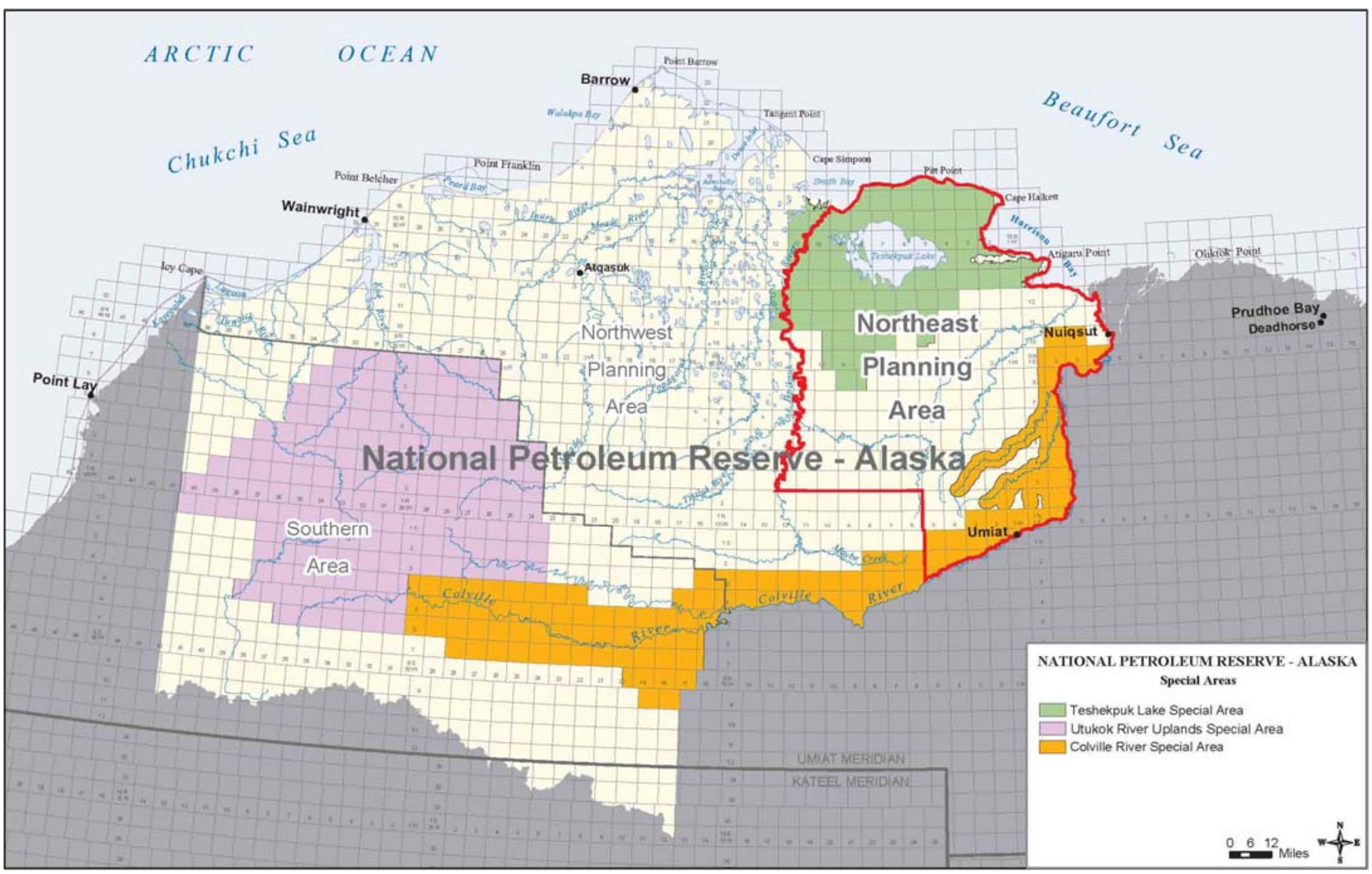
Avian Population Response to Ecological Change Along the Arctic Coastal Plain



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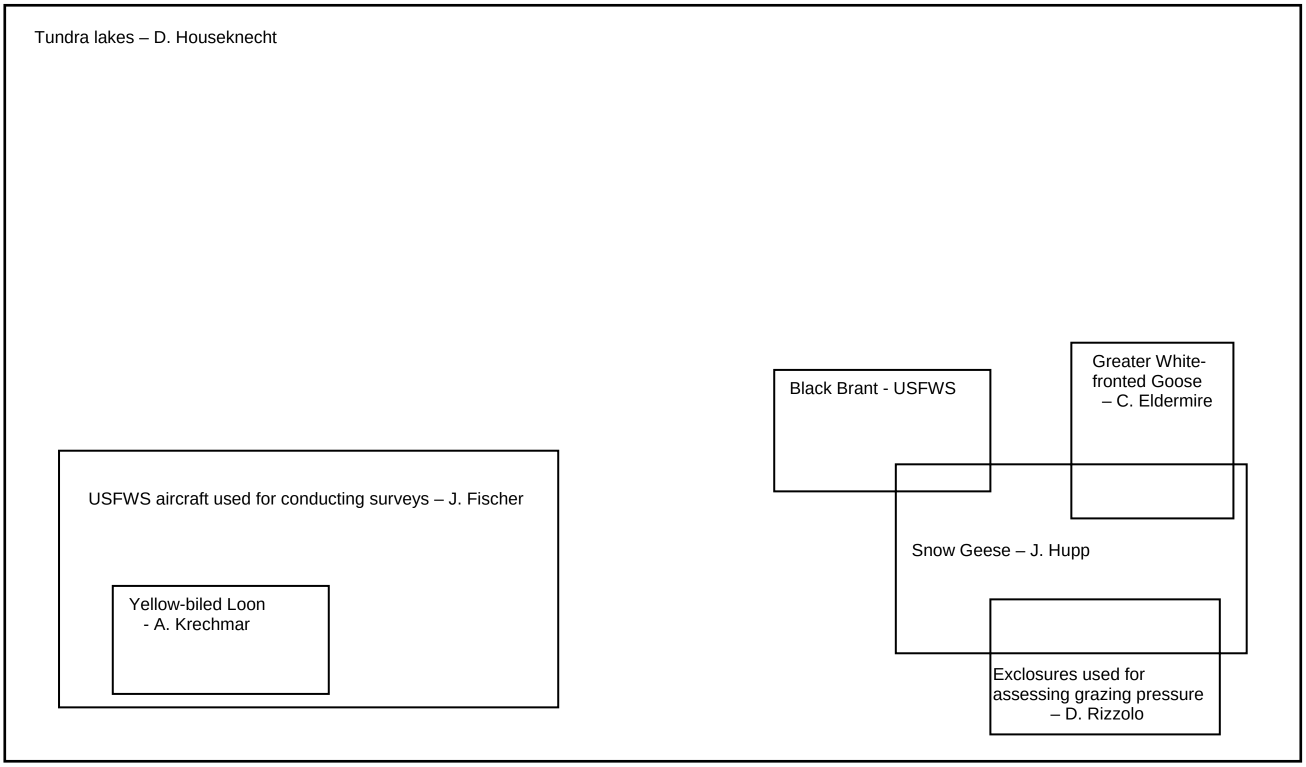

AVIAN POPULATION RESPONSE TO ECOLOGICAL CHANGE ALONG THE ARCTIC COASTAL PLAIN

Progress Report, January 2005

Alaska Science Center
U.S. Geological Survey

Executive Summary

In 2004 the U.S. Geological Survey (USGS) directed funding to a new study, through the USGS DOI Landscape Initiative, to develop a decision support science model to assess how recent and ongoing ecological change affects the distribution and abundance of important vertebrates on the Arctic coastal plain of Alaska. Our initial efforts focused on bird populations and the National Petroleum Reserve – Alaska (NPRA) as both foci have a wealth of data critical to development and testing of a prototype model. Our goal is to understand how physical variability in the environment may manifest biological change, and thus provide us with some ability to predict future change, which will be especially important when deciding how to manage increased resource development activities. Using expertise from the biology, geology, mapping, and water disciplines of USGS, our initial work has concentrated on the populations of geese that spend their flightless molting period on the large, shallow lakes in the Teshekpuk Lake Special Area (TLSA) within the NPRA. Our goal is to understand the extent to which geese change in spatial distribution over time, whether such change is a consequence of habitat change, and what are the physical and biological processes causing habitat change. With such an understanding, we could better predict future distributions of molting geese, which would benefit land management decisions.

Our analyses of the long-term distribution of four species of geese revealed that their distribution has shifted since the establishment of the TLSA. In particular, Black Brant, whose numbers are near a lower level that mandates restrictive management actions, have shifted eastward while White-fronted Geese have concurrently increased in numbers, particularly in the central portion of the TLSA. One hypothesis for these distributional changes is that habitats have changed. We examined a time-series of aerial photographs of 17 lakes, and 15 of these lakes increased in size by 3 to 36% between 1979 and 2002. The two lakes that decreased in size were the two that had been breached and drained by the Arctic Ocean. We speculate that much of this lake change is due to shoreline erosion caused by wind driven waves and ice gouging. Exclosure experiments in 2004 confirmed that most goose feeding activities occur along lake margins and forage availability may be limiting. Photo interpretation of habitats near the margins of one of these large lakes revealed that the proportion of flooded tundra had decreased by > 10% between 1979 and 2002, whereas the proportions of moist tundra, wet tundra, and shoreline moss had all increased. These results may be a consequence of increased temperatures in recent decades causing reduced snowpack and earlier snow melt in winter and spring or greater evaporative water loss.

Further examination of this time series of aerial photographs revealed substantial amounts of coastal erosion. In some areas, hundreds of meters of shoreline were lost between 1979 and 2002, with as much as 60 meters in 2004. High rates of coastal erosion have led to saltwater intrusion into freshwater habitats, particularly in the northeast part of the TLSA, and such intrusion is expected to quickly alter foraging habitats for geese.

We anticipate subsequent work on the TLSA will continue on several fronts. First, field experiments will address the relative preference and value of different habitats to geese, and how this relates to changes in both goose species composition and habitat composition. Second, photographic interpretation is needed to complete our analysis of change among lakes and along the coastline of the TLSA. Using these data, we can then start building a mechanistic model of factors that are driving change. For example, we envision greater hydrological sampling as well as using data from our climate monitoring stations to create predictive models of landscape evolution. This modeling approach will also ideally be extended to erosive processes along the coast. Finally, we envision exporting these methods to areas outside of the TLSA but within the NPRA and the Arctic coastal plain to address other important bird populations. For instance, other long-term USFWS data sets from this area document spatial and temporal trends of many waterbirds, including loons and eiders. Spatial change over time has not been examined in any of these species, but may be ongoing if ecological change of their relevant habitats is occurring.

Introduction

Arctic ecosystems are dynamic and historically have exhibited greater annual variability than other areas. More recently, this pattern has been accentuated by progressive climate change, with many consequent effects on high latitude ecosystems. The interactions between climate change and the high Arctic have been recently documented by the Arctic Climate Impact Assessment project (www.acia.uaf.edu), an international effort involving hundreds of scientists, that just released a report entitled "Impacts of a warming climate." These types of changes in the Arctic environment pose many new challenges for resource managers in the Department of the Interior, who have jurisdiction over many of the development activities in our nation's Arctic regions. At the forefront of these challenges is the ability to understand and predict how such physical changes in the Arctic environment will cascade into important biological effects on populations of trust species that the Department of the Interior is obligated to manage. These species serve important ecosystem functions, and are of value to subsistence communities, both locally and internationally. Further, within the United States, high Arctic ecosystems are sites with high potential energy resources. The goals of effective development of these resources and concurrent conservation of trust species are a challenge; implementation actions frequently result in negotiation and/or litigious actions. The ability of the Department of the Interior to adequately respond to such actions is constrained by uncertainty associated with our limited abilities to differentiate between climatic, environmentally induced effects and effects of resource development

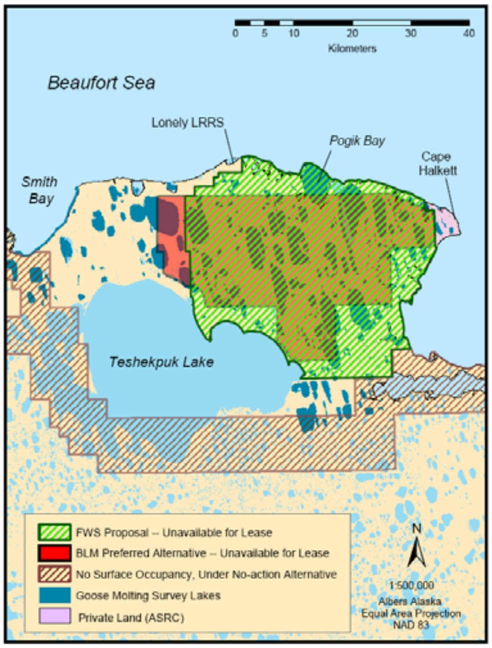

Figure 1. USFWS proposal for lands unavailable for lease within the TLSA, in relation to Goose Molting Lakes and the BLM Preferred Alternative (Prepared by P. Martin, USFWS).

on variation in abundance of trust species and changes in their habitat. Therefore, it is imperative that we begin expanding our knowledge of how the physical variability of the Arctic environment causes changes in habitats, and how those changes impact the distribution and abundance of important vertebrates.

For this project, we selected waterbirds of the Arctic coastal plain as our initial focal group for two reasons. First, there exists a time-series of data on both bird abundance and habitat distribution (replicate aerial photographic surveys) to immediately begin assessing how ecological changes in the landscape correlate with each species' response in distribution or numbers. Second, several waterbird populations on the Arctic coastal plain are the focus of intense conservation and management interest. Our current emphasis is on the geese that use the large, shallow lakes of the Teshekpuk Lake Special Area (TLSA) within the National Petroleum Reserve – Alaska (NPRA). The TLSA is located in the northeast corner of the NPRA, and up to 100,000 Black Brant, Canada Geese, Snow Geese, and White-fronted Geese molt their flight feathers in this area during July. Differing views about the most efficient way to protect habitats important to these geese (Figure 1) implies that we need a better understanding of temporal changes in their distribution, lake-specific attributes that geese prefer, and how these attributes may change over time due to climatic and other environmental factors. Similar concerns about changes in habitats and concordant changes in avian abundance and distribution exist for several other species, as the Arctic coastal plain contains internationally significant numbers of breeding shorebirds, loons, and eiders.

Work for this project is being conducted by each of the four disciplines of the USGS to collectively provide data and models to relate physical drivers of ecological change to biological response of these trust species. USGS biologists in collaboration with the U.S. Fish and Wildlife Service (USFWS) are documenting changes in goose populations and collecting experimental evidence of causes of population change. USGS remote sensing methods are being applied to quantify the spatial pattern of lake and terrestrial habitat change and coastal erosion in the TLSA. Our water discipline staff is providing hydrological data to address the correlation between geese and water quality changes. Ultimately, a mechanistic understanding for how hydrology may drive lake area changes that may be of significance to geese will be developed. The USGS through its earth processes program, operates a series of climate monitoring stations that provide data that can feed spatially explicit models of landscape evolution. Finally, the energy program is examining the potential for, and geospatial distribution of, energy and other resources. Collectively, these efforts are summarized in Figure 2. Below, we further expand on our activities.

Biological Context

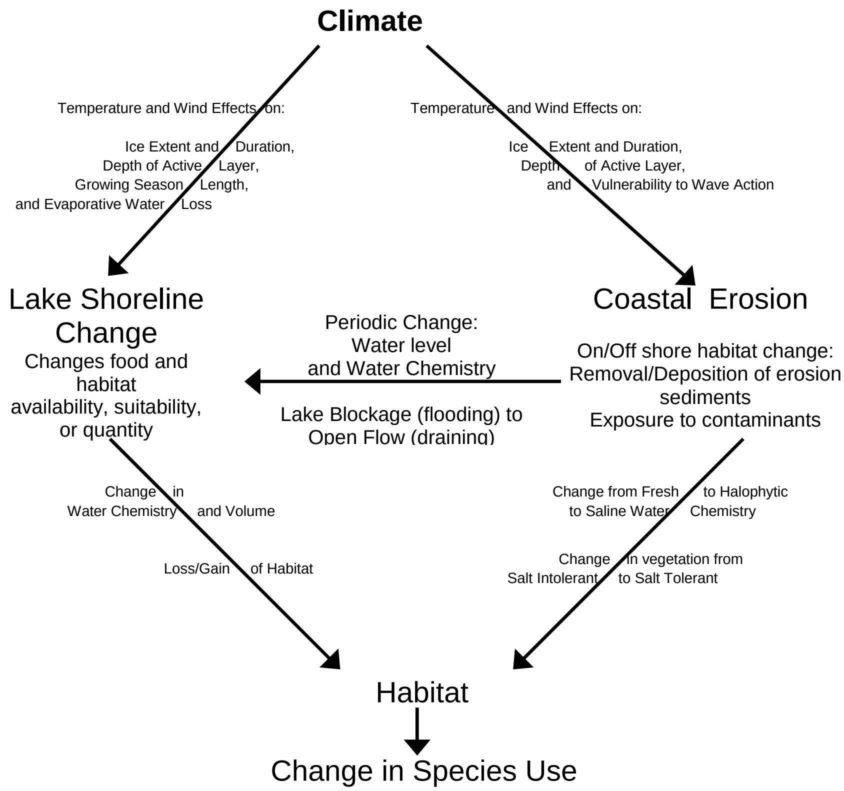

Figure 2. Physical and biological attributes measured by USGS integrated work and their hypothesized relationship to ecological changes.

Molting geese in the TLSA have been counted for 26 years using aerial surveys conducted by the USFWS. Results from these surveys show that numbers of Black Brant have been stable or slowly declining, and are currently close to a level that requires restrictions on subsistence and sport harvest. Canada Goose numbers have been stable, and White-fronted Goose numbers have increased rapidly. Snow Geese are comparatively rare, but have increased from a few hundred to a few thousand in just the last 8 years. Dividing the TLSA into western, central, and eastern strata, Black Brant are principally in the central and east strata, White-fronted Geese are in the western and central strata, and Canada Geese are distributed throughout. Examining lake-specific trends, Black Brant are declining on lakes where White-fronted Geese are increasing, and overall Black Brant are shifting eastward. One hypothesis for this redistribution is that Black Brant are being forced out by competition from the increasing numbers of White-fronted Geese. Alternatively, habitats may be changing such that geese are moving by choice to more preferred habitats. Black Brant typically forage on salt tolerant plants, and plant community change in response to saltwater intrusion may actually be beneficial to this goose species.

In 2004 we assessed grazing pressure on different plant communities at 12 lakes in these three strata by comparing biomass in 1-m^2 plots open or closed to grazing. Plots were located up to 300 m from each lake, but only those close to the lake (mostly < 50 m) received significant grazing pressure. This implies that changes to shorelines by natural phenomena such as erosive action and evaporative water loss (see Geospatial

Figure 3. A flock of 206 geese in moss/peat cover type, as seen in a 130 x 50 m digital photograph.

Context) may have direct impacts on food habits of geese. We also tested the ability of aerial videography to identify plant communities at a resolution relevant to geese over the lakes where plots were located (Figure 3). These videographic techniques provided synoptic views of the plot locations and surrounding habitats, and thus allow us a way to more finely but extensively examine potential habitat changes identified through photo interpretation (see Geospatial Context).

Geospatial Context

We obtained 1:60,000-scale (inch to the mile) aerial photography for the whole TLSA from 3 time periods: 1955 black and white (used for the baseline topographic maps of the area), and color infrared photography flown in 1979 and 2002. After scanning and geo-referencing these data sets and entering them into a geographic information system (GIS), we began quantifying how lake area had changed over time. For 17 lakes examined in 1979 and 2002, 15 lakes increased in size; the two that did not were breached and drained by coastal erosion. Increases in lake area ranged from 3 to 36%, with as much as a 454 ha increase in size. For East Long Lake, lake area increased 3% during 1955-1979, and an additional 2% during 1979-2002 (Figure 4). For this lake, we interpreted aerial photos to assess habitat types in 30 200-m^2 plots within a 900-m buffer around the lake. An analysis of the plots indicated that the amount of flooded tundra decreased dramatically between the three dates, as did small ponds of water due to shoreline erosion (Table 1). Other habitats, such as wet and moist tundra increased, probably as the flooded tundra dried out and transitioned into wet or moist tundra. Monitoring sites (see Climate Perspectives) have documented a 3.6° C increase in permafrost temperatures since 1989, which has caused reduced snowpack, earlier snow melt, and possibly greater evaporative water loss, all of which may facilitate these changes in tundra vegetation.

Table 1. Percent change in habitat between 1955 and 2004 based on 30 200-m sample blocks along the shoreline of East Long Lake.

Habitat	1955 to 1979	1979 to 2002
Lake	5.0	8.3
Small Ponds	2.6	-1.9
Shoreline Moss	-0.1	0.1
Flooded Tundra	-6.5	-10.7
Wet Tundra	-0.7	0.2
Moist Tundra	0.6	2.7
Upland Tundra	-10.3	0.4

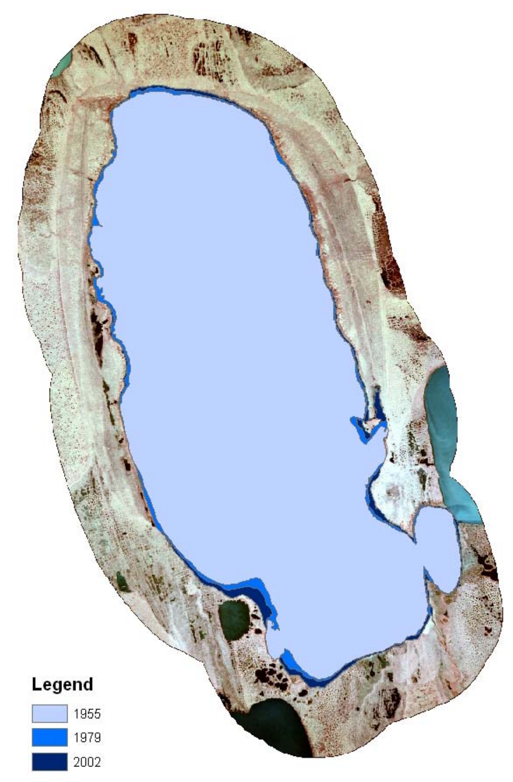

Figure 4. Changes in surface area over time for East Long Lake, located in east-central TLSA. A 900 m buffer of land is shown around the lake.

Figure 5a. Photographic assessments of erosion along the coastline within the TLSA. The J.W. Dalton test well site is 3 km east of Pitt Point in northcentral TLSA (shown on the title page map). Figure 5b,5c. Cameron Point West is 14 km east of Pitt Point.

We also used these time-series of photographs to begin examining the extent of coastal erosion. Dramatic amounts of erosion have occurred in some places. For instance, at the J.W. Dalton test well in northcentral TLSA, over 60 meters of coastline were lost just between 2003 and 2004, with a large portion of this loss occurring between July and August 2003 (Figure 5a). The amount lost since 1979 is far greater. Many other examples of coastal shoreline change have been documented, such as that shown in Figures 5b and 5c. We hypothesize that increased rates of coastal erosion are affected by reduced sea ice extent, as ice forms a buffer from waves, and from increased thawing of permafrost which makes the land more vulnerable to wave action.

Lake Limnology

Of the 12 lakes sampled using exclosures in 2004, 7 were also sampled for water quality. We measured turbidity, ammonia, nitrate, phosphorous, sodium, chloride, chlorophyll-a, nitrogen, conductance, temperature, and dissolved oxygen content. All lakes were shallow and well-mixed. Chlorophyll-a, an indicator of primary productivity, varied substantively among lakes, but without any clear relation to goose abundance. None of the lakes showed evidence of salt water intrusion, although some of the lakes that were not sampled for water quality had experienced salt water intrusion (based on photo interpretation), and should be included in future sampling. We found that ammonia and nitrate concentrations were positively correlated with goose densities on lakes. We expect that this relationship is indicative of fecal input to lakes. More sampling is required to determine if primary productivity of lakes may be affected by such fecal input.

Climate Perspectives

There is little historical weather data specifically for the NPRA. Data from the nearest National Weather Service facility in Barrow are often inconsistent with data recently acquired

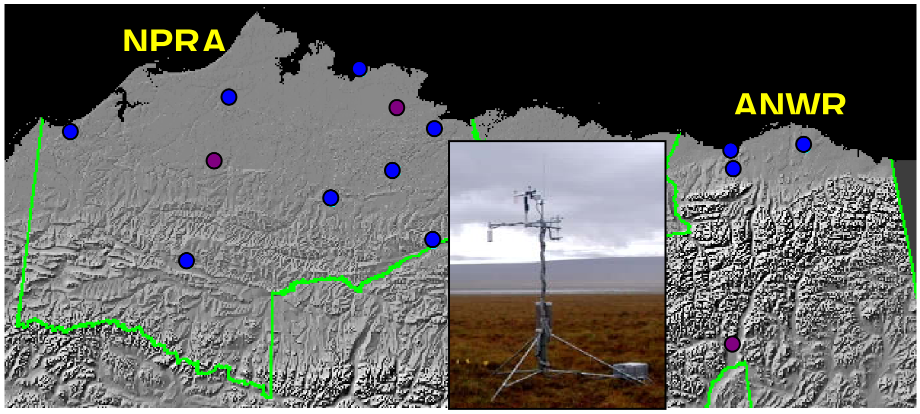

Figure 6. Locations of climate-monitoring stations (shown in middle insert) established since 1998 on the Arctic coastal plain. Ones shown in purple were established in 2004. Many of these stations are paired with deep boreholes, which monitor permafrost.

from the NPRA. Beginning in 1998, the Department of the Interior began deploying automated climate-monitoring stations on federal lands in northern Alaska (Figure 6). These stations continuously monitor soil temperature and moisture, air temperature, snow depth, wind speed and direction, albedo, and cloudiness. From these data we also monitor for changes in the date of spring snowmelt, length of growing season, maximum depth of the seasonal active layer, thawing and freezing degree days, and a number of other factors that potentially affect arctic ecosystems and landscapes. With the help of the DOI Landscape initiative, we now have broad spatial coverage in northern Alaska with 10 monitoring stations within the NPRA and 4 in the Arctic National Wildlife Refuge. The climate-monitoring stations complement a 21-element deep borehole array in the NPRA that is used to monitor for changes in the thermal state of permafrost. The primary objectives for establishing these two arrays are: a) climate change detection, b) monitoring the response of the arctic landscape to climate change, and c) acquisition of improved climate/permafrost data to better document current conditions and for models used for impact assessments. Such models include regional climate models, landscape change models, and engineering models.

Sufficient data have now been acquired from the climate-monitoring network to establish the magnitude of interannual climate variability on the Arctic coastal plain, discern spatial patterns within the NPRA, and to detect climate anomalies (e.g. extraordinarily cold winters, early snowmelt, etc.). Analysis of data from the borehole array show that mean-annual temperatures have warmed 3°C in the NPRA since 1989 (Figure 7). This warming likely resulted from the combined effects of increasing air temperatures and changes in the thickness

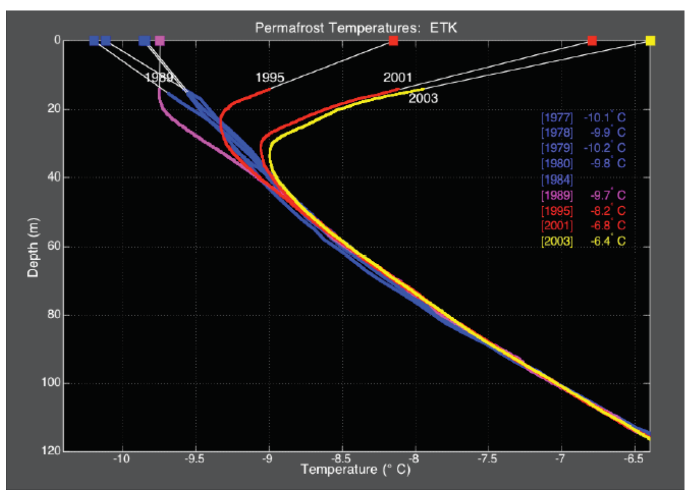

Figure 7. Temperature of permafrost from the surface to 120m in depth, as measured in the Teshekpuk Lake deep borehole during 1977 to 2003. Note the 3.6° C increase in surface permafrost temperature since 1989.

and duration of the seasonal snowpack. Finally, we now have a state-of-the-art regional climate model from the National Center for Atmospheric Research (Boulder, CO) running on USGS/ESD modeling computers that is capable of simulating changes in atmospheric conditions and interactions with the ground surface at resolutions as fine as 1 kilometer; a similar scale model for permafrost is in development.

Energy Context

Understanding the overlap in distributions of biological and mineral/geologic resources is essential for identifying and predicting areas of conflict and mitigating potential impacts. In the landscape of the northeastern NPRA, the USGS is attempting to develop an enhanced understanding of the geologic processes, particularly the geomorphology and sedimentology of this complex system, to better characterize the nature and distribution of Quaternary sediments. This knowledge is an essential piece of the landscape puzzle because these sediments directly influence topography and the distribution of flora, control the stability and engineering properties of the surface and shallow subsurface, and locally include coarse-grained facies (gravel and gravelly sand) that are in demand for construction of petroleum production infrastructure. Our integration of remote sensing (Landsat and IFSAR [interferometric synthetic aperture radar], Figure 8), field studies, and analysis of vintage geologic map and seismic shothole data has generated a set of preliminary products that are useful for delineation of Quaternary facies and for interpreting post-Pliocene events that sculpted the coastal plain. In contrast to previous interpretations, our limited field work suggests the distinctive "linear dune" geomorphology, so prominent on the coastal plain, may be the result of incision by fluvial processes and localized subsidence by thermokarst processes (especially thaw lake formation) of an extensive blanket of mostly Pliocene – Pleistocene fluvial, eolian, and shallow marine deposits. If our hypothesis is correct, there is potential to develop predictive models for the distribution of fluvial gravels, a potential resource for construction material. Such models would be useful for interdisciplinary work in NPRA; for instance, potential development impacts on important bird species may be reliant on the degree of spatial overlap of their populations with anticipated gravel resources.

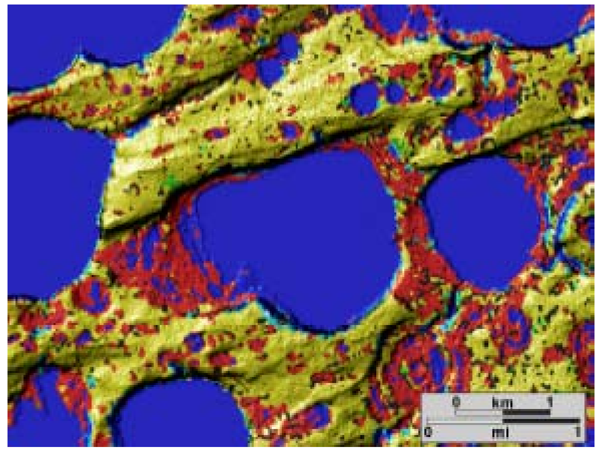

Figure 8. Image of part of northeastern NPRA coastal plain showing eolian sand dunes dissected by thaw lakes. This image is a fusion of an IFSAR bare earth image representing high resolution digital elevation and a Landsat 7 image in which color represents the following surface sediments: yellow = dry, vegetated sand; red = wet, vegetated mud and sandy mud; cyan = slightly muddy sand; green = vegetation; blue = water.

Conclusions and Directions for the Future

Our work to date confirms that ecosystems within the NPRA are highly dynamic and are capable of changing dramatically in just a couple decades. Concurrent with these changes, our focal model test taxa (i.e., geese within the TLSA) have varied in number and redistributed themselves, potentially in response to the types of physical and plant community changes we detected. Additional work is needed to further assess these changes and to identify the specific biological linkages between geese and the physical environment. For instance, we do not know if salt water intrusion, caused by erosive coastline processes, results in plant community change nor whether such botanical change differentially affects the four goose species because of species-specific habitat preferences. Also, a better assessment of the magnitude, spatial breadth, and causative factors of shoreline and coastal erosion is needed, including an assessment of how far inland habitats may be affected by such processes. By integrating climate data with other physical data on erosion rates, ice coverage, and permafrost changes, we expect to build predictive models of future erosion. Finally, the literature indicates that the degree to which high Arctic lake ecosystems may change in response to climatic warming has been considered much less than for terrestrial habitats. Further work on the rate of change and documentation of consequent cascading effects on biological productivity of these lake ecosystems may prove particularly valuable. These lakes provide important habitat for geese, loons, many other waterbirds, and for a variety of fish species of ecological and subsistence importance. Understanding and predicting these ongoing, broad scale, changes within Arctic ecosystems is essential for minimizing and mitigating potential future perturbations.

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Spring break-up along the arctic coast. Photo by Jonel Kiesau.

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