Annual Report for Period: 03/2011 - 02/2012
Submitted on: 02/14/2012
Principal Investigator: Shaver, Gaius R.
Award ID: 1026843
Organization: Marine Biological Lab
Submitted By:
Shaver, Gaius - Principal Investigator
Title:
Arctic LTER: Climate Change and Changing Disturbance Regimes in Arctic Landscapes

Project Participants

Senior Personnel

Name: Shaver, Gaius
Worked for more than 160 Hours: Yes
Contribution to Project:
Shaver is lead PI of the project and also participates in terrestrial research on plant ecology and C-N interactions, and on fire and other disturbance impacts.

Name: Bowden, William
Worked for more than 160 Hours: Yes
Contribution to Project:
Bowden is a member of the project Executive Committee and coordinates streams research as well as research on thermokarst.

Name: Luecke, Chris
Worked for more than 160 Hours: Yes
Contribution to Project:
Luecke is a member of the project Executive Committee and coordinates Lakes research; his personal research interests are in lake food webs.

Name: Kling, George
Worked for more than 160 Hours: Yes
Contribution to Project:
Kling is a member of the project Executive Committee and coordinates Land-Water interactions research as well as his own research on lake and catchment biogeochemistry

Name: Giblin, Anne
Worked for more than 160 Hours: Yes
Contribution to Project:
Giblin is a member of the Executive Committes and oversees the project's chemical analytical lab and personnel. Her research is on biogeochemistry of sediments and soils.

Name: Peterson, Bruce
Worked for more than 160 Hours: Yes
Contribution to Project:
Peterson is an aquatic ecologist and biogeochemist; in this project his main research interests are in stream ecology and biogeochemistry

Name: Deegan, Linda
Worked for more than 160 Hours: Yes
Contribution to Project:
Deegan is an aquatic ecologist with research on the role of fishes; in this project most of her research is on fishes in streams

Name: Huryn, Alex
Worked for more than 160 Hours: Yes
Contribution to Project:
Huryn is an aquatic community ecologist, working mainly on stream communities.

Name: Hobbie, John

Worked for more than 160 Hours: Yes

Contribution to Project:

Hobbie is the former PI of this project; he is a microbiologist interested in the role of microbes in both aquatic and terrestrial ecosystems.

Name: Gough, Laura

Worked for more than 160 Hours: Yes

Contribution to Project:

Laura Gough is a plant ecologist interested in the regulation of plant diversity and community composition, in plant-animal interactions, and in controls on plant productivity and distribution.

Name: Moore, John

Worked for more than 160 Hours: Yes

Contribution to Project:

Moore is a terrestrial ecologist who does research on food webs, especially in soils, including modeling and theory development

Name: Wallenstein, Matthew

Worked for more than 160 Hours: Yes

Contribution to Project:

Wallenstein is a soil microbiologist with research interests in soil enzymology and C and N cycling

Name: Budy, Phaedra

Worked for more than 160 Hours: Yes

Contribution to Project:

Budy is a lake ecologist with particular interests in fish and lake trophic structure

Name: Boelman, Natalie

Worked for more than 160 Hours: Yes

Contribution to Project:

Boelman is a specialist in remote sensing of terrestrial ecosystems including research on vegetation phenology and on plant-animal interactions

Name: Tang, Jianwu

Worked for more than 160 Hours: Yes

Contribution to Project:

Tang is a terrestrial biogeochemist with a particular interest in soil C cycling and ecosystem C balance

Name: Rastetter, Edward

Worked for more than 160 Hours: Yes

Contribution to Project:

Rastetter is an ecosystem modeler with particular interest in multiple resource interactions and biogeochemistry

Name: Bret-Harte, Syndonia

Worked for more than 160 Hours: Yes

Contribution to Project:

Bret-Harte is a terrestrial plant ecologist and physiologist, interested in controls on plant growth, productivity, and vegetation composition

Name: Mack, Michelle

Worked for more than 160 Hours: Yes

Contribution to Project:

Mack is a terrestrial plant/soil ecologist with a particular interest in species effects on biogeochemistry, and on the role of fire in northern ecosystems

Post-doc

Graduate Student

Name: Daniels, William
Worked for more than 160 Hours: Yes
Contribution to Project:
Beginning PhD student at Brown, working on lakes

Name: Longo, William
Worked for more than 160 Hours: Yes
Contribution to Project:
Beginning PhD student at Brown, working on Lakes

Name: Dombrowski, Jason
Worked for more than 160 Hours: Yes
Contribution to Project:
Master's student at University of Michigan, working on Land-water exchanges and biogeochemistry

Name: Ward, Collin
Worked for more than 160 Hours: No
Contribution to Project:
PhD student at University of North Carolina, working on organic photochemistry

Undergraduate Student

Name: Papworth, Brittany
Worked for more than 160 Hours: No
Contribution to Project:
Undergraduate at University of North Carolina, workingon organic photochemistry

Name: Fisher, Kate
Worked for more than 160 Hours: Yes
Contribution to Project:
research assistant

Name: Moore, Hannah
Worked for more than 160 Hours: Yes
Contribution to Project:
research assistant

Technician, Programmer

Name: Schuett, Elissa
Worked for more than 160 Hours: Yes
Contribution to Project:
Streams research assistant, based at University of Vermont

Name: Binderup, Andrew
Worked for more than 160 Hours: Yes
Contribution to Project:
Aquatic research assistant

Name: Koenig, Lauren
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Laundre, James

Worked for more than 160 Hours: Yes
Contribution to Project:

Name: van der Pol, Laura
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: White, Daniel
Worked for more than 160 Hours: Yes
Contribution to Project:
Lakes research assistant, based at MBL

Name: Kostrzewski, Jennifer
Worked for more than 160 Hours: Yes
Contribution to Project:
Senior research technician for land-water research, based at University of Michigan

Name: Yelen, Lauren
Worked for more than 160 Hours: Yes
Contribution to Project:
Technician at the University of Michigan. Runs analytical equipment to analyze chemistry of samples collected at Toolik during summer

Name: Fortin, Sara
Worked for more than 160 Hours: Yes
Contribution to Project:
Analyzes water chemistry. At Toolik in summer. Based at University of Michigan. Runs equipment to analyze water chemistry.

Other Participant

Research Experience for Undergraduates

Name: Waldvogel, Genna
Worked for more than 160 Hours: Yes
Contribution to Project:
Student at University of Vermont

Name: Hendrix, Christopher
Worked for more than 160 Hours: Yes
Contribution to Project:
Student at University of Texas Arlington

Organizational Partners

Sanchez Industrial Design

Horn Point Laboratory, U. Maryland

Alaska Bird Observatory

Other Collaborators or Contacts

Mike Gooseff, PI, Pennsylvania State University
Wil Wollheim, PI, University of New Hampshire,
Michael Flinn, PI, Murray State University
Peter Ray, PI, University of Alaska Fairbanks
Bethany Neilson, PI, Utah State University
Rose Cory, PI, University of North Carolina
Erik Hobbie, PI, University of New Hampshire
Michael Flinn, PI, Murray State University
Parton, Bill, co-PI, Colorado State University
John Wingfield, PI, U. of California-Davis
Nick Bouwes, Adjunct Research faculty, Utah State University
Brett Roper, Research Faculty, Utah State University, US-Forest Service
Gary Thiede, Research Associate, Utah State University
Kyle Whittinghill, postdoc, University of New Hampshire
Marjan van de Weg, postdoc, MBL
Kristina Schaedel, postdoc, University of Florida
Javier Vidal, post doc, UCSB
Edmond W. Tedford, post doc, UCSB
Jennie McLaren, postdoc, University of Texas-Arlington
Rod Simpson postdoc, Colorado State University
Akihiro Koyama, Colorado State University
Malcolm Herstand, MS Student, University of Vermont
Adam Wlostowski, MS Student, Pennsylvania State University
Clair Treat, PhD student, University of New Hampshire
Jeff Kampman, MS Student, Murray State University
Julia Larouche, PhD Student, University of Vermont
Michael Kendrick, PhD student, University of Alabama
Heidi Golden, PhD student, University of Connecticut
Shannan Sweet, Grad Student, Columbia University
Jesse Krause, Grad Student, UC Davis
Matthew Rich, Grad Student, U Texas Arlington
Karen Word, Grad Student, UC Davis
Jonathan Perez, Grad Student, UC Davis
Camila Pizano graduate student, University of Florida
Martijn Slot graduate student, University of Florida
Laura Schreeg graduate student, University of Florida
Julie Shamhart, Graduate Student, UNH
Jessica Ernakovich Graduate student, Colorado State University
Caroline Melle Graduate student, Colorado State University
Oscar Marquina, MS student, Utah State University
Madeline Merck, MS student, Utah State University
Patrick Tobin, Undergraduate Research Assistant, University of Vermont
Cameron MacKenzie, technician, MBL
Verity Salmon, RAII, MBL
Miriam Johnston, RA, MBL
Jake Schas, RA
Kira Taylor-Hoar, summer undergraduate assistant, University of Florida
Greg Selby, RA Colorado State University
Jason Leverton, Undergraduate Colorado State University
Mary Hunter-Laszlo, Teacher, Colorado State University
Dave Swartz, Teacher, Colorado State University
Rebecca Waterford, REU, undergrad,UCSB
Jade Lawrence, REU, undergrad, UCSB
Brian Emery, technician, UCSB

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)
see attached file

Findings: (See PDF version submitted by PI at the end of the report)
See attached file.

Training and Development:
Supported 2 REU students and 4 graduate students in 2011

Outreach Activities:
Our Schoolyard program, based in Barrow, serves as an outreach program through weekly public lectures about science in northern Alaska

Journal Publications

Adams, H. E., B. C. Crump and G. W. Kling, "Temperature controls on aquatic bacterial activity and community dynamics.", Environmental Microbiology, p. 1319, vol. 12, (2010). Published,

Boelman, NT; Gough, L; McLaren, JR; Greaves, H, "Does NDVI reflect variation in the structural attributes associated with increasing shrub dominance in arctic tundra?", ENVIRONMENTAL RESEARCH LETTERS, p. , vol. 6, (2011). Published, 10.1088/1748-9326/6/3/03550

Boelman, N.T., A.V. Rocha, and G.R. Shaver, "Understanding burn severity sensing in Arctic tundra: exploring vegetation indices, suboptimal assessment timing and the impact of increasing pixel size.", International Journal of Remote Sensing, p. 7033, vol. 32, (2011). Published, DOI:10.1080/01431161.2011.611187

Budy, P. and C. Luecke., "Understanding the drivers of fish population dynamics in unique, Arctic lakes with special consideration of the role of climate and climate change", Oceologia, p. , vol. , (2012). Accepted,

Conant, RT; Ryan, MG; Agren, GI; Birge, HE; Davidson, EA; Eliasson, PE; Evans, SE; Frey, SD; Giardina, CP; Hopkins, FM; Hyvonen, R; Kirschbaum, MUF; Lavallee, JM; Leifeld, J; Parton, WJ; Steinweg, JM; Wallenstein, MD; Wetterstedt, JAM; Bradford, MA, "Temperature and soil organic matter decomposition rates - synthesis of current knowledge and a way forward", GLOBAL CHANGE BIOLOGY, p. 3392, vol. 17, (2011). Published, 10.1111/j.1365-2486.2011.02496.

Elmendorf, Sarah C., Gregory H.R. Henry, Robert D. Hollister, Robert G. Bj????rk, Anne J. Bjorkman, Terry V. Callaghan, Elisabeth J. Cooper, Johannes H.C. Cornelissen, Thomas A. Day, Anna Maria Fosaa, William A.Gould, J????rnger????ur Gr????tarsd????ttir,, "Global assessment of simulated climate warming on tundra vegetation: Heterogeneity over space and time", Ecology Letters, p. 164, vol. 15, (2012). Published,

Elmendorf, S. C., G.H.R. Henry, R. D. Hollister, R. G. Bjork, No???????mie Boulanger-Lapointe, E. J. Cooper, J. H.C. Cornelissen, T. A. Day, E. Dorrepaal, T. G. Elumeeva, M. Gill, W. A.Gould, J. Gr???????tarsd???????ttir, J, Harte, D. A. Hik, A. Hofgaard, " Tundra vegetation change and recent climate warming: is there evidence at the plot scale?", Nature Climate Change, p. , vol. , (2012). Accepted,

Euskirchen, E.S., M.S Bret-Harte, G.J. Scott, and G.R.Shaver, "Seasonal patterns of carbon and water fluxes in three representative ecosystems in the northern foothills of the Brooks Range, Alaska", Ecosphere, p. 4, vol. 3, (2012). Published, http://dx.doi.org/10.1890/ES11-00202.1

Gough, L, JC Moore, GR Shaver, RT Simpson, and DR Johnson., "Above- and Belowground Responses to Increased Nutrients in Arctic Tundra: A Test of EEH", Ecology, p. , vol. , (2012). Accepted,

Graham D., M.D. Wallenstein, et al., "Microbes in Thawing Permafrost: The Unknown Variable in the Climate Change Equation.", ISME Journal, p. , vol. , (2012). Accepted, Hagen, E.M., McCluney, K.E., Wyant, K.A., Keller, A.C., Soykan, C.U., Wilson, K.C., Holmes. E.J., Moore, J.C., Sabo, J.L., "Effects of detritus on food web structure in marine, freshwater and terrestrial ecosystems.", Oikos, p. , vol. , (2012). Accepted,

Hobara, S., K. Koba, AE Noriharu, AE Giblin, K. Kushida, and G.R. Shaver, " Geochemical Retention of Dissolved Organic Matter and Its Replacement by Phosphorus in Organic Layer of Arctic Tundra Ecosystems.", Biogeochemistry, p. , vol. , (2012). Submitted,

Hobbie, J. E., and E. A. Hobbie., "Amino acid cycling in plankton and soil microbes studied with radioisotopes: measured amino acids in soil do not reflect bioavailability.", Biogeochemistry, p. 339, vol. 107, (2012). Published, 10.1007/s10533-010-9556-9

Johnson, D.R., M.J. Lara, G.R. Shaver, G.O. Batzli, J.D. Shaw and C.E. Tweedie.Johnson, DR, MJ Lara, GR Shaver, GO Batzli, JD Shaw and CE Tweedie., "Exclusion of brown lemmings reduces vascular plant cover and biomass in arctic coastal tundra: resampling of a 50+ year herbivore exclosure experiment near Barrow, Alaska", Environmental Research Letters, p. 045507, vol. 6, (2011). Published,

Keller, K., J. D. Blum, and G. W. Kling, " Stream geochemistry as an indicator of increasing thaw depth in an arctic watershed.", Chemical Geology, p. 76, vol. 273, (2010). Published,

Lang, S., H. Cornelissen, G.Shaver, M. Ahrens, T. Callaghan, U. Molau, C. ter Braak, A. Holzer, and R. Aerts., "Arctic warming on two continents has consistent negative effects on lichen diversity and mixed effects on bryophyte diversity.", Global Change Biology, p. , vol. , (2012). Accepted,

Laurion, I; Vincent, WF; MacIntyre, S; Retamal, L; Dupont, C; Francus, P; Pienitz, R, "Variability in greenhouse gas emissions from permafrost thaw ponds", LIMNOLOGY AND OCEANOGRAPHY, p. 115, vol. 55, (2010). Published,

MacIntyre, S; Jonsson, A; Jansson, M; Aberg, J; Turney, DE; Miller, SD, "Buoyancy flux, turbulence, and the gas transfer coefficient in a stratified lake", GEOPHYSICAL RESEARCH LETTERS, p. , vol. 37, (2010). Published, 10.1029/2010GL04416

Mack, MC; Bret-Harte, MS; Hollingsworth, TN; Jandt, RR; Schuur, EAG; Shaver, GR; Verbyla, DL, "Carbon loss from an unprecedented Arctic tundra wildfire", NATURE, p. 489, vol. 475, (2011). Published, 10.1038/nature1028

McMahon, SK; Wallenstein, MD; Schimel, JP, "A cross-seasonal comparison of active and total bacterial community composition in Arctic tundra soil using bromodeoxyuridine labeling", SOIL BIOLOGY & BIOCHEMISTRY, p. 287, vol. 43, (2011). Published, 10.1016/j.soilbio.2010.10.01

McMillan, HK; Clark, MP; Bowden, WB; Duncan, M; Woods, RA, "Hydrological field data from a modeller's perspective: Part 1. Diagnostic tests for model structure", HYDROLOGICAL PROCESSES, p. 511, vol. 25, (2011). Published, 10.1002/hyp.784

Melack, JM; Finzi, AC; Siegel, D; MacIntyre, S; Nelson, CE; Aufdenkampe, AK; Pace, ML, "Improving biogeochemical knowledge through technological innovation", FRONTIERS IN ECOLOGY AND THE ENVIRONMENT, p. 37, vol. 9, (2011). Published, 10.1890/10000

Merck, M. and B. T. Neilson., "Modeling In-Pool Temperature Variability in a Beaded Arctic Stream", Hydrological Processes, p. , vol. , (2012). Accepted,

O'Brien, W.J. and C. Luecke, "Zooplankton community structure in arctic ponds: shifts related to pond size.", Arctic, p. 483, vol. 64, (2011). Published,

Loranty, MM; Goetz, SJ; Rastetter, EB; Rocha, AV; Shaver, GR; Humphreys, ER; Lafleur, PM, "Scaling an Instantaneous Model of Tundra NEE to the Arctic Landscape", ECOSYSTEMS, p. 76, vol. 14, (2011). Published, 10.1007/s10021-010-9396-

Rastetter, EB, "Modeling coupled biogeochemical cycles", FRONTIERS IN ECOLOGY AND THE ENVIRONMENT, p. 68, vol. 9, (2011). Published, 10.1890/09022

Rastetter, EB; Williams, M; Griffin, KL; Kwiatkowski, BL; Tomasky, G; Potosnak, MJ; Stoy, PC; Shaver, GR; Stieglitz, M; Hobbie, JE; Kling, GW, "Processing arctic eddy-flux data using a simple carbon-exchange model embedded in the ensemble Kalman filter", ECOLOGICAL APPLICATIONS, p. 1285, vol. 20, (2010). Published, Robertson, G.P., N. Brokaw, S. Collins, H. Ducklow, D. Foster, T.L. Gragson, C. Gries, S. Hamilton, D. McGuire, J.C. Moore, E. Stanley, R. Waide, and M.W. Williams, "Strategic Role of the Long-term Ecological Research Network in Ecological and Environmental Science and Education", Bioscience, p. , vol. , (2012). Accepted,

Rueda, FJ; MacIntyre, S, "Modelling the fate and transport of negatively buoyant storm-river water in small multi-basin lakes", ENVIRONMENTAL MODELLING & SOFTWARE, p. 146, vol. 25, (2010). Published, 10.1016/j.envsoft.2009.07.00

Wyant, KA; Draney, ML; Moore, JC, "Epigeal Spider (Araneae) Communities in Moist Acidic and Dry Heath Tundra at Toolik Lake, Alaska", ARCTIC ANTARCTIC AND ALPINE RESEARCH, p. 301, vol. 43, (2011). Published, 10.1657/1938-4246-43.2.30

Yano, Y, GR Shaver, EB Rastetter, AE. Giblin, and JA Laundre, "Nitrogen pool distribution in arctic tundra soils: effects of soil age, fertilization, and warming", Oecologia, p. , vol. , (2012). Submitted,

Books or Other One-time Publications

Moore, J.C., "Biodiversity, taxonomic versus functional", (2012). Book, Accepted
Editor(s): S. Levin (ed.
Collection: Encyclopedia of Biodiversity 2nd Edition.
Bibliography: Elsevier, Oxford

Moore, J.C., "Energetic Food Webs: An analysis of real and model ecosystems.", (2012). Book, Accepted
Editor(s): Moore, J.C. and P.C. de Ruiter
Collection: Energetic Food Webs: An analysis of real and model ecosystems.
Bibliography: Oxford University Press, Oxford UK

Moore, J.C., and P.C. de Ruiter., "Bottom-up Control", (2012). Book, Accepted
Editor(s): Hastings, A. and Gross, L.
Collection: Sourcebook in Theoretical Ecology
Bibliography: University of California Press

de Ruiter, P.C., and J.C. Moore, "Top-Down Control", (2012). Book, Accepted
Editor(s): Hastings, A. and Gross, L.
Collection: Sourcebook in Theoretical Ecology, Hastings
Bibliography: University of California Press

Prowse et al., "Changing Lake and River Ice Regimes: Trends, Effects and Implications. Chapter 6.", (2012). Book, Accepted
Collection: Snow, Ice, Water, and Permafrost in the Arctic
Bibliography: A publication of the Arctic Monitoring and Assessment Program

Wallenstein, M.D., S. Allison, J. Ernakovich, J.M. Steinweg, R. Sinsabaugh., "Controls on the temperature sensitivity of soil enzymes: A key driver of in-situ enzyme activity rates.", (2010). Book, Published
Editor(s): Girish Shukla and Ajit Varma, eds.
Collection: Soil Enzymology
Bibliography: Soil Enzymology

Kling, G.W., C. Johnson, A. Balser, T. Coolidge, W.B. Bowden, A. Giblin, "The impacts of thermokarst failures on lakes: rapid attentuation of major impacts gives way to potential long-term effects on benthic processes", (2010). Conference proceeding, Published
Collection: American Geophysical Union meeting, 13-17 December 2010, San Francisco, CA
Bibliography: GC52A-04

Cory, R.M. and G.W. Kling, "Dynamics of photochemical and microbial processing of newly exposed terrestrial DOM in arctic surface waters", (2010). Conference proceeding, Published

Collection: American Geophysical Union meeting, 13-17 December, San Francisco, CA
Bibliography: B11I-07

Allen, A.R., W.B. Bowden, G.W. Kling, E. Schuett, J.M. Kostrzewski, C. Kolden Abatzoglou, R.H. Findlay, "Tundra fire alters stream water chemistry and benthic invertebrate communities, North Slope, Alaska", (2010). Conference proceeding, Published
Collection: American Geophysical Union meeting, 13-17 December, 2010. San Francisco, CA
Bibliography: GC43A-0958

Shaver, G.R., A.V. Rocha, G.W. Kling, M.C. Mack, "Impacts of wildfire on biogeochemistry and energy balance of the North Slope of Alaska", (2010). Conference proceeding, Published
Collection: American Geophysical Union meeting, 13-17 December 2010, San Francisco, CA
Bibliography: GC51J-07

Bowden, W.B., C. Maki, E. Schuett, A.R. Allen, J.R. Larouche, G.W. Kling, "Impacts of a large and intense tundra wildfire on the hydrological export of carbon, nitrogen, and phosphorus", (2010). Conference proceeding, Published
Collection: American Geophysical Union meeting, 13-17 December 2010, San Francisco, CA
Bibliography: GC51J-08

Merck, M. F. and B.T. Neilson, "Types and Variability of Instream and Bank Storage in Beaded Arctic Streams", (2010). Conference proceeding, Published
Collection: Eos Trans. AGU Fall 2010 Meet. Suppl
Bibliography: Abstract H21B-1042

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:
See Findings attached file

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Conference Proceedings

Special Requirements

Special reporting requirements: None
Change in Objectives or Scope: None
Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Any Web/Internet Site
Any Product
Contributions: To Any Other Disciplines
Contributions: To Any Human Resource Development
Contributions: To Any Resources for Research and Education
Contributions: To Any Beyond Science and Engineering
Any Conference

Annual report 2011

Terrestrial Group: Findings

1. *Thaw Depth and Soil Nitrogen:*

    From our 2010 data, we documented that thaw depths were greater in control plots than fertilized plots (Fig. 1); differences were most pronounced in the oldest treatments. These results were paralleled by soil temperatures which remained cooler in the fertilized plots, likely because the increase in leaf litter in those plots insulates the soils.

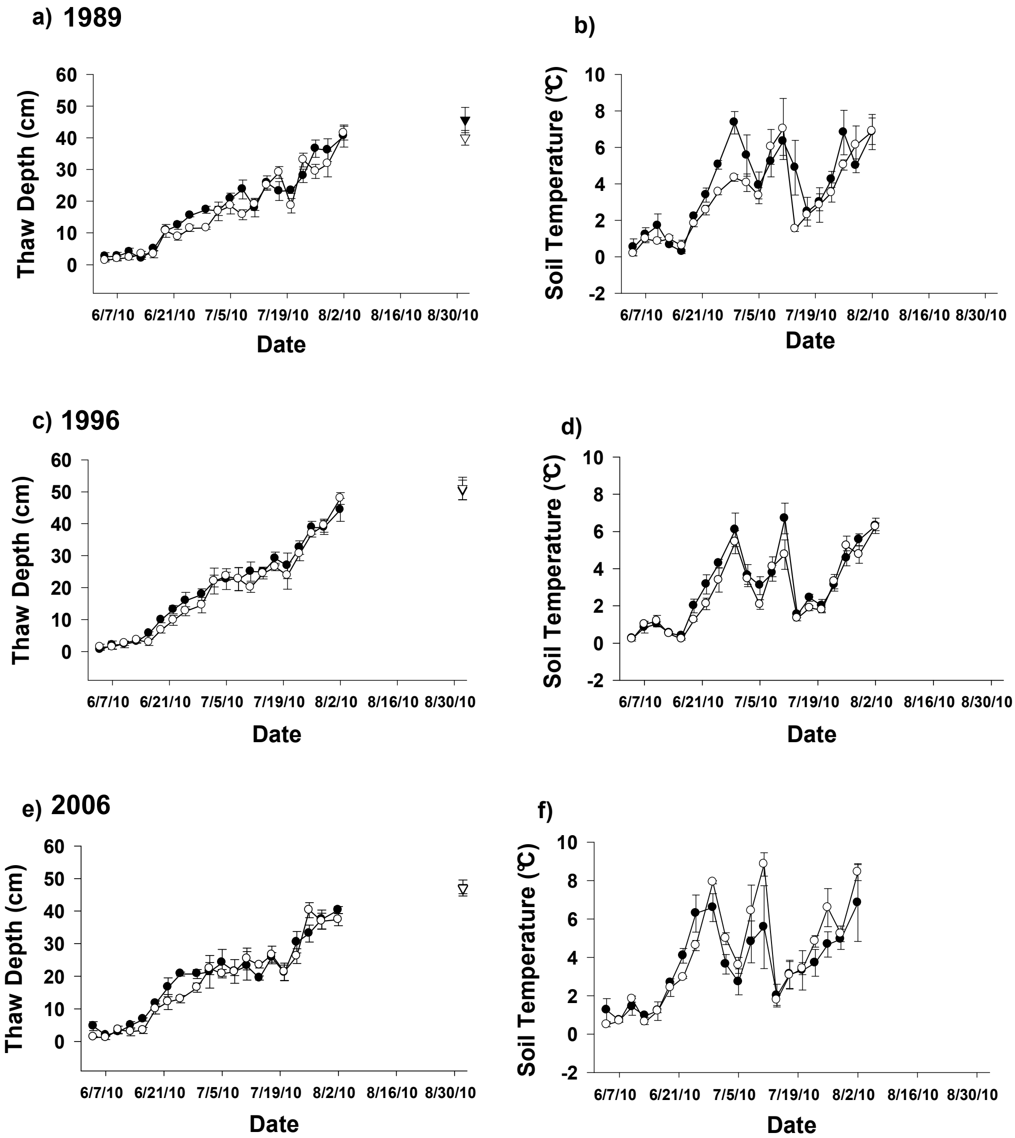


Fig. 1 Thaw depth (a,c,e) and soil temperature at 5cm depth (b,d,f) in control (solid circles) and fertilized (open circles) plots for experiments in which fertilization began in 1989 (a,b), 1996 (c,d) and 2006 (e,f).

In 2010 soil ammonium concentrations were higher in fertilized plots for the two oldest sets of treatments (those beginning in 1989 and 1996), with differences most pronounced early in the season, immediately after fertilization treatments are imposed (Fig. 2). The 2006 plots showed little difference in available ammonium between fertilized and control treatments – high nitrogen demand resulting in immediate plant uptake of available nitrogen likely quickly reduced ammonium concentrations in fertilized plots to control levels in this set of treatments. Amino acids availability did not show a clear seasonal pattern, and make up a small proportion of the total N availabile.

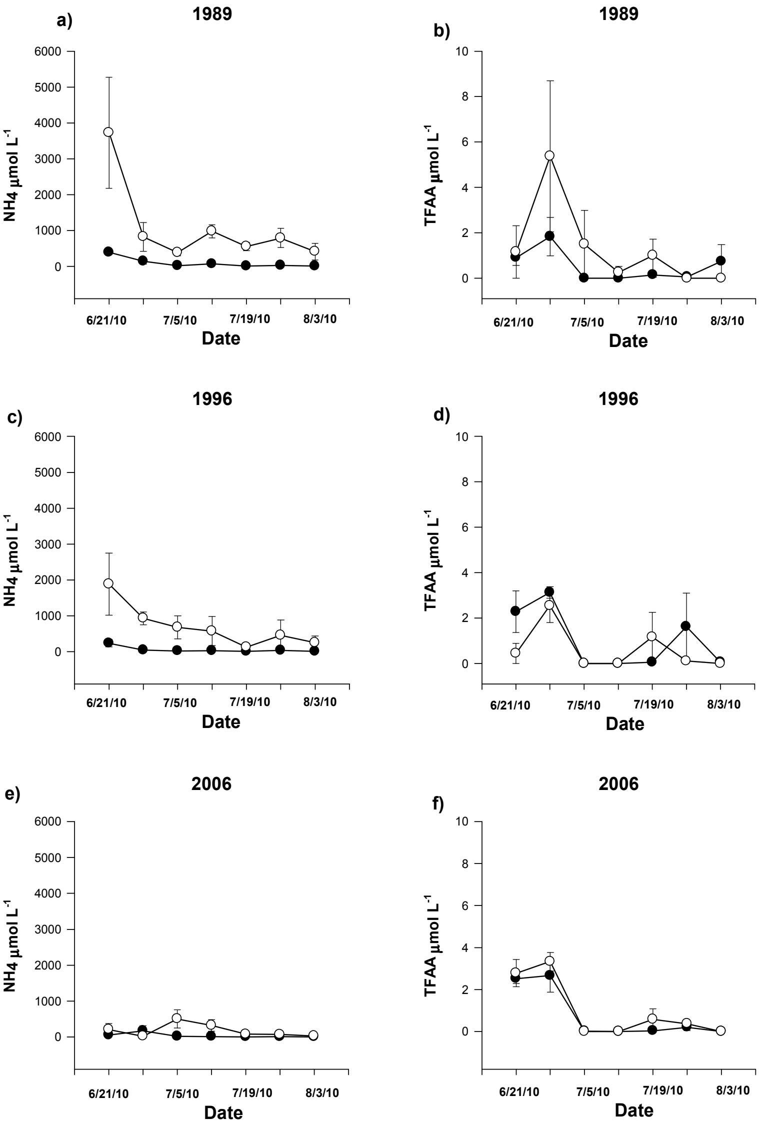


Fig 2. Ammonium (a,c,e) and Total free amino acid (TFAA; b,d,f) availability in soil water collected weekly from control (solid circles) and fertilized (open circles) plots for experiments in which fertilization began in 1989 (a,b), 1996 (c,d) and 2006 (e,f).

2. *Root Biomass Harvest*

   Root biomass for soil cores collected in June 2010 was separated into coarse (>2 mm diameter), fine (0.5 – 2 mm) and ultra-fine (<0.5 mm) components in organic and mineral layers of the soil. Preliminary results (based on root biomass standardized per cm depth of soil) show that in organic layers, the three size components made up similar proportions of the root biomass, regardless of treatment. Fertilized and control plots had similar total root biomass for the two older sets of treatments (those beginning in 1989 and 1996), but in the newer-established treatments, control plots have higher total biomass than fertilized plots. In the mineral soils, the ultra-fine roots make up the largest proportion of total root density of the three size classes. In contrast with the organic soils, the control plots had higher root biomass in the mineral soil only in the oldest (1989) set of treatments, with fertilized and control plots showing similar biomass in plots which have been treated since 1996 or 2006. Processing of the August samples will be completed in fall 2011, and we will have a more complete description of root growth patterns in these plots after further analysis of root biomass data from both soil core collections.

3. *Plant Community Composition*

   The plant communities in the 2006 fertilized plots have begun to shift away from relatively equal abundance of sedges, dwarf deciduous shrubs, and dwarf evergreen shrubs towards dominance by Betula nana (dwarf birch). Two grass species have also increased in abundance in these plots. In the 1996 fertilized plots Betula and Rubus (a forb) dominate, and in the 1989 plots almost all the other vascular species have been eliminated.

4. *Soil Food Web*

   Nutrient additions have affected the trophic structure of the belowground food web. In all cases, the food web was overwhelmingly dominated by microbes, especially fungi. In soils from the 2006 plots, microbes and upper trophic positions appear to have increased biomass with fertilization (Table 1). In soil fertilized since 1996 and 1989, the upper trophic levels had lower biomass than the control (Table 2). These results are consistent with our hypotheses and predictions on how the system might respond to fertilization. With time we anticipated structural shifts within the web.

Table 1. Biomass Carbon of belowground food web groups from soils collected from organic, interface, and mineral soil layers in plots established in 2006. A). Biomass (mg C/m^2) of non-microbes. B) Biomass (g C/m^2) of bacteria and fungi.

A	**2006 Control (mg C/m^2)**			**2006 Low N+P (mg C/m^2)**			**2006 High N+P (mg C/m^2)**		
Non-Microbes	**Upper O**	**Interface**	**Mineral**	**Upper O**	**Interface**	**Mineral**	**Upper 0**	**Interface**	**Mineral**
Predatory Mites	2.60	1.95	0.52	6.44	0.36	0.00	6.38	0.28	0.24
Nematophagous Mites	1.06	1.03	7.05	6.62	1.96	0.65	6.93	1.41	1.11
Predatory Nematodes	0.01	0.13	0.00	0.01	0.11	0.00	0.05	0.00	0.00
Omnivorous Nematodes	0.45	0.16	0.00	0.36	0.51	0.17	0.60	0.23	0.15
Tardigrades	0.00	0.00	1.49	0.00	0.00	0.00	0.00	0.00	0.00
Amoebae	1.82	2.57	7.45	1.54	20.48	73.46	7.12	0.41	0.33
Ciliates	0.03	0.11	0.72	0.68	0.76	13.32	0.99	0.11	0.50
Rotifers	0.02	0.05	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Collembola	3.76	7.77	0.55	5.66	1.62	1.44	2.63	0.63	1.05
Cryptostigmata	1.15	0.84	0.19	4.39	0.23	0.22	4.20	0.85	0.20
Non-Cryptostigmata	0.13	0.07	0.00	0.23	0.42	0.04	0.14	0.04	0.08
Fungivorous Nematodes	0.06	0.02	0.12	0.17	0.26	0.02	0.11	0.09	0.02
Flagellates	0.25	0.18	0.39	0.42	0.31	1.28	0.06	0.08	0.49
Bacterivorous Nematodes	0.12	0.03	0.00	0.19	0.07	0.05	0.27	0.11	0.03
Phytophagous Nematodes	0.04	0.04	0.09	0.16	0.12	0.00	0.17	0.09	0.02

B	**2006 Control (g C/m^2)**			**2006 Low N+P (g C/m^2)**			**2006 High N+P (g C/m^2)**		
Microbes	**Upper 0**	**Interface**	**Mineral**	**Upper O**	**Interface**	**Mineral**	**Upper O**	**Interface**	**Mineral**
Fungi	217.34	441.23	561.60	161.05	562.28	403.07	231.98	293.17	396.70
Bacteria	0.86	2.53	7.45	0.54	2.66	5.34	1.02	1.26	3.73

Table 2. Biomass Carbon of belowground food web groups from soils collected from organic, interface, and mineral soil layers in plots established in 1989 and 1996. A) Biomass (mg C/m^2) of non-microbes. B) Biomass (g C/m^2) of bacteria and fungi.

A	**1989 Control (mg C/m^2)**			**1996 N+P (mg C/m^2)**			**1989 N+P (mg C/m^2)**		
Non-Microbes	**Upper O**	**Interface**	**Mineral**	**Upper O**	**Interface**	**Mineral**	**Upper O**	**Interface**	**Mineral**
Predatory Mites	1.65	0.17	0.00	0.41	0.07	0.00	0.34	0.01	0.32
Nematophagous Mites	1.08	1.53	0.16	0.99	0.33	0.02	0.66	0.41	0.01
Predatory Nematodes	0.31	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Omnivorous Nematodes	2.04	0.66	0.11	0.92	0.37	0.21	0.55	0.30	0.19
Tardigrades	0.00	2.23	0.00	0.00	0.00	0.00	0.00	1.81	0.00
Amoebae	3.11	6.78	59.97	8.76	17.93	0.03	28.88	25.20	3.85
Ciliates	0.33	0.28	47.05	2.38	1.23	0.23	6.07	4.31	3.76
Rotifers	0.15	0.06	0.00	0.01	0.11	0.00	0.09	0.19	0.00
Collembola	3.89	4.15	0.06	5.14	0.31	0.05	3.01	0.58	0.03
Cryptostigmata	5.85	0.65	0.12	1.45	0.20	0.22	0.92	0.07	0.00
Non-Cryptostigmata	0.23	0.15	0.05	0.14	0.02	0.00	0.11	0.01	0.00
Fungivorous Nematodes	0.32	0.26	0.01	0.16	0.15	0.04	0.22	0.09	0.00
Flagellates	0.20	0.67	1.47	0.40	0.28	0.02	0.49	0.81	0.38
Bacterivorous Nematodes	0.19	0.15	0.00	0.08	0.10	0.05	0.13	0.10	0.00
Phytophagous Nematodes	0.08	0.06	0.00	0.05	0.13	0.00	0.05	0.00	0.00

B	**1989 Control (g C/m^2)**			**1996 N+P (g C/m^2)**			**1989 N+P (g C/m^2)**		
Microbes	**Upper O**	**Interface**	**Mineral**	**Upper O**	**Interface**	**Mineral**	**Upper O**	**Interface**	**Mineral**
Fungi	195.89	598.47	560.26	232.64	277.66	346.89	228.09	244.60	295.41
Bacteria	0.66	3.24	6.19	1.04	1.76	4.73	0.59	2.10	7.01

5. *Soil Carbon and Nitrogen Content*

On a whole-profile basis, carbon content was greater in control soils than fertilized ones (Table 3). However, the upper organic horizon of fertilized soils contained more carbon than the control. The C:N of all soils declined with depth.

6. *Modeling*

Objective 4 of our project aimed to develop a process-oriented quantitative model of soil pedogenesis that incorporates the role of plants, microbes and invertebrates in SOM distribution and dynamics. To meet this objective we parameterized the DAYCENT model (Fig. 3) for moist acidic tundra as a first step to achieve the Objective 4.

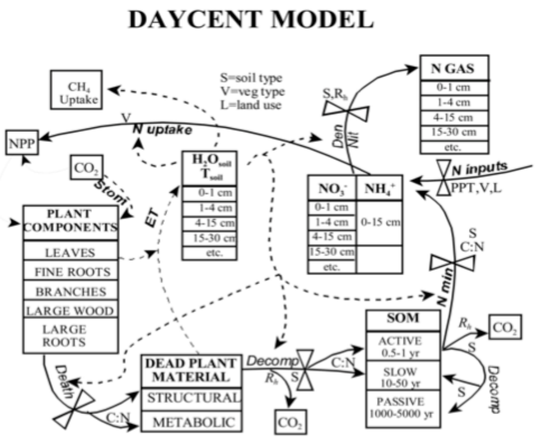


Fig 3. The schematic of the DAYCENT model (Parton et al. 2001).

Table 3. Carbon and nitrogen content (g/m^2) of soils collected in August 2010.

Treatment	Horizon	Soil Carbon g C m^{-2}		Soil Nitrogen g N m^{-2}		Carbon:Nitrogen	
		mean	SE	mean	SE	Mean	SE
Controls from 1989	Organic	2515.8	293.7	25.3	4.8	46.28	6.20
	Interface	6398.9	642.2	51.6	6.8	30.74	3.77
	Mineral	4303.9	586.4	11.1	1.5	20.59	0.78
1989 N+P	Organic	3249.1	730.4	50.2	14.7	30.43	2.53
	Interface	4269.3	1443.9	35.9	11.6	26.05	2.21
	Mineral	2750.4	689.4	4.6	1.2	20.53	0.96
1996 N+P	Organic	2993.8	261.2	41.9	6.4	22.70	0.38
	Interface	3190.4	337.0	26.6	9.7	22.52	1.32
	Mineral	3786.9	1014.0	9.2	4.0	20.66	0.48
Controls from 2006	Organic	1981.8	82.4	19.9	0.8	43.83	1.68
	Interface	4729.4	576.1	40.8	13.2	27.65	3.23
	Mineral	3248.3	1065.0	6.6	3.4	18.30	1.20
2006 LOW N+P	Organic	2363.6	230.8	29.3	4.8	35.78	1.01
	Interface	4008.4	904.2	28.3	4.8	28.93	1.79
	Mineral	2659.6	272.3	4.8	1.0	18.35	0.73
2006 LOW N+P	Organic	2905.4	834.4	42.0	12.6	31.15	1.87
	Interface	2888.3	535.8	25.2	11.3	22.60	1.63
	Mineral	2573.6	499.5	8.8	3.9	15.10	3.33

Table 4. Data used to parameterize the DAYCENT model

Data	Data type	Sources
Daily precipitation	Input variable	Arctic LTER Data Catalog
Daily min. and max. temperature	Input variable	Arctic LTER Data Catalog
Max. leaf area index	Input variable	Shippert et al. 1995
Above- to below-ground biomass ratio	Input variable	Gough and Hobbie 2003
Above-ground biomass	Reference for output	Shaver et al. 2001
Above-ground NPP	Reference for output	Mack et al. 2004

Data included in the Arctic LTER Data Catalog on-line and published in peer-reviewed articles have been used for parameterization (Table 4). The DAYCENT model was parameterized for evergreen and deciduous shrubs and graminoids, separately, due to their significant differences in biomass allocation (Gough and Hobbie 2003). Validity of parameterized models was tested with observed net primary productivity (NPP) and plant biomass. We have mainly used vegetation data collected from the plots fertilized since 1981 and their controls because more published data are available than for the other experiments.

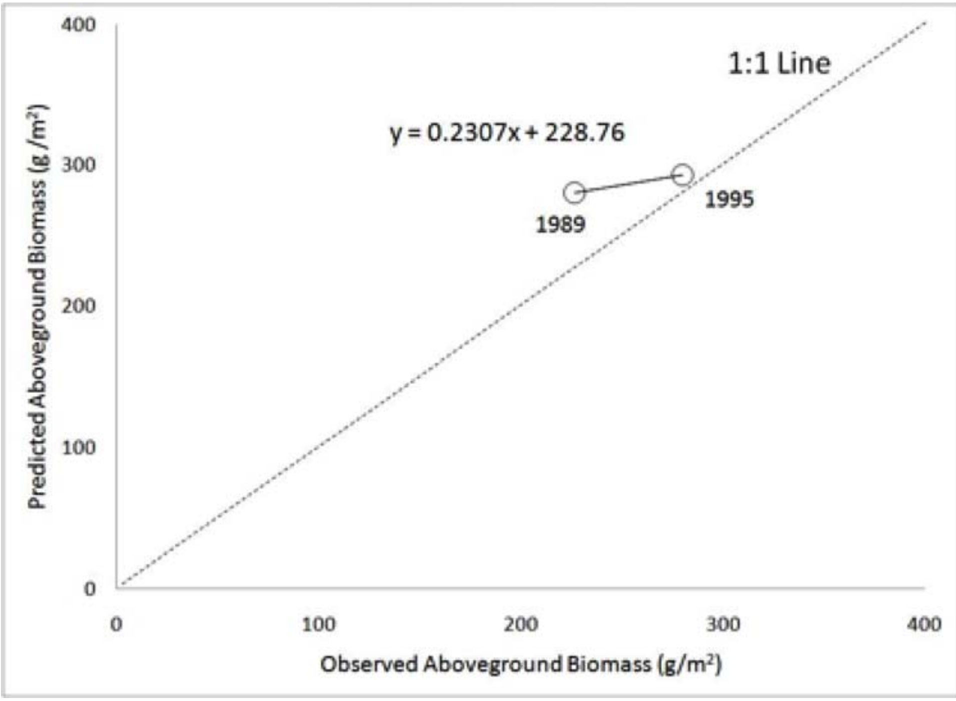


Fig. 4. Above-ground biomass of shrub predicted from the DAYCENT model were plotted against observed above-ground biomass in the control sites. The observed Above-ground biomass values were of 1989 and 1995 (from Shaver et al. 2001) and 2000 (from Mack et al. 2004). Predicted values were calculated with an assumption that deciduous and evergreen shrubs cover 26% and 30% of a given surface, respectively.

The parameterized model can predict above-ground biomass and NPP in the same magnitude as observed (Fig. 4 and 5). However, it cannot predict year-to-year variations in above-ground NPP and biomass observed (Fig. 4 and 5). This indicates that there are important factors affecting above-ground biomass and NPP other than air temperature and precipitation. For instance, NPP can be affected by soil temperature during the growing season which the model overestimates (Fig. 6). Our next step is to further parameterize the DAYCENT model for precision and accuracy. We will use data from the sites fertilized since 1996 and their controls because more data are available in the Arctic LTER Data Catalog along with meteorological data.

In addition, we are developing a soil food web sub-model based on a published model (de Ruiter et al. 1995) using R (R Development Core Team 2011). Soil microbial data collected during summer in 2011 will be used to simulate soil food web dynamics for fertilization effects. We will integrate this sub-model with the parameterized DAYCENT model to simulate biogeochemical dynamics for the moist acidic tundra with fertilization treatments.

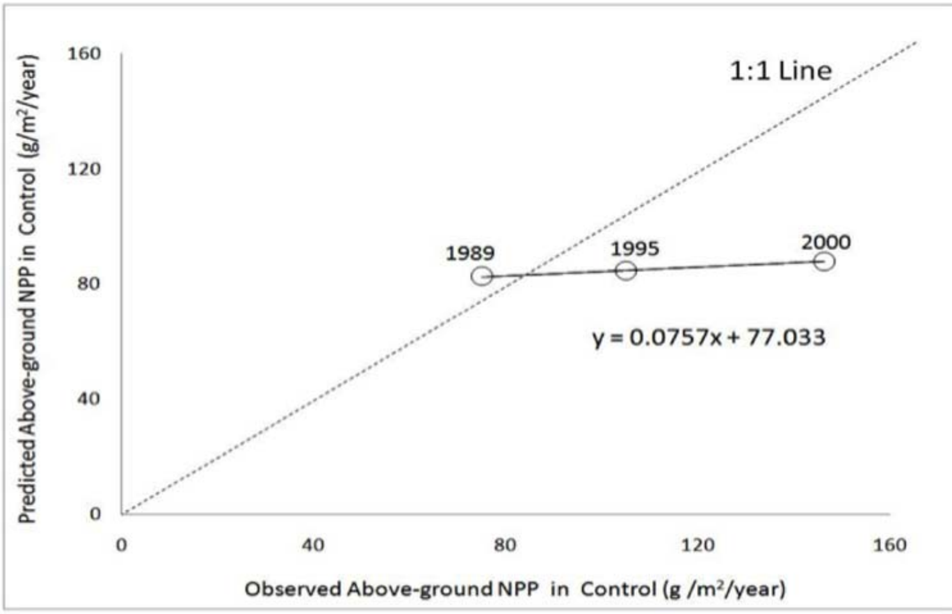


Fig. 5. Above-ground NPP values of shrubs predicted from the DAYCENT model were plotted against observed NPP values in the control sites. The observed NPP values of 1989 and 1995 were from Shaver et al. 2001, and 2000 from Mack et al. 2004. Predicted values were calculated with an assumption that deciduous and evergreen shrubs cover 26% and 30% of a given surface, respectively (Hobbie et al. 2005).

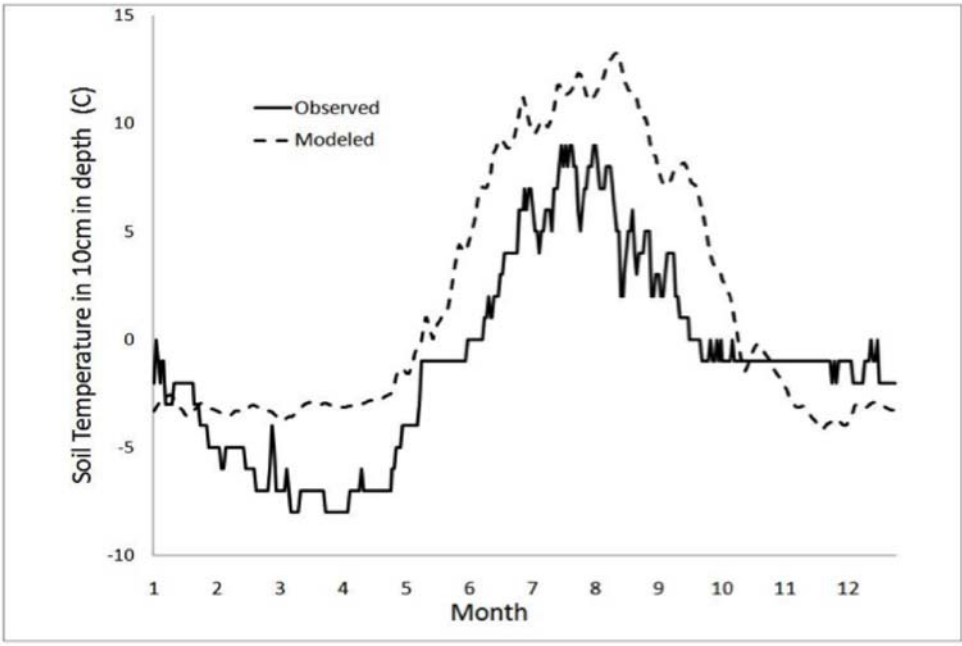


Fig. 6. Observed and modeled soil temperature at 10cm in depth in 1997 at the Toolik LTER site. The observed data were from Arctic LTER Data Catalog.

Terrestrial Group: Findings

FORMAL FINDINGS:

1. Boelman and Gough had a manuscript published in Environmental Research Letters as a contribution to a Special Issue on 'Recent vegetation dynamics in arctic and sub-arctic terrestrial ecosystem'. Title: Does NDVI reflect variation in the structural attributes associated with increasing shrub dominance in arctic tundra? Authors: Natalie T. Boelman, Laura Gough, Jennie McLaren and Heather Greaves Abstract: This study explores relationships between the normalized difference vegetation index (NDVI) and structural characteristics associated with deciduous shrub dominance in arctic tundra. Our structural measures of shrub dominance are stature, branch abundance, aerial percent woody stem cover (deciduous and evergreen species), and percent deciduous shrub canopy cover. All measurements were taken across a suite of transects that together represent a gradient of deciduous shrub height. The transects include dwarf shrub and riparian shrub tundra communities located in the northern foothills of the Brooks Range, in northern Alaska. Plot-level NDVI measurements were made in 2010 during the snow-free period prior to deciduous shrub leaf-out (early June, NDVIpre-leaf), at the point in the growing season when canopy NDVI has reached half of its maximum growing season value (mid-June, NDVIdemi-leaf) and during the period of maximum leaf-out (late July, NDVIpeak-leaf). We found that: (1) NDVIpre-leaf is best suited to capturing variation in the percent woody stem cover, maximum shrub height, and branch abundance, particularly between 10-50 cm height in the canopy; (2) NDVIpeak-leaf is best suited to capturing variation in deciduous canopy cover; and (3) NDVIdemi-leaf does not capture variability in any of our measures of shrub dominance. Because shrubs are increasing in size and regional extent in several regions of the Arctic, investigation into spectrally based tools for monitoring these changes are worthwhile as they provide a first step toward development of remotely sensed techniques for quantifying associated changes in regional carbon cycling, albedo, radiative energy balance, and wildlife habitat. (See Figure 2)

2. Matt Rich (Gough's Masters Student) gave a poster presentation on the current project at the 2011 Arctic LTER meeting: Title: Changes in Arctic Arthropod Communities Due to Recent Climate Warming Authors: Matt Rich, Laura Gough, John Wingfield, and 'Team Bird 2010' Abstract: Recent global warming, which has been severe in the Arctic, has caused advancement in the timing of snowmelt, expansion of shrubs into open tundra, and changes in the occurrence of severe and unpredictable storms. Such an altered climate may directly and indirectly (via effects on vegetation) affect arctic arthropod populations. We conducted research at four sites in the vicinity of the Arctic Long Term Ecological Research (LTER) site at Toolik Lake Field Station (TLFS) in northern Alaska in the summer of 2010 to determine how vegetation structure affects arthropod abundance and diversity. We hypothesized that sites dominated by shrubs have higher abundance and taxa richness of arthropods as a result of a more favorable microclimate compared with more exposed open tundra with few shrubs. Shrubs are known to reduce wind

speeds and thus may keep temperatures warmer underneath their canopies. Arthropod abundance was significantly greater in shrub plots than open plots, with more dramatic differences in the two sites with the tallest shrubs. However, taxa richness was quite similar among sites and between vegetation types. Advantages of greater shrub height and complexity, including favorable weather conditions and higher plant temperatures, are likely determining these patterns. As climate warming continues to increase over the coming decades, and with further shrub expansion likely to occur, ensuing changes in arthropod communities may play an important ecological role in arctic food webs as they are a major food source for migratory songbirds.

PRELIMINARY FINDINGS FROM 2010:
1. Canopy greenness (NDVI) is higher in Open compared to Shrub plots following snow melt, but in mid-June Shrub plot NDVI rapidly increases, and remains higher than Open plots through late July (ex. Figure 2a).

2. Flying and ground insect abundances were greater in Shrub plots compared to Open plots throughout the breeding season of 2010 (ex. Fig. 2b and c). While the abundance of ground dwelling insects peaked in early to mid-June at all sites, the abundance of flying insects peaked later, in the second half of June (compare Fig. 2b to c). The above two findings are particularly interesting when considered in relation to the timing of life history events of the songbirds we are studying (Fig. 2d). For example, canopy greenness and flying insect abundance both peak during the period of songbird fledging, while ground dwelling insect abundance peaks during the nesting phase. 3. Spatial patterns, both among vegetation types (ie. Shrub tundra vs. Open tundra) and among our four study sites, of songbird abundance and species presence/absence upon arrival and nesting were similar in 2011 and 2010.

Terrestrial Group Findings, Soil bacteria and mycorrhizae:

The heterotrophic bacteria in plankton and in soil follow the same rules – in nature they are nearly all starved for carbon and energy all the time. Because there are 1000 times more bacteria per CC in soil than in plankton, this plays out so that most of the bacteria in soil have adopted a life style of very slow metabolism while keeping the ability to immediately take up, transport, and respire any amino acids that become available.

Key results: Labeled amino acids cannot be used to study amino acid cycling in soil because all of the substrate added in an experiment is immediately taken up because of the excess and starving biomass. Given this immediate use, concentrations of free amino acids cannot build up in soil; concentrations found by analysis and soil must be hidden in soil structure or otherwise inaccessible to microbes.

Terrestrial Group Findings, Ecotypic variation in plants:

Natural selection against 'alien' genotypes in the reciprocal transplant garden has been strong in the extreme environments of snowbed and fellfield for Dryas octopetala at Eagle Creek. In fact, at the extreme ends of the gradient, there have been zero survivors of the other extreme ecotype, meaning complete selection against the extreme 'wrong' morphs.For Eriophorum, median survival since 1980 was 70%. However, there was considerable variation in median survival among gardens, ranging from 40% at No Name Creek to 97% at Eagle Creek. The patterns of selection varied considerably among the different populations. At Eagle Creek and Toolik Lake survival was high and there was no difference between northern and southern populations. At No Name Creek and Coldfoot the southern populations had higher survival, whereas at Sagwon the northern populations had higher survival. Thus, there appears to be selection against the alien population at some sites, but not others.In terms of flowering in Eriophorum, the picture is much clearer, with home site advantage being evident. Maximum assimilation also showed significant home-team advantage. No interaction between garden and population origin was observed for dark respiration, and Fv/Fm. However, dark respiration measured at 15-17 C increased from south to north along the gradient. Fv/Fm decreased significantly from south to north.

We found that stomatal traits of Eriphorum vaginatum differed among populations and among sites. Our results demonstrate a cline in stomatal conductance in E. vaginatum, with some ability of populations to plastically produce an appropriate phenotypic response in a new environment. As Arctic temperatures continue to increase we would expect to see a shift toward decreased conductance, and hence increased water use efficiency, with increased latitude.

Streams Group: Findings

Flow in the Kuparuk River was very low this year. There were several reaches that are known to go hyporheic and that did so again in 2011, remaining dry from mid-July until early September. The phosphorus concentration was raised in the river, with a target of 0.3uM above ambient, but reaching 0.8uM, due to low flow.

Sestonic and benthic chlorophyll *a* was measured three times during the summer. Sestonic chlorophyll *a* was greater in the fertilized reach in July, while during August the chlorophyll *a* concentration was greater in the re-fertilized reaches, dropping in the fertilized reach. Epilithic chlorophyll *a* was greater in the fertilized reaches (re-fertilized 1, re-fertilized 2, and fertilized) than the reference reach.

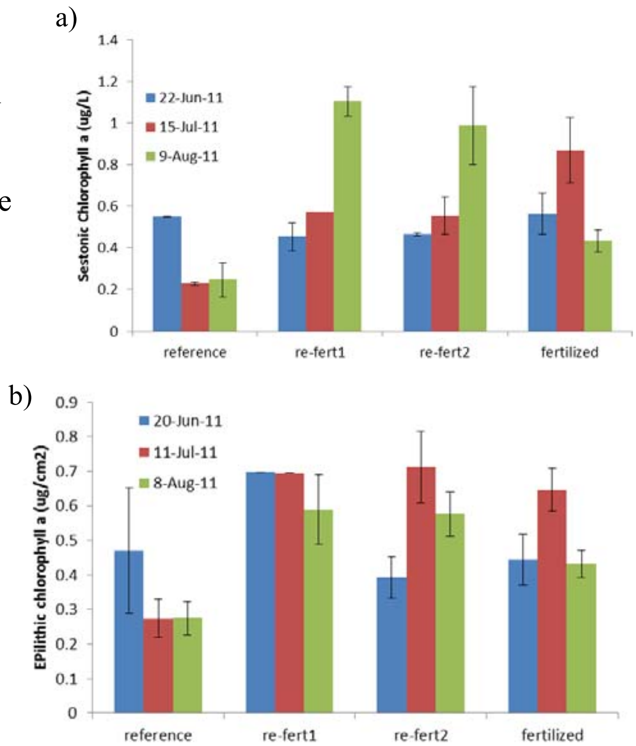


Figure 1 Mean sestonic (a) and epilithic (b) chlorophyll *a* during summer 2011

Moss point transects were done on 26-27 June and 29-30 July of this year. The June sampling date was one day after phosphorus addition began and was effectively a pre-fertilization condition. *Hygrohypnum* was present in the fertilized and extended reaches in June and July, but some was also present in the re-fertilized reach in July. *Hygrohypnum* has been seen at one particular site (1.0k) in previous years, but with the addition of phosphorus this year its cover increased during the summer. There was also more green filamentous algae in both of the re-fertilized reaches during July, and it was also observed growing on top of the *Hygrohypnum* in the fertilized reach. Orthocladius were present later than ever previously observed (pers. comm. M. Kendrick). *Didymosphenia geminata* was observed more extensively than in recent years, and was particularly apparent growing on *Schistidium*.

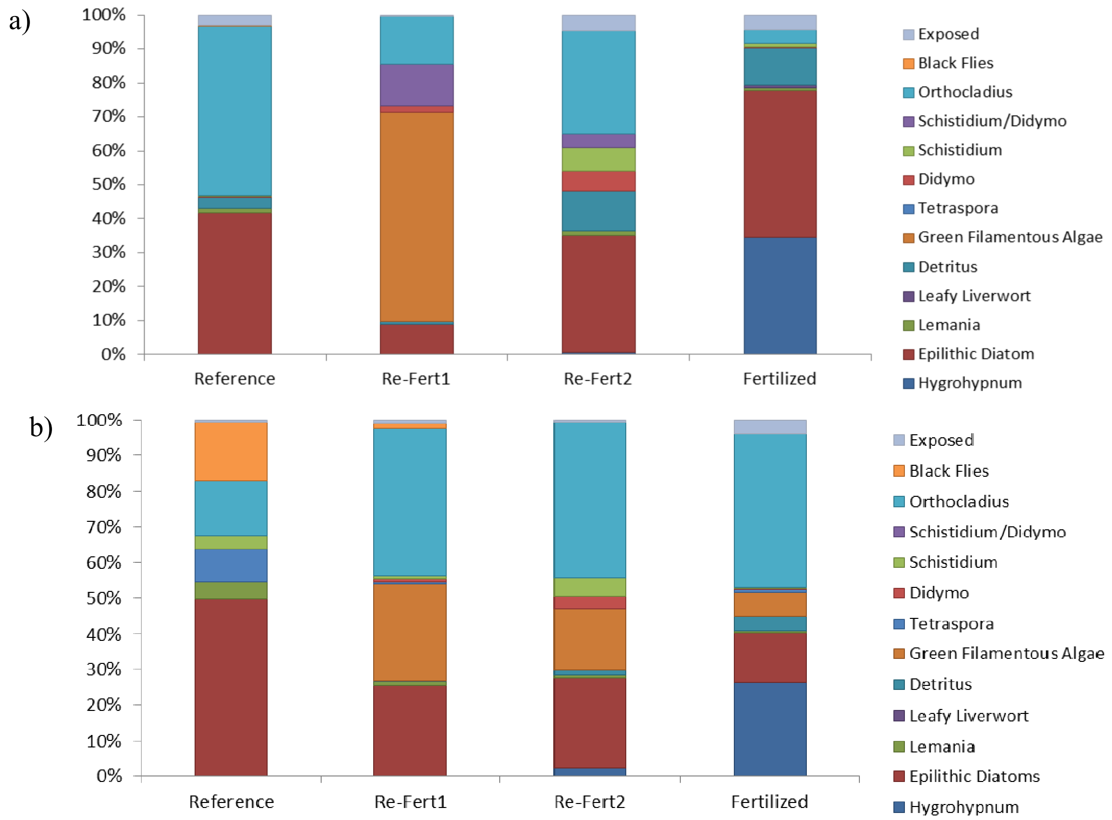


Figure 2 Moss point transects in June (a) and July (b).

Young-of-the-year grayling were first observed on the Kuparuk on 28 June 2011. Eve Kendrick spearheaded the YOY collection this year as part of her Research Experience for Teachers project. The YOY were collected throughout the summer and weighed and measured at Toolik. The YOY from the Kuparuk fertilized reach gained the most mass throughout the summer. The YOY from Oksrukuyik were seen a few days earlier than the Kuparuk YOY, which is typical. The Oksrukuyik YOY grew the longest during the course of the summer.

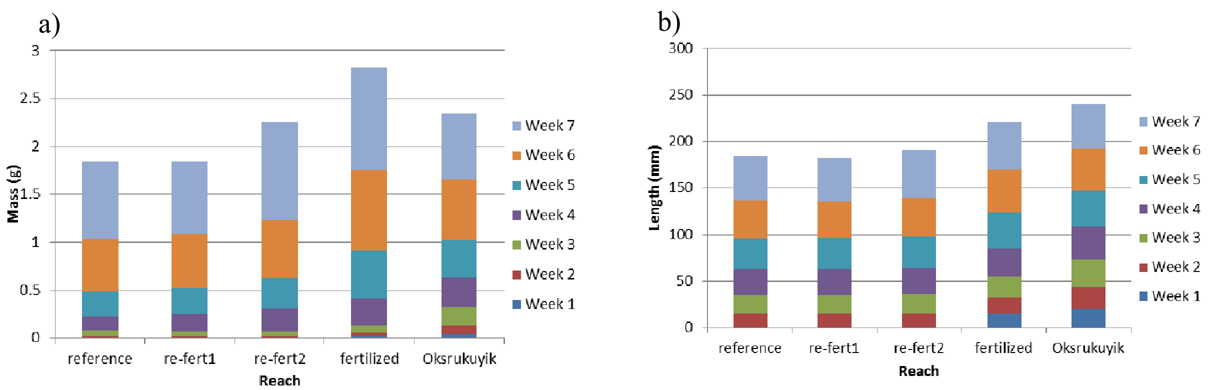


Figure 3 Young-of-the-year growth during the summer 2011. a) mass, b) length

Surveys of adult (>30 cm total length) and juvenile grayling growth were undertaken by the Fishscape group this summer. Survey teams captured and measured grayling in each of the reaches 28 June – 7 July, and recaptured the same individuals 27 July – 11 Aug. Approximately 40 individuals were recaptured in each of the reaches, except the Re-fert reach where 18 individuals were recaptured. Adult and juvenile growth within the reaches were similar. Grayling gained the most mass in the ReFert reach (mean 33.2g) and the least mass in Oksrukuyik creek (mean -7.85g).

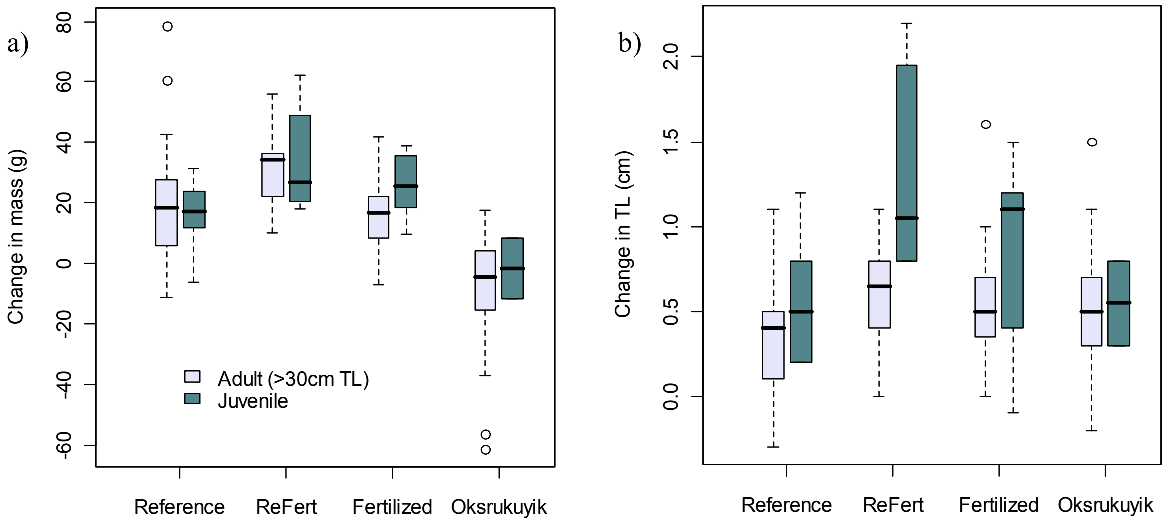


Figure 4 Adult and juvenile growth during the summer 2011 a) mass b) length

Lakes Group: Findings

Fertilization of Lakes E5 and E6:

We have carried out a low-lever fertilization of a paired deep and shallow lake for a decade. Primary production has been stimulated in the pelagic zone of the both lakes. Water column chlorophyll concentrations in the shallow lake are quite variable but have been higher than pre-fertilization levels every year with some years although some years they are not significantly different than baseline while in others they are fold higher (Fig 1). Chlorophyll concentrations in the deep lake are 2-4 times higher than baseline and the last two years have had the highest chlorophyll levels of the study (Fig. 1) Benthic production has increased in the shallow lake, although the degree of stimulation appears to be quite variable and may depend upon seasonal light conditions. Bottom water oxygen conditions in the shallow lake have not been affected but there has been a decline in late summer oxygen concentrations in the deeper lake during the last few summers (Fig 2). However, the lake has not experience anoxic conditions. Both whole system measures of water column nutrients, and core studies indicate that nutrient return from the sediments is small.

Zooplankton abundances in lakes receiving low levels of nitrogen and phosphorus have increased by 50% since the initiation of increased nutrient additions in 2001. Water clarity is greatly reduced in the fertilized lake and Hydra has become more a more dominant part of the benthic community. Densities of arctic char have increased and the age structure reflects a much younger population in the fertilized lake compared to two other reference lakes. A strong legacy effect of adding isotopically enriched nitrogen in 2001 still remains in the fertilized lake, nine years later, a pattern worthy of closer exploration.

Food web analyses indicate the presence of two distinct feeding morphs of char, surprisingly a larger, older littoral morph and a smaller, younger pelagic morph (Figure 1 Budy and Luecke). The population of char in one of the long-term study reference lakes appears to be at a very low point in the population structure and is completely dominated by a small number of mature, large char with low to no successful recruitment. Based on observed population dynamics in other long-term study lakes, we anticipate either a recruitment pulse in this lake, or it may be recolonized by grayling. Populations of fish in all study lakes remain particularly sensitive to day of ice-off, an environmental variable that may change significantly with climate change. Over the short term (< 10 years), we predict increased growth rates, increased net reproductive rate, and an in increase in the net biomass of fish. However, over the longer-term (> 10 years), we predict a dramatic increase in amplitude and duration of fish population structure cycles with a concordant increase in the probability of local extinction (e.g., lake level) (Figure 2 Budy and Luecke).

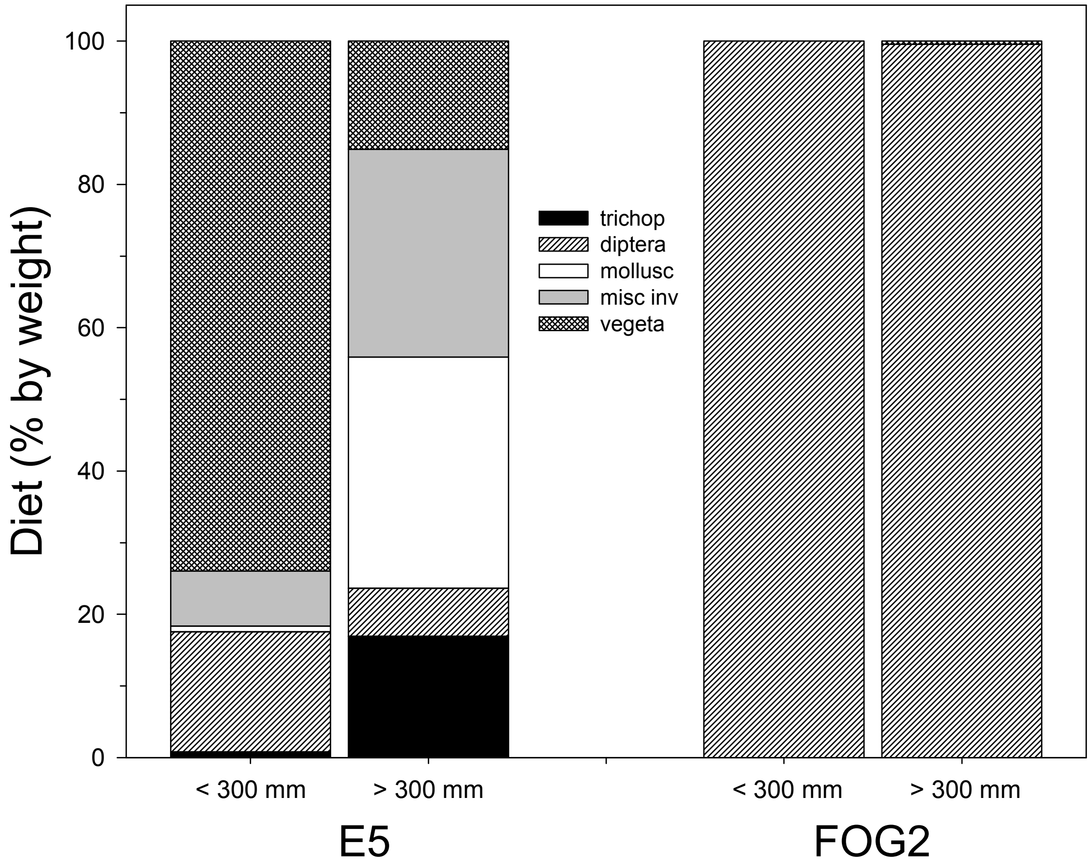


Figure 1 Budy and Luecke. Diet proportion by weight from Arctic char collected in long-term study lakes E5 and Fog2 in spring 2011. Data are shown for fish greater and less than 300 mm.

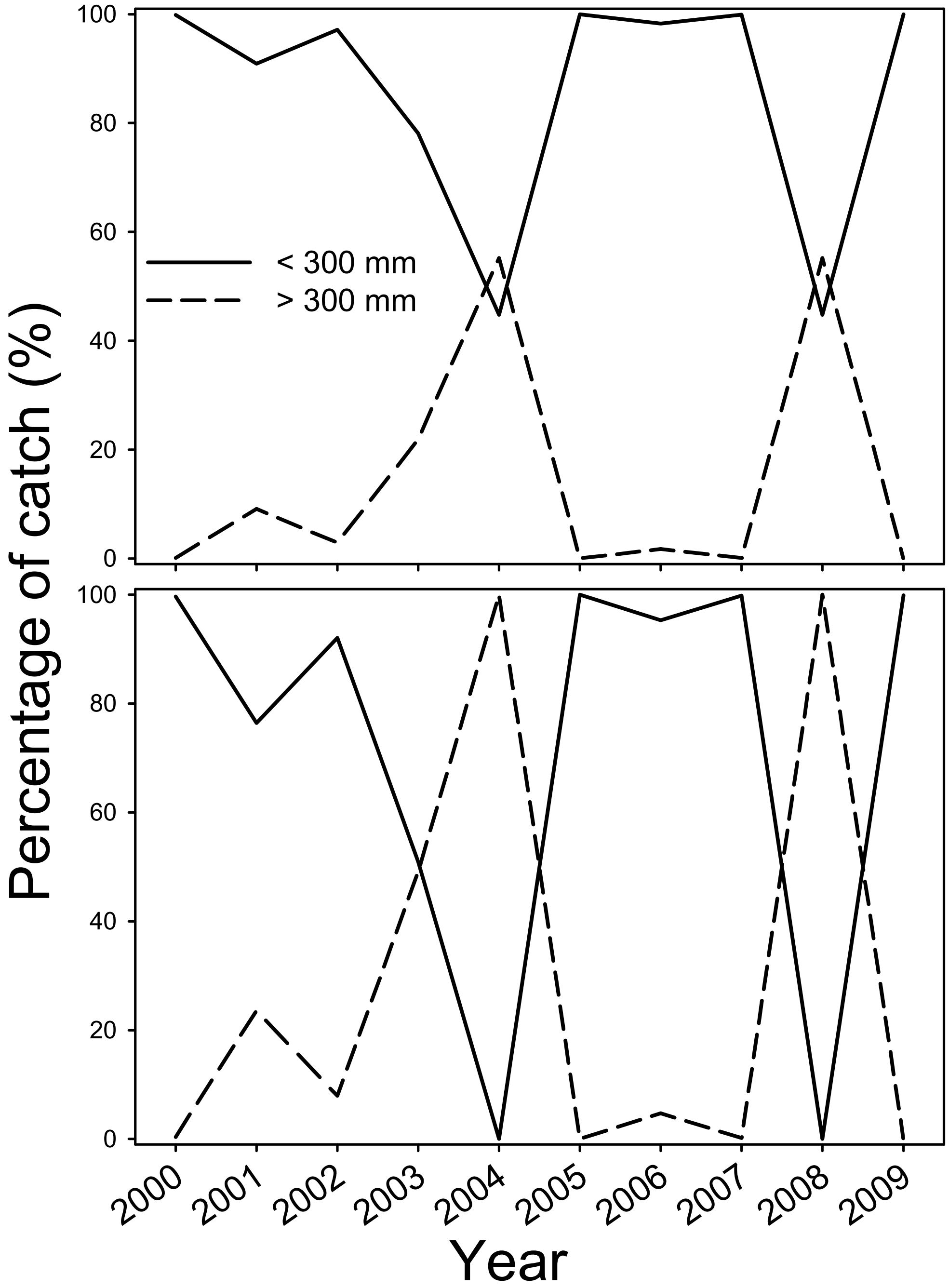


Figure 2 Budy and Luecke. Projected population structure cycle based on empirical data (top) and under climate change scenario CCS3 (bottom; 4 degrees warmer, summer + early ice-off) for Arctic char in long term study lake E5. The solid line represents char <300 mm and the dashed line represents char less than 300 mm.

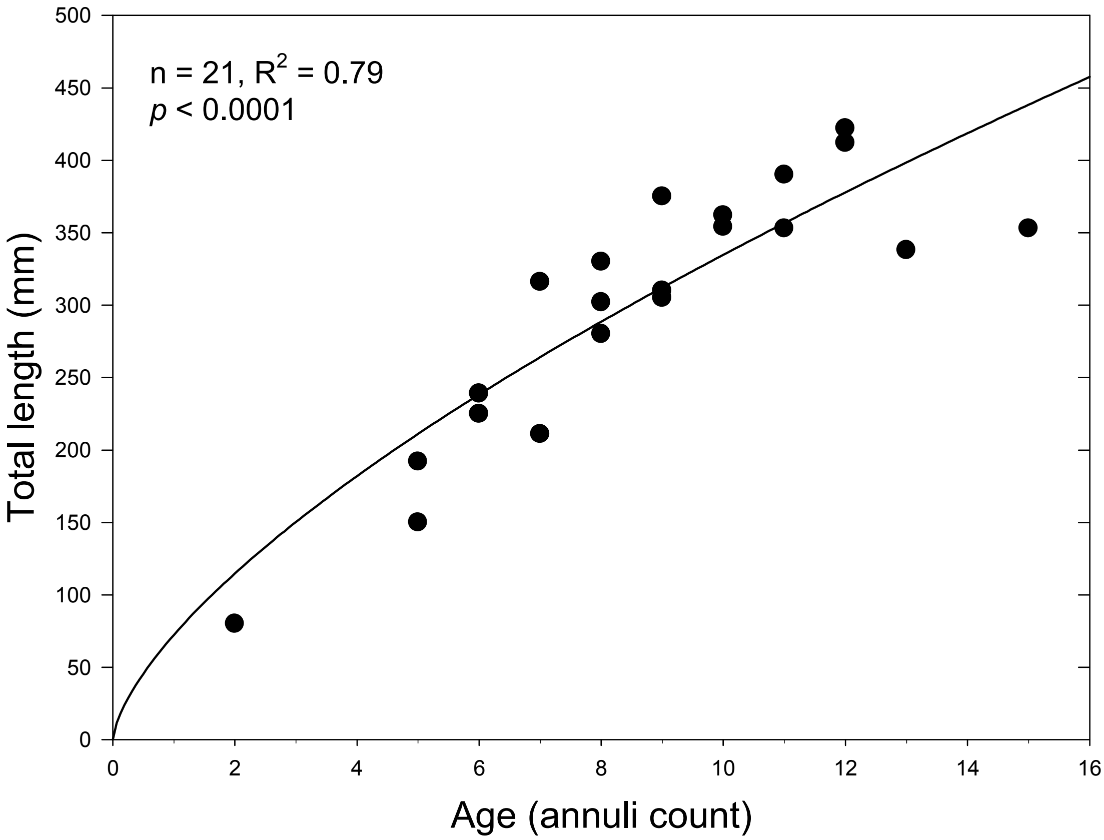
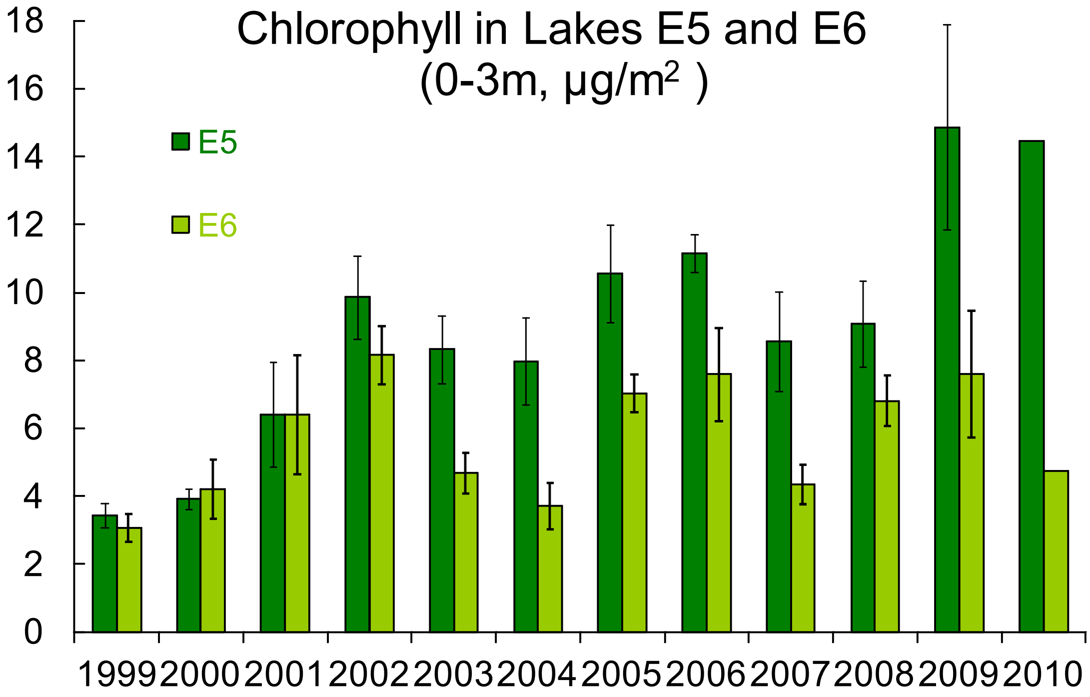
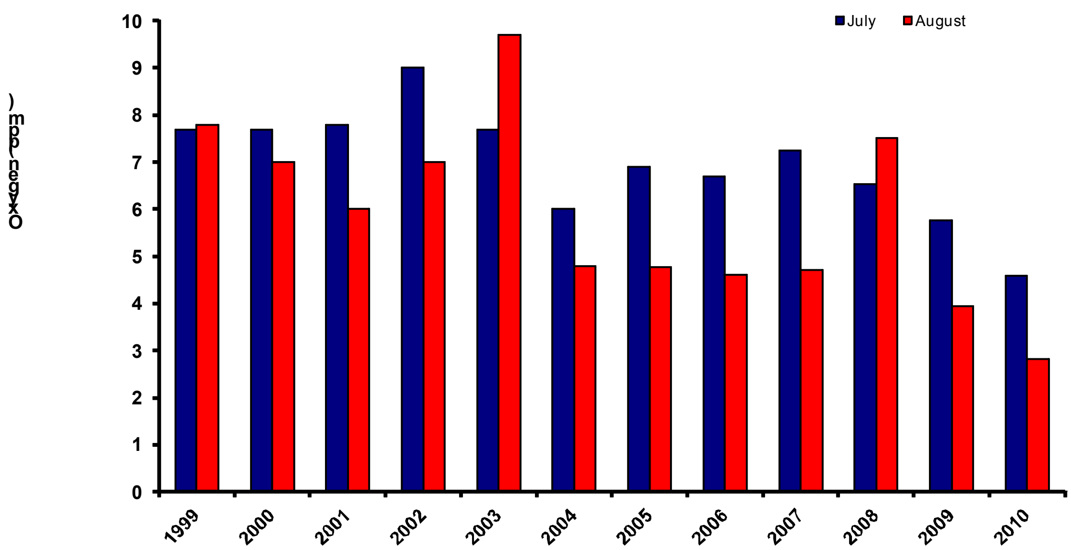


Figure 3 Budy and Luecke. Size at age based on otolith ageing of Arctic char in long term study lakes E5 and Fog 2. Mean of 5 ager with outliers disregarded. Line is a power function.



E5 oxygen at 8m



Mixing Dynamics under the Ice -

Our time series temperature measurements complemented by either time series conductivity measurements or profiles with a conductivity, temperature, depth (CTD) profiler show that mixing dynamics at ice off in Toolik Lake and two nearby smaller lakes differ from the classical picture. Other studies have shown that mixing at ice off is driven by convection, and generally, the full water column circulates once the water temperatures reach 4^{o}C, the temperature of maximum density in freshwater. As a result of the analysis of our recently collected time series temperature data, we are developing a new understanding of processes regulating mixing.

CTD casts show that before snowmelt, specific conductivity, that is conductivity normalized to 25^{o}C, is uniform in the upper water column and usually to within 1 or 2 m of the lake bottom. The near bottom increases in conductivity are likely due to remineralization of organic matter. Snowmelt introduces cold water into the upper 5 m of the lake which increases stratification due to both temperature and the lower conductivity of the introduced water. Convective mixing under the ice from spring heating is always sufficient to erode the stratification from the introduced waters, but proceeds to variable depths depending on the concentrations of dissolved constituents. Density changes very little in response to small changes in temperature near 4^{o}C. Due to this non-linearity, weak chemical stratification can retard convection and lakes can still be stratified at ice off (Vincent et al. 2008; Parsons-Field 2008). For the eight years in which we have temperature time series data, only in one year was the lake well mixed at ice off. In the other years, stratification persisted in the lower water column (Vidal, Parsons-Field, and MacIntyre in prep). Seasonal stratification sets up quickly in arctic lakes (MacIntyre et al. 2009). Hence, despite internal wave induced mixing which is initiated by wind after ice off, dissolved species are not necessarily mixed into the upper water column. Toolik Lake is among the larger of the lakes in arctic Alaska. Some of the smaller lakes are anoxic in the lower water column at ice off and have reduced rates of mixing over the summer. Understanding the dynamics in Toolik Lake and in the other smaller lakes will allow us to predict changes in the incidence of full circulation after ice off for other arctic lakes as a function of size and changing wind regimes.

Hydrodynamics of Small Lakes -

Two dimensional flows cause considerable transport in small arctic lakes. For instance, in 400 m long, 1.6 ha Lake N2, both differential cooling and upwelling cause vertical and horizontal exchanges (Figure A).

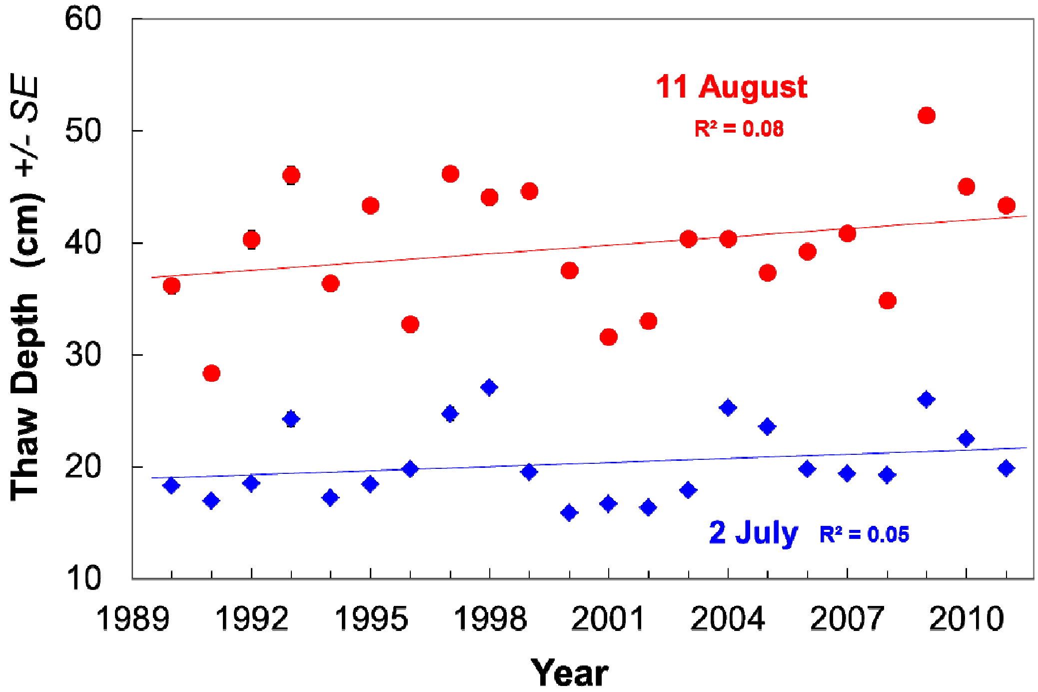
Quantifying these processes correctly is essential for quantifying the metabolism of lakes using free-water oxygen techniques. Further, phytoplankton are primarily located in the stably stratified waters just below the mixed layer. The gravity currents from differential cooling can transport nutrients from incoming stream water or groundwaters to the phytoplankton, and intrusions which form after upwelling can transport nutrients remineralized in the lower water column into the chlorophyll maximum. The data illustrated were obtained during fall cooling. These two processes, which are enabled in basins with sloping bottom boundaries, hasten full mixing with consequences for sediment temperatures and related under ice circulation patterns.

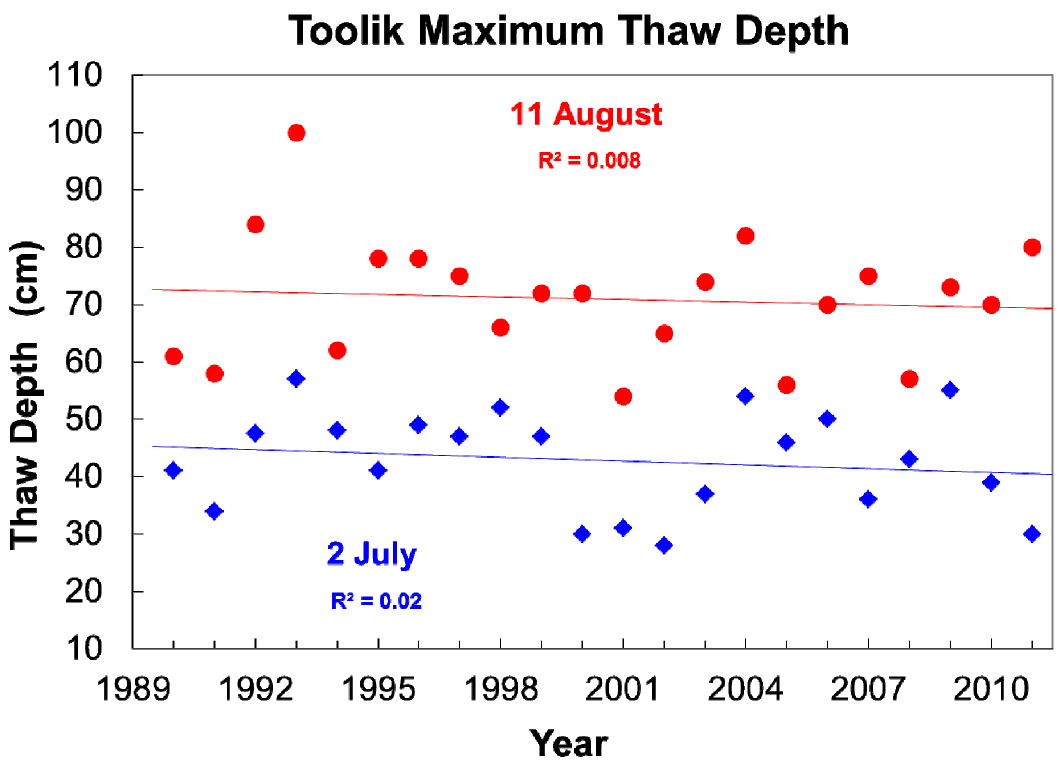
Land-water Interactions group: Findings

(1) There is a landscape-level connection between lakes and streams which affects the patterns of chemistry and biology among sites, and which produces temporal coherence in the behavior of these sites. This connection is due to the processing of materials (inorganic and organic) in lakes and streams, and the consistent differences between how this processing occurs among all lakes, and among all streams. This last summer (2011) we continued to expand on this research (started in 2008) to show that the processing of materials in soil waters by microbes strongly affects the chemistry of water as it moves from uplands to lowlands and streams and lakes.

(2) Despite arctic warming, thaw depth measurements using steel probes have not increased at Toolik. Although 2011 appears to be a "shallower thaw year", there is still no long term trend in thaw depth at Toolik, always measured on the same two days in July and August (*first graph below*). We can verify this finding by examining the maximum thaw depth on our grid, where we also see no change over time (*second graph below*). However, we have observed trends in stream chemistry over time that can only be explained by a change in thaw depth of some part of the basin. The ratio of $^{87}Sr/^{86}Sr$ in soils of the basin decreases with depth, meaning that as water flows through deeper and deeper soils its Sr isotopic ratio will decrease. This decrease in $^{87}Sr/^{86}Sr$ has been observed in the Toolik Inlet stream water over the last 10 years (Keller et al. 2010). The implication is that the flowpath of water in the Toolik Lake basin has progressively deepened and is now in contact with previously unfrozen soils with different chemical composition. It is likely that the thaw bulb under streams and lakes has deepened the most, which would account for the lack of observed changes in thaw depth of the uplands.

Thaw Depth near Toolik – *no increase over time*





(3) <u>The extent and variability of water storage and residence times throughout the open water season in beaded arctic streams is much stronger than we thought, and separation of water masses within the stream pools was consistent, and unexpected</u>. Data collected in Imnavait Creek, a beaded stream just east of Toolik, were used to better understand the effects of in-pool and riparian storage on heat and mass movement through beaded streams. Temperature data of high spatial resolution within the pools and surrounding sediments were used with discharge and electrical conductivity to identify storage areas within the pools, banks, and other marshy areas within the riparian zone, including subsurface flow paths that connect the pools. These subsurface flows were found to alter water conductivity and the character of dissolved organic matter (DOM) in short reaches (10s of m) while influencing the chemistry of downstream pools. During low flow periods persistent stratification occurred within the pools due to absorption by dissolved organic matter of strong solar radiation inputs coupled with low wind stress at the pool surface (*see Figure below*). This consistent separation of surface and bottom water masses in each pool will increase the travel times through this and similar arctic watersheds, and therefore will affect the evolution of water chemistry and material export.

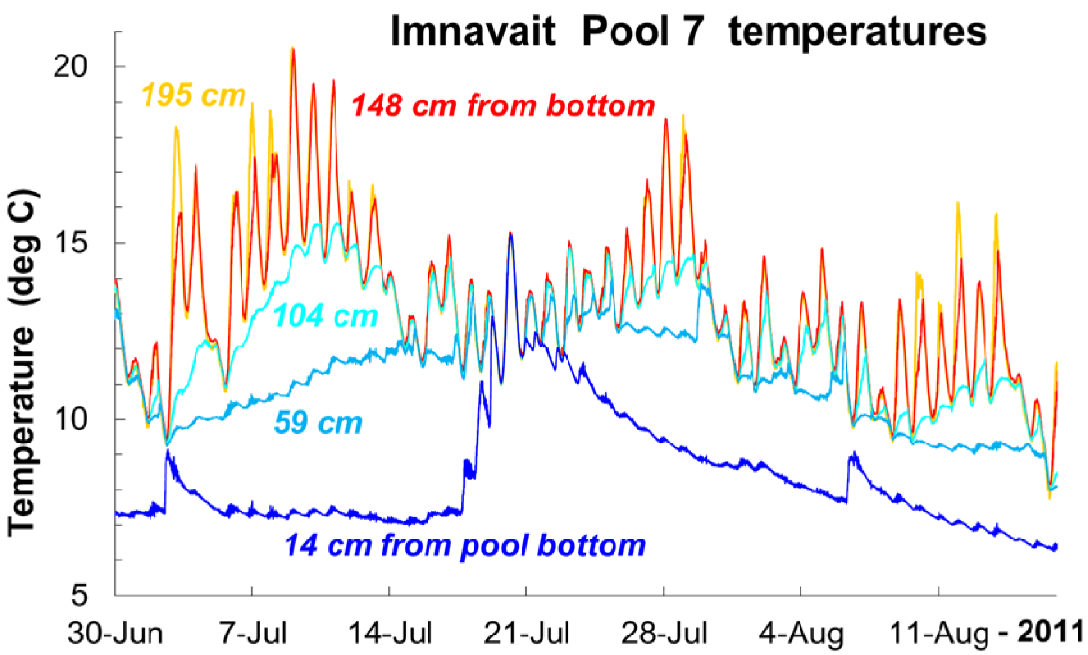


Figure showing thermal stratification (isotherms from thermistors placed at different depths in the pool) in an Imnavait Creek pool. At low discharge in early July the stratification was extremely strong (>10°C difference from top to bottom), effectively isolating the surface and bottom waters. During stratification the bulk of stream discharge acted as an overflow on top of the separated bottom layer. After a substantial rainstorm on ~20 July, this pool mixed as shown by the isotherms collapsing to ~12°C, after which the pool re-stratified.

(4) <u>We found that the subsurface topography along the frozen soil strongly mimics the soil surface topography, and thus controls the subsurface water flow paths</u>. One of the most difficult aspects of understanding the dynamics of water flow within a catchment is to define water flow paths in areas of low hydrological gradient. These areas are typically found in valley bottoms and include the riparian zone adjacent to streams. Knowing exactly what flow paths the water takes when it moves from the hillslope into the riparian zone is important for determining how that water is changed chemically on its way to the stream and finally out of the basin. In regions with permafrost this difficulty is compounded by the changing depth of soils as summer progresses and the upper soil layers thaw more deeply. In summer 2011 we used high-resolution GPS measurements of the soil surface coupled with co-located measurements of thaw depth to determine the relationship between the topography of the soil surface and the subsurface "thaw front" (*see Figure below*). We found that the two surfaces are highly correlated, which is important because it means that (1) surface mapping in areas of low relief is possible, and that (2) we can use the surface topography to estimate the below ground topography and thus where the water is flowing in this critical riparian area of the catchment.

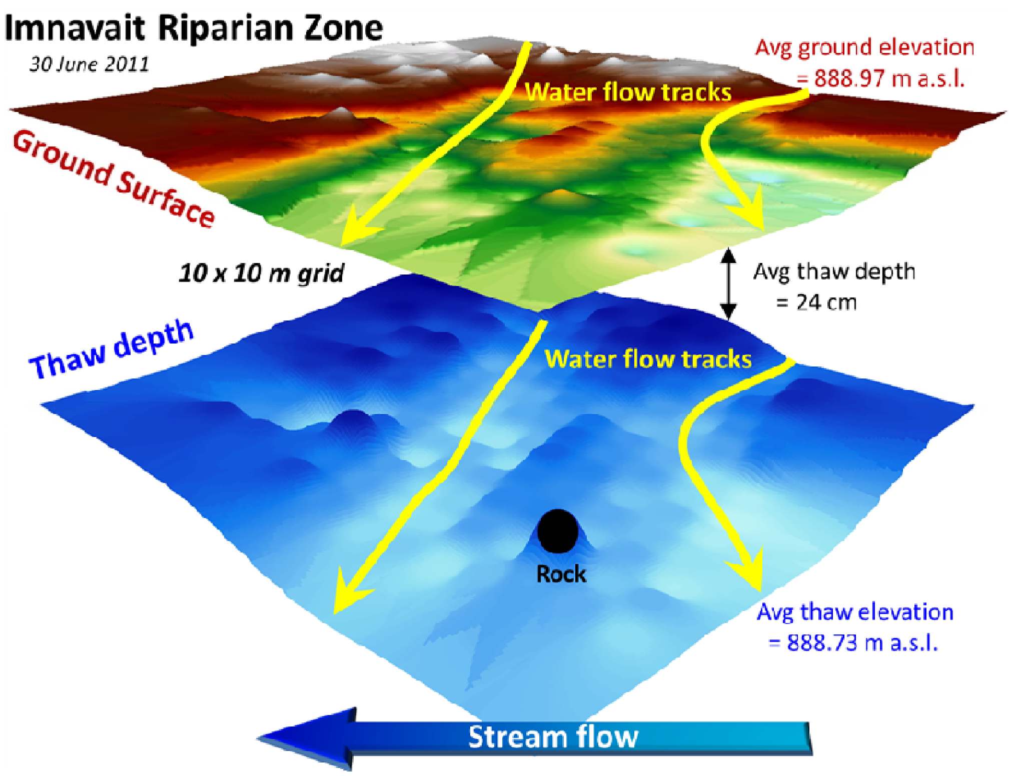


Figure showing a graphical representation of a 10x10 m topographic grid in the Imnavait riparian using high-resolution GPS measurements (soil surface topography at top) matched with co-located measurements of thaw depth (depth to frozen ground); N=276 points, range of thaw depth is 15-39 cm. Main water flow tracks in yellow (drawn by eye) show the likely routing of water. The correlation between surface and subsurface thaw topography was 94%, indicating that subsurface flowpaths can be modeled using surface expressions of topography.

Arctic (ARC) LTER: Activities in Year 1 of Funding Period

The ARC LTER is organized into four main groups, each group focused on different kinds of ecosystems or ecosystem interactions including (1) Terrestrial, (2) Streams, (3) Lakes, and (4) Land-Water Interactions. Activities of each of these groups are reported separately below, arranged by subproject within each group:

Terrestrial Group: Major field and lab activities

<u>I. Vegetation and Soils at the Anaktuvuk River Burn site:</u> The principal new activity in 2011 was sampling of soils and vegetation along 6 of the transects where vegetation cover and regrowth had been monitored in previous years. The six transects included 2 severely burned, 2 moderately-burned, and 2 unburned:

AR101 – severe burn, near severe flux tower
AR103 – moderate burn, near Dimple Lake
AR104 – moderate burn, near moderate flux tower
AR108 – control, near Dimple Lake
AR109 – control, near control flux tower
AR114 – severe burn, near South River

Sampling along these transects was by harvest methods including removal of 10x40 cm chunks of tundra including all aboveground plant parts and the upper 5-10 cm of soil, followed by removal of deeper soil cores from immediately adjacent to and beneath the quadrat samples. These samples were then transported to Toolik Field Station for sorting and extraction. Weighing and chemical analysis are currently underway at the MBL in Woods Hole, MA.

We also reestablished and maintained three eddy covariance/micromet towers in unburned, moderately-burned, and severely-burned sites, as we did in 2008-2010), and we maintained a network of 5 automated stream samplers in selected catchments through each summer. These instruments are all powered using solar panels and backup batteries. Instrument maintenance and data recovery are achieved on regular visits by helicopter from Toolik Field station. Additional transect of vegetation and soils were described in sites of varying burn severity, and estimates of C and N loss and recovery are available. Aquatic communities (lake and stream) were described as well as changes in lake and stream chemistry.

Data from the 2011 season are still being calculated, and samples are still being analyzed. Data from previous years are available via the Arctic LTER data base at http://ecosystems.mbl.edu/arc/,

<u>II. Long term experimental manipulations, species composition, and trophic structure</u>: We continued our collaboration with the Gough/Moore "Biotic Awakening" project in 2011. Across 3 fertilization experiments in moist acidic tundra (begun in 1989, 1996 and 2006), measurements in fertilized and control plots included:

1. Species Composition and cover of vascular plants and mosses (July 2011)
2. Weekly measurements in the field of thaw depth, soil temperature and collections of soil water for determination of available N (NO3, NH4 and TFAA) (May – Sept 2011)
3. Collection of field samples and sample processing in the lab for 2 decomposition experiments exploring influences of fertilization on litter decomposition rates (Sept 2011)
4. Processing in the lab of soil samples collected in June and August, 2010, for determination of Root biomass (Dec 2010-Dec 2011)
5. Litter measurements in the field to determine standing crop of litter and annual litter production (June, Sept 2011)
6. Collection of seed rain samples and re-deploy seed rain mats (May, Aug 2011)
7. Greenhouse experiment to look at fertilization effects on seed banks (Sept-Dec 2010)

8. Soil collected and processed for soil microbial biomass (bacteria and fungi), protozoan biomass, invertebrate biomass (nematodes, enchytreaids and arthropods), soil carbon and nitrogen content, inorganic nitrogen, microbial enzyme activity and soil chemistry (July 2011)
9. Soil collected and processed for soil microbial community structure (classification into dominant phyla using molecular methods) and enzyme activity (July 2011)

In addition to the above, postdoctoral fellows Marjan van de Weg (MBL) and Jenny McLaren (Texas-Arlington) made a series of measurements of leaf level photosynthesis and litter and soil respiration in control and fertilized plants, and established a litter decomposition experiment including both leaf and root litter. This work was also done in the long-term LTER fertilizer experiments.

III. Changing Seasonality of Tundra Nutrient Cycling: We have developed three collaborations with another OPP funded project based at Toolik Field Station (PIs: M Weintraub, Ed Rastetter, Joshua Schimel, Heidi Steltzer, Paddy Sullivan, Matthew Wallenstein); Title: The Changing Seasonality of Tundra Nutrient Cycling: Implications for Ecosystem and Arctic System Functioning). Together, we: (1) have set up pitfall traps for arthropod sampling in the early snowmelt treatment plots and control plots at their study site, which is located adjacent to one of our own sites at Imnavait Creek; (2) have set up a field protocol that expands upon Steltzer's project by including the response of caterpillar abundance and body condition to earlier snowmelt and climate warming, and; (3) are exploring the effects of the shrub canopies on summer soil temperatures at three depths.

In early May 2011, field crew members (including undergraduate students, graduate students and research assistants) from the Boelman, Gough and Wingfield labs traveled to the Arctic LTER site (Toolik Field Station,TFS). In general, the arrival of songbirds on the North Slope of Alaska along the Dalton Highway from the Atigun Valley to the Sagavanirktok River DOT station (tundra zone) was documented in detail beginning in early May. As was done in 2010, particular attention was paid to arrival biology of the white-crowned sparrow, Zonotrichia leucophrys gambelii, (GWSP) and Lapland longspurs, Calcarius lapponicus, (LALO). This was done at the four study sites that we established in 2010: Atigun Valley, where the birds first migrate through the mountains to reach the tundra of the North Slope; TFS; Imnavait Creek; and near the Sagavanirktok River DOT Camp, approximately 30 km north of TFS. Our meteorological sensors and acoustic recording units were also deployed at each site in early May so that birdsong could be recorded beginning with arrival of the birds in mid to late May. Weekly sampling of vegetation and arthropods began in our previously established (2010) permanent vegetation and arthropod transects/quadrats at each site immediately during snowmelt in late May and early June, including: spectral reflectance of the vegetation, old berry and catkin counts (in order to determine vegetation based food resources available to the birds upon arrival), shrub canopy structure (in plots that were not measured for this in 2010), plant phenological stages, ground arthropod sampling (with pitfall traps), and aerial arthropod sampling (with sweep nets and sticky traps). In our first season (2010), arthropod sampling was conducted via sweep nets and pitfall traps only. This season, we added sticky traps to our arthropod data collection techniques, in order to ensure that we are sampling not only the ground dwelling (via pitfalls) and flying insects that tend to dwell on vegetation (via sweep netting), but also those arthropods that spend a significant amount of time flying (via sticky traps). At each site, GWSP and LALO blood samples were taken, and body condition was assessed as they settled on breeding territories and began nesting. All birds caught were banded. Air and ground temperature and wind speed were measured along transects for shrub and open tundra plots to assess microhabitat characteristics to which arriving and nesting birds are exposed. Nests of the two focal species were located at all sites where possible and monitored for fledgling success. In mid-late July, the current season's berries and catkins were counted and assessed for ripeness (berries) to determine food resources available for the birds at this late point in the breeding season. Weekly vegetation, arthropod and bird sampling concluded in late-July after the birds completed fledging.

IV. Ecotypic variation in tundra plants: This work was done in collaboration with the McGraw/Fetcher

Ecotypes project, on plots established by G Shaver and N Fetcher in 1979 and maintained by the ARC LTER. The work was focused on 6 6 reciprical transplant gardens of Eriophorum vaginatum. We visited each of the transplant gardens for the Eriophorum vaginatum experiment and measured the tillers that we had tagged the year before. Then we harvested the tussocks, wrapped them carefully to prevent the tags from falling off, and transported them to Toolik Lake Field Station. At Toolik, we determined whether the tagged tillers had produced daughters for the stage demographic analysis and aged a haphazardly chosen group of tillers for age demographic analysis. We selected 25 tillers to determine mass per tiller and nutrient content. We also saved 2-3 tillers from each tussock for genetic analysis. We also measured temperature response curves for respiration of 3 different populations at the NoName, Coldfoot, Toolik, and Sagwon gardens.We have submitted a manuscript describing a cline in stomatal density to the American Journal of Botany. The senior author is Caitlin Peterson, a former undergraduate at Stetson University, who participated in the 2010 expedition.

<u>Terrestrial Group--Teaching/education</u>

- The Changing seasonality group hosted two Earth Science teachers and the Education Director from the Alaska Bird Observatory (ABO, www.alaskabird.org) at the Toolik Lake Field Station from May 31 – June 6, 2011. The teachers were from public schools in Fairbanks, AK: Carol Scott (Science Teacher at Randy Smith Middle School in Fairbanks), and Wendy Ehnert (Science Teacher at West Valley High School in Fairbanks). The Education Coordinator from ABO is Tricia Blake. Wingfield also met with Ms. Blake in early May at the ABO in Fairbanks. The goal of involving the teachers is to integrate our research into their classroom curriculum, but also to guide them in setting up a small, related research project in Fairbanks that will involve their students making a similar suite of measurements at the ABO, to the ones we are making for the current project on the N. Slope. We plan to continue our interactions with these teachers in various ways, including skype interviews with us during the school year, and providing continued assistance as they work on their field observations in Fairbanks.
- Gough spoke to kindergarten and second grade students at Cottonwood Creek Elementary, Coppell, TX about the project. Using the project webpage as a guide, she described the food web relationships among plants, arthropods, and birds in arctic tundra and brought in arthropod samples from 2010 for the children to examine.
- Boelman gave a Saturday morning lecture for Lamont-Doherty Earth Observatory's 'Earth 2 Class' program in April 2011. This program is a unique professional development program created jointly by classroom teachers, research scientists, and educational technology specialists at Columbia University. The program integrates science content knowledge with increased understanding and skills about learning and technology in the classroom.
- Gough was a guest lecturer in a course in "Contemporary Science" at UT Arlington in June 2011. Students in this course are current K-12 teachers pursuing a Masters degree in Interdisciplinary Science. Her lecture focused on climate change in the Arctic and included aspects of this study. She distributed four papers from the primary literature prior to the class for discussion, all of which focused on changes in vegetation towards increasing shrubbiness in arctic tundra. Teachers commented that their perceptions of the Arctic changed after the discussion and discussed how they could incorporate aspects of climate change in the Arctic into their own classrooms.
- Shannan Sweet (Graduate Student at Columbia University), hosted six high school students and a PhD Candidate IGERT Resilience and Adaptation Program School of Natural Resources and Agricultural Sciences, University of Alaska Fairbanks (Kimbereley Maher), for a day of field work in mid-July 2011. The students are from the UAF Rural Alaska Honors Institute (RAHI) which is designed for students who are finishing their junior or senior year of high school. The students visiting are all Alaska Native students and hail from Noatak, Kwethluk, Palmer, Sand Point, and Unalakleet. DATA SHARING: We have shared our meteorological data from 2010

with the Arctic LTER, who will make it publically available on their website: http://ecosystems.mbl.edu/arc/datacatalog.html

- Boelman gave a public lecture talk at the Lamont-Doherty Earth Observatory Open House 2011 event where she gave a talk on her work based out of the Arctic LTER.
- Boelman is teaching a mini-lecture/seminar style course (1-3 college drecits) in the Department of Earth and Environmental Sciences of Columbia University titled 'Arctic Tundra and Climate Change'. Students are upper level undergrads and grad students.
- During the academic year, three UT Arlington undergraduates were engaged in soil core processing. They were all students of Gough's in formal courses, allowing them to connect what they were learning in the classroom with hands-on lab research.
- Our summer field crew for 2011 included one undergraduate (Chris Hendrix, UT Arlington, REU paid by ARC LTER), one lab technician (Greg Selby from Colorado State), three postdoctoral scientists (Jennie McLaren from UT Arlington; Aki Koyama and Rod Simpson from Colorado State), and one graduate student (Kirsten Holfeder, Colorado State). Another grad student from UT Arlington (Matt Rich) assisted with field activities. The team also included K-12 teachers from the Poudre School District in Colorado: Mr. Dave Swartz and Ms. Mary Hunter-Lazlo. While in residence at TFS, all members of our field crew attend the weekly "Toolik Talking Shop" informal lecture series to learn about research activities at the site. They are engaged in sampling activities and data processing, and interact frequently with Gough and Moore.

Terrestrial Group--Talks and meetings

i. Arctic LTER meeting in Woods Hole: presentations by Laura Gough and John Moore (Feb 2011)
ii. Project meeting for clarification of goals on soil carbon model at Colorado State University. Attended by: Moore, Wallenstein, Parton, McLaren, Simpson (March 2011)
iii. Ecological Society of America Annual Meeting: Presentations by Gough and Simpson
iv. Boelman is co-convening a scientific session at Fall AGU 2011 in San Francisco (Dec 5-9) with Prof. Eric Post (https://homes.bio.psu.edu/people/faculty/post/eric.html) "Multi-trophic level response to climate change in the Arctic tundra ecosystem' (Session ID: B55). Session description: Evidence accumulating from many disciplines shows that the Arctic is currently undergoing a warming trend and multiple models predict this warming will continue. As highlighted by the Arctic Climate Impact Assessment (ACIA), climate change responses across trophic levels are understudied in Arctic systems compared to in others. We welcome studies that consider the cascade of changes that are triggered, either directly or indirectly, by Arctic warming. In particular, we encourage studies focused on the impact of changing seasonality on cross-trophic level dynamics. Empirical studies based on field observations and experiments, as well as those based in either terrestrial or aquatic habitats are all welcome.
v. Wingfield gave the "Howard Bern" lecture at the annual national meeting of the Society for Integrative and Comparative Biology, January 2011. He is co-convening a symposium on "Endocrinology in Extreme Environments" at the inaugral meeting of the North American Society of Comparative Endocrinology, University of Michigan, July 2011.
vi. Gough gave an oral presentation in an organized oral session at the Ecological Society of America annual meeting in August 2011 on trophic dynamics in arctic tundra. She will include this study as an example of research focused across multiple trophic levels.
vii. Boelman was invited to give the Biology Department's seminar at the University of Chattanooga (Nov 4 2011), where she gave a talk on her work based out of the Arctic LTER.
viii. John Hobbie gave a talk at the Annual Meeting of the Ecological Society of America J.E. Hobbie, "The heterotrophic microbial biomass in soil is unsupportable by the measured inputs of carbon: How do microbes survive and why should ecologists care?"
ix. J. Tang, S. Hackley, Carbon fluxes from soils and plants in Arctic tundra and their responses to warming, presented in the ARC LTER annual meeting, Woods Hole, Feb. 18-20, 2011.

x. Michelle Mack gave the following related talks during 2010-2011:Brown University, Providence, RI. “Climate change and novel disturbance regimes in arctic tundra,” 4/10, AND: Columbia University, Lamonte-Doherty Earth Observatory, NY. “Climate change, novel disturbance regimes, and the resilience of arctic terrestrial ecosystems,” 2/11.

Terrestrial: Other Contributions

1. Outreach Activities
   - Moore, Wallenstein and Parton included K-12 teachers in the project through the Research Experience for Teachers and Teacher in Residence programs at CSU – Dave Swartz and Mary Hunter-Lazlo from the Poudre School District in Colorado
   - Gough presented an update on the activities of this project in a Toolik Talking Shop in early June 2011.
   - During June 2011, elements of the project were included in the CSU Summer Soil Institute. Moore and Wallenstein were part of the leadership team for the 2011 Summer Soil Institute (June 12-24, 2011). Concepts and techniques from this project were used in the lectures and training sessions. The two-week institute included instructional, field and laboratory sessions on soil physics, chemistry, and biology, the questions and methods integral to our project, as well as sessions in the use of the DayCent and Food Web models that are featured in our project. Participants compared alpine tundra to grassland soils. Participants included faculty, graduate students, postdoctoral fellows and K-12 teachers.
   - Also in June 2011, Gough gave a guest lecture in a course entitled “Contemporary Science” at UT Arlington for current K-12 teachers pursuing a Masters degree in Interdisciplinary Science. Her lecture focused on global change in the Arctic and the carbon cycle in terrestrial arctic ecosystems. For group discussion she assigned several recent papers from the primary literature concerning the shift to increased shrubs with climate warming, a topic directly related to this project.
   - Boelman was invited to give a weekend public lecture in April 2011 for the Lamont-Doherty Earth Observatory’s Public Lecture Series. The lecture can be viewed online: http://www.ldeo.columbia.edu/news-events/events/public-lectures.
   - Boelman was invited by the Quebec Government Office in New York to give a presentation and take part in discussions at a working luncheon with Prof. Louis Fortier of ArcticNet Canada. The topic was ‘Arctic and Northern Issues’. As a result of this meeting, Boelman will be organizing and leading a panel discussion on ‘The Arctic’s Response to Climate Warming: Ecosystems, people and impacts on the rest of the planet',through a collaboration between Lamont-Doherty, Quebec Government Office in New York, and The Earth Institute of Columbia University.
   - McGraw, J. B. 2011. A Darwinian view of climate change: How long-term ecological studies provide key insights. FEb. 11, Stetson University invited speaker.
   - Shockey, M. and M. Vavrek. 2011. Biodiversity in transplanted Eriophorum vaginatum
   - tussocks.Chi Beta Phi Mini Conference, April 16, GSC, Glenville, WV
   - Shockey, M. and M. Vavrek. 2011. First Annual Pioneer Showcase Creative Arts and Research Forum, April 5, GSC, Glenville, WV
   - Bennington, C. C. 2011. Arctic plants in novel environments: ecological implications for a changing climate. April 21, Low Country Institute on Spring Island, SC.
   - McGraw, J. B. and N. Fetcher. 2011. Implications of ecotypic variation for the response of tundra plants to climate change. Toolik LTER meeting. Feb. 17-19, 2011, Woods Hole, MA.
2. MEDIA:
   - Boelman blogged from Toolik Field Station (late May through early June, 2011) on the current project for the New York Times ‘Scientist at work’ online feature. We had high readership and many positive Comments posted by our readers who came from diverse and international

backgrounds. Published blog entries can be found here: http://scientistatwork.blogs.nytimes.com/author/natalie-boelman/

- Boelman created a Project Website that will be updated on a regular basis, and can be found here: http://www.ldeo.columbia.edu/~nboelman
- Boelman recently did a telephone interview with Newsday (http://www.newsday.com/) who are considering writing about the current project either in their online or hardcopy publication.
- Boelman recently did a telephone interview with the Editor of the Lamont-Doherty Earth Observatory Alumni Newsletter who will be featuring her current work in their Fall issue. (http://www.ldeo.columbia.edu/about-ldeo/alumni/alumni-newsletter)
- In the collaboration with the Ecotypes project, two new graduate students and three new undergraduates were introduced to Alaskan field ecology and obtained experience in studying tundra plants. The students also received training in oil field safety prior to visiting the site at Prudhoe Bay. All were introduced to the broad range of questions being addressed about climate change, especially during their time at Toolik Lake LTER where they interacted with summer-long field teams resident at the LTER.

Streams group: Major field and lab activities

Long term fertilization of the Kuparuk River with phosphoric acid continued for the 29th season. We moved the location of the phosphorus addition to a point ~1.4 km upstream to initiate a new experiment to test a fundamental question about the degree to which a previously fertilized reach of the Kuparuk River had recovered from the past treatment. Phosphorus was added near the original 0.0k location and a secondary dripper was also used at the 1.4k location. This arrangement created five experimental reaches: reference (above 0 km), refertilzed-1 (0-0.59 km, previously fertilized 3 years by no mosses), refertilized-2 (0.6-1.4 km, previously fertilized 13 years, mosses for 6 years), fertilized (1.4-5.5 km, fertilized continuously for 29 years), extended (below 5.5 km, fertilized for 29 years but at higher level in 2011).The primary dripper added phosphorus at 2.4mL/min, the secondary dripper added phosphorus at 1.2mL/min in order to maintain phosphorus concentrations throughout the fertilized reach to downstream of 4.0k. Maintenance level monitoring of nutrients and young-of-the-year grayling was continued on the Kuparuk River and Oksrukuyik Creek. Moss point-transects were done twice during the summer on the Kuparuk. Additional monitoring was done as part of Michael Kendrick's PhD research for the Fishscapes project, including macroinvertebrate sampling, adult insect collection, metabolism, and measurement of *Orthocladius* individuals as well as using historical macroinvertebrate samples to determine the effects of changing seasonality on macroinvertebrate life-history and community.

The Anaktuvuk River Fire study was continued with ISCO autosamplers and field collections of samples three times throughout the summer. Additional activities included the sampling of sites in the Upper Kuparuk watershed as well as some new sites that are tributaries to the Itkillik River. The sites were visited a total of four times during the summer and fall.

Collaborations and involvement with other projects included working with the Fishscapes project, particularly on the Kuparuk River, led by Linda Deegan. Other projects that included many researchers involved in streams research were the ARCSS/Thermokarst project and the Changing Seasonality of Arctic Stream Networks, both led by Breck Bowden.

Streams Group: Talks and meetings

- Bowden, WB, and ARCSS/TK Collaborators. Winter review and planning meeting. In association with American Geophysical Union meeting, San Fransisco, CA. 12 December, 2011.
- Bowden, WB Ecohydrological perspective of climate change aspects of northern catchments. North-Watch Workshop. Hubbard Brook, USA. 14-17 April 2011. Invited keynote presentation.
- Bowden, WB. Interactions of hydrology, biology, and geochemistry in arctic landscapes: thermokarst failures as agents of landscape change in a rapidly warming climate. Poster presented at the Vulnerability of Permafrost Carbon Research Coordinating Network meeting. Seattle, WA. 1-3 June 2011.

- Bowden, WB. An Introduction to Changing Permafrost in the Arctic Environment. Presentation to the National Science Board Taskforce on Mid-Scale Research. National Science Foundation. Washington, DC. 5-7 June 2011.
- Bowden, WB and ARCSS/TK collaborators. Summer review and planning meeting. Toolik Field Station, Alaska. 21 June 2011.
- Bowden, WB. Member. SEARCH Science Steering Committee.
- Deegan, MacKenzie, and Peterson. Changing seasonality of Arctic hydrology disrupts key biotic linkages in Arctic aquatic ecosystems. American Fisheries Society annual meeting, Seattle, WA, Sept 2011.
- Golden. Habitat connectivity and metapopulation dynamics of Arctic grayling (Thymallus arcticus) on Alaska's North Slope. Arctic Grayling Symposium and Workshop, Grand Prairie, AB, Canada, June 2011.
- Gooseff, M. Social and ecological responses to the effects of climate change and land-use on water availability: contrasting resilience among major river basins of the US and Canada; LTER Synthesis Workshop, November 16-19, 2011; Sevilleta National Wildlife Refuge and LTER
- Kendrick, MR, AD Huryn, and LD Deegan. Seasonality of primary and secondary production in an arctic river. AGU Fall Meeting. San Fransisco, CA. December 2011.
- Kendrick MR and EO Kendrick. From Alaska to Alabama: Taking climate change research back to the southeastern US. Barrow SchoolYard Talk. June 2011
- MacKenzie and Deegan. FISHSCAPE: Assessment of shifting seasonality in Arctic grayling migration. Arctic Grayling Symposium and Workshop, Grand Prairie, AB, Canada, June 2011.

Streams Group: Teaching/education

- Bowden, Flinn, Larouche, Kampman, Gooseff and several other collaborators gave webinars as part of the international web seminar on Introduction to Changing Permafrost in the Arctic Environment. The webinar was hosted by the Arctic Polar Early Career Scientists and was funded by the ARCSS Thermokarst Project, on which Bowden is the Lead PI. In all, 12 seminars were offered to an international audience.
- Eve Kendrick received NSF Research Experience for Teachers (RET) funding and was stationed at Toolik Field Station in 2011 doing a comparison study of Arctic grayling young-of-the-year dynamics across the North Slope of the Brooks Range. In June, Michael Kendrick and Eve Kendrick both participated in the Arctic LTER Schoolyard Saturday, a weekly seminar series by visiting and resident scientists, based at Barrow, Alaska. They presented lectures on Arctic stream ecology.

Lakes Group: Activities

- We continued fertilization of two lakes and monitoring the effects of fertilization on phytoplankton production, phytoplankton biomass, benthic production and respiration and zooplankton and fish abundance patterns.
- Continued an integrated study of the series of inlet lakes and streams to Toolik Lake
- Continued our weekly long-term monitoring of limnological characteristic of Toolik lake
- Continued sampling of 16 additional lakes for limnological characteristics.
- Comparison of limnological characteristics of these lakes during the past two decades.
- Continued annual fish sampling for population dynamics and community structure in long-term study lakes (field) including mark-recapture study. As part of this activity, we continued laboratory assessment of age/size structure of char populations using otolith aging and size frequency evaluations (Figure 3 Budy and Luecke).
- Continued annual food web structure analyses using isotopic composition and dietary analyses. Over this reporting period, we quantified alternative pathways of secondary and tertiary energy flow not previously investigated in depth.

- Addition of a new study lake in anticipation of local extinction in one of the long-term study lakes.
- Attempted the incorporation of new sampling techniques to quantify early char recruitment success.

Lakes group: Anaktuvuk River Burn site: Six lakes were sampled during the summer: Dimple, Luna, Horn, Shasta, Perched (3 times each) and North (twice). Lakes were sampled for:

- *Lake profiles.* Temperature, conductivity, dissolved oxygen, pH, and chlorophyll were measured in profile at the deepest point in each lake using a hydrolab.
- *Water Column Chemistry.* 2-3 liters of water were brought back from each lake on each visit. Samples were split for the following analyses: chlorophyll a, TSS, POC, PON, C and N stable isotopes, PP, black carbon, NH_4-N, NO_3-N, TDN, SRP, TDP, anion, cations, alkalinity, and DOC. Nutrient analysis (SRP, NH_4^+, NO_3^-) and TSS were analyzed at Toolik Field Station, other samples were preserved and analyzed at home institutions.
- *Benthic Metabolism.* 8 sediment cores were taken from Horn Lake on two occasions for measurement of benthic primary production and respiration.
- *Sediment Characteristics.* One sediment core each was taken from Dimple, North, and Shasta Lakes for paleolimnologic analysis.

Lakes group: Lake physics activities -
Javier Vidal, a postdoctoral fellow who initially came to UCSB with funding from a Fulbright Fellowship, began processing and analyzing the time series temperature data from the overwintering thermistor chains. Prior to 2005, thermistors were Onset Stowaways with accuracy of 0.2°C. Once GPS were able to locate instruments within 5 m, we began to use RBR Instruments TR1050 temperature loggers supplemented with RBR XR420s with conductivity. This high quality data has been obtained in Toolik Lake beginning in 2005. Two small lakes have had overwintering thermistor chains with up to 3 conductivity loggers installed for 2 or 3 winters. Temperature sensors were Onset Water Temp Pros. Although their accuracy is 0.2°C, their resolution is an order of magnitude better. Javier has also successfully modeled fall cooling in 1.6 ha Lake N2 using the 3 dimensional hydrostatic Estuary Lake Coastal Ocean Model (ELCOM). One manuscript is in preparation which characterizes the physical aspects of the data set. Two others are in the planning stages. Javier conducted an experiment for six weeks in summer 2010 to quantify the turbulence associated with variable surface forcing and internal wave dynamics. During the current period, he has processed and analyzed that data set and a manuscript is in preparation.

Edmund W. Tedford (Ted) was hired as a postdoctoral fellow for **ARC-0714085** and DEB-0919603 in Sept. 2010. In spring 2011, Ted worked with Oliver Fringer of Stanford University. Fringer's model SUNTANS, a 3 dimensional non-hydrostatic hydrodynamic model, has successfully described non-linear internal waves in a number of lake and ocean settings. This effort was motivated by the failure of DYRESM, a one dimensional hydrodynamic model, to accurately characterize changing thermal structure in 1.5 km^2 Toolik Lake when wind speeds were high enough for non-linear wave formation. Due to the weak stratification in Toolik, such events occur frequently during the stratified period. SUNTANS successfully modeled the internal wave field in Toolik Lake and vertical and horizontal transports. The model is currently forced by wind. Ted has begun the process of adding heating and cooling so that changing mixed layer dynamics are successfully incorporated.
We conducted a study of the hydrodynamics of Lake N2 in summer 2011. We instrumented the lake with thermistors, an acoustic Doppler current profiler (ADCP), an acoustic Doppler velocimeter (ADV), and oxygen sensors. We profiled for turbulence using the self-contained autonomous microprofiler

(SCAMP). We have processed all the data and computed surface energy budgets. A manuscript is in preparation.

Lakes group: presentations*:*

- Budy, P. and C. Luecke. 2011. Understanding the drivers of fish population dynamics in unique, Arctic lakes with special consideration of the role of climate and climate change. Woods Hole – marine Biological Laboratory.
- MacIntyre, S. Stanford University, Climate Related Variations in Mixing Dynamics in an Arctic Lake. January 2011.
- MacIntyre, S. Stanford University, Variations in Mixing Dynamics in Lakes Across Latitudes. January 2011.
- MacIntyre, S. UC Berkeley, Variations in Mixing Dynamics in Lakes Across Latitudes. March 2011.
- MacIntyre, S. Plenary Address, Physical Processes in Natural Waters, Mixing Dynamics in Lakes across Latitudes. Burlington, Ontario, July 2011.

Education -
Data collected in Toolik Lake an in nearby smaller lakes are being used in an upper division undergraduate class entitled, 'Flow in Aquatic Ecosystems'. Students are taught Matlab and learn techniques for data processing, analysis, and graphing using the observational data from the arctic lakes.

Land-Water Group: ACTIVITIES

The major research activities of the Land-Water subgroup include collection and analysis of inorganic and organic water chemistry in several long-term study lakes (E5, E6, Toolik lake) and in a series of lakes and streams in the Toolik Lake and Kuparuk drainage (25 sites total). We also measure the flow of water into Toolik Lake and in several streams in the "inlet series" of lakes and streams of the Toolik Lake basin using automated water-level gauges calibrated with hand measurements of discharge. In addition, we have aided in the measurement of bacterial production in Toolik Lake (weekly) and in the series of lakes draining into Toolik Lake (3 times per summer). Finally, we also conduct a thaw depth survey twice each summer in two catchments, Imnavait Creek, and the Tussock Watershed just south of Toolik Lake.

We coordinate our sampling closely with two other NSF projects: (1) the LTREB program (Dr. Byron Crump, lead PI) – these results related to the LTER program are described under the section provided by Byron Crump, and (2) the DOM-Photochemistry project (Dr. Rose Cory lead PI, University of North Carolina). Our activities on this second project included collection of water samples and soil core samples for analysis of chemistry and bacterial activity, and for experiments on the effects of photo-oxidation on water chemistry and biological activity. These photo-oxidation experiments were done at Toolik Lake.

In the summer of 2011 we used LTER support to help investigate the biogeochemical consequences of physical stratification in beaded stream pools, and the nature of riparian zone interactions with uplands and the stream. This work was done with Dr. Beth Neilson at Utah State University, and we set up and monitored to surface waters (lakes, streams) and soil waters of a large tundra fire north of Toolik Lake. Our activities included collection of water samples and soil core samples for analysis of chemistry and bacterial activity, and for experiments on the effects of photo-oxidation on water chemistry and biological activity. These photo-oxidation experiments were done in 2010 with Dr. Rose Cory at the University of North Carolina.

Land-water group: Education and training: Educational activities included the training of three Masters and one Ph.D. student at the Toolik Lake field site. One of the MS students has graduated (M. Merck, Utah State University). We have also provided opportunities in this first year for3 technicians to learn about and practice field and laboratory ecology both at the University of Michigan and at our field station in northern Alaska near Toolik Lake.

Land-Water group CONTRIBUTIONS to:
(*a) the principal discipline(s) of the project;*

The Land-water group has made 4 main contributions to the disciplines of ecology, ecosystem studies, and environmental science: (1) We have shown that the functioning of aquatic ecosystems on the landscape is better understood when the interactions between ecosystems, such as lakes and streams, are taken into account. These interactions not only affect the chemistry of ecosystems, but also the biological activity and the community of species in the lakes and streams. (2**)** Soil and especially root production of dissolved materials that can be exported to surface waters is extremely high, but the net export is low and thus processing by microbes must be substantial. In the processing the microbial community composition and activity are strongly linked, and there are distinct and consistent patterns of microbial processing at key points in terrestrial and aquatic ecosystems across the landscape. (3) We have now demonstrated that the productivity of lakes (and probably oceans) has been underestimated by the commonly used methods of incubating bottles at fixed depth. This underestimation is due to the positive effect of phytoplankton cells being moved upward in the water column by internal waves, where this upward movement increases the available light for photosynthesis much more than does the paired downward movement on the wave -- this asymmetry in effect is because the light in all waters is extinguished exponentially with depth, so that upward movement gives much greater increases in available light. (4) The final contribution is the finding that slight increases in thaw depth of the tundra can have large geochemical impacts on the streams draining the landscape, especially in terms of the amounts of inorganic carbon and nutrients contained in the water flow.