



global glimpses

Center for Global Change &
Arctic System Research

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The Global Change Student Research Grant Competition

One very visible and rewarding activity of the Center for Global Change and Arctic System Research (CGC) is the annual Global Change Student Research Grant Competition. Now in its 12th year, the competition is designed to give students experience in proposal writing and the peer review system as practiced by science funding agencies. It provides support to UAF students for research on global change topics presented in an interdisciplinary context, with an arctic or subarctic focus, in a variety of research areas (see box on page 2 to learn more about the competition).

Getting the Word Out: A New Workshop

To further increase campus awareness of the grant competition, in January 2003 we hosted a 90-minute informational workshop aimed at both students and advisors. Since in previous years nearly all submitted proposals were from students in the natural sciences, we made a special effort with this workshop to attract students in social science disciplines and in engineering. To our great delight, over 50 participants were on hand, exceeding our most optimistic expectations.

“What is global change?,” “Why apply to this competition?,” and “How can you design your research to be relevant to global change?” were among the questions addressed by a panel of faculty representing the natural and social sciences and engineering. Panel members included CGC Science Steering Committee members David Valentine, Forest Sciences, moderator; Colin Read, Economics; Peter Schweitzer, Anthropology; Dan White, Civil & Environmental Engineering; and Glenn Juday, Forest Sciences. Jason Vogel, a former recipient of a student award, provided valuable insight from the student perspective. Posters featuring work by Jason and other past student awardees were set up at the back of the room, providing further illustration of points made during the workshop.

A Record-Breaking Year

Perhaps as a result of the workshop, the 2003 competition generated a record number of proposals. The overall quality was quite high, and we are pleased to report that a record number of awards were made as well—of the 35 proposals submitted, 18 will be funded. (The previous record was set

in 2001, with 25 proposals submitted and 12 funded.) Students from anthropology, biology and wildlife, forest sciences, geophysics, marine sciences and northern studies were funded to pursue a wide range of research projects (see page 3). Four of these awards are made possible by the generosity of two funding partners, the Alaska Sea Grant College Program and the Office of the Vice Provost for Research, UAF.

Our Co-Sponsors and Partners

Since 2002 the competition has been sponsored jointly with the International Arctic Research Center (IARC). This is a natural partnership given IARC’s goals of studying global climate change and supporting the participation of graduate and undergraduate students in arctic research. The addition of IARC funding to this competition has made it possible to support 4–5 more student grants each year.

Contributions from the Cooperative Institute for Arctic Research (CIFAR) further increase the core funding for this competition. CIFAR, a joint institute between the University of Alaska and NOAA, is co-located with the Center for Global Change. One of its missions is to expand the opportunities available to students to participate in research programs.

Our partner in this grant competition since 2000, the Alaska Sea Grant College Program has supported one or more student research grants per year. Their rationale is

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◆ Articles by student research grant recipients

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straightforward—wise use and management of Alaska’s marine resources depends on understanding the effects of climate change as well as other natural and human-induced environmental change. Supporting graduate students is a high priority of the Alaska Sea Grant College Program and they have found that supporting these students has been an extremely cost effective investment in both generating new information and training future scientists and resource managers.

Global Change Student Research Grant Competition

An Introduction

Eligibility: Students must have graduate or undergraduate status in a degree-granting program at UAF at the time the work will be conducted.

Research Areas: Social sciences, physical sciences, biological sciences, engineering

Award Duration and Amount: One or two years, up to \$5,000 for each year

Proposal Content and Page Length: Proposals should contain an abstract, introduction, project description (e.g., experimental design, methodologies) and timetable. Maximum page length is 5 single-spaced pages.

Evaluation Criteria: Proposals are judged according to the following criteria:

1. Scientific and technical merit of the proposed research.
2. Relevance to global change and arctic research.
3. Feasibility of the proposed research.
4. Interdisciplinary nature of proposed work, or presentation of the work in an interdisciplinary context.

Review Process: Proposals are sent to three UAF faculty for review (mail review). Following this, a review panel of UAF faculty meets to discuss the proposals and mail reviews and make funding recommendations.

Timing: Generally, the competition is announced in December, with proposals due in early March, awards announced in late April or early May, and funds made available in July.

More information on this competition can be found at <http://www.cgc.uaf.edu>

The Office of the Vice Provost for Research (VPR) is committed to funding undergraduate research at UAF, and has held a number of small competitions to award funds to worthy students. In addition to State funds budgeted to the Provost’s Office, funding provided by the Williams Companies was also spent on undergraduate student research grants this past year. This program works collaboratively with the Alaska EPSCoR Program and with the International Arctic Research Center to provide funding opportunities for undergraduate research participation. The VPR agreed to fund the two undergraduate student proposals recommended for funding by the competition’s review panel.

We are grateful to our funding partners for their continued commitment to undergraduate and graduate global change research at UAF, and offer our warm congratulations to the 2003 grant recipients. It is a great pleasure to be involved in a program that has a direct and positive impact on the lives and careers of so many of UAF’s outstanding students!

—Barb Hameister, *Publications & Meetings Manager*
—Patricia Anderson, *Associate Director*

Center Outreach Activities

Continuing Education. In April, four members of the CGC Science Steering Committee gave informal lectures for a “Global Climate Change” class, part of the spring curriculum of the UAF Adventures in Lifelong Learning (ALL) program. This program, open to anyone aged 50 or older, offers classes and study groups in a wide variety of interesting topics (see <http://www.uaf.edu/all> for more information). Glenn Juday, Colin Read, Elena Sparrow and Nicole Mölders contributed their time, enthusiasm and expertise. Thank you!

Visiting Speakers. The Center for Global Change has hosted or co-hosted two visiting speakers in the past year. In August of 2002 we joined forces with the Alaska Quaternary Center to bring Dr. Julie Brigham-Grette of the University of Massachusetts Amherst to UAF. Dr. Brigham-Grette presented a seminar entitled “Beringian Responses to Glacial/Interglacial Change: Lessons from both Sides of the Bering Strait.” In May of 2003 we sponsored Dr. George Seielstad, Associate Dean of the Center for Aerospace Studies at the University of North Dakota, who gave a seminar on “Mitigating Environmental Change in the Northern Great Plains.”

Science Calendar. The Center for Global Change continues to publish the *UAF Weekly Science Calendar* as a service to the campus community. The calendar features seminars, workshops, thesis defenses and other science-related events, in a “one-stop-shopping” package. During the school year the calendar is published weekly, and is provided to campus units and individuals in hard copy, by fax, e-mail, and on-line. In summer, information is disseminated on an event-by-event basis only, by e-mail and on the web. For more information, contact Barb Hameister (cgc@iarc.uaf.edu, 474-5818) or see <http://www.cgc.uaf.edu/calendar.html>.

2003 Student Research Grant Recipients

Funded by the Center for Global Change, the International Arctic Research Center, and the Cooperative Institute for Arctic Research:

Mike Anderson, Biology and Wildlife: *Quantifying N₂-fixation in Expanding Arctic Populations of *Alnus fruticosa*: A Phylogeographic Approach*

Stacia Backensto, Biology and Wildlife: *The Common Raven (*Corvus corax*) in Relation to Oil and Gas Activities on the North Slope of Alaska*

Kendra L. Calhoun, Biology and Wildlife: *The Relationship Between Above and Belowground Species Composition in Boreal Coniferous Forests: The Missing Link in the Assessment of Biodiversity and Ecosystem Function?*

Amy Breen Carroll, Biology and Wildlife: *Toward an Understanding of the History of Balsam Poplar Plant Communities in the Arctic*

Ross Coen, Northern Studies: *The Voyage of the S.S. Manhattan: Climate Change and Industrial Development in the Arctic*

Paul Duffy, Forest Sciences: *The Role of Climate in the Disturbance Ecology of the Alaskan Boreal Forest: Implications for Future Climate Change*

Evan S. Kane, Interdisciplinary Program (Forest Ecology): *The Interaction Between Production and Landscape Position in Controlling Soil Carbon Accumulation in Fire-prone Black Spruce Ecosystems*

Tiffany L. Lefrancois, Anthropology: *An Historical and Human Ecology of Sea Otter Exploitation*

Andrew Mahoney, Geophysical Institute: *Processes and Changes in Alaskan Landfast Sea Ice Evolution*

Mette R. Nielson, School of Fisheries and Ocean Sciences: *The Biological Coupling of Sea Ice Biota with Higher Trophic Levels off Barrow, Alaska*

Jonathan A. O'Donnell, Biology and Wildlife: *Nitrate Flux in a Boreal Forest Watershed: The Influence of Discontinuous Permafrost on Denitrification*

Louann Rank, Anthropology: *Yupik Traditional Knowledge in Global Change Assessment*

Joni Reese, Biology and Wildlife: *Abiotic Factors Controlling Species Composition in Calcareous Fens, Tongass National Forest, Southeast Alaska*

Casie Stockdale, Biology and Wildlife: *Population Dynamics of *Vicia cracca* (Fabaceae): Insight into Invasion Success in Alaska*

Funded by the Alaska Sea Grant College Program:

Jeremy Kasper, Marine Science and Limnology: *Modeling the Effects of River Discharge, Windstress and Sea Ice on Arctic Coastal Erosion*

Wongyu Park, School of Fisheries and Ocean Sciences, Juneau: *Glacier Bay as a Natural Field Laboratory for Measuring the Effects of Global Climate Changes on Larval Crab Recruitment*

Funded by the Office of the Vice Provost for Research, UAF:

Jamelle L. Duszynski and Brenda Naber, Anthropology: *Human and Natural Impacts on Steller Sea Lions over the Past 6500 Years: A Case Study on Archaeology and Human Ecology*

Maegan Weltzin, Biology and Wildlife: *Effects of Hibernation Arousal on Learning and Memory in the Arctic Ground Squirrel AND Study of the Arctic Ground Squirrel's Natural Fear Response in the Wild*

Student Research Grant Reports—Past Recipients

Comparing the Nutritional Quality of Steller Sea Lion Diets Based on Historical Changes in Diet Composition

by **Monica K.H. Bando**, *Institute of Marine Science, School of Fisheries and Ocean Science, University of Alaska Fairbanks*

Introduction

Steller sea lions inhabit coastal waters of the North Pacific from California through Alaska to the Kuril Islands and northern Japan and their numbers have been declining precipitously over the past three decades within portions of their range. In 1990 Steller sea lions were listed as threatened under the Endangered Species Act. Between 1956 and 1960, the greatest abundance of Steller sea lions was observed in the western Gulf of Alaska and Aleutian Islands. These western Alaskan populations have since drastically declined, whereas populations between southeast Alaska and northern California have stabilized and even increased.

Although the primary cause(s) of the Steller sea lion decline remains unknown, one hypothesis is nutritional stress, which is defined here as a reduction in the amount and/or quality of available prey that results in the reduced fitness of an organism. Steller sea lions are opportunistic predators whose primary prey vary geographically and temporally (Pitcher, 1981; Merrick et al., 1997). Common prey species include walleye pollock, Atka mackerel, Pacific herring, Pacific cod, Pacific sand lance, capelin, rockfishes, flatfishes, sculpins, salmon, greenlings, octopus and squid (Pitcher, 1981; Merrick et al., 1997; Loughlin, 1998). Decreases in the quantity and/or quality of Steller sea lion prey may be attributable to environmental fluctuations (Francis and Hare, 1994).

The North Pacific sea surface temperature changed rapidly from a cold water regime from 1947 through 1976 to a warm water regime from 1977 onward (Ebbesmeyer et al., 1991). This regime shift resulted in the abrupt displacement of forage fish species, such as capelin (Van Pelt et al., 1997), by gadids, such as walleye pollock (Anderson and Piatt, 1999). The primary objective of this study was to compare the nutritional quality of three different diet compositions formulated to represent diets at times and places of different Steller sea lion population trajectories, which coincide with climatic regime shifts. To address this objective, it was necessary to first determine the nutritional quality, defined here as the energy density (kcal/g), of each prey species comprising the different diet regimes.

Methods

Sample collection and analysis. Three different feeding regimes, representative of Steller sea lion diets (1) prior to their population decline (Gulf of Alaska, 1970s), (2) during their decline (Gulf of Alaska, 1980s), and (3) from a stable or

growing population (southeast Alaska, 1990s) (Merrick and Calkins, 1996), were determined by Don Calkins of the Alaska Sea Life Center (ASLC) and Vladimir Burkanov (National Marine Fisheries Service (NMFS), formerly ASLC), based on Calkins' research (D.G. Calkins and E.A. Goodwin, Investigation of the Declining Sea Lion Population in the Gulf of Alaska, unpublished report, Alaska Department of Fish and Game, Anchorage, AK, 1988; Calkins, 1998; Merrick and, Calkins 1996). The three regimes differed in composition, frequency of occurrence and biomass of ten prey species: walleye pollock, Pacific herring, octopus, pink salmon, Pacific cod, Dover sole, rock sole, Pacific sand lance, capelin, and squid. Samples for this study came from commercially harvested prey items purchased by the ASLC to feed their captive Steller sea lions.

For each prey item, bomb calorimetry energy values and proximate composition estimates of energy density were determined and compared to one another to cross-check values. Whole body energy content and proximate composition analyses were conducted at the ASLC, Seward, AK; Fishery Industrial Technology Center (FITC), Kodiak, AK; and the University of Alaska Fairbanks, from May to August 2000 and August 2001. Protein and lipid content values were used to calculate whole body energy density estimates for each species:

$$\text{Energy or caloric density (kcal/g wet mass)} = \text{protein (\%)} \times 5.65 + \text{lipid (\%)} \times 9.50.$$

Statistical Analysis. Multivariate analysis of variance procedures (MANOVA) were used to analyze differences in water, ash, protein and lipid content across species. General linear model (GLM) procedures were used because of unbalanced data. Replicate subsamples collected from each individual prey item were averaged to provide mean values. Data reported here were log₁₀ transformed. Statistical analyses were performed using SAS 8.2.

Results and Discussion

Whole body energy content and proximate composition. Proximate composition components varied across the ten Steller sea lion prey species analyzed. Water content ranged from 64.7% in Pacific herring to 85.6% in octopus. Ash content ranged from 1.7% in squid to 3.6% in rock sole. Protein content ranged from 10.8% in octopus to 19.3% in pink salmon. Lipid content varied from 0.8% in octopus to 17.1% in Pacific herring. These results complement the growing volume of literature as evidence that opportunistic predators, such as Steller sea lions, consume a variety of prey items, each of which provides different nutritional quality (Van Pelt et al., 1997; Payne et al., 1999; Anthony et al., 2000).

As a result of nutritional stress being hailed as a cause of the Steller sea lion decline, studies such as this one focus on

energy and lipid content of prey items, though other bioenergetic parameters, such as foraging, digestive and assimilation efficiencies, require further investigation prior to making any conclusions about the Steller sea lion decline. In addition, the nutritional composition and energy density within fish species can vary with respect to age, weight, length (Hislop et al., 1991), season (Smith et al., 1990; Robards, 1999) and location (Anthony et al., 2000).

Feeding Regimes. The pre-decline and stable regimes provided similar energy densities using either proximate composition estimates ($p = 0.084$) or bomb calorimetry values ($p = 0.293$). The decline diet, however, provided significantly lower energy density compared with the pre-decline and stable diets ($p < 0.0001$) using both values.

Because energy density is calculated from protein and lipid content values, these components were compared across species and across feeding regimes to determine how different species compositions affected proportions of these two sources of energy for each feeding regime. The pre-decline and stable diets provided similar amounts of protein ($p = 0.387$) and lipid ($p = 0.496$) on a dry mass basis. Significantly higher protein was contained in the decline diet than in the pre-decline ($p = 0.020$) and stable ($p = 0.009$) diets. The decline diet simultaneously provided significantly lower lipid content than either the pre-decline ($p = <0.0001$) or stable ($p = <0.0001$) diets.

Summary

Results from this study indicate that the prey composition representing a declining Steller sea lion population diet provides lower energy than either the pre-decline or stable population diets. Based on the nutritional quality of prey species analyzed and the feeding regimes formulated for this study, these results are consistent with the possibility that nutritional stress was a factor contributing to the Steller sea lion decline. The formulated compositions representative of pre-declining, declining and stable Steller sea lion population diets provide generalized hypothesized diets reflecting large-scale temporal shifts in primary prey consumed by Steller sea lions. These feeding regimes do not, however, address seasonal or fine-scale geographic differences in prey consumption, nor do they account for potential long-term changes in the nutritional quality of prey species. For instance, primary productivity prior to the 1976 regime shift may have provided higher fat herring than post-1976 regime shift. Therefore, when addressing nutritional stress as a factor contributing to the Steller sea lion decline, it is important to recognize how greatly each of the aforementioned caveats contribute to the over- or underestimation of the nutritional quality of prey consumed by Steller sea lions. Future studies addressing the nutritional stress hypothesis should consider when Steller sea lions depend on various prey resources on a seasonal basis, how dominant prey items consumed vary with location, what the nutritional state of their prey are when they are most heavily consuming them, and the foraging efficiency of consuming various prey items. As studies continue to encompass and account for seasonal and geo-

graphic differences in the composition, quantity, quality and foraging efficiency and assimilation of various diets, the better we can address how great a role nutritional stress plays in the decline of Steller sea lions.

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Integrating Nitrogen Sinks and Losses with Belowground Carbon Cycling in Stands of White Spruce (*Picea glauca*) and Balsam Poplar (*Populus balsamifera*) on the Tanana River Floodplain, Interior Alaska

by Richard Brenner, Institute of Arctic Biology, University of Alaska Fairbanks

Overview

In this study we examined soil water chemistry during an important boreal forest plant successional transition in order to investigate ecosystem nitrogen losses through the process of leaching. Nitrogen is a limiting nutrient to plant growth in many high latitude ecosystems. Thus, the availability of soil nitrogen in these systems has a direct influence on the ability of plants to sequester atmospheric carbon dioxide into plant biomass. In early plant successional communities, such as those established after fires or floods, warm soil temperatures contribute to high internal rates of nitrogen cycling and nitrogen inputs are often large due to the fixation of atmospheric nitrogen (N_2) from plant symbiotic relationships. However, in older successional communities nitrogen becomes increasingly limiting as nitrogen fixation inputs decrease, soil nitrogen cycling slows due to colder soil temperatures, and stand nitrogen increasingly becomes tied up in recalcitrant woody biomass. In addition to a decrease in the availability of nitrogen, we hypothesized that nitrogen leaching losses would be higher in late-succession stands of white spruce (*Picea glauca*) compared to mid-succession stands of balsam poplar (*Populus balsamifera*). This hypothesis was based on the rationale that soil microbial populations, which presumably subsist on low-quality carbon in a cold environment, would have a reduced capacity to immobilize pulses of nitrogen that move down through the soil profile.

Methods

This study took place in stands of balsam poplar and white spruce within the Bonanza Creek Long Term Ecological Research (LTER) sites located on the Tanana River floodplain, approximately 20 km south of Fairbanks, Alaska. These stand types represent a dramatic shift from mid-succession deciduous communities (poplar), where plant productivity and nitrogen utilization are relatively high, to late-succession coniferous communities (white spruce), which are less productive and have lower nitrogen demands.

Arrays of tension lysimeters (five per depth) were placed in the upper organic soil (~12 cm) and deeper mineral soil (~40 cm) within both stand types (three plots per stand type) during June of 2000. Tensiometers (used to measure soil water potential) were installed at three depths (above, between and below the lysimeters) during the same time. Our goal was to examine the soil solution and water potential within the primary rooting zone as well as below the rooting zone in the deeper mineral soil. Following installation the lysimeters were not sampled for approximately six weeks in order to minimize disturbance effects to soil water chemistry. Sampling of soil solution from the lysimeters began in late

July of 2000 and continued weekly during frost-free periods until mid-October of 2001. At each sampling period we also measured soil water potentials and frost depth. Samples were taken back to the laboratory, where they were filtered and frozen until analysis. Analysis included pH, electrical conductivity, dissolved organic carbon, dissolved organic nitrogen, nitrate, ammonium, chloride, sulfate, calcium, magnesium, manganese and aluminum.

Results and Conclusions

General patterns. Our results indicate that nitrogen, in the forms of dissolved organic nitrogen (DON) and nitrate, moves from surface horizons into the deeper mineral soil in both mid and late plant successional communities. The concentration of ammonium was near or below detection limits in most samples measured and was not an important source of nitrogen. Dissolved organic nitrogen was found to be the dominant form of soluble nitrogen in all depths of the two stand types (Figure 1). However, the concentration of DON was significantly lower in the 40 cm mineral soil than in the surface organic horizon, probably as a result of adhesion to soil particles as it moves through the soil profile. Unlike DON, the concentration of nitrate was significantly higher in the mineral soil vs. the organic soil of both stand types. We believe that nitrate moves down through the soil profile much more quickly than DON. Nitrate is negatively charged and does not readily adhere to soil particles, which are also negatively charged. Thus, even though the concentration of DON was approximately four times higher than nitrate below the rooting zone, nitrate may constitute an equally important source of nitrogen leaching in this system.

Leaching across succession. Results from this experiment do not provide conclusive evidence to support our original hypothesis that nitrogen leaching increases in the late-succession stands of white spruce compared to the mid-succession stands of balsam poplar. Concentrations of nitrate

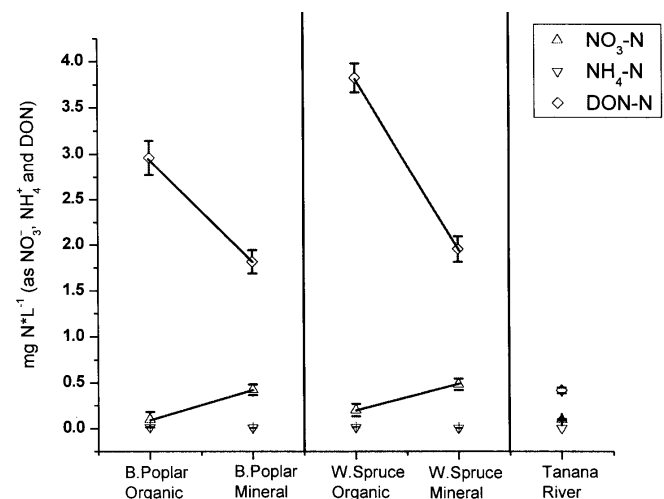


Figure 1. Mean and standard error of nitrogen as nitrate (NO_3^-), ammonium (NH_4^+) and dissolved organic nitrogen (DON) in the soil solution of forest stands along the Tanana River. Nitrogen in river water is included for comparison.

were generally similar in both stand types throughout the course of the study; however, nitrate was significantly higher in the white spruce stands ($0.708 \text{ mg NO}_3\text{-N}\cdot\text{L}^{-1}$) during the fall (mid-August to October) compared to stands of balsam poplar ($0.294 \text{ mg NO}_3\text{-N}\cdot\text{L}^{-1}$). While the sampling of lysimeters terminated in early October when the Tanana River began to freeze, we believe that leaching losses may continue long after this period until surface organic layers freeze solid.

Contribution of river water to soil solution nitrogen. The Tanana River, adjacent to all field sites in this study, contains significantly less nitrate and DON than either stand type (Figure 1). River water may infiltrate into groundwater and then travel up through the soil profile; however, we do not believe that nitrogen inputs from river water constitute a major source of soil solution nitrogen in our research plots since there was no correlation between measurements of soil moisture and river height. The soil in all plots was at its driest point from early to mid July—a period when the Tanana River was already fairly high and was rising quickly. Soil moisture did not increase substantially until mid August, when it began to rain steadily. Our research plots may have been on terraces that were high enough to be placed out of the influence of river water; or frozen soil, found in many of our plots, may have prevented river water from moving into the surface horizons.

Water movement and frozen soil. At this point we do not fully understand the effects of frozen soil on the movement of nitrogen within the soil profile on the floodplain. Some sites in this study contained a high percentage of sand and may be permeable to the movement of groundwater into surface horizons or vice versa. In contrast, sites that contained fine soil particles were likely impermeable to water movement, as these sites tended to have a persistent ice layer during the entire growing season with liquid water pooled on top of this layer. These pools may often be the source of water that moves up the soil active layer during a large portion of the growing season as was shown by measurements of soil water potential. The downward movement of water (as saturated flow) was observed infrequently (~10% of our measurements); however, we suspect that these events are important for transporting nitrogen below the rooting zone and should be given further attention in future research.

Comparison to other ecosystems. Soil solution measurements of DON and nitrate in this study were similar to those of other high-latitude ecosystems which are relatively free from anthropogenic disturbances such as the deposition of nitrogen and acid. As in other undisturbed ecosystems, the concentration of soil solution DON in our study was relatively high compared to inorganic nitrogen. In contrast, large tracts of forest in northern Europe, Scandinavia and eastern North America receive heavy industrial inputs of nitrogen and have soil solution nitrogen that is dominated by nitrate. This may indicate that the forests on the Tanana River floodplain are relatively unaffected by human alterations of the nitrogen cycle. ❖

Genetic Consequences of Pleistocene Glaciations for a Northern Mammal–Tapeworm System: Current Progress and Future Work

by **Kurt Galbreath**, *Department of Biology and Wildlife, University of Alaska Fairbanks, and the University of Alaska Museum; now at Cornell University*

Introduction

During the repeated glacial and interglacial periods of the Pleistocene, northern populations of plants and animals were fragmented by the movements of massive ice sheets, and fluctuating sea levels alternately exposed and inundated vast expanses of continental shelf. These events caused temperate species to be forced southward as glaciers advanced, while northern species were collected into ice-free glacial refugia. Such significant effects on species' distributions probably had equally significant genetic consequences. For example, isolation in refugia is often invoked to explain patterns of genetic differentiation, and reduced genetic diversity in northern populations may have resulted from genetic bottlenecks during post-glacial population expansion.

Beringia, the region that is centered on the Bering Strait and spans eastern Siberia, Alaska, and northwestern Canada, provides an ideal natural laboratory for examining the genetic consequences of ice age events. Glaciations, climate-driven ecological shifts, and the opening and closing of the Bering Land Bridge all had repeated impacts on the historical biogeography of Beringia. The genetic patterns that resulted from these paleoenvironmental influences provide a window into the past that permits us to begin to understand species' responses to historical events.

As a model for examining these historical responses, my work is focused on the tundra vole, *Microtus oeconomus*, and one of its tapeworm parasites, *Hymenolepis horrida*. Tundra voles are one of only a handful of rodent species found in both Eurasia and North America, and numerous lines of evidence indicate that they colonized North America recently via the Bering Land Bridge. If this is the case, their genetic structure should reflect recent glacial cycles, which should in turn simplify reconstruction of historical events. The tapeworm of the vole is being examined in an attempt to provide further resolution of historical geographic and evolutionary patterns. Because of their strong dependence on host distributions and diet, parasites track hosts predictably through evolutionary time, which means that they can reveal much about their hosts' evolutionary and biogeographic histories.

Pleistocene glaciations and tundra vole evolution. This work has been primarily directed by two specific questions: 1) What was the role of Pleistocene glaciations in promoting or inhibiting genetic differentiation? and 2) What effect did post-glacial colonization have on genetic diversity?

In order to address these questions, a hierarchical approach was used in which both deep evolutionary relationships among populations and shallow genetic patterns within populations were examined. Initially, mitochondrial DNA sequences were collected from over 200 tundra voles that

represented 29 populations distributed across eastern Siberia, Alaska, and northern Canada. These data were used to create a phylogenetic tree (a branching diagram that depicts estimated evolutionary relationships among individual animals), which is useful for understanding how genetic patterns are distributed across the geographical range of sampled populations.

Two features of the phylogenetic tree stood out immediately. The first was that despite the fact that the Alaskan and Siberian tundra voles have been isolated across the Bering Strait for over 10,000 years, they did not differ very much genetically. This suggests that the cycles of sea level changes during the Pleistocene did not have a major impact on tundra vole evolution. Perhaps more interesting, though, was a strong genetic break that separated populations in Central Asia from those in eastern Siberia and Alaska (i.e., Beringia). This genetic break provided the opportunity to examine the first of the two questions that prompted this research.

If a glacial barrier initially separated the Central Asian and Beringian populations and caused them to follow independent evolutionary pathways, we would expect to see: 1) a history of glacial activity in the region of interest, 2) similar genetic differences in co-distributed species, and 3) the same genetic pattern in independent molecular markers (DNA sequences) from tundra voles. All of these criteria are met. The genetic break lies along the western boundary of Beringia, which was heavily glaciated during recent glacial maxima. Roughly congruent breaks are also observed in lemmings of the genera *Dicrostonyx* and *Lemmus*, and the same is true for morphological characteristics and an independent nuclear gene that was sequenced from 63 of the tundra voles.

All of this provides strong evidence that populations in western Beringia were split historically across some barrier, but it does not demonstrate that the barrier was a glacier. If, however, the age of the genetic break could be estimated using a molecular clock, it might be possible to directly link the divergence event to a specific glacial period. Unfortunately, the uncertainty inherent in calibrating molecular clocks produced a range of estimates that fell across glacial and interglacial periods alike. However, even the most recent age estimate for the break (~166,000 years) predates both the last major ice age and the interglacial that preceded it. Such timing suggests that even if the Central Asian and Beringian populations were isolated initially by glacial barriers, their separation was maintained through long warm periods during which glaciers were nonexistent. We should therefore consider the potential importance of climate-driven ecological shifts during interglacial periods in maintaining isolation of populations in northern species. Glacial history by itself does not explain the observed structure.

My second research question focuses on the effect of post-glacial colonization on genetic diversity in northern populations. For temperate species, colonization following glacial retreat has often led to reduced genetic diversity in northern populations, but is this the case for arctic and subarctic

species like the tundra vole? To answer this question, two lines of evidence were examined: 1) measurements of genetic diversity were compared directly between populations that had been established post-glacially and those that were from non-glaciated regions, and 2) populations from regions with different glacial histories were tested for historical bottlenecks, which would be expected if they had undergone a reduction in diversity during colonization.

Initial results from these tests were superficially in conflict with each other. Regions with different glacial histories did not differ significantly in genetic diversity, but evidence for genetic bottlenecks was seen in those areas that had been glaciated and not in those that were historically free of ice. In order to clarify these findings, estimates were calculated for the age of the implied bottlenecks. If post-glacial colonization was responsible for the bottlenecks, then the timing estimates should match those of recent glacial periods. Surprisingly, all of the bottleneck timing estimates were roughly equivalent, despite significant variation in the timing of different glacial events. The implication is that a single, wide-reaching bottleneck was largely responsible for the population genetic structure of the entire region, and that event was not necessarily associated with any particular glaciation. Once again, this suggests that despite their impressive impacts on the Beringian landscape, Pleistocene glaciations were probably not the sole factor—or even the most important one—responsible for shaping current patterns of genetic structure.

Tapeworms, rodents, and biodiversity in the north

As previously indicated, examining the evolutionary relationships between parasites and their hosts (often referred to as host-parasite coevolution) can lead to greater insight into the historical biogeographic and ecological associations of the organisms of interest. The tapeworm *Hymenolepis horrida* is a widespread parasite of tundra voles and other northern rodents, which makes it a good candidate for coevolutionary studies. However, very little is known about even its most basic characteristics (e.g., genetic structure, life cycle, distribution). In fact, some researchers have suggested that it is not even a single species, but actually a complex of multiple species that look very similar. Before sophisticated coevolutionary analyses can be pursued, some basic descriptive work must be completed.

This work on *Hymenolepis horrida* is still in progress, but some very interesting preliminary findings have already been made. A portion of mitochondrial DNA has been sequenced from 163 *horrida*-like tapeworms that were collected from voles, lemmings, and squirrels in Alaska and Siberia. In addition, morphological diversity among the specimens is being examined in collaboration with Dr. Eric Hoberg of the U.S. National Parasite collection. Phylogenetic analysis of the DNA sequences has revealed at least six distinct sub-groups (clades). With few exceptions, each of these clades is associated with a specific type of rodent host, and there are clear morphological characters that distinguish them. It is

highly probable that each clade represents a distinct species, and at least three of them are probably entirely new, undescribed species. Two of the other clades probably represent species that were identified and separated from the *H. horrida* complex only recently. The discovery of so many species where once there was thought to be only one is somewhat astounding, and it highlights the importance of molecular tools in identifying hidden diversity. It also reaffirms the incredible diversity of life that exists in the north, and suggests that more awaits discovery.

The work with the *H. horrida* complex will continue. Once the complex is fully described we will begin to look for matching genetic patterns between parasites and hosts that imply shared biogeographic history. Non-matching genetic patterns can be informative as well, as they can provide evidence of important historical events such as host switching, dispersal, or lineage extinction that may have been induced by environmental effects. Each species provides a distinct perspective on the historical processes that have driven the evolution of northern organisms, which permits more rigorous tests of specific hypotheses. ❖

Mapping Glacier Equilibrium Line Altitudes in Southern Alaska

by *Daniel Elsberg*, *Geophysical Institute, University of Alaska Fairbanks* and *T.J. Fudge*, *G.I. REU Intern, Bowdoin College*

Motivation

Open up a newspaper lately and you are likely to see an article about how one glacier or another is disappearing quickly (Pianin, 2002, for example). This is not surprising, as glaciers can provide dramatic examples of the effects of climate change. In fact Alaska glaciers did, on the whole, melt more than twice as fast throughout the late 1990s than over the preceding 40 to 50 years (Arendt et al., 2002). Satellite programs will someday catalog and measure all of the world's glaciers over time to track their fluctuations. But for the near future, ground-based mass balance and airborne altimetry and mapping programs provide the most practical and accurate information on how much ice is melting or accumulating over seasonal to multi-year time scales.

Since glaciologists on skis or in airplanes can only observe a small sample of the glaciers in any one region, they must extrapolate their measurements to the surrounding unmeasured ice masses. Arendt et al. (2002) calculated the volume change of Alaska glaciers using measurements of glaciers covering 20% of the glacierized area in Alaska. Improvements in the data extrapolation method could refine their numbers and aid in other regions of the world where scientific observations can cover a relatively smaller number of glaciers.

On temperate glaciers, such as those in southern Alaska, location of the snowline (which delineates bare ice or firn from the previous winter's remaining snowcover) at the end of the summer melt season corresponds fairly closely with

the equilibrium line (Paterson, 1994). A glacier's equilibrium line marks the boundary between the portion of the glacier with a net gain of snow and ice over the year (the accumulation zone) and the portion with a net loss (the ablation zone). Its location and mean elevation (called the equilibrium line altitude or ELA) vary from year to year. Records of ELAs are generally anti-correlated with those of yearly (net or annual) mass balances for any given glacier, although it takes at least several years of both those measurements to establish just what the specific relationship is (Meier and Post, 1962). Because of the close relationship between ELA and a glacier's "health," we chose to look at the geographical pattern of ELAs in a glacierized region to help extrapolate isolated mass balance or geodetic volume change measurements to nearby unsampled glaciers.

Methods

The data collection portion of this project took on two aspects: (1) mining archival photograph databases for coverage of snowlines taken near the end of summer, and (2) incorporating a vertically oriented digital camera into an existing laser altimetry system to acquire new snowline images in conjunction with ongoing laser altimetry field work. Regardless of the source of an image, it must fulfill several criteria to be useful in an ELA mapping project: depict the snowline so that it can be located geographically (through ground control or knowledge of the camera location and orientation), be unobscured by clouds, be taken close to the end of the summer but not too late such that new snow has fallen, and finally the exact date of acquisition must be known in order to correct for snowmelt between the image date and the end of the summer.

We explored several sources for appropriate archival photographs, mainly the vertical photography used by the USGS to prepare topographic maps (mostly taken in the late 1940s or early 1950s), the USGS Ice and Climate Project photographs taken by Austin Post, Bob Krimmel, and Larry Mayo from the 1950s through the 1990s, and the Alaska High Altitude Aerial Photography collection which covers most of Alaska and was flown from 1978 to 1986. In all we found 65 photographs covering snowlines on 25 glaciers located between Valdez and Petersburg, Alaska. (We began by limiting our search to the glaciers we flew with the digital imaging system described below.) The snowlines were manually transferred to the corresponding USGS 15-minute series topographic maps and then digitized and imported into a geographical information system (GIS) database.

By adding the digital camera to our laser altimetry system, we were able to piggyback the collection of new imagery onto other field work which was already planned. The airborne laser altimetry equipment includes a global positioning system receiver used to locate the airplane throughout each flight, a fiber-optic gyroscope to determine the attitude (pitch and roll), and a laser rangefinder to measure the distance from the airplane to the glacier surface. The camera is a compact digital video camera operating at 15

frames per second and with a high shutter speed—this allows us to select from hundreds of images taken as we pass over a portion of the glacier. All of the equipment communicates with a central data acquisition computer to synchronize timing of the measurements. Post-processing of the position, attitude and rangefinder data along with the selected digital images allows us to create video maps (georeferenced images) of the portion of the glacier which passed beneath the airplane during flight. In the same GIS database mentioned above, we were able to extract the locations of the video snowlines. We acquired images during August and September 2000, and returned to most of the same glaciers one year later for repeat measurements.

Because the snowline images of both types were acquired anywhere between August 15 and September 9, they had to be adjusted to account for the time between the date of acquisition and the maximum or late summer snowline elevation (which corresponds with the ELA). We used the output from a glacier mass balance model which produces a time series of snowline elevation for each year of weather station data input (Tangborn, 1999). Graphs depicting the snowline rise over each summer from 1950 to 1998, as predicted for the Seward/Malaspina glacier system, showed that on average the maximum snowline elevation was reached on September 3, before winter snow accumulation quickly brought the snowline back down the glacier. This is a model based on weather station data and topography of a glacier up to several hundred kilometers away from our subject glaciers. To correct the elevations, we took the difference between the modeled ELA at the time of image acquisition and September 3. Because the snowline rise curve was only used as a correction to the actual observations, and the average correction was 24 m, the lack of field-checked snowline rise data specific to each glacier and year was not a large source of uncertainty.

Results

Figure 1 shows one of the video snowline images from Johns Hopkins glacier. This and the other images were used to measure 100 ELAs on 25 glaciers, with anywhere from two to nine separate years of data from each glacier. Due to the interannual variability of glacier ELAs, our data are not sufficient to show time-dependent trends over the last 50 years. They do, however, show that there are consistent geographical patterns among the years with simultaneous data from many glaciers. While the ELAs do vary from year to year, the relative elevations among individual glaciers appear to be fairly consistent. In the Chugach Mountains, the only area where our coverage traverses from the coast to a considerable distance inland, we see a trend of increasing ELA with distance from the coast (Figure 2). Those glaciers outside of the Chugach Mountains (in the St. Elias Mountains and Coast Range) display a pattern of ELAs which are neither as smooth geographically nor as consistent from year to year.

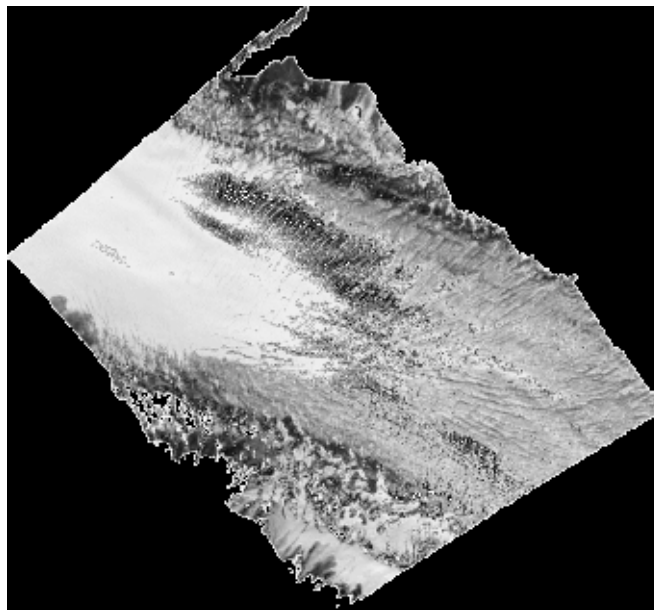


Figure 1: Georeferenced image of the snowline on Johns Hopkins Glacier, acquired with the video imaging system on August 29, 2000. This image is made up of 36 frames of video stitched together using GPS, attitude and altimetry data.

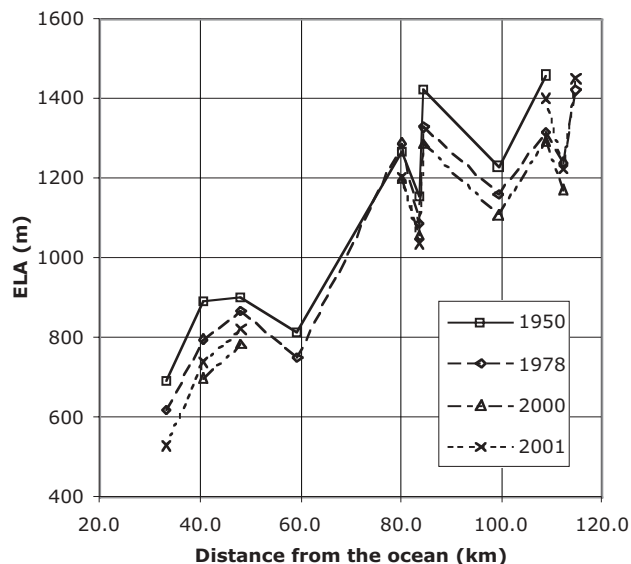


Figure 2: Plot showing the consistent pattern of ELAs in the eastern Chugach Range over time. Similar plots for other parts of the state did not show such a consistent pattern.

Future work

The next task in this project is to use satellite imagery to increase the area covered by our measurements. We have found that it can be difficult to locate appropriate satellite images which fit the same criteria we used for our images (unobscured and timed near the end of summer). Our knowledge of the patterns found in the aerial images will help us in

a similar manner as ground truthing does in other studies which use satellite data. We have already acquired Landsat 5 Thematic Mapper images covering the Chugach range and will proceed to use them in conjunction with the photograph and video data to compile a map of ELA distribution throughout the region. From there we will look for trends which can aid in the extrapolation of volume change data from a few glaciers to those nearby.

Acknowledgments

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Global Change and Song Sparrow Populations in Alaska: An Assessment of Temporal and Spatial Changes using Molecular Markers

by **Christin L. Pruett**, Department of Biology and Wildlife, University of Alaska Fairbanks, and the University of Alaska Museum; currently at Texas A&M University, College Station, Texas.

Introduction

How will global change affect coastally distributed high latitude organisms? I addressed this question by examining how historic and contemporary changes have affected the structure of song sparrow (*Melospiza melodia*) populations in Alaska. Several factors make song sparrows a model species for determining how past and recent climatic changes have affected the population structure of a high latitude taxon. First, they are spatially diverse. They range over the entire southern coast of Alaska and are one of only a few landbird species that are distributed throughout the Aleutian Islands (Murie, 1959). Second, they were probably strongly affected by past glacial events, because most of their range in Alaska

was completely glaciated during the last glacial maximum (Barnosky et al., 1987). Third, they are morphologically variable (as many as eight subspecies are described in Alaska; Peters, 1970), which might be due to past glacial isolation of populations. Fourth, there is some mtDNA sequence evidence that Pleistocene glaciation caused the current distribution of many North American populations of song sparrows (Fry and Zink, 1998). Fifth, preliminary mtDNA sequence data indicates that Aleutian Island populations were isolated from mainland populations before the last glacial maximum. This factor alone suggests that song sparrows have a complex history of population change in response to climatic changes. A final factor is that song sparrows are coastally distributed throughout much of their range in Alaska, primarily feeding in inter-tidal areas and nesting and raising their young in nearby vegetation (Murie, 1959; personal observations). These areas would be strongly affected if predicted sea level changes occur (ARCUS, 1998).

Methods

mtDNA sequences and microsatellite loci were used to examine song sparrow populations. These markers are known to evolve at different rates (Shields and Wilson, 1987; Fleischer et al., 1998; McDonald and Potts, 1997), and thus both historical and more recent population structure can be examined. Spatial comparisons were also performed by sequencing (n = 59) and genotyping (n = 208) individuals from eight populations of song sparrows in Alaska. These methods were used to address three major questions: 1) how did glaciation affect song sparrow populations? 2) how have populations changed since glaciation? 3) what is the current status of song sparrow populations?

Results and Discussion

Effects of historic glaciation. Much of the current range of song sparrows in Alaska is thought to have been completely glaciated during the last glacial maximum (Hamilton et al., 1986). Thus, a very recent expansion into the entire Alaska range seems likely. However, estimates of divergence dates based on mtDNA sequences (>10,000 years before present) show that there were three or four refugial populations within the current distribution of western song sparrows. These include several previously identified refugial areas in southeast Alaska and the Queen Charlotte Islands (Scudder and Gessler, 1989; Byun et al., 1997) and an only recently identified location in the Aleutian Islands (Holder et al., 1999; Congdon et al., 2000).

Estimates of historical effective population size (the number of breeding adults that contribute their genes to the next generation) based on mtDNA sequences indicate that the Aleutian refugial populations had few individuals. This suggests that glacial isolation probably caused these populations to become bottlenecked. It is likely that historic climate change fragmented song sparrows into multiple small populations, some of which persisted through the last glacial maximum.

Post-glacial population shifts. While estimates of effective population size based on mtDNA sequences show that refugial populations were smaller than non-refugial populations, effective sizes based on microsatellite analyses indicate that all populations currently have similar sizes. This suggests that Aleutian refugial populations have rebounded in size since the last glacial maximum.

Genetic diversity in the geographically most isolated island populations (Aleutian Islands) is significantly lower than in populations closest to the center of the species range (e.g., southeast Alaska). Some of these populations also show signs of having been glacially isolated. Therefore, it is difficult to determine whether this low genetic diversity is due to isolation by distance or by glacial isolation. Because some populations that have refugial signatures (estimates of divergence that pre-date the last glacial maximum) have higher genetic diversity, it is likely that the continued geographic isolation (and thus a lack of current gene flow) of island populations played a major role in maintaining the limited diversity found in Aleutian populations.

Status of song sparrows in Alaska. The genetic evidence indicates that there is little contemporary gene flow between populations that were described as different based on morphology alone. This finding lends support to the continued recognition of these morphological subspecies.

Populations that have the lowest genetic diversity (and are thus theoretically the most at risk for extinction; Futuyma, 1989) are found in the Aleutian Islands and have coastally restricted distributions (Murie, 1959). Thus, if sea levels were to fluctuate quickly, these populations could be in jeopardy. However, estimates of population divergences indicate that the Aleutian populations have persisted through past climate changes, and thus might have maintained a level of diversity sufficient to withstand the climate changes of the future.

Arctic Research Video Available

A new documentary film on climate change research in the Arctic, "A Changing Landscape: Investigating a Warming Arctic," has recently been released. This film features research from the National Science Foundation's Land-Atmosphere-Ice Interactions (LAI) program, and focuses on fieldwork on the Seward Peninsula and at Barrow. The video aired on KUAC/Alaska One in April 2003, and will be distributed more widely by KUAC.

A limited number of complimentary copies of the video are available through the Center for Global Change/LAI Science Management Office. E-mail cgc@iarc.uaf.edu with your request, or call 474-5818.

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