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The North Central Climate Science Center (NC CSC) is one of eight regional CSCs under the National Climate Change and Wildlife Science Center (NCCWSC). Our mission is “to provide the best available climate science and tools to inform natural resource management within the North Central domain.” The NC CSC is a collaborative, applied research group that works with others across our domain to unite climate science with management decisions. The North Central University Consortium (NCUC), comprised of nine university partners in the region, provides foundational science needs and additional opportunities for integration with climate science users.

The NC CSC is dedicated to being a “Resource for Vulnerability Assessment, Adaptation, and Mitigation Planning” (ReVAMP, Figure 1). The ReVAMP concept is a centralizing theme that coordinates research done through the NC CSC and provides a mechanism by which the NC CSC can help serve stakeholder needs. The ReVAMP concept builds on three Foundational Science Areas (FSAs) led by the North Central University Consortium members. The three FSAs offer an integrated approach to informing resource managers and researchers in our region:

- **Climate Drivers:** Understanding and quantifying drivers of regional climate changes
- **Impact Analysis:** Assessing impacts of climate change on the natural resources of the region and the resulting vulnerability of social-ecological system components
- **Adaptation:** Characterizing adaptive capacity of communities and natural resources
The strength of the ReVAMP concept is bringing state-of-the-science climate information into simulation of ecological impacts in a collaborative, co-production of knowledge with scientists and managers. The NC CSC is bringing computing tools, climate data, and management needs together to address complex situations and help stakeholders explore possible future scenarios. The NC CSC takes advantage of the Resource for Advanced Modeling (RAM - fort.usgs.gov/sites/default/files/RAM/index.html) (Figure 2), which provides an opportunity to collaboratively address the inherently complex integration of climate data into ecological modeling in a way that directly supports resource management decision making in a changing climate.

The vision for the NC CSC is a coordinated and integrated regional approach to the management of the nation’s land, water, fish and wildlife, and cultural heritage resources that utilizes the best possible understanding of past, present, and future climate in the decision process. Technical components are vital to implementing this vision via downscaling and regionally informed climate projections, ecological response models, and assessing social ecological vulnerabilities and adaptation planning.

The NC CSC activities are organized to provide the best available climate science and inferences on impacts and adaptation strategies for natural resource management entities within the North Central Domain. The NC CSC provides the knowledge and information needed by decision makers in the region so that a more complete understanding of potential impacts and adaptation strategies for a broad range of natural, cultural, energy, and other resource management activities is available. This knowledge and information exchange is provided through the ReVAMP platform to help interpret an array of climate information on changes, impacts, and responses. The aim of these activities is to develop integrated information relevant to our natural resource managers and to ensure that these managers have access to products AND can use them in their decision-making process. The NC CSC is directing its five-year science agenda toward science delivery through ReVAMP. Co-development of research products with managers working in partnership with research groups is a key component of our ReVAMP development efforts.

The NCUC has assembled a team of researchers to lead integrated research activities to enable the NC CSC to provide climate-relevant information to guide decision-making in the region. That is, the NCUC is providing the scientific foundation to be used within the ReVAMP.
The ReVAMP concept has served as a centralizing theme to coordinate research done through the NC CSC, and will also provide the mechanism by which the NC CSC can help serve stakeholder needs. NCUC efforts are organized around the three foundational research themes, which provide an integrated approach to inform resource managers and researchers in our region:

- Understanding and quantifying drivers of regional climate changes
- Assessing impacts of climate change on the natural resources of the region and the resulting vulnerability of social-ecological system components
- Characterizing vulnerabilities, adaptive capacity, and management response options of communities and natural resource managers

Collaboration between decision makers, the climate modeling community, and researchers within the NCUC enhanced the integration of relevant climatological, ecological, energy, cultural, and management disciplines. Specifically, NCUC research includes:

- Region-specific approaches for developing targeted climatological information that respects the full range of temporal and spatial scales of climate processes in order to understand vulnerability of conservation targets to changing climate and opportunities for renewable energy given future climate scenarios
- Capacities to provide enhanced climate information at relevant spatial and temporal scales, both for historical climate and projections of future climate
- Ecological response modeling with enhanced climate information that respects non-stationarity
- Social-ecological vulnerability and adaptation response studies of the social-ecological system

Research coordination activities have been carried out through discussions with university consortium members, LCC leaders, and other federal and tribal partners associated with the Joint Stakeholder Committee (the advisory group for both the NC CSC and the USDA Northern Plains Regional Climate Hub) for the NC CSC. Research activities in three Foundational Science Areas (FSAs) of focus are being designed and implemented to build on our initial community analytical platform to evaluate impacts and response options for management entities to consider. The FSAs - climate dynamics, impact analysis, and adaptive capacity and decision making - are described below.

NC CSC Foundational Science research incorporates the three concepts within a social-ecological system framework. This approach allows for better integration of research findings into a solution-oriented decision-making process due to the enhanced awareness of social dimensions of changes and impacts across the North Central region. This framework allows for specific research to be carried out within certain disciplinary domains while providing a platform to link various findings within the system framework.

The NC CSC used directed funds in 2015 to support NCUC efforts to continue work in the three FSAs to address climate drivers, impacts, and adaptation, with a focus on drought. The details of that work are given in the following three sections. The final summary section describes how these foundational research areas will persist through science teams, and how synergistic research activities have been identified to further develop linkages between these elements to enhance the delivery and synthesis of information to the management process, including vulnerability assessments, adaptation, and mitigation.
Foundational Science Area #1

Understanding and Quantifying Drivers of Regional Climate Changes

Team Lead: Imtiaz Rangwala, NOAA
Co-Investigator(s): Joseph Barsugli, University of Colorado, Boulder

The Climate FSA team identifies and addresses climate science challenges that are important for ecologists and land managers in the North Central region. In order to understand how climate change will affect the ecosystems of the North Central region, it is essential to improve our ability to understand, measure and model the surface water balance, and how that balance might change over the next several decades to a century. One of our main objectives is to improve the datasets and methods regarding evapotranspiration, and in particular, evaluate and promote a more appropriate and physically-based measurement of potential evapotranspiration (PET) and develop an improved understanding of the drivers of long-term change in evaporative demand.

One of the main integrative themes across the different NC CSC FSAs is drought, as a present-day stressor, but also how it could manifest under future climate change. Drought is a dominant driver of ecological, economic, and social stress in the region, and is expected to be a major mode in which the impacts of climate change will be manifested in the region.

The Climate Drivers team’s work includes:

a) Evaluation of climate conditions, both historical and 21st century, in different regions of the North Central domain which would lead to drought conditions (e.g., extended heat conditions, extended periods of low precipitation, soil moisture deficits, and anomalies and trends in the evaporative demand) as well as their association with the large-scale climate drivers

b) Evaluation of climate products that are related to the surface water balance and drought (for example, evapotranspiration, soil moisture and streamflow projections)

c) Synthesis of existing information on drivers of drought in the North Central domain for use in adaptation

d) Continuing stakeholder outreach and engagement to enhance usability of this information

Related Activities and Deliverables

This research focus provides climate information across the region that will be tailored to resource management decision-makers’ needs, and informs researchers on the drivers of change across an array of natural and cultural resource areas. This information will be analyzed over historical periods and will include projections of a variety of future climate scenarios.

Specific 2015 deliverables for the Climate Drivers team include:

- Climate Postdoc Appointment at CIRES/NOAA/Western Water Assessment to assist with the Climate FSA proposal submitted by J. Barsugli on Evapotranspiration Research
  ○ Candida Dewes was hired for the position, and she started on July 1, 2015.
- Evapotranspiration Research Activities across CIRES/NOAA, NIDIS & NC CSC funded projects were a large effort with several different activities, including the following.

Annual Report - 2015
Compiled daily historical and climate model (CMIP5) data
Used data to estimate evaporative demand
Explored methods to analyze complementary relationship between evaporative demand and actual evapotranspiration over the Northern Great Plains and how it affects local hydrological systems
- Have analyzed 2000-2014
- Hope to extend approach using datasets that cover longer periods

- Development and outreach related to Evaporative Demand Drought Index (EDDI)
  Evaluated the relevance of EDDI as an appropriate and effective drought indicator tool (in particular, for early drought warning and capturing signals of rapidly evolving drought conditions)
  Strengthened collaboration with Mike Hobbins (NIDIS) to foster development of EDDI datasets and maps for NC CSC funded projects, and stakeholders in general
  Produced a two-page publication to inform a broad user group about the significance of EDDI
  [link]
  Engaged with the Western Water Assessment (WWA) to bring EDDI information to the WWA Dashboard
  Presently, EDDI information release only covers the states of CO, WY and UT. In the future, will expand to cover the rest of the NC CSC domain.
  Exploring funds for a possible development of an EDDI app

- Workshop organized on “High Resolution Climate Modeling for the Northern Great Plains” in Boulder, CO
  September 24-25, 2015 workshop on the application of high-resolution climate models for socio-ecological adaptation in the NC CSC region
  Motivation for the workshop was to explore the recent advances in HRCMs and discuss how they can better inform ecological impacts modeling and adaptation projects in the U.S. Northern Great Plains and mountains.
  Workshop attended by climate modelers and expert users of climate information for socio-ecological impacts assessment
  - 3 themes: convective precipitation, land-surface feedbacks, usability of HRCM output
  - EOS briefing report publication
    [link]
  - NC CSC webinar (October 22, 2015)

- Wind River Indian Reservation (WRIR) Drought Vulnerability Project
  Rangwala is a co-lead on the project’s climate team
  Barsugli and Dewes visited WRIR in October 2015 for the all-hands project meeting.
  Research activities include:
  - Developing future climate scenarios for the WRIR region, including quantifying change in specific hydro-climatic variables and drought indices
  - Assessing relationships among the components of the water cycle at the sub-basin scale and using remote sensing and ground based measurements
  - Evaluation of ENSO-related impacts
Foundational Science Area #2
Impacts and Vulnerability: Connecting Climate Drivers to Management Targets

Team Lead: Andrew Hansen, Montana State University
Co-Investigator(s): Arjun Adhikari, Montana State University

Whereas climate drivers are a fundamental research component for the CSCs, they are often not the primary concern for most management issues. For example, land managers are often more concerned about animal populations or ecosystem services than they are about changes or trends in annual average temperature or precipitation. Yet climate drivers are linked to the conservation targets of concern. This research element is directed toward understanding and quantifying that linkage through ecological response models. Ecological response models, as enumerated in Glick and others (2011) help bridge between climate information and management goals.

This research area looks at leveraging ongoing and active research and expertise in ecological response models where translational climate analysis can advance that work. The connection to management actions links this research area to the adaptation and decision-making research area listed below. The NC CSC is looking to build ecological response models that can both (a) be improved with enhanced climate information that respects nonstationarity and (b) serve management issues that have been prioritized by the stakeholders. The ReVAMP infrastructure facilitates these connections and interactions. The related research in this focus area must be open to and agile enough to iterate with both the climate-drivers research component and relevant resource management goals and objectives.

Related Activities and Deliverables

The goal of this FSA is to assess the vulnerability of forest, shrubland, and grassland vegetation to climate change and drought in the greater ecosystems centered on public and Native American lands across the NC CSC domain.

Objectives

1. Quantify change in the spatial patterns of natural cover types as influenced by land use intensification for 2000 to present
2. Summarize the responses of ecological processes to past (1950-present) and projected (2010-2100) climate change
3. Develop species habitat distribution models for dominant forest/shrub species and project species habitat suitability under IPCC climate scenarios.
4. Statistically relate grassland phenology to climate, soil and landform and project potential changes in grassland phenology under IPCC climate scenarios.
5. Synthesize the results from Objectives 1-3 in a vulnerability assessment for major greater wildland ecosystems in the NC CSC domain.

Specific 2015 deliverables for the Impacts team include the following:

- Impacts team meeting: November 5-6, 2015
- Ecosystem Vegetation Modeling Workshop: December 7, 2015
  - Collaborative NC CSC and Montana EPSCoR ecosystem modeling workshop focused on Fire-BGC, LPG-GUESS, state
and transition models, modeling philosophy, potential applications, pitfalls, and training in ecological modeling

http://nccsc.colostate.edu/sites/default/files/events/MSU_Vegetation%20Workshop.pdf

- The theme of the workshop was to compare and contrast various vegetation modeling approaches being used within the NC CSC and elsewhere and identify opportunities for improving the models and increasing use by the CSC.
  - Mapping of ecosystems centered on public lands across the NC CSC domain
  - Quantified change in land use and land cover for the period 2000-2010
  - Evaluated the extent of fragmentation of natural cover types within the domain
  - Prepared a technical report, *Land use change across the Greater Wildland Ecosystems of the North Central Climate Science Center Domain: Effects on Natural Vegetation Cover*
  - Preparing publications ongoing
  - The impacts team has coordinated activities with Jennifer Wellman of the Wind River Indian Reservation Drought Project. They have provided data sets on projected climate suitability for vegetation for the Yellowstone Area, provided their book manuscript on climate vulnerability, and provided an analysis of land use change and habitat fragmentation in the Wind River area.

*Research activities include the Wind River Reservation land in Wyoming. Photo by J. Stephen Conn*
Foundational Science Area #3
Characterizing Adaptive Capacity of Stakeholder Communities and Informing Management Options

Team Leads: Dennis Ojima and Shannon McNeeley, Colorado State University

The goal of this project is to develop a better understanding of drought vulnerabilities, risks, and responses in high-risk, multi-jurisdictional landscapes across the Missouri River Basin area that extends from the Rocky Mountains into the Great Plains. Our research poses the following questions:

1. How do different resource managers from the Department of Interior (DOI), other federal agencies, and tribal communities perceive and characterize drought risk in the same geographic area?
2. How are their respective grassland/rangeland, fish and wildlife, and forest management decisions affected by those drought risk perceptions?
3. What are their differential capacities for responding to and preparing for drought risks?

Related Activities and Deliverables

The adaptation science focus area provides a critical analysis of how the different regional management entities represented on the Joint Stakeholder Committee (JSC) have the ability to implement adaptation and mitigation strategies. This analysis will evaluate the options available to these entities to both address the impacts on the system and identify potential vulnerabilities. This information will provide a framework to build capacity to cope or respond to different stressors.

Specific 2015 deliverables for the Adaptation team include the following:

- Employing an interdisciplinary social-ecological systems (SES) approach, including using instrumental data of local and regional drought indicators and conducting key stakeholder interviews and workshops with natural resource managers and others
- Collaboration with the Climate Drivers and Impacts teams on three specific drought-themed case studies
  - Northwest Colorado and Southwest South Dakota
    - Exploratory analysis completed of case studies to characterize local vulnerabilities, risks and response options of land and resource managers on DOI and tribal lands
    - Results indicate that the social-ecological contexts and scales at which natural resource management occurs matter for local impacts and responses
  - Wind River Indian Reservation (WRIR), Wyoming
    - Initial interviews completed with tribal water and resource managers
    - Production of quarterly climate summaries which include current season conditions and outlooks - climate summaries can be found here http://nccsc.colostate.edu/revamp/project/wind-river-drought-preparedness
    - WRIR case study has developed into an interdisciplinary drought preparedness project
• Northwest Colorado case study evolved into collaboration with the Colorado BLM and Western State University – to conduct a multi-scalar social vulnerability analysis
  – Goal: develop a methodological approach for a social vulnerability assessment on public lands and for individuals whose livelihoods depend heavily on these lands.
  – Completed a review of methodological approaches to social vulnerability analysis focusing on indicators, scenario analysis, integrated assessment and case studies
  – Interview protocols have been developed
  – Land managers have been identified for interviews
  – Base indicator data have been aggregated for geospatial analysis
• Collaboration with Capacity Building team to develop an analytical framework for integrating social science and local knowledge into climate change research on public lands
• Monthly webinars with invited speakers for the Adaptation Working Group (a regional group of collaborators)
Synergies and Continuation of Teams

The NC CSC five-year science agenda is founded on the three focus areas described above. We have maintained work in these areas, continuing and building on the integrated work among the three foundational science teams, and have integrated that work into the other work at the Center and in the region.

Financial Support

The foundational science work was re-supported in 2015. The NC CSC provides resources to each team. Each team has a leader who is responsible for organizing the work within that area as well as connecting the work within that area to both of the other FSAs and into the ReVAMP science delivery mechanism. Team resources can support time for the team leader, a post-doctoral researcher, and team workshops. It is up to the team lead, working in collaboration with the NC CSC, to utilize the budget to maximize the impact of each team.

Selection of Team Leads and Governance

Long-term planning efforts on how the NCUC will be able to continue support of research efforts in the region will be carried out by the lead of these research elements. As such, the NCUC helps to lead the selection of the team leads. The team leads, continuing from 2013 and re-selected in 2015, are Dr. Joseph Barsugli and Dr. Imtiaz Rangwala for Climate (University of Colorado), Dr. Andrew Hansen for Impacts (Montana State University), and Dr. Dennis Ojima for Vulnerability and Adaptation Responses (Colorado State University). These leads continue in their leadership role as it was defined at the May 2012 science-planning workshop. Their initial interest and work contributed to the NC CSC five-year plan.

The NC CSC hosted a joint meeting of the FSA teams in Fort Collins on February 24, 2015. This meeting allowed the team leads and other project representatives to come together to discuss progress and opportunities for collaboration and cross-sharing of data.

Consultation to Assist with Directed Work

In addition to the specific funding dedicated to each team lead, the team leads act as consultants to the NC CSC for recommendations and insight on how to spend directed funds available through the center. In 2015, the NC CSC spent approximately half of its research funds on solicited/competed work and maintained roughly half for directed funding. As competed funds are awarded, the foundational science team leads have been consulted with to augment the work of the solicited projects and fill any critical climate-science research gaps.

Assistance with Coordination

The foundational science teams help to ensure coordination with other national and regional initiatives. Priority regional coordination opportunities include working with the NOAA’s Western Water Assessment, the USDA Northern Plains Climate Hub, and Landscape Conservation Cooperatives. Priority national level coordination opportunities include working with NOAA’s National Climate Projection and Prediction program, the National Climate Assessment (NCA; disseminating information from the 2013 NCA and helping prepare information for the 2017 NCA), and the National Center for Atmospheric Research (NCAR).

Support for the Mission of the NC CSC

Finally, it is the ultimate objective of the three Foundational Science teams to support the mission of the NC CSC to deliver the best possible climate-related science to regional resource managers. Currently, the lead investigators for each of the three elements (i.e., climate, impacts, and adaptation) routinely communicate on research efforts and prioritization of research activities to enhance the linkage of research products. This collaboration across elements improves efficiency, understanding and utility for use in natural resource management decision making. With the resources and objectives outlined here, the NC CSC hopes it will be possible to further enhance coordination among elements to develop a more integrated climate-ecological-social system framework.

Cross-project meetings (face-to-face and virtual) among the foundational research groups, other funded investigations, coordinated efforts, and management entities working with the NC CSC have been and will continue to be held to co-develop research products and translational materials that are relevant, useful, and usable for natural resource management decisions. The Foundational Science teams are playing a major role in the development of this integrated synthesis of research products aimed to meet natural resource management needs. An important product of this integrated research activity will be a development of synthesis papers outlining the implications of climate change effects on natural resources in the region and the potential response options that may be feasible.
Management-Focused Projects

The NC CSC funds competitively selected multi-year projects with a clear “articulation of the decision that is being considered and how it addresses important Department of Interior land, water, fish and wildlife, or cultural heritage resources in the region” and the inclusion of resource management decision makers as collaborators and/or investigators. These solicited projects help connect the foundational science work with critical resource management needs and are helping to define the specific capacity that will be built into the ReVAMP framework.

Selected Project Areas in North Central Climate Science Center Region

More information about the following projects is available in their project reports on ScienceBase at https://www.sciencebase.gov/catalog/items?q=&filter=tags%3DNorth+Central+CSC

Yellowstone River, Wyoming. Photo by Loren Kerns
In southwestern Colorado, climate change includes higher temperatures, more frequent and prolonged drought, accelerated snowmelt, larger and more intense fires, more extreme storms, and the spread of invasive species. These changes put livelihoods, ecosystems, and species at risk.

To help human and natural communities cope with climate change, this project is creating opportunities for scientists, land managers, and affected residents to learn from each other and identify actions that each can take individually or collectively to reduce the negative impacts of climate change in the San Juan and Gunnison Basins in Colorado. These adaptation strategies and the processes that created them are being documented by the participating scientists to assist communities elsewhere in identifying goals and actions that conserve key species, ecosystems, and resources, and address the needs of local communities and natural resource managers in the face of a changing climate.

**2015 Activities, Deliverables, and Progress**

- The project management team met by phone twice monthly to discuss project activities, progress towards goals, integration of ecological-social goals, and plan the full PI team meetings to share insights and lessons learned.
- Team meeting: January 14-15, 2015. Objectives: review results, insights and knowledge from work conducted to date; develop a process for generating adaptation strategies that integrate social, ecological and climate components; create a work plan and execution plan for April-May, 2015 adaptation strategy workshops.
- Neely, Rondeau and Bidwell attended the Climate Smart Adaptation Training (NCTC) in Santa Fe, NM (October 26-28, 2015). Compared project process with workshop guidance and refined strategy with worksheets from training.
- October 13, 2015: the team met to review strategies that were developed in the basins, develop a method for including two additional scenarios, and revise schedule for the end of the project. As follow up to meeting, they discussed final deliverables and how products will coalesce into the tool kit and publications.
- December 2015: Wildlife Conservation Society Training. Burkardt, Orth, Neely, Cadiente, Bidwell and two agency partners. Team reviewed results and updates from previous work and fine-tuned process for identifying strategies through a criteria-based system. This
will assist with prioritizing interventions. This workshop allowed the team to directly involve DOI project managers in education opportunities and a chance to work across basins.

- The San Juan team met with stakeholders to select targets; conduct interviews with agency staff, tribal partners, and members of the public; and host a series of workshops and meetings with our partners.
- The San Juan Social Science Interview Report was completed in 2015.
- The San Juan project team conducted two ecological response modeling work sessions in January 2015: Pinyon-juniper ecological response modeling and Seeps and Springs ecological response modeling.
- The team hosted a workshop on May 5–6, 2015 to develop preliminary interventions for pinyon-juniper landscapes and seeps and springs for one climate scenario.
- Work on the institutional analysis, to identify barriers to climate adaptation, in the San Juan and Gunnison basins is underway.
- The Gunnison project team completed the social science interview report, drafting the social science focus group report, hosted a two-day climate adaptation workshop (April 2015) to identify intervention points for one climate scenario for sagebrush and spruce-fir landscapes. They also held a one-day climate adaptation workshop in November 2015 to identify intervention points for two other climate scenarios. The team completed a report summarizing the results of the April workshop and a table of impacts and interventions resulting from the November workshop.

**Surrogate Species for Wetland-Dependent Birds in the Prairie Pothole Region
Selection, Evaluation, and Management Application in the Face of Climate Change**

**Principal Investigator(s):** Susan Skagen (U.S. Geological Survey, Fort Collins Science Center) and Barry Noon (Dept of Fish, Wildlife and Conservation Biology, Colorado State University)

**Co-Investigator(s):** Helen Sofaer (Colorado State University); Valerie Steen (USGS Fort Collins Science Center); Ben Rashford (University of Wyoming); John Stamm (USGS South Dakota Water Science Center); Kevin Doherty (USFWS, Prairie Pothole Joint Venture); Neil Niemuth, (USFWS, Habitat and Population Evaluation Team); Cami Dixon (Zone Biologist, USFWS Region 6, National Wildlife Refuge System); Mark Chase (Director, USFWS Natural Resource Program Center); Natalie Sexton (Chief, Human Dimensions Branch, USFWS Natural Resource Program Center); Lee O’Brien (Ecologist, USFWS National Wildlife Refuge System); Socheata Lor (USFWS, Regional Inventory and Monitoring Coordinator); Rick Nelson and Mike Olson (Plains and Prairie Pothole Landscape Conservation Cooperative (PPPLCC))

The Prairie Pothole Region spans parts of North and South Dakota, Minnesota, Montana, Iowa and south-central Canada and contains millions of wetlands that provide habitat for breeding and migrating birds. Because this is the continent’s most important breeding area for waterfowl, conservation and management largely focuses on protecting habitat for nesting ducks. However, other wetland-dependent birds also rely on this region, and it is important to understand the degree to which habitat conserved for ducks provides habitat for other species, and how the quality of this habitat will be affected by climate change.

The "prairie pothole" region is characterized by depressed regions that formed as a result of glacier activity. These "potholes" fill with water every spring and create wetlands that are important habitats for migratory waterfowl. Photo courtesy of USFWS
The Surrogate Species team is testing whether waterfowl are effective representatives, or surrogates, for other wetland-dependent birds by predicting how climate change will affect habitat suitability for waterfowl and other species. They are also considering how climate change is likely to affect land-use patterns and agricultural conversion risk, and are using these predictions to identify areas of the landscape where both waterfowl and other species are expected to have suitable habitat in the future. This research will help managers to efficiently direct their resources towards conserving areas that will provide habitat to a broad suite of species.

2015 Activities, Deliverables, and Progress
- Slightly revising methodology for assessing surrogate relationships among wetland-dependent birds. Grouping species using three different approaches: species archetype models, hierarchical agglomerative clustering, and trait-based clustering. Considering each of these approaches as members of an ensemble.
- Using network analyses, the group combines multiple outputs to represent the agreement among approaches in species groupings.
- Developing approach provides a framework for quantifying variation in the strength of surrogate relationships, to address a major challenge in multi-species management.
- Using three approaches to identify areas of the landscape that are likely to provide suitable habitat for wetland-dependent birds under future climatic and land use conditions.
  - Directly modeled the effects of climate on wetlands
  - Modeled how climate may affect land conversion from grassland/ranching to agriculture
  - Modeling current and future distributions of wetland-dependent birds
- Predictions to the past and projections to ten future GCMs were compared to assess potential climate change impacts to the distribution and abundance of wetlands.
- Based on the land-use decision indicated by USDA’s annual Cropland Data Layers, the group modeled annual land-use transition probabilities after developing methods to account for mapping errors.
- Summarized resulting probabilities regionally.
- Updating models of current and future bird distributions, explicitly addressing uncertainty, using an ensemble of statistical predictive models and incorporating CMIP5 climate projections.
- Outreach to managers is ongoing.

Principals Investigator(s): Cathy Whitlock and Andrew Hansen, Montana State University
Co-Investigator(s): GYCC WBP Subcommittee: Karl Buermeyer (Bridger Teton NF); Kristen Legg (NPS I&M); Dan Reinhart, (YNP). GYCC: Virginia Kelly (Executive Coordinator). USGS Northern Rocky Mountain Science Center: Greg Pederson. Great Northern LCC: Tom Olliff (Co-coordinator). NPS I&M: John Gross, Bill Monahan. University of Montana: Helen Naughton (Economics Dept.). Montana State University: Virginia Iglesias, Todd Kipfer (Institute on Ecosystems); Nathan Piekielek (Ecology Dept.); Elizabeth Shanahan (Political Science Dept.); Arjun Adhikari.
WBP is a keystone and candidate endangered species that has undergone high levels of mortality related to climatic warming. The GYCC WBP Subcommittee has developed over the past decade a strategy for WBP in the GYA, but without adequate information on climate change. The subcommittee is participating in this project because of their high interest in using climate science to enhance implementation of the strategy. Ecosystem processes and WBP habitat suitability are being forecast under downscaled future scenarios to 2100 with existing funding. Paleodata from GYA is being used to quantify WBP/climate relationships over the past 15,000 years and growth rates during extreme climate events over the past 800 years. The team is developing four WBP management alternatives consistent with the GYCC WBP Strategy. The team is evaluating these alternatives relative to WBP status (viability and ecosystem function), costs of implementation, and public valuation of change in ecosystem services using conjoint analysis and public surveys. A scenario planning workshop is planned to derive recommendations based on both the results and uncertainty in the results. These recommendations can thus be immediately acted upon by the GYA management community and the approach and methods will be readily applicable to several other tree species that are undergoing die-offs under changing climate.

2015 Activities, Deliverables, and Progress

- Ecological Forecasting: projection of WBP climate suitability in the Greater Yellowstone Ecosystem (GYE), meta-analysis of WBP suitability and vulnerability across the Northern Rockies was completed (publication: Hansen and Phillips 2015)
- Paleo Relationships: evaluation of WBP presence in the GYE throughout the Holocene (publication: Iglesias et al. 2015)
- Management Alternatives: worked with the Greater Yellowstone Coordinating Committee WBP subcommittee to review recent findings on climate impacts on WBP ecology and to review policy and management actions on WBP in GYE, developed a detailed, spatially-explicit management plan for the GYE that places treatments based on projected climate suitability for WBP, competing tree species and mountain pine beetles, working with WBP subcommittee to make the management plan spatially-explicit
- Evaluation of Management Alternatives: performing a simulation experiment across four landscapes within the GYE with the Fire BGC model to climate and management scenarios
- Social Survey: the social science research is addressing the following research questions:
  - What factors influence people's willingness to pay for WBP management in the face of climate change?
  - What is the level of concern for loss of WBP?
  - What level of support is there for management of this species under climate change, especially on restricted federal lands such as Wilderness Areas?
- A tri-state survey was completed to understand the attitudes of residents in the Northern Rockies toward WBP and WBP management strategies across varying land designations.
Climate change is expressed in both regional climatic shifts (e.g., temperature and precipitation changes) and local resource impacts. Resource management in a changing climate is challenging because future climate change and resource responses cannot be precisely predicted. Scenario planning is a tool to assess the range of plausible future conditions. However, selecting, acquiring, synthesizing, and scaling climate information for scenario planning requires significant time and skills.

This project has three goals:
1. Synthesize climate data into 3-5 distinctly different but plausible climate summaries for the northern Great Plains region
2. Craft summaries of these climate futures that are relevant to local land management units
3. Apply these local summaries to further develop quantitative climate-resource-management scenarios through participatory workshops and simulation models

This team is engaging with multiple stakeholders in two focal areas within the region: southwestern South Dakota in the vicinity of Badlands National Park, and central North Dakota in the vicinity of Knife River Indian Villages National Historic Site. This effort will increase climate change planning efficiency in the region; promote collaborations across jurisdictions; and develop a prototype for a novel, efficient, and replicable form of scenario planning that could serve additional management units.

2015 Activities, Deliverables, and Progress
- In 2015 the project focused on orientation meetings, local climate summaries, scenario planning workshops, and modeling for each of the two focal areas (central North Dakota and southwest South Dakota)
- Project orientation meetings (August 21 and 24, 2015): to create relevant scenarios and focus workshops on pertinent management concerns
- Local climate summaries: developed four mid-term (2020-2050) quantitative climate scenarios for each focal area that meet four criteria (plausible, challenging, relevant, and divergent). These scenarios were vetted with local meteorologists and NC CSC Climate FSA leads, Imtiaz Rangwala and Joe Barsugli.
- Scenario planning workshops (November 12-13, 2015-central ND; January 20-21, 2016-southwest SD): used the local climate summaries as a basis for workshops. Objectives of workshops were to help local resource managers and scientists understand ongoing and future climate change and how to use scenario planning to make management and planning decisions based on assessments of critical future uncertainties.
- Modeling: incorporating quantitative modeling into work with managers using approaches tailored to the resource concerns in each focal area. For central ND, estimation of peak river flow behavior in the selected climate scenarios. For southwest SD, presentation of the framework of the state-and-transition simulation model of grassland vegetation that is being developed with the input of workshop participants and other regional experts.

**Principal Investigator(s):** Benjamin Poulter, Montana Institute on Ecosystems and Department of Ecology, Montana State University; benjamin.poulter@montana.edu

**Co-Investigator(s):** Peter Adler, Utah State University; Cameron Aldridge, USGS; Bethany Bradley, University of Massachusetts. John Bradford, USGS; Caroline Curtis, University of Massachusetts; Andy Kleinhesselink, Utah State University; Jen Pierce, Boise State University; Daniel Schlaepfer, University of Wyoming; Eric Thacker, Utah State University Extension. Mary Manning, U.S. Forest Service; Renee Chi, Utah BLM; Robert Means, Wyoming BLM; Steve Torbit, Fish and Wildlife Service.

The future of sage grouse depends on the future of sagebrush, yet there is limited ability to anticipate impacts of climate change on sagebrush populations. Current efforts to forecast sagebrush habitat typically rely on species distribution models (SDMs), which are prone to a variety of well-known weaknesses. However, by integrating SDMs with complementary research approaches, such as historical data analysis and mechanistic models, it will be possible to provide increased confidence in projections of habitat vulnerability to climate change.

The goal of this project is to forecast the effect of climate change on the distribution and abundance of big sagebrush in order to inform conservation planning, and sage grouse management in particular, across the Intermountain West. The novelty of this work is the integration of model projections based on spatial, temporal, and mechanistic relationships between climate and sagebrush cover. The project will culminate in a working group meeting bringing together land managers and researchers to discuss how integrated metrics for climate vulnerability can be used to inform management. The team will take advantage of existing USGS infrastructures already in place to efficiently disseminate our final report to management agencies.
2015 Activities, Deliverables, and Progress

- In 2015, the research team made significant progress towards:
  - Parameterizing a sagebrush functional type in LPJ-GUESS
  - Assembling benchmarking data
  - Processing climate data
  - Standardizing the procedure for model synthesis and comparison
- LPJ-GUESS Sagebrush Parameterization: creation of new species in LPJ-GUESS, determination if it was necessary to model sagebrush at the subspecies level (decided to lump subspecies together in model), defined the bioclimatic space of sagebrush, estimated five key bioclimatic parameters that are used in the model to limit establishment and survival, improved model performance by adding a new establishment sub-routine, adjusted the physiological and allometric parameters in model to adapt model for use with a shrub functional type, working on evaluating the sensitivity of sagebrush productivity and distribution to carbon uptake and allocation parameters
- Benchmarking data: working on assembling benchmarking data to compare the model outputs. So far, the team has field-based estimates of NPP, above- and below-ground biomass, and shrub height, diameter, and crown area. Working to expand the spatial and temporal coverage of benchmarking data to ensure parameterization of sagebrush in model is robust across a wide range of climatic conditions.
- Climate Data Processing: Modifications have been made to the model so that it can now read in climate and soil data from several different sources
- Model Comparison: Selected 726 locations to use for model comparison.

The Wind River Indian Reservation’s Vulnerability to the Impacts of Drought and the Development of Decision Tools to Support Drought Preparedness

**Principal Investigator(s):** Cody Knutson, Research Associate Professor and Leader of the Planning and Social Science Program, National Drought Mitigation Center (NDMC), School of Natural Resources, University of Nebraska-Lincoln; cknutson1@unl.edu

**Co-Investigator(s):** Mitchel Cottenoir, Tribal Water Engineer, Shoshone and Arapaho Tribes Office of the Tribal Water Engineer; Jennifer Wellman, Hydrologist, Wyoming Experimental Program to Stimulate Competitive Research (EPSCoR) Coordinator at Wind River Reservation; Shannon McNeely, Research Scientist, Colorado State University/NC CSC; and Mark Svoboda, Climatologist and Leader of the Monitoring Program, NDMC, University of Nebraska-Lincoln

**Project Management Team (PMT):** The PIs listed above plus Northern Arapaho Tribal Liaison, Gary Collins, and Al C’Bearing, Baptiste Weed, Jim Pogue, Office of the Tribal Water Engineer

This project is conducting an interdisciplinary, technical assessment of key social-ecological vulnerabilities, risks, and response capacities of the Wind River Indian Reservation (WRIR) to inform development of decision tools to support drought preparedness. It is also providing opportunities for:

1. Development of tribal technical capacity for drought preparedness
2. Educational programming guided by tribal needs, Traditional Ecological Knowledge (TEK), and indigenous observations of drought for tribal members, with a longer-term goal of transferring lessons learned to other tribes and non-tribal entities

This project has foundational partnerships between the Eastern Shoshone and Northern Arapaho tribes of the WRIR, the National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln, the North Central Climate Science Center (NC CSC) at Colorado State University, University of Wyoming EPSCoR, and multiple government agencies and university partners. These partners are working together to develop decision tools to support drought preparedness. Other partners include the USDA Northern Plains Regional Climate Hub and NRCS, the Western Water Assessment at CU-Boulder, NOAA National Integrated Drought Information System (NIDIS), the High Plains Regional Climate Center, U.S. Fish and Wildlife Service, USGS, BIA, Great Northern LCC, and other North Central University Consortium
scientists. The project's decision target is a WRIR Drought Management Plan that integrates state-of-the art climate science with hydrologic, social, and ecological vulnerabilities and risks, and identifies response capacities and strategies to support the Tribal Water Code and related resources management.

2015 Activities, Deliverables, and Progress

- The project has three teams: social science, physical science and ecological impacts teams.
- Social Science Team (Leads: McNeeley and Knutson)
  - McNeeley has completed initial interviews with tribal water and resource managers. Analysis is ongoing.
  - Production of quarterly climate summaries that include current season's conditions and outlooks in consultation with tribal members, the High Plains Regional Climate Center, NC CSC, NDMC, and the University of WY. [http://nccsc.colostate.edu/revamp/project/wind-river-drought-preparedness](http://nccsc.colostate.edu/revamp/project/wind-river-drought-preparedness)
  - Team meetings have been held to plan telephone interviews with drought planners from other tribes to describe their drought vulnerability assessment and planning process.
  - Institutional Review Board (IRB) protocol submitted to University of NE-Lincoln.
  - Literature review of other tribes’ drought plans/vulnerability assessments conducted to inform telephone interviews.
  - Initial workshop/webinar held with tribal natural resource managers and policy makers to discuss development of a reservation-wide drought plan and how vulnerability assessment results can be integrated into the drought planning process.
  - Webinar held with researchers from the University of WY facilitating the development of an Agricultural Resources Management Plan for the WRIR to develop a plan to ensure the sharing of information and alignment between tribal engagement efforts and project outputs.
  - Data management plan has been developed.

Above and right: Outreach with tribal managers in the NC CSC region has included educational and training opportunities, like this Climate Smart Conservation course that was held in Rapid City, South Dakota, July 28-30, 2015 in partnership with the Bureau of Indian Affairs.
• Physical Science Team (Leads: Svoboda and Rangwala)
  ▪ Development of a GIS base map of the WRIR for analyzing climate, hydrological and drought indicator/impact information
  ▪ July 2015 – hosted technicians from the Tribal Water Engineer’s Office on climate/drought and the creation of the operational, quarterly climate and drought summaries
  ▪ Work on inclusion of hydrology data into the Drought Risk Atlas (DRA)
  ▪ Identification of additional stations to be included in the DRA for Wyoming
  ▪ Development of real-time EDDI maps and user guidance materials, webinar (October 9, 2015) and development of two-page informational pamphlet on EDDI for user guidance and engagement, weekly EDDI maps produced
  ▪ November 30, 2015 project meeting – presentation of preliminary results from the analysis of CMIP5 model output
  ▪ Exploration of El Niño impacts for the region
  ▪ Development of research paper on the climate/hydrological and management processes related to the 2015 irrigation season in the WRIR (McNeeley and Dewes).

• Ecological Impacts Team (Lead: Wellman)
  ▪ Gathered existing resources and research to characterize the Wind River watershed and its surrounding ecosystem: biological and physical habitat data, examining preliminary model results, and outlining new sources of information from the GYE to support further analysis
  ▪ Meeting with WRIR leaders and natural resource managers to define the species of interest and those that are important to the Eastern Shoshone and Northern Arapaho tribes
  ▪ Production of maps of current and future soil water balance for the WRIR (University of WY)
  ▪ Applied aquatic ecology and population and community ecology, fisheries and conservation biology research (USGS University of WY Cooperative Unit and USFWS)
  ▪ Analysis of impacts of climate change on whitebark pine, aspen, cottonwood, and other landscape-scale ecological implications of drought (Montana State University)
  ▪ Discussion of certain areas that require further study and concentrated attention

• Evaluation
  ▪ Conducted an evaluation of the project through in-person and internet surveys to collect baseline evaluation data on stakeholders and team members' expectations and metrics for success (McNie)

• Educational Activities
  ▪ Outreach to WRIR students and community members: field trips to drinking water systems and other watershed facilities; retreats, discussion, and events like drought and climate awareness
  ▪ WY EPSCoR installed new streamflow measuring equipment and a weather station in Fort Washakie to improve local weather and water resource data collection
  ▪ Outreach to Eastern Shoshone Boys and Girls Club included science programming about local weather and watershed conditions.

• Communication with Decision Makers
  ▪ Ongoing communication with multiple managers from the Tribal Water Engineer’s Office, Wind River Water Resources Control Board, and other resource managers, tribal leaders, and producers
Establishing connections among natural landscapes is the most frequently recommended strategy for adapting management of natural resources in response to climate change. The U.S. Northern Rockies still support a full suite of native wildlife, and survival of these populations depends on connected landscapes. Connected landscapes support current migration and dispersal as well as future shifts in species ranges that will be necessary due to our changing climate.

Working in partnership with state and federal resource managers and private land trusts, this team is working to 1) understand how future climate change may alter habitat composition of landscapes expected to serve as important connections for wildlife; 2) understand how wildlife species of concern are expected to respond to these changes; 3) develop climate-smart strategies to help stakeholders manage public and private lands in ways that allow wildlife to continue to move in response to changing conditions; and 4) explore how well existing management plans and conservation efforts are expected to support crucial connections for wildlife under climate change. Ultimately, this project aims to ensure that the iconic landscapes of the Northern Rockies and the wildlife they support endure in a changing landscape for the benefit of future generations.
2015 Activities, Deliverables, and Progress

- Project kicked off with project partners’ meeting on May 29, 2015
- Monthly calls to keep all project partners abreast of progress and to seek their input and feedback
- Number of partners doubled with addition of participants from Idaho Dept of Fish and Game, Montana Dept of Transportation, BIA, NPS Inventory and Monitoring Program, Confederate Salish-Kootenai Tribes, and Crown Managers Partnership
- All datasets needed for assessing exposure and adaptive capacity have been acquired and processed. Spatial analysis steps have been planned and are on-going.
- Project team has agreed on a list of 16 focal species for which both climate change impacts and connectivity are a concern and that are felt to be representative of habitat needs throughout the study areas.
- Existing sensitivity scores and associated information regarding factors contributing to sensitivity have been compiled from the Climate Change Sensitivity Database and supplemented with additional sources of information.
- Partner agencies’ existing climate adaptation goals, strategies, and actions have been synthesized. This will help to later identity opportunities to tie proposed adaptation strategies into existing components of management frameworks or to identity the need for these components in future plan revisions.
- Identify conservation targets: picked a new model to use (Dave Theobald-unpublished) that represents regional-scale, biome-level connectivity, including alpine, forest, shrubland and grassland
- Assess vulnerability: updated choice to vegetation models used to assess exposure and picked a more flexible and management-relevant spatial unit of analysis (raster-based)
  - Exposure: chose climate change projections from Shafer and Bartlein (2015) and Bachelet et al. (in press)
  - Sensitivity: examine species-specific sensitivity to biome-level transitions in vegetation due to climate change for focal species selected from species of concern among partner agencies and organizations.
  - Adaptive capacity: derive an impact score that integrates the degree of human modification across the landscape and the presence of high-risk roads identified from wildlife carcass data as barriers to movement in response to climate change. Scheduled a work session in the RAM facility in Fort Collins (February 3-4, 2016).

Principal Investigator(s): Christopher J. Anderson [Climate Science Program, Iowa State University, cjames@iastate.edu], Peter T. Wolter [Dept Natural Resource Ecology and Management, ptwolter@iastate.edu], Hongli Feng [Dept Economics, Iowa State University; hfeng@iastate.edu]
Co-Investigator(s): Kaylan Carrlson (Manager of Conservation Planning, Ducks Unlimited, Inc.); Martha Kaufmann (Managing Director, Northern Great Plains, World Wildlife Federation US); Heather Johnson (Regional Private Lands Coordinator, U.S. Fish and Wildlife Service); Scott McLeod (N. Dakota Private Lands Coordinator, U.S. Fish and Wildlife Service); Adnan Akyüz (N. Dakota State Climatologist); Peter Bauman (S. Dakota State Univ. grassland extension specialist); Juan M. Murguía (Dept. of Agric. & Applied Economics, N. Dakota State Univ.); Ben Rashford (Dept. of Agric. & Applied Econ., Univ. of Wyoming); Susan Skagen (USGS, Fort Collins, Colorado); Rick Nelson (Plains and Prairie Pothole Landscape Conservation Cooperative).

What remains of the U.S. prairie ecosystem is threatened by economic forces and a changing climate. Grassland conversion to cropland in the Dakotas would imperil nesting waterfowl among other species and further impair water quality in the Mississippi watershed. This team is working with grassland conservation managers to better target the use of public and private funds allocated toward incentivizing grassland preservation on private lands in the Dakotas. They are assembling data on historical land switching in the area and on land conversion costs, and are analyzing crop vulnerabilities to weather and climate change.
The team is working to provide practical analytical tools to assess the likelihood of grassland conversion to cropping and of the costs of protecting these lands under different climate and economic scenarios. These tools, together with insights they are obtaining from partners in the area allow them to work with land conservation managers to identify lands to target for grassland protection incentives under alternative climate and economic conditions. Outputs will be used to collaborate with land conservation managers when comparing strategies for ensuring that lands providing high wildlife, habitat and hunting benefits at low conservation cost are conserved while private landowners are happy to forgo land use alternatives.

2015 Activities, Deliverables, and Progress
- The funding for this project was delayed with a change in PI (Hennessy to Anderson) at the beginning of the project. The start date was pushed back to September 2015. In the few months the project has been active, work began at Michigan State (and students were recruited) in November 2015. The group has some crop yield modeling and focus group findings, but they have not begun on the satellite analysis yet.
Capacity-Building in the NC CSC Domain

Capacity-Building Team:

**PI:** Dennis Ojima, Colorado State University

**Capacity-Building Leads:** Geneva Chong, USGS and LCC Liaison; Brian Miller, CSU Research Scientist

**Collaborators:** Bob Gough, Intertribal Council on Utility Policy; Dan Wildcat, Haskell University; Jeff Morisette, USGS

In addition to supporting funded projects selected through its solicitation process or the directed funds going to the FSAs, the NC CSC also targets funds to support capacity-building work to help the NC CSC achieve its mission. This project supports work that builds capacity among stakeholders that have been otherwise left out of the major projects funded by the NC CSC. The objective of this project is to focus on stakeholder capacity building with two activities related to enhancing tribal capacity in understanding and adapting to climate variability, and a third activity to provide technical support for phenology cameras (or phenocams) at multiple locations within the NC CSC domain.

During the course of the project, a goal was added to provide climate education opportunities to capitalize on the opportunity to improve outreach and capacity building by leveraging training already being implemented by the U.S. Fish and Wildlife Service National Conservation Training Center (NCTC).

PhenoCams

The NC CSC and AmericaView have established eleven phenocams. Images are uploaded to a central server every 30 minutes, and both raw data and general analyses are available via the National Phenocam Network website. These transmitted data can build capacity by allowing landscape-level scientists and researchers to have access to land conditions 365 days a year. Cameras are currently stationed in Colorado, Wyoming, Montana, North Dakota, South Dakota, Kansas, Nebraska, and Iowa.

In addition to establishing phenocam sites, the NC CSC has developed and documented protocols for establishing off-grid cameras and acquiring and analyzing additional phenology data through MODIS and Landsat. Joseph Krienert, USGS/National Association of Geoscience Teachers intern, made significant advances with the latter in determining the field of view of the phenocam to allow direct comparison with remotely sensed data on a pixel-by-pixel level. Colin Talbert (USGS, NC CSC) is advancing the work that Joe started, and initial phenocam and MODIS phenology data analyses were presented by Brian Miller at the American Geophysical Union Fall Meeting. Students Morgen Burke (University of North Dakota) and Trey Stafford (University of Nebraska-Lincoln) also conducted preliminary data analyses and delivered a white paper about these analyses to the NC CSC.

Tribal Capacity Building

Collaborator Dr. Dan Wildcat (Haskell Indian Nations University) is overseeing the implementation of this activity. Wildcat and his students have undertaken data collection to establish the concept for further collection efforts. Students have begun making observations of culturally and traditionally significant plants to generate data sets for use in climate change impact assessments. Thus far, over 400 positive phenophase observations (i.e., visual confirmation that a phenological status is present) from the Wakarusa Wetlands Indigenous Trail have been uploaded to Nature’s Notebook (data can be downloaded from USANPN). Wildcat, Miller (NC CSC Staff), and Morisette (NC CSC USGS Director) presented a poster on this work at the Rising Voices 3 Workshop (Boulder, CO June 29 – July 1, 2015).

During the Rising Voices 3 Workshop (partially funded by the NC CSC), Wildcat, Miller, and Morisette also participated in a breakout session focused on phenology (the timing of plant and animal life-history events). Although this was a productive session, there was a need to continue the group’s discussions about phenology beyond the workshop itself. As a result, Miller organizes a monthly call that convenes an indigenous phenology working group, whose overarching mission is to develop an infrastructure for integrating stories, data, and communities in order to achieve a more complete understanding of the impacts of environmental change on tribal resources using phenology as a primary tool for investigation.

Educational Opportunities/Training

The North Central CSC recently partnered with the Bureau of Indian Affairs to lead a Climate Smart Conservation course for tribal managers that was held in Rapid City, South Dakota, July 28-30, 2015. Dr. Valerie Small from the Crow Nation of Montana helped lead the course along with Jeff Morisette and Brian Miller of the NC CSC. NC CSC scientist, Shannon McNeeley, gave a presentation on the NC CSC’s work with Tribes. Morisette and Small also served as instructors for a regional offering of the NCTC Climate Change Vulnerability Assessment course, October 26-28, 2015, in Santa Fe, NM.
Joint Retreat of NC CSC, Western Water Assessment, and USDA Northern Plains Climate Hub

The NC CSC, Western Water Assessment (WWA) and USDA Northern Plains Climate Hub (NPCH) met for a joint and collaborative retreat twice in 2015, on May 28-29 and November 9-10, in the shortgrass steppe outside of Fort Collins to set a collective vision and direction for future work. Attendees included representatives from our FSA teams, and staff from each of the organizations.

Quarterly NC CSC Newsletter

The NC CSC has continued producing a quarterly newsletter in 2015, with the topic of the newsletter rotating between a focus on adaptation, climate drivers, ecological impacts, and capacity building. This quarterly publication highlights various aspects of the work that the Center is doing in each of the FSAs plus Capacity Building and introduces the public to the NC CSC team, their publications and work, and upcoming opportunities for involvement. See our 2015 Winter, Spring, Summer, and Fall newsletters (http://nccsc.colostate.edu/products).

NC CSC Monthly Check-ins

The NC CSC holds monthly check-in webinars that feature a science presentation by one research team, and allow updates from all research projects for the shared benefit of all NC CSC and project personnel.

Contributions to semi-annual Software for Habitat Modeling Trainings (Capacity Building)

NC CSC staff members Colin Talbert and Marian Talbert collaborate with the U.S. Geological Survey to hold semi-annual trainings on using the Vistrails habitat modeling software at the USGS Fort Collins RAM facility. 2015 SAHM trainings were held on March 24-24 and September 8-9.

Project Management and Reporting

PDASH is now being used for project management and reporting. Automated reminders get sent to funded PIs when reports are due or as reminders to fill out the monthly Google docs spreadsheet which we have instituted so each project can report on monthly activities, needs, and synergies before each monthly webinar. We are also collecting highlights from NC CSC staff to report to NCCWSC on a weekly basis.
2015 Open Science Conference

The NC CSC hosted its first Open Science Conference on May 20-22, 2015 in Fort Collins, CO. The theme of the conference was, “Integrating Research and Management of Change from the Mountains to the Plains.”

- ~120 attendees
- Representation
  - From Colorado: 70, other states: ~50
  - From NCUC institutions: CSU, Montana State, Iowa State, University of MT, CU, University of NE, University of WY
  - Managers/government agencies/NGOs: 46
  - Students: 27
- Wide array of disciplines represented

The conference offered research scientists and stakeholders the opportunity to actively engage with the North Central Climate Science Center. The conference brought the topics of western science, indigenous perspectives, and land management needs together to both assess what the NC CSC has achieved and chart a path forward to build on successes and fill gaps in our current understanding. This was one step in many used to help inform the ReVAMP framework and advance the mission of the center to bring the best available research to bear on land management actions in the region.

A number of key themes emerged from the conference, including: producing actionable science and making research useful and usable by resource managers; collaboration that incorporates the end user from the first stages of research; creating climate-smart plans for drought planning and management in partnership with our indigenous colleagues; recognizing and working through climate uncertainty; and understanding the context of on-the-ground management. See the Summary Report for more information. [http://nccsc.colostate.edu/sites/default/files/2015%20NC%20CSC%20Open%20Science%20Conference%20Summary%20Report.pdf](http://nccsc.colostate.edu/sites/default/files/2015%20NC%20CSC%20Open%20Science%20Conference%20Summary%20Report.pdf)

Student/Early Career Training

In conjunction with the Open Science Conference, the NC CSC offered a two-day student/early-career training session (May 18-19, 2015) for graduate students, postdocs, and early career scientists and managers from the North Central region. This training introduced the ~20 attendees to the foundational science areas and tools used at the NC CSC.

Joint Steering Committee

In 2015, the NC CSC transitioned from having a Stakeholder Advisory Committee to a Joint Steering Committee that is shared between the NC CSC and the USDA Northern Plains Climate Hub. This group met in Fort Collins, CO on December 11, 2015.

Website

In 2015, the URL for the NC CSC’s website was changed to http://nccsc.colostate.edu/. This was done to make searches for the center more effective and to make the URL similar to other CSCs’ URLs.

Communications

Leeann Sullivan, the communications specialist hired in January 2015, left the center in August of 2015. Leeann worked with the NC CSC on the website, on newsletters and information releases, and helping the center to convey messages to the public and other audiences.
NC CSC Office

Additional furniture was purchased for the NC CSC conference room and break room in 2015 to facilitate useful and comfortable meeting spaces.

NCTC Trainings

Jeff Morisette and Brian Miller, both trained as NCTC trainers, participated in two NCTC trainings in 2015. Shannon McNeely also provided case study presentations at both training sessions. The first was the Climate Smart Conservation Training (July 28-30, 2015) in Rapid City, SD. The second was the Climate Change Vulnerability Assessment Training (October 26-28, 2015) in Santa Fe, NM. Valerie Small (Crow Nation) was also brought on as a short-term training consultant in 2015 in order to help tailor the content of the NCTC regional trainings to be relevant for tribal participants.

Climate Adaptation for Conservation Training

This training (December 9-10, 2015), which was led by the Wildlife Conservation Society and hosted in Fort Collins, CO by the NC CSC, provided hands-on training in how to consider climate change information in conservation planning and identify adaptation actions for implementation. It also furnished participants with feedback and coaching on their own real-world climate adaptation project.

EcoDrought Workshop

This workshop held in Fort Collins, CO, December 7-8, 2015, was hosted by the NC CSC, the University of Maryland Center for Environmental Science Integration & Application Network, and the USGS National Climate Change and Wildlife Science Center. Participants in the workshop synthesized the current understanding of ecological drought in the region (synthesis report).

Modeling Activities

Tom Hilinski is working with Dennis Ojima and Bob Flynn to perform NC CSC-region simulations using the DayCent model with Daymet weather at 1K resolution, to establish baseline soil water, soil organic matter, and NPP spatial characterization. Simulations will include natural vegetation and major crops. Colin Talbert is developing VisTrails workflows to iterate over a range of climate inputs using byGDP calls, currently applying to the SAHM tutorial, and is providing SAHM VisWall, and RAM support and debugging. Colin is also obtaining and preparing local (Fort Collins Science Center) copies of high-value datasets, including Daymet, CMIP5 BCSD, Maurer Observational, PRISM
4km, Worldclim, WRF, and topowx. He specializes in building tools/workflows to process local climate data to derive custom climate products, metrics and analyses that are required by partners using python, ultimately to be ported to a VisTrails platform for wider distribution.

Marian Talbert is providing continued support for the software for assisted habitat modeling (SAHM). She is also developing code to pull climate data and generate climate primers for national parks and other organizations and partners. Marian is writing, with Colin Talbert, a USGS CIDA FY15 proposal to deliver a ‘climate primers’ ArcMap toolbox to make more widely available the technique that she is using to develop these climate primers.

Brian Miller specializes in quantitative scenario planning; that is, simulation modeling of the environmental effects of climate and resource management scenarios. During the reporting period he developed a state-and-transition simulation model of white-bark pine growth and disturbance in the Greater Yellowstone Ecosystem. He has also been supporting the NC CSC funded project being led by Amy Symstad by developing a state-and-transition simulation model of grassland vegetation dynamics in southwest South Dakota that is based on qualitative scenario planning workshops and knowledge from local experts.

NC CSC Staff Climate-Related Publications

Student and Early Career Training

During 2015, NC CSC actively contributed to the training of at least 16 graduate and undergraduate students, post-docs, and early career researchers:

**NC CSC Staffing:**
Amanda Weber (CSU, undergraduate student)

**FSA Adaptation project:**
Tyler Beeton (CSU, PhD student)
Trevor Even (CSU, MA student)

**FSA Climate Drivers project:**
Candida Dewes (CU-Boulder, postdoc)

**FSA Impacts project:**
Arjun Adhikari (MSU, postdoc)
Erica Garroutte (MSU, MS student)

**Surrogate species project:**
Valerie Steen (CSU, PhD student)
Helen Sovaer (CSU, postdoc)
Gordon Reese (Fort Collins Science Center, postdoc)

**Whitebark pine project:**
Tony Chang (MSU, PhD student)
Katie Ireland (MSU, postdoc)

**SW Colorado project:**
Patricia Orth (CSU, PhD student)
Katherine Clifford (CU, PhD student)

**Landscape connectivity project:**
Meredith McClure (Center for Large Landscape Conservation, early career researcher)
Bray Beltran (Heart of the Rockies, early career researcher)

**Sagebrush distribution project:**
Katie Renwick (MSU, postdoc)

North Central Climate Science Center on the Web

http://www.doi.gov/csc/northcentral/
http://nccsc.colostate.edu/

Reports


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Redrock Lake, Montana. Photo by Troy Smith
Appendices

Publications

Climate FSA


Impacts FSA and Whitebark Pine Project (Whitlock and Hansen)


Adhikari, A., A.J. Hansen. 2015. Land Use Change across the Greater Wildland Ecosystems of the North Central Climate Science Center Domain: Effects on Natural Vegetation Cover. Landscape Biodiversity Lab Technical Report, Montana State University, Bozeman, MT.


Adaptation FSA


McNeeley, S.M., T.A. Beeton, B.W. Miller, and D Ojima (In Preparation). Integrating social science and local knowledge into climate change research on public and tribal lands: Towards a holistic analytical framework for complex social-ecological systems.

Southwest Colorado Project (Burkardt and Schuster)


Neely, B., Rondeau, R., Gunnison Basin Climate Adaptation Workshop, Phase 1: Sagebrush and Spruce-Fir Landscapes. DRAFT


**Surrogate Species Project (Skagen and Noon)**

Sofaer H, SK Skagen, JJ Barsugli, BS Rashford, GC Reese, JA Hoeting, AW Wood, BR Noon. In review. Projecting wetland densities under climate change: habitat loss but little trade-off between conservation investments under historical and future climatic conditions. Ecological Applications

**Wind River Project (Knutson)**

Dewes and McNeeley. The 2015 Water Year at the Wind River Indian Reservation: Anatomy of an Irrigation Season (in preparation)

**Presentations**

**Climate FSA**

Rangwala I. (Mar 24, 2015). Climate Scenarios for Southwest Colorado. Webinar presented to the stakeholders of the NCCSC Southwest Colorado Project.
Rangwala I. and coauthors (Dec 15, 2015). The Understanding of Elevation Dependent Warming from Climate Models. AGU Fall Meeting (Invited Talk).

**Impacts FSA and Whitebark Pine Project (Whitlock and Hansen)**

Hansen, A.J. Which tree species and biome types are most vulnerable to climate change in the U.S. Northern Rocky Mountains? Great Northern LCC Webinar. March 2015.

Adaptation FSA

McNeeley, S. Thinking the Earth Conference, Brown University, invited speaker, April 23-4, 2015
NCCSC Open Science Conference, Colorado State University, early career training and plenary presentations, May 2015
McNeeley, S. Wind River Reservation presentation on initial results of interviews with managers – Fort Washakie, WY, June 9, 2015
McNeeley, S. Climate Smart Conservation training, NCTC-NCCSC-BIA invited presentation, Rapid City, SD, July 30, 2015
McNeeley, S. Northwest Climate Bootcamp, Pack Forest, WA, keynote speaker, August 16, 2015

Southwest Colorado Project (Burkardt and Schuster)

Betsy Neely, Renee Rondeau and Marcie Bidwell participated in the NCTC Climate Smart Training in Santa Fe, NM January 27-29, 2015, representing the project as peers to other DOI partners.
Betsy Neely, TNC, will present an update on the project to the Gunnison Basin Gunnison sage-grouse Strategic Committee on March 18, 2015.

Surrogate Species Project (Skagen and Noon)

Steen, V, BR Noon, H.R. Soa, and SK Skagen. Modeled impacts of climate and land-use change to waterbirds in the Prairie Pothole Region. AOU/COS annual meeting, Norman OK, 28 July – 1 August 2015.

Scenario Planning Project (Symstad)

Ray, Symstad, Miller, Fischell, Schuurman, Friedman, and Rowland. “Scaling climate change adaptation in the northern Great Plains through
regional climate summaries and local qualitative-quantitative scenario planning workshops”. Talk at American Geophysical Union Fall Meeting, December 2015.

Sagebrush Distribution Project (Poulter)
Renwick, K, B Poulter, P Adler, Forecasting Changes in Sagebrush Distribution and Abundance under Climate Change: Integration of spatial, temporal, and mechanistic models, North Central Climate Science Center 2015 Open Science Conference, Fort Collins, CO.
Emmett, K, K Renwick, B Poulter. Attributing Causes of Wildfire, Vegetation, and Hydrologic Climate Change Impacts, University of Utah
Restoring the West Conference, Salt Lake City, UT
Renwick, K, B Poulter, P Adler. Impacts of Climate-Disturbance Interactions on Current and Projected Species Distributions, Boise State University, Boise, ID
Renwick, K, B Poulter, P Adler, D Schlaepfer. Forecasting Changes in Sagebrush Distribution and Abundance under Climate Change: Integration of spatial, temporal, and mechanistic models, USGS, Boise, ID

Wind River Project (Knutson)
WRIR Project Kick-Off Workshop, Fort Washakie, WY, June 11, 2015
Wind River Region Climate Summary Development Workshop, Lincoln, NE, July 14 – 16, 2015.
WRIR project “all hands” workshop/webinar with the tribes’ Water Resources Control Board to discuss initial project activities, October 7, 2105
McNeely, S., Climate Smart Conservation training, NCTC-NCCSC-BIA invited presentation, Rapid City, SD, July 30, 2015
McNeely, S., Northwest Climate Bootcamp, Pack Forest, WA, keynote speaker on working with Tribes, August 16, 2015
McNeely, S. Presentation on co-production with Tribes at Wind River, American Geophysical Union Annual Meeting, San Francisco, CA, December 14, 2015.

Landscape Connectivity Project (Hostetler)

Capacity Building Project (Ojima)