### Monday, May 19, 2008

**South Central Agricultural Laboratory (Clay Center)**

<table>
<thead>
<tr>
<th>Title</th>
<th>Presenter(s)</th>
<th>Page</th>
</tr>
</thead>
</table>
| *Ensuring the Environmental Sustainability of Biofuel Systems* | Ken Cassman, Director, Nebraska Center for Energy Sciences Research, UNL  
Suat Irmak, Associate Professor, Biological Systems Engineering, UNL | 5    |
| *Characterizing Recharge across Climatic and Land Use Regions of the Great Plains* | Greg Steele, Hydrologist, USGS Nebraska Water Science Center | 7    |
| *Remote Sensing and Geographic Information Systems: Tools for Climate-Change Research* | Sunil Narumalani, Professor, School of Natural Resources & Faculty Associate, Center for Advanced Land Management Information Technologies | 9    |

<table>
<thead>
<tr>
<th><strong>USGS/UNL Research Plot at Nature Conservancy</strong></th>
<th></th>
</tr>
</thead>
</table>
| *Evaluating the Role and Importance of Ecological Diversity in Creating Ecological Resilience – University of Nebraska and The Nature Conservancy* | Chris Helzer, Director of Science and Stewardship, Nature Conservancy Central Nebraska Project Office  
Craig Allen, Leader, Nebraska Cooperative Fish and Wildlife Research Unit, USGS/UNL | 11   |

<table>
<thead>
<tr>
<th><strong>Rowe Sanctuary</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Potential Risks to the Midcontinent Population of Sandhill Cranes from Climate Change</em></td>
<td>Gary Krapu, Biologist, USGS Northern Prairie Wildlife Research Center</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>USGS Woodlands Evapotranspiration Site, North Platte River</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Water Balance of Riparian Woodlands Along the Platte River, Nebraska</em></td>
<td>Dave Rus, Hydrologist, USGS Nebraska Water Science Center</td>
</tr>
<tr>
<td><em>Exchanges of Carbon Dioxide and Water Vapor in Key Ecosystems</em></td>
<td>Shashi Verma, Professor, School of Natural Resources, UNL</td>
</tr>
<tr>
<td><em>Shaping Drought on the Plains: Adding Climate Change to the Mix</em></td>
<td>Mike Hayes, Professor, School of Natural Resources, UNL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>USGS Aquifer Optimization Site</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Test Hole Drilling as Part of Aquifer Optimization</em></td>
<td>Jim Goeke, Professor, School of Natural Resources, UNL</td>
</tr>
<tr>
<td><em>Geophysics for Hydrologic Characterization</em></td>
<td>Jim Cannia, Hydrologist, USGS Nebraska Water Science Center</td>
</tr>
</tbody>
</table>
# Tuesday, May 20, 2008

## USGS Dismal River Stream Gauging Station

<table>
<thead>
<tr>
<th>Title</th>
<th>Presenter(s)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dismal River Long-term Integrated Monitoring</td>
<td>Ron Zelt, Hydrologist, USGS Nebraska Water Science Center&lt;br&gt;Bob Swanson, Director, USGS Nebraska Water Science Center</td>
<td>27</td>
</tr>
</tbody>
</table>

## Gudmundsen Sandhills Laboratory

<table>
<thead>
<tr>
<th>Title</th>
<th>Presenter(s)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welcome to the Sandhills</td>
<td>Senator LeRoy J. Louden</td>
<td>30</td>
</tr>
<tr>
<td>Overview of the Ranch</td>
<td>Don Adams, Director, UNL West Central Research and Extension Center</td>
<td>30</td>
</tr>
<tr>
<td>Hydrogeologic Investigations at Gudmundsen Sandhills Laboratory</td>
<td>Jim Goeke, Professor, School of Natural Resources, UNL</td>
<td>31</td>
</tr>
<tr>
<td>Beef Cattle Research in the Sandhills</td>
<td>Rick Funston, Associate Professor, Animal Science, UNL</td>
<td>33</td>
</tr>
<tr>
<td>Recent Insights into the Geologic History of the Sand Hills</td>
<td>David Loope, Professor, Geosciences, UNL</td>
<td>35</td>
</tr>
<tr>
<td>Rangeland Ecology and Grazing Research in the Nebraska Sandhills</td>
<td>Jerry Volesky, Associate Professor, Agronomy &amp; Horticulture, UNL</td>
<td>37</td>
</tr>
<tr>
<td>Effects of Precipitation and Groundwater on Grassland Productivity in the Nebraska Sandhills: I.) Water</td>
<td>Dave Billesbach, Professor, Biological Systems Engineering, UNL</td>
<td>39</td>
</tr>
<tr>
<td>Effects of Precipitation and Groundwater on Grassland Productivity in the Nebraska Sandhills: II.) Carbon</td>
<td>Tim Arkebauer, Professor, Agronomy &amp; Horticulture, UNL</td>
<td>41</td>
</tr>
</tbody>
</table>

## Cedar Point Biological Station

<table>
<thead>
<tr>
<th>Title</th>
<th>Presenter(s)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Nutrient Network</td>
<td>Johannes (Jean) M.H. Knops, Professor, School of Biological Sciences, UNL</td>
<td>43</td>
</tr>
<tr>
<td>The Value of Longterm Ecological Research in the Sandhills</td>
<td>Svata Louda, Professor, School of Biological Sciences, UNL</td>
<td>45</td>
</tr>
<tr>
<td>Potential Contributions of Behavior and Physiology to an Understanding of the Impact of Climate Change on Animals</td>
<td>Gwendolyn Bachman, Associate Professor, School of Biological Sciences, UNL</td>
<td>47</td>
</tr>
<tr>
<td>Using Duckweed Communities as a Model to Understand the Effect of Climate Change on Food Web Interactions</td>
<td>Chad Brassil, Assistant Professor, School of Biological Sciences, UNL</td>
<td>49</td>
</tr>
</tbody>
</table>

## Wednesday, May 21, 2008  Sandhills Conference Center, North Platte

<table>
<thead>
<tr>
<th>Title</th>
<th>Presenter(s)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation of Yukon Gap Analysis</td>
<td>Pete Murdoch, Research Hydrologist, USGS</td>
<td>51</td>
</tr>
</tbody>
</table>
Ensuring the Environmental Sustainability of Biofuel Systems
Ken Cassman, Director, Nebraska Center for Energy Sciences Research, UNL
Suat Irmak, Associate Professor of Biological Systems Engineering, UNL

Irrigated agriculture plays a critical role in economic development of the central Great Plains, and irrigated corn represents the largest use of water resources in this region. Other important irrigated crops include alfalfa, dry beans, wheat, sugar beets. With rapid expansion of biofuel production capacity in response to high petroleum prices, corn-ethanol now represents about 5% of the U.S. gasoline supply and will soon reach about 10% because corn’s highest-value use now is for biofuel compared to human food or livestock feed. This situation is likely to remain so long as petroleum prices are above $75 per barrel.

Irrigated crop production in the Great Plains is linked to climate change, water quality/quantity and wildlife habitat concerns in several ways, and these linkages present the region with a number of significant challenges:

1. The 12 million acres of irrigated crops represent the largest single use of surface and ground water in the Great Plains, and widespread deployment of irrigated land affects regional climate directly through the additional evapotranspiration released to the atmosphere compared to the native plant communities adapted to this semi-arid environment. Estimating and measuring climatic signals related to environmental change in the Great Plains must do so against the background "noise" caused by irrigated agriculture.

2. High commodity prices, due in part to use of corn for biofuel, will motivate farmers to increase crop yields and expand irrigated areas with substantial consequences for land use, water consumption and water quality. At issue is how to meet the increased demand for both food and biofuels without increasing water withdrawals, losing nitrogen and phosphorus to ground and surface water bodies, or expanding crop area to marginal land not suited for intensive crop production. To date, agriculture has not been very successful in both increasing yields and decreasing negative environmental impacts, which attests to the magnitude of this scientific challenge.

3. Because of concerns about the impact of biofuels on greenhouse gas emissions, the 2007 Energy Independence and Security Act mandates that biofuels meet GHG emission reduction targets. At issue is whether production of corn ethanol from irrigated corn in the Great Plains can meet these standards based on thorough life-cycle assessment of the corn-ethanol system. Initial results suggest they can meet these standards, but only if corn producers use highly efficient irrigation and nitrogen fertilizer management practices. Likewise, other dedicated biofuel crops, such as native perennial grasses or low-input high diversity native prairie grasses, may provide additional options for dedicated biofuel crops with a significant potential for mitigating GHG emissions.

4. Irrigated agriculture affects wildlife and wildlife habitat. Irrigated crop lands and the crop residue and grain left after harvest provide critical habitat and food for migrating birds such as the Sandhill crane and several goose and duck species. Nitrogen and phosphorus loss to surface water bodies affects the suitability of aquatic habitat for fish communities. Overuse of both surface and ground water can reduce stream flows and have negative impact on fish numbers and species diversity.

The University of Nebraska and its USDA-ARS partners have state-of-the-art research projects in progress that address each of the above issues. During the stop at the South Central Agricultural Laboratory in Clay Center, research projects that focus on the following topics will be discussed, namely: (a) how to achieve high irrigated crop yields well above current average farm yields while also reducing the amount of irrigation water and the potential for nutrient losses; (b) research on the potential for carbon sequestration in major cropping systems of the Great Plains; and (c) life-cycle assessment of biofuel systems for impact on GHG emissions and net energy efficiency, and software tools for performing certification of individual ethanol plants and their feedstock supply in relation to the new 2007 EISA renewable fuels standards.

Citations


Additional information about the Biofuel Energy Systems Simulator (BESS) and two articles, “Biofuels Food Security” and “Food & Fuel for All,” can be found elsewhere in the Workshop folder.

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Dr. Kenneth Cassman is director of the Nebraska Center for Energy Sciences Research at UNL and the Heuermann Professor of agronomy. In previous positions, Dr. Cassman has worked as a research agronomist in the Amazon Basin of Brazil, Egypt’s Nile Valley, and at the International Rice Research Institute in the Philippines. Academic appointments include seven years on the faculty at the University of California–Davis, and eight years as head of the Department of Agronomy at the University of Nebraska. His research, teaching, and extension efforts have focused on ensuring local and global food security while conserving natural resources and protecting environmental quality. Current research examines the environmental impact of biofuel systems. Dr. Cassman received a Ph.D. (1979) from the University of Hawaii’s College of Tropical Agriculture, and a B.S. degree in biology from the University of California, San Diego (1975). He is a fellow of the American Association for the Advancement of Science, the American Society of Agronomy, the Crop Science Society of America and the Soil Science Society of America.

Dr. Suat Irmak is an associate professor in UNL’s Department of Biological Systems Engineering. He received his Ph.D. degree in agricultural and biological engineering at the University of Florida with emphasis on land and water resources engineering.

Although he has statewide responsibilities, Dr. Irmak conducts most of his research at the South Central Agricultural Laboratory (SCAL) near Clay Center. He provided leadership in the development of UNL’s SCAL water management research facility, regarded as one of the premier center pivot, subsurface-drip irrigation and evapotranspiration research facilities in the U.S. His research and Extension programs evolve around application of engineering fundamentals in water resources engineering, including irrigation engineering, measurement of surface energy balance components, microclimate effect on crop production, crop water stress and yield relationships. He has established two subsurface drip irrigation systems to study the hydraulics and dynamics of irrigation and fertigation for corn and soybeans. He installed a 4-span hydrostatic and continuous-move center pivot irrigation system to develop deficit irrigation best management practices and measure crop water use and crop coefficients for eight corn hybrids.
Characterizing Recharge across Climatic and Land Use Regions of the Great Plains

Greg Steele, Hydrologist, USGS Nebraska Water Science Center
with J.J. Gurdak, and J.C. Cannia

Managing Water Resources

Successful management of the ground water and surface water during a time of potential climatic change in the Great Plains relies on understanding its water budget. Computer-based hydrologic models can aid in understanding these resources, including the complex interaction of ground and surface water, and in forecasting future climatic and anthropogenic impacts. One such ground-water flow model, the U.S. Geological Survey’s (USGS) regional aquifer-system assessment (RASA) covers the entire High Plains aquifer (figure 1) and is planned to be re-evaluated in 2009. Another regional scale model was developed by the Nebraska Platte River Cooperative Hydrology Study (COHYST) and covers about 30,000 mi².

Importance of Recharge

If a ground-water flow model is properly conceived and calibrated, then it may effectively support environmental management decisions. Recharge is an important model input about which little field data is usually available. Furthermore, alternative conceptual models abound as to whether recharge variations are driven more by changes in climate or land use. Yet, the magnitude of recharge typically is over- or underestimated, sometimes by more than an order of magnitude.

Recharge, in the context of a ground-water model, refers to the amount of water infiltrating the land surface, moving downward through the soil and ultimately reaching the water table to replenish the aquifer. Recharge rates vary under different land-use and geologic settings, and they also vary temporally in response to natural climate variability or climate change. Accurate measurement of recharge rates is challenging because there are no easy or direct methods to observe water movement that reaches the water table, which may be tens to hundreds of feet below land surface across the Great Plains.

Unsaturated-Zone Research Network

Beginning in 2000, the USGS High Plains Unsaturated-Zone Research Network (figure 1) has been used to measure water, chemical and gas movement through the unsaturated zone and to test hypotheses regarding climatic and land-use controls across the High Plains aquifer (McMahon et al., 2006; Gurdak et al., 2007). Data from this network are used to understand the rates and chemical quality of recharge under important land-use practices, such as irrigated cropland and natural grassland, and across the dominant climate gradients of the region.

Research Capabilities

The instrumentation at most sites in the network includes multiple nested-suites of suction lysimeters and gas-sampling ports to collect and measure the chemistry of unsaturated water and gas. Heat dissipation probes are used to measure real-time changes in temperature and water content to understand recharge rates and chemical transport. A pressure transducer records real-time changes in

Figure 1. Approximate location of proposed recharge sites and existing USGS recharge
water level within a shallow-monitoring well. During installation, sediment cores are collected for analyses of water content, hydrologic properties, and isotopes of water and nitrate that are necessary for computer modeling and to understand the sources and processes of nitrate reservoirs and transport in the unsaturated zone.

Additionally, selected sites have weather stations to collect weather parameters, including temperature, precipitation, wind speed/direction, barometric pressure, humidity and evaporation. The coupled weather and unsaturated-zone monitoring enable understanding of recharge and chemical transport responses to climate variability and change. For example, recent (2003 and 2004) episodic deep-percolation events and subsequent mobilization of unsaturated-zone nitrate and chloride reservoirs were recorded with the network (Gurdak et al., 2007). Future mobilization of these large chemical reservoirs could have substantial effects on ground-water quality.

**Collaboration and Partners**

Although originally designed for the USGS High Plains regional ground-water quality study (http://co.water.usgs.gov/nawqa/hpgw/HPGW_home.html), recent collaboration with the Central Platte Natural Resource District (CPNRD) has provided an opportunity for expansion of the network and installation of eight new sites (two sites in 2007; three in 2008; and three in 2009) in the COHYST model area. In addition, these new sites will help provide recharge information to improve the predictive accuracy of the COHYST ground-water models. Other previous and on-going partners include Kansas State Geological Survey and Texas Bureau of Economic Geology.

**References**


Remote Sensing and Geographic Information Systems: Tools for Climate-Change Research

Sunil Narumalani, Professor, Natural Resources and Faculty Associate, the Center for Advanced Land Management Information Technologies (CALMIT)

Geospatial technologies such as remote sensing and geographic information systems are important tools in research aimed at climate change. The Center for Advanced Land Management Information Technologies (CALMIT) at UNL is uniquely equipped and staffed to undertake cutting-edge approaches in climate-change research. Current investigations include analyses focused on linking spectrally derived quantitative indices with biophysical characteristics of vegetation such as leaf area, an important input to climate models. CALMIT researchers are also monitoring selected Nebraska lakes with an airborne hyperspectral imaging sensor to identify toxic algae, a potential environmental response to changing climate patterns. With linkages to the National Drought Mitigation Center (NDMC), CALMIT scientists are engaged in projects that utilize satellite imagery for a variety of vegetation studies that address drought-related issues. The Center operates state-of-the-art field and aircraft sensors and systems for monitoring and analyzing the Earth’s surface.

The Airborne AISA-Eagle Imaging Spectrometer

Introduction: The Center for Advanced Land Management Information Technologies (CALMIT), School of Natural Resources, University of Nebraska-Lincoln, owns and operates the Airborne Imaging Spectrometer for Applications (AISA)-Eagle remote sensor. The AISA-Eagle is a product of Specim, Ltd., Oulu, Finland.

Technical Specifications: The sensor field of view (across track), provides for 1000 pixels per swath. The spectral sensitivities are from 400 to 970 nm, and the system is programmable from 1 to 512 spectral channels. The typical spectral configuration, for spatial resolutions of 1 or 2 meters, allows data collection in approximately 95 individual channels in the visible and near-infrared. The high spectral resolution of the system allows users to work with both color images of ground features and diagnostic spectral profiles that facilitate target identification and diagnoses. The system allows for placement of spectral channels as well as particular band-widths from 2 to 10 nanometers. An upward-looking fiber optic captures downwelling irradiance to facilitate calculation of radiance or apparent at-platform reflectance. Integrated differentially corrected GPS and an inertial navigation system allow for image geo-referencing. Aircraft pitch, roll, and yaw are encoded in the data stream.

Applications: The AE sensor has been flown by CALMIT for a variety of applications ranging from agriculture to coral reefs. The nature of an imaging spectrometer, providing both images and diagnostic spectral profiles, means that the system can be used for not only mapping / monitoring projects but also basic research.
**Data Processing:** Mission post-processing options include atmospheric correction and data output as radiance and/or at-platform reflectance in RSI-ENVI format. Additional products are available upon request.

**Examples AISA Imagery and Associated Spectral Profiles**

AISA image (false-color composite) of Tate’s Hell, Apalachicola Bay, Florida, acquired by CALMIT on October 17, 2002. The upper portion of the image is upland forest while the lower portion is marsh.

Spectral profiles for marsh pixels contained in the image at left. Compare to spectra for upland forest (lower left).

Spectral profiles for upland forest pixels contained in the AISA image above. These spectra were developed by means of RSI-ENVI software and pointing at pertinent pixels in the forest area of the image at left.

AISA image (false-color composite) of Bangs Lake, MS. Acquired by CALMIT in October of 2002.

Dr. Sunil Narumalani is a professor in the School of Natural Resources, and a full-time faculty associate at the Center for Advanced Land Management Information Technologies (CALMIT), University of Nebraska–Lincoln. He received his Ph.D. in geography from the University of South Carolina in 1993. Dr. Narumalani has taught courses in physical geography, and introductory/advanced remote sensing and GIS and has mentored 15 M.A. and 5 Ph.D. students. His research focuses on the use of remote sensing for the extraction of biophysical information, integration of geospatial data for biogeographical mapping and monitoring, and development of new image analysis techniques. Dr. Narumalani has 33 refereed publications and has authored/co-authored well over 50 papers delivered at meetings of the AAG, ASPRS, IGARSS and elsewhere. He has received several awards including an award from the 3436th Military Intelligence Detachment for geospatial assistance, the ASPRS Autometric Award for Outstanding Paper, and the University of Nebraska Certificate of Recognition for Contributions to Students.
Evaluating the Role and Importance of Ecological Diversity in Creating Ecological Resilience – University of Nebraska and the Nature Conservancy

Chris Helzer, Director of Science and Stewardship, Nature Conservancy Central Nebraska Project Office
Craig Allen, Leader, Nebraska Cooperative Fish and Wildlife Research Unit, USGS/UNL

We are evaluating the way in which biological diversity in grasslands increases the ecological resilience of those systems and their ability to withstand threats associated with rapid climate change.

Grasslands provide:
- Habitat for thousands of plant and animal species
- Agricultural production (grazing, haying, etc.)
- Ecological services – pollination, pest control, carbon storage, water infiltration

Big Picture

There are many threats to grasslands and their ecological functions. The most severe of these include invasive species and the fragmentation and isolation of habitat patches. These threats are likely to increase in scope and severity with rapid climate change. Building and maintaining the resilience of grassland ecosystems is critically important if we are to sustain the services those grasslands provide to both humans and nature.

Theory suggests that biological diversity is one of the keys to ecological resilience in natural systems. Because biological diversity is maintained through land management, it is essential to design and test management practices that are both effective and practical. However, to mitigate the negative impacts of habitat fragmentation and isolation, we must also increase the size and connectivity between grassland patches with restoration. To fully restore ecological function, restoration must entail more than simply replanting grasses around and between grassland fragments. Prairie restoration methods have evolved to the point where high-diversity grassland communities can be restored over large areas, but those methods are expensive and time-consuming. We need to understand the relative benefits of high-diversity vs. low-diversity restoration methods in order to make intelligent conservation decisions in the face of a changing world.

Diversity Plots

To investigate the importance of biological diversity at a relevant spatial scale, we established 24 research plots of ¾ acre each in the spring of 2006. Within the plots there are four seeding treatments. Two treatments (12 plots) were seeded with 100 species of plants and two were seeded with 15 species. In addition, two different seeding rates (high and low) were used for each of the diversity mixes. The result is the following four treatments: High-diversity/low seeding rate, High-diversity/high seeding rate, Low-diversity/low seeding rate, Low-diversity/high seeding rate.

The 15 species mixture follows the requirements for the Natural Resource Conservation Service’s CP-25 seeding standard, a commonly-used seeding for wildlife habitat purposes. This will allow us to better evaluate the long-term benefits of an existing practice used on private lands as well as one used mainly on conservation land.

Resistance to Invasion

Within the 24 plots, we are looking for differences in the abundance and spread of two invasive species between treatments, sweet clover and bull thistle. Both species were present prior to the seeding and we are monitoring their spread over time.

In addition, we introduced an invasive perennial grass, smooth brome, by both seed and transplant methods to measure differences between treatments in rate of spread and “invisibility” with that species. This is being done in a carefully controlled manner to allow us to remove the brome, if necessary, before it completely takes over the site.

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H = High Diversity
L = Low Diversity
2 = High Seeding Rate
1 = Low Seeding Rate
**Soil Development**
We are looking for differences in the way soils develop over time between the treatments. Particularly, we are looking at carbon, nitrogen, nitrate and ammonium levels.

**Invertebrates**
We will be looking for differences in the abundance and diversity of above-ground predatory and herbivorous insects and below-ground invertebrates (nematodes) between treatments and also looking at the ratio of predators to prey. Invertebrates profoundly affect vegetation structure, decomposition rates, primary production, pollination and soil development. In addition, predator populations are important for maintaining a balance of predator/prey numbers both in prairies and adjacent agricultural areas.

**Related Research Projects**

*Pollination and Insect Herbivory (TNC, UNL, UNO)*
In 2008 we are following up on a pilot study we did in 2005 that showed higher pollinator visitation rates to flowers in high-diversity grassland restorations as compared to degraded pastures. In addition, a current graduate student project with the University of Nebraska-Omaha is showing higher rates of insect herbivory in degraded pastures than in high-diversity restorations, and we are evaluating the implications of that.

*Patch-Burn Grazing (TNC)*
We are evaluating a grassland management technique called patch-burn grazing that appears to increase biological diversity and habitat quality while maintaining livestock production. The technique is being tested in both restored and remnant prairies.

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Chris Helzer is the Eastern Nebraska Program Director for The Nature Conservancy. Chris has worked for the Conservancy since 1997, mostly as a land steward and ecologist. Besides overseeing the restoration and management of approximately 5,000 acres of Conservancy-owned land along the Platte River, he also works to develop, test and export grassland restoration and management techniques. Chris has particular expertise in high-diversity grassland restoration and patch-burn grazing.

Chris graduated from the University of Nebraska-Lincoln with a B.S. in forestry, fisheries and wildlife in 1994 and an M.S. in natural resources (landscape ecology emphasis) in 1996. He is based in Aurora, Nebraska, where he lives with his wife and three children.

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Craig Allen is the unit leader for the Nebraska Cooperative Fish and Wildlife Research, located at the University of Nebraska–Lincoln. Before coming to Nebraska, he was the unit leader for the South Carolina Cooperative Fish and Wildlife Research Unit and an associate professor in the Department of Forestry and Natural Resources and the Department of Biological Sciences at Clemson University.

Dr. Allen received his Ph.D. in wildlife ecology and conservation from the University of Florida in 1997, an M.S. in wildlife science from Texas Tech University in 1993 and a B.S. in biology from the University of Wisconsin–Green Bay in 1989. He held a post-doc position in zoology at the University of Florida, working with C.S. Holling on investigations of the relationships between diversity and resilience, and variability and scale breaks in biological and other systems. He was born in Berkeley, California, raised mostly in Madison, Wisconsin, and also has lived in South Hampton and Oxford, England, and Katwijk Aan Zee, the Netherlands.
Potential Risks to the Midcontinent Population of Sandhill Cranes from Climate Change

Gary Krapu, Biologist, USGS Northern Prairie Wildlife Research Center

The Central Platte River Valley (CPRV) is the primary spring staging area for the midcontinent population (MCP) of sandhill cranes, which contains ~600,000 birds. Cranes acquire a major part of fat reserves used to meet their energy requirements for migration and reproduction during the annual spring stopover. I began to study sandhill cranes in 1977 after encroachment of woody vegetation on river channels in the CPRV led to concerns that declining flows in the Central Platte may be adversely affecting MCP sandhill cranes. From this project, a final report and series of papers were published that addressed the habitat needs and nutritional requirements of sandhill cranes during their stay in the CPRV.

By the mid-1990s, a new list of information needs had surfaced, in part in response to evidence that sandhill cranes were having difficulty securing their nutrient needs while in the CPRV. In the same period, Central Flyway sandhill crane managers approached NPWRC requesting research to gain a detailed understanding of the geographic distribution and habitat needs of the MCP throughout the annual cycle. In 1997, sandhill crane studies to address both information needs began under the USGS Central Platte Priority Ecosystem Study.

To gain a detailed understanding of the geographic distribution of the MCP throughout the year, we took advantage of recent advances in satellite telemetry to deploy PTT tags on a representative sample of MCP cranes and monitor their distribution throughout the annual cycle. With this new technology, we delineated 4 subpopulations; estimated subpopulation sizes; identified major breeding grounds (Fig. 1), migration routes, spring- and fall-staging areas and wintering locations; and obtained precise information on when cranes from each known breeding affiliation used a specific area. With a detailed knowledge of the distribution of the MCP throughout the annual cycle has come a better understanding of habitat needs and an increased awareness of how global climate change may affect sandhill cranes.

Research on sandhill cranes during their spring stopover in the CPRV has focused primarily on defining dietary and roost-site needs of the birds during their annual spring stopover, determining length and pattern of use by each subpopulation, and identifying factors influencing availability of resources cranes require during their stay in the CPRV.

Research on crane feeding ecology in the CPRV has shown the birds are continuing to rely almost exclusively on waste corn, as in the 1970s, to meet their maintenance energy requirements and for fat synthesis. From the 1970s to the 1990s, waste corn available to sandhill cranes underwent a major decline (Fig. 2) due to improved harvest efficiency, a major increase in numbers of snow geese stopping in late winter and early spring in the CPRV, and increased planting of soybeans, a crop poorly suited to meeting crane nutrient needs. As a result of declining availability, waste corn is no longer available in excess of crane needs, and as a result, fat...
storage is now inversely related to crane size in contrast to the 1970s (Fig. 3). With the aid of satellite telemetry, we have established that virtually all of the MCP stops along either the Central Platte or North Platte Rivers in March to build fat reserves, including cranes that winter as far west as Arizona and fly an extra 1,000 miles to Nebraska to meet nutritional needs for migration and reproduction.

From information identifying resources needed by the MCP and the role of the CPRV in providing needs of the population, an opportunity exists to explore potential risks to the MCP from global climate change. At first glance one might conclude that sandhill cranes are among the least likely species to be at risk from global climate change. After all, the species has survived through periods of extreme climate change. Recent genetic studies suggest that greater and lesser sandhill cranes that form the MCP split from a common ancestor 1.2-2.3 million years ago. The species survived continental glaciers covering a major part of North America several times and did so in the presence of a wide array of formidable predators. Also, sandhill cranes have been exceptionally successful in adapting to an extreme range of environments as reflected in a breeding range that extends from tropical savannah in Cuba to the tundra of Banks Island in the high arctic of Canada.

Despite sandhill cranes being a highly successful species, our research findings suggest several potential risks to the birds from the combined effects of global climate change and existing development pressures. In my presentation, I will address how our research findings on sandhill cranes relate to global climate change and explore avenues by which predicted changes in climate could adversely affect the MCP.

Gary L. Krapu has been a research biologist at the USGS Northern Prairie Wildlife Research Center at Jamestown, North Dakota, since 1970, where his research has centered on identifying habitat requirements and factors limiting populations of sandhill cranes, waterfowl and arctic-nesting shorebirds.

A native of North Dakota, Dr. Krapu received a B.S. in zoology at North Dakota State University in 1966 and both M.S. and Ph. D. degrees in animal ecology from Iowa State University at Ames in 1968 and 1972, respectively. His research has focused primarily on migratory birds on their breeding grounds and migration stopovers in the central and northern Great Plains. Research on the mid-continent population of sandhill cranes over the past decade has included data collection over the species’ entire range from wintering grounds in Mexico to breeding sites throughout central and northern Canada, Alaska and northeastern Russia. He began his sandhill crane research in the Central Platte River Valley in 1977 and continues his studies there.

Dr. Krapu has published about 100 peer-reviewed scientific papers from his migratory bird research and currently is preparing three monographs on sandhill cranes, including one that focuses on his long-term research in the Central Platte River Valley, Nebraska.
Evapotranspiration (ET) in riparian areas is a poorly understood component of the regional water balance in the Platte River Basin, where competing demands have resulted in water shortages in the ground-water/surface-water system. From April 2002 to March 2006, the U.S. Geological Survey and Nebraska Platte River Cooperative Hydrology Study Group conducted a micrometeorological study of water and energy balances at two sites in central Nebraska near Odessa and Gothenburg, to improve understanding of ET rates and factors affecting them in Platte River riparian woodlands. Because much of the riparian woodlands are comprised of phreatophytes that have the capability of directly using ground water, a secondary objective of the study was to use the water balance to constrain estimates of ground-water ET demands in these areas.

Both study sites are located on large islands within the Platte River characterized by a cottonwood-dominated forest canopy on primarily sandy alluvium. The water balance at each site included measurements of ET, precipitation, soil-moisture storage and ground-water storage. ET was determined from eddy covariance sensors installed on towers 27.4 meters tall. Precipitation was measured using tipping-bucket rain gages. A series of sensors measured soil-moisture availability within the unsaturated zone in two different profiles at each site. Ground-water levels were monitored to infer changes in ground-water storage. The energy balance at each site was characterized to ensure accuracy of the ET values, and included measurements of net radiation, latent-heat flux, sensible-heat flux, soil-heat flux and plant-heat storage.

During the study, ET was less variable than precipitation. Annual ET fluctuated about +/- 7 percent from the four-year average, ranging from about 514 to 586 millimeters per year (551 on average) at the Odessa site and 535 to 616 millimeters per year (575 on average) at the Gothenburg site. Conversely, annual precipitation fluctuated by about +/- 35 percent from the study average and long-term average, ranging from 429 to 844 millimeters per year at Odessa (30-year average of 630 millimeters) and 359 to 791 millimeters per year at Gothenburg (30-year average of 560 millimeters). Between 9 and 12 percent of this precipitation was intercepted by the forest canopy before it could infiltrate into the soil.

For the 4-year period, annual ground-water recharge from the riparian zone averaged 76 and 13 millimeters at Odessa and Gothenburg, respectively, to satisfy the water balance at each site. This indicates that, from an annual perspective, ground-water reductions caused by riparian ET were minimal during the study. This effect varied somewhat and was primarily influenced by fluctuations in precipitation.

During the driest study year (2002), ground-water discharge occurred, whereas ground-water recharge occurred from 2003 to 2005. These results do not exclude ground water as an important source of water to riparian vegetation during high ET periods in the summer, particularly during periods of lower than normal precipitation. However, the calculations indicate that, on an annual (or longer) net-flux basis, ground-water use by riparian woodlands was balanced by periods of recharge from excess precipitation at other times of the year. In contrast to more arid settings, where literature indicates that ground water may supply a large fraction of the water used for ET by riparian vegetation, precipitation along the Platte River of Nebraska was great enough—and generally greater than ET—that most or all of the annual ET demand was satisfied by available precipitation.

Simple-linear-regression and multiple-linear-regression models between explanatory variables and ET indicated that the relation of ET to environmental factors was different on days with precipitation than on dry days. At Odessa, ET was influenced by vapor-pressure deficit, solar radiation, air temperature, leaf-area index and depth to water on days without precipitation, but only by solar radiation and leaf-area index on days with precipitation. At Gothenburg, ET was a function of vapor-pressure deficit, solar radiation and leaf-area index regardless of precipitation, but air temperature also became important on days without precipitation.

Despite phreatophytic vegetation paired with shallow ground water, measured ET was substantially less than potential ET (based on the modified Penman method), consistent with plant-stomatal regulation of
ET in response to environmental and meteorological factors. Although annual ET rates generally were similar, the two sites exhibited different patterns with respect to moisture availability and its effect on ET and vegetation health. Smaller seasonal declines in ground-water levels and a lack of understory shrubs at the Gothenburg site as compared to the Odessa site may explain why Gothenburg ET persisted later into the summer and was not dependent on depth to water (as identified by the multiple-linear regression model). These differences also may explain why, during years of increased precipitation, ET rates increased at Odessa but not at Gothenburg.

Dave Rus is a graduate of the University of Nebraska–Lincoln with a degree in biological systems engineering, and says he is presently on the “10-year plan” working toward a master’s degree. He has been a hydrologist with the USGS Nebraska Water Science Center since 1998. He has authored or co-authored papers on fluvial geomorphology, aquifer characterization, floodplain modeling, riparian evapotranspiration, sediment loading and holistic water-quality assessments. A native Nebraskan, Mr. Rus is married with two young children. He recently traded in his pickup for a minivan.
Exchanges of Carbon Dioxide and Water Vapor in Key Ecosystems

Shashi Verma, Professor, School of Natural Resources, UNL

Objectives

- Quantify net ecosystem exchange of mass and energy (CO₂, water vapor, and heat) in major ecosystems: seasonal and interannual variability.
- Improve our basic understanding of biophysical processes that govern CO₂ and water vapor exchanges in these ecosystems.
- Test and improve terrestrial biosphere models of CO₂, water, and energy exchanges.

Tower Flux Studies

Landscape-level (Eddy Covariance)
Measurement of CO₂ and Other Fluxes

Measuring Components of Solar Radiation

Close-up of Eddy Covariance Flux Sensors

Seasonal and Interannual Variability:
Daily Net Ecosystem CO₂ Exchange (NEE)
Maize & Soybean: Irrigated & Rainfed
Mcad, Nebraska

Site 1
Irrigated Continuous Maize

Site 2
Irrigated Maize-Soybean Rotation

Site 3
Irrigated Maize-Soybean Rotation
Dr. Shashi Verma is a Charles Bessey Professor in the School of Natural Resources at UNL. His research interests include micrometeorology/biometeorology, carbon sequestration, atmospheric trace gas dynamics and evapotranspiration. For the past seven years, Dr. Verma has led an interdisciplinary research program (involving 15 faculty members from six UNL departments) on carbon sequestration. The goal of this research program is to improve our understanding of relevant biophysical factors controlling carbon sequestration in dryland and irrigated agroecosystems. Dr. Verma also collaborates with many scientists in North America and Europe to help synthesize results on carbon dioxide, water vapor and energy fluxes from a variety of ecosystems (e.g., agricultural crops, grasslands, forests).
Shaping Drought on the Plains: Adding Climate Change to the Mix
Mike Hayes, Professor, School of Natural Resources, UNL

The National Drought Mitigation Center's mission is to reduce societal vulnerability to drought. We advocate mitigation -- taking steps ahead of time, such as gathering data and planning, to reduce drought's impacts. Drought is a normal part of virtually every climate on the planet, although its characteristics differ from place to place. We can't prevent it and we usually can't predict it, but we can reduce our vulnerability to it. Drought mitigation includes monitoring rain and other components of water supply, understanding drought's impacts, and coordinated planning.

Monitoring: Recognizing Drought Before It's Too Late

Drought is a shortfall of precipitation. Because normal precipitation varies greatly from one place to another, the National Drought Mitigation Center (NDMC) recommends that decision-makers at all levels, from farm or ranch to federal agency, adopt a definition of drought based on their specific water supply and uses. They should know ahead of time what normal precipitation is for a given place and season, and they should know how they will recognize an emerging drought. Even though drought is a slow-moving disaster, people are much better off when they act on an early warning instead of waiting until there is a full-blown crisis. For example, farmers may choose to plant less, or to plant more drought-resistant crops. Ranchers may decide to reduce herd sizes. A homeowner might wait to plant a new lawn.

Impacts: Identifying and Reducing Exposure to Risk

Knowing drought's effects in an area helps policymakers, agricultural producers, and others be better prepared and less vulnerable to future drought. When planners use risk management to prepare for drought, they examine impacts to learn where the greatest losses occur and what actions might be most effective in reducing risk. Examples of actions to reduce drought risk could include changes in agricultural or energy policy, changes in zoning and land use laws, building a water treatment plant, and teaching people about alternatives to thirsty lawns.

Planning: Leadership and Education

The United States has no single water policy. State laws vary, River system managers, local water suppliers, and individual agricultural producers each have different decision-making authority. When the NDMC consults with state, tribal, and foreign governments on drought planning, we recommend that drought monitoring and impact analysis be part of a task force led by the executive office. We also advocate teaching private citizens, students, business owners, farmers, ranchers and others about water, drought management, and the interconnections between urban, rural and uncultivated land. This helps build a base of support for policy that is based on the best available information about natural resources, and increases the likelihood that individual decisions will reflect the understanding that water is a limited renewable resource. One of the most difficult messages to convey is that certain growth patterns may increase vulnerability to drought, either by straining limited water supplies or by reducing the ability of an area to handle variation in precipitation and climate.
Abstracts, page 20 of 52

Drought Monitoring Provides Early Warning, Triggers Aid

U.S. Drought Monitor

The U.S. Drought Monitor has been operational since 1999 and is widely used by media and policymakers. It synthesizes many indicators and a vast amount of data into a single map that is released each Thursday morning. The Drought Monitor is used to trigger drought aid such as a tax deferral on livestock losses in 2005, the U.S. Department of Agriculture (USDA) Livestock Assistance Program in 2006, the USDA Dried Milk Program in 2002-03, and the release of land from the Conservation Reserve Program for emergency haying and grazing.

The U.S. Drought Monitor is the work of nine rotating authors and 240 reviewers across the country. It physically resides on servers at the National Drought Mitigation Center in Lincoln, Nebraska. Drought Monitor authors work for the NDMC, the National Oceanic and Atmospheric Administration, and the USDA. It is based on real-time data from automated rain, snow, soil moisture and streamflow networks, on purely statistical drought indices, on reported impacts, and on the authors' best judgment.

Since it first became operational, the Drought Monitor has undergone continual refinement, working toward meeting the demand for information at ever-finer spatial scales. It has also gone international. A North American Drought Monitor, produced monthly in partnership with Canada and Mexico, became operational in 2003.

Related tools under development with sponsorship from the USDA's Risk Management Agency include the Drought Monitor-Decision Support System, which will integrate several tools and types of data, and the Drought Atlas, with historic drought information.

Vegetation Drought Response Index (VegDRI)

The Vegetation Drought Response Index (VegDRI) is expected to have its first fully operational growing season in 2008, covering 22 central and western states, and expanding to the eastern 26 in 2009. VegDRI is based on data from satellites and incorporates many variables to show whether grass and crops are drying out. It is expected to be of greatest use to ranchers and land managers. The NDMD is developing VegDRI in conjunction with the U.S. Geological Survey's Center for Earth Resources Observation and Science, and with sponsorship from the USDA's Risk Management Agency.

A related effort, the Vegetation Outlook (VegOut), is experimental. Based on satellite data and other variables, it projects current conditions and patterns several weeks into the future.

Standardized Precipitation Index

Depending on what type of pattern someone is looking for, there are many ways to view climate data. The Standardized Precipitation Index (SPI) is particularly good at detecting drought on a variety of time scales. The NDMD has produced a suite of monthly SPI maps since 1996. More recently, we are working with the High Plains Regional Climate Center to provide a Daily Gridded SPI, with data updated each day.
Tracking Impacts Helps Planners Reduce Risk

Drought Impact Reporter

The Drought Impact Reporter (DIR) tracks drought’s impacts for researchers, planners, policy makers, and the general public. It first became operational in July 2005. Right now, media reports are the main source of impact data. Meteorologists call impacts from hundreds of news stories generated by an automatic clipping service each week, and associate them with affected states and counties.

The DIR is online at http://droughtreporter.unl.edu. Users can drill down to the state and county level. When the cursor hovers over a state or county, a statistical summary of impacts by category appears in a small box on the screen.

Now, based on more than two years of experience and user input, the DIR is undergoing substantial refinement, with a new look and new functionality expected to be online in summer 2008. DIR 2.0 will use a more sophisticated, fully searchable database. The new system will distinguish between reports and impacts, capturing early indicators of drought reflected in media before quantifiable losses are incurred. Systematic sampling of media outlets will provide a way to benchmark baseline drought awareness.

The new system will be well equipped to handle input from a variety of federal and state networks as well as individual users. The NDMC is currently working with the states of Arizona and Hawaii to develop ways to combine their local impact gathering with our nation-wide reporting system. We are also undertaking discussions with CoCoRaHS to connect their network of 9,000 weather observers to the DIR.

The NDMC is developing the DIR with sponsorship from the Risk Management Agency and the National Oceanic and Atmospheric Administration.

Economic Impacts of Drought

The NDMC and partners are devising a method to quantify economic impacts of drought, with sponsorship from the USDA’s Risk Management Agency. Direct agricultural losses are relatively well understood, but inconsistent mixes of production losses, indemnity payments, and relief costs are often quoted by the media and misused by decision makers. Drought’s effects on other profit making sectors such as energy and tourism and recreation are less frequently addressed.

In the diagram at right, area “B” denotes hypothetical agricultural drought impacts. In this case, farmers’ revenue losses do not tell the whole story. Drought-induced losses are not completely borne by farmers. Consumers pay higher prices, too, and farmers may receive crop insurance payments and/or direct disaster aid from the federal government. Higher prices may also attract goods from other areas, particularly in a national or global market, so that producers in non-drought areas may benefit from the drought.
Dr. Michael Hayes became the director of the National Drought Mitigation Center in August 2007 and has worked at the NDMC since 1995. The NDMC now has 20 faculty and staff working on local, tribal, state, national and international drought- and water-related issues. Dr. Hayes is also an associate professor in the School of Natural Resources at the University of Nebraska-Lincoln. His responsibilities include conducting research on the economic, environmental and social impacts of drought; developing new drought monitoring and impact assessment methodologies; assisting states and American Indians tribes with the development and review of drought plans; and helping to organize and conduct drought workshops and conferences. Dr. Hayes received a bachelor’s degree in meteorology from the University of Wisconsin-Madison, and his master’s and doctoral degrees in atmospheric sciences from the University of Missouri-Columbia. Dr. Hayes also spent a short time working with the National Biological Service investigating the impacts of climate on endangered plant populations in the central U.S.
Test Hole Drilling as Part of Aquifer Optimization
Jim Goeke, Professor, School of Natural Resources, UNL

Since the early 1930s, the Conservation and Survey Division (Nebraska State Geological Survey) has drilled about 5500 test holes to survey the geologic and water resources of Nebraska. Most of this drilling has been done through a cooperative program with the United States Geological Survey.

Test hole cuttings are collected through a well developed field process and transferred to Lincoln where they are dried, split and stored. Field descriptive logs are kept in a standard format and also filed in Lincoln. Test hole log summaries are available for many Nebraska counties. In addition to these test holes, drillers logs are available through the Nebraska Department of Natural Resources for most of the 104,908 irrigation wells and for over 40,469 smaller capacity domestic and stock wells drilled since 1993. Regional hydrogeologic studies and groundwater models depend on data from these test holes to characterize the aquifers and geology of Nebraska.

In 1992 E. Gilroy, USGS statistician, said, "All models are wrong, some are useful...". By this comment he acknowledges both the complexity of most stream/aquifer systems and the need to simulate these essential systems for future water use.

At the Lexington site the aquifer optimization started with drilling test holes to characterize the aquifer. The test hole for the production well was drilled to a depth of 460 ft. The depth to water is about 40 ft., and the production well was drilled to 430 ft., providing a saturated thickness of 390 ft.

The test drilling procedure developed over decades is designed to provide the most accurate characterization of the subsurface materials possible. Accurate land surface elevation is essential and provided by either 7.5 minute topographic maps or GPS measurement or both. With an accurate legal location and elevation pits were dug to mix drilling mud and collect excess cuttings. A bentonitic mud with polymers was mixed with a viscosity of 38-40 seconds by Marsh funnel. Drilling was in 5 ft. intervals, with a delay every 5 ft. to make sure cuttings were separated. Samples were broken out in 5 ft. intervals or less as determined by color or composition combined with drilling action. Sample intervals were also determined by much communication between the driller and the sample collector.

Close by the drill rig at a sample table, the recorder times how long it takes to drill each 5 ft. interval. In addition he notes drilling action, hydraulic pressure, and calcareous content. The 5 ft. interval is brought to the sample table as a single sample or in intervals less than 5 ft., and each interval is described and bagged with a label identifying the sample interval. Before bagging, each interval is described as to the material, grain size and distribution, texture, hardness, color, and any other pertinent details. Wet colors are estimated using a Munsell Soil Color chart. Bagged samples are taken to Lincoln for preparation and archiving.

Standard Conservation and Survey/USGS drilling procedure includes running downhole SP (spontaneous potential) and resistivity electric logs, but on this project these and other more advanced downhole and surface geophysical logs were employed to build on the test hole drilling to better characterize aquifer parameters. In addition, extensive aquifer pump tests are being performed to provide a complete characterization of aquifer hydraulic parameters.

Jim Goeke is a research hydrogeologist with the University of Nebraska-Lincoln’s Institute of Agriculture and Natural Resources and Conservation and Survey Division, stationed at UNL’s Research and Extension Center at North Platte. Goeke works with local agencies, and individuals to identify, monitor and manage groundwater problems. He also assists in developing groundwater supplies, as well as defining and interpreting regional geology. His current research includes a base line water quality study with the Twin Platte Natural Resources District; a meadow hydrology study at the 12,500-acre UNL Gudmundsen Sandhills Research Laboratory located five miles northeast of Whitman; and an assessment of the effects of groundwater pumping on the flow of the Republican and Platte Rivers. Since 1985 he has been the site manager for the North Platte Acid Rain Station, and he recently initiated a dioxin monitoring station. Goeke received his B.S. in geology from the University of Wisconsin in 1966 and his M.S. in
groundwater geology from Colorado State University in 1970. From 1970-76 he worked for the UNL Conservation and Survey Division in Lincoln where he was in charge of the state’s test drilling program across much of Nebraska. Since 1976, he has been involved in groundwater studies in the Sandhills and the Republican Valley. He also has been active in local and regional tree planting activities and in 1995 received the Nebraska Statewide Arboretum Tree Planters State Award and the Nebraska Forest Service State Foresters Award. Goeke is a member of numerous state and national organizations.
Geophysics for Hydrologic Characterization

Jim Cannia, Hydrologist, USGS Nebraska Water Science Center

In cooperation with the Central Platte Natural Resources District, Nebraska Natural Resources Commission, and Priority Ecosystem Science, Platte River Basin.

Geophysics for hydrologic characterization

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Introduction

The Central Platte River valley is naturally important as ground water for water supply. Ground water is the largest component of Nebraska's Water. Detailed water models have been used to understand the geology and hydrology of the Central Platte river valley. This valley's water resources are currently under development. The goal of this project was to evaluate the effectiveness of the magnetic resonance soundings (MRS) technique. The results will be used to evaluate the effectiveness of the MRS technique.

Magnetic resonance soundings (MRS) can be used to conduct geophysical survey techniques for water-related problems. MRS surveys are conducted by placing a large magnet on the ground and measuring the magnetic field generated by the magnet. The magnetic field is then measured at various locations by placing the magnet at different depths. The data collected is then analyzed to determine the presence of water or other materials. MRS surveys are non-invasive and can be conducted quickly and efficiently.

Magnetic sounding has been used in conjunction with ground water models to identify potential sources of ground water. MRS surveys have been conducted in the Central Platte valley to identify potential sources of ground water. The results of the MRS surveys have been used to develop a ground water model for the valley.

Time Domain Electromagnetic (TDEM) soundings

Borehole geophysics

Site 1 MRS soundings

MRS soundings compared to borehole log

Site 2 MRS soundings

Site 3 TDEM soundings

* Geophysical information available upon request
Jim Cannia is a registered professional geologist in Nebraska and Wyoming and is currently a hydrologist with the U.S. Geological Survey in Mitchell, Nebraska. He is the team leader for the Nebraska USGS geophysical program focusing on hydrogeologic framework and ground water-surface water studies. He has worked on various geologic, hydrologic and hydrogeologic investigations within Nebraska and Wyoming on surface water, ground water, quality water, geology, geologic hazards and geophysics. He has been the principal investigator or senior author for various scientific reports and journal articles. Recent work has included the “2006 Annual Evaluation of Availability of Hydrologically Connected Water Supplies” from the Department of Natural Resources. He also served as the COHYST Western Model Area modeler and founding member of the COHYST technical team. He was a founding member of the State of Nebraska Board of Geologists. He served 17 years as district geologist for the North Platte Natural Resources District with responsibility for ground water in the North Platte River Valley and the western Sand Hills of Nebraska. He also was a hydrogeologist for Conservation and Survey Division in the Panhandle of Nebraska.

Mr. Cannia’s current work as project chief includes canal seepage mapping in the North Platte Valley; hydrogeologic studies of the Sandhills in central Nebraska; determining ground water resources in the eastern Nebraska glacial till area; the Central Platte Natural Resources District magnetic resonance soundings study to determine aquifer properties; Elkhorn-Loup Model area canal seepage mapping; and a helibourne electromagnetic survey for the hydrogeologic framework of the North Platte valley. In addition, Jim currently serves as representative to the Nebraska State Map program.
Dismal River Long-Term Integrated Monitoring
Ron Zelt, Hydrologist, USGS Nebraska Water Science Center
Bob Swanson, Director, USGS Nebraska Water Science Center

Water Quality and Biological Monitoring

Dismal River samples collected prior to 1985 generally had smaller concentrations of nitrate than did National Water Quality Assessment (NAWQA) samples from the Dismal River collected during 1991-95, although only 1 of 32 samples exceeded the proposed regional aquatic criterion of 0.56 mg/L for total N (upper graph). Dismal River samples collected during the season June 1 through August 8 have averaged 0.77 mg/L of total N, but that is very low relative to NAWQA samples collected in 2003 from Loess Hills streams (not shown on map). Similarity, concentrations of total phosphorus in the Dismal were relatively low in relation to Loess Hills streams, but all exceeded the recommended regional criterion.

The Dismal River fish community typically is dominated by shiners, suckers, and creek chubs, and relatively low species richness (upper graph). The seven most abundant species in 2002-04 (left pie graph) comprised 97.3 percent of the total sample of 2,197 individual fish. Annual NAWQA samples collected during 1999-05 were dominated by creek chubs and had greater abundance of bigmouth shiner than in samples collected during 2002-04, that were dominated by sand shiners and had greater red shiner abundance than in the earlier period. Samples were collected annually during all 3 years of both periods.
Hydrology and Climate

Unlike flows in many western streams where snowmelt runoff has been occurring earlier in the year, the annual center point (by volume) of Dismal River runoff has remained stationary at March 31 ± 1 to 2 days. But annual streamflow has risen more than 10 percent since 1979 at the same time that snowfall has decreased (graph below). The snowfall trend is seen more clearly when plotted as the moving sum of 3 years’ cumulative snowfall.

![Graph showing annual streamflow and snowfall trends](image)

EXPLANATION
- CENTER OF TIMING OF ANNUAL STREAMFLOW (with LOWESS)
- ANNUAL MEAN DISCHARGE (with LOWESS)
- CUMULATIVE 3-YEAR SUM OF SNOW PRECIPITATION (with LOWESS)
- ANNUAL SNOW PRECIPITATION AT HALSTY, NEBR. (with LOWESS)
- PALMER HYDROLOGIC DROUGHT INDEX, CLIMATE REGION 2, NEBR.

Fluvial Processes

At right is shown the suspended sediment rating graph for the Dismal River stream gage. Most samples collected since 1992 were data collected for the NASA Water project. Although basin conditions since 2000 have been less wet than during the previous 7 years (see graph above), streamflows sampled for suspended sediment were similar or somewhat higher, yet suspended sediment concentrations have more frequently been less than 200 mg/L than during the earlier periods. One possible factor may be improved vegetative cover across the basin, which may have decreased erosion delivery of sediment to the stream.

The hydraulic geometry relations between instantaneous discharge and mean velocity and instantaneous discharge and mean depth (below), indicate that as the transport of bedload intensifies, especially as driven on the streambed, the mean depth of the channel cross-section actually becomes shallower. (This assumes that transport capacity is proportional to discharge.)

![Graph showing hydraulic geometry relations](image)

The regional Palmer hydrologic drought index (PHDI; dimensionless) varied about a mean value of 0.25 for the first 187 months of the Dismal River streamflow record (graph at left). In mid-1982 commenced a 20-year period when the PHDI averaged 2.48. Since April 2002, the mean PHDI has been 0.80 through the end of water year 2007. After El Niño events (graph above) also had a positive trend in mean discharge during the 1979 through 1995 period. Since then, streamflows have remained on average at a level at least 10 percent higher than they were ca. 1970. Middle Loop River discharge is as consistent as that of the Dismal River, whereas the North Loop River is more responsive to short-term periods of increased rainfall (e.g., 1983-84, 1993, 1999). Detention of subtle changes in climate effects on streamflow and its watershed controls is enhanced for rivers such as the Dismal or Middle Loop.

Dismal River near Thedford

![Graph showing Dismal River near Thedford](image)

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Ron Zelt presently serves as the associate director for NAWQA of the USGS Nebraska Water Science Center, and is responsible for Nebraska coordination of four water-quality monitoring projects with national Program leaders. His duties also involve developing and overseeing hydrologic studies focused on questions involving instream environmental flows, characterizing and comparing streamflow regimes, and relating riparian habitat and cover to water quality and biological responses; and reviewing information products for quality improvement. Ron returned to Lincoln in 2002 after 8 years with the USGS-WRD Kansas District and a 6-year assignment with the USGS-WRD Wyoming District. He received the M.A. in Geography from UNL in 1988 and later earned the M.S. in Watershed Science from Colorado State Univ. Together with wife, Cindy, they have two daughters majoring in International Studies at UNL and two sons in high school. Ron is a Michigan native and enjoys archery, hiking, gardening, and music.

Bob Swanson is the Director of the USGS Nebraska Water Science Center (NEWSC). The NEWSC has about 45 dedicated water science professionals located in Lincoln, Ord and North Platte. He joined the United States Geological Survey as a hydrologic technician working for the Lincoln Subdistrict Office in 1978. Bob gained a wide range of experience in the Data Section as a hydrologic technician and hydrologist in the Cambridge, Ord, and North Platte Field Offices. He served as field hydrologist for the National Water Quality Assessment program’s Central Nebraska River (CNBR) Basins Study Unit research team and later as CNBR Study Unit Chief. Bob moved on to the USGS Wyoming Water Science Center as the Chief of Hydrologic Surveillance in 1999 and returned to Nebraska as Director in 2004. He is responsible for developing and overseeing USGS hydrologic investigations and data collection for ground-water, surface-water and water-quality programs in Nebraska. Bob is a native Nebraskan and graduated from Doane College with a major in biology and minors in geology and environmental studies.
Welcome to the Sandhills
LeRoy J. Louden, Senator, Nebraska Legislative District 49

Senator Louden lives and ranches in Ellsworth, Neb., and represents District 49. Elected to the Nebraska Legislature in 2002 and 2004, he serves on the following committees: Natural Resources (chairperson), Nebraska Retirement Systems, Transportation and Telecommunications and Building Maintenance.

He and his wife SharonAnn have six children. He is a member of Nebraska Cattlemen, Elks Club, Fraternal Order of Eagles and Ellsworth Bowling Club. He serves as president of the Sandhills Independent Collection Membership Association; on the District 3 board of directors of the Panhandle Rural Electric Membership Association; and on the legislative committee of the Nebraska Rural Electric Association. He formerly served as a member of the Sheridan County School Reorganization Board; secretary of the District 119 School Board; and president of the Area 11 Nebraska Stockgrower’s Association.

Overview of the Ranch
Don Adams, Director UNL West Central Research and Extension Center

Please see a related article, "Research and education for managing resources within the Nebraska Sandhills: The Gudmundsen Sandhills Laboratory," elsewhere in the Workshop packet.

Don Adams, professor of animal science at the University of Nebraska-Lincoln, is director of the West Central Research and Extension Center and associate dean of the Nebraska College of Technical Agriculture. He received his Ph.D. from New Mexico State University in 1980 and his M.S. from Utah State University in 1978, both in animal science. Prior to coming to UNL, Dr. Adams was an animal scientist at the USDA-ARS Fort Keogh Livestock and Range Research Laboratory in Miles City, Montana.

He has been recognized for his research and extension work in range beef systems and beef cow nutrition and for multidisciplinary work with agricultural economists, agronomists and animal scientists. He has been an invited lecturer at a variety of institutions, including Universidad Autonoma in Chihuahua, Mexico, University of Wyoming and Montana State, Kansas State, Colorado State, North Dakota State, and New Mexico State Universities. In addition, he has presented conferences and workshops throughout the Midwest as well as in Alberta, Canada.

Dr. Adams has published over 250 abstracts, field day reports and extension circulars; almost 70 refereed journal publications; and over 30 symposium/conference proceedings.
Hydrogeologic Investigations at Gudmundsen Sandhills Laboratory
Jim Goeke, Professor, School of Natural Resources, UNL

The Gudmundsen Sandhills Laboratory (GSL) began operation about 1980, focusing on beef and range research on its 12,800 acres centered on the intersection of Grant, Hooker and Cherry counties. Also in 1980 the United States Geological Survey (USGS) published Professional Papers 1400 A-E, under the general title "Geohydrology of the High Plains Aquifer in Parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming." The High Plains Aquifer underlies 174,000 square miles in these 8 states, where saturated thicknesses range from less than 100 ft. to over 1000 ft. GSL is situated over a relatively small area where saturated thickness exceeds 1000 ft.

In addition, dozens of stockwells were drilled all over the ranch.

Early shallow wells for range research in the main valley and dry valley area indicated the presence of organic material at a depth of 40 ft. in the main valley and approximately 160 ft. in the east valley. Intrigued by the possibility of a dateable C-14 unit, a deep test hole was drilled in September of 1988, midway between the two wells, atop the large dune that terminates the east end of the main valley. Drilled to a depth of 1634 ft., test hole 12-SH-88 encountered organic material from 160 ft. to 185ft. Even though the saturated thickness exceeded 1000 ft., no gravels were encountered and the coarsest sediments traces of coarse to very coarse sand.

Carbon dating of the organic material produced a date of 13,160 + or - 450 years BP (before present), indicating implacement of this large dune in the last 13,000 years. This insight has been followed up with the location and dating of several other organic horizons exposed in blow-outs and by the incision of the South Branch of the Middle Loup River.

At the same time the deep test was being drilled, a water quality survey was made of all the stock and domestic wells on the ranch. In addition, the irrigation well was sampled along with the ditch in the main valley and the south branch of the Middle Loup River.
Two wells in the main valley, one in the south valley, and another in the northeast portion of the ranch showed nitrate concentrations above 7.5 parts per million.

In 1992 and 1993, as part of a meadow hydrology study, single wells and nested piezometers were drilled at 12 sites in the main valley and 10 sites in the east dry valley. This drilling and these wells anchored the construction of a water table contour map for the ranch and north-south and east-west cross sections of flow, as indicated in the accompanying figures 1-3. Water levels in these wells are still being monitored by ranch staff.

Despite the abundance of available groundwater, shallow supply wells drilled to a depth near the organic material often produced water with excessive sediment and a hydrogen sulfide, rotten egg odor. This condition is common in the area and despite the saturated thickness available, local lore held that the water just got worse the deeper you drilled. In July of 2003, a 670 ft. well was drilled as the main supply well for the headquarters area. Dispelling the local lore, the water is of excellent quality and 5-6 degrees warmer than water from the shallower sources.

Most recently a U. S. Climate Reference Network (USCRN) station was established in September of 2004 on top of the dune separating the main ranch valley and the valley to the south.

The USCRN is a network of climate stations recently installed to provide future long-term observations of temperature and precipitation accurate enough to detect present and future climate change. The USCRN also will provide the United States with a reference network that meets the requirements of the Global Climate Observing System (GCOS). The USCRN site at Gudmundsen Sandhills Laboratory is one of about 110 planned sites in the U.S. It was chosen for its unique setting and because it is expected that land use and ownership will be stable thereby overcoming the problems in other networks where station moves and land use change can introduce serious changes into the observation record. Other sites in Nebraska include the Agate Fossil Beds, near Harrison, and two sites near Lincoln.

*Note: See additional images in separate handout elsewhere in the Workshop packet.*

*NOTE: Everyone involved with hydrogeologic research at GSL would like to acknowledge the invaluable assistance of the ranch staff, without which the research would not be possible.*

Jim Goeke is a research hydrogeologist with UNL’s Institute of Agriculture and Natural Resources and Conservation and Survey Division, stationed at the Research and Extension Center at North Platte.
Beef Cattle Research in the Sand Hills
Rick Funston, Associate Professor, Animal Science, UNL

Background
The Nebraska Sandhills, which encompass about 12.75 million acres of rangeland, are home for about 535,500 head of beef cows. The Nebraska Cattlemen Association reports that the top three beef cow counties in the nation for 2007 were in the Nebraska Sandhills: No. 1 Cherry County, with nearly 166,000 cows; No. 2 Custer County (100,000) and No. 3 Holt County (99,000). Lincoln County ranks No. 13 (69,000). As a state, Nebraska ranks second for live animal and meat exports with $666 million; second for cash receipts from cattle and calves, $6.6 billion; and second for commercial cattle slaughter with 7.07 million head (this represents 20.6 percent of U.S. commercial cattle slaughter.) Nebraska also ranks second in the nation for the number of cattle on feed with 2.7 million head, representing 18.9 percent of the nation's beef supply. At any given time, Nebraska is home to 1.88 million head of beef cows or 5.8 percent of the U.S. herd.

Here we describe two recent studies conducted at the university's Gudmundsen Sandhills Laboratory near Whitman.

Effects of Dam Nutrition on Growth and Reproductive Performance of Heifer Calves
Spring-calving beef cows that receive supplemental nutrition late in pregnancy tend to produce heftier heifers that have improved pregnancy rates later. This three-year study is the first research to demonstrate the impact of late-gestation nutrition on the performance and subsequent reproductive efficiency of heifer calves. The UNL research grew out of an earlier study that focused on decreasing input costs by testing two management practices: early weaning of the cows to improve their body condition headed into winter and feeding a protein supplement to help provide extra nourishment at a time when the dormant Sandhills range falls short of meeting their needs. Neither practice improved the cows' future pregnancy rates. Instead, we decided to follow the progress of the calves produced by these late-supplemented cows and found that calves from cows that received late supplements were about 60 pounds heavier.

In a subsequent study evaluating late gestation supplementation:

- Eighty-eight percent of heifers from cows that received a protein supplement late in pregnancy achieved first-service pregnancy, compared to just 45 percent of those from cows receiving no supplement.
- Ninety-four percent of heifers from supplemented cows eventually became pregnant, compared to 73 percent of those from nonsupplemented cows.
- Heifers from supplemented cows calved eight days earlier on average and had fewer calving problems (69 percent unassisted births, compared to 38 percent for heifers from nonsupplemented cows).

The supplemented group received about 1 pound of a 42% crude protein supplement per head per day from Dec. 1 to Feb. 28. If animals are restricted in late gestation, there's potential negative impact on the unborn fetus, both from the carcass weight standpoint and in the reproduction of heifer calves.

We also found that cows that grazed subirrigated meadows after calving, but were not fed a protein supplement in late gestation, weaned heavier calves. However, the weight advantage wasn't maintained and there was no effect on the heifers' reproductive performance.

Heifer Development
Studies in numerous species provide evidence that diet during development can partially control physiological changes necessary for puberty. Energy balance or plane of nutrition influences reproductive performance in heifers and cows. Numerous studies have reported inverse correlations between postweaning growth rate and age at puberty, and pregnancy rates in heifers were shown to be dependent upon the number displaying estrus prior to or early in the breeding season. Thus, rate of postweaning growth was determined to be an important factor affecting age of puberty, which in turn influenced pregnancy rates.

This and other research conducted during the late 1960s through the early 1980s indicated puberty occurs at a genetically predetermined size, and only when heifers reach their target weight can high pregnancy rates be obtained. Guidelines were established stating replacement heifers should be fed to achieve 60 to 65% of their expected mature body weight by the time breeding starts in order to reach puberty. Therefore, traditional approaches for postweaning development of replacement heifers during the last several decades have primarily focused on feeding heifers to achieve or
exceed an appropriate target weight, thereby maximize heifer pregnancy rates. However, substantial changes in cattle genetics and the economy have occurred over this time, necessitating re-evaluation of traditional approaches.

Intensive heifer development systems may maximize pregnancy rates, but not necessarily optimize profit or sustainability. Developing heifers in this manner requires significant use of fossil fuels and cereal grains and high capital investment in equipment and facilities. The fuel requirement to harvest feed and deliver it to cattle creates high energy demands in this development system. Cereal grains, often used as a major energy source in heifer diets, detract from the system’s sustainability due to growing demand for cereal grains as human food and in ethanol production. Feeding replacement heifers to a traditional target weight increases development costs relative to more extensive heifer development.

Research at UNL reported similar pregnancy rates from the initial through fourth breeding seasons for heifers developed to reach either 53% or 58% of mature weight prior to breeding as yearlings. Heifers developed to only 53% of mature weight could achieve similar initial pregnancy rates and retention as those achieved by heifers developed to 58% of mature weight. Further research using the same herd found pre-breeding weights as low as 51% of mature weight (RLX) to be more cost effective than development to 57% of mature weight (INT) when lighter heifers were allowed 60 days to become pregnant (Martin et al., 2007). Extending the breeding season by 15 days for lighter heifers resulted in similar first-calf conception rates for both systems (45 vs. 60 day breeding season for INT and RLX systems, respectively).

Retrospective analysis considering only RLX heifers bred within the first 45 days of the breeding season, based on days pregnant at pregnancy diagnosis, revealed 45-day pregnancy rates of 89.8 and 77.9% for INT and RLX systems, respectively. During the extended breeding period (from 45 to 60 days) for the RLX heifers, an additional 9.3% of heifers became pregnant. Interestingly, further characterization of non-pregnant heifers within each system revealed 78.9% (14 of 17) of open RLX heifers (after a 60-day breeding season) were pre-pubertal prior to start of the breeding season, but only 45% (5 of 11) of open INT heifers (after a 45-day breeding season) were pre-pubertal prior to start of the breeding season.

These results lend support to the hypothesis that one of the major determinants of a heifer’s ability to conceive during her first breeding season is the age at which she reaches puberty, especially in relation to the start of the breeding season. However, feeding heifers to meet traditional recommendations may be unnecessary for successful heifer development. In fact, feeding heifers to traditional target weights increases development costs per pregnant 2-year-old cow.

Rick Funston is a reproductive physiologist and an associate professor in the animal science department at UNL. On the Extension side, he provides leadership and subject matter expertise for educational programs in cow-calf production management for the West Central District, and statewide expertise in beef reproductive management programs. He also conducts research addressing cow/calf reproductive problems unique to West Central Nebraska and to other beef producers within the state.

He held previous academic positions at Montana State University, Chadron State College and Colorado State University. He received his Ph.D. in reproductive biology from the University of Wyoming, an M.S. in animal science from Montana State University, and a B.S. in animal science from North Dakota State University.

Dr. Funston is a member of the American Society of Animal Science, the National Beef Reproduction Leadership Team, the North Central Region Bovine Reproduction Task Force and the Nebraska Cattlemen’s Beef Quality Assurance and Integrated Resource Management advisory board.
The presence of 400-foot-high sand dunes in the Central Plains is a strong testimonial to the importance and extent of climate change in the region. Although now stabilized by lush prairie vegetation, dunes in the Nebraska Sand Hills have been intermittently active for at least the last 18,000 years. Although perhaps exacerbated by overgrazing and fire, the episodes of dune activity are best interpreted as prolonged hydrologic droughts that are without precedent in recorded climate history. Our recent research has used optically stimulated luminescence (OSL) dating of dune sand and radiocarbon dating of buried, interdune peat deposits to delineate times of dune activity (ancient droughts). The last major episode of activity was during the Medieval Warm Period—about 800 to 1000 years ago. Other important recorded droughts include periods centered about 2500 years before present (yBP), 3800 yBP, and a long interval from 6600-9400 yBP (Miao et al., 2007).

Our work also suggests that the winds that generated the Sand Hills were different from the winds that prevail today. Many of the dunes that were active 800-1000 years ago are oriented NW-SE. Modern winds would generate dunes with SW-NE trends. Modern winds are northerly to northwesterly today, but growing season winds (May-July) are southerly and bring moisture from the Gulf of Mexico. Dune orientations suggest that during droughts, winter winds continued to blow out of the N and NW, but May-June-July winds were from the SW (and thus not from the Gulf of Mexico). We interpret this change in the direction of spring-summer winds to have had a devastating effect on vegetation, resulting in wind erosion and dune migration (Sridhar et al., 2006). The prolonged, ancient droughts clearly dropped the regional water table, allowing sand to be driven far out into peatlands (Mason et al., 2004) and enabling dunes to block streams (Loope et al., 1995). Our current research goal is to better understand the conditions that can lead to destabilization of dunes (length and severity of droughts) as well as to decipher the different responses to drought in different parts of the dunefield.


Pdf’s of these and other papers are available at:
http://www.geosciences.unl.edu/~dloope/

David Loope is a professor of geosciences at UNL and has been doing field work in the Nebraska Sandhills for about 25 years. He is interested in this dunefield as a record of climatic and environmental change within the core of the North American continent during the last 10,000 years. The orientation and internal structure of the dunes provide key information on directions of ancient winds, and the characteristics and distribution of buried tracks, burrows and soils show how animals and plants coped with the changing ecological conditions. Loope’s graduate work at the University of Wyoming focused on eolian (wind-deposited) sandstones that are exposed in southeastern Utah’s Canyonlands National Park. The migration direction of ancient dunes (hundreds of millions of years old) can be measured in the field, yielding information on ancient wind regimes. In collaboration with atmospheric scientists at UNL, Loope is trying to use insights from the sandstones of southwestern U.S. to better understand atmospheric circulation over the Supercontinent Pangea.
Rangeland Ecology and Grazing Research in the Nebraska Sand Hills
Jerry Volesky, Associate Professor, Agronomy & Horticulture, UNL

Rangeland ecology and grazing research in the Nebraska Sandhills is primarily conducted at two facilities, the Gudmundsen Sandhills Laboratory (GSL) (5,182 ha) and the Barta Brothers Ranch (BBR) (2,105 ha). Within the Sandhills, GSL is located in the west-central region (42° 05’N 101° 27’W) and BBR is located in the east (42° 13’N 99° 38’W). Annual precipitation averages 43.9 cm at GSL and 51.7 cm at BBR.

Recent and current research at GSL covers a diversity of topics, many of which provide insight into managing rangeland resources in the Sandhills. This research has been designed to provide critical information pertaining to the structure and function of upland and wet meadow plant communities, grazing and drought responses, seasonality of plant-grazing interactions, and grazing-wildlife interactions. This information has been used to develop decision support tools for sustainable livestock enterprises and grassland habitat management. Examples of recent research and outreach are given in the following publication list.


Grazing research at the UNL Barta Brothers Ranch was initiated in 1999. The primary emphasis has been on a long-term grazing systems research project. The
grazing systems that are being compared include a 4-pasture, deferred rotation and an 8-pasture, short-duration rotation. The objectives of the research are to: 1) compare the effects of grazing system on herbage production, livestock performance, functional plant group composition and frequency of occurrence; 2) develop a model predicting seasonal herbage production based on such variables as soil moisture, precipitation, and topographic position; and 3) determine the effect of grazing date on herbage production in subsequent years.

Other recent or on-going projects have examined grazing system effects on cattle diet composition, the yield and forage quality of cool- and warm-season plant communities on subirrigated meadows, and utilization of leadplant by grazing cattle. Examples of recent research are given in the following publication list.


Dr. Jerry Volesky, a range and forage specialist, is an associate professor of agronomy and horticulture at UNL’s West Central Research and Extension Center in North Platte. His research focuses on the fundamental understanding of environmental and management controls that affect rangelands and grazing livestock productivity. He is working to identify effective native rangeland and seeded pasture management practices that will increase farm and ranch profitability and sustain the productivity of these forage resources.

Before coming to UNL, Dr. Volesky was a research scientist with the USDA-ARS Grazinglands Research Laboratory in El Reno, Oklahoma. He received his Ph.D. in range science from South Dakota State University; his M.S. in botany from North Dakota State University; and his B.S. in biology from Dickinson State University.
Effects of Precipitation and Groundwater on Grassland Productivity in the Nebraska Sand Hills: I.) Water

Dave Billiesbach, Professor, Biological Systems Engineering, UNL

One unique feature of the Nebraska Sand Hills (58,000 km²) is their close proximity to the High Plains (or Ogallala) Aquifer, which contains about as much water as Lake Huron and accounts for 30% of the groundwater irrigation in the U.S. Because it intersects the land surface in the Sand Hills, it is a major contributor to their current ecological state. The Sand Hills are the largest grass-stabilized sand dune field in the world. Without the grass cover, the Sand Hills would be indistinguishable from the Sahara or Gobi Deserts. Despite being a semiarid region (average annual precipitation at the Gudmundsen Sandhills Laboratory is about 18 inches or 450mm), it is the prairie grass cover that enables this region to support one of the most productive cattle raising economies in the world.

The topography of the dunes creates five distinct ecosystems in the Sand Hills: lakes, wetlands, wet meadows, dry valleys and uplands. Lakes and wetlands make up only about 2% of the total Sand Hills area and are formed when the local water table rises above the land surface.

Wet meadows, like the hay meadow near the GSL headquarters, are areas where the water table usually lies less than a meter below the surface, although at times it may reach the surface. Often, wet meadows are artificially created by draining wetlands. In total, they make up about 10% of the Sand Hills land area.

Dry valleys are interdunal valley floors where the water table never intersects the land surface and usually lies several meters below. They also constitute about 10% of the land surface. The remainder of the Sand Hills is classified as dunal uplands where the water table is many meters below the surface. Along with the dry valleys, they make up the majority of Sand Hills grazing land.

The key difference among these ecosystems is their depths to water table, greatly affecting the types and amounts of grasses that grow there. This difference also suggests a strong linkage among ground water, precipitation and grass productivity in these ecosystems. One important component of this linkage is the surface water balance. How much water enters the ecosystem (via precipitation) and how much water leaves the land surface? The primary mechanism for surface water loss is evapotranspiration (ET), consisting of two components: simple surface evaporation and plant transpiration. The relative size of each can vary greatly, depending on time of year and other factors (such as drought).

Until we began our work in 2003, there had been only estimates of the surface water balance in the Sand Hills. These estimates relied on deep monitoring well data and mathematical models that make many assumptions about the state of the surface vegetation. While many stations record precipitation and surface meteorology (HPRCC), to our knowledge only one study directly measured ET, and that was from a wetland site south of Valentine (Ballards Marsh). Previous estimates of ET had little in the way of calibrating or supporting data.

We are attempting to fill this gap in the ecological and hydrological record by directly measuring ET in three key ecosystems (a wet meadow, a dry valley and two dunal upland sites). Because this effort is unfunded, we have chosen the most inexpensive technique to measure ET, the Bowen Ratio/Energy Balance (EBBR) method. A more direct and accurate (as well as expensive) measurement, Eddy Covariance, has been installed at our GSL dry valley and our Barta Brothers Ranch uplands sites, but not at our wet meadow or GSL uplands site.

To date, we have been able to confirm several of our initial hypotheses. First, the most water is transferred to the atmosphere from wet meadows, followed by dry valleys and dunal uplands; second, the close proximity to the aquifer acts as a buffer to both wet meadows and dry valleys, but not to dunal uplands; and third, ground water buffering is most affected by regional rather than local precipitation events.

The figures on the left (on the next page) show reference ET (representative of modeled values) in green, measured ET in blue and measured precipitation in red. This series from 2007 shows the errors that can come from models and the differences in the three represented ecosystems. Note especially that aquifer recharge (precip > ET) only happened in the dunal uplands. The top two figures on the right show that changes in the deep (100cm, shown in red) soil moisture (at the dry valley) are somewhat disconnected from the shallower depths where individual precipitation events are clearly evident. While the seasonal pattern for the upper soil/sand layers (10cm,
25cm and 50cm) is roughly the same for 2005 and 2006, the regional drought of 2006 is clearly reflected in the deeper, 100cm data. The lower right hand panel shows soil moisture from the dunal uplands site in 2006. Clearly, moisture can be a much more limiting factor to upland grass productivity.

We continue learning from this experiment; however, our biggest challenge is in obtaining funding to improve the instrumentation and to keep these sites operational.

Professor Dave Billesbach is a third-generation native Nebraskan, born, bred, and educated in the heart of the Great Plains. He earned a Ph.D. in experimental solid state physics at the University of Nebraska and promptly began working with a UNL group measuring the exchange of greenhouse gases between the ecosystem and the atmosphere. In the mid 1990s, he was part of a group that made the first continuous, high-precision measurements of methane emissions from wetlands in north-central Minnesota and in central Saskatchewan. One of those wetlands, however, was located in the Nebraska Sand Hills, south of Valentine, Neb. (Ballards Marsh). He is now studying the exchange of water, CO2 and energy between the land surface and the atmosphere in grassland and cropland ecosystems. Currently, he is a research professor in the Department of Biological Systems Engineering at UNL. Besides his projects at Gudmundsen Sandhills Research Laboratory and Barta Brothers Ranch, he works with a group of scientists from the Lawrence Berkeley National Laboratory on similar problems in northern Oklahoma croplands as part of a larger DOE effort (ARM).
The Nebraska Sand Hills cover more than 50,000 km² and are the largest stabilized dune field in the world. The thin layer of vegetation that covers the land surface stabilizes the dunes against wind-driven movement seen in other desert environments. One of the distinguishing features of the Sand Hills is the intersection between parts of the land surface with the High Plains Aquifer, creating a region with great variances in water availability. The dominant land-surface types are sub-irrigated meadows, dry valleys, and dunal uplands (in order of increasing water table depth). There are also numerous small wetlands and lakes, but they do not comprise a significant fraction of the Sand Hills land area.

It has long been assumed that the Sand Hills are a recharge zone for the underlying aquifer, and that local precipitation more than accounts for the water usage of the surface vegetation. This assumption is mostly based on ground water flow patterns and modeled evapotranspiration (ET) estimates.

To explore this issue, we initiated a pilot-scale program to measure evapotranspiration and precipitation in representative land-surface types. Our goal was to examine the budgets of water and energy at the land surface and to understand the energy partitioning in terms of surface hydrological and ecological processes. (See Billesbach abstract for more information on the water balance portion of our research.)

The initial data piqued our interest. We have long realized that water is only half the story for the Sand Hills (or, in general, for any vegetated land surface). Since the stomata on leaf surfaces represent avenues for simultaneous water loss as well as carbon gain, in order to really understand the system we need to understand the relationship between water and the vegetative land cover – in other words, we also need to look at carbon. This is considerably more expensive, so we are still looking for funding to continue doing this work.

We deployed an eddy covariance system at our GSL dry valley (east valley) site to supplement the Bowen Ratio measurements and to measure fluxes of carbon dioxide between the vegetated surface and the atmosphere.

This carbon exchange is the result of two major processes: carbon gain or loss by the plant canopy and soil surface CO₂ emission. It is our long-term goal to study both of these components and elucidate the influence of relevant biophysical factors (e.g., temperature, vapor pressure deficit, CO₂ concentration) on the fluxes of carbon and water in the Sand Hills systems.

The figures below show the CO₂ exchange (determined by the eddy covariance technique) between the surface and the atmosphere on the y-axis and the day of the year on the x-axis. The data are from 2006 and 2007. On these graphs, a positive number indicates CO₂ moving from the surface to the atmosphere and a negative number indicates CO₂ moving from the atmosphere to the surface. It is clear that there is a high amount of variability over the year for both years. During the day, during summer, canopy
photosynthesis dominates the CO₂ exchange and the net flux is negative. At night, and during the winter, respiratory processes predominate and the net flux is positive. It is interesting to note that in both years there is a mid-season decrease in the daily maximum rates of CO₂ uptake near day 200 (July 20). This is most likely due to plant water stress and subsequent stomatal closure. When the stomata are closed the plants reduce water loss; however, this response comes at the cost of reduced carbon uptake (photosynthesis).

There is also year-to-year variability in the patterns of CO₂ exchange, most likely due to differences in environmental conditions (e.g., soil water content, air temperature) between years.

Through the measurement and analysis of data sets from three ecosystems (wet valley, dry valley, dunal uplands) we are currently elucidating the influence of vegetation on groundwater dynamics (and groundwater availability on vegetation dynamics) at GSL. The two are clearly coupled and a full understanding of water use, groundwater recharge and productivity depends on understanding these interactions.

Dr. Tim Arkebauer is a crop environmental physiologist in the Department of Agronomy and Horticulture at the University of Nebraska in Lincoln. He has a research and teaching appointment at UNL and is currently involved in teaching a graduate course in plant-water relations, as well as a freshman-level introductory plant science class. He has a B.S. in botany from Michigan State University, an M.S. in horticulture from the University of Florida and a Ph.D. in agronomy from the University of Nebraska-Lincoln. He also did postdoctoral work with the Systems Ecology Research Group at San Diego State University. His research interests include field measurements of plant and canopy gas exchange, soil surface trace gas emissions, and water, carbon and energy fluxes in natural and managed ecosystems. He is currently a member of the UNL Carbon Sequestration Project team. In addition to his present work in the Nebraska Sand Hills and at the ARDC near Mead, Neb., his research has included projects in Alaska, Saskatchewan, Florida, California, Kansas and Minnesota.
The Nutrient Network (NutNet)

*Abstracts, page 43 of 52*

A global experiment investigating the effects of resources and consumption on ecosystem processes

Jean Knops, Professor, School of Biological Sciences
with Dave Wedin

Two of the most pervasive human impacts on ecosystems are alteration of global nutrient budgets and changes in the abundance and identity of consumers. Fossil fuel combustion and agricultural fertilization have doubled and quintupled, global pools of nitrogen and phosphorus, respectively, relative to pre-industrial levels. Concurrently, habitat loss and degradation and selective hunting and fishing disproportionately remove consumers from food webs. At the same time, humans are adding consumers to food webs for endpoints such as conservation, recreation and agriculture, as well as accidental introductions of invasive consumer species.

In spite of the global impacts of these human activities, there have been no globally coordinated experiments to quantify the general impacts on ecological systems. The Nutrient Network (NutNet) is a grassroots research effort to address these questions within a coordinated research network comprised of more than 40 grassland sites worldwide.

**NutNet Focal Research Questions:**

- How general is our current understanding of productivity-diversity relationships?
- To what extent are plant production and diversity co-limited by multiple nutrients in herbaceous-dominated communities?
- Under what conditions do grazers or fertilization control plant biomass, diversity and composition?
- What are the effects of plant invasions on the richness and spatial heterogeneity of grasslands?

**NutNet Goals:**

1. To collect data from a broad range of sites in a consistent manner to allow direct comparisons of environment-productivity-diversity relationships
among systems around the world. Collection is currently occurring at each site in the network, and these data, when are compiled, will allow us to provide new insights into several important, unanswered questions in ecology.

2. To implement a cross-site experiment requiring only nominal investment of time and resources by each investigator, but quantifying community and ecosystem responses in a wide range of herbaceous-dominated ecosystems (i.e., desert grasslands to arctic tundra).

**Central U.S. Sites:**
- Colorado: Boulder, Niwot Ridge LTER, Shortgrass Steppe LTER
- Kansas: Konza Prairie LTER
- Minnesota: Cedar Creek LTER
- Nebraska: Barta Brothers, Cedar Point

Dr. Johannes J.M. (Jean) Knops is an assistant professor in the School of Biological Sciences at UNL. His research focuses on ecosystem and plant ecology, especially questions that deal with how plant communities and ecosystems are structured by their environment and how plants in turn change their geochemical environment. Species matter, as grasses structure grasslands and trees forest. However, individual species, like a nitrogen-fixing legume or a tree invading a grassland, can change the functioning of entire ecosystems.

Dr. Knops is interested in developing a mechanistic understanding of factors (such as fire, herbivory, soil fertility and dispersal) that control species abundances and how these factors and the species’ composition structure ecosystems. Insights into these processes are especially important today, as major issues like global climate change are impacted by carbon and nitrogen cycling, both of which are controlled by terrestrial vegetation. He also is interested in the functioning of agricultural ecosystems, because they dominate most of the earth today and have a major impact on global and regional biodiversity and element cycling.

Specifically, Dr. Knops is working with a group of researchers on an experiment examining the interactions of biodiversity loss, increasing nitrogen deposition and increasing atmospheric CO2 (http://www.lter.umn.edu/biocon). He also is starting a new project in which he will examine the impact and the mechanisms by which species control nitrogen and carbon fluxes and pools.

Dr. Knops received his Ph.D. from Arizona State University.
The Value of Long-Term Ecological Research in the Sandhills
Svata M. Louda, Professor, School of Biological Sciences, UNL

The problem: The evidence shows that global climate is changing, so the key forward-looking questions now are: how much?, how fast? and with what consequences? Clearly, the consequences will affect us and our capacity to prosper, especially in a state like Nebraska, with some of the world’s most productive agriculture and native grasslands.

Key points for this workshop: In relation to the goal of forming an intensive research framework to develop an integrated, real-time knowledge base and climate change response system, I want to make four main points. 1) Biological research is needed, as well as physical change research; 2) highly relevant biological expertise is available at UNL; 3) long-term ecological research provides a foundation for predictive resource management; and 4) our research on the environmental costs as well as potential benefits of biological control of weeds provides an example of such long-term research.

1) Biological research required for management of natural resources: Ecological research provides practical as well as basic insight for management of natural resources. Ecological factors determine productivity and sustainability of natural resource use. Thus, ecological research, on the relationship of organisms (including humans!) to their environment, provides a critical set of data for quantifying, predicting and managing the biological consequences of climate change. Informed policy and stewardship require that research on physical resources (aquifer, surface waters, land cover, geomorphology) be complemented with comparable research on biological resource responses (crops, grasslands, rivers and wetlands; impacts of invasive species) to climate change.

2) Ecological expertise at UNL: UNL’s School of Biological Sciences has a vigorous group of empirical and theoretical-mathematical ecologists involved in cutting edge research. These biological experts are providing dynamic scientific data and new modeling capabilities for the forecasting needed for informed decision-making to mitigate the biological impacts of climate change. Such expertise contributes to giving Nebraska an edge in gaining both knowledge of biotic responses to global change and federal dollars for relevant research.

3) Why long-term ecological research? Long-term studies provide the data needed to see how biological resources respond to environmental change, producing knowledge of the balance to ecosystems and the consequences of disruptions to balance. The only ways to know what is happening are to monitor the biological responses for pattern and to experimentally test the mechanisms proposed to explain the emerging patterns. Thus, long-term monitoring studies are a critical tool to assist in sustainably managing grassland, agricultural land and wetlands for sustainable use in Nebraska. For example, our long-term research on grassland plants and the effects of insect pest pressure on them illustrates the use of ecological approaches to improved rangeland weed management, for sustainability and profitability.

4) Our discovery — A problem with biological control efforts for rangeland thistles: Our long-term research on native thistles, such as Platte thistle (Cirsium canescens; see picture below) and Wavyleaf thistle (C. undulatum) in the Sandhills and Tall thistle (C. altissimum) in eastern Nebraska, was inspired by the question: Why are the native thistles not weedy, when exotic thistles like Musk thistle (Carduus nutans) and Canada thistle (Cirsium arvense) are major problems in Nebraska range and pasture? Our experiments clearly showed that native insects are critical in suppressing the weediness of native thistles.

In the midst of these long-term studies, a new insect invaded the prairie — Rhinocyllus conicus, a weevil introduced for biological control of exotic thistles. The long-term monitoring effort led to our ability to quantify, better than any other study, the “non-target” effects and biological costs of this invasion.
and attempt to use exotic biocontrol agents against weeds. As weevil numbers increased, the numbers of native insects plummeted and the numbers of the native thistle declined dramatically. Thus, our long-term monitoring and experiments clearly showed that, instead of controlling the exotic thistles, the weevil was invading new communities and damaging the native plants. These findings are changing how biological control of weeds is planned, evaluated, and executed today.

Overall, then, the collaborative research in my lab is an example the value of long-term basic research, including monitoring and experimental tests of the mechanisms causing the patterns, for developing both a knowledge basis of grassland system response to change and an improved grassland system management. Our work has clearly shown:

- Use of individual species and their interactions can be valuable as "bio-indicators" of biological responses to change.
- Not all thistles are bad (weeds); in fact, we’ve documented the fact that some thistles (like Tall thistle, C. altissimum) actually provide economic benefits (resistance to invasiveness of known weedy thistles, such as Bull thistle, C. vulgare) here in Nebraska.
- Major biological responses to environmental change, such as invasions, cannot be anticipated, so quantitative, long-term monitoring studies are critical for determining response patterns and planning policy and management to mitigate change.
- Basic biological research in the field (ecology) has direct inputs and benefits for natural resource management, such as weed control strategies; such input is likely to be crucial to assessment and management of biotic response to physical environmental change.
- Observational and experimental ecological research is important in understanding the processes leading to the patterns and preparing for unanticipated events and changes.

Svata Louda is George Holmes University Professor of Biological Sciences. Her special expertise is in the analysis of insect pest pressure on plant performance – in both native prairie plants and invasive exotic weeds. Her research on insect-plant interactions is focused on a set of inter-related problems of great significance to the state of Nebraska as well as national and international rangeland weed management. Her research in the Nebraska Sandhills has produced some of the best data on the side effects of biological control of weeds and has provided quantitative information on the role of native insects in limiting the invasiveness of some exotic plants. Thus, her long-term, Nebraska-centered grassland research is of both scientific and practical significance.

Dr. Louda obtained her Ph.D. in 1978 and joined the UNL faculty in 1983, after doing post-doctoral research at both Yale University and Duke University. She was elected a fellow of the American Association for the Advancement of Science in 1992, received the Sigma Xi Outstanding Scientist Award in 2001, was named a UNL Charles Bessey Professor in 2002, was promoted to the George Holmes University Professor in 2006, has twice been invited to speak at the prestigious Gordon Conferences, and held visiting professorships at the Rocky Mountain Biological Laboratory, University of California-Santa Cruz, Kansas State University and the University of Queensland in Australia.
One of the goals of this workshop is to discuss what Nebraska may look like 100 years from now in light of the current trends in climate change. The development of predictive models requires a detailed understanding of the causal relationships among the key variables. One of my goals in this presentation is to emphasize the importance of an approach that incorporates the behavioral and physiological responses of individual animals to changes in their physical environment.

Much of the data used to document the impact of climate change on animals seem to focus on establishing a correlation between changes in climatic variables and the number and distribution of animals. On its own, this approach is unlikely to provide an explanation for any resulting correlations and does not address the fact that climate change may not only affect animal numbers and distribution, but also may lead to evolution.

Changes in temperature, water, and food availability, immediately lead to behavioral and physiological responses in individual animals. The nature of the specific responses directly affects reproductive output and survival. Thus, the behavioral and physiological responses of individuals to climate change will not only result in changes in animal numbers and distribution, but also may lead to evolutionary adaptation. Studies of behavior and physiology can provide a quantitative and detailed understanding of how animals adjust to their physical and social environment and can provide critical data for models.

The flow diagram below presents one view of how climate change can lead to changes in population size and distribution in a given animal species.

One example of the way in which climate change can affect animal populations through behavior can be illustrated with the impact of potential changes in migratory patterns. Changes in food resources could lead to new migratory patterns in animals that are able to change patterns – birds for example – but relatively few mammals and ectotherms can do so. The resulting increase or decrease in birds in a community may have a profound impact on insect population sizes and community structure. Where bird densities increase, insect numbers may decrease and vice versa, confounding any attempts to correlate temperature change with insect densities.

Additionally, a change in animal distribution can potentially introduce new interspecific or intraspecific interactions that can impact reproductive success and survival. For example, male dark-eyed juncos (a songbird) historically over-winter at more northerly latitudes than female juncos. Warmer winters are associated with females migrating shorter distances. Consequently, females may interact more with males in winter. Because males are dominant to females at winter foraging sites, female condition and reproductive success in spring may be compromised.
In ectotherms, such as the ornate box turtle that we are studying at Cedar Point Biological Station, the relationship between temperature and behavior and physiology is equally complex. Energy requirements as well as the ability to be active vary directly with temperature. If temperatures decrease, the concomitant reduction in metabolic rate and activity may be detrimental during the breeding period, when mate searching behavior (on the part of males, in particular) requires movement over large areas.

In contrast, cooler temperatures over the winter benefit ectotherms and hibernating endotherms by allowing them to save energy. Warmer environmental temperatures may increase activity levels but will also increase energy demands. Warm temperatures, particularly in winter, may be detrimental or even fatal to ectotherms. Warmer winters will increase energy used during hibernation and may consequently reduce reproductive output.

My work at UNL’s Cedar Point Biological Station examines the physiological ecology and behavior of *Terrapene ornata*, the Ornate Box Turtle. Turtles are well known to be relatively long-lived species (as much as 30 years). Our primary question is: How do box turtle behavior and physiology respond to changes in temperature, water and food availability? Because the box turtle is a long-lived, slow-reproducing species, we anticipate finding coping mechanisms that favor diverting energy toward survival over reproduction. Where is the critical cut-off where reproduction become so abbreviated that the population is threatened?

To begin with, we are looking at how this animal’s activity, energy requirements and reproductive decisions are affected by temperature throughout the year. The methods we use include radio-telemetry, behavioral observations, measures of body and environmental temperatures and respirometry (oxygen consumption & carbon-dioxide production) at rest and while running.

Dr. Gwen Bachman obtained her Ph.D. from UCLA in 1992, and joined the UNL faculty in 1998. Dr. Bachman’s research combines questions and methods in behavioral ecology and physiological ecology. This area involves an attempt to explain physiological adaptations by focusing on the role of energy as a currency of fitness. To investigate the influence of energy intake, storage and expenditure on animal decision making, she combines experimental field studies of behavior with in vivo estimates of body composition and energy expenditure. Her past and current research examines aspects of foraging decisions and mating tactics in birds and mammals. Presently, research in the lab is focusing on various aspects of the reproductive behavior and energetics of Belding ground squirrels, thirteen-lined ground squirrels, ornate box turtles, sharptailed-grouse and woodpecker species.

Dr. Bachman has been a six-time winner of the Parent’s Association Award in Recognition for Contributions to Students. Additional honors include a Mortar Board award, the T.O. Haas Award in 2004 for instructional ability, and the College of Arts & Sciences Distinguished Teaching Award in 2004. She has chaired the UNL Institutional Animal Care & Use Committee (IACUC) since 2005.
Using Duckweed Communities as a Model to Understand the Effect of Climate Change on Food Web Interactions
Chad E. Brassil, School of Biological Sciences

The scientific community can predict with high certainty that global carbon emissions will lead to increases in average temperatures. We are far less certain as to the ecological consequences of those changes in temperature, especially when it comes to the effect on complex food webs. I am using a simple food web consisting of duckweed and its associated insects as a model system to understand how changes in mean temperatures affect the abundance of the species that compose this food web.

Indirect interactions in food webs is a general term describing how changes in one species can cascade through a food web—even to those species with which the focal species does not directly interact or consume. We expect increases in mean temperature to alter the magnitude or direction of indirect interactions in our model duckweed community.

In addition, while one associates global climate change with increased temperatures, models of global climate change also predict more variable weather patterns—i.e. more droughts and more hurricanes. I have done mathematical work demonstrating how increased variation might alter indirect interactions in food webs. My lab will be testing some of those predictions in duckweed communities. While increased temperatures can be experimentally manipulated in the field, increased temporal variation is most easily manipulated in the laboratory. The duckweed can easily be observed at the size of ponds around Cedar Point Biological Station and experimentally manipulated in coffee cup sized containers in the laboratory.

This research examines how fundamental ecological processes are affected by global climate change. Primarily we use mathematical tools and the duckweed community to address these questions empirically. Ultimately, the answers to these questions will help to inform applied questions related to the impact of climate change on food webs. For example, systems for integrated pest management, management of invasive species and fisheries management are fundamentally food web systems that will be impacted by global climate change. Even flagship species, such as cranes, are ultimately embedded in food webs that will react to climate change in complex ways. In order to understand the applied, complex food webs, we need to develop principles in simplified, tractable, experimental and mathematical systems.

Selected Publications


Dr. Chad E. Brassil is an assistant professor in the School of Biological Sciences at UNL. He uses mathematics to understand fundamental principles in ecology and evolution. Specifically, he has done theoretical work examining the effect of temporal variation on indirect interactions in food webs. He also has expertise in developing maximum likelihood techniques to analyze complex relationships in data, especially data on aging in wild populations. Some of his current work involves examining temporal variation empirically in duckweed communities, models of invasive species establishment in grasslands and analysis of equilibrium population dynamics in grassland plots. Dr. Brassil received his Ph.D. from the University of Toronto, and did post-doc work at the Kellogg Biological Station, Michigan State University.
Pete Murdoch is a Research Hydrologist with the Watershed Research Group of the U.S. Geological Survey in Troy, New York. Since 1982 he has led research projects on watershed processes and the effects of acid rain and climate change on aquatic systems. In the mid-1990s he served as the Department of Interior representative to the White House Committee on Environmental and Natural Resources, where he co-authored “Framework for Environmental Monitoring and Research.” In 2004-06, he served as the DOI representative to an interagency committee that oversees the North American Carbon Program. His current role is as the Director of the DOI National Climate Effects Science Network, which is being initiated in 2008 through a multi-agency study on the effects of permafrost thawing in the Yukon River basin and north slope of Alaska. The CESN is a program within the new USGS Global Change Program Office.
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