Arctic LCC Progress Report

1. PROJECT INFORMATION

Title:	Changing Seasonality of Invertebrate Food Resources across the Arctic Coastal Plain
Report period	15 May to 15 November 2011
Report submission date	26 January 2012; revised 2 August 2012
Author of Report	Malcolm G. Butler

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2. PROJECT OVERVIEW

a. Briefly (4-5 sentences) describe both the research purpose and the underlying need for this research.

The purpose of this research is to improve our understanding of how climate, and potentially climate change, shapes the availability of prey for tundra-nesting birds that rely on aquatic invertebrates in the Alaskan Arctic. We seek to understand how water temperature in ponds on Alaska's Arctic Coastal Plain regulates (A) the seasonal timing of aquatic insect emergence - a crucial event for a majority of tundra-nesting bird species - and (B) the availability of invertebrate biomass for benthic-feeding birds such as eiders and other waterfowl. ALCC-supported work in 2011 builds on recent (2009-2010) data from similar National Fish and Wildlife Foundation (NFWF)-funded work, as well as legacy data collected by the PI (Butler) at Barrow in the 1970s. Avian biologists seek a better understanding of temporal and spatial variability in prey resources for tundra-nesting birds. We are generating information on environmental regulation of invertebrate abundance and seasonality that is relevant to the needs of avian research groups such as the Arctic Shorebird Demographic Network (ASDN), who seeking to understand how a changing arctic climate may alter prey resources for tundra-nesting birds.

b. List the objective(s) of the project, exactly as described in your Statement of Work.

The primary objective of ALCC-supported work in 2011 is to provide information helpful in predicting the seasonal timing of adult insect emergence from tundra ponds. Related work by D. Rinella, in conjunction with the ASDN, targets development of models for predicting the seasonality of emerging insect biomass under different climate scenarios. We will also continue NFWF-supported work on the composition and size structure of aquatic communities under different thermal regimes, and temperature effects on life-history events relevant to the timing of insect emergence.

3. PROGRESS SUMMARY

a. Describe report period progress.

A team consisting of the PI (M.G. Butler), collaborator Dr. D.C McEwen, MS student S.D. Braegelman, and undergraduate student E.J. Herman spent 65 man-days in the field, collecting data at Barrow and Atqasuk over the period 6 June to 15 July 2011.

Specific objectives from 2b (above) involve the following:

1. Obtain information to help predict emergence timing of aquatic insects:
- **(A)** Monitor emergence in ponds at Barrow and Atqasuk, along with pond temperatures.
- **(B)** Evaluate inter-annual and pond-to-pond variation in emergence timing of dominant insect populations, in relation to their thermal environments.
- **(C)** Evaluate and improve methods for obtaining data on the seasonal pattern of emerging insect biomass for use in monitoring changes in avian food resources.
- **(D)** Investigate how insect emergence is regulated at the population level.

2. Evaluate variation in the composition and size structure of aquatic invertebrate communities across a climatic gradient:
- **(A)** Collect empirical data on taxonomic composition and size structure of pond benthic communities at Barrow and Atqasuk.
- **(B)** Compare growth and development rates of representative species under differing climatic conditions (Barrow vs. Atqasuk).

<u>Activities during this reporting period toward these objectives</u>:

1(A): We monitored insect emergence from 8 tundra ponds at Barrow (4 ponds at the International Biological Program (IBP) Site & 4 ponds in the Barrow Environmental Observatory). We collected data from the onset of emergence in mid-late June through the second week of July at both sites, using standardized sweeps for pupal exuviae (PE sweeps) at 2-3 day intervals. We obtained data on insect emergence phenology at Atqasuk from three ponds, with PE sweeps collected at least twice weekly via four visits by our team combined with the generous assistance of plant ecologists from Grand Valley State University working at that site. HOBO Pro temperature loggers monitored hourly temperature at the sediment surface in five of the eight shallow (<50cm) Barrow ponds where we monitored emergence, and in two sites representative of the three ponds sampled at Atqasuk.

1(B): We processed most of our 2011 emergence samples from Barrow (but not from Atqasuk) during the reporting period, and have begun to evaluate these data in comparison to data collected with NFWF support in 2009-2010, as well as historic emergence data from Barrow ponds in the late 1970s (Butler 1980).

1(C): In all four ponds monitored at the IBP site, we maintained emergence traps with the same sampling frequency to assess the efficacy of the PE sweep net method in comparison to the trapping method used by Butler in the 1970s.

1(D): We conducted field experiments at Barrow, and in an incubator at NDSU, to test the hypothesis that the highly synchronous emergence of arctic chironomid populations is regulated largely by exposure to a fixed thermal constant after thaw. Under this theory, larvae that reach a critical developmental stage the prior year will pupate and emerge following a fixed number of degree-hours in their final summer. Experiments in 2011 expanded on preliminary tests in 2009 and 2010 that evaluated the heat sum required by the abundant midge *Trichotanypus alaskensis* to complete pupation. Different midge species may require varying amounts of larval development prior to pupation in the year of emergence, contributing another variable to seasonal emergence timing. Thus we also looked at the amount of larval growth and development preceding pupation in *T. alaskensis*.

2(A&B): Insect larvae living in pond sediments are important prey for some avian consumers, especially adult waterfowl such as nesting eiders. A second focus of our NFWF-supported project is

to assess the contributions of (a) species composition and (b) larval insect population dynamics in shaping benthic community structure. Our ALCC objectives overlap with this work, but most of our field effort in 2011 focused on insect emergence issues described under Objective 1 above. MS student D.J. Peterson continued work on an extensive set of larval community samples collected in 2010 at both Barrow and Atqasuk. In 2011 we collected a more limited set of benthic samples from selected ponds at both locations to follow up on previous findings regarding larval growth rates and population structures. Progress on this work will be summarized in our March 2012 final report to NFWF.

b. Describe preliminary results.

1(A): Our field data on emergence timing in Barrow ponds during 2011 adds a third year of record to the data collected under NFWF support in 2009-2010. Adding to data from 1975-1977, we can now illustrate the magnitude of year-to-year variation in emergence timing at the community level. Figure 1 shows seasonal timing of the 16 most abundant chironomid species emerging from a single Barrow pond during seven years that span three decades. The general sequence of species is conserved, although not all taxa appear every year. Actual date of peak emergence by a species is variable, as are the onset, overall span, and end of midge emergence. We anticipate that differences in date of thaw will account for much, but not all, of this variation.

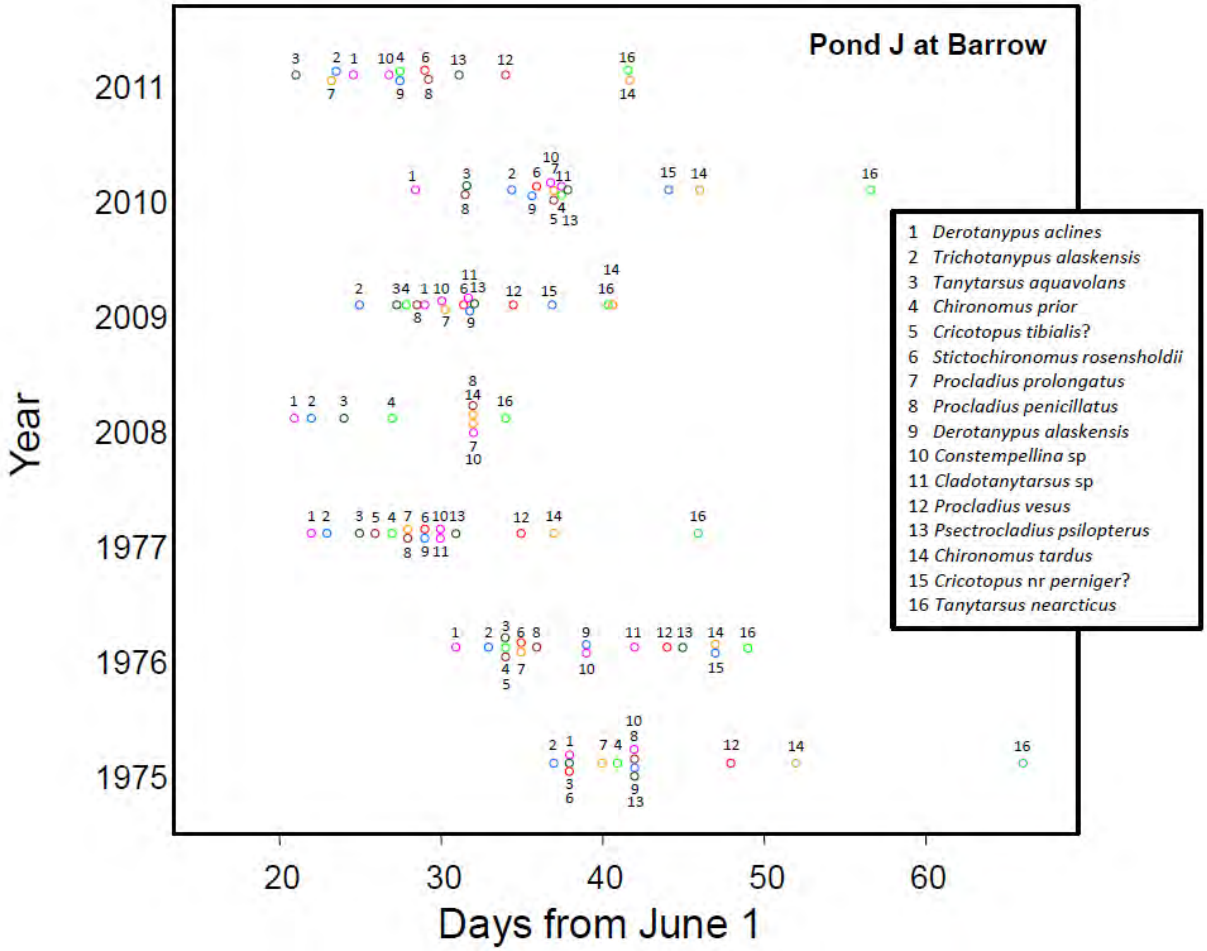

Figure 1. Emergence phenologies of the dominant chironomid species from a single pond at Barrow, AK during seven years. Species are numbered based on sequence of occurrence in 1976, when all 16 species were collected. Early data are from emergence traps; later data are from PE sweep samples.

In 2011 we also extended our data on hourly temperatures throughout the year, thus documenting actual dates of pond thaw (defined as persistent, positive water temperatures in spring). Some ponds have now been monitored continuously since mid-June of 2007. Although we downloaded most pond loggers at least once in June 2011, logistical problems prevented later downloads of some Barrow loggers. Thus complete thermal data (through peak emergence) is not yet in hand for all insect species in the Barrow community. The data remain in the loggers, and will be retrieved in 2012.

1(B): Analyses of our field data on insect emergence timing in relation to temperature data are not complete, and we will report more fully in June. Preliminary findings indicate the following:

- Spatial and temporal variation in the onset and duration of insect emergence depend on (a) date of pond thaw, (b) composition of the emerging insect community, and (c) pond temperatures in the period from thaw to emergence.
- The sequence of emerging species is quite predictable, but there is considerable variation in which species emerge from a given pond each year, and from year to year.
- It may be possible to predict date of peak emergence for a given species from date of thaw plus subsequent thermal regime, but more work is needed. Braegelman and Butler have submitted an abstract on this topic for the May 2012 SFS Meeting in Louisville.
- Integrating emergence across ponds at a site mutes some temporal variation arising from among-pond differences in thermal regime and community composition. This produces a more stable pattern of emerging insect biomass on a regional basis. Nonetheless, year-to-year variation in thaw date and weather can lead to substantial variation in the seasonal availability of adult insect prey for nesting birds.

1(C): Having advocated for use of PE sweep sampling to monitor the phenology of emerging prey at ASDN sites, we sought to confirm the expectation that this method would provide data on emergence timing equivalent to that of the emergence traps used previously in Barrow ponds by Butler (1980). While most of the samples have been processed, these data have not yet been analyzed. Initial observation shows that with a few curious exceptions, there is high concordance between the two methods in detecting the onset, peak, and duration of emergence by the most abundant insect species. PE sweeps collect many more specimens, and integrate across more microhabitats, than is possible with a reasonable trapping effort. Thus standardized PE sampling produces a more complete picture of community composition, as well as the emergence timing of rarer species.

1(D): Earlier experiments with the abundant tundra-pond chironomid *Trichotanypus alaskensis* indicated that pre-emergence development of this highly cold-adapted midge conforms to a "thermal time" model, with a thermal threshold for development of 0°C. Some experiments in 2011 were intended to test for other factors that might influence emergence timing and population synchrony in this model species. Due to rearing problems with the incubator experiments, we obtained no support for any alternative hypothesis, but were able to collect baseline data on thermal-time requirements of two other midge species. Field experiments at Barrow added additional data supporting the constancy of thermal exposure (temperature x time) needed for pupation, with a mean thermal requirement of about 1500 degree-hrs.

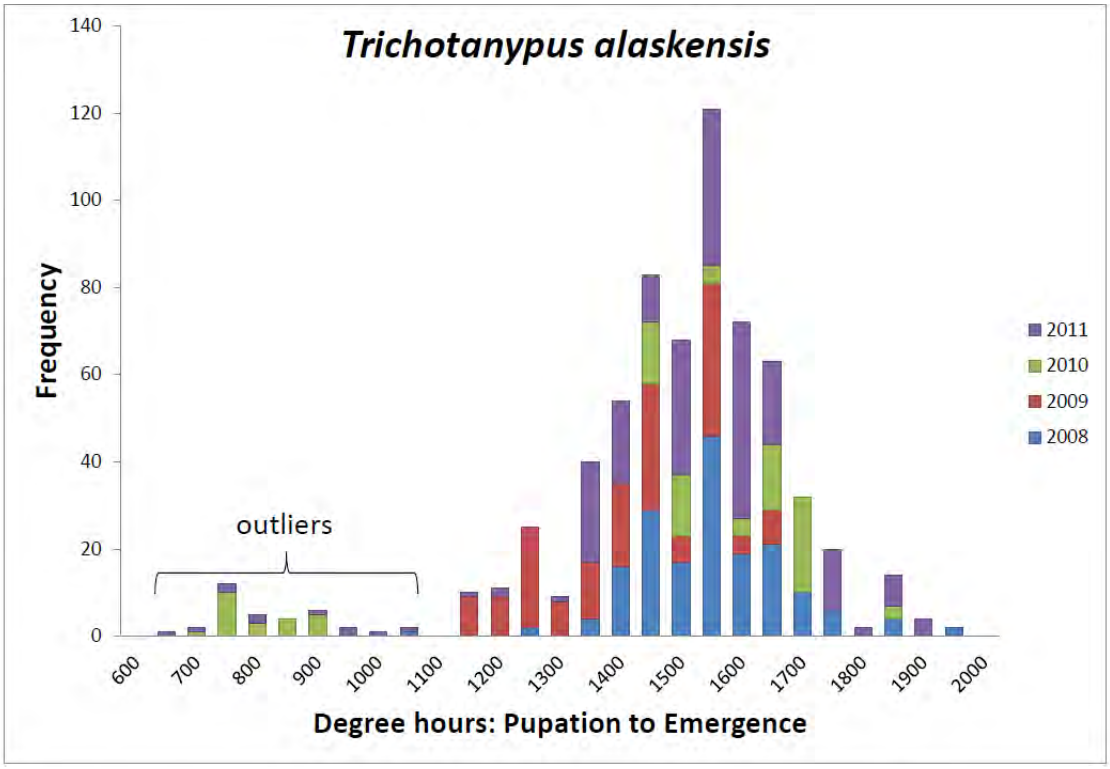

Figure 2. Compilation of thermal requirements for pupation by *T. alaskensis*. Final instar larvae were reared from pupation to adult emergence under differing temperature regimes. Each color shows the distribution of the observed thermal requirement (in degree-hours) for pupation in all experimental treatments used each of four years. Data from 2008 are from incubator experiments at NDSU, using larvae collected at Barrow. Other experiments were conducted in ponds at Barrow with differing thermal regimes. Average thermal requirement for pupation across all animals, excluding outliers, is 1494 degree-hours. Outliers may be animals whose actual pupation date was not initially noted, or that entered the rearing chamber from the pond after pupation.

In addition to the time required for pupation, an insect's emergence date will be influenced by time spent as a larva from thaw to pupation. This early-emerging species at Barrow was thought to represent the Absolute Spring Species (ASS) model proposed by Danks & Oliver (1972) for regulation of emergence timing by arctic chironomids. The ASS model posits overwintering of pre-pupal larvae needing no additional feeding and growth prior to pupal development in the spring of their emergence. We noticed that *T. alaskensis* larvae were overwintering in early stages of the final instar, yet were emerging with high synchrony as one of the earliest midges each season (see Fig. 1). In 2011 we monitored pre-pupation growth and development by *T. alaskensis* larvae in one of the rearing pools used for our pupation experiment. In Fig. 3 we show that larvae of this early-emerging, univoltine chironomid nearly double their weight over a nine-day period while completing a majority of their prepupal development within the final instar. This midge may be uniquely adapted to arctic conditions. Growth and development leading to the emergence of other chironomids, and other insects in the in the tundra pond community, may follow different patterns and controls. Understanding major categories of life-history regulation will improve our ability to anticipate how these animals, as a community, will respond to environmental change such as a warming climate.

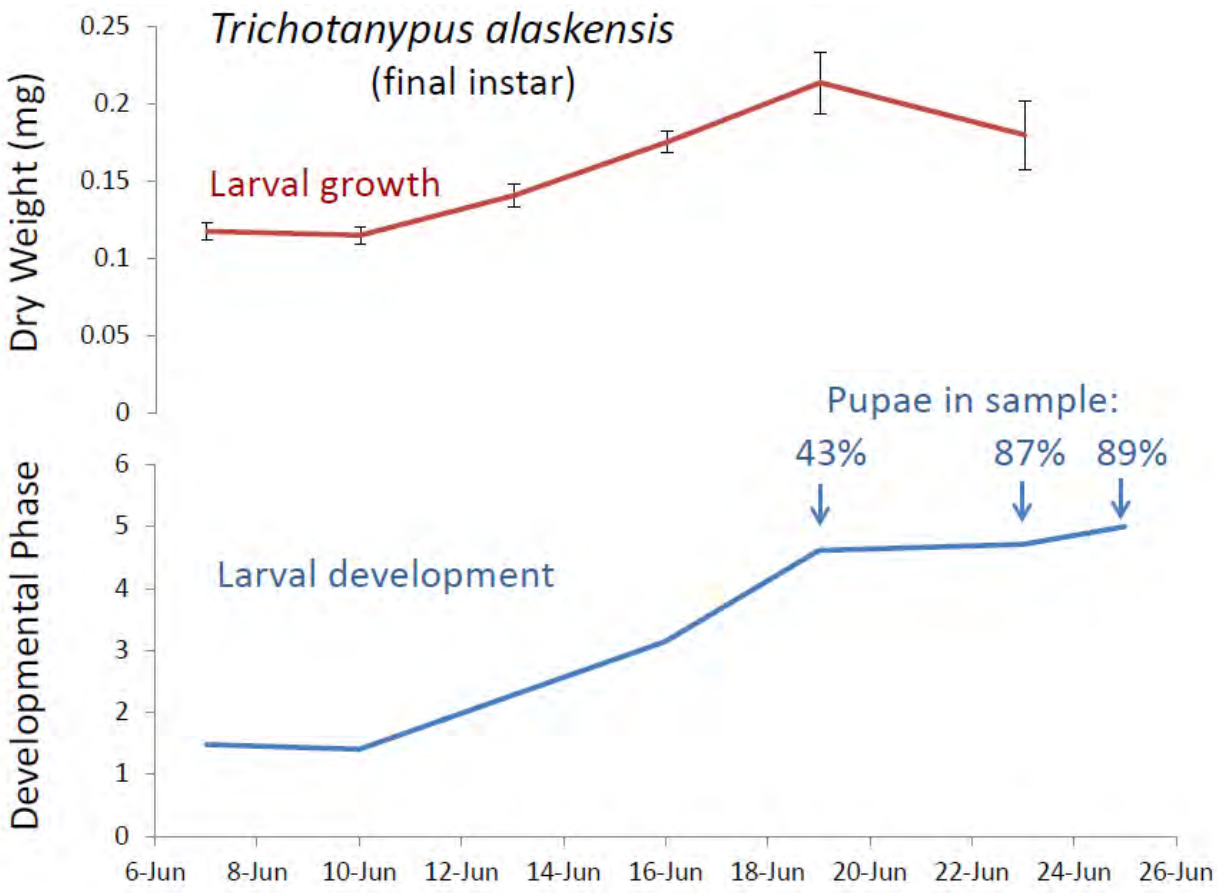

Figure 3. Spring growth and development of final instar *T. alaskensis* larvae prior to pupation in 2011. Larvae were immature at pond thaw on June 6-7, but doubled weight while developing rapidly to pupation over 10-15 days.

2(A&B): While primarily supported by NFWF funding, work on larval insect populations has some relevance to our ALCC objectives. Here we note some preliminary findings from our on-going analyses of benthic samples:

- Benthic communities in tundra ponds at both Barrow and Atqasuk are dominated by insects, primarily chironomid larvae. Species composition differs substantially between the two sites, while most genera are the same. Communities at Atqasuk appear to have higher larval abundance, but with smaller average size than at Barrow.
- The *Chironomus* populations that dominated benthic biomass in Barrow ponds in the 1970s (Butler et al. 1980) were reported by Butler as requiring seven years to complete the life cycle. Recent samples from the same ponds indicate that this life cycle is now taking only (!) six years. Butler reported this result at the 2011 meeting of the North American Benthological Society (now Society for Freshwater Science). More confirmatory work is needed before publication.
- Analysis of available temperature data from Barrow ponds (early 1970s and 2007-2009) in conjunction with air temperature records indicates warming of Barrow tundra ponds by an average of 2°C over the four decades (McEwen & Butler, in review).
- *Chironomus* populations occur in some ponds at Atqasuk, where preliminary analyses (of a different *Chironomus* species) suggest a life-cycle duration of about five years. A species of the chironomid *Propsiloceras* (a genus not previously reported from North America) found in an Atqasuk pond clearly spends three years as a larva, only reaching the size of an 3rd

instar *Chironomus* (~0.5mg dry weight) before pupation and emergence. Atqasuk ponds are significantly warmer that ponds at Barrow.

- We have been successful in developing new regression models for estimation of insect larvae biomass from digital photos. The approach is faster and more precise than traditional length-weight relationships. We are working on validation of biomass-prediction models for adult chironomids that can be extended for use on pupal exuviae.

c. Publications, conference papers, and presentations.

Publication:

Lougheed, V.L., **M.G. Butler, D.C. McEwen**, and J.E. Hobbie. 2011. Changes in tundra pond

Conference papers:

Butler made an oral presentation, coauthored with **McEwen**, in the Climate Change Session at the Annual Meeting of the North American Benthological Society (now Society for Freshwater Science) held in Providence RI on 24 May 2011:

Tundra Pond Chironomids reduce Life Cycle Duration as Arctic Climate Warms

d. Education and outreach.

Butler and McEwen each gave public outreach presentations at Barrow during summer 2011, through the BASC-sponsored Saturday Schoolyard Program:

- **Malcolm Butler** (25 June 2012): *What's for dinner? Tundra Pond Insects!*
- **Dan McEwen** (2 July 2012): *Climate Change Impacts on Tundra Ponds – A Historical Perspective*

e. Other products resulting from the project.

Data collected during 2011 have been entered into Excel spreadsheets, in many cases added to similar data collected under NFWF support the prior two years. Processed samples of insect emergence, larval specimens, and experimental animals are archived in vials, on slides, or in photographs. No specimens have yet been archived with museums, nor have any photographs been posted on the internet.

f. Describe any concerns you may have about your project's progress.

We experienced prolonged uncertainty in negotiating logistics arrangements with the Barrow Area Science Consortium in 2011. These delays confounded planning for field work this year, and ultimately our costs substantially exceeded the amounts budgeted for this support. Nonetheless, BASC in the end did provide very adequate facilities and services, for which we are appreciative. Supplemental support from NFWF for 2011 helped make the 2011 field season possible. Other mitigating factors included enthusiastic volunteer efforts by students working with Dr. Robert Hollister of Grand Valley State University, who collected many of the emergence samples at Atqasuk. Sample processing following field work is always more time-consuming (and thus expensive) than anticipated. To meet this need and cover logistics shortfalls, the personnel budget has been spent exclusively on student salaries.

4. PROGRESS STATUS

The goals of this ALCC-funded project overlap with those of related work supported by NFWF under its Alaska Fish and Wildlife Grants Program (NFWF Project # 2009-0035-013). The NFWF project ended in 2011, with a final report due in March 2012. Thus we have had a solid foundation for our ALCC-supported efforts. The uniquely ALCC elements of this broader research effort have been largely successful to date, in that we have extended our detailed monitoring of pond temperatures and insect emergence at the two study sites, have validated our current methods, and are gaining new insight into factors regulating insect emergence timing, that should inform efforts to model this process at broader scales. Much work lies ahead on the two MS thesis projects supported by both funding sources, with completion dates anticipated during the current year (coincident with our final report to ALCC).

Prior to June 15 this year we expect to complete analysis of emergence data from Barrow, and continue processing samples from Atqasuk. Braegelman and Butler will present their analysis of Barrow emergence data at the Society for Freshwater Science meeting in May, and McEwen and Butler will submit a currently-drafted manuscript on pond temperature analysis to Limnology & Oceanography. Work will also continue on comparison of larval community structures at Barrow and Atqasuk, comparative analyses of chironomid life histories under different thermal regimes, and development of improved regression models for predicting biomass of adult and larval insects.