University of Colorado Boulder Hosted
North Central Climate Adaptation Science Center
Year 4 Annual Report

July 2022

Submitted by: William R. Travis (University Director)

North Central
Climate Adaptation
Science Center

1. TERM SHEET
The Term Sheet for the North Central Climate Adaptation Science Center (NC CASC) USGS-University of Colorado (CU) Boulder Cooperative Agreement is located in **APPENDIX I**.

2. ADMINISTRATIVE
Award Recipient: Dr. William R. Travis
Issued to: The Regents of the University of Colorado
Attn: Janice Salinkas
Office of Contracts and Grants
3100 Marine St STE 481 572 UCB
Boulder, CO 80309-0001

Institution of the Award Recipient: University of Colorado Boulder
Award Agreement Number: G18AC00325
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Period of time covered by the report: October 1, 2021 to September 30, 2022

2. PURPOSE AND OBJECTIVES
Despite the continued challenges of COVID-19, the NC CASC made significant progress towards meeting its goals in core areas: partnerships; science; capacity building; and communications and outreach. The efforts we describe in this report are the result of key partnerships with stakeholders, including for example the Department of Interior (DOI) U.S. Fish and Wildlife Service (FWS) and National Park Service (NPS) Climate Change Response Program, U.S. Forest Service (USFS), and Tribal Colleges.

Year 4 science highlights (see **RESULTS: Science**) include climate science support for FWS species status assessments, climate impact assessment and adaptation tool development and maintenance, and garnering and disseminating new insights into drought effects in our region. Key consortium partner activities include: collaboration with Wyoming Game & Fish Department to update the Wyoming Statewide Habitat Plan (Molly Cross, Wildlife Conservation Society); completion of a west-wide synthesis of post-fire conifer regeneration and potential climate change impacts on post-fire forest recovery (Kim Davis, University of Montana); and leveraged work with DOI, USFS and NOAA stakeholders to publish a special feature on the scientific and management principles of the Resist-Accept-Direct (RAD) framework (Shelley Crausbay, Conservation Science Partners).

Year 4 capacity building activities include continuation of the Tribal Climate Leaders Program (TCLP), launch of the newly funded Climate Adaptation Scientists of Tomorrow (CAST) pilot program at CU Boulder, and training sessions as part of *Climate Solutions Days*.

This year we expanded our communications and outreach capacity with the addition of Ulyana Horodyskyj Peña (Communication Specialist) to our team, and increased effort on communication and event planning activities by Dawn Umpleby (Professional Assistant). Key activities include an update to the *NC CASC Communication and Outreach Plan*, spotlight stories on the website, creation of reusable video content in support of *NC CASC Climate Solutions Days 2022*, growing our social media presence, and updates/maintenance to our website. During Year 4 the NC CASC consortium wrote 23 peer-reviewed publications conveying actionable science, including a publication co-written with resource managers for a joint special issue with the journals *Climate* and *Earth*, titled *Uncertainty, complexity and constraints: How do we robustly assess ecological responses under a rapidly changing climate?* Our team

also co-wrote 12 pre-published works that include two multi-chapter USGS Professional Papers for the *Grasslands Synthesis Project* (see **APPENDIX IV**).

During Earth Week (April 19-22, 2022) we hosted *NC CASC Climate Solutions Days 2022*. The event utilized the diverse expertise of our team (CU Boulder Team, Consortium Partners, Tribal Liaison and USGS-partners) to host a virtual à la carte offering of presentations, workshops and trainings that addressed pressing climate problems and solutions in the North Central region. *Climate Solutions Days 2022* resulted in the creation of reusable video content that is available on our YouTube channel (see **OUTREACH**).

3. ORGANIZATION AND APPROACH

Our continuing goal is to efficiently utilize the resources (i.e., budget, human resources, space, equipment, etc.) made available by the cooperative agreement, the University, and additional avenues, so that the mix of science, administration, training, outreach, partnerships, and communications achieve the best possible outcomes for managing climate-sensitive natural and cultural resources in the North Central region. Key to achieving this goal is our ability to draw on a part-time team with diverse expertise, plus multiple external cooperating units. A summary table of funded University of Colorado (CU) personnel is located in **APPENDIX II**.

Institutions receiving sub-awards: Sub-awards to a consortium of science and applications institutions in the region extends this expertise and keeps the Center in touch with regional challenges and opportunities. These include: Conservation Science Partners (CSP): co-PI Shelley Crausbay; South Dakota State University (SDSU) Extension: co-PI Laura Edwards; University of Montana (UM): co-PIs Phil Higuera and Kim Davis; and Wildlife Conservation Society (WCS): co-PI Molly Cross.

Consortium governance, operations, and interactions: The role of each consortium partner (CP) is to produce actionable science on a dedicated management theme, serve as a connector between researchers and stakeholders in the region, and help guide the overall efforts of the NC CASC. Supported CP activities are co-determined by the CPs and the CU team. Monthly calls with CPs, monthly CSSP calls, and an annual CP meeting are key touch points for consortium interactions.

Contributions from personnel funded outside of the Host Agreement:

- Christy Miller Hesed (Postdoctoral Fellow) is the project coordinator for the *Grasslands Synthesis Project* (see **RESULTS: Science**).
- Stefan Tangen (Tribal Resilience Liaison) collaborates with the NC CASC through a variety of meetings/activities, including our bi-monthly NC CASC All Hands Staff meeting, and monthly Climate Science Support Platform, NC CASC Stakeholder Engagement, and CP meetings.
- Ulyana Horodyskyj Peña (Communications Specialist) works part-time with the NC CASC team. This position is supported by a USGS CASC funded research project, *Creating a North Central Regional Invasive Species and Climate Change (NC RISCC) Management Network* (PI R. Chelsea Nagy), and the NC CASC Host Agreement.
- Earth Lab made an in-kind contribution to the NC CASC host activities by providing a dedicated 40-hour per week Graduate Research Assistant in Summer 2022 (see **RESULTS: Science**).

4. RESULTS

A selection of key results from Year 4 are summarized here for our core area goals: partnerships; science; capacity building; and communications and outreach.

Partnerships: Our ongoing stakeholder tracking efforts illustrate that we continue to work with and/or maintain contact with stakeholders from 107 different organizations or groups, including: 25 Tribal Nations or inter-Tribal organizations; 12 Tribal Colleges or Native American education organizations (two new in Year 4); 13 Federal government agencies (two new in Year 4); 10 state government agencies; 20 academic or research institutions (three new in Year 4); 12 nonprofit organizations; and two regional boundary organizations. The *Grasslands Synthesis Project* (see **RESULTS: Science**) continues to be a key mechanism for creating new connections and strengthening existing ties. James Rattling Leaf's outreach and engagement activities have been key to building/strengthening partnerships with Tribal organizations and colleges in the North Central region (see **APPENDIX IV**). Part of Heather Yocum's time coordinating the *Grasslands Synthesis Project* is supported by the NC CASC Host Agreement, including her effort to coordinate with and leverage the USDA Northern Plains Climate Hub's vulnerability assessment for U.S. Forest Service grasslands. The Stakeholder Engagement Working Group (includes Yocum, Rangwala, Wolken, Travis, Tangen, Peña, and Miller Hesed) continues to meet monthly to coordinate outreach efforts.

Science: In Year 4, the NC CASC continued to advance the understanding of the impacts of climate change and variability on fish, wildlife, plants, water, land, and people by providing relevant and usable science, data, and analytic tools to support sound resource management and adaptation in the North Central region.

We continued to provide climate science support to partners in the region. Imtiaz Rangwala developed climate data summaries for FWS species status assessments for the Regal Fritillary Butterfly, Western Bumble Bee, Narrow Foot Hygrotus Diving Beetle, Canada Lynx, and Ute Lady Tress. The NC CASC (Rangwala and Edwards) also continued to collaborate with Robin O'Malley (former USGS NC CASC Director) and Chad McNutt (formerly with NOAA/National Integrated Drought Information System (NIDIS); co-founder Livestock Wx) to support the development of the Rosebud Sioux Tribe Climate Adaptation Plan (completed May 2022)--NC CASC provided historic climate and potential futures data for Rosebud Tribal lands with liaison support from James Rattling Leaf (CU Boulder) and Stefan Tangen (Tribal Resilience Liaison).

Tool building and maintenance comprised a large part of our Year 4 science support activities. Imtiaz Rangwala and Prasad Thota (Graduate Research Assistant) developed six R-Shiny Apps for downloading observations and future projections for: Vapor Pressure Deficit (VPD) Extremes; Standardized Precipitation Index (SPI); Standardized Precipitation Evapotranspiration Index (SPEI); Evaporative Demand Drought Index (EDDI); Forest Drought Stress Index (FDSI); and snowfall and rain projections. Rangwala also continued operations of the Landscape Evaporative Response Index (LERI) webtool with NOAA PSL, and the Drought Index Portal (DrIP). This was also a transformative year for the Climate Futures Toolbox (CFT). Operational issues with CFT in 2021 required Ty Tuff (Data Scientist) to re-write the CFT package and add a parallelized function in response to the National Park Service's request for a high-volume download. In Summer 2022, an Earth Lab Graduate Research Assistant spent four weeks cleaning and updating documentation for CFT, and adding new advanced functionality to the package.

The NC CASC is able to reach a diversity of partners and land managers in the region through our Consortium Partners (CP). Year 4 CP highlights are summarized below (additional details listed in **APPENDIX III**):

- Conservation Science Partners (CSP): Shelley Crausbay worked with DOI (FWS, NPS, BLM), USFS and NOAA stakeholders to publish a special feature on the Resist-Accept-Direct (RAD) framework, which included a paper that introduces the RAD Framework and a paper that unveils a research agenda for

science to support application of the RAD framework. Crausbay also completed novel paleoecological analyses at the landscape-scale to show the risk of rapid rates of ecological change and ecological transformation after 2°C and 5°C warming, respectively. Additionally, Crausbay's USGS FY20 Pass-Through funded project, *Exploring the Past to Plan for the Future: Integrating Indigenous Knowledge and Paleo Perspectives to Inform Climate Change Adaptation with the Ute Mountain Ute Tribe* is beginning to inform the NC CASC's co-production model and best practices for combining western science and Traditional Ecological Knowledges. Leveraged work by Crausbay includes research on transformational drought, visualizing ecological drought and changes in the phenology of important nectar-plants due to climate change, and development of drought planning that integrates ecosystems and the governance of ecologically available water.

- Great Plains Tribal Water Alliance (GPTWA): Stefan Tangen (Tribal Resilience Liaison) continued to strengthen partnerships between the NC CASC and tribes in the region via his engagement in NC CASC operational meetings/events, and contributions to the National Climate Assessment Northern Great Plains chapter and Tribal Nations chapter of the *Grasslands Synthesis Report Volume 1* (**APPENDIX IV**). Tangen also co-led a Tribal partnerships session with James Rattling Leaf at *NC CASC Climate Solutions Days 2022* (see **OUTREACH**).
- South Dakota State University (SDSU): Laura Edwards and Sean Kelley's plans to engage with stakeholders were disrupted due to ongoing COVID-related concerns and regional hazards (i.e., drought and flooding). Jennifer Zavaleta Cheek replaced Sean Kelley as the SDSU co-PI in May 2022.
- University of Montana (UM): Kim Davis developed a west-wide synthesis of post-fire conifer regeneration and the potential impacts of climate change on post-fire forest recovery. This project was also supported by funding from The Nature Conservancy (TNC) and brought together a group of 60 scientists from federal agencies, TNC, and universities across the region to contribute to the synthesis and write a manuscript. Results from the synthesis were presented at two conferences and at the *NC CASC Climate Solution Days 2022*. At *Climate Solution Days* Davis solicited feedback from potential users of a web app designed to share the results of this synthesis. Davis also applied models developed as part of the synthesis to the 2020 fires in Colorado to predict the probability of post-fire conifer regeneration within their perimeters. These projections will be published as part of a white paper in preparation with collaborators at the Ecological Restoration Institute at Northern Arizona University, Colorado Forest Restoration Institute, and Colorado State University (expected publication September 2022).
- Wildlife Conservation Society (WCS): Molly Cross shared results of her collaboration with Wyoming Game & Fish Department (WGFD) to update the Wyoming Statewide Habitat Plan to include climate change via several public webinars, a conservation biology professional conference, and a submitted manuscript that is co-authored by colleagues at WCS and WGFD. Additionally, Cross is working with a colleague at WCS to summarize results from a virtual workshop led by WCS in 2021 and review recent literature on evaluating beaver-related adaptation projects in the Intermountain West. In Year 5, Cross and colleagues plan to share results from the workshop and literature review with managers in the region to further solicit and hone key areas of future research that could help advance beaver-related adaptation actions in the region. Leveraged work by Cross includes an evaluation of 10-years of climate adaptation funded projects in the United States via the WCS Climate Adaptation Fund and contributing to a project led by CSP Senior Scientist and NC CASC Consortium Partner Shelley Crausbay on analyzing and visualizing ecological drought in Montana and Oregon.

The *Future of Fire Project* (led by Postdoctoral Fellow Jilmarie Stephens) is funded partially by the NC CASC Host Agreement and the National CASC Climate Adaptation Postdoctoral (CAP) Fellows Program, with supervision by co-PI Jennifer Balch, and co-mentors Jane Wolken and Imtiaz Rangwala. The NC

CASC-led project aims to project the future size and number of fires, total burn area, and rates of change among years and across space in the contiguous United States (CONUS). Unlike most future fire projections, this effort applies Bayesian methods to map human demography to estimate human ignitions. Modeled climate and population data were used along with historical fire data to predict the number and size of fires. Initial results indicate that CONUS-wide the number of fires and burned area increase by 160% and 167% in 2020-2060 compared to baseline (1984-2019). With climate change, fires are now spreading into regions where historically they were rare (i.e., the East), and for regions where fires were common (i.e., in the West), fire size is increasing unprecedentedly. This research will inform the National CASC CAP Fellows Program regional-to-national syntheses of climate change impacts on future fire regimes, management, and response effort. Data from this work is provided to US FWS biologists for the Canada Lynx species status assessment and we plan to make the projections data from this research more accessible for future projects via an online application.

The *Grasslands Synthesis Project* (PI Heather Yocum and Postdoctoral Fellow Christy Miller Hesed) is funded by a USGS CASC directed research grant, and leverages university CASC supported time for Heather Yocum, Bill Travis, Jilmarie Stephens, and Imtiaz Rangwala. In addition, the host funding supported graduate research assistants on the project in Year 3 (Shelby Ross and Sarah Jaffe). The project also benefited from the work of Stefan Tangen (Tribal Resilience Liaison), Anthony Ciocco (BIA Pathways Intern), and Shelby Ross (TCLP student) on the Tribal Nations chapter. Despite the challenges of the pandemic, this project successfully engaged 42 stakeholders (including representatives from BLM, FWS, NPS, USFS, Tribal Nations, BIA, state natural resource departments, and NGOs) who volunteered their time to serve alongside NC CASC researchers on two working groups and an advisory committee to establish a baseline of information to inform NC CASC efforts about the climate science needs of grassland resource managers. In mid-2020 through December 2021, the *Management Priorities Working Group (MPWG)* collected, reviewed, and synthesized grassland management plans and documents from Federal, State, and Tribal agencies and NGOs in the North Central region. The *MPWG* report was submitted to USGS for publication in June 2022 (**APPENDIX IV**: Grasslands Synthesis Report Volume 1). From summer 2021 to present, findings from the *MPWG* report informed the *Climate & Ecology Working Group (CEWG)*, which synthesized existing science to answer questions and identify areas where the NC CASC could conduct additional research. The *CEWG* report has undergone internal review by the Advisory Committee and the *MPWG*, and was submitted to USGS for peer review in June 2022 (**APPENDIX IV**: Grasslands Synthesis Report Volume 2). Initial findings from these two reports were used to inform the NC CASC USGS FY23 Project Solicitation.

Capacity Building: A primary goal of the NC CASC is to build a community of researchers and managers with expertise in climate adaptation, and to foster their leadership in science-based resource management. In Year 4, we helped train the next generation of earth and environmental scientists and research managers through a data-intensive remote half-day workshop Climate Data 101 in Python Workshop on November 17, 2021. The event was co-hosted with Conservation Science Partners and aimed at federal and state agency employees, members of tribal organizations, university researchers, graduate students, and others who use climate data to understand global environmental change in their work. Participants learned how to use Python to open, subset, and visualize MACAv2 climate data in the NetCDF hierarchical data format using the xarray Python library. There was overwhelming interest in this workshop--we received 77 RSVPs and were able to teach 45 people from 15 states across the U.S and four countries.

The Tribal Climate Leaders Program (TCLP) is a pilot program coordinated by Heather Yocum that provides fully-funded, two-year fellowships to Native American graduate students affiliated with one of

the 32 federally-recognized tribes in the North Central region. The TCLP currently supports: Shelby Ross (PhD student, Geography); William Crawford (MA student, Environmental Studies); Ida Clarke (MS student, Environmental Engineering); and Violet Eagle (professional research assistant, Evolutionary Biology). COVID-19 continues to pose challenges to TCLP fellows, and the program has responded by increasing flexibility to meet student needs. For example, we petitioned USGS and CU for approval for one student to remain remote during the pandemic and support coursework outside of their degree program; these courses were key to the long-term career goals of the student. Additionally, we reallocated funding from a student who had to leave the program in 2021 to hire another Tribal member as a professional research assistant for the Ecology and Evolutionary Biology program in order to better prepare her for graduate school in the future. These efforts include participating in CASC-network discussions, and working with CU researchers to include support for Native American graduate students in grant proposals, with the TCLP providing in-kind programmatic support.

The NC CASC successfully competed to host one of the National CASC's Climate Adaptation Scientists of Tomorrow (CAST) pilot programs, which aims to increase justice, equity, diversity, and inclusion in climate adaptation fields. Heather Yocum is the Program Coordinator for the CU CAST program, which has three parts: (1) hosting three undergraduate summer research fellows for two summers; (2) providing seed funding to support relationship building between CU and Tribal Colleges and Universities in our region; and (3) administering small professional development grants for NC CASC students. In Summer 2022, the NC CASC hosted three undergraduate CAST fellows: Steelle Stevens (Integrative Biology: Fish and Wildlife major; Northeastern State University, Tahlequah, OK) is working with CU's Earth Lab on understanding compound disturbances in the mountains near Boulder; and Kandice Agudo (Biochemistry major at Regis University, Denver, CO) and Jamie Ma (Environmental studies major, University of Southern California, Los Angeles, CA) are working with Dr. Julie Korak (Environmental Engineering) on post-fire water sampling and analysis in the Marshall Fire burn near Boulder. These students will return in Summer 2023 to continue their training.

In Year 4, the NC CASC supported Prasad Thota (PhD student in Civil Engineering) as a Graduate Research Assistant. He worked under the direction of Imtiaz Rangwala to support research and tool development for the NC CASC Climate Science Support Platform (i.e., R-Shiny Apps described above). Bill Travis and Imtiaz Rangwala also mentored five undergraduate students in the Earth Data Science Corps (EDSC) program in Summer 2022; the project is focused on understanding the relationship between snow and streamflow in the upper Colorado River Basin, and the use of different scenarios of future streamflow in the basin.

Communications and Outreach: Communications and outreach are intertwined and embedded in all NC CASC activities, and integrate our co-produced science, partnerships, and capacity building efforts. In Year 4, we increased our communication and outreach activities with increased effort on communication and event planning activities by Professional Assistant Dawn Umpleby, and the addition of Ulyana Horodyskyj Peña as Communications lead on our team.

Peña led an update to the *NC CASC Communication and Outreach Plan* that more clearly defines our communication goals, objectives and evaluation metrics for our communication tools (described below). Areas of active growth in communication include spotlight stories for the website, Twitter campaigns (e.g., #CSD2022), and video content for our YouTube Channel (see **OUTREACH).** Additionally, Peña was selected for the American Geophysical Union's Voices for Science program in April 2022, which trains scientists on communicating science to key decision makers and public audiences. She is leveraging this opportunity to provide in-house communication training to NC CASC scientists and partners.

We use the following tools to communicate our activities to our partners and stakeholders:

NC CASC Website/Social Media/Newsletter: With additional communication support from Peña and Umpleby we increased the number of spotlight stories for our website and videos for our YouTube channel. Two new pages were added to the website, including "Spotlight Stories" and "Climate Solutions Days." Another page dedicated to the CAST program will be launched in Fall 2022, as well as an upgrade to the website homepage. We continued to host a For Tribal Partners page that contains content organized by Stefan Tangen (Tribal Resilience Liaison), including archived issues of the Tribal Climate Adaptation Newsletter, and videos of the Tribal Climate Webinars. The NC CASC Newsletter is currently issued on a bi-monthly basis and distributed via Mailchimp and posted to our website. Since 2021, our social media presence/subscriber list has grown for Facebook (322 followers, up from 281), Twitter (965 followers, up from 791), and Mailchimp (1185 contacts, up from 689).

NC CASC YouTube Channel: The NC CASC YouTube channel has 141 subscribers. In Year 4 we have almost tripled the number of videos on the channel to 75 (up from 27 from 2018-2021). New content includes a short introductory video to the NC CASC; seven new NC CASC monthly webinar recordings; four new Tribal Climate Webinars; 29 videos from the *Climate Solutions Days 2022* sessions; and four new training videos for the Climate Futures Toolbox.

NC CASC Webinar Series: The NC CASC Webinar Series was held monthly from October 2021 through May 2022; webinars will resume in Fall 2022. The webinars highlight ongoing research from the NC CASC network, as well as feature topics of critical importance to natural resource managers and other stakeholders in the region. Since August 2021, we have had 656 registered participants (503 unique individuals, 153 who attended more than one webinar; attendance is ~60-75% of registered participants). Registrants came from 56 different units from federal agencies, 13 Tribal nations and organizations, 50 academic institutions, four other regional CASCs, 25 non-profit organizations, eight private organizations, and 44 US states.

NC CASC Help Tickets: The NC CASC help ticket system (Spiceworks) is utilized by the team to process communication requests internally. For the period October 1, 2021 to July 12, 2022, Umpleby and Peña processed 232 individual help ticket requests, with the majority of tickets requiring multiple responses.

5. OUTREACH

In April 2022, we hosted *NC CASC Climate Solutions Days 2022* (see agenda). The event was hosted virtually to accommodate the challenges and constraints associated with the ongoing COVID-19 pandemic. *Climate Solutions Days 2022* provided scientists and practitioners with a venue to share insights on pressing climate problems and solutions in the North Central region via an à la carte offering of presentations, workshops and trainings throughout Earth Week (April 19-22, 2022). Key products resulting from *Climate Solutions Days 2022* include videos describing *Who We Are*, *The Future of Fire*, and a Climate Solutions Days 2022 playlist of short segments organized by session and speaker on the NC CASC YouTube channel. The event involved significant contributions from all members of the NC CASC team (CU team, Consortium Partners, Tribal Resilience Liaison and USGS-partners).

In Year 4, the NC CASC (CU team and Consortium Partners) produced 23 peer-reviewed publications and technical reports, and 12 pre-published works (includes two reports from the *Grasslands Synthesis Project*). In addition to *Climate Solutions Days 2022*, the NC CASC engaged in several outreach activities, including 40 presentations/webinars, 10 major stakeholder engagement activities, 3 blogs/ websites/press releases, and 4 media requests (see **APPENDIX IV**).

6. NEXT STEPS

Our Strategic Science Plan (2019-2024), Cooperative Agreement with USGS (**APPENDIX I**), and shared vision (Year 3 *NC CASC Theory of Change*) of our core goals (partnerships, science, capacity building, and communications and outreach) will guide our Year 5 activities.

Partnerships: In Year 5 we will build on the successes of *NC CASC Climate Solutions Days 2022* by hosting a series of smaller targeted stakeholder engagements on relevant regional topics (e.g., fire, ecological transformation, grasslands and Tribal water resources). These engagements will include scientists and practitioners engaged in '*climate solutions'* focused research and management challenges in the North Central region. We will also continue to strengthen partnerships within the CASC-network through our engagement in cross-CASC meetings and collaborative activities (e.g., CASC-network calls, National CASC CAP Fellows Program, and the Climate Adaptation in Early Career Workshop in October 2022).

Science: Key science efforts in Year 5 include continued climate science support for our stakeholders, including FWS species status assessments, technical support and contributions to the Fifth National Climate Assessment (NCA5) chapter on Water, and tool development for resource managers looking to incorporate climate change into their management plans. The NC CASC Climate Science Support Platform (CSSP), which underlies provision of actionable science, has elaborated over the past four years and will be strengthened further in our fifth year. Our goal is to define and provide cutting edge 'adaptation science' by better integrating climate, ecological, and social science to address the climate science needs of our partners and stakeholders. We will utilize new hires (a social scientist and a new postdoctoral fellow), re-allocated staff time and effort, improved communications strategies, and continued commitment to addressing problems faced by stakeholders in the region, guided by the gaps and opportunities identified by the team's paper *Uncertainty, complexity and constraints: How do we robustly assess ecological responses under a rapidly changing climate?* Key planks in the CSSP effort in Year 5 will include work to assure that the tools we are building can be effectively used by managers, addressing and reducing the uncertainty in climate scenarios for our region, especially for elements of critical importance (e.g., drought, fire conditions, and extreme events), building on ecological science to improve projections of transformations, integrating the team's efforts to clarify the role and effectiveness of scenario planning, decision analysis and the RAD framework in long-term adaptation to the changing climate, and identifying and better meeting the climate adaptation needs of underserved communities.

Capacity Building: The NC CASC is committed to building capacity and increasing diversity, equity, and inclusion in science. We will continue to look for ways (both in- and outside the CASC-network) to continue the Tribal Climate Leaders Program (TCLP) beyond the inaugural cohort, and support the CU CAST program in its second year.

Communications and Outreach: In Year 5 we look forward to further expanding our communications and outreach efforts with the formation of a communication team to implement our updated *NC CASC Communication and Outreach Plan*. Planned areas for growth include an update to our newsletter format, an increase in the number of Spotlight stories/blog posts for the website, and an increase in the number of outreach products (e.g., videos, informational handouts) aimed at both lay and technical audiences. Project specific outreach products in Year 5 include a peer-reviewed journal article for the *Grasslands Synthesis Project*, and a team manuscript on a climate adaptation science framework to inform adaptation strategies among NC CASC stakeholders.

7. BUDGET

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APPENDIX I--Term Sheet

*****Term Sheet Removed from this Version*****

APPENDIX II: Funded University of Colorado (CU) personnel

Budget Year 4 (10/1/2021 to 9/30/2022) funded University of Colorado (CU) personnel; NCASC=National CASC; CAST=Climate Adaptation Scientists of Tomorrow. Personnel changes: with the departure of Leah Wasser in February 2022, Nathan Quarderer joined the NC CASC as Interim Education Director to assist Elsa Culler with the training responsibilities of the host agreement. Ty Tuff joined the NC CASC in September 2021 to oversee the update and maintenance of the Climate Futures Toolbox (CFT).

Person	Role	Responsibilities	Total Months of Effort on Host Agreement
William R. Travis	University Director/ Adaptation Co-Lead	Responsible for overseeing and directing all elements of the host cooperative agreement.	***Content Removed from this Version***
Jane Wolken	Program Manager	Oversees day-to-day university operations of the NC CASC, engages in cross-CASC activities, including network calls/meetings, working groups and CAP Fellows Program support, supervises Ulyana Horodyskyj Peña, and co-mentors Jilmarie Stephens.	
Imtiaz Rangwala	Climate Science Lead	Provides primary climate expertise to the NC CASC-directed projects, works with boundary organizations to facilitate effective integration of climate research into natural resource management and planning, co-hosts the NC CASC Webinar Series, mentors Prasad Thota, and co-mentors Jilmarie Stephens.	
Heather Yocum	Stakeholder Lead	Facilitates research-to-operations processes, convenes/structures stakeholder engagement between scientists and information users, expands the stakeholder base, solicits user feedback to refine information content and delivery platforms, co-hosts the NC CASC Webinar Series, serves as the primary contact for the Tribal Climate Leaders Program and NCASC CAST pilot program, and is PI for the *Grasslands Synthesis Project*.	
Dawn Umpleby	Professional Assistant	Manages website development, maintenance/content design, social media platforms, newsletter creation/distribution, logistics planning for events, HR support, purchasing, budget, and space management. Supervised Katherine Halama.	
James Rattling Leaf, Sr.	Research Associate	Performs outreach and engagement activities to build/strengthen partnerships with Tribal organizations and colleges in the North Central region.	
Ulyana Horodyskyj Peña	Communications Specialist	Translates the science, education and outreach activities of the NC CASC into engaging communication products for a diversity of audiences and outlets, updates the NC CASC communication and outreach plan, and supports the science communication activities of the CASC-network.	

Ty Tuff	Data Scientist	Provides programming support for the CFT and works with members of the CU team to model and visualize climate data.	***Content Removed from this Version***
Leah Wasser	Education Lead	Oversaw the development of the training plan and material for climate data.	
Nathan Quarderer	Interim Education Director	Oversees the development of the training plan and material for climate data.	
Elsa Culler	Education Trainer	Assists with the development of course materials for the climate science education workshops.	
Lisa Dilling	Adaptation Co-Lead	Advices the development of adaptation strategies and their implementation through the co-production and consortium process.	
Katherine Halama	Communications Assistant	Assisted the Professional Assistant with website and social media content and maintenance, and newsletter content and creation.	
Jilmarie Stephens	Postdoctoral Fellow	Conducts future of fire research in the North Central region. Results will inform the NCASC CAP Fellow Program *Future of Fire* project.	
Prasad Thota	Graduate Research Assistant	Develops climate datasets, workflows and tools.	

APPENDIX III--Planned Consortium Partner Activities

Summary of planned consortium partner activities; CU=University of Colorado; CSP=Consortium Science Partners; WCS=Wildlife Conservation Society; UM=University of Montana; SDSU=South Dakota State University; and GPTWA=Great Plains Tribal Water Alliance.

Consortium Partner	Year 2 (Oct 2019-Sep 2020)	Year 3 (Oct 2020-Sep 2021)	Year 4 (Oct 2021-Sep 2022)	Year 5 (Oct 2022-Sep 2023)
CU	● Host virtual CP meeting	● Annual CP meeting, with CSP host	● Annual CP meeting, with SDSU host (canceled due to COVID)	● Annual CP meeting, with GPTWA host
CSP		● Host annual CP meeting ● Synergistic Research: *Transformational Drought project (NCASC; Rangwala) *Visualizing Ecological drought project (NOAA-NIDIS; Cross)	● Planned work informed by RAD framework	
WCS	● Postponed due to CP funding	● Ongoing work with WY Game & Fish Department ● Evaluation of WCS adaptation projects + publication ● Virtual workshop on Measuring Climate Adaptation Outcomes (July 2021)	● Presentations and peer-reviewed article preparation and submission on climate science co-production project with WGFD ● Literature review on effectiveness of beaver-related adaptation approaches.	● 2-day workshop – Evaluating adaptation success: Focus on beaver-related adaptation approaches (target: Fall 2022)
MT	● Postponed due to CP funding	● Workshop with fire stakeholders (Feb 2021) ● Developing science and outreach tools to aid in post-fire vegetation management decisions	● Continue to develop science and outreach tools to aid in post-fire vegetation management decisions	
SDSU	● Postponed due to COVID-19	● Meetings with local stakeholders to ID climate information and research needs.	~~● Local meetings~~ (Delayed due to COVID and compound hazards in SD) ~~● Host CP meeting~~ (Canceled due to COVID)	● Local meetings
GPTWA	● 2-day workshop postponed due to COVID		● 2-day workshop	● Host CP meeting

APPENDIX IV--Outreach Products and Activities

Published peer reviewed journals, non-peer reviewed technical reports and op-eds:
NC CASC researchers/consortium partners appear in **bold** text; ***** indicates a product was not funded by the NC CASC, but leverages the expertise of NC CASC researchers/consortium partners in support of NC CASC strategic science goals; **#** indicates a product not reported in Year 3:

- *****Brown, M.B., Morrison, J.C., Schulz, T.T., **Cross, M.S.**, Püschel-Hoeneisen, N., Suresh, V. and Eguren, A. (2022). Using the Conservation Standards framework to address the effects of climate change on biodiversity and ecosystem services. *Climate*, 10(2):13, https://doi.org/10.3390/cli10020013.
- Buono, P., Rondeau, R., Bidwell, M., Monroe, S., Rank, G., Roberts, S., **Cross, M.**, and **Rangwala, I.** (2021). Prioritized drought resilience strategies for the Mancos watershed. Prepared for Mancos Watershed Group, https://tinyurl.com/8ek638kk.
- Colón-Burgos, D., **Rangwala, I.**, Hobbins, M., and **Senay, G.** (2021). Decadal-scale changes in drought-related climate parameters: Assessing the consistency of global climate models in projecting changes in the Northern Great Plains, https://doi.org/10.5065/aszf-wf02.
- **Crausbay, S.**, Sofaer, H.R., Cravens, A.E., Chaffin, B.C., Clifford, K.R., Gross, J.E., Knapp, C.N., Lawrence, D.J., Magness, D.R., Miller-Rushing, A.J., Schuurman, G.W., and Stevens-Rumann, C.S. (2022). A science agenda to inform natural resource management decisions in an era of ecological transformation. *BioScience*, 72:71-90, https://doi.org/10.1093/biosci/biab102 (Special section: The Resist-Accept-Direct Framework).
- ***#**Haynie, H.J., Kavanagh, P.H., Jordan, F.M., Ember, C.R., Gray, R.D., Greenhill, S.J., Kirby, K.R., Kushnick, G., Low, B.S., and **Tuff, T.** (2021). Pathways to social inequality, *Evolutionary Human Sciences*, 3:e35, https://doi.org/10.1017/ehs.2021.32.
- Iglesias, V., **Balch, J.,** and **Travis, W.** (2022). U.S. fires became larger, more frequent, and more widespread in the 2000s. *Science Advances*, 8(11), https://www.science.org/doi/10.1126/sciadv.abc0020.
- *****Iglesias, V., **Balch, J.K.**, Cobian, J., Stefan, L., Nagy, C., Hester, C., Barrett, K., Reid, C., Wiedenmyer, C., Woolner, E., and **Travis, W**. (2022). Fires that matter: Reconceptualizing fire risk to include interactions between humans and the natural environment. *Environmental Research Letters,* 17:045014, https://doi.org/10.1088/1748-9326/ac5c0c.
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- *****Miller, C.A, **Higuera, P.E.**, McWethy, D.B., Metcalf, A.L., Metcalf, E.C., Black, A.E., Clarke, L., and Hodge, H. (2021). Developing strategies to support social-ecological resilience in flammable landscapes: A structured approach for natural resource managers and other stakeholders, *Research Note RMRS-RN-92*, USDA Forest Service, Rocky Mountain Research Station, https://doi.org/10.2737/RMRS-RN-92.
- ***Miller Hesed, C.D.**, Paolisso, M., Van Dolah, E.R., and Johnson, K.J. (2021). Using cultural consensus analysis to measure diversity in social-ecological knowledge for inclusive climate adaptation planning, *Weather, Climate, and Society*, 14(1):51-64, https://doi.org/10.1175/WCAS-D-21-0047.1.
- Nagy, R.C., **Balch, J.K.**, Bissell, E.K., Cattau, M.E., Glenn, N.F., Halpern, B.S.,… **Travis, W.R**…., and Zhu, K. (2021). Harnessing the NEON data revolution to advance open environmental science with a diverse and data-capable community. *Ecosphere,* 12(12):e03833, https://doi.org/10.1002/ecs2.3833.

- *Oakes, L.E., Peterson St-Laurent, G., **Cross**, **M.,** Washington, T., and Hagerman, S. (2022). Strengthening monitoring and evaluation of multiple benefits in conservation initiatives that aim to foster climate change adaptation. *Conservation Science and Practice,* 4(6):e12688, http://dx.doi.org/10.1111/csp2.12688.
- *Paolisso, M., Van Dolah, E., Johnson, K.J., and **Miller Hesed, C.D.** (2022). Deal Island Peninsula Partnership: Applying environmental anthropology, ethnography and collaborative learning, *In* Profiles in Anthropological Praxis, T.M. Redding and C.C. Cheney (eds.), pp. 68-78. New York, NY: Berghahn.
- *Peterson St-Laurent, G., Oakes, L.E., **Cross, M.,** and Hagerman, S. (2022). Flexible and comprehensive criteria for evaluating climate change adaptation success for biodiversity and natural resource conservation. *Environmental Science and Policy,* 127:87-97, https://doi.org/10.1016/j.envsci.2021.10.019.
- **Rangwala, I.**, **Moss, W.**, **Wolken, J.**, Rondeau, R., Newlon, K. Guinotte, J., and **Travis, W.R**. (2021). Uncertainty, complexity and constraints: How do we robustly assess biological responses under a rapidly changing climate? *Climate,* 9(12):177, https://doi.org/10.3390/cli9120177.
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- **Rattling Leaf, J., Sr.** (2022). What is traditional ecological knowledge and why does it matter? *Frontiers in Ecology and the Environment*, 20(1):1-3, https://doi.org/10.1002/fee.2465.
- Schuurman, G.W., Cole, D.N., Cravens, A.E., Covington, S., **Crausbay, S.**, Hawkins Hoffman, C., Lawrence, D.J., Magness, D.R., Morton, J.M., Nelson, E.A., and O'Malley, R. (2022). Navigating ecological transformation: Resist-Accept-Direct (RAD) as a path to a new resource management paradigm. *BioScience*, 72:16-29, https://doi.org/10.1093/biosci/biab067 (Special section: The Resist-Accept-Direct Framework).
- *Skikne, S., **Cross, M.**, Press, D., and Zavaleta, E. (2021). The landscape of climate change adaptation aspirations in the US non-profit conservation sector. *Conservation Science and Practice,* 3(12):e557, https://doi.org/10.1111/csp2.557.
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- *Webster, S.E., Donovan, E.C., Chudoba, E., **Miller Hesed, C.D.**, Paolisso, M., and Dennison, W.C. (2022). Identifying and harmonizing the priorities of stakeholders in the Chesapeake Bay environmental monitoring community. *Current Research in Environmental Sustainability,* 4:100155, https://doi.org/10.1016/j.crsust.2022.100155.
- ***Yocum, H.M.**, Metivier Sassorossi, D., and Ray, A.J. (2022) Assessing the use of climate change information in State Wildlife Action Plans. *Conservation Science and Practice*, 4(3):e608, https://doi.org/10.1111/csp2.608.
- *Zachmann, L.J., Wiens, J.F., Franklin, K., **Crausbay, S.D.**, Landau, V.A., and Munson, S.M. (2021). Dominant Sonoran Desert plant species have divergent phenological responses to climate change, *Madroño*, 68(4), https://doi.org/10.3120/0024-9637-68.4.473.

Pre-published research:

- *Cravens, A.E., Goolsby, J., Jedd, T., Bathke, D., **Crausbay, S.**, Cooper, A., Dunham, J., Haigh, T., Hall, K., Hayes, M., McEvoy, J., Poděbradská, M., Ramirez, A., Wickham, E., and Zoanni, D. (*In Review*). The patchwork governance of ecologically available water: A case study in the Upper Missouri Headwaters, Montana, USA. *Journal of the American Water Resources Association.*

- **Cross, M.S.**, Oakes, L.E., Kretser, H.E., Bredehoft, R., Dey, P., Mahoney, A., Smith, N., Tator, I., and Wasseen, J. (*In Prep*). Tackling the research-implementation gap in a warming world: Using co-production to incorporate climate change into natural resource management. Submitted to *Environmental Management*.
- **Davis, K.T.**, Rozance, M.A., Wynecoop, M., Swenson, K., Lyons, D., Dohrn, C., and Krosby, M. (*In Prep*). Advancing management of post-fire vegetation transitions.
- **Davis, K.T.**, Robles, M., Kemp, K.B., **Higuera, P.E.**, et al. (*In Review*). Reduced fire severity offers near-term buffer to climate-driven declines in conifer resilience to wildfire across the western United States. *Proceedings of the National Academy of Sciences*.
- Gude, J., DeCesare, N., Proffitt, K., Sells, S., Garrott, R., **Rangwala, I.**, Biel, M., Coltrane, J., Cunningham, J., Fletcher, T., Loveless, K., Mowry, R., O'Reilly, M., Rauscher, R., and Thompson, M. (*In Press*). Demographic uncertainty and disease risk drive climate-informed mountain goat management. *Journal of Wildlife Management and Wildlife Monographs*.
- *****Klemm, T., Peck, D.E., **Miller Hesed, C.D., Yocum, H.M., Wade Wilcox**, A.A., Kelley, W.K., Halofsky, J., Elliott, J., Reeves, M.C., and **Jaffe, S.M.** (*In Prep*). Assessing the vulnerability of Northern Mixed-Grass Prairie vegetation and livestock to climate change. *Rangeland Ecology & Management*.
- *Shuman, J.K., **Balch, J.K.**, Barnes, R.T., **Higuera, P.E.**, Roos, C.I., Schwilk, D.W., Stavros, E.N., Banerjee, T., Bela, M., Bendix, J., Bertolino, S., Bililign, S., Bladon, K.D., Brando, P., Breidenthal, R.E., Buma, B., Calhoun, D., Carvalho, L.M.V., Cattau, M., Cawley, K.M., Chandra, S., Chipman, M.L., Cobian, J., Conlisk, E., Coop, J., Cullen, A., **Davis, K.T.**, Dayalu, A., Dolman, M., Ellsworth, L.M., Franklin, S., Guiterman, C.H., Hamilton, M., Hanan, E.J., Hansen, W.D., Hantson, S., Harvey, B.J., Holz, A., Huang, T., Hurteau, M.D., Ilangakoon, N.T., Jennings, M., Jones, C., Klimaszewski-Patterson, A., Kobziar, L.N., Kominoski, J., Kosovic, B., Krawchuk, M.A., Laris, P., Leonard, J., Loria-Salazar, S.M., Lucash, M., Mahmoud, H., Margolis, E., Maxwell, T., McCarty, J., McWethy, D.B., Meyer, R., Miesel, J.R., Moser, W.K., Nagy, R.C., Niyogi, D., Palmer, H.M., Pellegrini, A., Poulter, B., Robertson, K., Rocha, A., Sadegh, M., De Sales, F., Santos, F., Scordo, F., Sexton, J.O., Sharma, A.S., Smith, A.M.S., Soja, A., Still, C., Swetnam, T., Syphard, A.D., Tingey, M.W., Tohidi, A., Trugman, A., Turetsky, M., Varner, J.M., Wang, Y., Whitman, T., Yelenik, S., and Zhang, X. (*In Review)*. Reimagine fire science for the Anthropocene. *Proceedings of the Academy of Science Nexus*.
- *****Shrum, T. and **Travis, W.R.** (*In Press*). Experiments in ranching: Rain-index insurance and investment in production and drought risk management. *Applied Economics Perspectives & Policy*.
- *****Sudol, T., **Miller Hesed, C.D.**, Clark, J., and Moser, F. (*In Review*). Resisting-Accepting-Directing sea level rise on the Chesapeake Bay: Agricultural producers' motivations and actions. *Journal of Environmental Management*.
- *****Wolf, K., **Higuera, P.E.,** and **Davis, K.T.** (*In Review*). Conifer seedling demography reveals mechanisms of initial forest resilience to wildfires in the northern Rocky Mountains. *Forest Ecology and Management*.
- <u>Grasslands Synthesis Report Volume 1</u>:
  Miller Hesed, C.D., and **Yocum, H.M.**, eds**.** (*In Press*) Grassland Management Priorities for the North Central Region. *U.S. Geological Survey*. Authors and chapter titles listed below:
    - **Miller Hesed, C.D.**, **Yocum, H.M.**, and **Jaffe, S.** Chapter A. Background, Methods, & Guide to this Report.
    - **Miller Hesed, C.D., Yocum, H.M.**, Beckmann, J.P., Wheeler, B., **Jaffe, S., Rangwala, I.**, and Wood, D.J.A. Chapter B. Introduction to the North Central Grassland Ecoregions.

- **Miller Hesed, C.D., Yocum, H.M.**, Beckmann, J.P., **Bamzai-Dodson, A.**, Hall, K., **Cross, M.**, Ahlering, M., Boyd-Valandra, E., **Mosher, D., Wheeler, B., Miller, B.W.,** and **Jaffe, S.** Chapter C. Grassland Management Goals, Challenges, and Information Needs.
- **Miller Hesed, C.D., Yocum, H.M.,** Wheeler, B., Beckmann, J.P., and **Jaffe, S.** Chapter D. Differentiating Threats and Management Opportunities by Grassland Ecoregion.
- **Miller Hesed, C.D., Yocum, H.M.**, and Ahlering, M. Chapter E. Introduction to Grassland Management Agencies, Departments, and Organizations.
- **Miller Hesed, C.D.,** and **Jaffe, S.** Chapter F. Bureau of Land Management.
- **Yocum, H.M., Miller Hesed, C.D., Bamzai-Dodson, A.,** and **Jaffe, S.** Chapter G. U.S. Fish and Wildlife Service.
- **Bamzai-Dodson, A., Mosher, D., Miller, B.W., Miller Hesed, C.D.,** and **Jaffe, S.** Chapter H. National Park Service.
- **Cross, M., Miller Hesed, C.D.,** and **Jaffe, S.** Chapter I. U.S. Forest Service.
- **Miller Hesed, C.D.** Chapter J. Natural Resource Conservation Service & Farm Service Agency.
- **Ross, S.**, **Miller Hesed, C.D.**, Boyd-Valandra, E., **Tangen, S.G., Ciocco, A.W.,** and **Jaffe, S.** Chapter K. Tribal Nations.
- **Miller Hesed, C.D.** and **Jaffe, S.** Chapter L. Colorado Parks and Wildlife.
- Beckmann, J.P., **Miller Hesed, C.D.,** and **Jaffe, S.** Chapter M. Kansas Department of Wildlife & Parks.
- **Cross, M., Miller Hesed, C.D.,** and **Jaffe, S.** Chapter N. Montana Fish, Wildlife, and Parks.
- Wheeler, B., **Miller Hesed, C.D.,** and **Jaffe, S.** Chapter O. Nebraska Game and Parks Commission.
- **Yocum, H.M., Miller Hesed, C.D.,** and **Jaffe, S.** Chapter P. North Dakota Game and Fish.
- **Yocum, H.M., Miller Hesed, C.D.,** and **Jaffe, S.** Chapter Q. South Dakota Game, Fish, and Parks.
- **Miller Hesed, C.D.,** and **Jaffe, S.** Chapter R. Wyoming Game and Fish Department.
- Ahlering, M. Chapter S. The Nature Conservancy.
- Hall, K. Chapter T. Migratory Bird Joint Ventures.
- **Miller Hesed, C.D.** Glossary.
- **Miller Hesed, C.D.** Appendix 1. Grassland Management Documents Included in Synthesis.
- **Jaffe, S.**, and **Miller Hesed, C.D.** Appendix 2. Methods used to Create Maps and Calculate Acreages.
- **Miller Hesed, C.D.,** and **Yocum, H.M.** Appendix 3. Complete List of Information Needed and Relevance to Grassland Management Entities.
- **Yocum, H.M., Miller Hesed, C.D.**, Beckmann, J.P., **Bamzai-Dodson**, A., Hall, K.R., **Cross, M.**, Ahlering, M., Boyd-Valandra, E., **Mosher, D.**, and Wheeler, B. Appendix 4. Information Needs as Articulated in or Inferred from Management Documents.
- **Yocum, H.M.** Appendix 5. Species of Greatest Conservation Concern in the North Central Region.

- Grasslands Synthesis Report Volume 2:
  Miller Hesed, C.D., and **Yocum, H.M.**, eds. Synthesis of Climate and Ecological Science to Support Grassland Management Priorities in the North Central Region. *Under Review* for submission to *U.S. Geological Survey*.
  - **Miller Hesed, C.D.** Chapter A. Background, Methods, & Guide to this Report.
  - **Rangwala, I., Stephens, J.**, Chase, K.J., McKenna, O., and Hoover, D. Chapter B. Climate Change Projections and Expected Impacts on Water Availability and Wildfire Behavior.

- Symstad, A., Wood, D.J.A., **Crausbay, S.**, Nippert, J., Porensky, L., Nagy, C., **Miller, B.W.**, and **Mosher, D.** Chapter C. Climate Impacts to Vegetation.
- Ellison, K., Davidson, A., Ahlering, M., Giocomo, J., Lightfoot, D., Zale, A.V., and **Miller Hesed, C.D.** Chapter D. The Roles of Wildlife: Past, Present, and Future Scenarios.
- Martin, J.M., and Klemm, T. Chapter E. Climate Change Impacts on Large-Bodies Grazing Ruminants and Forage Grazing.
- **Yocum, H.M., Miller Hesed, C.D.,** and Elliott, J. Chapter F. Land Use Change.
- **Miller Hesed, C.D.**, Wood, D.J.A., **Yocum, H.M.**, **Miller, B.W., Rangwala, I.**, Ahlering, M., Porensky, L., and Martin, J. Chapter G. Discussion and Next Steps: Addressing Management Priorities and Research Gaps.
- **Miller Hesed, C.D.** Glossary.
- **Miller Hesed, C.D.**, and **Yocum, H.M.** Appendix 2. Crosswalking the Findings and Research Needs in this Report by the Information Needs Identified by the Management Priorities Working Group.

Project-related conference presentations, seminars, webinars, workshops, and public presentations:

- **Crausbay, S.**, **Moss, W.**, and **Rangwala, I.** (20 July 2022)--Transformational Drought: climatic implications and management options in grasslands. Joint FWS - USGS CASCs Climate-Grasslands Training Webinar.
- **Crausbay, S.**, **Cross, M.**, **Bamzai-Dodson, A.**, Hall, K., and O'Malley, R. (18 July 2022)--Three approaches to crafting actionable science that focus on different organizational scales. North American Congress for Conservation Biology, Reno, NV.
- **Crausbay, S.** (2022)--RADical Science. NPS Natural Resource Stewardship and Science Webinar Series.
- **Cross, M.** and Dey, P. (October 2021)--Setting habitat protection and restoration priorities in a warming world: Lessons from Wyoming, Webinar presentation hosted by the National Climate Adaptation Science Center, National Conservation Training Center, and Association of Fish and Wildlife Agencies.
- **Cross, M.** and Dey, P. (December 2021)--Setting habitat protection and restoration priorities in a warming world: Lessons from Wyoming, North Central Climate Adaptation Science Center Webinar Series.
- **Cross, M.** (July 2022)-- Organized symposium at the North America Congress on Conservation Biology (NACCB) titled, *Towards effective and actionable climate science: Frameworks and case studies of stakeholder engagement and information use*. In this session, panelists will present a framework for engagement of stakeholders that characterizes strategies in terms of the nature and degree of participation and empowerment and describe methods for characterizing and evaluating climate information use. Subsequent speakers will share stories of actionable climate science in action, including descriptions of the type of end-user involvement and examples of how the developed information is being used (or how they plan on monitoring its use going forward). The session will feature 6 speakers, 5 of whom are affiliated with the North Central CASC (**Alisa Wade, Shelley Crausbay, Christy Miller Hesed, Kim Davis,** and **Molly Cross**).
- **Davis, K.T.**, Robles, M., **Higuera, P.E.**, and Kemp, K. (December 2021)--Climate drivers of post-fire conifer regeneration across the western US. *9th International Fire Ecology and Management Congress*.
- **Davis, K.T.** (February 2022)--Co-facilitator of the Northwest Climate Adaptation Science Center Deep Dive on Ecological Transformation Follow-Up Workshop. This event was a virtual follow-up workshop attended by 22 managers and scientists to share and discuss new results related to

knowledge gaps about post-fire ecological transformation identified by the 2020 NW CASC Deep Dive.

- **Davis, K.T.** (April 2022)--Presentation *Science to inform post-fire conifer regeneration and reforestation strategies under changing climate conditions* at the BLM Missoula Field Office.
- Hoecker, T. and **Davis, K.** (April 2022)--Organized symposium *Stewarding forest ecosystems toward desirable futures with co-produced actionable science* at the *International Association for Landscape Ecology-North American Annual Meeting*, Virtual meeting held 11-14 April, 2022.
- **Davis, K.T.** (June 2022)--Presenter at a field trip "Reintroducing fire in mixed and high-severity fire regimes: Prescribed fire planning, implementation and effects in lodgepole and subalpine forests" hosted by the Northern Rockies Fire Science Network, https://www.nrfirescience.org/event/reintroducing-fire-mixed-and-high-severity-fire-regimes-prescribed-fire-planning**.**
- **Davis, K.T.**, Robles, M., and **Higuera, P.E.** (July 2022)--Developing actionable science and tools to inform forward-looking, post-fire reforestation decisions in western US conifer forests. *North American Congress for Conservation Biology*.
- **Davis, K.T.** (July 2022)--Presentation on post-fire regeneration in a changing climate, as part of the "Future of Forests" course for teachers to help them bring the "Future of Forests" curriculum into their classroom to explore patterns of landscape change following wildfires, https://cires.colorado.edu/outreach/events/teacher-workshop-future-forests-2-days-july-13-14.
- **Davis, K.T.**, Robles, M., **Higuera, P.E.**, Holden, Z.A., and Dobrowski, S.Z. (March 2022)--Developing actionable science and tools to support post-fire reforestation decisions through a spectrum of stakeholder engagement. *International Association for Landscape Ecology-North American Annual Meeting*.
- Klemm, T., **Miller Hesed, C.D.**, Peck, D.E., **Yocum, H.M.**, **Wade Wilcox, A.A.**, Kelley, W.K., Halofsky, J., Elliott, J., Reeves, M.C., and **Jaffe, S.M.** (16 December, 2021)--Grazing in a warmer world – Assessing the vulnerability of Northern Mixed-Grass Prairie and rangeland livestock production to climate change. *American Geophysical Union Fall Meeting*, Online, agu2021fallmeeting-agu.ipostersessions.com/Default.aspx?s=33-E1-28-EB-A8-B4-63-F1-57-66-BC-36-C1-4E-0B-8E.
- ***Miller Hesed, C.D.** (18 May, 2022)--Collaborative learning to build climate resilience in rural communities. U.S. Geological Survey Risk Community of Practice Webinar Series, Online.
- **Miller Hesed, C.D.** and **Yocum, H.** (23 March 2022)--Help wanted: Social science to support climate adaptation in the Great Plains, in environmental crises, changing landscapes at the *Society for Applied Anthropology 82nd Annual Meeting: The Revolutionary Potential of the Social Sciences*, Sheraton Salt Lake City Hotel, Salt Lake City, UT.
- **Rangwala, I.** (13 June, 2022)--Climate change projections and expected impacts on water availability and wildfire behavior in the US North Central Region. Webinar presented for Climate Change and Climate Adaptation Training for Grasslands Conservation Practitioners.
- **Rangwala, I.** (8 June, 2022)--Climate Science Applications for Ecological Impact Assessment and Conservation: A discussion with Civilian Climate Corps (CCC) Fellows and FWS, https://www.youtube.com/watch?v=VoIlz_bOd3M.
- **Prasad, T.** and **Rangwala, I.** (13-May 2022)--Interactive Web Application Platform for Projecting Climate and Drought Metrics into the 21st Century. Poster at Cooperative Institute for Research in Environmental Sciences (CIRES) Rendezvous 2022, Boulder, CO.
- Colón-Burgos, D., **Rangwala, I.**, Hobbins, M., and **Senay, G.** (23 January 2022)--Decadal-scale changes in drought-related climate parameters: Analyzing the consistency of global climate models in projecting changes in the Northern Great Plains. *American Meteorological Society, 102nd Meeting. Student Conference/35th Conference on Climate Variability and Change*.

- Xia, S., McEvoy, D.J., Hobbins, M.T., Huntington, J.L., **Rangwala, I**, and **Yocum, H.M.** (13-17 December 2021)--Identifying indicators and timescales of agricultural drought in the northeast United States using crop area-weighted drought indices. Abstract GC25E-0700, 2021 Fall Meeting, AGU, New Orleans, LA (Poster).
- **Rangwala, I.**, Smith, L.L., **Senay, G.B.**, Barsugli, J.J., Kagone, S., and Hobbins, M.T. (14 September 2021)--Landscape Evolution Response Index (LERI): High-resolution monitoring of anomalies in ET response across the contiguous US, Northeast DEWS Drought Indicators and Tools Webinar series (Webinar).
- Hobbins, M.T., McEvoy, D.J., **Rangwala, I.**, Xia, S., and **Yocum, H.M.** (14 September 2021). Drought indices and indicators for the Northeast: NOAA's Evaporative Demand Drought Index (EDDI). Northeast DEWS Drought Indicators and Tools Webinar series (Webinar).
- **Rangwala, I.** (9 September 2021). Climate change in North Dakota: Consequences for water availability. Standing Rock Sioux Climate Change Summit, Bismarck, ND.
- **#Rattling Leaf, J., Sr.** (1 September 2021)--USGS 2nd National Imagery Summit: Landsat & society.
- **#Rattling Leaf, J., Sr.** (2021). Open Source for Geospace (FOSSAG4)
- **Rattling Leaf, J., Sr.** (29 September, 2021- 1 October, 2021). Panel: Centering Justice in Indigenous Data Sovereignty, 9th Annual Rising Voices Workshop.
- **Rattling Leaf, J., Sr.** (20 October 2021). The diverse lenses of climate action and advocacy, Alliances for Climate Action.
- **Rattling Leaf, J., Sr.** (17 November 2021). Remote sensing and AI: Let's talk ethics, Geo for Good.
- **Rattling Leaf, J., Sr.** (19 January 2022). GeoInspirations podcast interview: Responsibility, reciprocity, relevance, and relationality, Directions Magazine.
- **Rattling Leaf, J., Sr.** (20 January 2022). Building relational and effective partnerships with Indigenous communities, Rising Voices/UCAR.
- **Rattling Leaf, J., Sr.** (22 February 2022). How can spiritual and faith-based knowledge systems inform the weather, water, and climate enterprise? American Meteorological Society Interfaith Committee Webinar.
- **Rattling Leaf, J., Sr.** (18 February 2022). Developing tribal strategies to deal with a changing climate, Lakota Food Sovereignty Coalition.
- **Rattling Leaf, J., Sr.** (30 March 2022). 2022 Worldwide Climate Justice Teach-in Event: Sound the Solutions.
- **Stephens, J**., Iglesias V., **Wolken J., Rangwala I., Tuff T.**, Mahood A., **Balch J**. (13 May 2022)--Future of Fire: Modeling Fires of Unusual Size. Poster at Cooperative Institute for Research in Environmental Sciences (CIRES) Rendezvous 2022, Boulder, CO.
- **Stephens, J**. (4-8 April 2022)--CASC CAPF Fire Cohort Synthesis Workshop, Online
- **Stephens, J.** (15 March 2022)--CASC CAPF Lightning talks on regional projects, USGS Wildland Fire Science Community of Practice, Online presentation
- **Stephens, J**. (2 March 2022)--Future of Fire: Modeling Fires of Unusual Size, In-person presentation to visiting scientist from The Finnish Environment Institute (SYKE).
- **Stephens, J.** (25-29 October 2022)--Future of Fire Synthesis: Workshop 1, Online.

Major engagements with regional decision-makers, stakeholders, and resource managers:
***** indicates an activity was not funded by the NC CASC, but leverages NC CASC researchers/consortium partners expertise in support of NC CASC strategic science goals.

- ***NC CASC Climate Solutions Days 2022*** (see agenda and Spotlight Story) provided scientists and practitioners with a venue to share insights on pressing climate problems and solutions in the North Central region via an à la carte offering of presentations, workshops and trainings

throughout Earth Week (April 19-22, 2022). This event involved significant contributions from the NC CASC team (CU team, Consortium Partners and USGS partners).

- **Shelley Crausbay** is beginning to engage in a co-production process with the Ute Mountain Ute Tribe to integrate insights about transformation from paleorecords and traditional ecological knowledge for the Tribe's climate adaptation planning process; in-person visit with the tribe upcoming for August 1-5, 2022.
- ***Shelley Crausbay** is developing ecological drought vulnerability analyses for drought planning with the State of Montana (*funded by NOAA-NIDIS).
- ***Shelley Crausbay** is engaging with an Advisory Board of practitioners for our scientific working group on Transformational Ecological Drought (TED) to help our technical group link science synthesis to climate adaptation planning (*funded by the National CASC).
- **Heather Yocum** attended the Chancellor's Annual Summit, 'Working to Forge a Just and Sustainable Future' to represent the NC CASC and the TCLP on February 23, 2022.
- **Heather Yocum, James Rattling Leaf, Stefan Tangen**, and **Jennifer Balch** attended the "Sensing the Earth" conference in Boulder, CO on June 15-17, 2022 to represent the NC CASC and forge connections with Tribal Colleges and Universities in the region.
- **Heather Yocum** and **Christy Miller Hesed** continue to work closely with the USDA Northern Plains Climate Hub on grasslands-related research and outreach in the region.
- **Heather Yocum** met with Senator John Hickenlooper's Congressional Aide (June 2022) to advocate for the NC CASC bill.
- **Heather Yocum** continues to volunteer with the Equity and Climate Action Team (ECAT) in their work with the municipal government of Longmont, CO to promote equitable, just environmental action and policies to create a more sustainable Longmont.
- **#Rattling Leaf, J., Sr.** worked with the Stand Rock Sioux Tribe to organize the Standing Rock Sioux Tribe Climate Change Summit, September 9-10, 2021.

Blogs, websites and press releases:

- **Cross, M.** (2021). Adapting the what, when, where, why and who of nature conservation to be more effective in a changing climate. The blog in the *Current Conservation* describes a paper published by Dr. Cross and colleagues in the journal *Conservation Science and Practice*, which introduces a rapid assessment framework to make nature conservation more resilient to climate change. The authors draw on lessons learned from a decade of funding over 100 adaptation projects designed to benefit wildlife and ecosystems. The new "5Ws" framework offers conservation practitioners initial steps to ensure their work will withstand climate impacts by considering the "what, when, where, why, and who" of their project design.
- WCS issued a Press Release on a new paper co-authored by **Dr. Molly Cross** on an adaptation "scorecard" for evaluating outcomes for climate-informed conservation and natural resource management projects. The research team interviewed and surveyed 18 climate adaptation researchers and funders and 47 practitioners to develop the flexible and comprehensive set of criteria, which can be tailored to an individual project's goals and context. This paper is part of a recent collection that draws on learning from the WCS Climate Adaptation Fund, which has supported over 100 climate adaptation projects in the U.S. designed to benefit wildlife, ecosystems, and the people that depend on them.
- NC CASC's **Edwards, Rangwala, Rattling Leaf, Tangen, Miller** and **Cross** contributed and reviewed content for the newly published section of the U.S. Climate Resilience Toolkit (toolkit.climate.gov) for the Northern Great Plains Region. Specifically, Rangwala led the *Ecosystems and Biodiversity* section, Tangen co-led the *Indigenous Peoples* section and Edwards co-led the *Water* section.

Media mentions and interviews:

- Molly Cross with the Wildlife Conservation Society was quoted in a German news outlet covering COP26: "There is some progress on financial investment in adaptation and country-level adaptation planning, but those efforts must be bolstered and expanded to meet the growing risks that both people and nature face from a changing climate," Molly Cross, science director for the WCS Climate Adaptation Fund, told DW. Cross said one critical aspect of helping humans adapt to climate change is the protection and restoration of intact and healthy ecosystems. "We must make significant investments in actions that help people and nature cope with and adapt to climate change-related impacts that are already underway," Cross said.
- **Jilmarie Stephens** gave an interview on January 13, 2022 to Angela Ufheil editor of 5280 magazine for background information on the Marshall Fire (Jennifer Balch was also quoted in the article).
- The Tribal Climate Leaders Program was mentioned in a write-up of the Chancellor's Summit: https://www.colorado.edu/globalclimatesummit/thought-leadership/summit-climate-change-human-rights-crisis.
- **Imtiaz Rangwala** was interviewed by CBC Radio, *As It Happens: Friday Edition* on June 17, 2022 regarding the impacts of climate change and drought on the Colorado River: https://www.cbc.ca/radio/asithappens/as-it-happens-friday-edition-1.6492565.