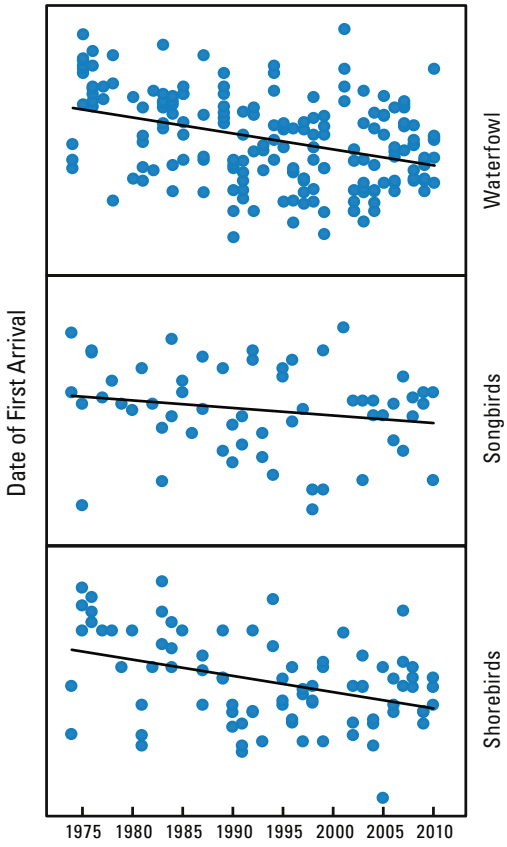
USGS
science for a changing world

Changing Arctic Ecosystems

Measuring and Forecasting the Response of Alaska's Terrestrial Ecosystem to a Warming Climate

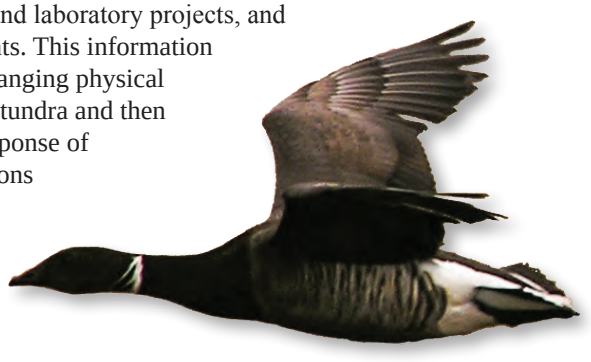
The Arctic Coastal Plain of northern Alaska is a complex landscape of lakes, streams, and wetlands scattered across low relief tundra that is underlain by permafrost. This region of the Arctic has experienced a warming trend over the past three decades, leading to thawing of on-shore permafrost and the disappearance of sea ice at an unprecedented rate. The loss of sea ice has increased ocean wave action, leading to higher rates of erosion and salt water inundation of coastal habitats. Warming temperatures also have advanced the overall phenology of the region, including earlier snowmelt, lake ice thaw, and plant growth. As a result, many migratory species now arrive in the Arctic several days earlier in spring than in the 1970s. Predicted warming trends for the future will continue to alter plant growth, ice thaw, and other basic landscape processes. These changes will undoubtedly result in different responses by wildlife (fish, birds, and mammals) and the food they rely upon (plants, invertebrates, and fish). However, the type of response by different wildlife populations and their habitats—either positively or negatively—remains largely unknown.

Collapsed permafrost block of coastal tundra on Alaska's Arctic Coast.



Trends toward earlier dates of spring arrival on the Arctic coast (1974–2010) for three types of birds. J. Helmericks and USGS data.

Through the Changing Arctic Ecosystems initiative, the U.S. Geological Survey (USGS) strives to inform key resource management decisions for Arctic Alaska by providing scientific information on current and future ecosystem response to a warming climate. The Changing Arctic Ecosystems initiative includes research across three ecosystems found in Arctic Alaska: sea ice, terrestrial, and the tundra–boreal forest ecotone. Here, we describe the conceptual framework of USGS research within the northern tundra or terrestrial ecosystem of the Arctic Coastal Plain and highlight on-going and future research. Research within the terrestrial ecosystem objective will provide scientific data through conceptual models, field and laboratory projects, and remote-sensing assessments. This information will quantify effects of changing physical processes on the northern tundra and then be used to forecast the response of different wildlife populations throughout the region. Results of this USGS led research will assist Federal and State land managers, local residents, and industry by providing sound scientific data for decision-making on issues related to land use, hunting and fishing, industrial development, and conservation.



Black brant goose

U.S. Department of the Interior
U.S. Geological Survey

Printed on recycled paper

Fact Sheet 2012–3144
December 2012

Changes in Plant Forage and Phenology and the Response of Wildlife Populations

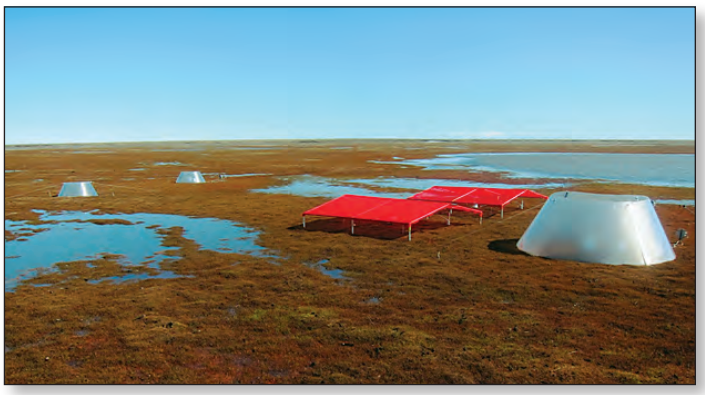
The warming climate and loss of sea ice is altering the tundra habitats of the Arctic Coastal Plain. Time series photo imagery and field sampling by the USGS have revealed habitat changes resulting from thaw of tundra permafrost and flooding of coastal lowlands by salt water. Research also has shown that warmer conditions cause plants to produce more biomass that is of relatively lower nutrient content. The USGS is studying different groups of herbivorous wildlife to understand the potential impacts of changing northern vegetation on a broad array of species. Current projects focus on geese, which must forage on plants that are high in nutrients and low in fiber, and caribou (*Rangifer tarandus*), which feed on plants that are relatively higher in fiber content and lower in nutrient content. Further, the USGS is experimentally manipulating forage, using shade and green houses to determine how a warming Arctic will influence the quality and quantity of forage plants. These data will allow scientists to estimate the quality of food resources under future climate scenarios and project how these changes will impact wildlife that feed on plants to fuel long-distance migrations, reproduction, and molting. Several species of migratory geese are already responding to habitat

White-fronted goose and goslings.

change. Thousands of black brant (*Branta bernicla*) undergo their flightless molting period on the Arctic Coastal Plain and are shifting to new coastal habitats created by saltwater flooding. This shift may be related to an increase in forage quantity following saltwater inundation of coastal sedge and grass meadows (primarily *Carex subspathacea* and *Puccinellia phryganodes*). The white-fronted goose (*Anser albifrons*) also is responding positively to habitat changes on both coastal and interior portions of the Arctic Coastal Plain, increasing its population size seven-fold in northern Alaska since 1980. This dramatic growth of white-fronted geese likely also has been facilitated by temperature driven changes in forage quantity. The effects of these habitat changes on invertebrates and fish are unknown but are currently under study by the USGS.

Wetland and low relief tundra habitats of the Arctic Coastal Plain.

Phenology is the study of recurring ecosystem processes such as seasonal plant growth or bird migration. The phenology of an ecosystem often responds to seasonal cues, such as changes in temperature. Increasing spring and summer temperatures in the Arctic are leading to earlier snowmelt and plant emergence. Migratory birds and mammals time their arrival to Arctic breeding areas to correspond with the onset of habitat and food availability. Seasonal changes in forage quality and abundance occur rapidly at high latitudes, and migration and reproduction of Arctic wildlife are often timed so that young are born near the peak of food availability. In this respect, climate change may have significant consequences for wildlife when timing of migration and breeding is tightly synchronized with food availability. Populations failing to adapt to changing are at risk of reduced reproductive success

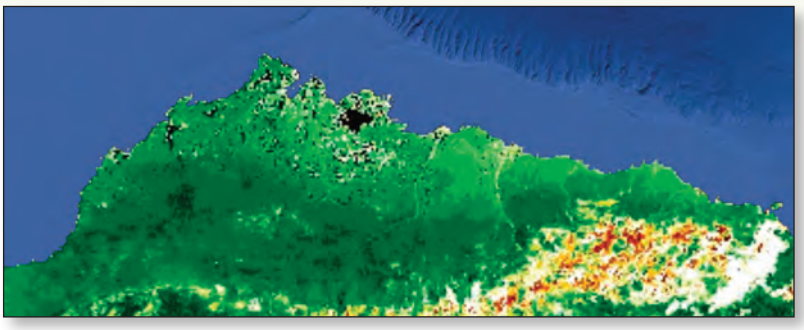


USGS field research site showing shade and green houses on coastal sedge tundra of the Arctic Coastal Plain. Vegetation within these experimental plots is monitored throughout the summer to quantify how slight changes in temperature affect the quality and quantity of plant forage for migratory birds.

Changes in Plant Forage and Phenology and the Response of Wildlife Populations (continued)

and declines in abundance. Species vulnerable to this phenological mismatch between spring arrival and plant phenology are being identified by the USGS through the study of migration behavior, source nutrients invested in reproduction, timing of reproduction relative to peak nutrient availability, and rates of juvenile growth on the Arctic Coastal Plain. The USGS is using satellite-based photography to calculate Normalized Difference Vegetation Index (NDVI) measurements that will provide a broad-scale perspective of the timing of vegetation phenology across the Arctic Coastal Plain. NDVI has been shown to be strongly correlated with net primary production, photosynthetic activity, and biomass. From this information, the USGS will develop a map to identify areas of high and low primary production or "greenness" across the Arctic Coastal Plain.

Caribou on the Arctic Coastal Plain.

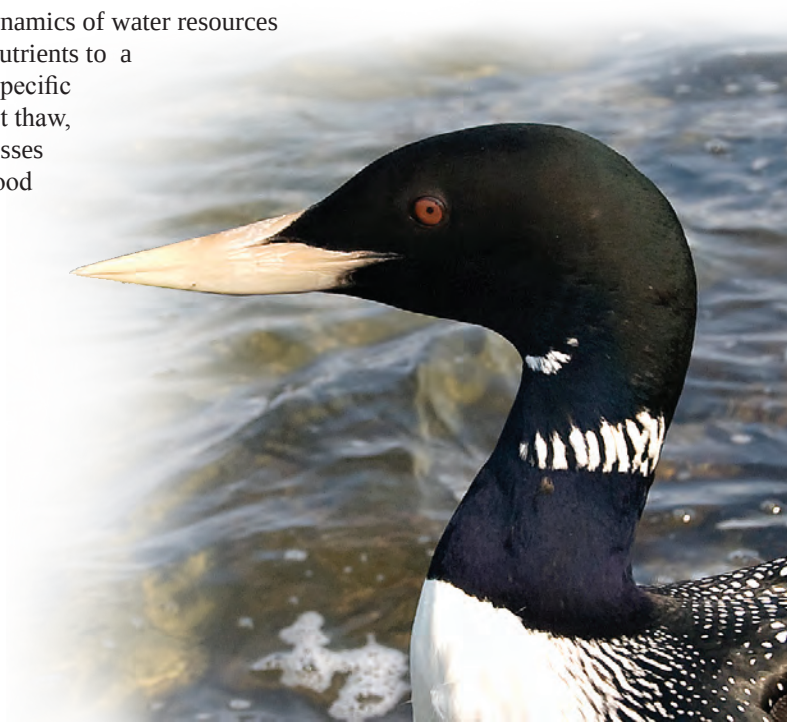


Monitoring of vegetation phenology using satellite imagery (eMODIS). From http://earthexplorer.usgs.gov/.

Predicted increases in temperature and changes in vegetation phenology also are expected to lead to changes in the summer habitats used by caribou. Four populations of caribou (Central and Western Arctic, Teshekpuk, and Porcupine) roam the Arctic Coastal Plain in summer, seeking out high quality plants to replenish energy and protein lost during winter. The phenology, nutrient content, and abundance of plant forage throughout the short summer growing season are critical for survival and reproduction in caribou. Although the predominant effects of climate warming will be on the phenology and quality of plant forage, it is unclear whether these changes will result in positive or negative impacts for tundra-dwelling caribou. Therefore, the USGS is incorporating empirical and simulation approaches to quantify the bottom up effects of climate change to these and other mammal populations across the northern terrestrial ecosystem of Alaska. For example, changes in the habitats used by large mammals are being quantified by repeating a series of habitat transects originally conducted in 1977 that extend from the Brooks Range to the Arctic Ocean.

Changes in Water Resources and the Response of Wildlife Populations

The warming of the Arctic Coastal Plain is expected to alter the dynamics of water resources of the region. Water is an integral part of the landscape and provides nutrients to a diverse array of tundra habitats. However, questions remain as to the specific effects increased temperatures will have on the flow, rate of permafrost thaw, and nutrient composition of water resources in the Arctic. These processes are critical to invertebrate and fish communities, which also provide food for other wildlife. The USGS is conducting field studies in northern habitats to quantify water and nutrient fluxes across the tundra and among lakes, and is testing how increases in temperature and nutrients will influence plant and invertebrate abundance. Changes in primary productivity may lead to increases in invertebrate grazers and, in turn, be beneficial to wildlife such as fish and birds. Isotopic and genetic analysis of birds and their prey (invertebrates and fish) will allow the USGS to understand how wetland resources are used by wildlife. Wildlife species likely to be influenced by changes to wetland invertebrate and fish populations include the Alaska population of the yellow-billed loon (*Gavia adamsii*), which nests almost exclusively on the Arctic Coastal Plain. During breeding, this species relies upon large, deep lakes that host fish populations. The breeding population of the spectacled eider (*Somateria fischeri*) on the Arctic Coastal Plain has remained stable over the past 10 years while numbers in western Alaska have increased, implying some localized effect that may be related to invertebrate forage.



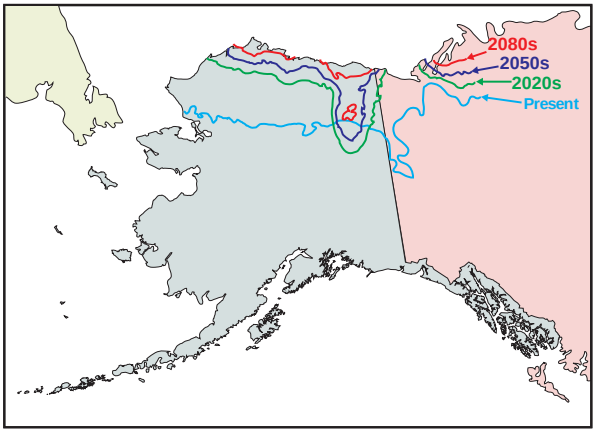
Yellow-billed loon.

The Response of Alaska's Wildlife in a Global Context

Many wildlife species that occur on the Arctic Coastal Plain in summer are highly migratory. Birds migrate to Alaska each spring from wintering areas as far away as South America and Asia, whereas caribou undertake migrations from winter ranges in the Brooks Range to the Arctic Coast each year. Wintering areas of these Arctic migrants include the open ocean and coastal and terrestrial habitats. Climate change also is affecting environmental and forage conditions in these diverse winter habitats. As a result, migratory wildlife carry the positive or negative influences of wintering area conditions with them to the Arctic. Thus, population trends of many wildlife species in the Arctic result from a combination of breeding and wintering area effects. For example, expected increases in the frequency and intensity of wildfires as a result of climate change will reduce the area of lichen-producing vegetation within the winter ranges of northern caribou. Increased ocean temperatures at wintering areas of black brant geese are linked with reduced breeding the following summer in Alaska. The USGS is using tracking devices, genetics, and studies of wildlife physiology to determine how changes to wintering areas are impacting reproductive success of species that migrate to the Arctic in summer.

Flat-lobed lichen *Cetraria nivalis*, and *Cladonia* spp.

Forecasting Future Wildlife Population Sizes and Distributions



Receding distribution of the barren ground shrew, a tundra specialist, as the tundra-boreal forest ecotone creeps northward. Present and future time frames based on preliminary USGS genetic and climate models.

Through the Changing Arctic Ecosystem initiative, the USGS is building new expertise in several novel analytical techniques to combine relevant climate data, expert knowledge, and scientific information to forecast the future response of wildlife populations to terrestrial ecosystem change on the Arctic Coastal Plain. Bayesian conceptual models are being used to determine the most critical information needed to predict the response of wildlife populations to climate change. Structured decision making is being used to assist resource managers with complex issues in the Arctic. The USGS also is adding new capabilities in molecular genetics to provide information on how wildlife species across Alaska responded to past changes in the earth's climate. By combining evolutionary genetic data with current and predicted climate scenarios, the USGS is modeling the predicted future distributions of wildlife populations in the Arctic and identifying key environmental variables that determine important animal habitat.

Publications

Flint, P.L., Mallek E.J., King, R.J., Schmutz, J.A., Bollinger, K.S., and Derksen, D.V., 2008, Changes in abundance and spatial distribution of geese molting near Teshekpuk Lake, Alaska: interspecific competition or ecological change? Polar Biology, v. 31, p. 549-556, doi:10.1007/s00300-007-0386-8.

Geiselman, J.A., DeGange, A.R., Oakley, K.L., Derksen, D.V., and Whalen, M.E., 2012, Changing Arctic Ecosystems—Research to understand and project changes in marine and terrestrial ecosystems of the Arctic: U.S. Geological Survey Fact Sheet 2011-3136, 4 p. (Also available at http://pubs.er.usgs.gov/publication/fs20113136.)

Hope, A.G., Speer, K.A., Demboski, J.R., Talbot, S.L., and Cook, J.A., 2012, A climate for speciation—Rapid spatial diversification within the *Sorex cinereus* complex of shrews: Molecular Phylogenetics and Evolution, v. 64, p. 671–684, doi:10.1016/j.ympev.2012.05.021.

Lewis, T.L., Flint, P.L., Derksen, D.V., and Schmutz, J.A., 2011, Fine scale movements and habitat use of black brant during the flightless wing molt in Arctic Alaska: Waterbirds, v. 34, p. 177-185, doi:10.1675/063.034.0206.

Lewis, T.L., Flint, P.L., Derksen, D.V., Schmutz, J.A., Taylor, E.J., and Bollinger, K.S., 2011, Using body mass dynamics to explain long-term shifts in habitat use of arctic-molting geese: evidence for ecological change: Polar Biology, v. 34, p. 1751-1762, doi:10L1007/s00300-011-1025-y.

Ravens, T.M., Jones, B.M., Zhang, J., Arp, C.D., and Schmutz, J.A., 2012, Process-based coastal erosion modeling for Drew Point, North Slope, Alaska: Journal of Waterway, Port, Coastal and Ocean Engineering, v. 138, p. 122-130, doi: 10.1061/(ASCE)WW.1943-5460.0000106.

Authors: John Pearce, Tony DeGange, Paul Flint, Tom Fondell, David Gustine, Leslie Holland-Bartels, Andrew Hope, Jerry Hupp, Josh Koch, Joel Schmutz, Sandra Talbot, David Ward, and Mary Whalen

For more information: U.S. Geological Survey
4210 University Drive, Anchorage, AK 99508
http://alaska.usgs.gov

Publishing support provided by the U.S. Geological Survey
Tacoma Publishing Service Center