted due to their larger size. These shorebirds have high value to the diet and economy of Native Alaskans, especially in western Alaska.

Non-consumptive uses of shorebirds include shorebird-viewing and tourism associated with that activity. Other areas of Alaska, such as Kachemak Bay, the Copper River Delta, and Cordova are developing this industry and depend on birds that pass through the Bristol Bay watershed. Attempts to develop the birding tourist industry in the Bristol Bay area have begun (<http://www.visitbristolbay.com/visitor-guide/wildlife.html>).

# LANDBIRDS

## ***Introduction***

Approximately 80 species of landbirds breed in the areas in and adjacent to the Nushagak and Kvichak watersheds, representing six orders and 27 families (USFWS, 2008; USFWS, 2010b). Published surveys of birds in this area include biological inventories from 1902 through 1959 (Gabrielson, 1944a; Gabrielson, 1944b; Hurley, 1931a; Hurley, 1931b; Hurley, 1931c; Hurley, 1932; Osgood, 1904; Williamson and Peyton, 1962). More recent work in this and adjacent areas includes inventories in the Kilbuck and Ahklun Mountains (Petersen et al., 1991), inventories in the montane regions of Lake Clark and Katmai NPPs (Ruthrauff et al., 2007), breeding bird surveys in Dillingham, Katmai, and King Salmon, and Christmas Bird Counts in Dillingham and King Salmon (National Audubon Society: [http://audubon2.org/cbchist/count\\_table.html](http://audubon2.org/cbchist/count_table.html)). Landbirds are generally associated with terrestrial habitats; examples include passerines (often called songbirds), woodpeckers, owls, raptors, and gallinaceous birds (grouse and ptarmigan). Bald eagles are addressed separately in this document.

Common landbirds in the region during the summer breeding season include, Swainson's thrush (*Catharus ustulatus*), American robin (*Turdus migratorius*), varied thrush (*Ixoreus naevius*), Arctic warbler (*Phylloscopus borealis*), orange-crowned warbler (*Vermivora celata*), and Wilson's warbler (*Wilsonia pusilla*) (USGS, 2011). Numerous other songbirds regularly nest in the region, including several species of swallows (Hirundinidae), thrushes (Turdidae), warblers (Parulidae), and sparrows (Emberizidae). Year-round resident species include northern goshawk (*Accipiter gentilis*), great-horned owl, common raven (*Corvus corax*), gray jay (*Perisoreus canadensis*), black-billed magpie (*Pica pica*), black-capped and boreal chickadees (*Poecile atricapillus* and *P. hudsonicus*), American dipper (*Cinclus mexicanus*), common redpoll (*Carduelis flammea*), and snow bunting (*Plectrophenax nivalis*) (ADNR, 2008; USGS, 2011). Of the relatively common species occurring in the area, two (short-eared owl (*Asio flammeus*) and rusty blackbird (*Euphagus carolinus*) are on the Partners In Flight (PIF) Continental Watch List. PIF is a multi-stakeholder partnership dedicated to the conservation of landbirds (Rich et al., 2004). Twenty-six of the Bristol Bay landbird species are on the PIF's Continental Stewardship list.

## ***Habitat***

Most landbird species occupy and defend individual breeding territories during the spring and summer. Few studies have focused on landbirds in the Nushagak and Kvichak watersheds and little site-specific information exists. Migratory species begin arriving in late April and may remain through late September (S. Savage (USFWS), pers. comm. 9/14/11).

The Nushagak and Kvichak watersheds are within, albeit near the border of, the PIF's Arctic avifaunal biome, (Rich et al., 2004). The diversity, population, distribution, and densities of birds in the watersheds are not well-understood. Although no comprehensive studies have been published for these watersheds, land bird density and diversity is probably highest along the numerous riparian corridors of the region (Boreal Partners in Flight Working Group, 1999; Williamson and Peyton, 1962). Riparian habitats in these watersheds include ribbons of tall shrub (willow/cottonwood/alder), as well as spruce, birch and mixed forests, which wind and branch across vast acreages of moist and wet tundra (ADFG, 2006; Nushagak-Mulchatna Watershed Council, 2007). Landbird densities are higher in riparian zones particularly where the surrounding habitats have lower plant species or canopy layer diversity (Stauffer and Best, 1980; Wiebe and Martin, 1998).

### ***Species Diversity***

From the few site-specific data available, characterization of local species diversity is as follows: for the Western Alaska Lowlands/Uplands Bird Conservation Region 2 (BCR 2), which includes the Ahklun Mountains and Bristol Bay-Nushagak Lowlands, passerine diversity is thought to be greatest in riparian tall shrub habitats (Boreal Partners in Flight Working Group, 1999).<sup>5</sup> Sixteen species of passerines, the American three-toed woodpecker (*Picoides dorsalis*), and the belted kingfisher (*Megaceryle alcyon*) have been recorded along the Alagnak River (Gotthardt et al., 2010), although proximity to the river and whether or not the records were associated with riparian habitats is unknown.

Mixed spruce-birch forests of the area may also have a relatively high species diversity, with 25-27 species noted by Williamson and Peyton (1962). Forty species were recorded in LCNPP within the upper Mulchatna and upper Kvichak watersheds; the survey area likely included some non-riparian areas (Ruthrauff et al., 2007).

No site-specific density information is available for the Bristol Bay watershed. For Interior Alaska, there were 11.8-45.4 passerine and woodpecker breeding territories per 10-hectare plot (most of which were in riparian habitats) (Kessel, 1998). However, substantial variability in landbird breeding densities reduces the usefulness of these figures for the Bristol Bay area.

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<sup>5</sup> BCR 2 includes most of the middle and lower areas of the Nushagak and Kvichak watersheds, but extends beyond them, from the Kuskokwim River to Unimak Pass.

## ***Food Habits***

Diets of landbirds include vegetation (seeds, berries), invertebrates (aquatic and terrestrial, as well as flying insects), and vertebrates (other birds, fish and mammalian carrion, juvenile fish, fish eggs). During the breeding season, adults face the high demands of producing eggs, feeding young, and molting. Young birds require considerable food resources to grow, and both young and adults must gain fat prior to migration. Even birds that consume a high proportion of seeds and other vegetative matter in the non-breeding season may switch to foods from higher trophic levels during the breeding season. In general, the timing of hatching and the subsequent rate of growth of young landbirds is directly related to the abundance of invertebrate food resources (Ehrlich et al., 1988). The abundance and diversity of emergent aquatic insects may be one of the reasons that riparian habitats are often associated with greater avian abundance (Iwata et al., 2003; Murakami and Nakano, 2002), because techniques for capturing invertebrates (e.g., foliage gleaning, ground foraging, aerial predating/flycatching) vary considerably so that landbirds as a group can exploit a variety of riparian invertebrate prey types (Murakami and Nakano, 2001).

## ***Interspecies Interactions***

Recent studies have indicated that the abundance of many species of songbirds is related to the presence of salmon carcasses in freshwater streams (Christie and Reimchen, 2008; Gende and Willson, 2001; Willson et al., 1998). Relationships among salmon and landbirds are complex and not yet fully understood (Christie and Reimchen, 2008; Gende et al., 2002). It appears that the seasonal accumulation of salmon carcasses has a positive effect on invertebrate populations (Helfield and Naiman, 2006). For example, huge numbers of aquatic invertebrate larvae feed on salmon carcasses (Wipfli et al., 1999), over-winter in the soil, and emerge in the spring as adults, subsequently becoming aerial prey for songbirds. This forms an important seasonal subsidy during the same period that terrestrial invertebrate biomass is low (Nakano and Murakami, 2001). Terrestrial invertebrate (e.g., litter detritivore) populations may also increase with the abundance of salmon carcasses, providing another important food source for passerines (Gende and Willson, 2001). Landbird species such as Pacific wren (*Troglodytes pacificus*) also feed directly on fly larvae within dead salmon in the fall (Christie and Reimchen, 2008).

Other important relationships between salmon and landbirds include the effects of increased plant productivity, that appears to result from MDN input from salmon, particularly in riparian areas (Gende et al., 2002; Helfield and Naiman, 2001; Hilderbrand et al., 2004; Naiman et al., 2002a). This increased productivity (e.g. reflected in an abundance of berries and seeds) in turn provides an increased vegetative food source for landbirds such as Swainson's and varied thrushes (Christie and Reimchen, 2008). American dippers may also benefit from spawning salmon. Dippers feed primarily on aquatic invertebrates, which appear to increase in abundance with salmon carcasses, and females switch to salmon eggs, fry, and small bits of carcasses during the egg-laying period (Morrissey et al., 2010). One study of dippers documented positive

correlations between both higher fledgling mass and less brood mortality with consumption of salmon fry (Obermeyer et al., 2006).

The trophic relationships among salmon, landbirds, invertebrate prey items, and other organisms are complex and not yet well understood, particularly in relatively remote and undisturbed boreal regions such as the Nushagak and Kvichak watersheds. However, these relationships are apparently significant to many aspects of landbird life history. Abundance, distribution, productivity, habitat use, and foraging habits of many landbird species may be affected by salmon. The temporal nature of the pulses of the abundant food source salmon provide is of particular importance to landbirds. Several researchers have examined seasonal resource subsidies in the riparian forest and it has been suggested that seasonal productivity differences between spatially linked habitats help foster the stability of food web dynamics (Takimoto et al., 2002; Wiebe and Martin, 1998; Zhang et al., 2003).

## APPENDIX A: LIST OF AUTHORS AND REVIEWERS

Species	Primary Author(s) (Affiliation)	Contributor or Expert Reviewer (Affiliation)
Overall Report	<ul style="list-style-type: none"> <li>• Phil Brna (USFWS/AFWFO)</li> <li>• Lori Verbrugge (USFWS/AFWFO)</li> </ul>	
Land Cover	<ul style="list-style-type: none"> <li>• Phil Brna (USFWS/AFWFO)</li> </ul>	<ul style="list-style-type: none"> <li>• David Selkowitz (USGS/ Alaska Science Center)</li> <li>• Jerry Tande (USFWS/NWI Program)</li> <li>• Julie Michaelson (USFWS/NWI Program)</li> <li>• Marcus Geist (The Nature Conservancy)</li> </ul>
Brown Bear	<ul style="list-style-type: none"> <li>• Colleen Matt (C.A. Matt; ADFG/Retired)</li> </ul>	<ul style="list-style-type: none"> <li>• Sterling Miller (ADFG/Retired)</li> <li>• Sean Farley (ADFG)</li> <li>• Grant Hilderbrand (NPS)</li> <li>• Cara Staab (BLM)</li> <li>• Susan Savage (USFWS/Alaska Peninsula-Becharof NWRs)</li> <li>• Patrick Walsh (USFWS/Togiak NWR)</li> <li>• Buck Mangipane (NPS/ Lake Clark NP)</li> <li>• Page Spencer (NPS/Retired)</li> <li>• Lem Butler (ADFG/Wildlife Conservation)</li> <li>• Meghan Riley (ADFG/Wildlife Conservation)</li> <li>• Jim Woolington (ADFG/Wildlife Conservation)</li> </ul>
Caribou	<ul style="list-style-type: none"> <li>• Lori Verbrugge (USFWS/AFWFO)</li> <li>• Ken Whitten (ADFG/Retired)</li> </ul>	<ul style="list-style-type: none"> <li>• Layne Adams (USGS/Alaska Science Center)</li> <li>• Dominique Watts (USFWS/Alaska Peninsula-Becharof NWRs)</li> <li>• Bob Tobey (ADFG/Retired)</li> <li>• Andy Aderman (USFWS/Togiak NWR)</li> <li>• Buck Mangipane (NPS/Lake Clark NP)</li> <li>• Cara Staab (BLM)</li> <li>• Jeff Shearer (NPS/Lake Clark NP)</li> <li>• Lem Butler (ADFG/Wildlife Conservation)</li> <li>• Meghan Riley (ADFG/Wildlife Conservation)</li> <li>• Jim Woolington (ADFG/Wildlife Conservation)</li> </ul>

<b>Species</b>	<b>Primary Author(s) (Affiliation)</b>	<b>Contributor or Expert Reviewer (Affiliation)</b>
		Conservation) <ul style="list-style-type: none"> <li>• Nick Demma (ADFG/Wildlife Conservation)</li> <li>• Bruce Seppi (BLM)</li> </ul>
Moose	<ul style="list-style-type: none"> <li>• Lori Verbrugge (USFWS/AFWFO)</li> <li>• Chuck Schwartz (ADFG and USGS/Retired)</li> </ul>	
Wolf	<ul style="list-style-type: none"> <li>• Lori Verbrugge (USFWS/AFWFO)</li> </ul>	<ul style="list-style-type: none"> <li>• Layne Adams (USGS/Alaska Science Center)</li> <li>• Buck Mangipane (NPS/Lake Clark NP)</li> <li>• Dominique Watts (USFWS/Alaska Peninsula- Becharof NWRs)</li> <li>• Ashley Stanek (UAA/ENRI)</li> <li>• Ken Whitten (ADFG/Retired)</li> <li>• Bob Tobey (ADFG/Retired)</li> <li>• Cara Staab (BLM)</li> <li>• Bruce Seppi (BLM)</li> <li>• Page Spencer (NPS/Retired)</li> </ul>
Bald Eagle	<ul style="list-style-type: none"> <li>• Maureen de Zeeuw (USFWS/AFWFO)</li> <li>• Lowell H. Suring (Northern Ecologic LLC)</li> </ul>	<ul style="list-style-type: none"> <li>• Denny Zwiefelhofer (USFWS/Retired)</li> <li>• Steve Lewis (USFWS/Migratory Birds)</li> <li>• Michael Swaim (USFWS/Togiak NWR)</li> </ul>
Landbirds	<ul style="list-style-type: none"> <li>• Maureen de Zeeuw (USFWS/AFWFO)</li> <li>• Susan Savage (USFWS/Alaska Peninsula-Becharof NWRs)</li> </ul>	<ul style="list-style-type: none"> <li>• Meghan Riley (ADFG/Wildlife Conservation)</li> </ul>
Shorebirds	<ul style="list-style-type: none"> <li>• Susan Savage (USFWS/Alaska Peninsula-Becharof NWRs)</li> </ul>	<ul style="list-style-type: none"> <li>• Bob Gill (USGS/Alaska Science Center)</li> <li>• Heather Coletti (NPS/Lake Clark NP)</li> <li>• Rick Lanctot (USFWS/Migratory Birds)</li> <li>• Steve Kendall (USFWS)</li> </ul>
Waterfowl	<ul style="list-style-type: none"> <li>• Tom Rothe (Halcyon Research; ADFG/ Retired)</li> </ul>	<ul style="list-style-type: none"> <li>• Christian Dau (USFWS/Migratory Birds)</li> <li>• Maureen de Zeeuw (USFWS/AFWFO)</li> </ul>
Species List	<ul style="list-style-type: none"> <li>• Maureen de Zeeuw (USFWS/AFWFO)</li> <li>• Susan Savage (USFWS/Alaska Peninsula-Becharof NWRs)</li> </ul>	

## APPENDIX B: SOUTHWEST ALASKA TERRESTRIAL VERTEBRATE SPECIES

### BIRDS

The following species are thought to regularly occur in the Nushagak and Kvichak watersheds based on surveys and observations documenting their presence in adjacent federal land management areas. The species are marked as breeders if they are known to breed in the adjacent areas. Other species that may occur as accidentals are not included here.

Sources: (Togiak NWR, Bird List 2006; D. Ruthrauff et al. 2007; Alaska Peninsula and Becharof NWR Bird List, 2010; with edits from S. Savage, M. Swaim, D. Ruthrauff)

<u>Common Name</u>	<u>Scientific Name</u>	<u>Breeder</u>
<b>Waterfowl</b>		
Greater White-fronted Goose	<i>Anser albifrons</i>	*
Emperor Goose	<i>Chen canagica</i>	*
Snow Goose	<i>Chen caerulescens</i>	
Brant	<i>Branta bernicla</i>	*
Cackling Goose	<i>Branta hutchinsii</i>	
Canada Goose	<i>Branta canadensis</i>	*
Trumpeter Swan	<i>Cygnus buccinator</i>	*
Tundra Swan	<i>Cygnus columbianus</i>	*
Gadwall	<i>Anas strepera</i>	*
Eurasian Wigeon	<i>Anas penelope</i>	
American Wigeon	<i>Anas americana</i>	*
Mallard	<i>Anas platyrhynchos</i>	*
Northern Shoveler	<i>Anas clypeata</i>	*
Northern Pintail	<i>Anas acuta</i>	*
Green-winged Teal	<i>Anas crecca</i>	*
Canvasback	<i>Aythya valisineria</i>	
Redhead	<i>Aythya americana</i>	
Ring-necked Duck	<i>Aythya collaris</i>	*
Greater Scaup	<i>Aythya marila</i>	*
Lesser Scaup	<i>Aythya affinis</i>	
Steller's Eider	<i>Polysticta stelleri</i>	
Spectacled Eider	<i>Somateria fischeri</i>	
King Eider	<i>Somateria spectabilis</i>	

<b><u>Common Name</u></b>	<b><u>Scientific Name</u></b>	<b><u>Breeder</u></b>
Common Eider	<i>Somateria mollissima</i>	*
Harlequin Duck	<i>Histrionicus histrionicus</i>	*
Surf Scoter	<i>Melanitta perspicillata</i>	*
White-winged Scoter	<i>Melanitta fusca</i>	*
Black Scoter	<i>Melanitta americana</i>	*
Long-tailed Duck	<i>Clangula hyemalis</i>	*
Bufflehead	<i>Bucephala albeola</i>	*
Common Goldeneye	<i>Bucephala clangula</i>	*
Barrow's Goldeneye	<i>Bucephala islandica</i>	
Common Merganser	<i>Mergus merganser</i>	*
Red-breasted Merganser	<i>Mergus serrator</i>	*
<b>Gallinaceous Birds</b>		
Spruce Grouse	<i>Falcapennis canadensis</i>	*
Willow Ptarmigan	<i>Lagopus lagopus</i>	*
Rock Ptarmigan	<i>Lagopus muta</i>	*
White-tailed Ptarmigan	<i>Lagopus leucura</i>	*
<b>Loons</b>		
Red-throated Loon	<i>Gavia stellata</i>	*
Pacific Loon	<i>Gavia pacifica</i>	*
Common Loon	<i>Gavia immer</i>	*
<b>Grebes</b>		
Horned Grebe	<i>Podiceps auritus</i>	*
Red-necked Grebe	<i>Podiceps grisegena</i>	*
<b>Tubenoses</b>		
Northern Fulmar	<i>Fulmarus glacialis</i>	
Sooty Shearwater	<i>Puffinus griseus</i>	
Short-tailed Shearwater	<i>Puffinus tenuirostris</i>	
Fork-tailed Storm-Petrel	<i>Oceanodroma furcata</i>	
Leach's Storm-Petrel	<i>Oceanodroma leucorhoa</i>	
<b>Cormorants</b>		
Double-crested Cormorant	<i>Phalacrocorax auritus</i>	*
Red-faced Cormorant	<i>Phalacrocorax urile</i>	*
Pelagic Cormorant	<i>Phalacrocorax pelagicus</i>	*

<u>Common Name</u>	<u>Scientific Name</u>	<u>Breeder</u>
<b>Hawks, Eagles, Falcons</b>		
Osprey	<i>Pandion haliaetus</i>	*
Bald Eagle	<i>Haliaeetus leucocephalus</i>	*
Northern Harrier	<i>Circus cyaneus</i>	*
Sharp-shinned Hawk	<i>Accipiter striatus</i>	
Northern Goshawk	<i>Accipiter gentilis</i>	*
Red-tailed Hawk	<i>Buteo jamaicensis</i>	*
Rough-legged Hawk	<i>Buteo lagopus</i>	*
Golden Eagle	<i>Aquila chrysaetos</i>	*
American Kestrel	<i>Falco sparverius</i>	
Merlin	<i>Falco columbarius</i>	*
Gyr Falcon	<i>Falco rusticolus</i>	*
Peregrine Falcon	<i>Falco peregrinus</i>	*
<b>Cranes</b>		
Sandhill Crane	<i>Grus canadensis</i>	*
<b>Shorebirds</b>		
Black-bellied Plover	<i>Pluvialis squatarola</i>	*
American Golden-Plover	<i>Pluvialis dominica</i>	*
Pacific Golden-Plover	<i>Pluvialis fulva</i>	*
Semipalmated Plover	<i>Charadrius semipalmatus</i>	*
Black Oystercatcher	<i>Haematopus bachmani</i>	*
Spotted Sandpiper	<i>Actitis macularius</i>	*
Solitary Sandpiper	<i>Tringa solitaria</i>	
Wandering Tattler	<i>Tringa incana</i>	*
Greater Yellowlegs	<i>Tringa melanoleuca</i>	*
Lesser Yellowlegs	<i>Tringa flavipes</i>	*
Whimbrel	<i>Numenius phaeopus</i>	*
Bristle-thighed Curlew	<i>Numenius tahitiensis</i>	
Hudsonian Godwit	<i>Limosa haemastica</i>	*
Bar-tailed Godwit	<i>Limosa lapponica</i>	*
Marbled Godwit	<i>Limosa fedoa</i>	*
Ruddy Turnstone	<i>Arenaria interpres</i>	
Black Turnstone	<i>Arenaria melanocephala</i>	*
Surfbird	<i>Aphriza virgata</i>	*
Red Knot	<i>Calidris canutus</i>	
Sanderling	<i>Calidris alba</i>	
Semipalmated Sandpiper	<i>Calidris pusilla</i>	

<u>Common Name</u>	<u>Scientific Name</u>	<u>Breeder</u>
Western Sandpiper	<i>Calidris mauri</i>	*
Least Sandpiper	<i>Calidris minutilla</i>	*
Baird's Sandpiper	<i>Calidris bairdii</i>	*
Pectoral Sandpiper	<i>Calidris melanotos</i>	*
Rock Sandpiper	<i>Calidris ptilocnemis</i>	*
Dunlin	<i>Calidris alpina</i>	*
Short-billed Dowitcher	<i>Limnodromus griseus</i>	*
Long-billed Dowitcher	<i>Limnodromus scolopaceus</i>	
Wilson's Snipe	<i>Gallinago delicata</i>	*
Red-necked Phalarope	<i>Phalaropus lobatus</i>	*
Red Phalarope	<i>Phalaropus fulicarius</i>	
<b>Gulls and Terns</b>		
Black-legged Kittiwake	<i>Rissa tridactyla</i>	*
Sabine's Gull	<i>Xema sabini</i>	*
Bonaparte's Gull	<i>Chroicocephalus philadelphia</i>	*
Mew Gull	<i>Larus canus</i>	*
Herring Gull	<i>Larus argentatus</i>	
Slaty-backed Gull	<i>Larus schistisagus</i>	
Glaucous-winged Gull	<i>Larus glaucescens</i>	*
Glaucous Gull	<i>Larus hyperboreus</i>	*
Aleutian Tern	<i>Onychoprion aleuticus</i>	*
Arctic Tern	<i>Sterna paradisaea</i>	*
<b>Jaegers</b>		
Pomarine Jaeger	<i>Stercorarius pomarinus</i>	
Parasitic Jaeger	<i>Stercorarius parasiticus</i>	*
Long-tailed Jaeger	<i>Stercorarius longicaudus</i>	*
<b>Alcids</b>		
Common Murre	<i>Uria aalge</i>	*
Thick-billed Murre	<i>Uria lomvia</i>	*
Pigeon Guillemot	<i>Cephus columba</i>	*
Marbled Murrelet	<i>Brachyramphus marmoratus</i>	*
Kittlitz's Murrelet	<i>Brachyramphus brevirostris</i>	*
Ancient Murrelet	<i>Synthliboramphus antiquus</i>	
Parakeet Auklet	<i>Aethia psittacula</i>	*
Rhinoceros Auklet	<i>Cerorhinca monocerata</i>	
Horned Puffin	<i>Fratercula corniculata</i>	*

<u>Common Name</u>	<u>Scientific Name</u>	<u>Breeder</u>
Tufted Puffin	<i>Fratercula cirrhata</i>	*
<b>Owls</b>		
Great Horned Owl	<i>Bubo virginianus</i>	*
Snowy Owl	<i>Bubo scandiacus</i>	
Northern Hawk Owl	<i>Surnia ulula</i>	*
Great Gray Owl	<i>Strix nebulosa</i>	*
Short-eared Owl	<i>Asio flammeus</i>	*
Boreal Owl	<i>Aegolius funereus</i>	*
Northern Saw-whet Owl	<i>Aegolius acadicus</i>	*
<b>Hummingbirds</b>		
Rufous Hummingbird	<i>Selasphorus rufus</i>	
<b>Kingfishers</b>		
Belted Kingfisher	<i>Megaceryle alcyon</i>	*
<b>Woodpeckers</b>		
Downy Woodpecker	<i>Picoides pubescens</i>	*
Hairy Woodpecker	<i>Picoides villosus</i>	
American Three-toed Wp.	<i>Picoides dorsalis</i>	*
Black-backed Woodpecker	<i>Picoides arcticus</i>	*
Northern Flicker	<i>Colaptes auratus</i>	*
<b>Flycatchers</b>		
Olive-sided Flycatcher	<i>Contopus cooperi</i>	
Alder Flycatcher	<i>Empidonax alnorum</i>	*
Say's Phoebe	<i>Sayornis saya</i>	
<b>Shrikes</b>		
Northern Shrike	<i>Lanius excubitor</i>	*
<b>Crows, Jays, Magpies</b>		
Gray Jay	<i>Perisoreus canadensis</i>	*
Steller's Jay	<i>Cyanocitta stelleri</i>	
Black-billed Magpie	<i>Pica hudsonia</i>	*
Northwestern Crow	<i>Corvus caurinus</i>	*
Common Raven	<i>Corvus corax</i>	*

<u>Common Name</u>	<u>Scientific Name</u>	<u>Breeder</u>
<b>Larks</b>		
Horned Lark	<i>Eremophila alpestris</i>	*
<b>Swallows</b>		
Tree Swallow	<i>Tachycineta bicolor</i>	*
Violet-green Swallow	<i>Tachycineta thalassina</i>	*
Bank Swallow	<i>Riparia riparia</i>	*
Cliff Swallow	<i>Petrochelidon pyrrhonota</i>	*
Barn Swallow	<i>Hirundo rustica</i>	*
<b>Chickadees</b>		
Black-capped Chickadee	<i>Poecile atricapillus</i>	*
Boreal Chickadee	<i>Poecile hudsonicus</i>	*
<b>Nuthatches</b>		
Red-breasted Nuthatch	<i>Sitta canadensis</i>	*
<b>Creepers</b>		
Brown Creeper	<i>Certhia americana</i>	*
<b>Wrens</b>		
Pacific Wren	<i>Troglodytes pacificus</i>	*
<b>Dippers</b>		
American Dipper	<i>Cinclus mexicanus</i>	*
<b>Kinglets</b>		
Golden-crowned Kinglet	<i>Regulus satrapa</i>	*
Ruby-crowned Kinglet	<i>Regulus calendula</i>	*
<b>Old World Warblers</b>		
Arctic Warbler	<i>Phylloscopus borealis</i>	*
<b>Thrushes</b>		
Northern Wheatear	<i>Oenanthe oenanthe</i>	
Gray-cheeked Thrush	<i>Catharus minimus</i>	*
Swainson's Thrush	<i>Catharus ustulatus</i>	*
Hermit Thrush	<i>Catharus guttatus</i>	*

<u>Common Name</u>	<u>Scientific Name</u>	<u>Breeder</u>
American Robin	<i>Turdus migratorius</i>	*
Varied Thrush	<i>Ixoreus naevius</i>	*
<b>Wagtails and Pipits</b>		
Eastern Yellow Wagtail	<i>Motacilla tschutschensis</i>	*
American Pipit	<i>Anthus rubescens</i>	*
<b>Waxwings</b>		
Bohemian Waxwing	<i>Bombycilla garrulus</i>	*
<b>Longspurs and Buntings</b>		
Lapland Longspur	<i>Calcarius lapponicus</i>	*
Snow Bunting	<i>Plectrophenax nivalis</i>	*
McKay's Bunting	<i>Plectrophenax hyperboreus</i>	
<b>Wood Warblers</b>		
Northern Waterthrush	<i>Parkesia noveboracensis</i>	*
Orange-crowned Warbler	<i>Oreothlypis celata</i>	*
Yellow Warbler	<i>Setophaga petechia</i>	*
Blackpoll Warbler	<i>Setophaga striata</i>	*
Yellow-rumped Warbler	<i>Setophaga coronata</i>	*
Wilson's Warbler	<i>Cardellina pusilla</i>	*
<b>Sparrows</b>		
American Tree Sparrow	<i>Spizella arborea</i>	*
Savannah Sparrow	<i>Passerculus sandwichensis</i>	*
Fox Sparrow	<i>Passerella iliaca</i>	*
Song Sparrow	<i>Melospiza melodia</i>	*
Lincoln's Sparrow	<i>Melospiza lincolnii</i>	*
White-crowned Sparrow	<i>Zonotrichia leucophrys</i>	*
Golden-crowned Sparrow	<i>Zonotrichia atricapilla</i>	*
Dark-eyed Junco	<i>Junco hyemalis</i>	*
<b>Blackbirds</b>		
Rusty Blackbird	<i>Euphagus carolinus</i>	*

**Finches**

Gray-crowned Rosy-Finch	<i>Leucosticte tephrocotis</i>	*
Pine Grosbeak	<i>Pinicola enucleator</i>	*
Red Crossbill	<i>Loxia curvirostra</i>	
White-winged Crossbill	<i>Loxia leucoptera</i>	*
Common Redpoll	<i>Acanthis flammea</i>	*
Hoary Redpoll	<i>Acanthis hornemanni</i>	*
Pine Siskin	<i>Spinus pinus</i>	

**MAMMALS**

(Cook and MacDonald, 2005; USFWS, 2009b)

<b>Common Name</b>	<b>Scientific Name</b>
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**Terrestrial Mammals****Shrews**

Masked shrew	<i>Sorex cinereus</i>
Pygmy shrew	<i>Sorex hoyi</i>
Tundra shrew	<i>Sorex tundrensis</i>
Alaska tiny shrew	<i>Sorex yukonicus</i>
Arctic shrew	<i>Sorex arcticus</i>
Montane shrew	<i>Sorex monticolus</i>
Northern water shrew	<i>Sorex palustris</i>

**Bats**

Little brown bat	<i>Myotis lucifigus</i>
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**Canids**

Arctic fox	<i>Alopex lagopus</i>
Coyote	<i>Canis latrans</i>
Wolf	<i>Canis lupus</i>
Red fox	<i>Vulpes vulpes</i>

**Cats**

Lynx	<i>Lynx canadensis</i>
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**Weasels**

River otter	<i>Lontra canadensis</i>
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Wolverine	<i>Gulo gulo</i>
Marten	<i>Martes americana</i>
Ermine	<i>Mustela erminea</i>
Least weasel	<i>Mustela nivalis</i>
Mink	<i>Mustela vison</i>

### **Bears**

Black bear	<i>Ursus americanus</i>
Brown bear	<i>Ursus arctos</i>

### **Ungulates**

Moose	<i>Alces americanus</i>
Caribou	<i>Rangifer tarandus</i>
Dall sheep	<i>Ovis dalli</i>

### **Rodents**

Hoary marmot	<i>Marmota caligata</i>
Arctic ground squirrel	<i>Spermophilus parryii</i>
Red squirrel	<i>Tamiasciurus hudsonicus</i>
Beaver	<i>Castor canadensis</i>
Meadow jumping mouse	<i>Zapus hudsonius</i>
Northern red-backed vole	<i>Clethrionomys rutilus</i>
Northern collared lemming	<i>Dicrostonyx groenlandicus</i>
Brown lemming	<i>Lemmus trimucronatus</i>
Northern bog lemming	<i>Synaptomys borealis</i>
Meadow vole	<i>Microtus pennsylvanicus</i>
Tundra vole	<i>Microtus oeconomus</i>
Singing vole	<i>Microtus miurus</i>
Muskrat	<i>Ondatra zibethicus</i>
Porcupine	<i>Erethizon dorsatum</i>

### **Lagomorphs**

Snowshoe hare	<i>Lepus americanus</i>
Tundra hare	<i>Lepus othus</i>
Collared pika	<i>Ochotona collaris</i>

## APPENDIX C: LITERATURE CITED

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