

**Hubbard Brook LTER Midterm Site Visit**  
**June 3-5, 2019**

**Summary**

The Hubbard Brook LTER (HBR, Gary Lovett PI), has been at the forefront of ecosystem ecology for decades. Its long-term data sets and watershed-scale experiments have transformed understanding of ecosystems and biogeochemistry. The work has been highly relevant to society and a powerful force in setting environmental policy. At the core of these achievements is the commitment of multiple generations of scientists who work together as a community to tackle fundamental, interdisciplinary questions at a range of spatial and temporal scales. The work on the current LTER grant maintains this tradition, and the site-visit panel was deeply impressed with both the quality of the work and strength and vibrance of the scientific community. The close working relationship between HBR and the United States Forest Service (USFS) has been critical to the long-term success of the LTER, and this collaboration continues to be valued by both parties. It is clear that the viability of both the HBR LTER and the Hubbard Brook Experimental Forest depend on the maintenance of this relationship.

The site-based research at HBR in this funding cycle is centered around the effects of disturbance on Northern Forest ecosystems with a focus on three broad drivers of ecosystem change: atmospheric chemistry, climate, and biota. HBR research also is guided by five cross-cutting, synthetic questions. The project is on-track to meet the goals of the proposal, with the recognition that some of the component parts face significant technical challenges. The site-visit panel was particularly impressed with the engagement of the LTER scientists across the disciplinary breadth of the project.

Information Management at HBR is top-notch, and the site-visit panel commends Mary Martin for her outstanding work. Information management is integrated into the full-cycle of research from the approval of a research project to the archiving of samples for long-term storage. HBR curates some of the most valuable ecological data globally. It is clear that they take the maintenance and continuation of these data streams seriously, and their personal commitment to this charge is impressive.

Education and Outreach work is fully integrated with the Hubbard Brook Research Foundation (HBRF). The education and outreach work is creative and reaches a broad audience. HBR and HBRF have successfully leveraged their collaboration to increase their impact. As with Information Management, the site visit panel was impressed with how well the Education and Outreach work is integrated with the scientific research at HBR.

HBR scientists have been deeply engaged in the LTER Network as a whole. In particular, the site-visit panel commends HBR Co-lead Peter Groffman for his leadership of the LTER Network. His leadership of the LTER Science Council and close work with the LTER Network Communications Office has promoted valuable scientific synthesis. At the site level, the HBR leadership has fostered an open, creative, and welcoming research community, which underpins the productive and creative science that is the hallmark of HBR. Of particular note, the site-visit panel was impressed with the open management structure that includes members from within and outside the LTER.

### **Site-visit Panel Report**

#### **1) Site-based Research**

The site-visit panel finds research at Hubbard Brook to be exciting, integrative, and highly synthetic. The project is on track for meeting the core goals of the proposal. Research at HBR is centered around a series of core, legacy datasets and the maintenance of these datasets is a central priority. The passion for maintaining the continuity of the data streams was exemplified by the donations and volunteer efforts that ensured their continuity during the last government shutdown. The HBR has made effective use of models to generate and test mechanistic hypotheses, and the site-review panel was impressed with how this was integrated into the proposal and research. Of particular note, the site-visit panel was impressed with the Bayesian modeling approaches used by Jaclyn Hatala Matthes, and also by the enthusiasm of senior LTER scientists in embracing these new methods.

There are many strengths in the HBR project. The quarterly meetings, annual meetings, and newsletters create a culture of collaboration and high productivity. During the course of this grant, and over the long term, HBR scientists have continued to produce many high-impact publications. Some of these have transformed the field of ecology and directly influenced national and global environmental policy.

The site-visit panel came away confident that scientists at all career stages enjoy working with and learning from each other, and can explain one another's research, fostering a culture of trust, collaboration, and an ecosystem approach to understanding the northern hardwood forest. The focus of HBR on large, integrated science questions with multiple, overlapping collaborators has created a tightly knit research community where everyone contributes. The HBR fosters a holistic understanding of natural history. The site-visit panel was impressed with the blurring of boundaries, e.g., the integration between aquatic and terrestrial biologists as well as researchers working at different trophic levels.

The research being conducted at HBR spans all of the five core LTER areas. The systems-level approach at HBR has led to an integrative understanding of how primary productivity, population dynamics and food webs, ecosystem processes and organic and inorganic biogeochemistry intersect over time, in space, and in response to disturbances. Few ecosystem research programs have as much breadth and depth. One example is the study of how impending ash decline might affect spring ephemerals, soil invertebrates, and mycorrhizae that feedback to soil and forest biogeochemistry.

The site-visit panel found the emphasis of current research to be balanced across the primary disturbances identified in the HBR conceptual model, and to give equal weight to the interactive responses to changes in atmospheric chemistry, climate and biota. The ice storm experiment is ambitious, and the hydrogeological research is novel. The hydrogeological work in the critical zone has the potential to transform understanding of biogeochemistry, at least for HBR.

The stream ecology component is at a good starting point. There is much more to be done to understand seasonal dynamics in primary productivity and ecosystem processes during shoulder seasons of spring and fall. Bernhardt and Rosi are building the necessary foundation for sustained research into drivers of stream ecosystem dynamics. The site-visit panel expects that once the methods and baseline measurements are developed, there will be stronger links between stream ecology and different watershed manipulations. The site-visit panel was unanimous in recognizing the value of this stream ecology research, as well as the methodological challenges in carrying out this work in the HBR ecosystem. To be successful, the stream ecology program will need a sustained commitment from HBR.

The proposal and presentations indicate that forest productivity is P limited or co-limited, suggesting that including P in the conceptual and predictive models of nutrient dynamics is necessary. The site-visit panel encourages better integration of the role of P in forest and stream dynamics in all experiments taking place, because the major emphasis at HBR is still on N dynamics. Further consideration of P biogeochemistry represents an exciting opportunity for future research with broad relevance from forest management to fundamental and groundbreaking research on coupled biogeochemical cycling of C, N, P, Ca and other cations.

Furthermore, recent HBR results suggest that reductions in snowpack and soil freeze-thaw increase root damage and reduce N uptake by plants. However, the site-visit panel noted that root productivity and mortality are not being measured. Adding such measurements would strengthen this aspect of the HBR research program.

Long-term legacy datasets are central to the work at HBR. The amount of data being collected, analyzed, and archived is impressive, appropriate for a program that serves as a model for so many other long-term ecological research programs worldwide. The HBR practices for sample collection, cataloging, and archiving, and data publishing are state of the art.

HBR is making significant progress on addressing the five core synthetic questions from the proposal, and the site-visit panel found the questions to be compelling. The use of these cross-cutting questions has been effective at integrating across the disciplinary boundaries of the conceptual framework, and facilitated the information exchange between the basic-science and management-oriented aspects of the project.

The project is maintaining the long-term experiments and making timely progress on fulfilling the stated goals of the most recent renewal proposal. The site-visit panel also noted that this research clearly fits within the proposal's conceptual framework, and there was no evidence that the project has started to shift in direction from proposal goals. Furthermore, the panel was pleased to see that the research plan is clearly informed by insights from modeling and analysis of long term datasets.

## **2) Information Management**

Effective information management presents a unique set of challenges that must be carefully balanced in order to address the ingestion, dissemination and long-term curatorial needs of any science program. NSF's LTER sites have additional responsibilities to implement best practices and procedures that handle data creation, ensure provenance, facilitate discovery, and ease access to the research outputs at each site. Finally, each version of every data set must be archived for reuse along with accompanying contextual metadata.

The LTER program gives each of its Information Managers a head start by supporting monthly online meetings in addition to annual in-person exchanges. Use of the EDI Repository is expected as well as adoption of the EML for their metadata. The HBR Information Management Team has strategically exploited these advantages and goes on to implement the right mix of cutting-edge and proven technologies and data management best practices resulting in a comprehensive system that meets the needs of both its internal and external users. From data collection through long-term archival, investigators and students alike expressed their support of the HBR Information Manager and stressed the importance of HBR's data system as an essential component of their research workflow.

The IM personnel have normalized use of HBR-IM procedures, such that it has become the most efficient way to submit and manage HBR's data throughout its lifecycle. The additional step of switching to the EDI as HBR's primary data catalogue provides improvements in system response time, and provides persistent identifiers, discovery metadata aligned with forward-looking standards and increases overall system resilience and data security. Weaving the IM system into the very fabric of the HBR research life ensures that every byte of research data is captured and curated through final archive.

The IM team does not miss many opportunities to provide "the little things" that aid in daily data management. Examples of such details include:

- Linking to and encouraging the use of EDI's code snippets on each dataset landing page (in MATLAB, Python, R), potentially reducing the "time to science" for any data user;
- Promoting dialogue with investigators and ensuring that each submitted dataset is in compliance with accepted formats, mnemonics, and QC standards;
- Participating in HBR's outreach efforts, which is an innovative way of aligning the content of the data holdings with the needs of the general public as well as its research community.

The site-visit panel suggests that continual improvements in the coming years should include a possible transition to cloud services (where appropriate), more in-depth data use statistics and an eventual migration to EML 2.2 to further align the metadata with existing controlled vocabularies. Monthly in-person or online "office hours", offered by the IM during the review, will likely reinforce the most important aspects of responsible research data curation. Additional integration of the digital system with an already comprehensive physical sample archive (already underway) will result in impressive full-stack data management environment.

The Hubbard Brook LTER's Information Management team is a shining example of optimal data curation by an NSF-funded program.

### **3) Education, Outreach and Training**

The site has a vigorous education and outreach program largely coordinated with the HBRF, a fully integrated partner. There is an impressively well developed approach to science communication and outreach, based on building relationships through direct engagement whenever possible. This includes strong ties to regional schools and community stakeholder organizations, and a Research Experience for Teachers (RET) program that leverages HBR data. Connections with stakeholders are also fostered through the Forest Science Dialogues Program, the Science Links Program, and the Science Policy Exchange. These connections are well aligned

with the site-based LTER research and ongoing synthesis activities. Scientists at HBR have high levels of participation in these programs. Education and outreach activities proposed in the 2016 renewal are already extensively developed.

#### *Environmental Literacy for K-12*

Efforts targeted toward K-12 students are robust and ongoing. Materials are developed with the concept that authentic data provide a place-based experience that maximizes learning. Recent accomplishments include a new unified website to distribute lesson plans and activities while tracking download statistics. Instructional materials appropriately synchronized with next generation science standards reach students throughout the region. Guided field trips engage 300 students per year and the team is seeking funds to support bus transportation for students from lower income districts to broaden participation. The children's book "Seeking the Wolf Tree" was distributed to every public elementary school and community library in NH. The author, Natalie Cleavitt, provided remarkable leadership. Structures are in place to track and quantify engagement as a measure of impact. Evaluation and assessment is accomplished through direct feedback from teachers, but plans are also in place to develop pre-and post field-trip quizzes. The team is clearly using state-of-the-art approaches to ensure their work is effective.

#### *Public engagement with science (PES)*

The HBRF has secured multiple NSF Advancing Informal STEM Learning (AISL) awards to develop and study their PES activities, in collaboration with the Harvard Forest LTER. The activities are structured to promote mutual learning between LTER scientists and diverse stakeholder groups. Highlights of their extraordinarily active program include roundtables, an Advisory Council that meets regularly, work with Corporate Sustainability Officers, and co-production work such as the Science Links and Science Policy Exchange. All indications are that the endeavor is grounded in evidence-based practices with a high degree of professional implementation leading to high impact outcomes.

#### *Art-Science Integration*

The site continues to develop and disseminate their signature Waterviz product, which stands out for its innovation. Created in collaboration with a Dartmouth neuroscientist and multiple artists, it has already garnered significant attention and Lindsey Rustad is in high demand to present and share the product through art shows, LTER science meetings, etc. The group has developed a website, created an app and a Music Now radio station. They continue to support their artist in residence program as proposed in the 2016 renewal.

#### *Research Experience for Undergraduates*

While the REU program is no longer supported by an independent NSF grant, HBR maintains a healthy cohort size of 10 students per summer using LTER funds (2 students) and supplements to individual PI projects. Student recruitment prioritizes those with an opportunity to extend their research experience at their home institution. The program targets members of underrepresented groups, and during the last four summers, 6 of 8 students were women.

The REUs are fully integrated into the research community and have ample opportunity to interact with graduate students, postdocs, scientists, and PIs. Some of this interaction is deliberately managed through “Science Nights” with PIs, presentations at the Cooperator’s Meeting, and an end of summer symposium. REUs are most directly mentored by graduate students and postdocs in addition to their PI mentors. Notably, three REUs co-authored recent manuscripts and 86% of past REUs are pursuing advanced degrees or working in a related field. An HBRF staff member has been attending the One Sky Institute that provides professional development for those working in public engagement with science, specifically to broaden participation. She plans to implement fresh practices to diversify future REU cohorts. The site review panel encourages continued efforts to diversity the REU cohorts.

#### *Research climate and community*

The climate at HBR is enviably collaborative, supportive, and intellectually stimulating. Graduate students feel empowered and respected. The site is clearly a highly desirable place to work and study, as evidenced by REUs and technicians who target their PhD program applications specifically in order to return to HBR. The site-visit panel endorses the recent development of a codified policy on conduct with clear instructions on how to deal with inappropriate behavior, including an explicit reporting structure.

#### **4) Network-Level Participation and Synthesis**

HBR PIs are frequent participants in LTER network-wide activities, especially HBR-LTER co-PI Peter Groffman, who has chaired the LTER Science Council and Executive Board for the past 4 years, chairs the LTER 40-year Review Self-Study Committee, and is PI of the Working Group on LTER-NEON Synergies. Peter Groffman’s time commitment to LTER leadership has been substantial, and this investment in the success of the LTER network as a whole is commendable.

HBR-LTER Information Manager Mary Martin is a member of the LTER Information Manager’s Committee and Co-chaired the LTER Website Guidelines Revision Committee. Since 2017, HBR scientists have participated in five separate LTER synthesis working groups and a cross-site LTER project on “Embedding Public Engagement With Science at LTER Sites” with the Harvard Forest

site. HBR also sent >20 scientists and students to the 2018 All Scientists Meeting, where they co-organized 12 different workshops.

The HBR quarterly COS meetings, which include many more people than just the LTER PIs, serve as a venue for participation and collaboration from non-LTER participants. LTER-PIs genuinely value their interactions with non-LTER scientists and provide a venue for involving new researchers in the core LTER projects, as well as providing pathways for deeper involvement in the LTER.

## **5) Site Management**

The site-visit panel was impressed with the open and collaborative nature of the management of HBR. The leadership fosters a deep sense of engagement at all levels, including graduate students, LTER scientists, and institutional partners. The HBR team should be commended for the development and maintenance of this scientific community. Importantly, it was evident that graduate students are respected, empowered, and valued as colleagues.

The LTER is currently co-led by Gary Lovett (lead PI) and Peter Groffman, who share primary responsibility for grant management and interaction with NSF and the LTER Network. The LTER research team is composed of 36 Co-PIs from 21 institutions. The core of the governance structure is the Committee of Scientists (COS), the 67 PI level scientists actively working at the site. This group includes both LTER and non-LTER affiliated scientists. The Scientific Coordinating Committee (SCC) serves in an executive capacity for the COS, and is composed of the Lead PI from the LTER, 4 elected members of the COS, the Lead Scientist for the Forest Service Hubbard Brook project, the Executive Director of the Hubbard Brook Research Foundation, and a non-voting external advisor. The site-visit panel was impressed with the openness of this management structure, which allows meaningful input from both LTER and non-LTER scientists. HBR graduate students share information, look out for each other, and proactively engage with the HBR leadership.

The LTER scientists, postdocs, and graduate students meet on a quarterly basis (usually about 30-40 participants) with a primary focus on scientific topics. In addition, there is a larger annual meeting. The site-visit panel was impressed with the commitment to, and participation in, the regular meetings, and recognized their importance for scientific synthesis and building the research community strength. In addition, these regular meetings have been used to revisit core synthesis questions from the proposal and identify new questions. The site-visit panel is impressed with the engagement of the scientists across disciplinary boundaries, which is likely an outcome of these regular, science-focused meetings.



The LTER has a close and collaborative relationship with both the USFS and the HBRF, and these three partners have made effective use of their respective strengths to their mutual benefit. Leaders from each of these groups emphasized that this partnership is invaluable and critical to one another's success.

Overall, the transparent and inclusive management of HBR facilitates the goals and mission of the project. In particular, this structure allows for substantive input from non-LTER scientists into the decision making process. The core governing body, the COS, for example, has a large representation of non-LTER scientists. The graduate students and early-career scientists felt that the senior scientists in the LTER listened to and valued their input. Similarly, the close and positive engagement with the USFS management and research personnel and the HBRF personnel is indicative of the value the LTER scientists place on external perspectives.

The LTER science team is composed of 36 scientists from 21 institutions. Of these, 44% are women, and 25% are early career, having received their PhDs less than 10 years before the proposal was submitted. There has been an active effort to recruit new scientists to the science team; 36% of the team are new to the LTER. While there are efforts to recruit REUs from underrepresented areas of the region, this has had limited success. The site-visit panel encourages the HBR team to place a higher priority on broadening engagement at all levels, though we recognize that the rural setting poses additional challenges.

There is a clear plan for leadership transition, which involves a co-leadership approach. Peter Groffman will be PI on the next renewal proposal (2023-2029) along with another co-leader to be chosen from the current co-PIs. We expect that the co-leadership model will lead to a smooth transition in leadership. It will be important to change the lead PI on the current proposal with NSF well in advance of the next renewal. The science leadership recognizes the importance of bringing in a woman as a Principal Investigator as leadership turns over. The site-visit panel concurs with the plans to broaden representation in leadership.

The site-visit panel discussed security with both the graduate students and the SCC, and were happy to see a proactive and respectful approach to safety and security, especially for the resident graduate and undergraduate students. The site-visit panel encourages HBR to keep the extensive information and training updated and current.

LTER funding is leveraged by substantial additional sources. The HBR team has been successful in bringing in additional, related NSF grants. In addition, a number of collaborating agencies and institutions provide significant support for the LTER, which greatly expands the scope of the

work that the team can achieve. Most notably, the USFS provides about \$1M annually in the form of staff salaries, facilities, and equipment. The USFS also operates 10 stream gauging stations and 7 meteorological stations on the site. Continued cooperation and support from the USFS is critical to the LTER. The HBRF also provides significant support totalling about \$500K per year for facilities and public outreach and education. Lodging and land use fees generate an additional \$145K per year.

The site-visit panel did not find any reason to be concerned about fiscal accountability.

This report was read and approved by all members of the Site-visit Panel.

Eric Seabloom (Chair)

Jill Baron

Stephen Diggs

Katherine McMahon

Michael Weintraub