

ABSTRACT

The goal of the Arctic LTER project is to predict the future ecological characteristics of Arctic Alaska based upon our knowledge of the controls of ecosystem structure and function as exerted by physical setting and geologic factors, climatic factors, biotic factors, and the changes in fluxes of water and materials from land to water.

The site lies at 68°N in the northern foothills of the Brooks Range, Alaska, in tundra vegetation of sedges and grasses mixed with dwarf birch and low willows. The tundra, streams, and lakes at the site have been undisturbed and unchanged for more than 5,000 years; caribou and moose move freely over this region pursued by wolves and grizzly bears. Populations of lake trout, char, and arctic grayling are in a pristine state, often dominated by very large and very old individuals. This allows the analysis of relationships in plants and animal communities in an ecosystem unaffected by an ecological legacy of human use.

The climate of northern Alaska has changed remarkably over the past 30 years; the 0.7°C per decade increase in temperature could result in much more than the 3–5° total change predicted by GCM models for a doubling of CO₂. Based on several types of observations, there appears to be a biotic response to this regional warming. The nature of this response, its controls, and its long-term implications are under investigation through:

1. **Long-term monitoring and surveys** of natural variation of terrestrial and aquatic ecosystems in space and time. Includes: climate, plant communities and productivity, thaw depth, stream flow, chemistry of streams and lakes, temperatures of streams and lakes, lake chlorophyll lake productivity, zooplankton abundance.
2. **Long-term experimental manipulation of terrestrial and aquatic ecosystems.** Includes: tundra warming, shading, and fertilizing, grazer exclusions, fertilization of lakes and streams, addition and subtraction of predators.
3. **Synthesis of results and predictive modeling** at ecosystem and watershed scales. Includes: stream N cycling, lake physics, bioenergetics of fish populations, water movement and transfer of DOC and nutrients from land to water, soil respiration, cycling and storage of C in tundra under different scenarios of future climates.

TERRESTRIAL RESEARCH

Predictions of long-term change based on short-term observations are notoriously unreliable. Two decades of experimental studies at the Arctic LTER site provide a unique opportunity to test such predictions and to improve the models that make the predictions. For example, when we harvested a 20 year old fertilizer experiment in moist acidic tundra in 2000, we found a net LOSS of almost 2000 g C m⁻² despite the fact that C inputs had been doubled for 20 years (Figure 1), through stimulation of NPP as a result of N addition (Mack et al. 2005). Most of this loss was due to large losses of old soil C, while plant and surface soil C pools increased. The most surprising result was that these large C losses were accompanied by large N losses, despite addition of 200 g m⁻² N over the same 20 year period (Figures 1, 2).

One possible explanation for the “missing N” in our experiment is that N is actually more mobile in these tundras than previously assumed in our modeling and other research. To test this possibility we added 15N at several points along a toposequence of vegetation types in the Imnavait Creek drainage near Toolik Lake (Figure 3).

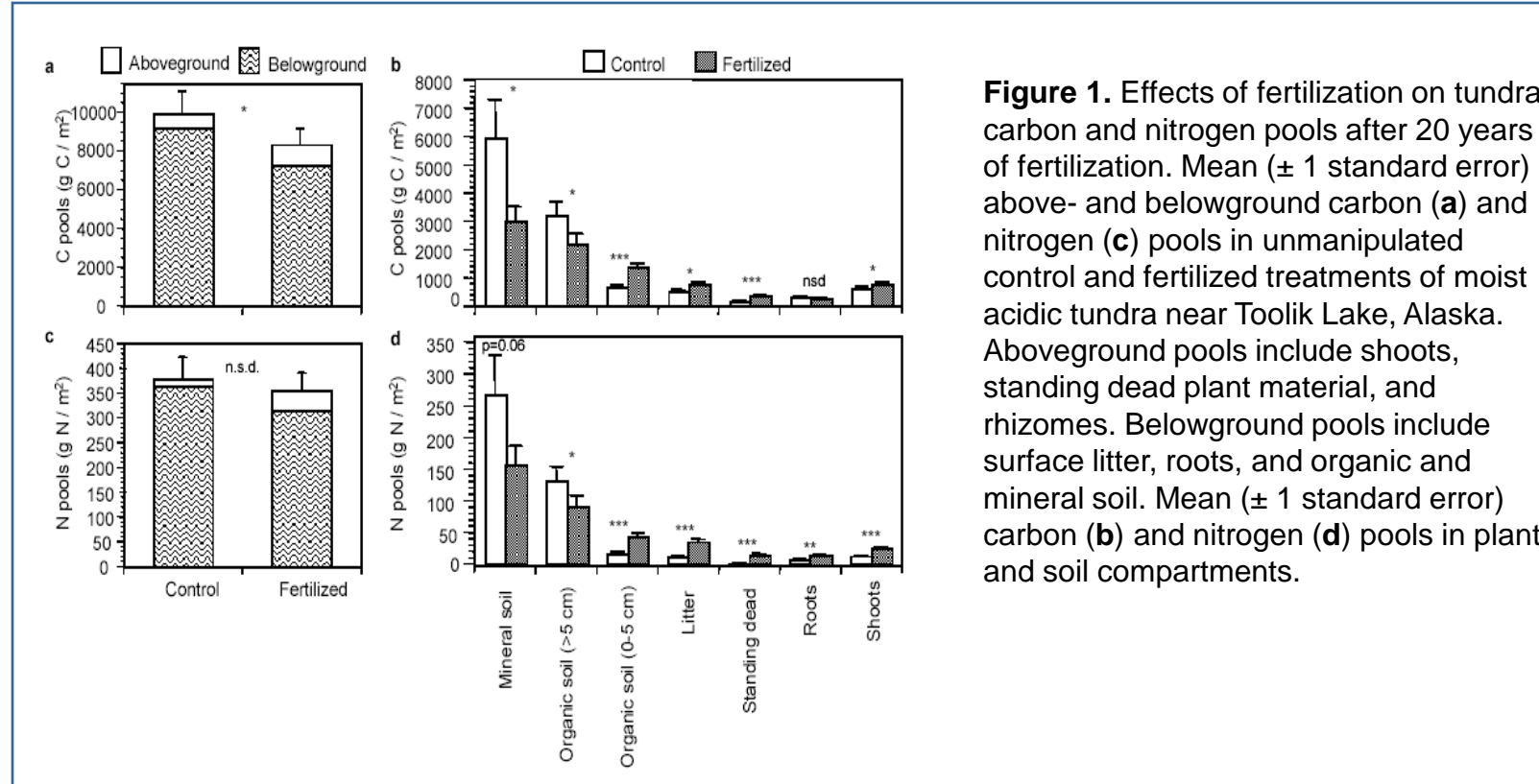


Figure 1. Effects of fertilization on tundra carbon and nitrogen pools after 20 years of fertilization. Mean (\pm 1 standard error) above- and belowground carbon (a) and nitrogen (b) pools in unmanipulated control and fertilized treatments of moist acidic tundra near Toolik Lake, Alaska. Aboveground pools include shoots, standing dead plant material, and rhizomes. Belowground pools include surface litter, roots, and organic and mineral soil. Mean (\pm 1 standard error) carbon (a) and nitrogen (b) pools in plant and soil compartments.

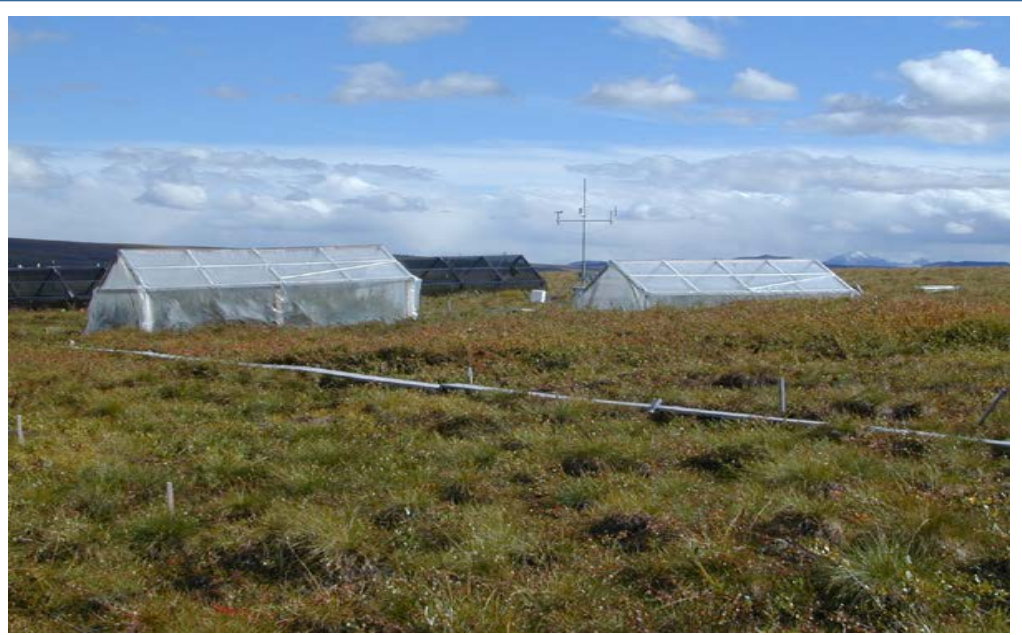


Figure 2. The middle ground in this photograph of moist acidic tundra shows a plot that has been fertilized with N and P for 17 years. The plot is now dominated by dwarf birch, *Betula nana*, and the greater height and density of the canopy reflects a doubling of NPP.

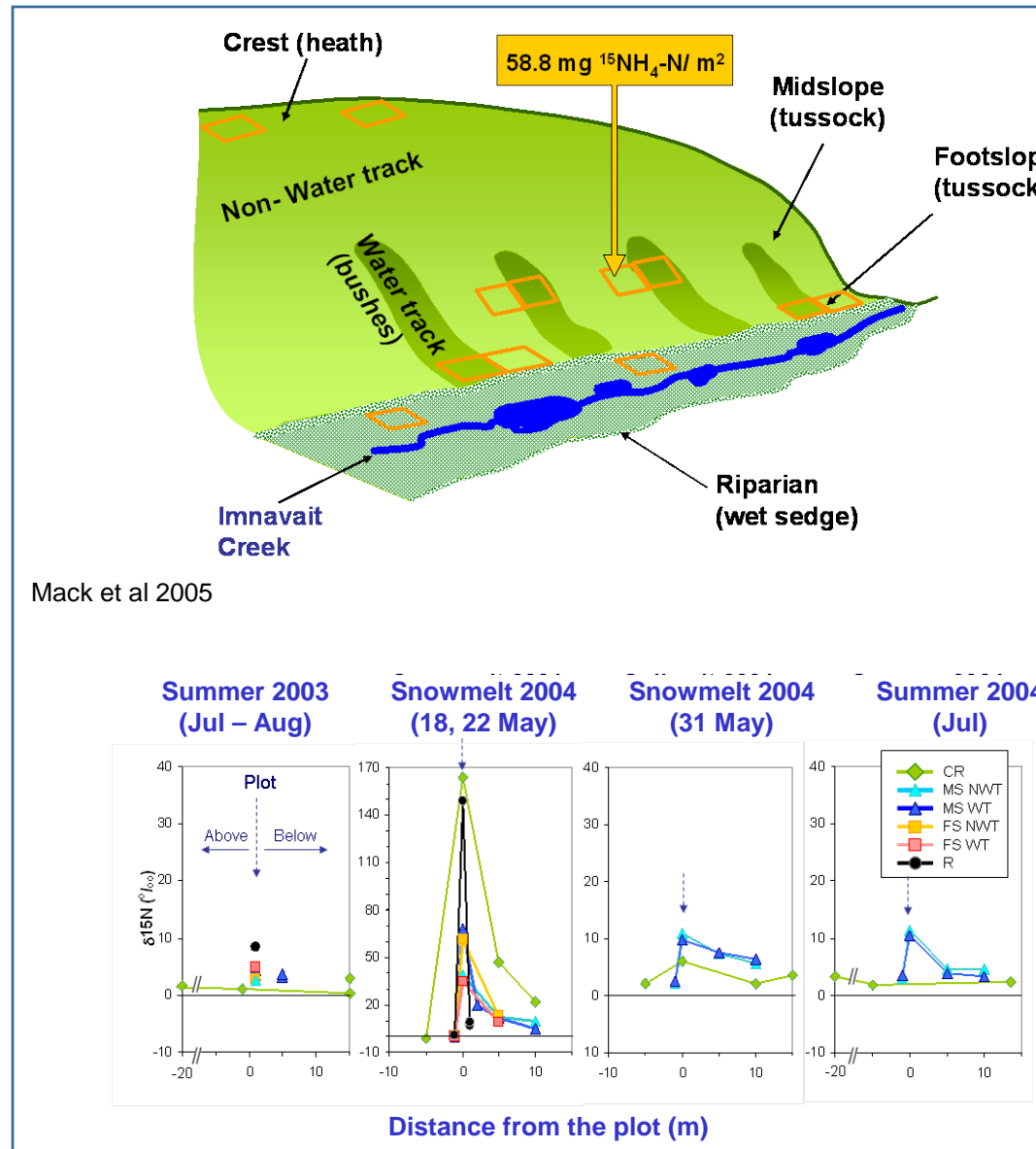


Figure 3. Addition of ¹⁵N along a toposequence at Imnavait Creek shows relatively little movement of the added N.

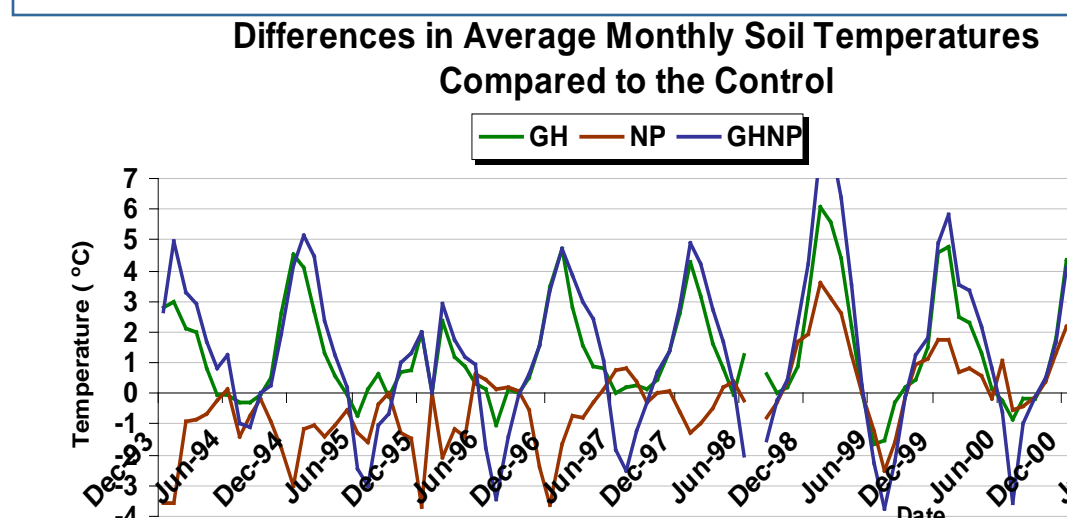
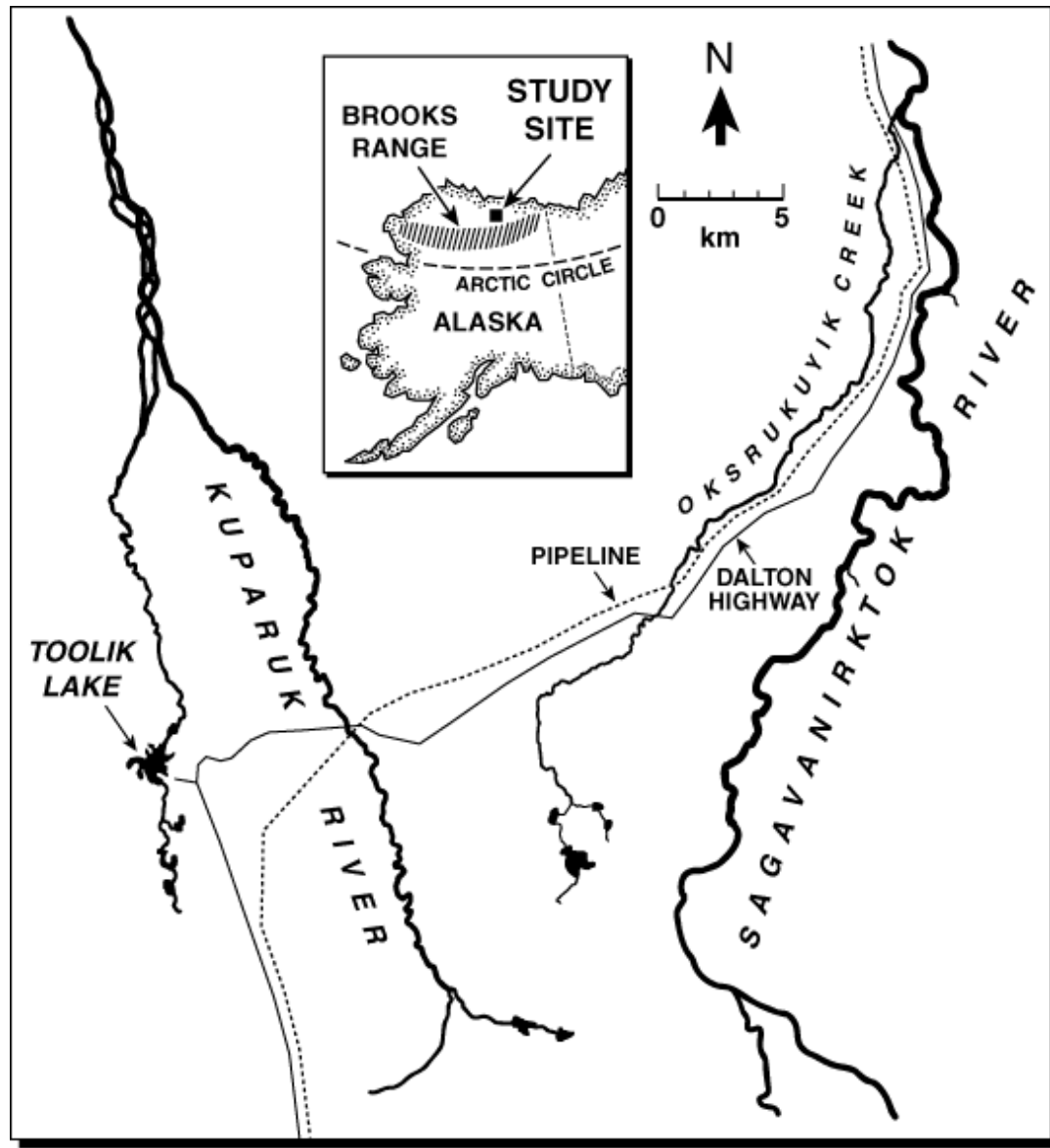


Figure 4. Soil temperatures beneath shrub-dominated plots are warmer in winter and colder in summer than in controls.

ARCTIC LTER

Predicting the Future Ecological Characteristics of the Toolik Lake Region



LOCATION

Toolik Field Station (University of Alaska) is at 68°N in northern foothills of Brook Range. The site lies in formerly-glaciated rolling hills covered with tussock tundra; the site also contains oligotrophic lakes (20 m d_{max}) and streams.

Air Temp	May	0.6°C
	June	8.1
	July	11.9
	August	7.4
	Yr Avg	-8.4
Precipitation	200-300 mm	

STREAMS

Human disturbance of the tundra and long-term climate change are causing changes in the input of nutrients to stream ecosystems. Certain aspects of these changes can be anticipated from the results of our experiments, monitoring and surveys in the Toolik foothills region. For example, a warming climate and human disturbances such as road construction and associated gravel removal can lead to increased seepage of nutrients into tundra streams. Streams research at Toolik has combined long-term monitoring and fertilization of the Kuparuk River with broad-scale surveys of tundra streams throughout the foothills region. Nutrient enrichment of streams that are naturally low in nutrients leads to rapid changes in the benthic diatom communities (Figure 1) and in microbial activity. However, these rapid responses of stream ecosystems are dwarfed by larger changes in the structure of stream ecosystems that occur on the decadal time scale. The riffles of the pristine Kuparuk river were initially covered by bare rocks with an occasional tuft of moss.

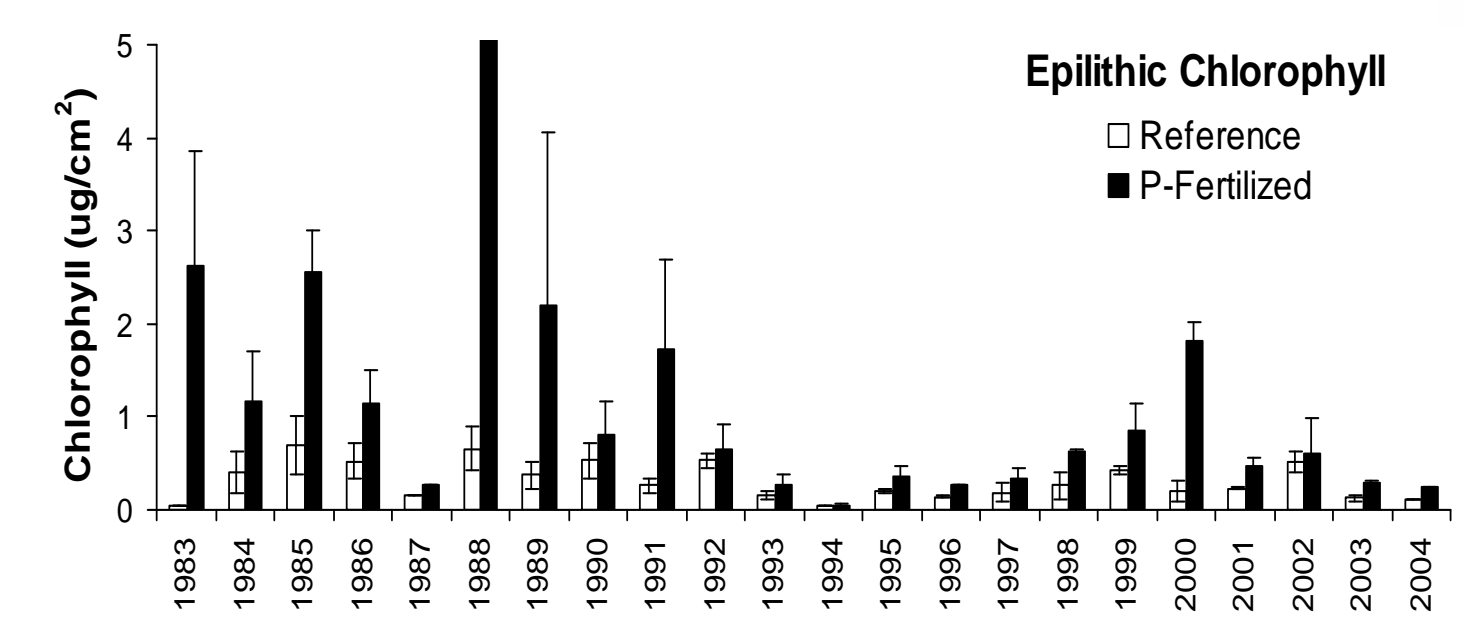


Figure 1. Epilithic total chlorophyll in the reference and fertilized reach riffles of the Kuparuk River. Chlorophyll values for 1987 and 1994 means only include August values. In 1988, fertilized reach chlorophyll values are inflated due to contamination by green algal filaments. Data are means \pm 1 SE, updated version of published data, K. Slavik, 2004.

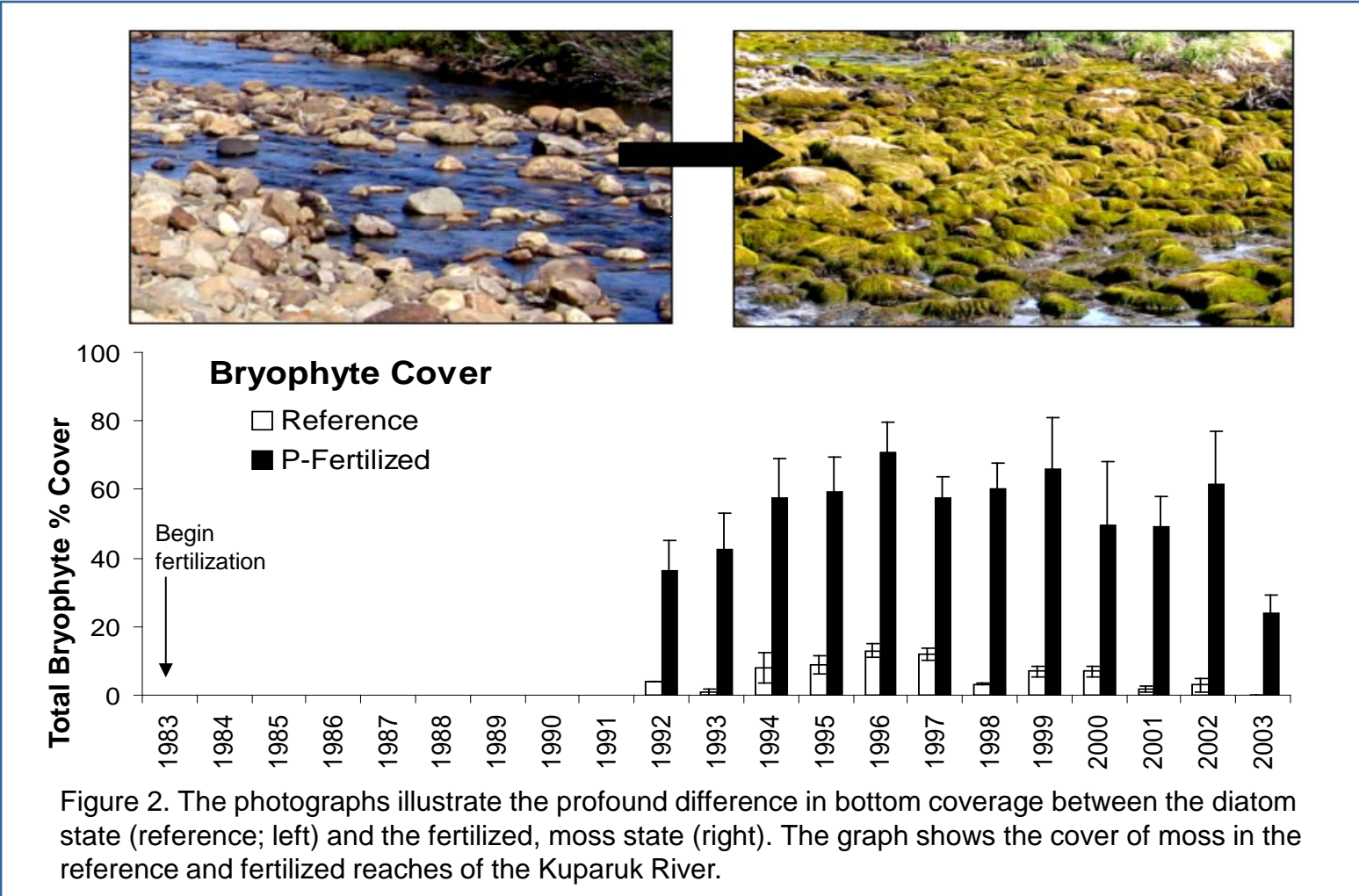


Figure 2. The photographs illustrate the profound difference in bottom coverage between the diatom state (reference; left) and the fertilized, moss state (right). The graph shows the cover of moss in the reference and fertilized reaches of the Kuparuk River.

We have used the long-term observations of the Kuparuk River combined with a first-order approximation inverse model to develop understanding of how the river ecosystem responds to inter-annual variations in temperature, discharge and solar radiation. The model was calibrated with climate and stream data from nine years and then challenged to predict stream ecosystem stocks and fluxes from climate data alone for years not used in the calibration (Figure 3). For several model compartments the calibration is very accurate and the model forecasts are fairly good. For example chironomids, black flies and fish growth can be estimated well from variation in climate drivers alone.

Climate change on the North Slope of Alaska during this century has been simulated with climate models (ACIA 2005). Predictions for river discharge and for solar radiation in 2090-2099 are similar to current conditions but temperatures are higher by about 2°C. Under these conditions, the model predicts lower diatom abundance, lower fish growth but higher chironomid abundance. Information is needed on future changes in nutrient inputs to improve these predictions. For example, should we use reference reach or fertilized reach model calibrations for long-range prediction and will the stream bottom be moss covered?

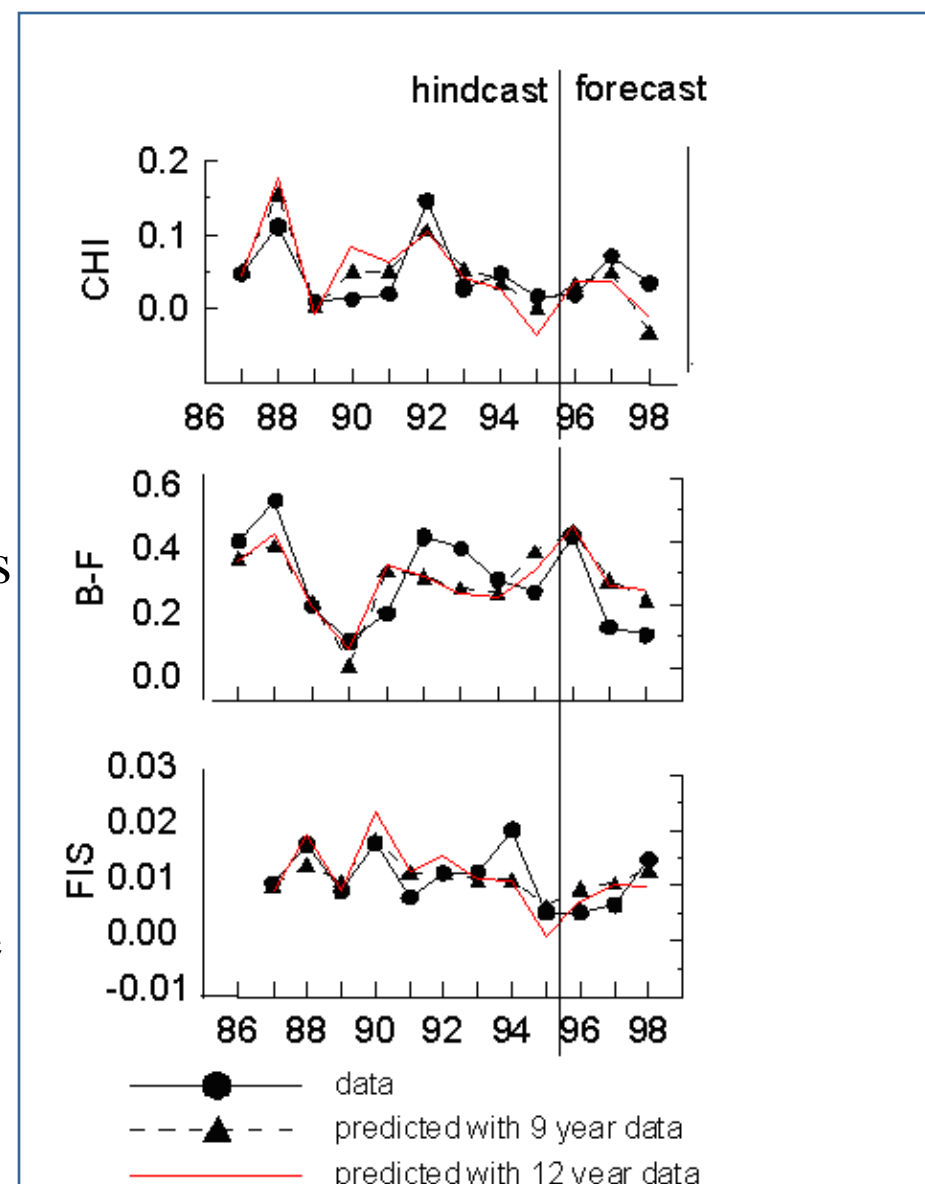


Figure 3. Comparisons of model predictions (triangles) with observations (dots) for chironomid (CHI), black fly (B-F), and fish growth (FIS) in the reference reach of the Kuparuk River. Years 87-95 used for calibration and 96-98 for testing. Red line shows 12 year model calibration.

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LAKES

As the climate continues to warm in Arctic landscapes, we expect that increased melting of permafrost will result in increased loadings of organic matter and associated inorganic nutrients to lakes. In 2001 we began a low level fertilization of two lakes to assess impacts of increased nutrient loadings on lake ecosystems.

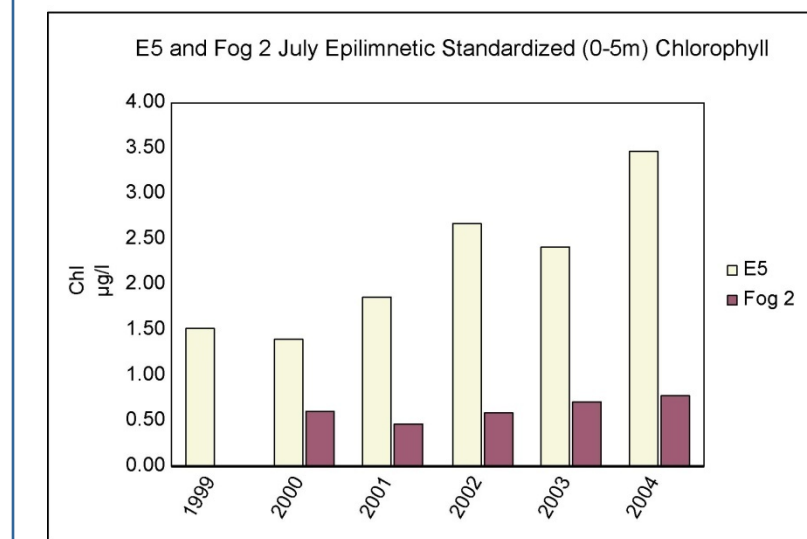
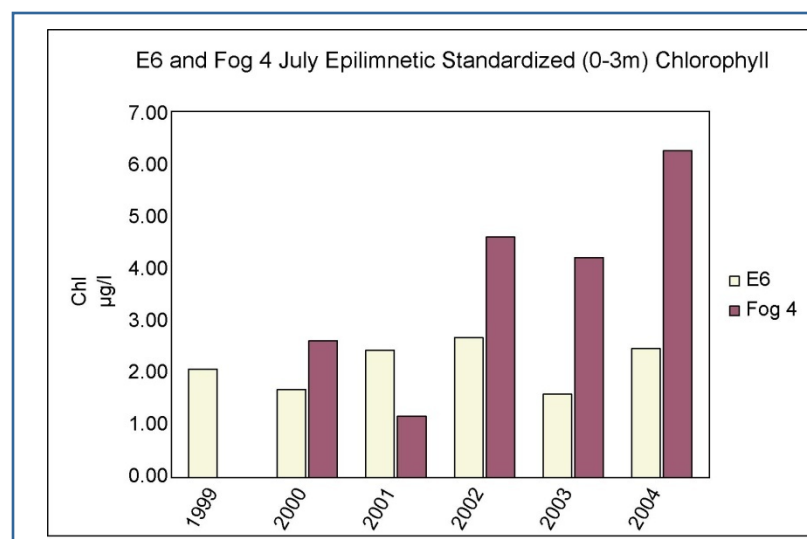


Figure 1. Chlorophyll increased in two fertilized lakes (E-5 and E-6) compared to reference lakes of similar morphology (Fog-2 and Fog-4) after fertilization began in 2001.



Results from mesocosm experiments indicated that this decrease in light can reduce benthic primary production and suggests that climate warming may increase pelagic production while decreasing benthic productivity in Arctic lakes (Figure 3). Analyses of fish feeding habits and stable isotope composition demonstrate that more than 90% of fish production is derived from benthic invertebrates. Results of these studies suggest that fish populations may be detrimentally affected by increased nutrient loading to Arctic lakes.

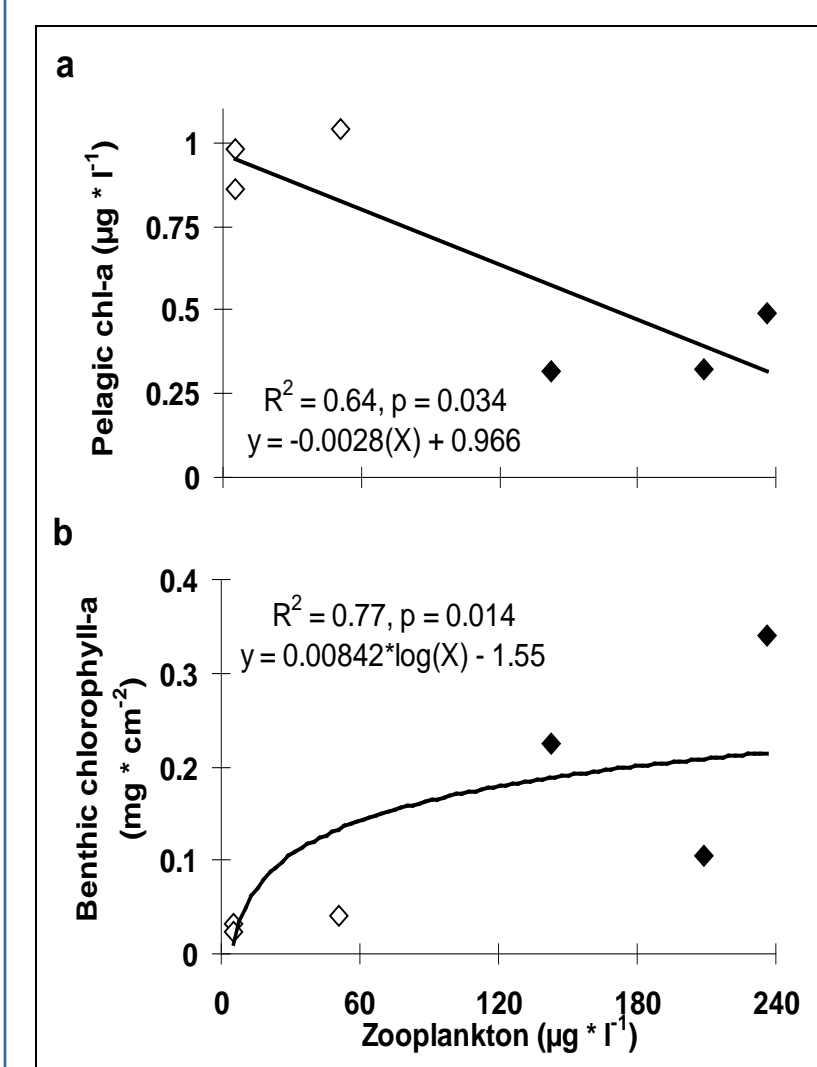


Figure 3. Mesocosm results indicated that benthic chlorophyll was reduced in enclosures where pelagic chlorophyll was high.