All Scientists Meeting Synthetic Paleoecology Workshop Report

James Rusak and David Foster convened the workshop on "Synthetic retrospective and paleoecology: Network-level investigations of broad-scale and long-term phenomena" at the 2006 LTER ASM. We had two primary goals in mind, the first was to generate recommendations and research initiatives that would inform and improve the network planning grant and the second was to identify synthetic research initiatives worth pursuing. To these ends we invited Dr. Peter Leavitt (Canada Research Chair in Environmental Change and Society, University of Regina, SK) as a plenary speaker to give participants examples of synthetic paleoecological research to inspire further ideas and discussion. Peter's talk highlighted the insights that arise when comparing paleoecological research over large spatial scales, both in terms of our ability to characterize long-term ecosystem variability and predict, in probabilistic terms, future ecosystem behavior.

The discussion that followed focused on the need to infuse a paleoecological perspective into the network planning effort. "Long-term" should not only mean "from the time I start monitoring until I die", but include the rich perspective that can be had from the historical and paleoecological record. We highlight the major points of discussion here and follow with vignettes from individual sites that demonstrate the "added value" obtained from a paleoecological perspective when applied in conjunction with monitoring or experimental approaches.

1. *Estimation of background temporal variability*: Only retrospective and paleoecological techniques can generate that temporal data necessary to properly characterize the temporal variability of ecosystems. Variable can be relatively easily reconstructed from a variety of sources to examine site-specific changes in parameters of interest (climate, productivity, plant and animal densities, biogeochemical cycles, etc.). Only with these data as a backdrop can we reliably begin to detect or assess a wide variety of ecosystem behaviors (e.g., thresholds, regime shifts, tipping points etc.).
2. *Spatial replication to examine site suitability*: As we began to expand our reach beyond individual LTER sites and potentially add new partners or non-LTER sites to the planning grant to increase our spatial coverage, it is imperative to include scientifically defensible criteria to aid in site selection. Paleoecological reconstructions of variables such as climate, productivity, and water availability can provide the context for such decisions (and in many cases the data already exist).
3. *Ability to extrapolate results in a regional context*: Our ability to generalize our results depends, in part, on whether the behavior of key ecosystem attributes is fundamentally different among or within regions. Paleoecological and historical data can quickly answer questions concerning the spatial heterogeneity of key attributes over time.
4. *Variance matching to evaluate large-scale experimental site choice*: Given that a key component of the Network Planning Grant will be experimental in nature, choosing similar experimental sites will be critical to the success of this effort. If sites differ dramatically in the past variability of key dependent or independent variables involved in the manipulation, detection of treatment effects becomes exceedingly difficult. Paleoecological data can easily estimate relative variance among sites over a variety of time scales.

5. *Response to disturbance*: Monitoring data are very useful in terms of examining many aspects of ecosystem response following disturbance events, however they are typically costly, difficult to acquire, and may not come quickly enough for management and policy decisions. Often the paleoecological record has already captured similar events in the past and can provide a valuable and timely tool to investigate questions of ecosystem response (resistance, resilience, alternative states, regime shifts etc.). Regime shifts, in particular have multiple causes, so studies must track multiple variables simultaneously for long periods of time.

Paleoecological data can and should be used to bolster long-term observations, facilitate comparisons of ecosystem responses across gradients of key drivers, help parameterize a wide variety of models, appropriately scale experiments in time and space and, ultimately, to test ecological theory and inform ecosystem management. Paleoecological and retrospective data need to become part of every site's vocabulary to help articulate a better understanding of the diversity of ecosystems across the network and lay the foundation for a truly synthetic approach to understanding socio-ecological systems.

Vignettes

We asked participants for examples of how paleoecological or retrospective data had changed or enriched their understanding of ecosystem function relative to what was learned from "neo"-ecological techniques. Here is a selection of the responses.

Experimental site selection in the Florida Everglades

Decreased freshwater flow through the Everglades to the coast, combined with sea level rise, has caused a landward migration of coastal vegetation zones. The $8 billion federal Everglades restoration program aims to slow this migration and restore freshwater habitats by removing levees to restore sheet flow through the marsh to the coast, and our LTER is capitalizing on this large-scale "experiment" to understand how water flow alters patterns of ecosystem productivity. However, our paleoecological work has shown that the rates of saltwater encroachment far exceed the projected capacity of post-restoration freshwater delivery to push back ecotone boundaries in a coastward direction. The paleoecological work was done in land-to-coast transects and relied on mollusk habitat affiliations for the reconstruction of ecotone boundary locations. Rates of coastward movement averaged 3.1 m yr-1. Without knowledge of this rate, we may have designed experiments and selected monitoring sites in our ecotone to detect a coastward progression, rather than further landward encroachment. (Gaiser – FCE)

Legacy effects of historical land use

Although similar in geology and climate, the plant communities of the Black Forest are strikingly different among sites. Attempts to explain species distributions and community composition given only information from the last century inevitably lead to the wrong conclusions. Long-term human land use practices are the main factors which differ among sites, but the practices which shaped the landscape are not ongoing today. Historically, the forest was composed of several kingdoms with differing inheritance practices. In one inheritance large tracts of land were kept intact over time and worked as large estates. In a bordering kingdom, land was repeatedly split into smaller pieces among heirs. As a result, the intensity and distribution of cropping, grazing and forestry differed. What we see today is a legacy of centuries of interaction between culture and ecology. (Scheintaub – SGS)

Resurrection ecology: genetic underpinnings of variation in ecosystem services

Coastal marshes provide critical ecosystem services like buffering rising sea-levels and providing wildlife habitat. Continuation of these services will depend on ecosystem stability under altered precipitation and salinity regimes resulting from a changing climate. An important yet vastly understudied aspect of ecosystem research is the potential for evolutionary change to alter long-term plant population responses to climate conditions. To better understand this phenomenon, we have resurrected seeds of a Chesapeake Bay brackish marsh sedge from a time-stratified seed bank spanning 110 years (1885 to 1995) to quantify long-term variation in molecular genetic and genetically-based phenotypic attributes of this species. Both molecular genetic analyses and growth experiments demonstrated significant differences between old and modern populations, including growth under contrasting salinity treatments. To provide an environmental context for our results, we explored relationships between variation in salinity tolerance among the resurrected populations and the paleo-salinity and historic rainfall records of the Chesapeake Bay. We found that salinity tolerance correlated most strongly with the 20-year trend in rainfall and that periods of decreasing rainfall were associated with more salinity tolerant populations. Although preliminary, the genetic and evolutionary framework presented here may be useful for future studies aimed at understanding the influence of genetic variation on ecosystem responses to climate change in coastal marshes and possibly other terrestrial and aquatic ecosystems. (Saunders – FCE)

The archaeological context of ecosystem structure

Archaeologist are currently helping to determine the extent of past land-use patterns along coastal hammocks. The human use of the coastal hammocks goes far back into antiquity. Preliminary data suggest that these areas served as intermittent habitation areas and special use sites for over 4000 years. This use by humans resulted in the deposition of considerable human waste material in the form of artifacts, consumed plant and faunal remains-- particularly shellfish. These various human-related activities have impacted the soil chemistry as well as the elevation of these topographic features. Currently, the GCE-LTER is involved in interdisciplinary research on these hammocks to investigate how the past uses of the landscape by humans has affected the composition of the modern plant communities found on these hammocks. (Thompson – GCE)

Spatial patterning of ecological attributes

The McMurdo Dry Valleys contain perennially ice-covered lakes, ephemeral streams, soils and glaciers and, as such, is one of the driest and coldest ecosystems on earth. This ecosystem harbors a distinctive biota capable of carrying out ecosystem processes under extreme environmental conditions. Paleoecological data has shown that physical constraints (not biotic) are responsible for the structure and function of this polar desert and that “legacies” of past climatic events are a major factor regulating contemporary ecosystem processes. For example, the presence of Lake Washburn, which inundated Taylor Valley between 24-6K years ago created old pools of organic carbon and nutrients in the soils and lakes that explain many of the biotic distributions and ecosystem processes we now observe. (Adams – MCM)

Testing ecological theory: diversity and ecosystem function

Insight into the causes and consequences of changes in aquatic biodiversity requires an improved understanding of the nature of the relationships between species richness and ecosystem function over a much longer temporal perspective than we currently possess. We used high-resolution paleoecological records from two prairie lakes to show that diatom species richness (as fossil frustules) was negatively correlated with diatom production during the past 2,000 yr. By comparing analyses from intervals of fresh and saline waters, we demonstrate that these significant richness–production relationships arose during freshwater periods and could be eliminated by disturbances such as droughts. Concordance of species change within freshwater communities and the change in richness– production relationships through time revealed that shifts in diatom community composition could have a large influence in determining the negative relationship between richness and production. Finally, significant correlations between past diatom species richness and ratios of stable isotopes suggested that C and N biogeochemical cycles are also linked to changes in algal biodiversity. Taken together, these analyses suggest that the ongoing disruption of climate and biogeochemical systems by humans may obscure the relationship between aquatic biodiversity and ecosystem function in the future. (Rusak – NTL)

Workshop attendees

Name	**Email**	**Interest**
Matthew Vadeboncoeur	envstudies@brown.edu	Hubbard Brook
Jess Zimmerman	jkzimmerman@uprrp.edu	carribean paleoclimate
Heidi Rantala	ranta001@bama.ua.edu	paleolimnology, trophic, landscape
Kate Morekeski	morkeski@vt.edu	large-scale patterns and drivers
Madeline Scheintaub	Madeline.Scheintaub@ColoState.EDU	Shortgrass Steppe
Byron Adams	bjadams@byu.edu	phylogeography
Colin Saunders	saunders@fiu.edu	historic and paleoveg modeling
Selene Baez	selene@sevilleta.unm.edu	cross-site research
Andrew Rassweiler	rassweil@lifesci.ucsb.edu	community-level phase shifts
Dick Lathrop	rlathrop@wisc.edu	lake eutrophication and restoration
Victor Thompson	vthompson@uwf.edu	human landscape archaeology
Evelyn E Gaiser	gaisere@fiu.edu	paleolimnology
Johan Pauw	johan@saeon.ac.za	network planning
Ted Gragson	tgragson@uga.edu	historical ecology
Kathy Elliot	kelliot@fs.fed.us	forestry
Peter Leavitt	Peter.Leavitt@uregina.ca	paleolimnology and systems ecology
David Foster	drfoster@fas.harvard.edu	
Jim Rusak	jarusak@wisc.edu	