LTER

The Network News

Y2K All Scientists Meeting a Success

by Robert Waide, Executive Director
LTER Netowrk Office

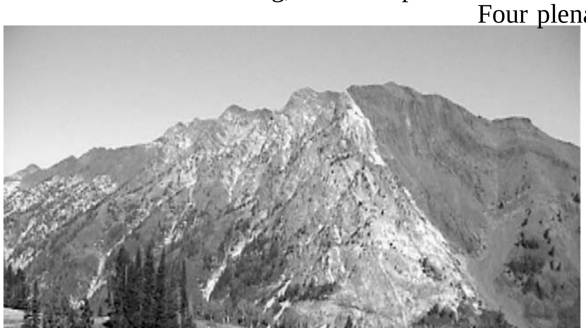
Nearly 750 LTER and associated scientists and researchers from 33 countries gathered to exchange ideas, synthesize ongoing projects and foster new research at the 4th LTER All Scientists Meeting at the Snowbird Ski and Summer Resort, located in the Wasatch National Forest of Utah, August 3-5 2000.

The “ASM 2000,” themed Long Term Ecological Research: Unifying Principles and Global Applications, filled three days with meetings, workshops, and discussions.

“The Snowbird meeting, like the past two All Scientists Meetings in Colorado, has proved its value in fueling new cross-site initiatives and establishing networking between scientists at the sites,” says Bruce Hayden, principal investigator at the Virginia Coast Reserve LTER. “The networking between international colleagues and U.S. LTER scientists at Snowbird was just excellent.”

Scott Collins (NSF), Bill Heal, and Jim Gosz laid the foundation for the meeting with discussions of the history and future of the LTER Network from the perspectives of the National Science Foundation, the International LTER Network, and the U.S. LTER Network. Four plenary addresses (by Diana Wall, Indy Burke, Chuck Redman, and Bruce Hayden) focused on major themes of the meeting. Dr. Rosina Bierbaum of the Office of Science and Technology Policy delivered the keynote address titled “Integrated and Interdisciplinary Science Needs: A National Perspective”. The program also included a reception for international participants, mixers, poster sessions, a presentation of the new ILTER video, and the first ever LTER Town Meeting. Sixty-six workshops and various ad hoc meetings rounded out the program.

“The ASM was an excellent introduction to the LTER Network and the LTER approach to ecological research,” says Dan Childers, principal investigator at the Florida Coastal Everglades (FCE) LTER. “We made numerous connections, and began what will surely prove to be many productive collaborations. Everyone returned from the ASM excited about the opportunities presented by our newly funded LTER program and eager to make an impression on what is a very impressive network of scientists. The ASM experience was particularly meaningful for the students.” Childers says the meeting was perfectly timed for a new site. “It is difficult to imagine where we could have learned so much, met so many people,



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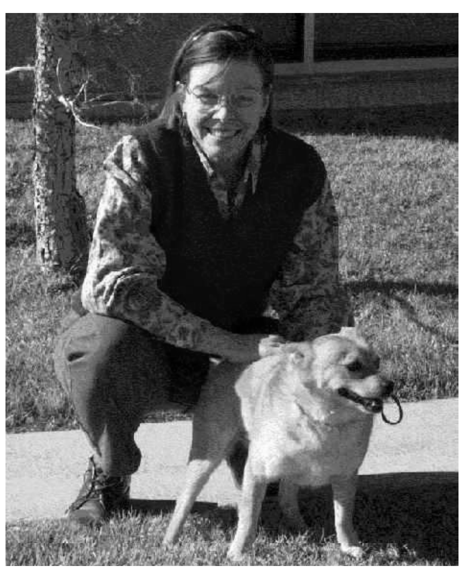
Newsletter

Changing of the Guard at the Network Office

Dr. William Michener joined the LTER Network Office (NET) in September. Bill initially will be involved with expanding collaborative ties with the Organization of Biological Field Stations (OBFS), primarily focusing on computer, communication, and information technologies. Some specific activities include enhancing OBFS network capabilities, creating or enhancing databases for sites, personnel, and research data, as well as related training and research activities. Bill comes to the Network Office after having served this past year as Program Director for the Ecology Program at the National Science Foundation.

Meanwhile, Christine French returned to her position at the National Science Foundation, International Programs division. During her three-year term at NET, CHRIS was instrumental in doubling the size of the International LTER Network, culminating in an outstanding international attendance at the Y2K All Scientists Meeting (see artilce, page 1). Over the past three-plus years, Chris catalyzed numerous exchanges between U.S. and international scientists and students, which stimulated the growth of the ILTER Network. Chris can be reached at NSF via e-mail:cfrench@nsf.gov NET recently gained significant additional computing and database expertise. David Blankman and Owen Eddins will be instrumental in NET's contribution to the KNB (see article, page 10) and Troy Maddox is busy structuring the LTER Site Database, among other tasks.



Chis and Rusty get ready for the long trip home to Washington D.C.

Luquillo LTER: A 'Field of Dreams' for Rain Chemistry Research

DougSchaefer Institute for Tropical Ecosystem Studies, University of Puerto Rico, and William McDowell Department of Natural Resources, University of New Hampshire.

Until satellite images made it obvious, we could not be completely certain that hazy skies in Puerto Rico meant that dust was blowing in from Africa. But now this source of chemicals in rain, and several others as well, have been identified by LTER research. Potential linkages between rain chemistry and climate have also been uncovered

History

Scientists at the Luquillo LTER in Puerto Rico have measured rain chemistry almost every week since 1985 as part of the National Atmospheric Deposition Program (NADP—see the WWW site: http://nadp.sws.uiuc.edu). Hurricane Hugo blew down the sampling tower in 1989, but it was rebuilt and several more recent hurricanes have been successfully sampled. The initial 48 months of data were presented by McDowell *et al*. (1990), and Schaefer and McDowell are now preparing a manuscript on the entire data set for the journal *Atmospheric Environment*. This article highlights the main points of that study.

By the Sea

Rain chemistry at LUQ is dominated by marine inputs, with sodium and chloride inputs combined averaging almost 150 kilograms per hectare annually. By comparison, even the coastal U.S. NADP sites receive less than 1/10 that amount, dissolved in 1/3 as much rainwater. Mixing one part seawater with 6000 parts pure water would give a fair approximation of LUQ rain. The marine aerosol is injected into the atmosphere by waves breaking at shore, and by whitecaps when winds over open water exceed 15 knots.

Out of Africa

Magnesium and potassium inputs also follow their seawater ratios, but calcium substantially exceeds the amount in sea water. The excess calcium was attributed to trans-Atlantic transport of Sahara dust by McDowell et al. (1990), but direct evidence for the process was lacking. More recently, global atmospheric optical thickness (or AOT, from the scattering of blue light), has been estimated by the National Environmental Satellite, Data and Information Service (NESDIS) on weekly and monthly scales. The results are translated into images, which may be viewed on Web at http://psbsgi1.nesdis.noaa.gov:8080/PSB/EPS/Aerosol/Aerosol.html These images (Figure 1) clearly show transport and arrival of Sahara dust clouds, and linear regression between AOT and weekly calcium deposition in excess of the sea salt ratio has an R^2 of 0.52. The relationship is even stronger when we account for weeks in which there was not enough rain fall to remove all the dust from the air. From these relationships we estimate that 2.7 kilograms per hectare (or about 60%) of the calcium in LUQ rain comes from the Sahara desert. In the continental U.S., only Midwestern farming areas receive this much calcium in rain, which comes from local sources in those areas.

Sahara dust reaches the Caribbean from June through September, but the emission season begins earlier. One of the larger events occurred in February 2000, and was pictured in the September 2000 issue of *National Geographic* magazine. Dust from the early-season events is washed out of the atmosphere by rain falling over the Atlantic Ocean. During the summer, rain over the Atlantic becomes concentrated into a series of tropical waves, and dust aloft in the spaces between the waves is transported further to the west. In any case, most of the Sahara dust ends up in the equatorial Atlantic. While the NADP does not analyze rainwater for iron, Sahara dust is rich in this element (Prospero et al., 1981). Whether this iron stimulates algal growth (and the subsequent uptake of atmospheric carbon dioxide) in the otherwise nutrient-poor surface waters of this part of the Atlantic Ocean has yet to be explored.

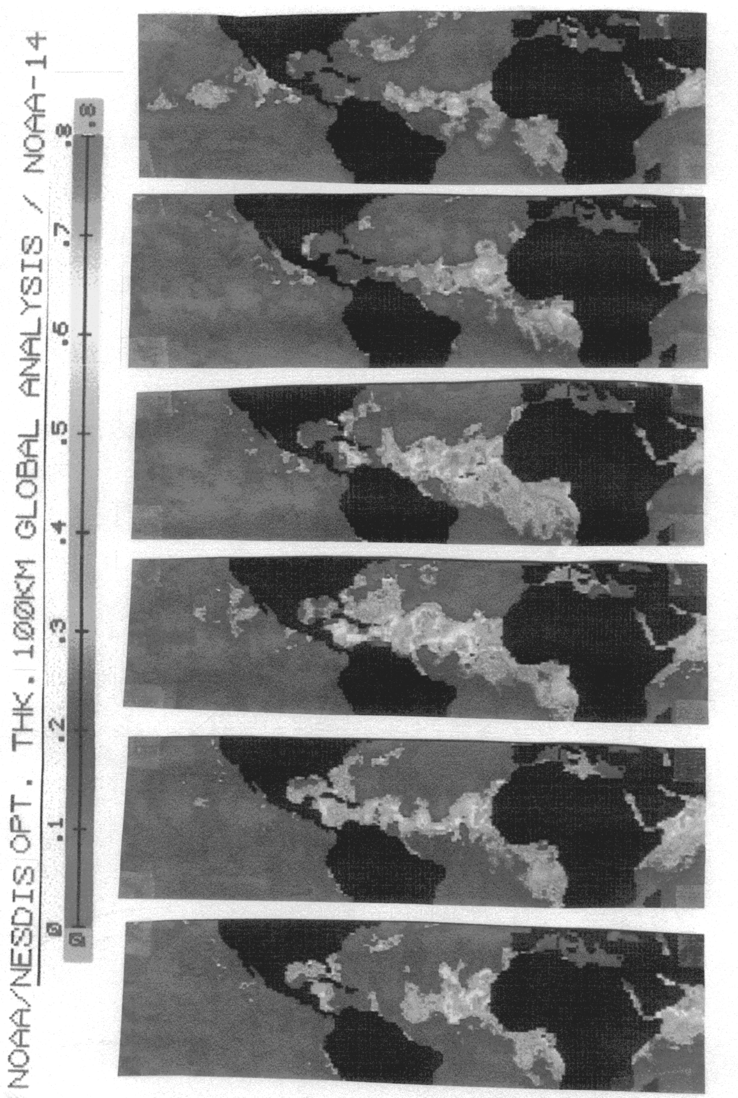
Anthropogenic Inputs

The pH of LUQ rain averages 5.3, much less acidic than the pH 4.5 or less falling on the northeastern U.S. Acidity, nitrogen and non-sea salt sulfate deposition at LUQ peak during April and May, when low pressure systems move off of the southeastern U.S. and enter the Caribbean. During other months much less anthropogenic pollution from North America reaches Puerto Rico.

Too Much Sulfate

The sulfate story is somewhat more complicated. NADP stations in the southeastern U.S. receive sulfur and nitrogen in rain at a mass ratio of 2.1 to 1, while the ratio at LUQ (after excluding marine sulfur) is 2.5 to 1. There seems to be an additional source of sulfate in LUQ rain beyond the smokestacks and the sea. Most interestingly, this additional sulfur peaks during July and August when the Atlantic surface waters are warm. Dimethyl sulfide (DMS) emissions from planktonic algae, oxidized to sulfate in the atmosphere, may be the answer but this has not been proven. How can we know for sure? The ratio of the stable isotopes of sulfur (mass 34 and 32) is higher than seawater in fossil fuels, and lower in algal DMS emissions (Brimblecombe and Lein, 1989). Thus we hypothesize that there is a seasonal pattern in sulfur isotope ratios in LUQ rain: high in April and May, low in July and August and at intermediate (sea water) levels in other months.

Screen shot from the NOAA Website. Image is turned sideways so the dust cloud coming across the Atlantic ocean can be clearly seen.



The Luquillo Experimental Forest has been an LTER site since 1988, and has archived these weekly rainwater samples throughout that time. We did not begin with the intention of analyzing sulfur isotopes in rain by mass spectrometry, but with the archive this hypothesis may now be tested. Its significance may extend well beyond a few kilograms of sufate in rain at LUQ – sulfate in the atmosphere forms cloud condensation nuclei, and more clouds mean less heating at the Earth's surface. If algal DMS emissions increase with sea surface temperatures, this could serve as a feedback loop to limit climate extremes.

As an LTER site, scientists at LUQ collect and store the samples, uncover the patterns, and formulate the hypotheses— illustrating one of the great strengths of long-term ecological research. Call it the research 'Field of Dreams' if you like. Find the patterns, and the mechanisms will come.

When the Hurricanes Blow

Finally, what about hurricanes? Even a "near-miss" can cause 0.5 meter of rainfall at LUQ, which averages 3.2 meters per year. Hurricane rain collected at LUQ is 50 percent more concentrated in marine ions than average rain, and very dilute in all the rest. Obviously hurricane winds are well above the 15-knot "speed limit" for marine aerosols. So, if your Caribbean island vacation is spoiled by rain, remember that the sources of its chemicals are varied and far-flung—sea salt, fossil fuel combustion products, desert dusts from across the Atlantic and possibly even marine algal emissions contribute to the chemistry of rain there.

References

Brimblecombe, P. and Lein, A. Yu. (1989) *Evolution of the Global Biogeochemical Sulphur Cycle*. Wiley, Chichester.

Broeker, W. and Peng T.-H. (1982) *Tracers in the Sea*. Lamont Doherty Geological Observatory, Palisades, New York.

McDowell, W. H., Gines Sanchez, C., Asbury, C. E. and Ramos Perez, C. R. (1990) Influence of aerosols and long-range transport on precipitation chemistry at El Verde, Puerto Rico. *Atmospheric Environment* 24, 2813-2821.

Prospero, J. M., Glaccum, R. A. and Nees R. T. 1981. Atmospheric transport of soil dust from Africa to South America. *Nature* 289, 570-572. Schaefer, D. A. and McDowell, W. H (in prep.) A 13-year record of precipitation chemistry in the Luquillo Experimental Forest of Puerto Rico. For *Atmospheric Environment*.

Science-Management Connections Help Protect Stream Ecosystems at the Luquillo LTER Site, Puerto Rico

The NSF LTER Program provides an important mechanism by which scientific data, collected within the 24-site LTER Network, can be used in resource management. A case in point involves science applications to water resource management in the Luquillo Experimental Forest (coterminous with the Caribbean National Forest) in the U.S. Commonwealth of Puerto Rico. The Luquillo Experimental Forest (~11,269 ha) is located in the highlands of northeastern Puerto Rico (Fig. 1) and serves as a key area for research, recreation, and tourism. It was declared a Biosphere Reserve in 1976 by UNESCO's Man and the Biosphere Programme and designated as an LTER site by NSF in 1988. The forest receives an average of 4 m of annual rainfall and includes the upper portions of nine river basins.

There is increasing pressure on the Luquillo Experimental Forest to provide drinking water for human populations in the lowlands: at least 600,000 people are dependent on water withdrawn from rivers draining the forest. It was not until 1994 that a water-use budget was constructed for Luquillo (Naumann 1994). Creation of this water budget was facilitated by longterm discharge data available from 12 established stream gages located within or closely adjacent to the forest. The water budget indicated that on an average day, more than 50% of riverine water is diverted into municipal water supplies before it reaches the ocean (Naumann 1994). A total of 21 water intakes are operational within forest boundaries, and 9 large intakes are located in lower stream reaches outside the forest (Fig. 1). Many streams have no water below their intakes for much of the year and it is increasingly common for saline waters from the ocean to intrude 2-3 km upstream in the absence of riverine inputs of freshwater (Benstead et al. 1999). Conditions are particularly severe during drought periods and severe water rationing to local communities is common. Streamdewatering also results in less water to dilute wastewater discharged by sewage treatment plants into lower river reaches outside of the national forest (Fig. 1), and is an increasingly important constraint to tourismdevelopment in the coastal lowlands (Pringle and Scatena 1999).

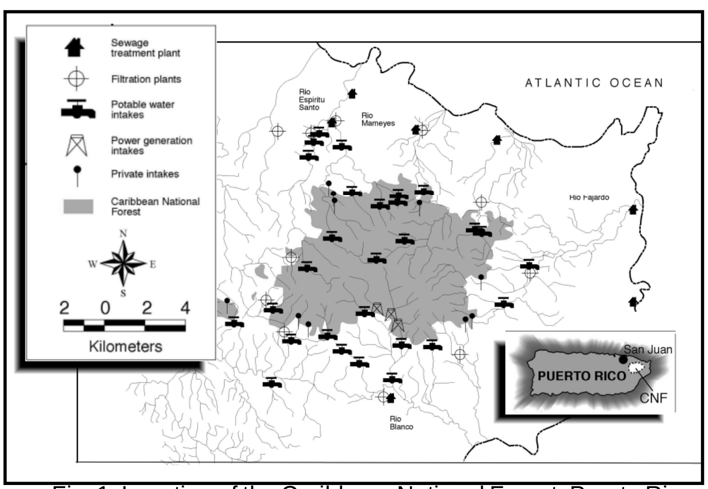


Fig. 1. Location of the Caribbean National Forest, Puerto Rico, sites of water withdrawals (i.e. intakes for potable water, power generation, and private), sewage treatment plants, and filtration plants. [Map provided courtesy of A. Garcia, U.S. Forest Service, International Institute of Tropical Forestry, Puerto Rico; From Pringle (2000)].

The sheer magnitude of hydrologic changes being proposed for streams draining the forest has kept resource managers busy evaluating and providing scientific information relevant to poorly planned proposals (F. Scatena, USDA Forest Service, International Institute of Tropical Forestry, San Juan, Puerto Rico, personal communication). Conflicts for water usage between local communities and tourist complexes geared to off-island residents are aggravated by the fact that the dry season coincides with the tourist season. These conflicts can only be expected to increase as tourism expands. The island has recently experienced severe water shortages, despite its historical reputation as "the land of many rivers" (Pringle and Scatena 1999). In 1994, the drought became so severe that Puerto Rico was declared an agricultural disaster area by the federal government and water rationing was imposed in the major metropolitan area of the island.

Managers of the Caribbean National Forest and scientists from both the Forest Service and academia are concerned about the aforementioned water resource issue—particularly how effects of human disturbance are transmitted upstream and how they affect the biotic integrity of the national forest itself (e.g., Pringle 1997, Fig. 2). While the forest has some of the last undeveloped water supplies on the island, water withdrawals conflict with other functions that the forest fulfills (e.g., recreation, research, and the maintenance of the original biodiversity of the island). For example, because all of the fish and shrimp species (e.g., Fig. 3) that inhabit the streams of the Caribbean National Forest are migratory (i.e., traveling from stream headwaters to estuaries or the ocean and back at some point in their life cycle), dams, water abstraction, and pollution along stream continua can affect their populations (e.g., Holmquist et al. 1998). This can, in turn, have potentially important effects on ecosystem dynamics in headwater streams because research shows a strong linkage between species assemblages and ecosystem properties (Pringle 1996, Pringle et al. 1999, March 2000, Crowl et al. in press).

Scientists and managers have brought water resource issues facing the Luquillo Experimental Forest to both local and national attention. Projects funded by NSF and/or the USDA Forest at this LTER site include: (1) long-term monitoring of shrimp populations (e.g., Covich et al. 1996); (2) evaluation of in-stream flow and habitat requirements of shrimp (Scatena and Johnson in press) and fishes (N. Hemphill and E. Garcia, Caribbean National Forest, unpublished data); (3) the timing of larval shrimp migration to estuaries (March et al. 1999); (4) estuarine shrimp larval development and upstream post-larval migration (Benstead et al. 2000); (5) effects of dams and water withdrawals on shrimp and fish mortality (Benstead et al. 1999); (6) genetics of shrimp populations between rivers (T. Crowl et al., Utah State University, unpublished data); (7) ongoing studies on effects of different types of water intakes on shrimp and fish mortality (J. March et al., University of Georgia, unpublished data); and (8) ongoing studies on the impacts of water extraction and sewage releases on water quality in the

Mameyes estuary (e.g., Scatena in press, and unpublished data).

Results of this research are being directly linked to management of hydrologic connections across the boundaries of the Caribbean National Forest. For example, Benstead et al. (1999) showed that water extraction over a two month period, from a major water intake located outside of the forest on the lower Espiritu Santo River (Fig. 2), resulted in high mortality (42%) of drifting first-stage shrimp larvae by entrainment during downstream migration. One hundred percent of drifting larvae were entrained by the intake during low flows when no water was discharged over the dam (Benstead et al. 1999). Field measurements of larval shrimp mortality, combined with a 30-year discharge record, were used to model the long-term impacts of different intake management strategies on shrimp mortality at the water intake. Results indicated that long-term mean daily entrainment mortality of shrimps ranged from 34 to 62%, depending on estimates of the water amount extracted from the river. A companion study on temporal patterns of shrimp migration (March et al. 1998), showed that larval shrimps drift during the night with a nocturnal peak occurring a few hours after dusk. This combined information was used to make recommendations for mitigation of negative environmental effects caused by water abstraction. Recommendations include: (1) 3-5 hour stoppages in water abstraction during peak nocturnal (i.e. post-dusk) larval drift ; (2) up-keep of functional fish ladders; (3) maintenance of minimum flows over dams; and (4) evaluation of different types of water withdrawal systems (March et al. 1998; Benstead et al. 1999).

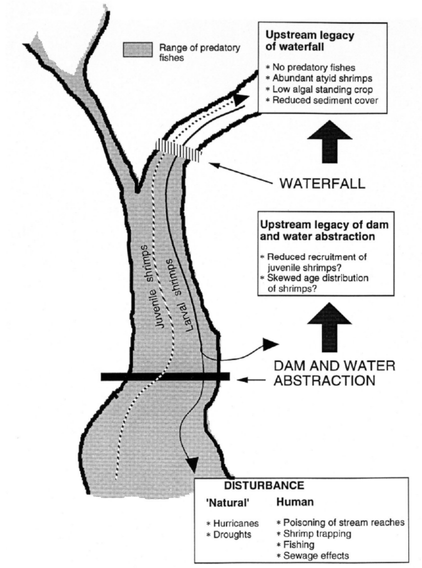


Figure 2: Schematic diagram of the Rio Espiritu Santo, Puerto Rico, illustrating observed and potential downstream-upstream effects. Barriers, both natural (waterfalls) and artificial (dams and associated water abstraction), act as selective filters along the stream continuum, modifying the distribution of biota upstream. Superimposed on the upstream legacies created by these filters are the legacies created by interactive effects of both natural (e.g., hurricanes and droughts) and artificial (stream poisoning events, fishing, shrimp trapping, pollution) disturbances (From Pringle 1997).

As a result of these findings, the designs of two new water withdrawal systems have been altered by the Puerto Rican Aqueduct and Sewage Authority to minimize mortality of migrating aquatic biota. Intakes also operate when stream flows are high so that base flows are maintained. Equally encouraging is that water withdrawal from another intake on the Culebrinas River has been prohibited from 7 to 11 PM and a fish ladder has been required.

These small successes aside, what are the cumulative impacts of water withdrawals on the biotic integrity of streams and rivers draining the Caribbean National Forest (Fig. 3)? How will droughts and island-wide water shortages exacerbated by burgeoning human populations affect water withdrawals and the biological integrity of the forest in the long term? These are some of the questions that long-term research at the Luquillo LTER site will help address.

In summary, the Luquillo Experimental Forest (a.k.a. the Caribbean National Forest) is like many public lands throughout the U.S. in that it is increasingly threatened by human alteration of hydrologic connections outside of its boundaries. Expanding human populations require more water and they often look to public lands to meet their demands. On a global scale, humans have already appropriated half of the accessible freshwater runoff, and conservative estimates indicate that this appropriation could climb to 70% by the year 2025 (Postel et al. 1996). Correspondingly, there is less fresh water available for the environmental needs and integrity of ecosystems that are not dominated by humans. Of great concern are situations where hydrologic alterations outside of the boundaries of managed areas end up controlling the hydrology and/or biology of those areas.

In a recent paper that just came out in a special issue of *Ecological Applications* devoted to the land-water interface and science for a sustainable biosphere(see references), the Luquillo Experimental Forest LTER site is provided as a case study, which highlights the critical need to address cumulative long-term effects of hydrologic alterations on public lands and to illustrate the synergism that can occur between field managers and scientists in implementing localized solutions.

Figure 3: Macrobrachium shrimp, Luquillo Experimental Forest, Puerto Rico.

References

Benstead, J. P., J. G. March, C. M. Pringle, and F. N. Scatena. 1999. Effects of a low-head dam and water abstraction on migratory tropical stream biota. Ecologi Applications 9:656-668.

Benstead, J. P., J. G. March, and C. M. Pringle. 2000. Estuarine larval development and upstream post-larval migration of freshwater shrimps in two tropical rivers of Puerto Rico. Biotropica 32 (3): 545-548.

Covich, A. P., T. A. Crowl, S. L. Johnson, and M. Pyron. 1996. Distribution and abundance of tropical freshwater shrimp along a stream corridor: response to disturbance. *Biotropica* 28:484-492.

Crowl, T. A., W. H. McDowell, A. P. Covich, and S. L. Johnson. In press. Freshwater shrimp effects on detrital processing and localized nutrient dynamics in a montane tropical rainforest stream. *Ecology* 00:00-00.

Holmquist, J. G., J. M. Schmidt-Gengenbach, and B. B. Yoshioka. 1998. High dams and marine-freshwater linkages: effects on native and introduced fauna in the Caribbean. *Conservation Biology* 12:621-630.

March, J. G., J. P. Benstead, C. M. Pringle, and F. N. Scatena. 1998. Migratory drift of larval amphidromous shrimps in two tropical streams, Puerto Rico. *Freshwater Biology.* 40:261-273.

March, J. G. 2000. The role of freshwater shrimps: patterns and processes along a tropical island stream continuum, Puerto Rico. Ph.D dissertation, Institute of Ecology, University of Georgia, Athens, GA 30602, 182 p.

Naumann, M. 1994. A water-use budget for the Caribbean National Forest of Puerto Rico. Special Report, U.S. Forest Service, Rio Piedras, Puerto Rico.

Postel, S. L., G. C. Dalily, and P. R. Ehrlich. 1996. Human appropriation of renewable freshwater. *Science* 271:785-788.

Pringle, C. M. 1996. Atyid shrimp (Decapoda: Atyidae) influence spatial heterogeneity of algal communities over different scales in tropical montane streams, Puerto Rico. *Freshwater Biology* 35:125-140.

Pringle, C. M. 1997. Exploring how disturbance is transmitted upstream: going against the flow. *Journal of the North American Benthological Society* 16:425-438.

Pringle, C. M. 2000. Threats to U.S. public lands from cumulative hydrologic alterations outside of their boundaries. *Ecological Applications* 10: 971-989.

Pringle, C. M. and F. N. Scatena. 1999. Freshwater resource development: Case studies from Puerto Rico and Costa Rica. Pages 114-121 in U. Hatch and M. E. Swisher, editors. *Tropical managed ecosystems: The Mesoamerican experience.* Oxford University Press, NY, USA.

Pringle, C. M., N. H. Hemphill, W. McDowell, A. Bednarek, and J. March. 1999. Linking species and ecosystems: Different biotic assemblages cause interstream differences in organic matter. *Ecology* 80:1860-1872.

Scatena, F. N. in press. Ecological rhythms and the management of humid tropical forests: Examples from the Caribbean National Forest, Puerto Rico. *Forest Ecology and Management* Special issue on New Directions in Tropical Forestry Research.

Scatena F.N., and S. L. Johnson. In press. Instream Flow Analysis for the Luquillo Experimental Forest, Puerto Rico: Methods and Analysis. USDA Forest Service Technical Report, Rio Piedras, PR.

Evapotranspiration Data Critical for Formulating Arid-land Water Budgets

A Study of the Middle Rio Grande Basin

Cliff Dahm, James Cleverly, Jim Thibault, and David Gilroy; Department of Biology; University of New Mexico, and Julie Coonrod; Department of Civil Engineering; University of New Mexico.

The need for accurate water budgets for rivers in arid and semi-arid regions of the world is growing due to ever increasing human demand for fresh water that leads to inevitable conflicts between the use of water for human needs and requirements for water by native ecosystems. The interplay between water availability and water demand has placed most arid land rivers and riparian zones in peril. The Middle Rio Grande of central New Mexico, a rapidly growing region of the United States where over half the population of the State of New Mexico presently resides, is an increasingly endangered river/riparian ecosystem. Drought threatens the very existence of surface water in this overextended and endangered ecosystem. Research at the Sevilleta LTER and other sites along the Middle Rio Grande is attempting to improve our knowledge of water depletions from river and riparian ecosystems. Here, we highlight results of a recent water budget for this reach of river and describe ongoing research on measuring annual growing season evapotranspiration (ET) rates from native and non-native riparian gallery forest or bosque.

The Middle Rio Grande of New Mexico is defined as the river reach between Otowi Gage just north of Santa Fe and Elephant Butte Dam at Truth or Consequences, a distance of about 320 kilometers (Figure 1). The Middle Rio Grande constitutes about 10% of the total length of the Rio Grande. The existing riparian gallery forest is now spatially limited by a system of levees and natural bluffs. Historically, the Middle Rio Grande was a flood-dominated ecosystem in which spring snowmelt from the mountains of southern Colorado and northern New Mexico produced peak discharge between mid-May and mid-June. Overbank flooding was once an integral component of the riparian forest ecosystem and the riparian zone was a complex mosaic of vegetation types including cottonwood (*Populus deltoides* ssp. *wislizenii*), Goodding willow (*Salix gooddingii*), wet meadows, marshes, and ponds. However, water management policies during this century have greatly altered many aspects of the floodplain ecosystem, and dam construction and river channelization have prevented annual spring flooding in recent decades. These conditions are exacerbated during dry years. Most of the remaining cottonwood gallery forest in the Middle Rio Grande reflects a legacy of flooding that occurred over half a century ago. Structural changes in the riparian vegetation have been rapid and well documented. For example, half of the wetlands in the Middle Rio Grande have been lost in just 50 years (Crawford et al. 1993). Cottonwood germination, which requires scoured sandbars and adequate moisture from high river flows, has declined substantially. Meanwhile, invasion by exotic phreatophytic plants such as salt cedar (*Tamarix ramosissima*) and Russian olive (*Elaeagnus angustifolia)* has greatly altered the species composition of the riparian forests within the valley. Native cottonwood stands are in decline. For example, the cottonwood-dominated bosque in Albuquerque has experienced a 40% decline in cottonwood leaf litterfall over the past decade (Molles et al. 1998).

Figure 2. Ten meter ET flux tower in a riparian salt cedar stand at the Sevilleta LTER site, New Mexico.

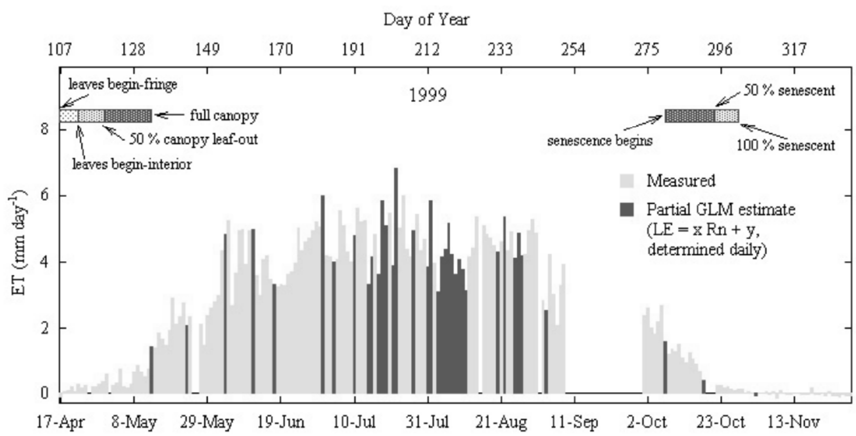


Figure 3. Evapotranspiration (ET) rates in a riparian salt cedar stand during 1999 at the Sevilleta LTER site, New Mexico.

A recent water budget developed for the Middle Rio Grande reflects these changes to river and bosque. An annual water budget for the Middle Rio Grande for the 26-year period from 1972-1997 has been produced (Middle Rio Grande Water Assembly 1999) to assist with water management decisions. It provides annual averages in units of acre-feet per year (af/y) for nearly all inflows, outflows, and changes in water storage. Natural variability is high for almost all of the numerical estimates in the budget, and uncertainties in the various estimates also are commonly large. The Otowi gage is the inflow point for the Middle Rio Grande reach. Flow records go back more than 100 years at this gage. Outflow is determined by discharge from Elephant Butte Reservoir. Major sources of water depletion within the Middle Rio Grande include 1) urban consumption, 2) irrigated agriculture, 3) aquifer recharge, 4) open-water evaporation, and 5) riparian plant transpiration. Many of these depletions vary substantially year-to-year and estimates for many of these terms come with very large measurement uncertainties. Best present estimates, however, suggest that on average the largest depletion term constituting about one-third of the total annual depletion comes from open-water evaporation (~220,000 af/y) with direct evaporation from reservoirs the largest single depletion loss. The second larg-

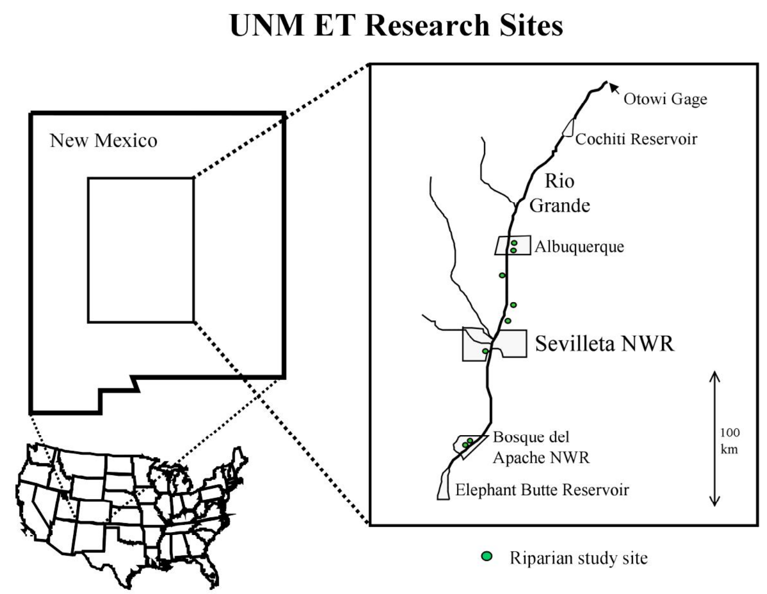


Figure 1. UNM riparian Evapotranspiration (ET) research sites along the Middle Rio Grande of New Mexico.

est depletion term, estimated to average about one-quarter of total annual depletion (~180,000 af/y), is riparian plant or bosque transpiration (annual estimates from 110,000-275,000 af/y). Considerable uncertainty presently exists regarding these estimates. For example, potential differences in annual transpiration rates between native and non-native riparian plant species are unknown, and effects of fluctuations in river discharge due to drought or flooding on transpiration rates have not been measured in the basin. Irrigated agriculture is estimated to account for approximately 20% of annual average depletions in the Middle Rio Grande (~135,000 af/y) with urban consumption and net aquifer recharge estimated to be of comparable magnitude and accounting for the 20-25% of the remaining estimated total annual depletion in the Middle Rio Grande.

We have established eight research sites with support from NASA along the Middle Rio Grande to better determine annual rates of bosque ET (Figure 1). Four sites are in stands dominated by exotic salt cedar and four sites are in stands dominated by native cottonwood. Occasional flooding occurs in two of the salt cedar and two of the cottonwood stands and does not occur in the other four stands. Two of the stands with salt cedar have 10 m towers (Figure 2) and two of the cottonwood stands have 25 m towers equipped with three-dimensional eddy covariance flux instrumentation to estimate water vapor fluxes. Eddies are characterized above the forest canopy by fast-response instruments that measure wind speed in three dimensions as well as vapor pressure. The covariance between vertical wind speed and vapor pressure is used to determine the flux of latent heat from the forest, which is converted to rate of ET using the density and latent heat of vaporization for water. The 2000 growing season will be the first year with data from all four towers while data in 1999 were gathered at the two salt cedar sites only.

ET rates for salt cedar at the Sevilleta LTER site are shown in Figure 3. Onset of ET occurred in the middle of April. Peak rates of ET of approximately 6 mm per day occurred in July. Daily rates of ET were well correlated with atmospheric humidity with lower ET occurring on more humid days. Measurable ET ceased on October 17 after a strong freeze. Integration of ET rates throughout the growing season at this site yielded a value of 57 cm. A second site at Bosque del Apache had an annual ET rate of 99 cm. This site floods regularly and contains a much denser stand of salt cedar.

Work in progress will use remote sensing techniques to more accurately classify the bosque vegetation and scale the stand estimates from the native and non-native sites to produce estimates of ET for the entire bosque of the Middle Rio Grande. Long-term measurements over multiple growing seasons will allow better estimates of interannual variability and address the effect of flooding on the amount of water used by various types of native and non-native vegetation. Data to date confirm high rates of water use by dense thickets of non-native vegetation and the importance of introduced species as a large source of water depletion for the Middle Rio Grande.

References

Crawford, C.S., A.C. Culley, R. Leutheuser, M.S. Sifuentes, L.H. White, and J.P. Wilber. 1993. Middle Rio Grande Ecosystem: Bosque Biological Management Plan. U.S. Fish and Wildlife Service, District 2, Albuquerque, New Mexico, 291 pages.

Middle Rio Grande Water Assembly. 1999. Middle Rio Grande water budget (where water comes from, and goes, and how much): averages for 1972-1997. Middle Rio Grande Council of Governments of New Mexico. 10 pages.

Molles Jr., M.C., C.S. Crawford, L.M. Ellis, H.M. Valett, and C.N. Dahm. 1998. Managed flooding for riparian ecosystem restoration. BioScience 48:749-756.

The LTER ASM 2000 *cont from pg one*

productive collaborations. Everyone returned from the ASM excited about the opportunities presented by our newly funded LTER program and eager to make an impression on what is a very impressive network of scientists. The ASM experience was particularly meaningful for the students." Childers says the meeting was perfectly timed for a new site. "It is difficult to imagine where we could have learned so much, met so many people, and heard so much good science in such a short time."

The meeting immediately preceded the Ecological Society of America annual meeting. Juxtaposing these two gatherings fostered interaction among the LTER community and the broader group of scientists that normally attends the ESA meeting. A large number of non-LTER scientists. Having the two meetings together allowed ESA's staff to help in the organization and registration tasks for the LTER meeting. In particular, special thanks are due to Ellen Cardwell, ESA's Meeting Coordinator, as well as Tricia Crocker, Darnell Pinson, Elizabeth Biggs, Frank McDonna, and Nicky Anarado of the ESA Office.

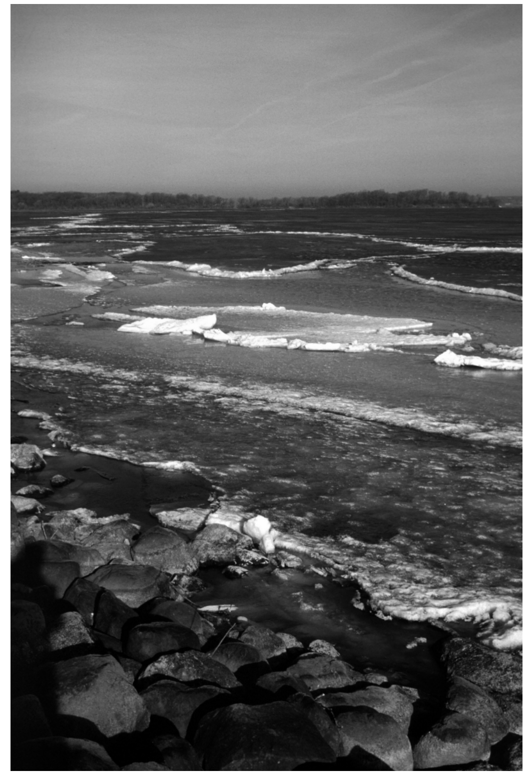
Bob Parmenter of the Sevilleta site and Bob Waide co-chaired the program, and the staff of the LTER Network Office performed the bulk of the organization for the meeting.

One of the most exciting aspects of the meeting was the participation of over 100 scientists from existing and aspiring LTER national networks. Thirty-three countries were represented, including all of the existing ILTER networks.

The vigorous participation by international colleagues indicates how far the ILTER network has come since it was founded in 1993. The generous support of the Division of International Programs of NSF contributed to the impressive turnout. On Wednesday night, a reception was held in honor of ILTER scientists. Other activities included a workshop on developing international scientific collaborations organized by Frances Li (NSF) and Ian Simpson (ECN-UK). The ILTER Coordinating Committee meeting was held on Saturday and was followed by an informal hike organized by Bill Chang of NSF. Post-meeting communications indicate the All Scientists Meeting initiated many collaborations between U.S. and International LTER researchers.

The first All Scientists Meeting was held in the mid-1980s. This initial meeting was a team building effort to encourage integration among the LTER sites existing at that time. Subsequent meetings were held in 1990 and 1993. The next ASM is tentatively planned for 2003, and we are soliciting volunteers to form a program committee.

Warming Trend Revealed in Global, Long-term Ice Breakup Study



Ice breakup on Lake Mendota in Madison, WI during the Spring of 2000. Lake Mendota is one of the lakes with 150-year ice formation and breakup records included in the journal Science study. Photo by: John Magnuson

From sources as diverse as newspaper archives, transportation ledgers and cultural traditions, a team of 13 scientists lead by John Magnuson, an investigator at North Temperate Lakes LTER site have amassed lake and river ice records spanning the Northern Hemisphere that show a 150-year warming trend.

The report, which was published in the Sept. 8, 2000 issue of the journal *Science*, includes 39 records of either freeze dates or breakup dates from 1846 to 1995 and represents one of the largest and longest records of observable climate data ever assembled. And while it is extensive, Magnuson and his colleagues explain that this study only scratches the surface in regard to the ecological effects of global warming.

Going Global

Countries with sites used in the study include Canada, Finland, Russia and Japan. Of those, 37 sites indicate warming. The average rate of change over the 150-year period was 8.6 days later for freeze dates; and 9.5 days earlier for breakup dates. A smaller collection of records going well past 150 years also are in the direction of warming, at a slower rate.

"We think this is a very robust observation: It is clearly getting warmer in the Northern Hemisphere," says Magnuson. "The importance of these records is that they come from very simple, direct human observations, making them very difficult to refute in any general way."

The findings also correspond to an air temperature increase of 1.8 degrees Celsius over the past 150 years. A temperature change of 0.2 degrees Celsius typically translates to a one-day change in ice-on and ice-off dates.

Freeze dates were defined in the study as the observed period the lake or river was completely ice-covered; the breakup date was defined as the last ice breakup observed before the summer open-water phase.

The long-term ice records have valuable attributes for climate researchers, Magnuson says. They can be gathered across a wide range of the globe, and in areas traditionally without weather stations. Their primary weakness is that early observers did not always document the methods used.

Magnuson's study acknowledges that 10,000 years ago much of the Midwest was covered by ice, "so we know it's getting warmer," he says. "What's troubling and scary to people is that these rates in recent decades are so much faster."

Climate models have predicted a doubling of total greenhouse gases in the next 30 years or so, a change that could potentially move the climate boundaries for fish and other organisms northward by about 300 miles, approximately the length of the state of Wisconsin, Magnuson says.

Demonstrating the Value of Networking and Long-term Research

The records in this study are part of a decade-long LTER project led by Magnuson and the UW-Madison Center for Limnology to build a database of lake and river ice records from around the world. "We reached out to colleagues around the world and asked for these records. It turned out some people had very rich stores of data."

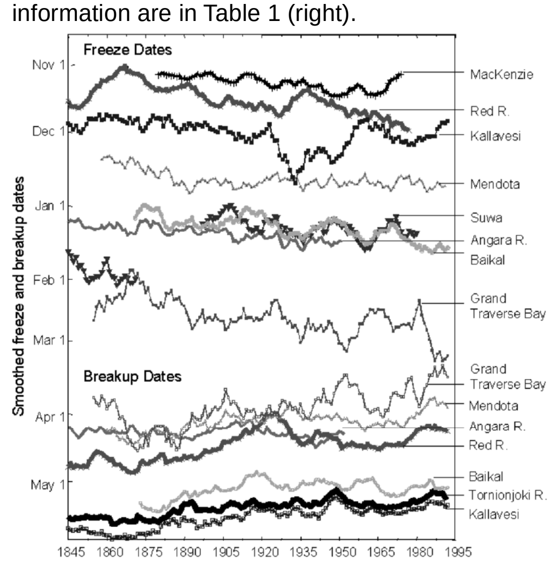
The records in this study represent the longest and most intact of 746 records collected through the project. Some individual records are of astonishing lengths, with one dating back to the 9th century, another to the 15th century and two more to the early 1700s.

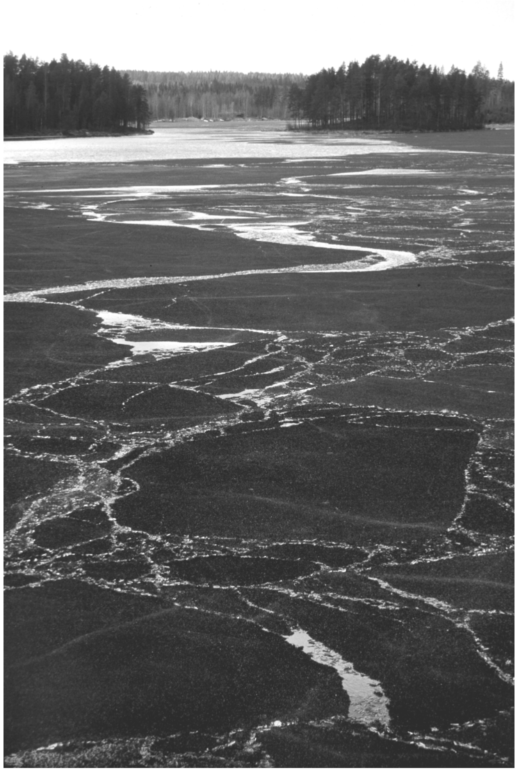
For example, Lake Suwa in Japan has a record dating back to 1443 that was kept by holy people of the Shinto religion. The religion had shrines on either side of the lake. Ice cover was recorded because of the belief that ice allowed deities on either side of the lake—one male, one female—to get together.

Lake Constance, a large lake on the border of Germany and Switzerland, has a peculiar record dating back to the 9th century. The data were derived from the records of two churches, one in either country, which kept a tradition of carrying a Madonna figure across the lake to the alternate church each year it froze. Two other long records come from Canada's Red and McKenzie rivers, which date back to the early 1700s and were kept because ice cover and open water were critical to the fur trade. Records from Grand Traverse Bay and Toronto Harbor, both on the shores of the Great Lakes, reflect their prominence as shipping ports.

Other records included in the study are from lakes Mendota, Monona and Geneva

Figure 1. Time series of ice freeze and breakup dates from selected Northern Hemisphere lakes and rivers (1846 to 1995). Data were smoothed with a 10-year moving average. Locations and related information are in Table 1 (right).





Candled ice during breakup of Lake Kallevesi in Finland during the Spring of 1997. Lake Kallavesi is one of the lakes with 150-year ice formation and breakup records included in the journal Science study. Photo by: Esko Kuusisto

from Wisconsin; lakes Detroit and Minnetonka from Minnesota; lakes Oneida from New York and Moosehead from Maine; Lake Kallavesi from Finland; and the Angara River and Lake Baikal from eastern Russia.

Another finding in the study, based on the 184 ice records from 1950 to 1995, showed the variability in freeze and breakup dates increased in the last three decades. Magnuson says it might be related to intensification of global climate drivers such as the El Nino /La Nina effects in the Pacific Ocean.

Future Challenges

While the data are extensive, there is still much research to be done. Magnuson says the observational nature of the study is “both its strength and its weakness,” and the results do not offer specific proof that greenhouse gases are driving the warming trend. However, the findings are consistent with computer-generated models that have been developed to estimate climate change from greenhouse gases over a 125-year time period, he says.

Magnuson says future studies might include examining inter-annual variability and how it has fluctuated over the same 150 years. “We’d like to be able to explain the variation that occurs through the 150 years owing to changes in the north Atlantic oscillation, the north Pacific oscillation, the Southern Ocean oscillation, and perhaps changes in the suns’ activity. We’d also like to test alternative models than a straight line to fitting the data.”

And I would be very interested in seeking out other long-term data sets on lakes and rivers and see if there are other long-term data--longer than the LTER programs record, 50 years and longer.”

Magnuson and colleagues conclude that the explanation of the long-term trend is significant. “Such questions should be addressed and are being addressed through activities of many other scientists and are being synthesized through the activities of the Intergovernmental Panel on Climate Change in their pending 2000 assessment.”

Finding funding for such projects always presents a challenge. “NSF provided an opportunity about five years ago for such synthesis of long-term records possible,” Magnuson says, “but future funding is always uncertain for international multiple-site and multi-country analyses.”

Above all, Magnuson acknowledges that it is only through significant cooperation among international colleagues that this type of study is possible, including in this study: D.M. Livingstone (Switzerland); T. Arai (Japan); V. Kuusisto (Finland); N.G. Granin and V.S. Vuglinski (Russia); T.D. Prowse (Canada); D.M. Robertson, R.H. Wynne, B.J. Benson, K.M., Stewart, R.A. Assel, R.G. Barry, and E. Card, (U.S.).

Table 1. Linear trends in freeze and breakup dates for lakes and rivers with more than 100 years of data from 1846 to 1995. All sites are lakes unless specified. Trends are based on all available data for the 150 year period. Location and p values (significance) of trend are provided. [1] Sites listed in bold in this column are illustrated in Figure 1 (left). Several values in this table have been corrected since original publication in *Science*; 2000, HIstorical Trends in Lake nd River Ice Cover in the northern Hemisphere, Vol. 289, No. 5485. p. 1743–1746.

			Freeze Date				Breakup Date			
ID #	**Site**	Location	Number Of Years	Years	Trend (Later) Days/100 Years	P value	Number Of Years	Years	Trend (Earlier) Days/100 Years	P value
	North America									
1	MacKenzie River	Canada	105	**1868-1991**[1]	6.1	0.007				
2	Red River	Canada	162	**1799-1981**	13.2	<0.001	180	**1799-1993**[1]	10.6	<0.001
3	Detroit River	U.S., Minn.					101	1892-1994	12.9	0.003
4	Osakis	U.S., Minn.					121	1866-1989	4.3	0.086
5	Minnetonka	U.S., Minn					112	1854-1989	2.0	0.444
6	Mendota	U.S., Wisc.	141	**1853-1995**	6.0	0.008	142	**1852-1995**	7.5	0.001
7	Monona	U.S., Wisc.	143	1851-1995	7.2	0.008	142	1851-1995	12.2	<0.001
8	Rock	U.S., Wisc.					107	1886-1992	1.9	0.544
9	Geneva	U.S., Wisc.					134	1862-1995	2.3	0.511
10	Grand Traverse Bay	U.S., Mich.	146	**1850-1995**	11.4	0.006	146	**1850-1995**	11.8	0.004
11	Toronto Harbor	Canada	111	1822-1985	36.9	<0.001	111	1822-1985	7.4	0.213
12	Oneida	U.S., NY					151	1845-1995	0.2	0.930
13	Otsego	U.S., NY	147	1849-1995	4.8	0.087	154	1842-1995	6.5	0.004
14	Schroon	U.S., NY					107	1872-1995	5.6	0.014
15	Cazenovia	U.S., NY	101	1844-1995	3.6	0.057	113	1838-1995	4.0	0.125
16	Moosehead	U.S., Maine					149	1847-1995	5.6	<0.001
17	Miramichi River	Canada					127	1829-1955	7.3	0.002
	Europe									
18	Tornionjoki River	Finland					304	**1692-1995**	6.6	<0.001
19	Vesijärvi	Finland	104	1885-1995	0.7	0.874	110	1870-1995	7.1	0.005
20	Paijanne	Finland	104	1885-1995	1.9	0.697	108	1870-1995	8.3	0.002
21	Kallavesi	Finland	161	**1833-1995**	5.3	0.038	163	**1833-1995**	9.2	<0.001
22	Näsijärvi	Finland	160	1836-1995	5.7	0.055	161	1835-1995	8.8	<0.001
23	Lej da San Murezzan	Switzerland					164	1831-1994	8.1	<0.001
	Asia									
24	Angara River	Russia	236	**1720-1955**	7.6	0.019	236	**1721-1956**	– 2.1	0.465
25	Baikal	Russia	128	**1868-1995**	11.0	<0.001	128	**1868-1995**	5.1	0.004
26	Suwa	Japan	415	**1443-1993**	-4.5	0.247				

KDI Update: Creating the Knowledge Network for Biocomplexity

Elizabeth Sandlin, NCEAS;
Stephen Cox, Texas Tech University;
Owen Eddins, LTER Network Office

Imagine that your research program could be considerably more efficient than it already is. Imagine that you could have access to a data catalog containing twice as much—or maybe ten or a hundred times as much—data as you could collect over your entire career. Imagine what new questions you would ask. Imagine having access to eager collaborators who want to share data and ideas and work together toward unraveling complex biological questions.

This is the premise of the Knowledge Network for Biocomplexity project, a collaborative project between the National Center for Ecological Analysis and Synthesis (NCEAS), the Long Term Ecological Research Network Office, Texas Tech University, and the San Diego Supercomputer Center (SDSC). In 1999, these organizations were funded jointly to develop the Knowledge Network for Biocomplexity (KNB), a depository and retrieval system for ecological data. The KNB will facilitate scientific research in ecology and related disciplines. The KNB project has three main components: Informatics research and development, large-scale Ecological and Biogeographical research, and Education, Outreach, and Training.

Informatics research and development: Work on the KNB has laid the groundwork for the infrastructure, software tools, and also for building a community of users. The next step (beginning in early 2001) involves installing user interfaces (software) at sites where data exist. These sites include your own computer as well as servers at NCEAS, LTER sites, OBFS sites, and various universities. A major component of the project involves gaining the interest and support of researchers (like you) so you will enter and register your data into the network.

Ecological data reside in many different formats, media, and locations, and currently have no centralized index. Finding those data, retrieving them, and analyzing them is often time consuming and inefficient. The KNB solves many of these problems by providing a set of data management tools (software) that is a single portal to all the data that reside within its network of databases. The KNB contains a sophisticated engine for searching a catalog of metadata to find specific types of data. The software allows users to search metadata by title, abstract, author, keyword, and full text, among many other possibilities. It also contains components that facilitate the creation of metadata and tie the metadata and data together, allowing users to view many types of actual data online. These software tools allow scientists to not only identify appropriate data for some project but also to easily retrieve and, eventually, analyze them by using the same software tools. The first release of the software, created at the NCEAS, is scheduled for January 2001.

For a more detailed description of SRB technology and its applications, see the article on the "LTER-Hyper-SRB Project" pg 13

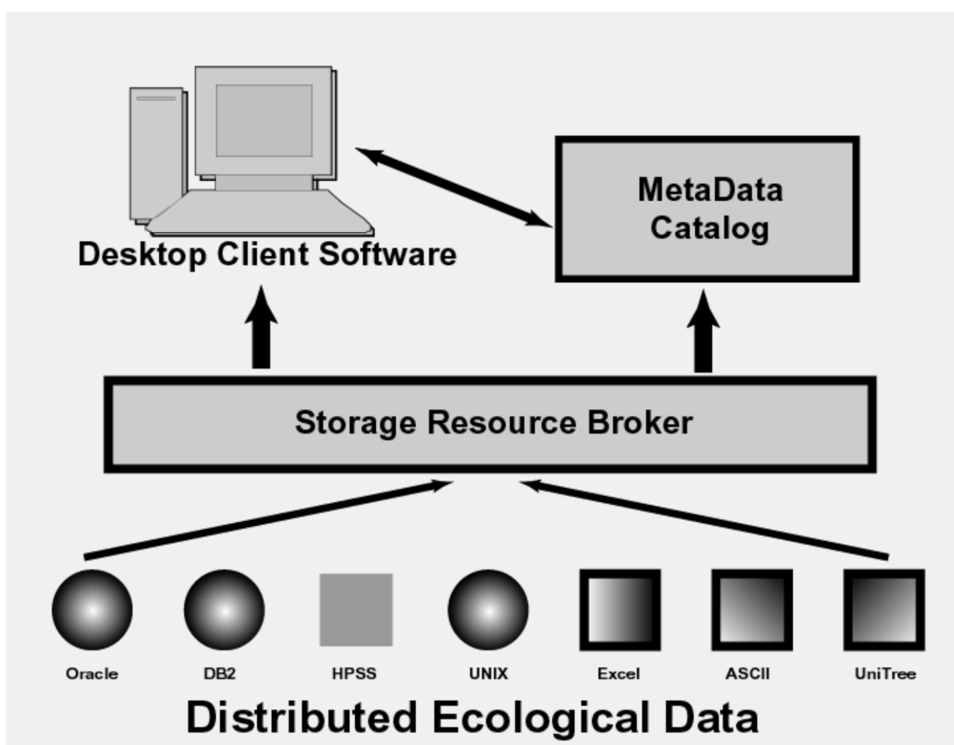
In order to give researchers ultimate control over how—and by whom—their data are used, the software that provides data management tools will contain a feature allowing researchers to set different levels of access to their data by users or groups. For example, you could specify unlimited access for anyone using your local server (where the data actually reside) but allow read-only privileges to people who access your data from a remote server.

The Storage Resource Broker (SRB), software developed at the SDSC, is one of the computer technologies that ties all the database servers together. This technology enables the KNB to share data that may be in multiple formats (e.g., comma-or tab-delimited text, SAS files, Excel spreadsheets, Matlab files, etc.) across multiple operating systems (e.g., UNIX, Windows, NT, MacOS, etc.). The LTER Network Office is directing the effort to install the SRB on various servers where the data currently reside. The first round of installations includes servers at the six LTER Network sites that provided data for an NCEAS Working Group project (see below) that explored the relationships between biodiversity and primary productivity.

Research efforts to examine large-scale Ecology and Biogeography

The relationship between biodiversity and productivity is receiving considerable attention in the current ecological literature. This is because the results from experimental and observational studies often conflict with theoretically-predicted patterns. Our hope is that synthetic studies that make use of data sets from various sources can provide a more complete understanding the "fit" between predicted and observed patterns. The primary goal of the NCEAS Working Group was to

Conceptual model of the Knowledge Network for Biocomplexity.



reconstruct, document, and analyze data about biodiversity and productivity from six LTER sites. Site representatives provided data that they had discovered, retrieved, and manipulated (i.e., secondary data). These data then were synthesized to examine relationships between productivity and diversity across sites.

The LTER program has an established policy on making data available on the Internet. Thus, researchers hoped that the original, unmanipulated data (i.e., primary data) from each LTER site could be identified and retrieved. In addition to providing a validation exercise for the KNB, this process would lead to the discovery of new data on biodiversity and productivity from the six LTER sites. However, several shortcomings of this approach to synthetic research soon became apparent. First, metadata (documentation about a data set), when available, were not consistent, even within the LTER Network. Second, an efficient means of searching metadata does not exist. Third, current metadata documents often do not contain enough information to assess the validity of comparing data from multiple sites. These findings demonstrate the considerable obstacles to conducting synthetic analyses of biodiversity issues, and they reinforce the necessity of developing the KNB.

The KNB should allow researchers to conduct synthetic ecological research in a more efficient and thorough manner. First-year work on the project has involved developing a data set to use for testing and validating the KNB—putting the software through its paces—as well as initiating further research on the relationship between biodiversity and productivity. Validation of the KNB will be based partially on the results from this study and on the previous study done by the aforementioned Working Group. Approximately half of the original and manipulated LTER data that were used for the original study have been retrieved and documented in a standardized format. The data used for this validation exercise are dispersed among six LTER sites, reside on multiple servers running different operating systems, and exist in various formats. This makes retrieving all the data from this study an excellent test of the data management tools developed by the Informatics team. It also tests how well those tools make the KNB accessible to researchers.

Because data retrieval, even within the LTER network, can be laborious and inefficient, we sincerely hope that the KNB will encourage participating researchers to work together to document data with appropriate metadata and to register the data with a KNB server. By sharing data and associated metadata, researchers can leave a permanent and endlessly useful legacy of data for generations of scientists to come.

Once the KNB is operational and populated with data, researchers will have access to data and expertise never before available. For example, scientists will be able to find data to use for a web-based pilot project—a project that might otherwise cost thousands of dollars or an entire field season. Researchers can use the KNB to advertise for collaborators who have expertise critical to a project's success, to increase sample sizes, to do time-series analyses, to gain new information about relevant subjects, etc. Ultimately, the array of research projects facilitated by the KNB will be limited by (1) the amount and types of data in the network and (2) your own imagination.

The KNB will require the cooperation and input of an entire network of researchers, including you. By entering your data, you—the researchers—are helping to build the KNB, and are helping yourselves and your colleagues to: 1) increase research efficiency; 2) gain a better understanding of large-scale biological patterns and processes; 3) enjoy collaborations with other ecologists, and; 4) identify other subject areas in need of further research.

Plans for Education, Outreach, and Training

Also in development is a nationwide (and, potentially, international) outreach program to train graduate students how to use the KNB to facilitate their own research. Beginning in January 2001, scientists at the NCEAS will coordinate a web-linked series of multi-institution graduate student research training seminars focused on multi-scale patterns of species richness and productivity. Students will use the KNB and the data management software on their local computers to design and complete a research project. They will engage in online collaborations among their various institutions. The seminars will culminate with collaborative Working Group meetings at the NCEAS. Targeting students early in their careers will foster computer-based research skills that will enable them to tackle complex ecological questions.

The KNB team is seeking collaborators and contributors who want to become part of this network-based research endeavor—an effort that involves more than 20 people working on state-of-the-art Informatics research and development, large-scale Ecological and Biogeographical research, as well as Education, Outreach, and Training. If you want to contribute to the informatics research and development, contribute data, participate in the seminar activities, or otherwise collaborate on this project, contact:

Informatics Collaboration:
Matt Jones (jones@nceas.ucsb.edu)
Biocomplexity Collaboration:
Stephen Cox (stephen.cox@TTU.EDU)
Seminar Collaboration:
Elizabeth Sandlin
(sandlin@nceas.ucsb.edu).

For more information
PLEASE VISIT THE WEBSITE:
http://www.nceas.ucsb.edu/kdi

Storage Resources (Ecological Data)
- Scattered among numerous storage sites (e.g., LTER sites, OBFS stations, other data archives)
- Stored in numerous formats

Storage Resource Broker
- Software that resides at storage sites
- Allows and controls access to storage resources

Metadata Catalog
- Describes the available data resources
- In standard (XML) format

Desktop Client Software
- Contains tools for creating and editing metadata
- Allows users to query all data in hypothesis format
- Identifies, retrieves, and integrates all relevant data

Landscape Ecology: Much More Than the Sum of Its Parts

A conversation between Bai-Lian (Larry) Li and Patricia Sprott

Prof. Bai-Lian (Larry) Li is mathematical and theoretical ecologist and director of the Ecological Modeling Lab at the University of New Mexico Department of Biology. His main research interest is ecological modeling and systems theory, and recent work has emphasized ecological scaling, spatio-temporal modeling techniques, energetic and thermodynamic foundations of ecological dynamics, and application of nonlinear dynamics and complex systems theories to multiple scale ecology. This article is excerpted largely from "Why is the holistic approach becoming so important in landscape ecology?" as it appeared in the journal Landscape and Urban Planning *50(1-3):27-41, Elsevier.*

Patricia (Patty) Sprott is editor of this Newsletter who strives to understand as much of the subject matter as possible. When considering this article, Patty turned to Larry again and again for clarification on this difficult material, producing this conversation.

Landscape ecology is a way of thinking about the evolution and dynamics of heterogeneous landscapes. The core of landscape ecology is viewed as the body of knowledge or facts about ecological space, spatial heterogeneity, and scaling.

Traditionally, landscape ecology has resorted to reductionism, borrowing models from other sciences because it has not formulated its own basic theories. In the reductionism tradition, landscape ecology studies have been dominated by taking things apart and individually characterizing various attributes of spatial patterns.

But shortfalls in reductionism are increasingly apparent. In terms of how biomolecules work, for example, reductionism has been used successfully to examine the components, but not the complex interactions between the components. Biology has spent decades trying to be like traditional physics, if only to utilize its basic theory of trying to understand complicated systems by understanding each part at its most basic level. Now biologists have found that its time to put it all back together, and there is no mechanism for doing this.

Herein lies the problem: Studies in landscape ecology generally do not address the intrinsic causality and underlying dynamics of the pattern. Therefore, they cannot explain why patterns change with biotic and abiotic conditions. Some of the field's most fundamental questions cannot be answered, as there are no mechanisms, no underlying theories for addressing them through this traditional reductionism approach. In other words, now that we have taken everything apart and have defined and described all the pieces, how to we reassemble them into a working whole? To do this, Larry Li proposes a 'holistic-mechanistic' approach.

Larry: Here, I propose a non-linear physics-based holistic approach--an 'operationable' holistic approach (something we can actually use), which I will call holistic-mechanistic, which defines a system-level or global property of ecological systems by using non-equilibrium thermodynamics of self-organization, synergetics, as well as other systems approaches.

Patty: So you are borrowing theories from non-equilibrium thermodynamics of self-organization, and synergetics, and adding some theories of your own, to form new methods for studying landscape ecology (SEE BOX).

Patty: O.k. so 'mechanistic' means mechanically determined and refers to Prigogine's theory of non-linear systems—and 'holistic' means relating to or concerned with wholes or with complete systems rather than with the analysis of, treatment of, or dissection into parts and refers directly to the "many parts working together to achieve some order" part of Haken's synergetics theory… How do these fit together?

Larry: The term 'ecosystem' refers to a holistic and integrative ecological concept that combines living organisms and their physical environment into a structural and functional, interacting entity (Tansley, 1935). Within this entity, the notion 'system' implies an irreducible complex of elements and subsystems in which the parts are interacting and producing a very special behavior, which can only be assigned to the total system—as a whole. These systems dynamics have to be analyzed as very specific qualities where the whole is more than the sum of parts.

Whenever the interrelations between 'parts' and 'wholes' are discussed in ecology, the central object of interest is the ecosystem with its hierarchical connections between superior and inferior spatio-temporal levels of organization.

The systems-level itself comprises features that are not predictable from the subsystem levels if these parts are observed in isolation. Such additional hierarchical qualities are nominated as emergent properties. They characterize specific systems levels; therefore, if such a level has to be described, the corresponding con't on page 15

Landscape Ecology 101

Here is a quick primer in the basic theories discussed in this article—Ilya Prigogine (b. Jan. 25, 1917, Moscow, Russia: Nobel Prize for Chemistry in 1977 for contributions to non-equilibrium thermodynamics) applied the second law of thermodynamics to complex systems, including living organisms. The second law states that physical systems tend to slide spontaneously and irreversibly toward a state of disorder (a.k.a. 'entropy'). The second law does not, however, explain how complex systems could have arisen spontaneously from less ordered states and have maintained themselves in defiance of the tendency toward entropy. Prigogine argued that as long as systems receive energy and matter from an external source, nonlinear systems (or dissipative structures, as he called them) could go through periods of instability and then self-organization, resulting in more complex systems whose characteristics cannot be predicted except as statistical probabilities. Prigogine's work was influential in a wide variety of fields, from physical chemistry to biology, and was fundamental to the new disciplines of chaos theory and complexity theory.

'Self-organization' is the process by which systems of many components tend to reach a particular state with no external interference. Self-organizing behavior is the spontaneous formation of well-organized structures, patterns, or behaviors, from random initial conditions. In nature, there is a universal tendency for spontaneous self-organization. Self-organizing structures can only be maintained by a constant flux of energy through them, and are therefore not in equilibrium. The most interesting behavior is found in the transition between order and chaos—edge of chaos—and classified as a kind of organized complexity. This behavior—many parts working together to achieve some order—is also known as synergetics [Haken, 1977].

The LTER-Hyper-SRB Project: A collection management system for LTER hyperspectral remote sensing data

A collaborative activity between the San Diego Supercomputer Center and the Long Term Ecological Research Network.

Recent developments in remote sensing technologies have provided new methods for gathering and interpreting landscape data. One type of remote sensing data that is of particular interest to LTER scientists is imaging spectroscopy. With imaging spectroscopy, the recorded data contain the full solar reflected spectrum of the imaged landscape. This data can be analyzed to provide information about vegetation and soil properties. Imaging spectroscopy is performed using a hyperspectral sensor. Current hyperspectral measurements of the Sevilleta and Jornada LTER sites are achieved using aircraft carrying the Airborne Visible InfraRed Imaging Spectrometer (AVIRIS). Later this fall NASA plans to launch a satellite carrying a similar instrument called Hyperion, providing the first spaceborne imaging spectrometer.

The collection, analysis, and application of hyperspectral data raises specific challenges in data management. In particular, the data files are large (the files comprising a single image my be as large as 80GB), there are numerous files (each overflight consists of numerous raw and processed data files), the research community is heterogeneous and distributed (the LTER researchers are geographically distributed and functionally diverse – i.e., some are involved in analysis, some are only data consumers), data load and demand are expected to increase significantly (especially with the launch of the Hyperion sensor), and the information infrastructure is dynamic (the hyperspectral data collections need to persist past changes to the current physical infrastructure). Other challenges for data management include organization (including metadata), access control and security, persistent archives and migration, and web-based access. These requirements are best addressed through the design and implementation of a scientific collections management system.

The focus of the LTER-hyper-SRB project is to design and implement a collections management system for the LTER hyperspectral data products. This system is being built using the NPACI resources available at SDSC, specifically, the high performance storage system (HPSS), the metadata catalog (MCAT), and the storage resource broker (SRB).

The SDSC High Performance Storage System (HPSS) is a general purpose parallel storage system that is scalable in several dimensions: data transfer rate, storage size, number of name space objects, size of objects, and geographical distribution. The SDSC HPSS provides the physical storage for the LTER hyperspectral data products. The HPSS is designed to use network-connected, as well as directly connected storage devices to achieve high transfer rates. The SDSC HPSS currently provides 480 terabytes, or 'Tbytes' of storage space, of which 170 TBytes is already in use.

The Metadata Catalog (MCAT) is a metadata repository system implemented at SDSC to provide a mechanism for storing and querying system-level and domain-dependent metadata using a uniform interface. The MCAT provides a resource and data-set discovery mechanism that can be used effectively to identify and discover resources and data sets of interest using a combination of their characteristic attributes instead of their physical names and/or locations. The MCAT also stores information about the locations where the replicas of the data sets are stored, access control lists for each data set, and audit trails of usage. Queries to the metadata catalog are resolved into (location, protocol) pairs for retrieval or manipulation of the data.

The SDSC Storage Resource Broker (SRB) is client-server based middle-ware implemented at SDSC to provide a uniform data handling interface to different types of storage devices. The SRB provides a uniform API (*Application Programming Interface*—a sort of a standardized library toolbox that other programs use, in this case to link to the SRB programs) to connect to heterogeneous resources that may be distributed and to access data sets that may be replicated. The SRB can be used to access data sets distributed across file systems, databases, and archives. The container is a key concept in SRB. Containers provide the ability to aggregate small files into a single physical file before storage in an archive. When a dataset is accessed, the SRB retrieves the appropriate container onto a disk cache, and then supports read/write commands on the data set that was stored in the container.

The SRB, in conjunction with the MCAT, provides a method for assembling distributed data sets into a collection. Since the data sets are controlled by the collection, it is possible to keep persistent identifiers associated with each data set, regardless of where they are moved.

Together, the HPSS, MCAT, and the SRB provide the foundation for constructing a scalable, robust, collections management system for the LTER hyperspectral data.

Plan The plan is to develop a prototype system at SDSC, utilizing the SDSC HPSS, MCAT, and SRB. The MCAT will reside in the SDSC Oracle database. Scripts will be developed/adapted to move data between Greg Asner's lab at the University of CO, Boulder, and SDSC. The initial system will implement a minimal set of functions (basic access control, security). User access will be provided through the SRB browser interface or the Unix command-line interface. Additional features will be added as needed, including additional metadata, web-access GUIs, and data cutter proxies for manipulating datasets. The option to migrate or replicate the collections management system will be considered in the future.

We envision that the system will serve as an accessible archive for LTER researchers, permitting data access similar to but more advanced than what LTER remote sensing researchers have experienced though the LTER Network Office archive for Landsat Thematic Mapper data (http://www.lternet.edu/research/technology/satellite/).

Current Status According to George Kremenek, we entered beta production mode on 6/24/00. Three compressed data files have been transferred to the SDSC SRB (HPSS), each 500MB. These have been uncompressed at SDSC and the smaller files have been stored into a SRB container. These files have been accessed through the SRB client at Greg Asner's Lab. Next steps will involve generating applications in the LTER Network, providing access to a broader community of users (consider web interface), and populating the system with additional data files.

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Publications
Recent Contributions from the LTER Community

Aerts, R., and Chapin, F.S., III. 2000. The mineral nutrition of wild plants revisited: a re-evaluation of processes and patterns. Advances in Ecological Research, 30: 1-67.

Ajwa, H.A., C.J. Dell and C.W. Rice. 1999. Changes in enzyme activities and microbial biomass of tallgrass prairie soil as related to burning and nitrogen fertilization. Soil Biology & Biochemistry 31:769-777.

Arft, A.M., Walker, M.D., Gurevitch, J., Alatalo, J.M., Bret-Harte, M.S., Dale, M., Diemer, M., Gugerli, F., Henry, H.R., Jones, M H., Hollister, R.D., Jónsdóttir, I.S., Laine, K., Lévesque, E., Marion, G.M., Molau, U., Mølgaard, P. Nordenhäll, U., Rashivin, V., Robison, C.H., Starr, G., Stenström, A., Stenström, M., Totland, Ø., Turner, P.L.,

Baines, S.B., K.E. Webster, T.K. Kratz, S.R. Carpenter, and J.J. Magnuson. 2000. Synchronous behavior of temperature, calcium and chlorophyll in lakes of northern Wisconsin. Ecology 81(3):815-25.

Banks,M.K., C. Clennan, W.K. Dodds and C.W. Rice. 1999. Variations in microbial activity due to fluctuations in soil water content at the water table interface. Journal of Environmental Science and Health 34:479-505.

Barber, V.A., Juday, G.P., and Finney, B.P. 2000. Reduced growth of Alaskan white spruce in the twentieth century from temperature-induced drought stress. Nature, vol. 405: 668-673.

Benson, B. J., J. D. Lenters, J. J. Magnuson, M. Stubbs, T. K. Kratz, P. J. Dillon, R. E. Hecky, and R. C. Lathrop. 2000. Regional coherence of climatic and lake thermal variables of four lake districts in the Upper Great Lakes Region of North America. Freshwater Biology 43: 517-527.

Blair, J.M., S.L. Collins and A.K. Knapp. 2000. Ecosystems as functional units in nature. Natural Resources and Environment 14:150-155.

Bledsoe, C.S., Fahey, T.J., Day, F.P., and Ruess, R.W. 1999. Measurement of static root parameters - biomass, length, and distribution in the soil profile. Standard soil methods for long-term ecological research. Edited by G.P. Robertson, D.C. Coleman, C.S. Bledsoe and P. Sollins. Oxford University Press. New York, NY. pp. 413-436.

Boles, S.H. and Verbyla, D.L. 2000. Comparison of three AVHRR-based fire detection algorithms for interior alaska. Remote Sensing of the Environment, 72: 1-16.

Boles, S.H., and Verbyla, D.L. 1999. Effect of scan angle on AVHRR fire detection accuracy in interior Alaska. International Journal of Remote Sensing, vol. 20, No. 17: 3437-3443.

Bolgrien, D. W., and T. K. Kratz. 2000. Lake shore riparian areas. Pages 207-217 in Verry, E. S., J. W. Hornbeck, and C. A. Dolloff (eds.) Riparian Management in Forests of the Continental Eastern United States. Lewis Publishers, Washington D.C.

Boone, R.D., Grigal, D.F., Sollins, P., Ahrens, R.J., and Armstrong, D.E. 1999. Soil sampling, preparation, archiving, and quality control. In Standard soil methods for long-term ecological research. Edited by G.P.Robertson, D.C. Coleman, C.S. Bledsoe and P. Sollins. Oxford University Press. New York. pp. 3-28.

Callaham, M. A., Jr., M. R. Whiles, C. K. Meyer, B. L. Brock, and R. E. Charlton. 2000. Feeding ecology and emergence production of annual cicadas (Homoptera: Cicadidae) in tallgrass prairie. Oecologia 123:535-542.

Cater, T.C., and Chapin, F.S., III. 2000. Differential species effects on boreal tree seedling establishment after fire: resource competition or modification of microenvironment. Ecology, 81: 1086-1099.

Cavitt, John F. 2000. Fire and a tallgrass prairie reptile community: effects on relative abundance and seasonal activity. Journal of Herpetology 34:12-20.

Cavitt, John F., A.T. Pearse, T.A. Miller. 1999. Brown Thrasher Nest Reuse: A Time Saving Resource, Protection From Search-strategy Predators, or Cues for Nest-site Selection? The Condor 101:859-862.

Chapin, F.S., III., Eugster, W., McFadden, J.P., Lynch, A.H., and Walker, D.A. 2000. Summer differences among arctic ecosystems in regional climate forcing. Journal of Climate, 13: 2002-2010.

Clinton, B.D. and C.R. Baker. 2000. Catastrophic windthrow in the southern Appalachians: characteristics of pits and mounds and initial vegetation responses. Forest Ecology and Management 126: 51-60.

Clinton, B.D. and J.M. Vose. 2000. Plant succession and community restoration following felling and burning in the southern Appalachian Mountains. In: Moser, W. Keith; Moser, Cynthia F., ed. Fire and Forest Ecology: Innovation Silviculture & Vegetation Management: Proceedings Tall Timbers Fire Ecology Conference; 1998 April 14-16; Tallahassee, FL. No.21: pg. 22-29.

Collins, S.L. 2000. Disturbance frequency and community stability in native tallgrass prairie. The American Naturalist 155:311-325.

Cully, J.F., Jr. 1999. Lone star tick abundance, fire, and bison grazing in tallgrass prairie. Journal of Range Management 52:139-144.

Densmore, R.V., Juday, G.P., and Zasada, J.C. 1999. Regeneration alternatives for upland white spruce after burning and logging in interior Alaska. Canadian Journal of Forest Research, 29: 413-423.

Descy JP, Higgins HW, Mackey DJ, Hurley JP, Frost TM. 2000. Pigment ratios and phytoplankton assessment in northern Wisconsin lakes. Journal of Phycology 36: (2) 274-286.

Dodds,W.K. and E. Welch. 2000. Establishing nutrient criteria in streams. Journal of the North American Benthological Society 19:186-196.

Elias, S., Hamilton, S., Edwards, M., Beget, J., Krumhardt, A., and Lavoie, C. 1999. Late Pleistocene environments of the western Noatak Basin, northwestern Alaska. Geological Society of America Bulletin, 111:769-789.

Elliott, K.J., J.M. Vose, and W.T. Swank. 2000. Fire as a silvicultural tool to improve southern Appalachian pine-hardwood stands In: W. Keith Moser and Cynthia F. Moser (eds.). Fire and Forest ecology: innovative silviculture and vegetation management. Tall Timbers Fire Ecology Conference Proceedings, No. 21. Tall Timbers Research Station, Tallahassee, FL.: 198.

Eom, A.-H., D.C. Hartnett, and G.W.T. Wilson. 2000. Host plant species effects on arbuscular mycorrhizal fungal communities in tallgrass prairie. Oecologia 122:435-444.

Eom, A-.H., D.C. Hartnett, G.W.T. Wilson and D.A. Figge. 1999. Effects of fire, mowing, and fertilizer ammendments on arbuscular mycorrhizas in tallgrass prairie. American Midland Naturalist 142:55- 69.

Epstein, H.E., Walker, M.D., Chapin, F.S. III, and Starfield, A.M. 2000. A transient, nutrient-based model of arctic plant community response to climatic warming. Ecological Applications, 10(3):824-841.

Fahey, T.J., Bledsoe, C.J., Day, F.P., Ruess, R.W., and Smucker, A.M. 1999. Fine root production and demography. Standard soil methods for long-term ecological research. Edited by G.P. Robertson, D.C. Coleman, C.S. Bledsoe and P. Sollins. Oxford University Press. New York, NY. pp. 437-455

Fay, P.A., J.D. Carlisle, A.K. Knapp, J.M. Blair and S.L. Collins. 2000. Altering rainfall timing and quantity in a mesic grassland ecosystem: Design and performance of rainfall manipulation shelters. Ecosystems 3:308-319.

French, N.F., Kasischke, E.S., Stocks, B.J., Mudd, J.P., Lee, B.S., and Martell, D.L. 2000. Carbon released during fires in North American boreal forests. In Fire, climate change and carbon cycling in the boreal forest. Ecological Studies Series. Edited by E.S.

Fritz, K.M., W.K. Dodds and J. Pontius. 1999. The effects of bison crossings on the macroinvertebrate community in a tallgrass prairie stream. American Midland Naturalist 141:253-265.

Frost, T.M. and J.M. Fischer. 2000. Assessing the effects of acidification on aquatic ecosystems. Pages 330-340 in: Sala, O., R. Jackson, H. Mooney, and R. Howarth, eds., Methods in Ecosystem Science. Springer, New York. 421pp.

Gough, L., C.W. Osenberg, K.L. Gross and S.L. Collins. 2000. Fertilization effects of species density and primary productivity in herbaceous plant communities. Oikos 89:428-439.

Gregory-Eaves, I., Smol, J.P., Finney, B.P., Lean, D.S., and Edwards, M. 1999. Diatom-based transfer functions for infering past climatic and environmental changes in Alaska. Arctic, Antarctic and Alpine Research,31: 353-365.

Gregory-Eaves, I., Smol, J.P., Finney, B.P., Lean, D.S., and Edwards, M.E. 2000. Limnological variation in lakes along a north-south transect in Alaska and its relationship to climate. Archiv fur Hydrobiologie, 147:193-223.

Grigal, D.F., Bell, J.C., Ahrens, R.J., Boone, R.D., Kelly, E.F., Monger, H.C., and Sollins, P. 1999. Site and landscape characterization for ecological studies. In Standard soil methods for long-term ecological research.Edited by G.P. Robertson, D.C. Coleman, C.S. Bledsoe and P. Sollins. Oxford University Press. New York. pp. 29-52.

Grogan, P., and Chapin, F.S., III. 1999. Arctic soil respiration: effects of climate and vegetation depend on season. Ecosystems, 2: 451-459.

Gulledge, J, and Schimel J.P. 2000. Controls on soil carbon dioxide and methane fluxes in a variety of taiga forest stands in interior Alaska. Ecosystems,3: 269-282.

Hansen, R.A. 2000. Diversity in the Decomposing Landscape. In: Coleman, D.C.; Hendrix, P.F., eds. Invertebrates as Webmasters in Ecosystem: New York: CABI Publishing, pp. 203-219.

Hansen, R.A. 2000. Effects of habitat complexity and composition on a diverse litter microarthropod assemblage. Ecology 81(4): 1120-1132.

Holland, E.A., Robertson, G.P., Greenberg, J., Groffman, P.M., Boone, R.D., and Gosz, J.R. 1999. Soil CO_2, N_2O, and Ch_4 exchange. In Standard soil methods for long-term ecological research. Edited by G.P.Robertson, D.C. Coleman, C.S. Bledsoe and P. Sollins. Oxford University Press. New York. pp. 185-201.

Houser, J.N., S.R. Carpenter and J.J. Cole. 2000. Food web structure and nutrient enrichment: effects on sediment phosphorus retention in whole-lake experiments. Canadian Journal of Fisheries and Aquatic Sciences 57: 1524-1533

Jacoby, G.C., D'Arrigo, R.D., and Juday, G. 1999. Tree-ring indicators of climatic change at northern latitudes. World Resource Review, 11: 21-29.

Kasischke and B.J. Stocks. Springer-Verlag. New York. pp.377-388.

Kasischke, E.S., and Stocks, B.J. 2000. Fire, climate change and carbon cycling in the boreal forest. Springer-Verlag. New York. 461 pp.

Kasischke, E.S., French, N.F., and Bourgeau-Chavez, L.L. 2000. Using satellite data to monitor fire-related processes in the boreal forests. In Fire, climate change and carbon cycling in the boreal forest. Ecological Studies Series. Edited by E.S. Kasischke and B.J. Stocks. Springer-Verlag. New York. pp. 406-422.

Kasischke, E.S., O'Neill, K.P., French, N.F., and Bourgeau-Chavez, L.L. 2000. Controls on patterns of biomass burning in Alaskan boreal forests. In Fire, climate change and carbon cycling in the boreal forest. Edited by E.S. Kasischke and B.J. Stocks. Springer-Verlag. New York. pp. 173-196.

Kasischke, E.S., O'Neill, K.P., French, N.F., Richter, D.D., Bourgeau-Chavez, L.L., and Harrell, P.H. 2000.Influence of fire on long-term patterns of forest succession in Alaskan boreal forests. In Fire, climate change and carbon cycling in the boreal forest. Ecological Studies Series. Edited by E.S. Kasischke and B.J. Stocks. Springer-Verlag. New York. pp. 214-238.

Keeler, K.H., and G.A. Davis. 1999. Comparison of common cytotypes of Andropogon gerardii (Andropoganeae, Poaceae). American Journal of Botany 86:974-979.

Kim, K., M.P. Anderson, and C.J. Bowser. 2000. Enhanced dispersion in groundwater caused by temporal changes in recharge rate and lake levels, Advances in Water Resources 23: 625-35.

Knapp, A.K., and E. Medina. 1999. Success of C4 photosynthesis in the field: lessons from communities dominated by C4 plants. Pages 251-283 In C4 Plant Biology (R.F. Sage and R.K. Monson, editors), Academic Press, NY.

Knapp, A.K., J.M. Blair, J.M. Briggs, S.L. Collins, D.C. Hartnett, L.C. Johnson and E.G. Towne. 1999. The keystone role of bison in North American tallgrass prairie. BioScience 49:39-50.

Kratz, T. K., and T. M. Frost. 2000. The ecological organization of lake districts: general introduction. Freshwater Biology 43:297-299.

Kuczenski, Tracy K., Donald R. Field, Paul R. Voss, Volker C. Radeloff and Alice E. Hagen. 2000. "Integrating Demographic and LandSat (TM) Data at a Watershed Scale." Journal of the American Water Resources Association 36(1):215-28.

Lewis, D.B. and J.J. Magnuson. 2000. Landscape spatial patterns in freshwater snail assemblages across Northern Highland catchments. Freshwater Biology.43: 409-420.

MacLean, R.M., Oswood, M.W., Irons, J.G., III., and McDowell, W.H. 1999. The effect of permafrost on stream biogeochemistry: a case study of two streams in the Alaskan (USA) taiga. Biogeochemistry, 47: 239-267.

Magnuson, J. J. and Kratz, T. K. 2000. Lakes in the Landscape: Approaches to Regional Limnology. Verh. Internat. Verien. Limnol. 27: 74-87.

Mann, D.H., and Plug, L.J. 1999. Vegetation and soil development at an upland taiga site, Alaska. Ecoscience, 6:272-285.

Maragni, L.A., A.K. Knapp and C.A. McAllister. 2000. Patterns and determinants of potential carbon gain in the C3 evergreen Yucca glauca (Liliaceae) in a C4 grassland. American Journal of Botany 87:230-236.

McMillan, B.R., M.R. Cottam and D.W. Kaufman. 2000. Wallowing behavior of American bison (Bos bison) in tallgrass prairie: an examination of alternate explanations. The American Midland Naturalist 144:159-167.

Milne, B.T., and W.B. Cohen. 1999. Multiscale assessment of binary and continuous landcover variables for MODIS validation, mapping, and modeling applications. Remote Sensing of the Environment 70:82-98.

Mooney, H.A., Canadell, J., Chapin, F.S., III., Ehleringer, J., Korner, C.H., McMurtrie, R., Parton, W.J., Pitelka, L., and Schulze, E.D. 1999. Ecosystem physiology responses to global change. The terrestrial biosphere and global change: implications for natural and managed ecosystems. Edited by B. Walker, W. Steffen, J. Canadell and J. Ingram. Cambridge University Press. Cambridge, UK. pp. 141-189.

Moore, D.L., Stephenson, S.L., Laursen, G.A., and Woodgate, W.A. 2000. Protostelids from boreal forest and tundra ecosystems in Alaska. Mycologia, 92(3): 390-393.

Myrold, D.D., Ruess, R.W., and Klug, M.J. 1999. Dinitrogen fixation. Standard soil methods for long-term ecological research. Edited by G.P. Robertson, D.C. Coleman, C.S. Bledsoe and P. Sollins. Oxford University Press. New York, NY. pp. 241-257.

Naeem, S., Chapin, F.S., III., Costanza, R., Ehrlich, P.R., Golley, F.B., Hooper, D.U., Lawton, J.H., O'Neill,R.V., Mooney, H.A., Sala, O.E., Symstad, A.J., and Tilman, D. 1999. Biodiversity and ecosystem functioning:maintaining natural life support processes. Issues in Ecology, 4: 1-12.

O'Lear, H.E., and J.M. Blair. 1999. Responses of soil microarthropods to changes in soil water availability in tallgrass prairie. Biology and Fertility of Soils 29:207-217.

Osterkamp, T.E., and Romanovsky, V.E. 1999. Evidence for warming and thawing of discontinuous permafrost in Alaska. Permafrost and Periglacial Processes, 10: 17-37.

Ott, R.A., G.P. Juday, and T.E. Garvey. 1999. Conducting a landscape-level wind risk assessment on northeast Chichagof Island, southeast Alaska, and its potential use for forest management. In Proceedings of the Annual Meeting of the Society of American Foresters. 20-24 September, 1998. Society of American Foresters. pp.202-210.

Owensby, C.E., J.M. Ham, A.K. Knapp and L.M. Auen. 1999. Biomass production and species composition change in a tallgrass prairie ecosystem after long-term exposure to elevated atmospheric CO_2. Global Change Biology 5:497-506.

Paul, E.A., Harris, D., Klug, M.J., and Ruess, R.W. 1999. The determination of microbial biomass. Standard soil methods for long-term ecological research. Edited by G.P. Robertson, D.C. Coleman, C.S. Bledsoe and P. Sollins. Oxford University Press. New York, NY. pp. 291-317.

Phillips, Michael J.; Swift, Lloyd W., Jr.; Blinn, Charles R. 2000. Best Management Practices for Riparian Areas. In: Riparian Management in Forests of the Continental Eastern United States. Lewis Publishers, Boca Raton, Florida: 273-285.

Qualls, R.G., B.L. Haines, W.T. Swank, and S.W. Tyler. 2000. Soluble organic and inorganic nutrient fluxes in clearcut and mature deciduous forests. Soil Science Society of America Journal 64: 1068-1077.

Riera, J. L., Magnuson, J. J., Kratz, T. K. & Webster, K. E., 2000. A geomorphic template for the analysis of lake districts applied to the Northern Highland Lake District, Wisconsin, USA. Freshwater Biology. 43: 301-318.

Rupp, T. S., F. S. Chapin III, and A. M. Starfield. 2000. Response of subarctic vegetation to transient climatic change on the Seward Peninsula in northwest Alaska. Global Change Biology 6: 541-555

Rupp, T.S., Starfield, A.M., and Chapin, F.S., III. 2000. A frame-based spatially explicit model of subarctic vegetation response to climatic change: comparison with a point model. Landscape Ecology, 15: 383-400.

Sala, O.E., Chapin, F.S., III., Armesto, J.J., Berlow, E., Bloonfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M., and Wall, D.H. 2000. Global biodiversity scenarios for the year 2100. Science, 287: 1770-1773.

Sala, O.E., Chapin, F.S., III., Gardner, R.H., Lauenroth, W.K., Mooney, H.A., and Ramakrishnan, P.S. 1999.Global change, biodiversity and ecological complexity. The terrestrial biosphere and global change: implications for natural and managed ecosystems. Edited by B. Walker, W. Steffen, J. Canadell and J. Ingram. Cambridge University Press. Cambridge, UK. pp. 304-328.

Schimel, J.P., Gulledge, J.M., Clein-Curley, J.S., Lindstrom, J.E., and Braddock, J.F. 1999. Moisture effects on microbial activity and community structure in decomposing birch litter in the Alaskan taiga. Soil Biology & Biochemistry, 31: 831-838.

Schulze, E.D., Scholes, R.J., Ehlringer, J.R., Hunt, L.A., Canadell, J., Chapin, F.S., III., and Steffen, W.L. 1999.The study of ecosystems in the context of global change. In The terrestrial biosphere and global change: implications for natural and managed ecosystems. Edited by B. Walker, W. Steffen, J. Canadell and J. Ingram. Cambridge University Press. Cambridge. pp. 19-44.

Simons, T.R., S.M. Pearson, and F.R. Moore. 2000. Application of spatial models to the stopover ecology of trans-gulf migrants. Studies in Avian Biology. 20: 4-14.

Smith, M.D., and A.K. Knapp. 1999. Exotic plant species in a C4-dominated grassland: Invasibility, disturbance and community structure. Oecologia 120:605-612.

Smith, M.D., D.C. Hartnett, and C.W. Rice. 2000. Effects of long-term fungicide application on microbial processes in tallgrass prairie soils. Soil Biology and Biochemistry 32:935-946.

Smith, M.D., D.C. Hartnett, and G.W.T. Wilson. 1999. Interacting influence of mycorrhizal symbiosis and competition on plant diversity in tallgrass prairie. Oecologia 121:574-582.

Song, J. 1999. Phenological influences on the albedo of prairie grassland and crop fields. International Journal of Biometeorology 42:153-157.

Sotomayor, D., and C.W. Rice. 1999. Soil air carbon dioxide and nitrous oxide concentrations in profiles under tallgrass prairie and cultivation. Journal of Environmental Quality 28:784-793.

Suominen, O., Danell, K., and Bryant, J.P. 1999. Indirect effects of mammalian browsers on vegetation and ground-dwelling insects in an Alaskan floodplain. Ecoscience, 6: 505-510.

Swank, W.T. ad D.R. Tilley. 2000. Watershed management contributions to land stewardship: case studies in the Southeast. In: Proceedings of the Land Stewardship in the 21st. Century: The Contributions of Watershed Management; 2000. March 13-16; Tucson, AZ. P-13: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 93-108.

Throop, H.L., and P.A. Fay. 1999. Effects of fire, browsers, and gallers on New Jersey Tea (Ceanothus herbaceous) growth and reproduction. American Midland Naturalist 141:51-58.

Uliassi, D.D., Huss-Danell, K., Ruess, R.W., and Doran, K. 200 Biomass Allocation and Nitrogenase Activity in Alnus tenuifolia: Responses to Successional Soil Type and Phosphorus Availability. Ecoscience, 7: 73-79.

Vose, J.M. 2000. Perspectives on using prescribed fire to achieve desired ecosystem conditions. In: Moser, W. Keith; Moser, Cynthia F., ed. Fire and Forest Ecology: Innovative Silviculture & Vegetation Management. Proceedings Tall Timbers Fire Ecology Conference; 1998 April 14-16; Tallahassee, Fl., No. 21: pg. 12-17.

Vose, J.M., W.T. Swank, G.J. Harvey, B.D. Clinton, and C. Sobek. 2000. Leaf water relations and sapflow in eastern cottonwood (Populus deltoides Bartr.) trees planted for phytoremediation of a groundwater pollutant. International Journal of Phytoremediation 2(1): 53-73.

Waide, R.B., Willig, M.R., Mittelbach, G., Steiner, C., Gough, L., Dodson, S.I., Juday, G.P., and Parmenter, R.1999. The relationship between productivity and species richness. Annual Review of Ecology and Systematics,30: 257-300.

Walker, L.J., Webber, P.J., Welker, J.M., and Wookey, P.A. 1999. Responses of tundra plants to experimental warming: meta-analysis of the International Tundra Experiment. Ecological Monographs, 69(4): 491-511.

Walker, M.D., Walker, D.A., Welker, J.M., Arft, A.M., Bardsley, T., Brooks, P.D., Fahnestock, J.T., Jones, M.H., Losleben, M., Parsons, A.N., Seastedt, and Turner, P.L. 1999. Long-term experimental manipulation of winter snow regime and summer temperature in arctic and alpine tundra. Hydrological Processes, 13:2315-2330

Webster, K. E., P. A. Soranno, S. B. Baines, T. K. Kratz, C. J. Bowser, P. J. Dillon, P. Campbell, E. J. Fee, and R. E. Hecky. 2000. Structuring features of lake districts: geomorphic and landscape controls on lake chemical responses to drought. Freshwater Biology 43:499-516.

Weigel, B., J. Lyons, S.I. Dodson, L.K. Paine, and D.J. Undersander. 2000. Using stream arthropods to compare riparian land-use practices on cattle farms in southwestern Wisconsin. Journal of Freshwater Ecology 15:93-106.

Willis, T. and J. J. Magnuson. 2000. Patterns in Fish Species Composition at the Interface Between Streams and Lakes. Can. J. Fish. Aquat. Sci. 57: 1042-1052.

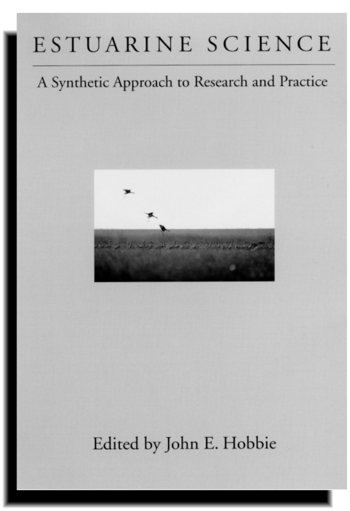
Wright, C.J. and D.C. Coleman. 2000. Cross-site comparison of soil microbial biomass, soil nutrient status, and nematode trophic groups. Pedobiologia 44: 2-23.

Wurtz, T.L. 2000. Interactions between white spruce and shrubby alders at three boreal forest sites in Alaska. United States Department of Agriculture. General Technical Report, PNW-GTR-481.

Wyckoff, P.H. and J.S. Clark. 2000. Predicting tree mortality from diameter growth: a comparison of maximum likelihood and Bayesian approaches. Canadian Journal of Forest Research 30: 156-167.

Zimov, S.A., Davidov, S.P., Zimova, G.M., Davidova, A.I., Chapin, F.S., III., Chapin, M.C., and Reynolds, J.F.1999. Contribution of disturbance to high-latitude amplification of atmospheric CO2. Science, 284: 1973-1976.

Estuarine Science: A Synthetic Approach to Research and Practice (Island Press, 2000) examines the current state of synthesis in estuarine research and the data and models necessary for improving management of estuaries in the future. The book includes contributions from Charles Hopkinson and James Morris, principal investigators at the Plum Island Ecosystem LTER; Bruce Peterson, Linda Deegan and Anne Giblin from the Plum Island and Arctic projects, and Tim Hollibaugh, Robert Hodson, Alice Chalmers, and Richard Wiegert from the Georgia Coastal Ecosystems LTER.



Landscape Ecology
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emergent properties should be included in any case.

If one considers subsystems of a grand complex landscape system, then one should also consider the connectivity among the subsystems. That the whole is more than the sum of the parts is the central theme for all holistic approaches.

Thermodynamics is concerned with the laws governing the macroscopic properties of systems subject to thermal change (e.g. energy, temperature, pressure, entropy). In Erwin Schrodinger's book *What is Life?* He discusses the metabolism of a living body in terms of entropy production and entropy flow (Schrodinger, 1944). If an organism is in a steady state, its entropy remains constant over time, and, therefore, $dS=0$. As a result, the entropy production d_iS is compensated by the entropy flow $d_iS+d_eS=0$, or $d_eS= -d_iS<0$. Life is associated with entropy production and, therefore, with irreversible processes.

Patty: Wait a minute—are equations really necessary? Can't you just use English?

Larry: Basically, No. Equations are the language of mathematics. If an equation could be explained in English, there would be no need for the equations. The 'proof' must have an equation – there is some abstraction that the language of math represents. Mathematic proof is fundamentally different than physical proof. For example: In a field study, the researcher sees no black rabbits. Therefore, the statement "all rabbits in this field during this study were white" is true. But physical proof cannot guarantee the future as can math proof, which can describe what has been as well as what will be. See, math can prove the future and so in general mathematical equations cannot be reduced to natural language.

Anyway, in equilibrium thermodynamics, the second law (i.e. the law of free energy decrease and entropy production) enables stable states to be distinguished in a definite way: in a stable state the free energy has at least a local minimum, and the entropy, at least a local maximum. In the theory of open systems, the second law of thermodynamics is no longer of help, since in non-equilibrium stationary states the free energy need not have a minimum, nor the entropy a maximum.

Near-equilibrium laws of nature are universal, but when they are far from equilibrium, they become mechanism-dependent (Prigogine, 1977). Considering ecological landscapes under constant influence of stresses and disturbances, the systems definitely are in a state far from thermal equilibrium. However, current energetic and thermodynamic perspectives of ecosystem theories are all based on non-equilibrium, but linear thermodynamics. We have to rethink some of the fundamental assumptions of physical laws for complex ecological systems accordingly.

On the basis of a holistic systems view and Prigogine and Haken's theories discussed above, a synergetic theory of ecological landscape systems can be formed-a combination of holistic and mechanistic approach —together.

Now I propose four basic principles on which to build landscape ecology.

1. Landscape wholeness and hierarchy (or 'holarchy') principle - much of the above discussion already focused on the principle. A holarchically (rather than hierarchically) integrated system is not a passive system, committed to the status quo. It is a dynamic and adaptive entity, reflecting in its own functioning the patterns of change over all levels of the system. It seems to me that the term holarchy may be more suitable here.

2. Landscape antagonism principle—there is an antagonistic action between endogenic (originating inside the landscape) and exogenic (originating outside the landscape) processes. Atagnoistic processes roughly balance each other in landscape development.

3. Landscape instability or multistability principle—dissipative systems can reach conditions in which the stochastic fluctuations lead to an intrinsic instability: this is at the root of the principle. The mechanistic reason for the operation of the instability principle lies in the frequent existence of a positive feedback mechanism.

4. Landscape selection principle—those landscape forms or types are selected by geophysical-chemical, biological and climatic processes which are thermodynamically the most stable ones at near or far-from equilibrium. The natural forms and configurations in a landscape are primarily those that are most stable under their own weight. All processes within the landscape are of irreversible type, thus producing entropy. The above four principles usually will work together.

Non-equilibrium, nonlinear physics is integral to our holistic mechanistic approach. Several examples showing how such a holistic approach can help us to get a better understanding of landscape systems and their dynamics are available in the article from which this conversation is derived (Li, 2000).

Patty: The "examples" are replete with sophisticated equations so I have spared our Newsletter readers the chore of flipping quickly past them.

Larry: Yes, well… Finally, we must ask: What makes a good theoretical model? If a model can be formally constructed from a body of existing theories with the addition of any necessary new development, if the theory takes into account the dominant processes operating, and if the theories are at the scale of interest, then the new theory should be as fundamental as that from which it is derived. Unfortunately, most of our existing models in landscape ecology have only an informal link to an accepted body of theory. I believe that theoretical concepts from the basic sciences (such as physics and chemistry) and mathematics should provide foundational principles for guiding the development of theories about landscape dynamics. What I have tried to demonstrate here are the criteria I used in this holistic theoretic framework/approach, that is, an explicit mathematical physical basis, simplicity, generality, richness and the potential for scaling-up and down. This, I believe, should be our ultimate goal in developing holistic or theoretical landscape ecology.

References

Haken, H. [1977]. *Synergetics*. Springer-Verlag. Normile, D., 1999. Exploring the systems of life. *Science* 284, 80-81.

Prigogine, I., 1997. *The End of Certainty: Time, Chaos, and the new Laws of Nature.* The Free Press, New York, 228 pp.

Schrodinger, E., 1944. *What is Life?* Cambridge University Press. Cambridge, 90 pp.

Tansley, A.G., 1935. The use and abuse of vegetational concepts and terms. *Ecology* 16, 284-307.

Calendar

Coming events of interest to the LTER Community

November 20-24, 2000
Korea LTER Network will host an international joint seminar on LTER jointly with the Chinese Ecosystem Research Network (CERN) on the theme of "Ecosystem Research and Sustainable Management," co-sponsored by both the Korea Science and Engineering Foundation (KOSEF) and the National Natural Science Foundation of China (NSFC), Seoul, Korea. Contact: Dr. Zhao Shidong, co-organizer zhaosd@cern.ac.cn

March 24-26, 2001
52nd Annual Meeting of the American Institute of Biological Sciences "From Biodiversity to Biocomplexity" Washington D.C.

February 12-16, 2001
American Society of Limnology and Oceanography Annual Meeting
Albuquerque, New Mexico

July 16-20, 2001
DETECTING ENVIRONMENTAL CHANGE: SCIENCE AND SOCIETY
Organised by: NERC Centre for Ecology and Hydrology and Environmental Change Research Centre, UCL with UK Environmental Change Network, in association with The International Long Term Ecological Research Network in London, UK
The Conference will focus on the detection and understanding of long-term changes in natural and disturbed environmental systems. It will review methods of environmental change detection across different disciplines by bringing together scientists and stakeholders

August 4-9, 2001
86th Annual Meeting of the Ecological Society of America
Madison, Wisconsin

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