Proposal Status | MAIN

Organization: Marine Biological Laboratory

Panel Summary #1

Proposal Number: 1026843

Panel Summary:
Panel Summary

Long-Term Ecological Research Program
Spring 2010 Renewal Panel

RESULTS OF PRIOR LTER SUPPORT:

The Arctic LTER is a very productive LTER site that has been in place for more than 35 years. This site is extremely important as a recognized "climate sentinel" of the Arctic, and has clearly been experiencing rapid changes such as the development of thermokarst and the increased incidence of fire.

Section 1 was informative and neatly organized to present research highlights within each of the environments. The publication list is extensive and varied, and a synthesis volume for the site (recommended by the midterm review committee) has been written. The section began with an historical account of the how the focus of the LTER has evolved with each of four funding cycles. This provided a nice context for evaluating the present research proposal. The work has revealed important results relative to how this system is responding to climate change and/or disturbance. As described in the proposal, it was sometimes difficult to discern the main points: (e.g., is the system close to tipping points? Are fires becoming more frequent or not?)

ARC has excelled in publications with some 130 journal articles, 21 book chapters and many student theses. Their outreach to local communities, educators and journalist has been very good, and their support of student research is high.

HOW HAVE PREVIOUS CRITICISMS FROM THE LAST SITE REVIEW BEEN ADDRESSED?

The mid-term site review highlighted several important recommendations:
1. Consider a focusing mechanism to connect the elements of your research according to the conceptual framework (e.g. a common watershed)
2. Consider re-setting priorities to allow more frequent sampling in critical environments
3. Consider temperature- or water-manipulations experiments
4. Recruitment of new leadership and a leadership team
5. An ARC synthesis volume

By and large the PIs have addressed all of these recommendations. The synthesis volume has been completed, experiments being conducted within the different ecosystem components were being co-located within watersheds (although it was difficult to tell if the placement of the experiments was logical), and changes were being made in the leadership structure. However, the panel felt that the recommendation to adjust sampling priorities needs more consideration. There was a sense that ARC's efforts to continue monitoring came at the cost of actually analyzing the results.

REVIEW CRITERION 1: Intellectual Merit.

The overall goal of the ARC is 'to understand changes in the arctic system at catchment and landscape scales as the product of (i) direct effects of climate change on states, processes and linkages of terrestrial and aquatic ecosystems; and (ii) indirect effects of climate change on ecosystems through a changing disturbance regime.' The proposed research includes 4 ecosystem compartments (terrestrial, streams, lakes, and landscape interactions), asking: (1) How does climate control ecosystem states, processes, and linkages; (2) how do disturbances change ecosystem states, processes, and linkages; and (3) how do climate and disturbance interact to control biogeochemical cycles and biodiversity at catchment and landscape scales.

STRENGTHS:
The panel felt that the new research directions that take into account climate change and changing disturbance regimes are important, and are a logical direction based on the long-term observations of change as the site. The PIs are well qualified to continue the long tradition of high quality research. Their models of coupled element cycles linked with hydrologic models, plant community models, and food web models (p. 2-7) are well-developed.

WEAKNESSES:
While ARC is a very data-rich site, the panel felt that some statements were NOT backed up by data. For example, the proposal mentions "tipping point" repeatedly but did not present the data to illustrate that. The evidence that fire is a major disturbance was not demonstrated with data but rather by the reference to Jones et al. 2009 of a "possible" increase in fire incidence.

There was some difficulty in how landscape interactions would work in parallel with the other three ecosystem components. This is potentially the unifying component of the project but it is not very clear how it would be tied in to the separate ecosystem components.

There was also some question about how the four common study watersheds would be designed in a way to relate the various projects. In short, are the projects designed in the upslope/downslope sense to capture the relationship between terrestrial and aquatic environments?

One missed opportunity is in terrestrial microbial ecology. DOC and other microbial-related research is mapped between terrestrial and aquatic components but there is not very much, and the value of linking microbial aspects to emissions seems to be missed. This could also provide an important link within BGC models for the site.

The models have not always been used to predict early warning criteria of when and where tipping points will happen and what might happen afterwards. It isn't clear how or if the models have been used to identify the pertinent feedbacks, the trajectory to a tipping point, when we can expect an ecosystem to cross it, what the sequence of events will be as the tipping point is crossed, and how the ecosystem reorganizes itself on the other side. It was not clear whether the modeling was connected to the field investigations or not; that is, do the field PIs understand the quantitative nature of identifying tipping points?

The inclusion of six eddy-covariance towers in the watersheds was of concern to the panel, as these will require quite a bit of manpower for maintenance and may impact other research at the site.

REVIEW CRITERION 2: Broader Impacts.

STRENGTHS:
A most important aspect of this site is its uniqueness and comprehensiveness in studying the response of the Arctic to climate change - this is the world's observatory on arctic response to climate change. As such, outreach is particularly important, but also a challenge given that there are and have been very few people living near Toolik Lake. The PIs have thus reached out to Barrow, the nearest town, and have done an excellent job of outreach there, particularly with the Schoolyard program. The panel particularly liked the way the LTER has engaged journalists.

WEAKNESSES: None identified

REVIEW CRITERION 3: Information management and technology.

Strengths:
The panel found that the ARC information management framework was adequate. A large number of data files are accessible both on the web site and through the LNO metadata repository, and the metadata for these was of generally high quality. It was also noted as a good model having dedicated RA's assist scientists with their metadata and data QA/QC.

Weaknesses:
The panel felt that ARC's IM solutions are unsophisticated, and this leads to some clumsiness in how the data are accessed, in terms of effective discovery or ease of use, for further integrative analyses. For example doing a within-site cross-station analysis of chlorophyll concentrations in lakes would require manual integration of a large number of files. The panel felt it would be useful to look for ways to coordinate IM tasks with other LTER IM personnel at MBL.

REVIEW CRITERION 4: Site management (including personnel, fiscal, administrative, institutional and logistical issues).

STRENGTHS:
The panel was satisfied with the site management and the transfer of leadership to Shaver.

WEAKNESSES:
There was a mention of expanding the number of people in the LTER, but the panel questioned this thinking given the already stretched nature of the site, and the limited funds. There is a need to expand on the plan to identify the next set of leaders for ARC.

REVIEW CRITERION 5:

STRENGTHS:
Network participation appears to be increasing, and discussion to increase work with BNZ is a good idea.

WEAKNESSES:
The obvious 'other' LTER site for cross-site work is NWT, and there does not appear to be much along these lines.

SYNTHESIS AND RECOMMENDATION:

The panel is overall pleased with the progress of ARC and with its renewed research plan for the next six years. However, the panel did have enough reservations about this site to give it a rating of: Renew with Conditions

These concerns are highlighted as follows:
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

This summary was read by the assigned panelists and they concurred that the summary accurately reflects the panel discussion.

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Proposal Status | MAIN

Organization: Marine Biological Laboratory

Review #1

Proposal Number:	1026843
NSF Program:	Long Term Ecological Research
Principal Investigator:	Shaver, Gaius R
Proposal Title:	Arctic LTER: Climate Change and Changing Disturbance Regimes in Arctic Landscapes
Rating:	Very Good

REVIEW:

What is the intellectual merit of the proposed activity?

Past Work/Productivity. ARC has been an LTER site for 23 years and has produced some extremely interesting and important findings. The most recent funding cycle resulted in 130 journal articles, 21 book chapters and many student theses. This makes it among the most productive of the LTERs and part of this is due to the large amount of collaborative work they have developed over the years û they have leveraged the LTER monitoring work to the benefit of many experiments and projects that are funded by LTER supplemental or independent awards. This is one of the roles LTERs should play and the ARC team is commended for facilitating that.

Network Participation, Cross-Site Research & Synthesis. Since the last funding cycle they have been involved in a cross-site shrub project, the LTER TRENDS project, and some comparative work with a field station in Sweden. They also have participated in large syntheses including an arctic climate impacts assessment and are also working with the International Tundra Experiment. In sum, they have been active in the LTER network, facilitate and initiate collaborative work and strive to do synthetic work.

Intellectual Merit. The research of this LTER is broadly split into three groups, by realm: terrestrial (soils to atmosphere); lakes, streams. Within each realm they have made significant accomplishments in the last 6 years but have not tightly coupled their work across the realms. For example, all fertilization experiments have been performed separately in each realm and it is not clear that these experiments have been directly linked or responses to fertilization across the realms compared (perhaps a comparison done in the upcoming edited book of Hobbie and King). The stream folks have done the most to explore interactions largely it is not really to consider terrestrial impacts exploring stream ecosystem dynamics.

The present proposal explicitly states a major effort to focus on the linkage between land, lakes, and streams by adopting a focused watershed framework and mass balance approach. They plan to address questions of how ecosystems respond to climate change and disturbances (thermokarsts, fires, changes in seasonabilty & phenology). The primary dependent variables for this integrative focus are biogeochemical. They indicate (page 2-2) they will also look at feedbacks to climate resulting from changes in the catchments; feedbacks they posit will occur via changes in carbon, water and nutrient budgets, as well as, changes in human land use.

They invoke the 'tipping point' idea by suggesting that disturbances that are small (spatially) may have very large impacts, perhaps even larger than the slow, 'press' stress of increasing temperatures. They repeatedly state that these disturbances have increased in their frequency but do not provide a plot of data showing the data nor do they provide clear citations that show this (maybe it is embedded in some of their publications?). I needed to get a sense of the changes in frequency and over what time period to better assess their plans. At one point they provide the Jones et al. 2009 citation saying there are possible increases in the incidence of fire' (àpossible?). Are they now or are they planning to capture these disturbance events (spatially and temporally) and developing a database on this?

They identify 4 watersheds as 'contrasting' and thus appropriate for testing their hypothesis that because the terrestrial and aquatic realms are linked, disturbances like fires or thermokarsts may be moving the systems toward tipping. But these watersheds don't just differ in terms of the linkage between the terrestrial and aquatic and the disturbance history but, as they admit, they also differ in terms of landscape age, geomorphology, and other factors. Direct manipulations of connectivity (linkages) such as what the MCM Antarctic site is planning would have provide a lot much stronger test of the hypotheses. I think they will end up trying to tease out a number of confounding effects/interactions ultimately. Further, their focus is still largely within-realm e.g., effect of fire as a disturbance on fluxes of CO2 and on C and nutrient budgets in soils. Perhaps their linkage 'measurements' are meant to be the monitoring of downslope water and nutrients (page 2-8) and that seems to be the case based on the text on 2-15. If they could do some additional tracer experiments, it would be most exciting.

The propose manipulative work via burning small patches of tundra and also to manipulate temperature, moisture and light (how û is this the mesocosm work??) û they will try to determine how and to what extent these burned materials are exported to surface waters (C,N,COM,etc.).

Finally, they discuss human dimensions research that is to be done by Kofinas and company evaluating perceptions of climate change & its impacts on subsistence lifestyles. It is great to see this arena being developed and some of the core funding moving this way but the work is not well connected conceptually or experimentally to the biophysical work.

What are the broader impacts of the proposed activity?

This region of the globe is undergoing unprecedented changes in climate begins to warm; the ecosystems are response and may be quite fragile. Thus the work has direct relevance to understanding the rate, mode, and type of changes that may have global consequences for people. Their work on CO2 fluxes is particularly important. They are now starting to include a focus on the native peoples which is important because their subsistence lifestyles may be greatly impacted by these changes and the response of these peoples to these changes may exacerbate (or not) the ecosystem changes.

Summary Statement

This LTER has a strong group of PIs with a productive track record. They are slowly with this proposal shifting to think integratively across terrestrial and aquatic realms. All the kinks are not worked out but this is an important step forward and good work will come of this.

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Proposal Status | MAIN

Organization: Marine Biological Laboratory

Review #2

Proposal Number:	1026843
NSF Program:	Long Term Ecological Research
Principal Investigator:	Shaver, Gaius R
Proposal Title:	Arctic LTER: Climate Change and Changing Disturbance Regimes in Arctic Landscapes
Rating:	Multiple Rating: (Excellent/Very Good)

REVIEW:

What is the intellectual merit of the proposed activity?

This proposal followed NSF guidance for information to be included in LTER renewals and provided all the information requested (in a way that was easy to find).

RESULTS OF PRIOR LTER SUPPORT
The prior results section is very nicely organized, showing the progression in foci since inception and clearly presenting major findings and synthesis for each of the four major themes û terrestrial, stream, lake and landscape. A pleasure to read. The publication record is impressive, as is the communication with the public through radio and printed word. The synthesis volume, recommended by the midterm review committee, has been written. It was refreshing to see a clear statement of how annual supplemental funds were used, and how that funding evolved into a major couple human dimensions thrust. Supplementary Table 2 û datasets û is incomplete; however, this must have been an error, as the additional datasets including lake and stream data are on the online data base and are well organized. Use statistics are provided.

PROPOSAL
With this proposal, the new focus of the ARC is on climate change, disturbance regimes, and their interaction in arctic landscapes is an evolution from results of past work. They now recognize a more complicated assessment of the indirect effects of climate change û i.e., the patchy nature of disturbance and patchy nature of response to disturb. This patchiness can cause large-scale effects, leading to changes on faster time scale than those that are direct responses to changes, for example, response to increasing temperature per se. In addition, they add a human-coupled dimension to their work by addressing subsistence land use and impacts of climate change on Native Alaskans.

They continue to use four watersheds, using three organizing questions (p. 2-1) for each. In response to the midterm review, they will reduce some long term sampling and will use ænatural' experiments of disturbance rather than large manipulation experiments û a cost effective approach. Surprising that they do not include insect infestation as a disturbance. Lake manipulations are of nutrient additions, but why not sediment additions as well as a disturbance? Perhaps slumping of thermokarst will serve that purpose.

The ARC LTER serves a key role in fostering collaborations among LTER and collaborating scientists and synthesis of arctic data. The experiments and observations are well thought-out, with the exception of omitting insects as a disturbance.

Site management.
ARC LTER research is done with >30 separately-funded projects that uses LTER sites, experiments, data bases, facilities, and personnel. The ARC management views their role as providing a structure to enable opportunities for synthesis. They seed to foster synthesis through working in the same watersheds and coordinating sampling of terrestrial, stream, and lake components. The role of the ARC LTER is nicely stated on p. 2-5 that they provide assistance to collaborating projects and core data, serve as a database for collaborating projects, and operate as a catalyst for synthesis and new research ideas.

They appear to be active with LTER network and other networks, and will interact with BNZ LTER more closely.

They state that they actively seek to broad minority participation and hire Native Alaskans to run the station. The project management seems to work, and they have actively planned for transition and have an organized program to bring in new investigators and new talent to leadership roles.

Information management.
They have four research assistants, who are actively involved in the research themselves, in charge of data and quality control in each of the four areas (terrestrial, etc.) û a good idea. The website is inviting and easy to navigate.

Budget.
Salary support for Shaver is reasonable, as he is at a soft-money institution; MLB leads the terrestrial component. Subcontracts are included for management of the landscape, stream and lakes components. Leverage funding from 35 currently-funded collaborating projects listed in Table 7-1 is $24M.

What are the broader impacts of the proposed activity?

Their activities in this area are excellent. Their educational activities in a Schoolyard, focusing on Barrow and Native Alaskans, hands-on courses in Arctic ecology for graduate and undergraduate students, and involvement of REU and graduate students in site research. Their Polar Hands-on Laboratory in science journalism generated a considerable radio and press exposure. Additional outreach includes briefings to federal and state Alaska management agencies. The human dimensions component will significantly add to understanding of how climate change will affect subsistence Alaska communities.

Summary Statement

The ARC LTER is productive, serves a synthesis role, and is appears to be well managed. The new focus is on the role of disturbance patches as accelerating climate change.

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Proposal Status | MAIN

Organization: Marine Biological Laboratory

Review #3

Proposal Number:	1026843
NSF Program:	Long Term Ecological Research
Principal Investigator:	Shaver, Gaius R
Proposal Title:	Arctic LTER: Climate Change and Changing Disturbance Regimes in Arctic Landscapes
Rating:	Good

REVIEW:

What is the intellectual merit of the proposed activity?

My comments are directed at the information management aspects of this proposal, based on criteria specified in v. 1.1 of "Review Criteria for LTER Information Management Systems".

Basic infrastructure and staffing-- it appears that there is one dedicted FTE for information management at ARC, although some IM duties are shared among four research assistants.

Web site-- "arc.lternet.edu" does resolve, however it does not go to the ARC site, but to its parent organization! The general URL for the site is-- http://ecosystems.mbl.edu/arc . This could be improved to more prominently feature the site. Overall the web site is effective... decent organization and content.

Data/metadata-- there are 1638 packages represented in the LNO repository. Some of these packages only have level 3 EML. Also, there are some odd renderings of attribute metadata, which would require improving the XSLT transformation scripts. The titles of a number of these packages were very cryptic, representing more a terse filename rather than a descriptive title. Access to the data on the web site is well organized, although often requiring drilling down through several levels of topically arranged hierarchy, rather than presenting a single unified querying interface. Attribute level EML is available for a large number of the datasets, and appropriate usage agreements are in place when accessing these from the LNO repository.

Publications-- ARC points to the LNO bibliographic search service, where 607 references are returned for ARC. Refining the search to subset for some specific ARC keyword or author does not seem possible with this service, at least at the basic interface level.

What are the broader impacts of the proposed activity?

ARC has developed a locked-down spreadsheet template to help researchers create metadata that is EML compliant. This template might be more broadly promoted as an easy way to assist researchers in the creation of EML, if they do not want to use a more comprehensive tool like Morpho for this purpose. Also some effort will be expended developing EML for GIS files, and any best practice approaches from this exercise should be shared with other members of the LTER community.

Summary Statement

Section 4 did not contain enough detail about the information architecture to gain a proper understanding of the current adequacy of information management solutions at this site. It may be that interactions with NSF's OPP must be considered as part of the information management solution at the ARC site. Even still, more specific details about IM staffing, hardware, software, etc. at ARC would be useful!

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Organization: Marine Biological Laboratory

Review #4

Proposal Number:	1026843
NSF Program:	Long Term Ecological Research
Principal Investigator:	Shaver, Gaius R
Proposal Title:	Arctic LTER: Climate Change and Changing Disturbance Regimes in Arctic Landscapes
Rating:	Good

REVIEW:

What is the intellectual merit of the proposed activity?

The ARC proposal builds on a long and impressive history of productive research in northern Alaska. In the current proposal, the long-standing basic mission has been expanded to focus on the separate and combined effects of climate change and disturbance on arctic landscapes. While signs of a gradually changing climate are apparently unfolding in the Toolik Lake region, the biggest changes may be altered disturbance regimes (more fires, more thawing of permafrost) that are imposed on more gradual shifts in temperature or season length. Researchers are organized into four groups corresponding to study systems (streams, lakes, terrestrial ecosystems, and landscapes), and each group will consider a shared set of questions about (1) climate, (2) disturbances, and (3) climate-disturbance interactions. A fifth group representing social dynamics is also getting integrated into ARC's program.
Overall, this is a clear, easy to read, and well organized proposal. Each group section explicitly addresses how the specific research is linked to the three general questions. In many cases though, explanation of how work would linked to the question of climate control (in particular) came down to saying 'we will monitor and measure x, y, and z...' That is, explanations of how work would be linked to core questions were often just lists of specific measurements or experiments and did not provide much insight.
All three major suggestions made by the site review team were embraced and incorporated into research plans for the next 6 years (but see later comment regarding the issue of scaling back and re-distributing resources). Results of prior funding include a lengthy list of past accomplishments, and it is clear that this is a very productive group that has been successful with publishing and funding. Although (or perhaps because) their synthesis book is now in press, it was surprising to see that the one area that looked thin on the results of prior funding was synthetic and retrospective studies. All those cited were from 2004 or before, indicating that they were products of work from pre-2003 (prior to the last funding cycle).
The conceptual framework for the next 6 years of ARC is straightforward. There are some hypotheses built into the proposal (which are more like predictions), and overall, the quota of exciting new ideas felt a bit low. The main growth area will be to understand the apparently increasing frequency of disturbances in the region, which are layered on top of slower and more homogeneous climate changes. Oddly, data to demonstrate these trends were sparse. Given that research has been ongoing at this site since 1975 and that changes in climate and disturbance regime form the basis for the next 6 years of work, it would have been nice to see some demonstration of these changes (e.g., increased fire frequency or shifting air temperatures- in addition to Fig. 2-16 showing discharge trends). Brief mention of some of these phenomena is made in results of prior funding (e.g., reports of greater thermokarst occurrence), but overall, use of the long term data record in the proposal was surprisingly limited. I may be getting carried away with this point, but wording such as "possible increases in fire incidence" is surprisingly ambiguous given that the premise of this round of funding is the shifting disturbance regime. In this same spirit, there were a couple of cases in which research ideas/plans were built on debatable data interpretation. For example, the case is made that ongoing changes in disturbance and/or climate are apparently responsible for higher nutrient concentrations in surface waters, as demonstrated by the long-term stream nitrate record (Fig. 2-11). There certainly has been a blip in NO3 in the past 6 yrs, but what about high concentrations at the beginning of the record? Again, this is probably a small point, but this sort of interpretation reflects a tendency to bypass potentially interesting variance and to over-simplify what are likely to be complex sets of causes and effects.
One of the concerns raised in the mid-term review and addressed in this proposal was the issue re-distributing resources to

allow the PIs to take on new research areas. Overall, choices to scale back on sampling (e.g., reducing frequency of sampling) made sense, although the reduction from 100 sampling points in 30 streams down to just 2 sites sounded pretty dramatic. This aside, while it seemed like the investigators were trying to re-assure reviewers about their ability to continue monitoring or start new initiatives by leveraging with other projects, I wasn't completely reassured. All LTER sites rely on outside funding to some degree. But here, it seemed like a lot of monitoring (e.g., lake temperature) or questions (e.g., benthic processes in burned and unburned lakes) were being funded from other sources. There is no arguing that the PIs involved in ARC have been extremely successful in acquiring outside funding, but there may still be a day of reckoning when questions or measurements listed in this proposal may not be possible.
Social science is beginning to get integrated into the ARC program. Doing so is clearly much more challenging for this site than it is for other sites strongly influenced by human activities (e.g., urban sites). But this phase of the work feels very much like a last-minute add-on that is following the lead being set by BNZ. The partnership with BNZ in general is a good strategy, but there are probably other opportunities for partnerships with other sites that could be further developed.
Synthesis activities are fostered by having all research groups use the same shared research areas (this seems like an obvious course of action and it's surprising to think that in the past that different groups went their separate ways to do their work). The investigators make a firm statement regarding ARC's commitment to collaboration and synthesis through a variety of activities (e.g., making long-term data available). It's reassuring to see this text, however, the list of supporting services sound like standard requirements for all LTER sites, with the exception of providing support for travel for possible collaborators. In short, information on synthesis activities felt more like LTER boilerplate than serious ideas to promote synthesis.
Site management at a remote location and among PIs from different organizations is particularly challenging. The strong productive record of this group indicates that they have mastered this challenge. Nonetheless, Shaver et al. recognize that there are issues to be addressed to keep things running smoothly, including recruiting new PIs and thinking about replacing some of the individuals in leadership positions. No specific plans are given, but the fact that these issues are on the radar screen is a step in the right direction, and this is not yet a critical issue. It is interesting to note that the mechanism to recruit new PIs is often to bring in former students and post-docs. This has the clear advantage of bringing in researchers who are familiar with the system and who are known entities (i.e., will get along with the group in a challenging field setting). But if this is the major pathway of recruitment, then there is the obvious risk of intellectual inbreeding.

What are the broader impacts of the proposed activity?

ARC supports a healthy variety of outreach and educational activities. This is additionally impressive because of the extra work that must be required given Toolik's remote location. SYLTR activities with Barrow schools have the potential to become well-integrated into social science research down the road. Also impressive was the development of a program for journalists, and strong involvement of undergraduate and graduate researchers. The PI's appear to be well-connected with agencies and with broad-sale science initiatives in arctic regions.

Summary Statement

The ARC group has a long history of superlative research productivity and support, and there is every reason to anticipate that this trend will continue because of the strength of the PIs involved. However, the plan for the next six years is fairly straightforward, which has its advantages, but also suggests the potential for oversimplification of a complex series of changes that are beginning to get underway. The good ideas in the proposal are contained within group-specific research activities rather than cross-cutting between the 4 research components, and certainly not cross-discipline since ARC investigators are predominantly community and ecosystem ecologists. Put another way, this proposal lays out the logistics and opportunities for interesting but straightforward research but has not pushed the envelope in terms of new and exciting ideas.

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Proposal Status | MAIN

Organization: Marine Biological Laboratory

Review #5

Proposal Number:	1026843
NSF Program:	Long Term Ecological Research
Principal Investigator:	Shaver, Gaius R
Proposal Title:	Arctic LTER: Climate Change and Changing Disturbance Regimes in Arctic Landscapes
Rating:	Very Good

REVIEW:

What is the intellectual merit of the proposed activity?

The goal of the Arctic (ARC) LTER site is to develop a predictive understanding of the landscape of Northern Alaska including a new emphasis on changing disturbance regimes and their interactions with climate change.

Datasets are primarily created by research associates (RAs) charged with joint data collection and information management responsibilities, with metadata being created using a spreadsheet-based template. Investigators and students also submit some data to that is subsequently reviewed by the RAs for inclusion into the database. Plans for the future include moving to a more database-centric framework.

What are the broader impacts of the proposed activity?

The LTER site has 1638 datasets listed in the LTER Network Data Catalog. This is the largest number of datasets provided by any LTER site, largely because data are not aggregated across sampling locations or times. Instead, each individual dataset typically focuses on a single type of data at a single site and during a single year. The ARC data access policy is in conformance with the LTER Network Information Management Policy. Arbitrarily, I selected from the Results of Prior Support section five types of data that I would expect to find (biomass [terrestrial], nitrate, fish, lake temperatures and microbial community composition). For terrestrial biomass, a search of the LTER Metacat found several data sets, but none had data more recent than 2006. All the other types of data were current through 2009. Publications from the ARC LTER in the LTER Network All-Site Bibliography also included 2009 publications. Metadata quality was generally good. Contrary to the assertion of the proposal that most legacy datasets lacked attribute-level metadata, I found that many of the Ecological Metadata Language documents generated by the site included both discovery and use-level metadata, including attribute-level data.

The ARC information manager is active in the activities of the LTER Network Information Management Committee. ARC is one of the first LTER sites to start using the LTER-wide Data Access Server to provide access to datasets. The site has started or planned implementation of most of the recommendations from the mid-term review, except for the recommendation that more of the data collected by graduate students should be captured into the database.

Summary Statement

The information management system at the ARC LTER, although not particularly technologically innovative, is solid and effective. It provides a wide array of data and good quality metadata.

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Privacy and Security

Proposal Status | MAIN

Organization: Marine Biological Laboratory

Review #6

Proposal Number:	1026843
NSF Program:	Long Term Ecological Research
Principal Investigator:	Shaver, Gaius R
Proposal Title:	Arctic LTER: Climate Change and Changing Disturbance Regimes in Arctic Landscapes
Rating:	Good

REVIEW:

What is the intellectual merit of the proposed activity?

Scientific merit/research within and across sites

Summary: ARC is a highly productive LTER site that represents >35 years of intensive, site-based science in the high arctic. In this fifth LTER proposal, the research is focused on the overall goal of understanding changes in high arctic ecosystems at catchmanent and landscape scales. The research focuses on terrestrial ecosystems, streams, lakes, and landscape interactions between the terrestrial and the aquatic "compartments". The proposed research has three themes and organizing questions that are applied to all four ecosystem compartments: (1) How does climate control ecosystem states, processes, and linkages; (2) how do disturbances change ecosystem states, processes, and linkages; and (3) how do climate and disturbance interact to control biogeochemical cycles and biodiversity at catchment and landscape scales. As would be expected given the intellectual mileu of the ecosystems center at MBL, synthesis and modeling focus on mass-balance modeling and biogeochemistry. The proposal is responsive in some areas to the mid-cycle review, but not in others. Overall, the proposal reflects intellectual evolution of the ARC focus, and increasing regionalization (including interactions and syntheses with BNZ LTER and the proposed NEON site at Toolik Lake Field Station).

Quality and critique: The first organizing question is how does climate control ecosystem states, processes, and linkages. In particular, there is a presumption (p. 2-3) that variability in climate and climatic change affects the overall disturbance regime (flood, drought, fire, thermokarst). Scant data are presented to support the climate-causes-change in disturbance "regime" hypothesis, and while the research plan of continued monitoring of climate and disturbance (pp. 2-4 to 2-5) may produce the relevant data, little attention is paid to how one might actually analyze it to demonstrate the causal chain of climate-to-disturbance regime. Simply accumulating more data from monitoring is not enough.

Furthermore, the PIs suggest that "an increase in disturbance may represent a 'tipping point' or 'resilience threshold' that drives the arctic landscape into a new state of interaction with the regional and global climate systems and with the people who use and benefit from the ecosystem services it provides" (p. 2-4). It certainly might. But it is not clear that the ARC PIs or research team can articulate or model how this would work. Thresholds and tipping points derive from interesting interactions and often non-linear changes in importance of negative vs. positive feedback loops between drivers and response variables. What are these in the ARC system? Where is assessment of them in the proposed research in any of the compartments? The conceptual framework (Fig. 2-3) implies feedbacks (two-headed arrows), but doesn't distinguish between negative or positive feedbacks. Fig. 2-14 on interactions between aquatic bryophytes and stream ecosystem dynamics suggests different feedbacks, but these are a long way from the climate-disturbance regime system. The forced translation of the ARC research program into the ISSE framework does not elaborate on these feedbacks either. In short, the vocabulary is here but it is not clear how the PIs or the overall ARC team will translate the ideas into hypotheses, models, or experiments. Intellectual linkages with BNZ will help here; M. Mack, whose unpublished data is cited on p. 2-4, is a co-I of both ARC and BNZ , where there is a better qualitative (but not quantitative!) understanding of how tipping points and thresholds work.

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experiments can be continued with appropriate resources to provide reliable sampling". The response is that "to accommodate our new research on disturbances, however, several of our older experiments will be discontinued or placed in 'mothball' stauts, and others will be maintained but sampled less often." Yet it is unclear which, if any, of the older experiments will be slowed, moth-balled, or discontinued. Given the importance of the first organizing question not only to ARC, but also to BNZ and to the success of NEON installations at both ARC and BNZ, the PIs need to really be clear about how this question will be addressed, and what other/existing projects will be reduced in order to allow for it to be addressed in a satisfactory and rigorous manner.

The proposed research for the terrestrial compartment (pp. 2-6 to 2-8) exemplifies these challenges. Many measurements will be continued and new ones will be added (including eddy covariance from six (!) towers. No existing measurements are slated for slowing, moth-balling, or discontinuing. No discussion of using either retrospective/historic or new data to illustrate how climate alters disturbance regime is presented ("all of these results will further expand our long-term data base and be used in our modeling and scaling efforts": p. 2-8). The models used are all mass-balance, ecosystem compartment models (GEM, MEL) that do not easily incorporate or output stochasticity (inputs) or degreee of uncertainty (outputs). ARC is fortunate in having one of the longest time-series of environmental data in the LTER network, and it would be straightforward to use time-series analysis or dynamic linear models to determine if there really has been an effect of (or even a threshold crossed) climate on disturbance.

The discussion of the stream compartment continues the theme. As noted above, Fig. 2-14 is one of the few instances in the proposal where both positive and negative feedbacks are illustrated. The long-term experiment with P-addition is well-placed to address thresholds/tipping points/resilience, and in fact it demonstrates hysteresis in response (as noted on p. 2-10; Benstead et al. 2007)! The PIs fail to place this response in the context of their overarching questions and themes, instead hypothesizing that reintroduction of phosphate will result in rapid reestablishment of residual bryophyte populations (p. 2-10). Examining these data in the context of Carpenter & Brock's quantitative modeling of threshold dynamics would be informative and might provide a number of alternative hypotheses. And again, what projects will be slowed to allow for the new data to be collected?

A similar linkage might be occurring in the lakes. Their own preliminary data suggests the possibility that P is being mobilized from lacustrine soils (p. 2-12), and other indicators of regime shifts are also suggested in the central paragraph on that page. This may be an early-warning indicator of a threshold change (see Carpenter & Brock 2006, Ecology Letters). The whole-lake experiments will be revealing in this regard, but application of the qualitative (not quantitative!) "hierarchical response framework" (p. 2-13; Smith et al. 2009) is not compelling. The PIs suggest that cumulative effects are difficult to study due to multiple non-linear responses. Why is this difficult? There are many statistical tools available that deal with non-linear data. The lake section is notable for pointing out reductions of sampling effort (on Lakes E5, E6, N1, N2) to allow for new activities, but it doesn't seem quite enough.

The land-water interactions is, to this reviewer, the most conceptually interesting, and at the same time the most responsive to the suggestions of the mid-cycle review team for scaling up the intellectual focus of ARC. The elucidation of microbial community structure and linkages with DOM is extremely interesting, and is a fruitful area for new research. Good experiments are proposed; are they doable with declining resources?

Finally, the human dimensions section is new for ARC and builds on LTER supplement-funded activities. It is time to mainstream these within ARC and the PIs clearly want to do this. Linkages with BNZ and LTER-MALS will certainly help, but the budget for this component should reflect its overall importance. Currently, only a single summer undergraduate RA will focus on this activity.

Productivity: ARC researchers have been very productive. In the most recent LTER funding cycle, they have produced 139 peer-reviewed papers, 21 book chapters and one book, 24 theses and dissertations, and >50 non-classifiable publications, including articles in the popular press, audio and video, and blogs. Importantly, the ARC synthesis volume has been completed and is being finalized for publication by Oxford University Press.

What are the broader impacts of the proposed activity?

ARC participates in many LTER network activities, international collaborative research (e.g., ACIA, ITEX, meta-analyses and syntheses), and ARC funding is highly leveraged by other complementary grants. Future synergies with the NEON arctic site will further these collaborations and broader impacts. ARC has a thriving schoolyard LTER program with extensive outreach to Barrow, AK. The Polar Hands-on lab for science journalists is outstanding outreach and ensures broader scientific literacy and communication about ecology to non-specialist audiences. Appropriate education of undergraduates and graduate students is a key part of ARC. Finally, there is solid interaction between ARC/MBL scientists and federal, state, and local agencies responsible for managing arctic ecosystems.

ARC LTER data are well-managed and easily accessible. With a bit of hunting, links to the key ecosystem models (e.g., GEM) developed by MBL scientists can be found on the ARC web site. The web-site itself is functional and easy to navigate; it is especially good to see associated and ancillary (non-LTER) Toolik data on the web site.

Summary Statement

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Proposal Status | MAIN

Organization: Marine Biological Laboratory

Review #6

Proposal Number:	1026843
NSF Program:	Long Term Ecological Research
Principal Investigator:	Shaver, Gaius R
Proposal Title:	Arctic LTER: Climate Change and Changing Disturbance Regimes in Arctic Landscapes
Rating:	Good

REVIEW:

What is the intellectual merit of the proposed activity?

Scientific merit/research within and across sites

Summary: ARC is a highly productive LTER site that represents >35 years of intensive, site-based science in the high arctic. In this fifth LTER proposal, the research is focused on the overall goal of understanding changes in high arctic ecosystems at catchmanent and landscape scales. The research focuses on terrestrial ecosystems, streams, lakes, and landscape interactions between the terrestrial and the aquatic "compartments". The proposed research has three themes and organizing questions that are applied to all four ecosystem compartments: (1) How does climate control ecosystem states, processes, and linkages; (2) how do disturbances change ecosystem states, processes, and linkages; and (3) how do climate and disturbance interact to control biogeochemical cycles and biodiversity at catchment and landscape scales. As would be expected given the intellectual mileu of the ecosystems center at MBL, synthesis and modeling focus on mass-balance modeling and biogeochemistry. The proposal is responsive in some areas to the mid-cycle review, but not in others. Overall, the proposal reflects intellectual evolution of the ARC focus, and increasing regionalization (including interactions and syntheses with BNZ LTER and the proposed NEON site at Toolik Lake Field Station).

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Summary Statement

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Proposal Status | MAIN

Organization: Marine Biological Laboratory

Review #8

Proposal Number:	1026843
NSF Program:	Long Term Ecological Research
Principal Investigator:	Shaver, Gaius R
Proposal Title:	Arctic LTER: Climate Change and Changing Disturbance Regimes in Arctic Landscapes
Rating:	Very Good

REVIEW:

What is the intellectual merit of the proposed activity?

Strengths-

This LTER has an excellent track record of discovering new aspects of arctic ecosystem structure and functioning. It is perhaps the leading research project on arctic ecosystems in the world.
The new direction of examining interaction of climate change with a changing disturbance regime, especially taking advantage of surprisingly large fires nearby, is a worthwhile focus for the next five years. I cannot think of any other direction more important.
The proposed work will focus on four watersheds of different geomorphic settings and disturbances (thermokarst and fire; p. 2-2). They have identified fairly concrete tipping points û increased fire frequency and size, shift to dominance by shrubs û so they have some idea of what to look for, which helps them design sampling programs and experiments.

The models of coupled element cycles linked with hydrologic models, plant community models, and food web models (p. 2-7) are well-developed and producing surprising predictions. But see also below under Weaknesses.

Weaknesses-

Table 2-2 lists an impressive record of long-term measurements, and about 1/3 of 34 figures in this proposal present data on long-term trends. However, most of these figures are for data on the aquatic systems, most especially the Kuparik River. The long-term data on terrestrial ecosystems, most notably Shaver's very interesting data on changes in phenology and growth along the Dalton Highway from Toolik to the Arctic Ocean, do not seem to have received the same scrutiny. Given over 30 years of measurements on a wide range of properties across the landscape, I would have like to have seen more sophisticated analyses of trends, time lags, correspondences across trophic levels, biomes, and landscape positions. It isn't enough for an LTER to monitor, collect, and archive long-term data. They should also be leaders on how to analyze it. The new research does not seem to be as motivated by interesting findings in these long term datasets as it might have been, except perhaps and only perhaps for the aquatic systems.

In response to review comments, they will "focus on four common study watersheds, chosen to facilitate comparisons between disturbed and undisturbed landscapes, and between watersheds with and without lakes." However, it is not clear how the projects within each watershed will relate to one another. Are they each producing the data on their respective ecosystems that each of the other projects needs? Although both terrestrial and lake systems in burn and in unburned watersheds will be studied, the locations of the terrestrial sampling plots in relation to lakes and streams is not clear. In other words, will the materials leaving the terrestrial plots in fact make it down to the particular lakes and streams being measured, or will they be delivered to a lake or stream that is not being monitored?

Exactly what is being tested by comparing these watersheds needs to be sharpened. For example, it is not clear what is being tested by comparing the Kuparik watershed (no lakes) with the Toolik Lake watershed (string of lakes upstream from Toolik).

What does the presence or absence of lakes in a watershed mean for nutrient and hydrologic transfers?

The models have not always been used to predict early warning criteria of when and where tipping points will happen and what might happen afterwards. Models are important to help the experimentalists ground their ideas of tipping points etc in logical reality. Without the models, such ideas can rapidly become handwaving and wishful thinking. The coupling of model analysis with the experimental and monitoring design could be stronger. The proposed experiments are not always well-informed by the model predictions and it isn't clear how experimental data will be used to "further develop the models". Ecosystems will move across so-called tipping points to so-called novel systems (when does a system become "novel"?) because of strong positive feedbacks or delayed negative feedbacks. Models are essential tools for identifying these feedbacks and experiments should be designed to enhance these feedbacks or shut them off and see how ecosystems respond. If the ecosystem does not move into a "novel" state when feedbacks are enhanced or shut off, then perhaps we will learn more than simply waiting for something to happen and proclaiming a tipping point post-hoc. It isn't clear how or if the models have been used to identify the pertinent feedbacks, the trajectory to a tipping point, when we can expect an ecosystem to cross it, what the sequence of events will be as the tipping point is crossed, and how the ecosystem reorganizes itself on the other side.

What are the broader impacts of the proposed activity?

Criterion 2: Broader impacts

Strengths-

The most important broad impact that this LTER will have it is that is the most comprehensive field effort in the world dealing with the structure and functioning of arctic ecosystems. The research done here is even broader than at Abisko in Sweden and much better coordinated. More than any other fieldwork in the arctic, the Toolik LTER will be the world's early warning observatory for the responses of tundra ecosystems to climate change.

There are no people living near Toolik, native or otherwise, other than the scientists at the station. This group is to be congratulated, therefore, for making a heroic effort to establish and maintain the schoolyard program at Barrow, a long ways away and in an entirely different ecosystem to be sure. The courses in Arctic Ecosystems to journalists are excellent outreach program because what happens to the tundra is important for everyone in the lower 48 as well as the North Slope. These will probably have a much broader positive societal impact than the Barrow Schoolyard Program.

Weaknesses-

The proposal says that the broad impacts go beyond simply studying the arctic and will be a model system for studying "controls on "resilience", "tipping points", and "thresholds" in populations, communities, ecosystems, and complex landscapes." While I agree, to be really effective these concepts need to be defined more precisely in this work (see above comments on using models to predict these things). Otherwise we run the risk of calling every change a "tipping point" and searching only for these changes and ignoring properties that don't change and discovering why they don't change.

Criterion 3: Information Management

I defer to the reviews by the information management specialists for comments.

Criterion 4: Management

Strengths-

The management of this LTER appears to follow the standard LTER model. I was pleased to see that Gus Shaver will be the new lead PI û he has the breadth of interests, experimental backgrounds, and taste in interesting problems that should help move this LTER forward.

Weaknesses-

The problems that almost every LTER faces are: (1) too many people spreading money and effort too thin and causing the project to lose focus. This LTER has added many researchers in the past several years and I wonder if they have now spread themselves too thin, especially given the logistic problems of working north of the Brooks Range. To read that they will expand

the number of researchers further (p. 3-2) is worrisome. (2) a crisis in intellectual and managerial leadership by not having a plan for replacing the PI on a regular basis. They say that they will identify the next generation of leaders in the next 6 years (p. 3-2), but they cannot wait that long. It is important that the next generation of leaders be identified by the next site visit, especially since some of the senior people will be retiring in 6 years. Someone on the Executive Committee needs to be the "PI-Elect" for the next proposal round. If no one on the Exec Comm wants to do this, then one of the other Co-PIs needs to be placed on the Exec Comm with this role in mind.

Criterion 5: Cross-site and Network Collaboration

Strengths-

Discussions with NEON are already beginning to build a basis for the Toolik LTER and the nearby NEON site. The Toolik LTER has participated in a few minor cross-site comparisons. They are laying the foundation for future collaboration with the boreal forest LTER at Bonanza Creek just south of the Brook Range, but there are few details about what this would look like.

Weaknesses-

Opportunities for collaboration with Niwot Ridge alpine LTER should be explored. I'm surprised that there does not even seem to have been a history of collaboration between these two tundra LTERs, to say nothing of cross-site collaboration with the Palmer and McMurdo Antarctic LTERs. Expansion of shrubs in a warmer climate has been forecast for alpine and short grass prairie ecosystems, and the Toolik, Niwot, and Short Grass LTERs should consider coordination of experiments, models, and data collection to address this emerging
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Summary Statement

A strong proposal with many interesting ideas, but the research group may be a bit too large and therefore losing focus a bit.

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Proposal Status | MAIN

Organization: Marine Biological Laboratory

Review #9

Proposal Number:	1026843
NSF Program:	Long Term Ecological Research
Principal Investigator:	Shaver, Gaius R
Proposal Title:	Arctic LTER: Climate Change and Changing Disturbance Regimes in Arctic Landscapes
Rating:	Good

REVIEW:

What is the intellectual merit of the proposed activity?

Overall

The Arctic LTER (ARC) is an exciting project located in one of the planet's most vulnerable environments with respect to climate change and potential future resource exploitation. The project has very broad programmatic goals, encompassing many of the area's critical ecosystems and their interrelationships, its participants represent many of the key disciplines. Some unique aspects of the region include the presence of cultures with subsistence-based livelihoods, large expanses of wilderness, and, as of yet, untapped mineral, energy and biological resources.

The overall goal of ARC for the next 6 years is to understand changes in the arctic system at catchment and landscape scales as a result of both direct effects of climate change (on states, processes and linkages of aquatic-terrestrial ecosystems) and indirect effects of climate change (on ecosystems through the changing disturbance regime).

The project has been very successful in generating/supporting more than 30 separately funded projects which could be quite challenging to integrate. ARC's solution is to pursue the same 3 "organizing questions" in 4 defined components (including 3 ecosystem groupings: terrestrial, streams, lakes, and landscape interactions). Research sites are collocated in same watersheds and sampling of the different components are coordinated.

Section 1: Scientific merit: Results of prior support

This is a very productive project. The results of prior support are numerous and diverse, but it was a huge challenge to plough through all this material. Overall, some of the exciting components (especially the research questions) of this research get lost in the summary and proposal (does the permafrost leak massive amounts of greenhouse gases? are we getting close to tipping points? how do fires interact?)

The integration of social science into the ARC program via supplemental funding and in collaboration with the BNZ LTER has led to collection of new types of data and monitoring of the human dimension of arctic ecosystems. This is crucial new research that should be expanded and carefully integrated into the more traditional (e.g. "human-free") environmental sciences due to the fact that this part of the world will undergo enormous change in the next few decades. Given the regulating services provided by the arctic for our planet, this is very important work.

Terrestrial microbial ecology is sorely underrepresented despite its significance in understanding responses to disturbance regimes (fire and thermokarst sites) and in response of this system to climate change (carbon sequestration, methane and nitrous oxide emissions). There is little evidence of the involvement of co-PIs Schimel (despite his long record of research in these ecosystems) and Moore. Models describing responses of biogeochemical cycling and greenhouse gas emissions could be advanced by including microbial parameters. In fact, the ARC LTER is poised to make major contributions to advancing how microbial ecology could be integrated into ecosystem ecology given the rapid changes this system is undergoing and thus the

high probability of being able to detect the linkages.

Organization of the research program into "components", based on type of ecosystem, seems to diminish cooperation and collaboration that would come from question-based organization (as in other LTER projects). I recommend that the ARC LTER evaluate some of the ways in which other LTERs have organized similarly complex programs. The Landscape Interactions research component is an important part of the project but it is not very clear how it interacts with the other ecosystem-based components.

Section 2: Scientific merit: Conceptual framework (synthesis long-term and short-term experiments, detail methods of new experiments)

Conceptual frameworks somewhat confusing. The fifth socio-ecological component has not been integrated yet into much of the proposal (though I recognize the funding to support this area is still limited) The proposed ARC LTER research translated into LTER ISSE research shown in Fig. 2-33 shows the commitment of the project to integrate the human dimension. A challenge is that many of the drivers changing the ARC system are external to Alaska, but, given the enormous magnitude of these external impacts on ARC's vulnerable ecosystems, they should be incorporated into the framework. Also, the framework should have a process of evolution with local, regional (and maybe national?) stakeholders, which is largely missing from their research process.

Network participation is very strong.

Section 3: Project (and site) management

I found the Project Management plan to be unexciting and lacking some of the types of activities that other LTERs have implemented to engage and integrate investigators, both among themselves, and with interested stakeholders (both locally but also globally). This is a particularly important area to evolve as the project moves into an increased emphasis on human-environment interactions.

The strengths of the project management organization is its strong historical and current leadership (which has recently changed, apparently with a smooth transition) and a committed and highly qualified Executive Committee that meets twice yearly, with conference calls in addition. The Committee is small, however, and does not represent some of the disciplinary areas important to the project. I echo the recommendation of the Mid Term review to expand and possibly rotate members to better represent all the needs of the project and to increase its age and gender diversity.

A winter meeting is when all investigators come together; however, this opportunity for exchange does not appear to be used very creatively. The meeting seems to follow the usual talking heads format. The management plan gives virtually no information about what is accomplished during this time. I would recommend that the ARC LTER evaluate how other LTER's use their annual meetings and also consider other means of connection.

Another option to consider is the organizational structure used by the Hubbard Brook project management, where sub-groups are focused on actual tasks (research approval, information committee, education and outreach) and all the scientists sit on the "Committee of Scientists." Or the Arizona Urban LTER has an interesting structure involving multiple committees that address short and longterm issues as well as the executive decisions. These types of organizational structure end up engaging more scientists by directly empowering them in helping guide the project's directions.

I can't find any response to the mid review team's recommendation to set up an External Advisory committee to provide guidance regarding research direction and funding opportunities. I strongly encourage formation of this committee to include researchers of other polar ecosystems, governmental representatives with oversight in the arctic region, community member representing interests of the native communities, etc.

Communication between the ARC and BNZ LTERs exists; however, greater interaction, particularly among its investigators and students, could be galvinizing with respect to opening up new research and employment opportunities and defining new research questions. Additionally, this meeting could provide a forum to develop strategies for scientists to be involved in solving some of enormous problems challenging this region, particularly if regulators, industry and other decision-makers are also invited.

Section 4: Information management

ARC's information management system seems very strong. Good outsourcing of data collection and good data management

policies.

In general for all LTERs, seems like it would be useful to have some synthesis datasets available as well.

What are the broader impacts of the proposed activity?

Section 5: Education and Outreach

The ARC LTER has a much smaller education and outreach program than many of the other LTERs, most likely due to its remote location. The Barrow Schoolyard Program seems to be of very high quality but has a small audience -- I strongly recommend to put the curriculum online and also maybe make videos available so kids all over the country could learn about the warming Arctic. This topic is of enormous national and international interest and such a resource would be extremely valuable as a portal for students and the general public (particularly semi-skeptics) into the topic of climate change.

Summary Statement

This important project needs better organization to foster cooperation and to encourage development of new research hypotheses that cut across ecosystems.

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