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To: Dr. Matthew D. Kane, Program Officer
Division of Environmental Biology
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From: Gaius R. Shaver, Senior Scientist
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Gaius R. Shaver

Re: NSF Proposal #1026843, "*Arctic LTER: Climate Change and Changing Disturbance Regimes in Arctic Landscapes*"

This letter was prepared in response to a request for additional information about NSF Proposal #1026843, a proposal for renewed support of the Arctic Long Term Ecological Research Project. Following up on results of Panel Review of this proposal the NSF Program Officer, Dr. Matthew Kane, requested additional information about the following six points before making a final recommendation:

1. Elaborate on the assertion that disturbance has actually increased.
2. Provide a stronger plan for ensuring succession/rotation of leadership for site management.
3. Prioritize the most important monitoring and data collection needs, and ensure there is a strategy for prioritizing which data collection will be discontinued or reduced if needed.
4. Clarification of money to purchase/maintain eddy flux towers.
5. How will different research groups be integrated?
6. Consider a stronger development of the soil microbiology work.

Responses to Dr. Kane's request were prepared by the Executive Committee of the Arctic LTER Project and the Principal Investigator of the proposal, Dr. Gaius R. Shaver, with inputs from Collaborating Investigators. These responses are given below (Note: full citations of literature and web sites are provided in the original proposal). Please reply to Dr. Shaver if additional information or further clarification is needed.

1. Elaborate on the assertion that disturbance has actually increased.

The increase in climate-related disturbances in arctic landscapes is documented in scientific publications and publicly-available data bases such as the Alaska Wildland Fire Data Base kept by the US Bureau of Land Management for the Alaska Interagency Fire Coordination Center (BLM data base; http://agdc.usgs.gov/data/blm/fire/index.html). The paper by Jones et al. (2009) that we cite in the ARC proposal, for example, used this data base to show that of the 20 known "natural" wildfires that have occurred on the North Slope of Alaska since 1950 (plus 2 fires known to be caused by human activity), 8 fires (40%) occurred between 2000-2007. Two more

North Slope fires occurred in 2008 (BLM data base). The total of 10 North Slope fires within the last decade account for over two-thirds of the total area burned north of the Brooks Range since 1950.

The increase in wildfire is driven not only by an increased frequency of warm, dry summers (ARC LTER data base) but also by a greater-than-tenfold increase in frequency of summer lightning strikes North of the Brooks Range (BLM data base). We did not discuss this in detail in our proposal because the lightning data are confounded by improvements made to the sensor network during the 1990s, although a large (several-fold) increase in lightning within the last decade is certain. The increase in lightning is almost certainly due to the greater summer warmth and the energy available to form convective thunderstorms even on the Coastal Plain, much farther north than in earlier decades.

The increase in thermokarst activity in Northern Alaska and specifically in the region near Toolik Lake is documented in two recent publications by ARC researchers (Bowden et al. 2008, Goosef et al. 2009) as well as by others (e.g., Hinzman et al. 2005), showing that the occurrence of thermokarsts "…has increased more than 200% since the 1980s". The forms taken by these disturbances are varied and include both hillslope thermokarsts and various forms of glacial and other ground-ice melting. A major collaborating project led by LTER PI Breck Bowden is currently funded to document these changes, including several sites on different kinds of thermokarsts near Toolik Lake. Since the Anaktuvuk River wildfire occurred in 2007, the ARC LTER and collaborating projects have also documented a number of thermokarst failures within the burn perimeter that appear to be caused by increased heat flux into the ground as a result of the fire; regardless of the exact mechanism, these thermokarsts clearly formed in response to the fire's effect on surface energy balances, meaning that as fire increases so will thermokarst failures. We are working rapidly to write up these results and publish them.

Several other forms of disturbance have also increased in the Arctic (reviewed by Hinzman et al. 2005). One that was documented in a recent publication by ARC LTER researchers is the intensification of stratification of Toolik Lake as a result of changes in lake physics (MacIntyre et al. 2009). Other disturbances include a changing hydrologic regime as documented by LTER researchers (Peterson et al. 2006) with consequent impacts on fish migration and stream communities (Deegan, Huryn, Peterson NSF Grant # 0902153), on element cycling of streams (Bowden, Peterson, Gooseff et al. NSF Grant # 0902106) and on inputs to the Arctic Ocean (Peterson et al. NSF Grant # 0732985). Climate change is also felt as a disturbance to the timing of key phenology events for plants and animals (Gough, Boelman, Wingfield NSF Grant # 0908602) and in soil processes (Schimel, Weintraub, Rastetter NSF Grant #0902038).

Finally, the increase in climate-related disturbances in the Arctic is increasingly noted in social science research on northern communities, particularly those dependent on subsistence hunting and fishing (e.g., *The Earth Is Faster Now: Indigenous Observations of Arctic Environmental Change*. Igor Krupnik and Dyanna Jolly, eds. Arctic Research Consortium of the United States, University of Alaska, Fairbanks, AK. xxviii+356 pp.). Our current efforts to develop a social science component of the ARC LTER are focused on improved understanding of how local, subsistence lifestyles are affected by climate change, including climate-related disturbances like fire and thermokarst. The native residents of northern Alaska increasingly report these disturbances as something that is affecting their lives and livelihoods (G. Kofinas unpublished data; Smithsonian Magazine, March 2010). In visits to several local communities (Barrow, Anaktuvuk Pass, Kaktovik) we have come away with the impression that, if anything, climate change-related disturbances are underreported in the available data bases.

2. Provide a stronger plan for ensuring succession/rotation of leadership for site management.

There are at least three elements to the issues of succession or rotation of project leadership, including (1) succession of the lead PI, (2) succession of the Executive Committee members and leaders of the terrestrial, lakes, streams, and land-water research groups, and (3) succession of senior collaborating investigators and continued recruitment of new investigators to the project. These are all linked in that a successful solution to the first depends on the second, which depends on the third. Because these are generally important management issues, we mentioned them in our proposal mainly to indicate that we are thinking forward, trying to anticipate management issues we can expect to arise not only over the next six years of LTER support (2010-2016), but that will affect the evolution of the ARC LTER over the very long term (2016 and beyond).

We assume for now that our current organizational structure, which has worked well for us in the past, will endure for at least the next 6 years of renewed funding. We also assume that the next lead PI will come from among the PIs and Collaborating Investigators who are most familiar with the ARC LTER, its history, and its long-term plans and goals. The model for transition of overall project leadership is thus the same one we have followed successfully in the transition from the current project (LTER IV; 2004-2010) to the renewed project (LTER V; 2010-2016), in which G Shaver, a long-time member of the ARC Executive Committee, replaced J Hobbie as lead PI.

The most important and immediate issue to address is the succession/rotation among members of the Executive Committee. Two members of this committee (representing the Terrestrial and Lakes research groups) must be replaced within the next year or two as Shaver becomes lead PI and Chris Luecke retires from the Committee. This will be accomplished after discussion among investigators within each of the research groups, with the selection made by the Executive Committee and the lead PI. We also have the general need to expand the pool of Collaborating Investigators with experience in the management issues that the Executive Committee handles; this includes issues such as budgeting, permitting, interactions with the LTER Network, interactions with NSF, organization and collation of various project reports, and sundry other tasks. We may have to replace other members of the Executive Committee over the next six years. As described in our proposal, we will handle these issues by inviting one or two "rotating" members to each meeting of the Executive Committee (twice a year in Woods Hole, in late fall and early spring, usually with a third meeting during summer at Toolik Lake). We will also invite collaborating investigators to participate in these meetings by conference call. Finally, we already engage collaborating investigators in several of the (mostly mundane) tasks that the Executive Committee handles, such as permitting and report-writing.

It is critical that we continue to attract new collaborating investigators to the project, not only because this invigorates our science but also because new investigators will eventually become project leaders. Every year we invite new, mostly younger investigators (frequently including those who have worked with the ARC LTER as students and postdocs) to join us at Toolik Lake. Often, these preliminary visits lead to longer-term commitments to collaborate with us and to independently-funded projects that take advantage of the long-term ARC experiments and data base. This sequence of increasing interactions creates a group of researchers from which new project leaders will emerge. The opportunities to nominate potential new collaborators have increased greatly in the last few years as the number of independent NSF-funded projects relevant to the ARC LTER and based at the Toolik Field Station has increased

A final, essential consideration in our planning for succession is the timing of all these changes. At present we believe we have at least 4-5 years to make a decision about who will be the next lead PI and whether there will be any changes to the makeup or responsibilities of the Executive Committee in LTER VI (2016-2022). Following our successful model of lead-PI succession, this would allow 1-2 years for the new lead PI and the Executive Committee to organize the writing of the next proposal, followed by the transition to LTER VI (just as Hobbie will transition to Shaver from LTER IV to LTER V). We expect that the changes to the Executive Committee will begin within the next year or two, with the appointment of new representatives of the Lakes and Terrestrial Groups. Recruitment of new investigators has already begun and opportunities for additional investigators to become involved in Executive Committee activities will begin with our meetings at Toolik Lake in summer 2010. As we did in the current funding period, we will use our 3-year project review in 2014 as a timely opportunity to discuss these planned changes, and our overall plan for succession of leadership, with the Review Team. This means that we must develop a more specific timetable and plan for discussion with the Review Team by the summer of 2014.

3. <u>Prioritize the most important monitoring and data collection needs, and ensure there is a strategy for prioritizing which data collection will be discontinued or reduced if needed.</u>

In answering this question we will first discuss the STRATEGY, then the PRIORITES we use for designing our monitoring and data collection program and integrating it with our research questions and goals.

Our monitoring and data collection STRATEGY is two-fold: <u>First</u>, we will build, over the long term, a data base that describes comprehensively the states, temporal trends, and temporal and spatial variability in the characteristic and representative terrestrial and aquatic ecosystems of the landscape near Toolik Lake. The data base includes both short- and long-term data sets ranging from organism function and distribution at the population and community-levels to data on ecosystem-level states and processes (e.g., element stocks and budgets, NEP, N-cycling) and the abiotic drivers of hydrology and meteorology. <u>Second</u>, we will build, over the long term, a data base that allows us to optimize our ability to address the fundamental issues in long term ecological research that are common to all ecosystems, and that we have chosen for particular emphasis in the ARC LTER. These strategic aims are pursued with several applications in mind, including:

(1) developing a basic understanding of the structure and functioning of these arctic ecosystems, how they are regulated, and how they change;
(2) developing the means to promote effective comparisons and synthesis of understanding of ecosystem structure and function among sites within the LTER Network, and among other sites and networks especially in the Arctic and Boreal regions;
(3) developing the means to interpret in the context of whole ecosystems and biogeochemical cycles the many more narrowly-focused studies on individual populations, communities, and biogeochemical and geophysical processes that are based at Toolik Lake;

(4) developing the means to "scale up" our understanding, in both space and time, to make large-area, long-term predictions of change in the ecosystems and landscapes near Toolik Lake.
(5) developing understanding of the specific topics in fundamental ecology that are particularly amenable to research in arctic landscapes; i.e., those topics where the particular characteristics of arctic ecosystems make them especially good "model ecosystems" for advancing our fundamental, broad understanding.

With this STRATEGY in mind, our PRIORITIES are determined as a series of tradeoffs involving the number and diversity of variables to be measured, and the frequency and replication of data collection needed to adequately implement our strategy. There are also tradeoffs involving short- versus long-term project goals and the constantly-changing array of opportunities for collaborations involving research on sites maintained by the ARC LTER. As the ARC LTER research has evolved over the last three decades, decisions about these tradeoffs have often resulted in decisions to discontinue, reduce replication, or reduce frequency of observations in collection of individual long-term data sets.

Overall data collection priorities are discussed at our annual project meeting and for the whole project they are reset every 6 years, as part of the preparation of the renewal proposal. In our currently-pending proposal (ARC LTER V), the results of this prioritization exercise are presented as Table 2-2 , "*Core monitoring and process studies to be carried out by ARC LTER personnel*" (NSF Proposal #1026843, pages 2-24 and 2-25). To develop this table, each of the four research groups underwent a prioritization exercise, as described below:

a. <u>Land-Water Interactions</u>: After the 2007 Site Review and prior to the writing of our renewal proposal, the Land-Water Interactions group reviewed and prioritized its data collection needs and monitoring activities. As a result, we have discontinued a semi-long-term experiment on water additions to tundra and we have reduced our monitoring of soilwater chemistry in two different watersheds. The justification for these decisions was based on consideration of the research results and especially the variance of long-term data. For example, the results from the watering experiment showed that the impacts on tundra soil chemistry were very slight even after 8-years of treatment. This is interesting in itself, but it also indicates that we have learned what we can from this experiment and it is time to move on. In our long-term monitoring of soil-water chemistry in the Tussock and Imnavait watersheds, we have seen that the variability in chemistry is fairly low throughout the summer, meaning that we can make measurements less frequently (e.g., 3x versus 10x sampling dates per summer) and still capture any long-term trends driven by climate change. Given these two criteria we were able to modify our data collection scheme and efforts in order to free-up time for new initiatives on monitoring the effects of fire and thermokarst disturbance on the tundra, which is a major focus of the new proposal.
b. <u>Streams</u>: The Streams group reviewed the extensive suite of streams that have been the focus of previous monitoring or experimental work. These efforts provided valuable information about the primary drivers that define important ecosystem characteristics of mountain, tundra, spring, and glacial streams. These findings have been published or are in press and in review. Sampling at some of these sites has been absorbed into independent research projects which will continue for several more years. For these reasons we decided to eliminate the extensive spatial monitoring of streams across the western North Slope region and focus on a few key streams that are close the Toolik Field Station and the subject of our longest term

monitoring (specifically the Kuparuk River and Oksrukuyik Creek). These streams are of interest for the long-term record we have maintained and because, in the case of the Kuparuk River, it will be the focus for new experiments that we outlined in the renewal proposal and that are part of two independent but related Changing Seasonality awards that focus on arctic Grayling migration (Deegan, Huryn, Peterson NSF Grant # 0902153) and on element cycling in stream networks (Bowden, Peterson, Gooseff et al. NSF Grant # 0902106) .

c. Lakes: The proposed plan for the Lakes research includes similar changes from past projects, designed to accommodate the growth and evolution of the ARC LTER project while maintaining progress toward our strategic data collection goals. For the next six years the highest priority will be placed on monitoring of lakes where active research is continuing and where new collaborations are starting. These lakes include the Inlet series and Toolik Lake itself – these two systems serve as general reference lakes and are also monitored by related projects (e.g., Crump, Kling NSF LTREB Grant # 0639805); they serve as well as references for the new research on lakes within in the Anaktuvuk River Burn site. Lake NE12 is also a high priority to continue sampling as a reference for research on thermokarst-impacted Lake NE14. Other high-priority lakes include the paired fertilized/unfertilized lakes of different sizes, E5/E6 and Fog2/Fog4. Lakes where we plan to reduce our sampling effort include those used for old manipulation experiments (e.g., lakes N1 and N2), where their long, slow recovery does not require high-frequency sampling to document. Other lakes where sampling effort will be reduced are those that were important parts of our early surveys and comparisons but that only require occasional sampling (not necessarily every year) to document long-term change and variability. We see these lakes as having a high priority but believe we now have enough knowledge to decrease the frequency in which they are sampled.

d. Terrestrial: In the past, much of the terrestrial group's effort has been devoted to maintaining and monitoring an extensive array of long-term experimental plots. Over the years many labor intensive biomass harvests were carried out but the number of plots has now exceeded our ability to do these on a regular basis. At the same time these plots have attracted the attention of many other groups and now much of the actual research on these plots is carried out by collaborating projects; currently these projects include research by investigators Bret-Harte, Gough, Moore, Boelman, Schimel, Wallenstein, Weintraub, Rastetter, and Shaver, and there is every reason to expect these long-term experiments to continue to attract a wide array of high-quality researchers. It is thus essential to maintain these experimental plots because they attract such productive collaborations; the principal "prioritization" issue for the terrestrial group is how much effort to devote to monitoring by LTER personnel and how much to ask the collaborating projects to perform. For the next six years we will continue to maintain these experimental treatments (adding fertilizer, setting out greenhouses) but we will do only minimal microclimatic monitoring and monitoring of "greenness" (multispectral reflectance indices) as indicators of biomass. We will ask our collaborators to do most or all of the other data collection. We will continue to help in major biomass harvests as the harvests are scheduled by the collaborating projects, but will not attempt to obtain a synoptic picture of the entire experimental array. We will continue to archive all of the data from these experiments (including results from collaborating projects) in the ARC LTER data base. These changes will free up significant time for the terrestrial group to participate in maintaining the eddy flux tower operations in both burned and unburned tundra.

Over the next six years of renewed funding, our plan is to reassess the data collection objectives outlined in our proposal (Table 2-2) at each annual winter meeting, using a prioritization process similar to that described above. Our long-term monitoring and data collection strategy and goals (defined above) are not expected to change. We do expect, though, that the individual priorities will change as our research evolves and especially as opportunities for collaboration with independently-funded projects evolve. We also expect that priorities will change as the LTER network evolves and develops opportunities for multisite and cross-site research.

4. Clarification of money to purchase/maintain eddy flux towers.

There are actually eight, not six, eddy flux towers currently operating or to be installed by the ARC LTER and collaborating projects in summer 2010, with continued operation in 2011-2016. This includes the three towers in the Anaktuvuk River Burn site and the three towers at Imnavait Creek that were described in our proposal, as well as one tower operating on Toolik Lake itself and one to be set up in a wetland site at the Inlet to Toolik Lake. *All of this equipment has already been purchased*, along with a considerable amount of calibration equipment, spare and replacement instruments, data loggers, and supplies. *Before the start of the renewed ARC LTER V* (December 2010), our aim is to have purchased, installed, and tested not only all the equipment needed to operate these eight towers, but also to have at least one spare for each of the major instruments (sonic anemometer, open-path CO_2/H_2O analyzer, short- and long-wave net radiometer, data loggers) and multiple spares for others (soil heat flux plates, PAR sensors, power supplies, etc.). In other words, we already have all the funding in hand that we need to purchase this equipment network, and most of it has actually been operating for 2 or 3 years or summers.

Funding to purchase and operate the eddy flux equipment thus far has come from four collaborating NSF grants (OPP-0808789, DBI-0829285, OPP-0632139/0632264, and OPP-085683) and from a major equipment supplement (DBI-0933922) from the NEON program to the current ARC LTER IV project. Gus Shaver, lead PI of the ARC LTER V proposal, is lead PI on all of these grants (one is a collaborative including the Woods Hole Marine Biological Laboratory and University of Alaska-Fairbanks, with MS Bret-Harte leading the UAF component).

ARC LTER project personnel are already actively involved in all aspects of maintenance and operation of these towers, in close coordination with personnel supported by these collaborating projects. We have already developed a maintenance routine and several members of the ARC LTER project have had experience with flux tower operation. Early data from these towers is already available in the ARC LTER data base, we have developed our own expertise as well as new methods in eddy flux data assimilation (Rastetter et al. in press), and we have published some of the early results (Rocha et al. 2009 & in press).

To maintain these towers over the next 6 years, our first priority is to renew the collaborating grants (OPP-0632139/0632264 and OPP-085683) that have so far provided most of the funds for their purchase and operation. We will also pursue continued support from the NSF-NEON program, which has already provided SGER funds (DBI-0829285) to start up the Anaktuvuk River Burn research as well as supplemental funds (DBI-0933922) to purchase the 7^{th} and 8^{th} flux towers. ARC LTER personnel will continue their current involvement in field maintenance, data downloading, and data archival as they are currently doing. The main issue is what to do if we fail to renew the collaborating grants. If both of the current collaborating grants fail to be renewed and we are unsuccessful at attracting new, related projects, the ARC LTER will maintain a smaller network of towers on a reduced schedule of operation (i.e., summer only). If this is necessary, we have requested sufficient helicopter time in our logistics request to accommodate this work (see proposal Budget Explanation section). The major additional costs here will be the personnel costs associated with tower and instrument maintenance, but because LTER personnel are already contributing significantly to these tasks (and we are already involved with management and archival of data from these towers), the additional costs of taking over the tower operations completely are small. If necessary, we believe we can accommodate these costs within the prioritized monitoring and data collection plan described in response to Question 3 above and in the renewal proposal (Table 2-2).

5. <u>How will different research groups be integrated?</u>

Integration among the four ARC LTER research groups will be achieved through a series of synthesis activities at the watershed scale. Our research design, focused on comparisons among contrasting kinds of watersheds, is intended to facilitate this integration, as is the collocation of research by all groups in common watersheds. We chose this design deliberately, in part because this was one of the principal recommendations of our 2007 Site Review, but also because we believe it is clearly timely and appropriate for ARC LTER at this stage in its evolution. Watershed or catchment-scale integration is also particularly appropriate to our new focus on how large disturbances introduce a new kind of large-area "patch dynamics" to the North Slope landscape. Apparently what we did not explain fully in the proposal is exactly what *kinds* of synthesis we intend to pursue (i.e., which topics), and what steps we will take to go from data to synthesis.

One key topic, probably the first we will focus on, will be a synthesis of carbon, water, and nitrogen budgets (and perhaps other elements as data are available) in contrasting whole watersheds including both terrestrial and aquatic components. Our overall design is ideally suited to this as it includes research in watersheds of different geologic ages, with and without lakes, and with and without wildfire (see proposal for details). The synthesis of terrestrial and aquatic research on budgets will allow us to identify, for example, the locations and relative importance of inputs and outputs of C and N to the whole landscape. We will be able to quantify losses from land to water as components of C and N budgets in greater detail and with greater accuracy than ever before, something we have been trying to do for decades (e.g., Kling et al 1991, Yano et al. 2010).

A second key topic for synthesis is the analysis of variation in aquatic communities in relation to variation in terrestrial vegetation and soils in contrasting watersheds (and subwatersheds). This, again, is a subject we have been working around the edges of for many years (summaries available in the ARC synthesis volume), but we have never actually brought together the data collected by the separate research groups.

A third topic is that of "tipping points" and resilience in the structure and function of whole tundra watersheds. Here our long-term observations of the recovery (or change to a new ecosystem state) of burned and thermokarst-impacted watersheds will include observations of the changing interactions among terrestrial and aquatic components. Viewing burned and thermokarst-impacted watersheds as large, whole-catchment manipulations, we can extend to a much broader scale our past research on "tipping points" associated, for example, with conversion of streams from no-moss to moss-dominated systems (Bowden et al. 1999, Slavik et al. 2004) or of tundra from mixed communities to shrub-dominated systems (Shaver et al. 2001, Bret-Harte et al. 2009).

As described in the proposal, we have set aside funds for promoting these synthesis activities by supporting a number of small workshops involving ARC LTER collaborators. We will also include cross-research group synthesis workshops as part of every annual winter meeting. Finally, as described in the proposal we have agreed with the BNZ LTER site to hold a joint synthesis workshop on "direct and indirect effects of climate change", probably in the third year of the renewed project (2013 or 2014).

6. Consider a stronger development of the soil microbiology work.

We agree strongly that additional and new research on soil microbiology represents an important opportunity and a priority for the ARC LTER. We have worked to promote research on this topic in the past and plan to promote collaborations with microbiologists in several ways in the future. Discussion of this past work and future plans was left out of the proposal, largely due to lack of space.

There are several components to our current and planned research on soil microbiology. In general this work is done by collaborating projects, which use the long-term experiments and monitoring plots that are maintained by the ARC LTER for much of their sampling and comparisons. LTER personnel contribute by maintaining the experimental treatments, by maintaining the data base about the experiments, by maintaining key long-term environmental observations, and by collecting key data on vegetation, soils, and biogeochemistry that facilitate integration of the microbiological research into our understanding of whole tundra ecosystems.

At present we have several projects collaborating with the LTER with a focus on soil microbiology. One project is a collaborative involving Josh Schimel, Mike Weintraub, Matt Wallenstein, and Ed Rastetter on "The Changing Seasonality of Tundra Nutrient Cycling: Implications for Ecosystem and Arctic System Functioning." This project builds largely on Schimel's long history of research in soil microbiology at Toolik Lake, most recently with a focus on microbial activity during the winter. The work includes characterization of microbial communities using molecular methods as well as documentation of microbial metabolism and role in carbon and nutrient mineralization on a year-round basis. One of Schimel's graduate students, Seeta Sistla, is also working on the ARC LTER's long-term fertilizer and greenhouse experiments to describe and interpret changes in soil microbial communities and activity in relation to changes in vegetation. Another student, Julie Deslippe of the University of British Columbia, finished a Ph.D. dissertation in 2009 in which she used ^{13}C labeling to trace the fate of recently-fixed C into soil microbes including fungi and bacteria. John and Erik Hobbie and their student, Julie Shamhart (University of New Hampshire) recently completed a study of C and N cycling through mycorrhizae. Finally, the work of John Moore and colleagues on soil food webs includes, importantly, the documentation of changes in these foods webs in response to our long-term fertilization and other treatments, changes that depend strongly on a switch from "fungal-based" to "bacterial-based" food webs.

The project by Schimel and colleagues ("Changing Seasonality") will continue for another three years, as will a new project by John Moore and Laura Gough on "A Biotic Awakening: How do Invertebrates, Microbes, and Plants determine Soil Organic Matter Responses to Release from Nutrient Limitation in Arctic Tundra?" (OPP-0909441/0909507). One particular opportunity we intend to follow up on is a greater integration between the terrestrial and the aquatic microbial research. George Kling and Byron Crump are already moving in this direction, with their LTREB project on “What Controls Long Term Changes in Freshwater Microbial Community Composition” (DEB-0639790), including comparisons and monitoring of seasonal and annual variation of both terrestrial and aquatic microbial communities.