# Section 7

# Climate Effects on Fish and Wildlife

## Birds

Over 80 species of birds regularly use terrestrial and aquatic (non-marine) habitats of the Alaska North Slope for nesting, brood-rearing, and fall staging. Nearly all are migratory, occupying the region for a portion of the interval between May and mid-November, but with the majority present June through August. Some species, such as the arctic tern and red phalarope, migrate over 10,000 km each year from wintering grounds in Antarctica and southern Africa, respectively. Other species arrive from wintering grounds in the Far East, Aleutian Islands, and the Americas. A few species, however, such as ptarmigans and the common raven, will overwinter on the North Slope.

Table 7.1 lists 80 species regularly found on the North Slope and provides basic information related to general diet and habitat preferences. Most of the species (waterfowl, shorebirds, loons, gulls, and terns) that use the Arctic Coastal Plain are wetland-dependent. The diversity of songbirds is greatest in the Brooks Range and Arctic Foothills, where shrub-associated species with taiga affinities (e.g., gray-cheeked thrush, American tree sparrow, white-crowned sparrow, and fox sparrow) reach the northern limits of their range. The Alaska breeding range of many tundra-associated species extends along the Chukchi Sea coast and as far south as the Yukon-Kuskokwim delta; populations of several species, however, are concentrated in northern Alaska. These include: yellow-billed loon, snow goose, king eider, spectacled eider, Steller's eider, red phalarope, stilt sandpiper, ruddy turnstone, red knot, white-rumped sandpiper, pectoral sandpiper, buff-breasted sandpiper, glaucous gull, black guillemot, pomarine jaeger, snowy owl, and Smith's longspur.

## Potential Climate Impacts on Birds

The potential for warmer summers and delayed freeze-up would likely improve reproductive success for some bird species. For example, there is evidence suggesting shorebird chick growth and survival is constrained by cold weather conditions (Soloviev et al. 2006), thus a warming climate could increase productivity in these species. A longer open water season should also improve fledging success for species like red-throated loons, for which early freezing temperatures are a significant source of mortality for pre-fledging juveniles (Dickson 1983).

If warmer summers result in drying of wetlands, however, species that rely on shallow lakes and ponds and wet meadows could be profoundly affected. Low-gradient wetlands and shallow lakes on the Arctic Coastal Plain are recharged largely by spring snow melt. As summer progresses, water loss through evapotranspiration is greater than input from precipitation, leading to lake drawdown (Bowling et al. 2003). Without a coincident increase in precipitation, warmer summer temperatures would result in drying. It is not only the net amount of precipitation input but also the timing of those events that will influence wetland habitats. If precipitation increases occur predominantly in winter, then most could be lost to spring runoff, and summer drying of the surface may still occur. A long-term drying trend would likely lead to changes in vegetation community composition and productivity of invertebrates, affecting herbivorous species as well as those dependent on arthropods.

The invertebrate community within arctic lakes is heavily influenced by the presence or absence of fish (Stross et al. 1980); therefore prey availability for aquatic birds is also affected. Changes in flow regimes that prevent fish from entering lakes (see Fish) would be detrimental to piscivores, but reduced competition for invertebrate prey would likely benefit other bird species. Furthermore, increased water temperatures and longer open-water season could increase primary and secondary productivity in aquatic systems, thus increasing food availability.

Despite overall increases in productivity, changes in seasonal patterns of food quantity and quality could be detrimental. The timing of breeding activities for many species of arctic birds appears closely linked to peak insect emergence (Hurd and Pitelka 1954, Holmes 1966, MacLean 1980). Juveniles, in particular, depend on the synchronous seasonal activity peak of surface-available arthropods for growth and survival (Tulp 2008). The timing of insect emergence is closely related to the timing of snowmelt, and might advance with warmer spring temperatures (Høye and Forchhammer 2008, Tulp 2008). If birds can not adjust migration and breeding schedules to optimize exploitation of food resources, a condition of "trophic mismatch" would develop, whereby the phenology of a consumer is out-of-phase with critical food resources (Coppack and Both 2002). Figure 7.1 illustrates some of the potential climate effects on birds, mediated through availability of invertebrate prey.

Beyond short-term phenological response to changing climate, seasonality may have profound long-term consequences for the distribution and abundance of arctic arthropods. Multi-year life cycles occur in many arctic invertebrates (MacLean 1980, Chernov 1985) as an adaptation to temperature-constrained growth rates. The prevalence of multi-year life cycles results in a large standing biomass of larval invertebrates available to predators throughout the summer season. A shift to shorter, even annual, life cycles could substantially influence the availability of larval biomass available to birds during portions of the breeding season, although the relationship is complex (MacLean 1980). In northern Alaska, species diversity of soil invertebrates increases substantially along a climatic gradient away from the colder coastal zone (MacLean 1975), suggesting that longer summer seasons will result in range shifts and changes in the composition of the soil invertebrate fauna.

Observed changes in coastal habitats will likely have a continued influence on bird habitat availability. A longer ice-free season for the Beaufort and Chukchi seas increases the probability of occurrence of storms with high erosive capacity. Indeed, recent studies confirm an increase in coastal erosion rates in the Beaufort Sea region (Mars and Houseknecht 2007, Jones et al. in press). Coastal erosion, accompanied by lake-breaching and salinization of adjacent low-lying areas, may result in changes in vegetation that influence habitat suitability differentially for bird species (Mars and Houseknecht 2001, Flint et al. 2008). Accelerated erosion rates may also be expected to increase the carbon and nutrient input into coastal lagoons (Jorgenson and Brown 2005). Increased stream sediment loads may result from thermokarst-associated bank erosion (Walsh et al. 2005); the persistence of deltaic mud-flat habitat is dependent on the balance of deposition rate vs. inundation from sea level rise. Hypothesized climate effects on the availability of coastal bird habitat are illustrated in Figure 7.2.

Figure 7.1. Hypothesized climate influences on birds, as mediated via invertebrate prey availability.

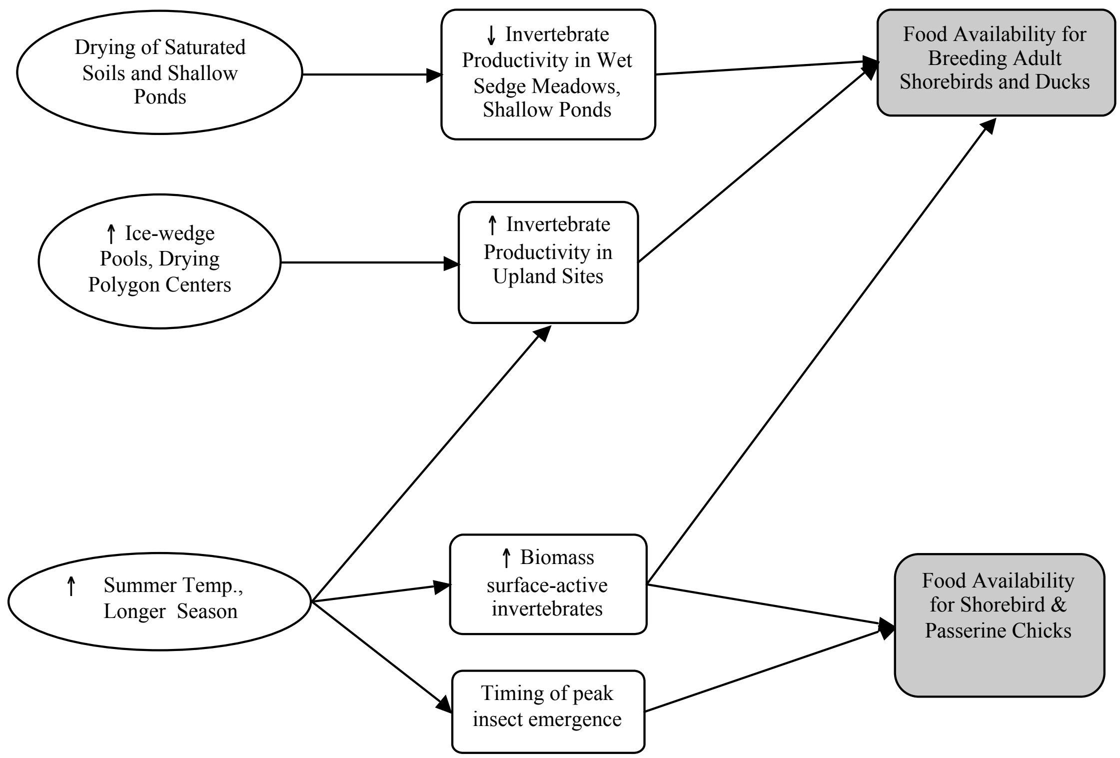


Figure 7.2. Hypothesized climate influences on coastal bird habitat availability.

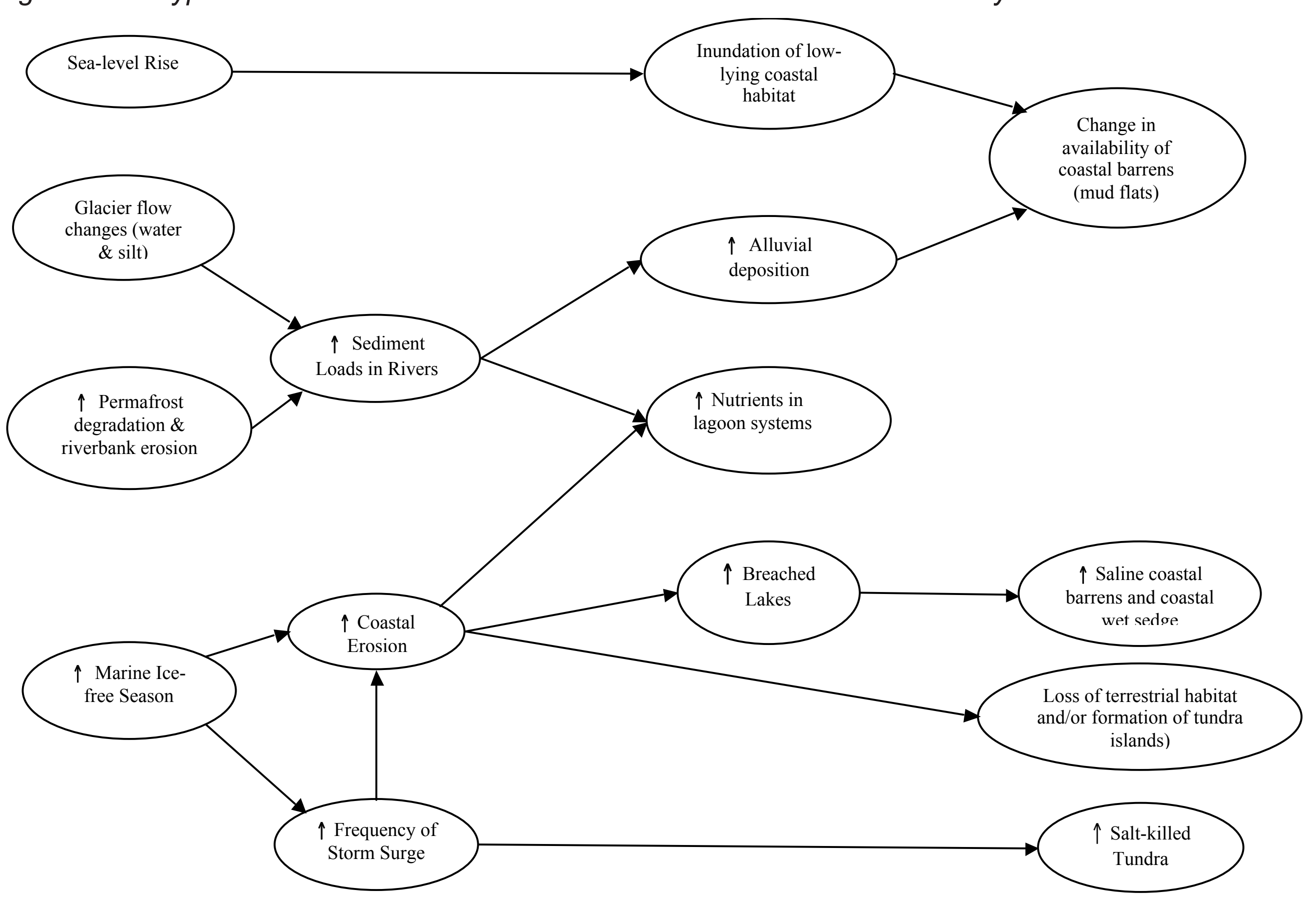

*Table 7.1. Diet (Poole 2005) and principal habitat affinities (TNC and ABR Inc., unpublished) of birds typical of arctic Alaska.*

| Common Name | Diet[1] | Habitat |
|---|---|---|
| Red-throated Loon | P | Lowland Wet Sedge Tundra, Lacustrine Marsh, Riverine Marsh |
| Pacific Loon | P | Lacustrine Marsh, Lowland Wet Sedge Tundra, Lowland Lake |
| Yellow-billed Loon | P | Lowland Lake, Riverine Waters, Lacustrine Marsh |
| Red-necked Grebe | P, I | Lacustrine Marsh, Lowland Lake |
| Tundra Swan | H | Lowland Moist Sedge-Shrub Tundra, Lowland Lake, Lowland Wet Sedge Tundra |
| Gr. White-fronted Goose | H | Lowland Wet Sedge Tundra, Lacustrine Marsh, Lowland Lake |
| Snow Goose | H | Coastal Wet Sedge Tundra, Lowland Wet Sedge Tundra |
| Canada Goose | H | Lowland Moist Sedge-Shrub Tundra, Lowland Wet Sedge Tundra, Lowland Lake |
| Brant | H | Coastal Wet Sedge Tundra, Lowland Lake, Lowland Wet Sedge Tundra |
| Green-winged Teal | H, I | Lowland Moist Sedge-Shrub Tundra, Lowland Wet Sedge Tundra |
| Mallard | H, I | Lowland Wet Sedge Tundra, Lowland Lake |
| Northern Shoveler | H, I | Coastal Wet Sedge Tundra, Riverine Marsh, Lowland Lake |
| Northern Pintail | H, I | Lowland Moist Sedge-Shrub Tundra, Lacustrine Marsh, Lowland Wet Sedge Tundra |
| Greater Scaup | H, I | Riverine Wet Sedge Tundra, Lacustrine Marsh, Lowland Lake |
| Lesser Scaup | I | Lowland Lake, Lowland Wet Sedge Tundra |
| Steller's Eider | I | Lacustrine Marsh, Lowland Lake, Lowland Wet Sedge Tundra |
| Spectacled Eider | H, I | Lowland Wet Sedge Tundra, Lacustrine Marsh, Lowland Lake |
| King Eider | H, I | Lacustrine Marsh, Lowland Wet Sedge Tundra, Coastal Wet Sedge Tundra |
| Common Eider | I | Coastal Water, Coastal Barrens, Lowland Wet Sedge Tundra |
| Harlequin Duck | I | Riverine Waters, Riverine Low Willow Shrub Tundra, Riverine Tall Alder-Willow Shrub |
| Long-tailed Duck | H, I | Lowland Wet Sedge Tundra, Lowland Lake, Lacustrine Marsh |
| White-winged Scoter | I | Lowland Lake, Riverine Waters |
| Red-breasted Merganser | I, P | Riverine Waters, Coastal Barrens |
| Northern Harrier | C | Riverine Dryas Dwarf Shrub Tundra |
| Rough-legged Hawk | C | Upland Bluffs, Upland Moist Sedge-Shrub Tundra, Upland Dryas Dwarf Shrub Tundra |
| Golden Eagle | C | Upland Bluffs, Alpine Mafic Dwarf Shrub Tundra |
| Peregrine Falcon | C | Upland Bluffs, Riverine Dryas Dwarf Shrub Tundra |
| Gyrfalcon | C | Upland Bluffs, Lowland Wet Sedge Tundra, Alpine Dryas Dwarf Scrub Tundra |
| Willow Ptarmigan | H | Lowland Moist Sedge-Shrub Tundra, Lowland Wet Sedge Tundra, Upland Shrubby Tussock Tundra |
| Rock Ptarmigan | H | Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra, Upland Moist Sedge-Shrub Tundra |
| Sandhill Crane | H, I, C | Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra |

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|---|---|---|
| Black-bellied Plover | I | Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra, Coastal Barrens |
| American Golden-Plover | I | Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra, Alpine Mafic Dwarf Shrub Tundra |
| Semipalmated Plover | I | Riverine Barrens, Coastal Barrens, Upland Dryas Dwarf Scrub Tundra |
| Wandering Tattler | I | Riverine Waters, Riverine Barrens |
| Upland Sandpiper | I | Lowland Wet Sedge Tundra, Upland Moist Sedge-Shrub Tundra |
| Whimbrel | I, F | Upland Moist Sedge-Shrub Tundra, Upland Dryas Dwarf Shrub Tundra, Upland Shrubby Tussock Tundra |
| Bar-tailed Godwit | I, F | Lowland Wet Sedge Tundra, Coastal Barrens, Lowland Moist Sedge-Shrub Tundra |
| Ruddy Turnstone | I | Coastal Barrens, Lowland Moist Sedge-Shrub Tundra, Lowland Wet Sedge Tundra |
| Surfbird | I | Alpine Mafic Dwarf Shrub Tundra, Alpine Noncarbonate Dwarf Shrub Tundra |
| Red Knot | I, H | Coastal Barrens, Upland Dryas Dwarf Shrub Tundra, Lowland Wet Sedge Tundra |
| Sanderling | I | Coastal Barrens, Lowland Wet Sedge Tundra |
| Semipalmated Sandpiper | I | Coastal Barrens, Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra |
| Western Sandpiper | I | Coastal Barrens, Lowland Moist Sedge-Shrub Tundra, Upland Moist Sedge-Shrub Tundra |
| Least Sandpiper | I | Coastal Barrens, Lowland Moist Sedge-Shrub Tundra, Lowland Wet Sedge Tundra |
| White-rumped Sandpiper | I | Lowland Moist Sedge-Shrub Tundra, Lowland Wet Sedge Tundra, Coastal Wet Sedge Tundra |
| Baird's Sandpiper | I | Lowland Moist Sedge-Shrub Tundra, Coastal Wet Sedge Tundra, Riverine Barrens |
| Pectoral Sandpiper | I | Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra, Upland Moist Sedge-Shrub Tundra |
| Dunlin | I | Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra, Upland Moist Sedge-Shrub Tundra |
| Stilt Sandpiper | I | Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra, Coastal Wet Sedge Tundra |
| Buff-breasted Sandpiper | I | Lowland Moist Sedge-Shrub Tundra, Upland Moist Sedge-Shrub Tundra, Lowland Wet Sedge Tundra |
| Long-billed Dowitcher | I | Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra, Coastal Wet Sedge Tundra |
| Wilson's Snipe | H, I | Lowland Wet Sedge Tundra, Lowland Spruce Forest, Upland Moist Sedge-Shrub Tundra |
| Red-necked Phalarope | I | Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra, Lowland Lake |
| Red Phalarope | I | Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra, Lowland Lake |
| Pomarine Jaeger | C | Lowland Wet Sedge Tundra, Upland Moist Sedge-Shrub Tundra, Lowland Moist Sedge-Shrub Tundra |

| | | |
|---|---|---|
| Parasitic Jaeger | C | Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra, Upland Moist Sedge-Shrub Tundra |
| Long-tailed Jaeger | C, I | Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra, Upland Moist Sedge-Shrub Tundra |
| Glaucous Gull | C, P, A | Lowland Lake, Lowland Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra |
| Sabine's Gull | H, I, P | Lowland Lake, Lowland Wet Sedge Tundra, Coastal Wet Sedge Tundra |
| Arctic Tern | I, P | Coastal Barrens, Coastal Wet Sedge Tundra, Lowland Moist Sedge-Shrub Tundra |
| Snowy Owl | C | Lowland Wet Sedge Tundra, Upland Moist Sedge-Shrub Tundra |
| Short-eared Owl | C | Lowland Wet Sedge Tundra, Riverine Wet Sedge Tundra |
| Common Raven | H, C, P, A | Human Modified, Upland Bluffs |
| American Dipper | I, P | Riverine Waters |
| Bluethroat | I | Riverine Willow Scrub Tundra, Upland Shrub Birch-Willow Tundra |
| Northern Wheatear | H, I | Riverine Dryas Dwarf Shrub Tundra, Upland Dryas Dwarf Shrub Tundra, Alpine Carbonate Barrens |
| Gray-cheeked Thrush | I, F | Riverine Low Willow Shrub Tundra, Upland Tall Alder Shrub, Upland Spruce Forest |
| Yellow Wagtail | I | Riverine Low Willow Shrub Tundra, Riverine Tall Alder-Willow Shrub |
| American Pipit | I | Alpine Carbonate Barrens, Alpine Noncarbonate Barrens, Alpine Noncar-bonate Dwarf Shrub Tundra |
| Northern Shrike | I, C | Riverine Low Willow Shrub Tundra, Upland Tall Alder Shrub, Upland Low Birch-Willow Shrub Tundra |
| American Tree Sparrow | I | Riverine Low Willow Shrub Tundra, Upland Tall Alder Shrub,Upland Low Birch-Willow Shrub Tundra |
| Savannah Sparrow | I, S | Lowland Moist Sedge-Shrub Tundra |
| Fox Sparrow | I | Upland Tall Alder Shrub, Riverine Low Willow Shrub Tundra, Riverine Tall Alder-Willow Shrub |
| White-crowned Sparrow | I, S | Upland Tall Alder Shrub, Riverine Low Willow Shrub Tundra |
| Lapland Longspur | I, S | Lowland Moist Sedge-Shrub Tundra, Lowland Wet Sedge Tundra,Upland Dryas Dwarf Shrub Tundra |
| Smith's Longspur | I, S | Lowland Wet Sedge Tundra, Riverine Low Willow Shrub Tundra, Lowland Moist Sedge-Shrub Tundra |
| Snow Bunting | I, S | Human Modified, Lowland Wet Sedge Tundra, Coastal Barrens |
| Common Redpoll | I, S | Riverine Low Willow Shrub Tundra, Lowland Low Birch-Willow Shrub |
| Hoary Redpoll | I, S | Riverine Low Willow Shrub Tundra, Upland Low Birch-Willow Shrub Tundra,Upland Shrubby Tussock Tundra |

1. H = herbivore (shoots, leaves), F = herbivore (fruit), S = herbivore (seeds), I = invertebrates, C = carnivore (mammals/birds), P = piscivore, A = anthropogenic

***References***

Bowling, L.C., D.L. Kane, R.E. Gieck, and L.D. Hinzman, 2003. The role of surface storage in a low-gradient Arctic watershed. Water Resources Research, 39(4), 1087.

Chernov, Yu. I. 1985. The Living Tundra. Cambridge: Cambridge University Press.

Coppack, T. and C. Both. 2002. Predicting life-cycle adaption of migratory birds to global climate change. In The avian calendar: exploring biological hurdles in the annual cycle (Both, C., and Piersma, T. Eds). Proc. 3rd Conf. European Orn. Union, Gronigen, August 2001. Ardea 90: 369-378.

Dickson, D. L. 1993. Breeding biology of Red-throated Loons in the Canadian Beaufort Sea region. Arctic 46: 1–7.

Flint, P.L., E.J. Mallek, R.J. King, J.A, Schmutz, K.S. Bollinger, and D.V. Derksen. 2008 Changes in abundance and spatial distribution of geese molting near Teshekpuk Lake, Alaska: interspecific competition or ecological change? Polar Bioology31:549-545.

Høye, T.T. and Forchhammer, M.C. 2008. Phenology of high-arctic arthropods: effects of climate on spatial, seasonal, and inter-annual variation. In Advances in Ecological Research 40. High arctic ecosystem dynamics in a changing climate: ten years of monitoring and research at Zackenberg Research Station, Northeast Greenland (Meltofte, H. , Christensen, T.R., Elberling, B., Forchhammer, M.C, and Rasch, M., Eds). London: Academic Press, pp. 300-322.

Hurd, P.D., and Pitelka, F.A. 1954. The role of insects in the economy of certain Arctic Alaskan birds. In Proceedings of the 3rd Alaskan Scientific Conference: Science in Alaska 1952. 2-27 September 1952. Mount McKinley National Park, Alaska. College, Alaska. Division of the American Association for the Advancement of Science, pp. 136-137.

Jones, B.M., K.M. Hinkel, C.D. Arp, and W.R. Eisner. In press. Modern erosion rates and loss of coastal features and sites, Beaufort Sea coastline, Alaska. Arctic 61: xxx-xxx.

Jorgenson, M.T., and J. Brown. 2005. Classification of the Alaskan Beaufort Sea Coast and estimation of carbon and sediment inputs from coastal erosion. Geo-Mar Lett 25: 69-80.

MacLean, S.F. Jr., (1975). Ecology of tundra invertebrates at Prudhoe Bay, Alaska. In Ecological Investigations of the Tundra Biome in the Prudhoe Bay Region, Alaska (J. Brown, Ed.) Biological Papers of the University of Alaska, Special Report 2, pp. 114-123.

MacLean, S.F. Jr. (1980). The detritus-based trophic system. In An Arctic Ecosystem: The coastal tundra at Barrow, Alaska (Brown, J., Miller, M.C, Tieszen, L.L., and Bunnell, F.L. Eds), Stroudsburg, PA: Dowden, Hutchinson, and Ross, Inc., pp. 411-457.

Mars, J.C., and D.W. Houseknecht. 2007. Quantitative remote sensing study indicates doubling of erosion rate in the past 50 yr along a segment of the Arctic coast of Alaska. Geology 35: 583-586.

Poole, A. (Editor). 2005. The Birds of North America Online: http://bna.birds.cornell.edu/BNA/. Cornell Laboratory of Ornithology, Ithaca, NY.

Soloviev, M.Y., Minton, C.D.T., and Tomkovich, P.S. 2006. Breeding performance of tundra waders in response to rodent abundance and weather from Taimyr to Chukotka, Siberia. Waterbirds around the world. Eds. G.C. Boere, C.A. Galbraith, and D.A. Stroud. The Stationery Office, Edinburgh, UK. Pp 121-137.

Stross, R.G., M.C. Miller, and R.J. Daley. 1980. Zooplankton. In Limnology of Tundra Ponds, Barrow (J.E. Hobbie, Ed.), Stroudsburg, PA: Dowden, Hutchinson, and Ross, Inc., pp. 251-296.

Tulp, I. and H. Schekkerman. 2008. Has prey availability for arctic birds advanced with climate change? Hindcasting the abundance of tundra arthropods using weather and seasonal variation. Arctic 61: 48-60.

Walsh, J.E., O. Anisimov, J.O.M. Hagen, T. Jakobsson, J. Oerlemans, T.D. Prowse, V. Romanovsky, N. Savelieva, M. Serreze, I. Shiklomanov and S. Solomon. 2005. Cryosphere and hydrology. Pp. 183-242 in Arctic Climate Impacts Assessment (ACIA), C. Symon, L. Arris, and B. Heal, Eds., Cambridge University Press, Cambridge, UK.

## Freshwater Resident and Anadromous Fish of the North Slope of Alaska

Aquatic habitats on the North Slope are extreme environments for fish. North Slope streams and lakes are characterized by low average temperatures, low prey densities, short open water periods each year, and limited overwintering habitat for fish (Craig 1989). During summer, strong freshwater flow from North Slope rivers mixes with coastal waters to produce a narrow nearshore band of relatively warm, brackish water that provides rich foraging opportunities for anadromous fishes. During winter, however, only the two largest rivers (Colville and Sagavanirktok), maintain sufficient flow to create a brackish water interface with the marine system (Craig and McCart 1975). The temperature of the marine water during winter falls to about -2 °C (O'Rourke 1974, Craig and Haldorson 1981), which is too cold for any of the anadromous species (Black 1957, DeVries and Cheng 2005). These environmental factors act together to impose unique constraints on fish populations in the region. A number of species, however, have adapted to thrive in these habitats.

Species in the family Salmonidae are perhaps the most diverse group of fishes that use North Slope freshwater habitats. They include lake trout *Salvelinus namaycush* and Arctic char *S. alpinus* that live exclusively in freshwater lake systems (Morrow 1980, Reist et al. 1997). Arctic grayling *Thymallus arcticus* and round whitefish *Prosopium cylindraceum* live in lakes and rivers and are rarely encountered in coastal waters. Many Dolly Varden *S. malma* populations are anadromous, migrating into nearshore coastal waters to feed during the summers and returning to freshwater rivers to spawn in the fall and to overwinter (McCart 1980). Other Dolly Varden populations, however, live entirely in freshwater. Similar to Dolly Varden, both anadromous and freshwater resident populations of least cisco *Coregonus sardinella* exist on the North Slope (Seigle 2003, Moulton et al. 1997). Broad whitefish *C. nasus*, and humpback whitefish *C. pidschian* populations are apparently all anadromous, although freshwater populations may exist in certain lakes or in upstream reaches of the Colville River (Craig 1989). Arctic cisco *C. autumnalis* encountered on the North Slope of Alaska are entirely anadromous and return to the Mackenzie River in northern Canada to spawn (Fechhelm et al. 2007). Chum salmon *Oncorhynchus keta*, pink salmon *O. gorbuscha*, and other Pacific salmon species are encountered in low numbers in nearshore coastal waters of the Beaufort Sea each summer (Stephenson 2005). Small numbers of spawning chum and pink salmon are regularly observed in the Colville River and occasionally observed in other streams as well. It is not clear at this time whether Pacific salmon in North Slope drainages are self sustaining populations or strays from populations in Kotzebue Sound or farther south.

A number of non-salmonid fishes of several families have also adapted to aquatic habitats on the North Slope. Ninespine stickleback *Pungitius pungitius* populations can be either resident or anadromous (Morrow 1980). They are found in freshwater and nearshore habitats across the North Slope, but never too far inland, and they play a critical role in the food webs of piscivorous birds (Poole 2005) and fish. Burbot *Lota lota* are common in stream and lake habitats of the western North Slope (Morris 2003), but they are rarely captured in coastal waters. Blackfish *Dallia pectoralis*, northern pike *Esox lucius*, slimy sculpin *Cottus cognatus*, and longnose sucker *Catostomus catostomus* are also found in freshwater habitats of the western North Slope.

Table 7.2 lists North Slope freshwater fish species and categorizes their use of major habitat classes, as defined below:

- Large streams are those with sufficient flow to allow instream (springs and deep areas) and estuarine (river delta) overwintering habitat. On the North Slope, only two rivers, the Colville and Sagavanirktok Rivers, fall into this habitat category.
- Small streams are those waterbodies that do not have sufficient flow to develop estuarine habitats. Some of these streams may provide instream overwintering habitat in the form of springs and deep pools.
- Deep lakes are those lakes whose depth allows for year-round use by fish. These lakes may be isolated or stream-connected.
- Shallow lakes do not provide overwintering habitat but may be used by fish during the open water season if there is access.
- Coastal water (Nearshore) is marine water that is somewhat warmer and of lower salinity than the ocean, due to fresh water inflow during the open water season (e.g., lagoons, river deltas, and marine waters close to shore). These habitats take on fully marine characteristics of salinity and temperature during winter, which

precludes their use by freshwater or anadromous species during that season. Lagoon systems may actually reach higher salinity and colder temperatures than open marine systems during winter.

- Coastal water (Ocean) is fully marine habitat that does not allow overwintering of any salmonid species because of low water temperatures.

## Potential Climate Impacts on Fish

The Intergovernmental Panel on Climate Change (IPCC) and the Arctic Climate Impact Assessment (ACIA) both identified the Arctic as an area where climate effects will most readily be observed (IPCC 2007, ACIA 2005). Furthermore, they suggest that aquatic systems within the region will act as keystone indicators of the timing, rate, intensity, and effects of the change. Both freshwater and anadromous fish are important components of these aquatic systems and are particularly vulnerable to effects from climate change (Reist et al. 2006a).

The insight gained from monitoring climate impacts to fish and their habitats will facilitate greater understanding of possible impacts to other aquatic biota and the humans that use these resources.

A warming climate is likely to increase ecosystem productivity and result in increased biomass and yields of many targeted species (Reist et al. 2006b). The magnitude of change in ecosystem productivity and fish biomass will depend on local conditions and population tolerances. Freshwater resident fish in lakes may potentially show increased production in comparison to those populations in flowing water. Increased productivity in nearshore areas could boost returns of anadromous fish. However, increased productivity in freshwater systems could lead to a decrease in the frequency of anadromy followed by a decrease in population production. An anadromous life history strategy provides for larger individual and population sizes (Gross et al. 1988), but increased freshwater productivity may allow some populations to forego migration to saltwater and switch to a freshwater resident form. Although the resident population would be sustainable, it would not likely attain the production levels attained from the anadromous strategy.

As water temperatures rise past optima, biomass and yields could decrease and lead to differing rates and locations of colonization, extinction, competition, and productivity (Tonn 1990). Increasing temperatures will have a direct effect on available habitats, most notably in populations reliant on thermal refugia below the thermocline in lakes (Reist et al. 2006c). Warmer waters may also affect the prevalence of diseases and parasites (Reist et al. 2006b). Longer term changes may also lead to a decoupling of environmental cues, such as photoperiod and water temperature, that may drive major life history actions, including gonadal maturation and fertilization success (Reist et al. 2006c). Changes in groundwater flows may affect the type and amount of instream sediment and substrate, alter chemical composition, and change temperature of the water. Changes to the physical and chemical properties of water may lead to changes in incubation success and availability of overwintering habitat. In addition, groundwater can alter instream habitat structure by its influence on ice formation. Changes in both groundwater and precipitation runoff may affect the flow regimes of rivers and streams and result in changes to the migration patterns of freshwater and anadromous fish (Prowse et al. 2006). An increase in sea level and coastal erosion may also disrupt traditional migration patterns or make current habitats unavailable (ACIA 2005).

Fisheries that rely on North Slope species must also change as the fish populations adapt to new conditions (Reist et al. 2006b). With changes in the local environment, fish abundance, species composition, and individual sizes of targeted fish, traditional access may not be feasible and harvest methods and timing may need to change. These changes could negatively impact small scale fisheries within local villages. Alternatively, changing environment and fish abundance may provide better access to fishing sites or opportunities for new fisheries that target colonizing species. Flexible and adaptive approaches will be critical to future successful management (Peterson et al. 1997).

*Table 7.2 Life history strategy[1] and seasonal habitat use by North Slope freshwater fish.*

| Species[2] | | LC | | AC | RW | BW | HW | LT | CH | DV | | PS | CS | AG | NS | | Total species & life histories by habitat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Life history | | A | R | A | R | A | A | R | R | A | R | A | A | R | A | R | |
| **Season** | **Habitat[3]** | | | | | | | | | | | | | | | | |
| **Open water** | Large streams | X | | X | X | X | X | | | X | X | X | X | X | X | X | **12** |
| | Small streams | | | | X | | | | | X | X | | | X | X | X | **6** |
| | Deep lakes | X | X | | X | X | X | X | X | | | | | X | X | X | **10** |
| | Shallow lakes | X | | | | X | X | | | | | | | | X | X | **5** |
| | Coastal water (Nearshore) | X | | X | | X | X | | | X | | X | X | | X | X | **9** |
| | Coastal water (Ocean) | | | X | | | | | | X | | X | X | | | | **4** |
| **Ice cover** | Large streams | X | | X | X | X | X | | | X | X | X | X | X | X | X | **12** |
| | Small streams | | | | X | | | | | X | X | | | X | X | X | **6** |
| | Deep lakes | | X | | X | X | X | X | X | | | | | X | X | X | **9** |
| **Total habitats by species & life history** | | **5** | **2** | **4** | **6** | **6** | **6** | **2** | **2** | **6** | **4** | **4** | **4** | **6** | **8** | **8** | |

1. Generalizations include adult and juvenile life stages. Least cisco, Dolly Varden char, and ninespine stickleback populations exhibit two life history strategies (R = freshwater resident, A = anadromous). Other species are considered to exhibit only one life history strategy.
2. Species codes:

| | |
|---|---|
| LC = Least cisco | CH = Arctic char |
| AC = Arctic cisco | DV = Dolly Varden char |
| RW = Round whitefish | PS = Pink salmon |
| BW = Broad whitefish | CS = Chum salmon |
| HW = Humpback whitefish | AG = Arctic grayling |
| LT = Lake trout | NS = Ninespine stickleback |

3. See text for description of habitat types.

### *References*


Arctic Climate Impact Assessment (ACIA). 2005. Cambridge University Press.

Black, V. S. 1957. Excretion and osmoregulation. Pages 163-205 in M. E. Brown, editor. The physiology of fishes, vol. 1, metabolism. Academic Press, Inc., New York.

Craig, P.C. 1989. An introduction to anadromous fishes in the Alaskan Arctic. in D. Norton, ed. Biological Papers of the University of Alaska, Research Advances on Anadromous Fish in Arctic Alaska and Canada, University of Alaska-Fairbanks, Fairbanks, AK.

Craig, P. C., and P. J. McCart. 1975. Classification of stream types in Beaufort Sea drainages between Prudhoe Bay, Alaska, and the Mackenzie Delta, N.W.T., Canada. Arctic and Alpine Research, 7:183-198.

Craig, P. C., and L. Haldorson. 1981. Beaufort Sea barrier island-lagoon ecological process studies: final report, Simpson Lagoon studies, part 4, fish. Environmental Assessment of the Alaskan Continental Shelf, Research Unit 467, Volume 7, BLM/NOAA, OCSEAP, Boulder, Colorado.

DeVries, A. L. and C.-H. C. Cheng. 2005. Antifreeze proteins in polar fishes. Pages 155-201 in A. P. Farrell and J. F. Steffensen, editors. The physiology of polar fishes. Academic Press, San Diego.

*Figure 7.3 Generalized examples of hypothesized influences from a deepening active layer (A) and a decrease in aufeis (B) on adult fish riverine habitat during summer and fall under increased temperature and increased precipitation scenarios (length of arrows unrelated to degree of influence). Freshwater input to rivers based on: 1) precipitation (direct and from runoff); 2) groundwater (precipitation filtered through the active layer); 3) springs (groundwater from below the permafrost); 4) aufeis (in channel frozen precipitation, groundwater, and spring water released during the open water season); and 5) glaciers.*

Fechhelm, R. G., B. Streever, and B. J. Gallaway. 2007. The Arctic cisco (Coregonus autumnalis) subsistence and commercial fisheries, Colville River, Alaska: a conceptual model. Arctic 60:421-429.

Gross, M.R., R.M. Coleman, and R.M. McDowall. 1988. Aquatic productivity and the evolution of diadromous fish migration. Science 239.

Intergovernmental Panel on Climate Change (IPCC). 2007. IPCC Fourth Assessment Report: Climate Change 2007. World Meteorological Organization, Geneva, Switzerland and United Nations Environment Programme, Nairobi, Kenya.

McCart, P. J. 1980. A review of the systematics and ecology of Arctic char, Salvelinus alpinus, in the western Arctic. Canadian Technical Report of Fisheries and Aquatic Sciences 935, Winnipeg.

Morris, W. 2003. Seasonal movements and habitat use of Arctic grayling (Thymallus arcticus), burbot (Lota lota), and broad whitefish (Coregonus nasus) within the Fish Creek drainage of the National Petroleum Reserve-Alaska, 2001-2002. Alaska Department of Natural Resources, Technical Report No. 03-02, Fairbanks.

Morrow, J.E. 1980. The Freshwater Fishes of Alaska. Alaska Northwest Publishing Company, Anchorage, AK.

Moulton, L.L., L.M. Philo, and J.C. George. 1997. Some reproductive charactoristics of least ciscoes and humpback whitefish in Dease Inlet, Alaska. Pages 119-126 in J. Reynolds, editor. Fish ecology in Arctic North America. American Fisheries Society Symposium 19, Bethesda Maryland.

O'Rourke, J.C. 1974. Inventory of physical oceanography of the eastern Beaufort Sea. Pages 65-84 in J.C. Reed, and J.E. Sater, editors, The coast and shelf of the Beaufort Sea. The Arctic Institute of North America, Arlington, Virginia.

Peterson, G., G.A. de Leo, J.J. Hellman, M.A. Janssen, A. Kinzig, J.R. Malcolm, K.L. O'Brien, and S.E. Pope. 1997. Uncertainty, climate change, and adaptive management. Conservation Ecology (online) 11. http://www.consecol.org/vol11/iss2/art14.

Poole, A. (Editor). 2005. The Birds of North America Online: http://bna.birds.cornell.edu/BNA/. Cornell Laboratory of Ornithology, Ithaca, NY.

Prowse, T.D. F.J. Wrona, J.D. Reist, J.J. Gibson, J.E. Hobbie, L.M.J. Levesque, and W.F. Vincent. 2006. Climate change effects on hydroecology of arctic freshwater ecosystems. Ambio 35.

Reist, J.D., J.D. Johnson, and T.J. Carmichael. 1997. Variation and specific identity of char from northwestern Arctic Canada and Alaska. Pages 250-261 in J. Reynolds, editor. Fish ecology in Arctic North America. American Fisheries Society Symposium 19, Bethesda Maryland.

Reist, J.D., F.J. Wrona, T.D. Prowse, M. Power, J.B. Dempson, J.R. King, and R.J. Beamish. 2006a. An overview of effects of climate change on selected arctic freshwater and anadromous fishes. Ambio 35.

Reist, J.D., F.J. Wrona, T.D. Prowse, J.B. Dempson, M. Power, G. Kock, T.J. Carmichael, C.D. Sawatzky, H. Lehtonen, and R.F. Tallman. 2006b. Effects of climate change and UV radiation on fisheries for arctic freshwater and anadromous species. Ambio 35.

Reist, J.D., F.J. Wrona, T.D. Prowse, M. Power, J.B. Dempson, R. Beamish, J.R. King, T.J. Carmichael, and C.D. Sawatzky. 2006c. General effects of climate change on arctic fishes and fish populations. Ambio 35.

Seigle, J.C. 2003. Determination of marine migratory behavior and its relationship to selected physical traits for least cisco (Coregonus sardinella) of the Western Arctic Coastal Plain, Alaska. Master's Thesis, Oregon State University, Corvallis.

Stephenson, S.A. 2005. The Distribution of Pacific salmon (Oncorhynchus spp.) in the Canadian western Arctic. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2737, Winnipeg.

Tonn, W.M. 1990. Climate change and fish communities: a conceptual framework. Transactions of the American Fisheries Society 119.

## Mammals

Table 7.3 lists 26 mammal species found in the Alaskan Arctic from the crest of the Brooks Range north to the Beaufort Sea. The mammals are grouped into 7 classes based on life history strategies, including food strategies (herbivore or carnivore/omnivore), winter strategies (active surface, active subnivean, dormant), and reproductive strategies (relative length of gestation/lactation, relative number and size of litters per year and whether offspring are altricial or precocial). Four classes are herbivores (H1, H2, H3 and H4), and 3 are carnivore/omnivores (C1, C2, C4). The table lists mammal species associated with each class, the attributes used to define each class, and summarizes ecological requirements in the winter and growing seasons for each class.

Table 7.4 uses these class designations to summarize hypothesized effects of climate change on classes of mammals in the winter and summer (growing) season.

Figures 7.4 and 7.5 graphically summarize possible effects of climate change on arctic mammals (grouped by species class from Table 7.3) in winter and during the growing season respectively

*Table 7.3. Arctic mammals grouped by life history strategy.*

| Class | Species | Diet[1] | Winter Strategy[2] | Reproductive Strategy[3] | Class Attributes | Requirements for Survival and Successful Reproduction |
|---|---|---|---|---|---|---|
| **H1** | Collared lemming<br>Brown lemming<br>Red backed vole<br>Singing vole<br>Tundra vole | H | S | SMA | Small herbivore, subnivean in winter, short gestation + lactation, multiple medium to large litters, altricial young. | Winter: access to stored food, hoar frost layer, snow cover. Summer: access to abundant forage, natal nests, escape cover. |
| **C1** | Shrews (3 species)<br>Least weasel | C | S | SMA | Small carnivore, active/subnivean in winter, short gestation + lactation, single/multiple medium to large litter, altricial young. | Winter: constant access to numerous prey; natal nests. Summer: constant access to numerous prey; natal nests. |
| **H2** | Arctic ground squirrel<br>Arctic marmot | H | D | MSA | Medium-sized herbivore, dormant in winter, medium gestation + lactation, single medium to large litter, altricial young. | Winter: winter/natal denning habitat, adequate snow. Summer: access to forage, escape cover (burrows). |
| **C2** | Ermine<br>Mink<br>Arctic fox<br>Red fox<br>River otter<br>Wolverine<br>Wolf | C | A | MSA | Medium to large carnivore, active in winter, medium lactation + gestation, single medium to large litter, altricial young | Winter: access to prey, natal dens. Summer: access to prey, natal and post natal dens. |

| | | | | | | |
|---|---|---|---|---|---|---|
| **H3** | Snowshoe hare<br>Porcupine | H | A | SSP | Medium sized herbivore, active in winter, short to long gestation + short lactation, single/ multiple small to medium litters, precocial young. | Winter: access to forage, shelter. Summer: access to forage, shelter. |
| **H4** | Caribou<br>Moose<br>Dall sheep<br>Muskox | H | A | LSP | Medium to large herbivore, active in winter, long gestation + lactation, single birth of 1-2 offspring, precocial young. | Winter: access to forage; energy conserving conditions (low snow). Summer: access to high quality abundant forage and insect relief |
| **C4** | Grizzly bear<br>Polar bear | C | D | VSA | Large carnivore/ omnivore, dormant in winter, delayed implantation + very long lactation, single birth of 1-3 offspring, altricial young. | Winter: access to winter/natal denning habitat. Summer: access to food resources |

**1. Diet:**

H = Herbivore

C = Carnivore/omnivore

**2. Winter strategy:**

A = Active in winter on surface

S = Active under snow (subnivian)

D = Dormant in winter den

**3. Reproductive strategy:**

SMA = short gestation/lactation; multiple medium to large litters; altricial young

MSA = medium gestation/lactation; single medium/large litter; altricial young

SSP = short to long gestation+short lactation; single/multiple small to medium litters; precocial young

LSP = long gestation/lactation; single birth of 1-2 offspring; precocial young

VSA = delayed implantation + very long lactation and period of parental care; single birth of 1-3 offspring; altricial young

*Figure 7.4 Possible effects of climate change on arctic mammals in winter (above) and the growing season (below).*

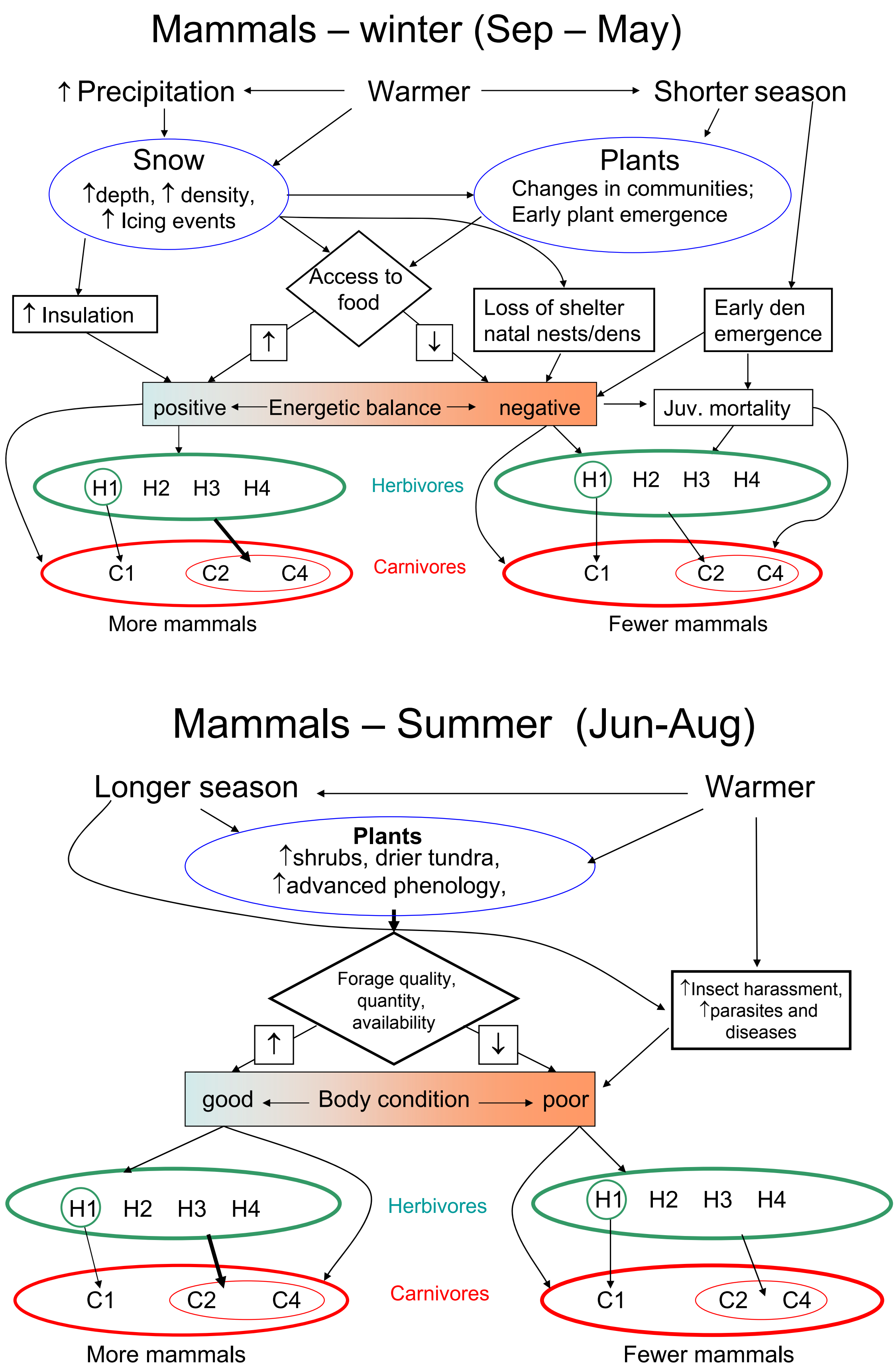

*Table 7.4. Possible effects on arctic mammals under scenarios of changing climate.*

| Class[1] | **Winter: warmer, deeper snow, shorter season:** | **Summer: warmer, drier, longer season:** |
|---|---|---|
| **H1** | • More icing events, deeper dense snow, reduced snow in early and late winter<br>• Loss of hoar frost layer = habitat loss; reduced access to stored food, runways, natal nests.<br>• Lack of insulation in early and late winter = lower survival and reproduction | • Shifts in plant communities; shifts in phenology, increased plant biomass, degrading permafrost, shifts in hydrology, early summer flooding, more diseases and parasites, reduction in insect relief habitat (aufeis and snow fields).<br>• Drier plant communities= benefit red-backed + singing voles, collared lemmings, but hurt tundra voles + brown lemmings.<br>• Flooded burrows = lower survival + reproduction.<br>• More disease/parasites = lower survival + reproduction. |
| **C1** | • Change in access to prey = low reproduction and survival.<br>• Prey loss critical: small carnivores need constant access to food. | • Change in access to prey = low reproduction and survival.<br>• Prey loss critical: small carnivores need constant access to food.<br>• Increase in disease/parasites = lower reproduction+survival. |
| **H2** | • Early den emergence = death of offspring, decreased survival of adults. | • Change in food types and/or availability = change in abundance.<br>• Shifts in phenology may reduce access to high quality forage.<br>• Increased parasites/disease = lower production + survival. |
| **C2** | • Less food during pregnancy+ lactation = smaller litters + lower survival. | • Less summer food = lower production + survival.<br>• Increased parasites/disease = lower production + survival. |
| **H3** | • Reduced forage availability = smaller + fewer litters. | • Increased plant biomass + shift to shrubs = increased productivity + survival<br>• Increased parasites/disease = lower production + survival |
| **H4** | • Reduced access to forage, increased energy expenditure = fewer calves born and increased adult mortality. | • Increased plant biomass = increased production + survival.<br>• Shift in plant composition to shrubs = increase summer forage but decrease winter forage.<br>• Shifts in phenology may reduce access to high quality forage during calving season = decreased successful reproduction<br>• Increase in lungworm infections + other diseases = lower reproduction + survival<br>• Reduced access to insect relief habitat (snow + aufeis) = stress + reduced body condition + increased parasites. |
| **C4** | • Early den emergence: death of neonatal cubs; lower survival of adults.<br>• Loss of denning habitat: | • Changes in plant communities and prey populations = shifts in diet which may or may not affect successful reproduction and survival.<br>• Increase in parasites/disease = lower production + survival. |

1. Species class codes from Table 7.3.