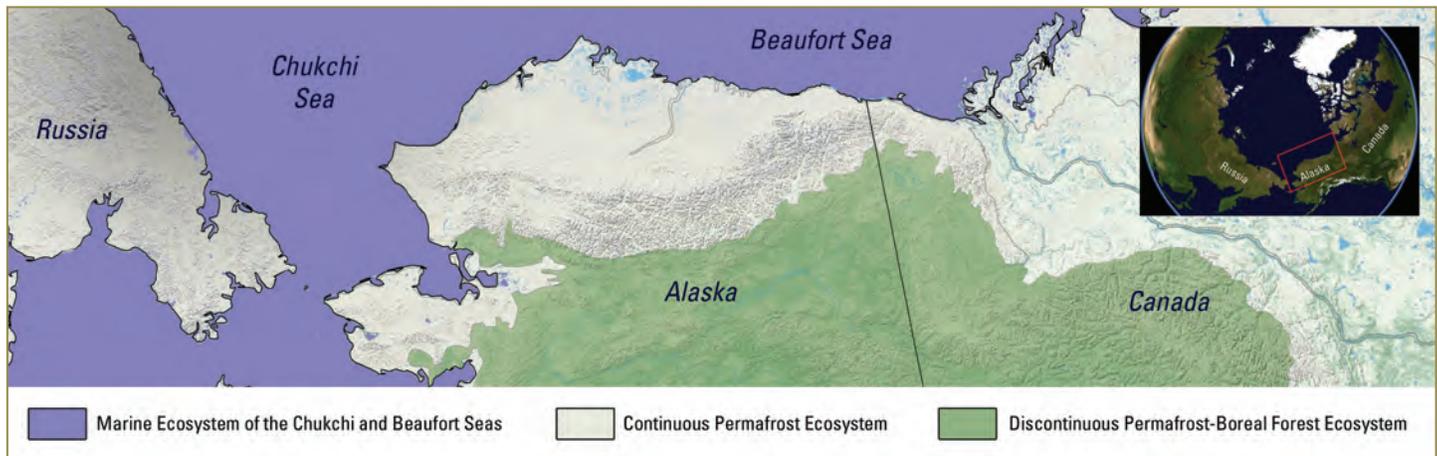




# Changing Arctic Ecosystems

Research to Understand and Project Changes in Marine and Terrestrial Ecosystems of the Arctic



Ecosystems and their wildlife communities are not static; they change and evolve over time due to numerous intrinsic and extrinsic factors. A period of rapid change is occurring in the Arctic for which our current understanding of potential ecosystem and wildlife responses is limited. Changes to the physical environment include warming temperatures, diminishing sea ice, increasing coastal erosion, deteriorating permafrost, and changing water regimes. These changes influence biological communities and the ways in which human communities interact with them. Through the new initiative Changing Arctic Ecosystems (CAE) the U.S. Geological

Survey (USGS) strives to (1) understand the potential suite of wildlife population responses to these physical changes to inform key resource management decisions such as those related to the Endangered Species Act, and (2) provide unique insights into how Arctic ecosystems are responding under new stressors. Our studies examine how and why changes in the ice-dominated ecosystems of the Arctic are affecting wildlife and will provide a better foundation for understanding the degree and manner in which wildlife species respond and adapt to rapid environmental change. Changes to Arctic ecosystems will be felt broadly because the Arctic is a production zone for hundreds of species that migrate south for the winter.

The CAE initiative includes three major research themes that span Arctic ice-dominated ecosystems and that are structured to identify and understand the linkages between physical processes, ecosystems, and wildlife populations. The USGS is applying knowledge-based modeling structures such as Bayesian Networks to integrate the work.



Photograph by Ken Wright.

## Theme I - Marine Ecosystem

### Enhancing Forecasts of Polar Bear and Walrus Population Response to a Rapidly Changing Marine Ecosystem



Photograph by Steve Amstrup.

This research focuses on the Arctic marine ecosystem, where sea ice extent and structure is undergoing rapid change. Sea ice is a critical platform for wildlife species to access food and to complete critical components of their life cycle, and it exerts a strong influence on pelagic and benthic food webs. Our research centers on two species dependent on the sea ice environment: the polar bear and the Pacific walrus. These focal species differ in trophic pathways (pelagic for the polar bear and benthic for the walrus) and differ in how much terrestrial habitat is incorporated into their life cycles. Understanding the responses of these two species to sea ice change will allow for a more holistic understanding of how projected changes in physical processes linked to sea ice will be

expressed through ecosystem processes to top consumers. Because polar bears and walrus currently are showing an increasing use of land, our research will seek to identify how this behavioral change affects these species. This USGS research will be linked to broader efforts to understand Arctic marine processes through collaborations with other agency and university programs.

The USGS recently developed Bayesian Network models that integrate information about stressors to polar bear and walrus populations and provide a framework for projecting their future status throughout the 21st century under various scenarios of sea ice and other environmental changes. To improve these models, our research is (1) assessing and projecting polar bear and walrus habitat quality, availability, and preferences; and (2) assessing and projecting polar bear and walrus population dynamics. Under the first area of investigation, CAE projects include modeling walrus-habitat associations and foraging energetics, energetic and behavioral responses of polar bears to changes in sea ice and food availability, and habitat models for polar bears in the seasonal and archipelago sea ice ecoregions. Under the second area of investigation, CAE projects are evaluating ramifications of increased use of land by polar bears in Alaska, modeling walrus population dynamics and bioenergetics, and determining demographic parameters of walrus estimated from onshore aggregations and from stable isotopes in archived teeth.



Photograph by Sarah Sonsthagen.

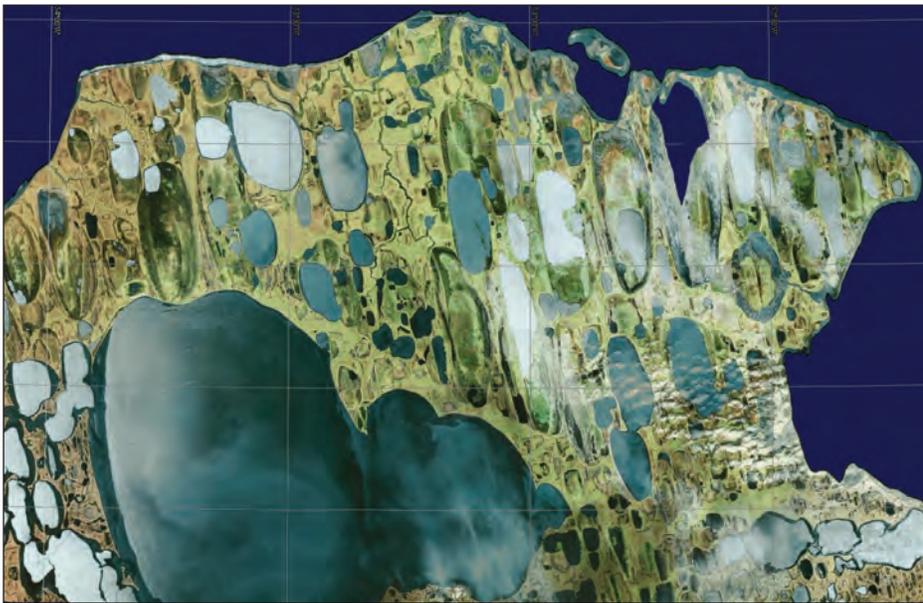
## Theme II - The Arctic Coastal Plain

### Measuring and Forecasting the Response of Wildlife Populations to Changes in Ecosystem Processes on the Arctic Coastal Plain

The projects under this theme take place on the coastal plain of northern Alaska, a complex landscape of low relief tundra underlain by continuous permafrost and overlain in major areas by a dominant hydrological complex of rivers and interconnected shallow lakes and wetlands. Here, coastal erosion is accelerating as sea ice retreats, storm patterns change, permafrost thaws, and the nature of water storage on this landscape is in flux. Observed and projected changes in precipitation and temperature are hypothesized to affect aquatic and terrestrial food webs critical to nationally and internationally important resident and migratory wildlife. Similar to Theme I, this research is an integrated study of a suite of focal species of high interest to the Department of the Interior (DOI) that were selected to explore the linkages among the many physical and ecological processes related to existing and projected permafrost change.



Photograph by Dave Gustine.



Landsat image from U.S. Geological Survey.

Projects under this research theme include determining recent landscape-scale changes to ecosystems of the Arctic Coastal Plain using remote sensing, effects of changing phenology on Arctic landscapes and biota, environmental drivers of distributional shifts of molting black brant, environmental changes facilitating population increases of breeding white-fronted geese, hydrologic influence on tundra, pond, and lake ecosystems important to avian herbivores, invertivores, and piscivores, and potential effects of changing tundra conditions on habitat quality and composition for ungulates.

Our research is (1) examining critical physical and landscape-scale changes in the environment; (2) assessing key ecological drivers of population change; and (3) projecting future abundance and distribution of focal species, including mammals, birds, fish, and aquatic invertebrates that use the landscapes of the Arctic in different ways and likely will express differently the consequences of changes to the associated ecosystems.

Photograph by Jeff Wasieley.



## Theme III - Boreal-Arctic Transition Zone

### Understanding the Role of Ecosystem Changes across the Boreal-Arctic Transition Zone on the Distribution and Abundance of Wildlife Communities

This research examines wildlife response in the Boreal-Arctic transition zone, which is expected to be one of the most dynamically changing zones in the far north. The boreal forest of Alaska grows near the physiological limits of trees, and the forest is underlain primarily by discontinuous permafrost. The forest also is an environment particularly sensitive to changes in temperature, precipitation, and permafrost loss. Fire is a primary driver of vegetation change in this region, and is expected to continue as an important ecological process in the future. Changes in hydrological processes influenced by degradation of permafrost have broad-scale effects on the extent and structure of wetlands. This combination of processes may cause unprecedented shifts in landscape biogeography throughout the present boreal region during this century. Understanding such processes is critical to structuring and constraining forecasts of potential new landscapes and associated wildlife of Arctic and boreal ecosystems.

The USGS is developing a community-level understanding of ecosystem changes, and with its focus on the Boreal-Arctic transition zone, the work will elucidate wildlife-ecosystem relationships that could help forecast responses in regions farther north and farther south, as factors such as climate warming progress. The initial emphasis is on landbirds and shorebirds. These birds are useful indicators because they are widely distributed, samples are collected by similar methods, and they occupy a wide variety of habitats including wetlands, forests, and shrublands. Using this broad approach will help us understand the “what” and focus attention on the various “why” factors central to the Changing Arctic Ecosystem initiative.

Projects in the Boreal-Arctic transition zone are (1) assessing existing population changes, (2) evaluating ecological drivers of population change, and (3) developing scenarios of future abundance and distribution within the boreal and Arctic coastal plain systems.



Photograph by Brian McCaffery.

## Other Goals of this Initiative

### Advancing Genomic and Physiological Parameters as Sensitive Biomarkers of Change

Genomic, physiological, and biochemical sciences are fields of investigation that are rapidly evolving and that rely on advanced technologies. The Alaska Science Center (Center) is expanding its genomics capability with next generation sequencing and bioinformatics. This expansion will enable the Center to sequence large, complex genomes and conduct transcriptome and gene expression studies. Additionally, the Center is exploring physiological and biochemical tools that assess the health status and body condition of wildlife species and the responses to changing food webs.

### Capacity Building for Modeling, Hydrology, and Landscape Ecology

The USGS and resource management agencies in Alaska are increasingly using Bayesian Networks (BNs), Structured Decision Making (SDM), and other similar knowledge-based modeling approaches. BNs provide a versatile framework for integrating empirical data with expert opinion, which often is required when modeling ecosystems where not much is known. SDM provides an objective, quantitative means to integrate ecological knowledge with multiple management objectives and constraints, to arrive at an optimal management decision. SDM is an integral component of adaptive management. The CAE initiative is developing additional USGS capacity in these modeling approaches. The Alaska Science Center also is building capacity in hydrology and landscape ecology.

### Data Management and Integration

The CAE initiative team is testing new approaches to data management and integration that support data access by team scientists, shared data products among partner agencies, and long-term archival of data and data products.

### Role of Monitoring in this Initiative

Monitoring of physical attributes through sampling and remote sensing, as well as monitoring of biological attributes, is a foundation to this research initiative. Existing datasets will be used as much as possible. The CAE initiative will evaluate databases from long-term monitoring efforts by the USGS and DOI partner bureaus. Linking documented relationships with downscaled weather models or generalized circulation models is crucial to predicting future population response to climate-induced change, one of the major ecosystem change drivers in the Arctic. Using long-term datasets in model experiments improves design of data collection methods and data analysis.

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