Aldo Leopold Wilderness Research Institute

FY2021 Progress and Accomplishments Report

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Advancing Wilderness Stewardship Through Transformational Science

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Chris Armatas is a conservation social scientist. His research focuses on wildlands management and planning through an interdisciplinary, social-ecological systems lens. Chris' desire to work in support stewardship of wilderness stems from years working on the Yellowstone River and exploring the wild places surrounding Yellowstone National Park.

Teresa Hollingsworth is a disturbance and plant community ecologist with a strong interest in the social-ecological consequences of climate change. At ALRWI, she is the Acting Deputy Director and has been involved in projects assessing research needs of partners and understanding past Indigenous fuels and fire management in wilderness.

Lisa Holsinger is a geospatial analyst with interests in fire ecology research directed toward understanding landscape-level interactions between changing climate, fire regimes, and vegetation. Her expertise is in conducting geospatial and remote sensing analyses to integrate landscape information at multiple spatial, temporal, and ecological scales.

Carol Miller is retired from the ALWRI where she was a research ecologist for nearly 20 years. Since receiving an M.S. degree in forest sciences and a Ph.D. in ecology at Colorado State University, she has studied various aspects of managing and restoring natural fire regimes.

Danette Paige is a program assistant, supporting business operations at the institute. Danette has been with the Rocky Mountain Research Station 19 years. Prior to joining the ALWRI, Danette worked at the Fire Sciences Lab with the Fire Behavior Project, first in a student temporary position, then as an office automation clerk.

Sean Parks is a research ecologist who is interested in the relationship between fire and climate, restoring fire as a natural process, improving the ability of satellites to characterize fire effects, and spatial interactions between past wildland fire and subsequent fire events. He has conducted several studies in the Gila, Selway-Bitterroot, Frank Church – River of No Return, and Bob Marshall Wilderness Areas.

Jason Taylor is a landscape ecologist and Director of the Institute. In addition to many years of leading protected areas management and science programs, Jason has an extensive background in the application of geospatial technologies. Jason's work has spanned the American West, Alaska, and the circumpolar Arctic.

Kathy Zeller is a spatial ecologist whose research integrates the fields of landscape ecology, wildlife biology, landscape genetics, and biostatistics to conduct quantitative analyses on wildlife populations and ecosystems. Much of her research is focused on understanding how patterns and processes of human-driven disturbance and climate change affect wildlife populations and large ecological networks.

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Cover image: Bridger Wilderness. Llamas pack string following a trail in Wind River Range. Courtesy photo by Wilderness Connect (https://wilderness.net/visit-wilderness/multimedia/image-library.php?ID=1972#image).

ALDO LEOPOLD
WILDERNESS RESEARCH INSTITUTE

Agency Acronyms

ALWRI – Aldo Leopold Wilderness Research Institute (Leopold Institute)

BLM – Bureau of Land Management

DOI – U.S. Department of the Interior

FWS – U.S. Fish and Wildlife Service

IWSC – Interagency Wilderness Steering Committee

NGO – Non-Governmental Organization

NPS – National Park Service

NOAA – National Oceanic and Atmospheric Administration

NWPS – National Wilderness Preservation System

PNW – Pacific Northwest Research Station

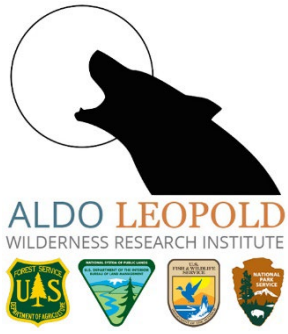
R&D – U.S. Forest Service, Research and Development

RMRS –Rocky Mountain Research Station

USDA – U.S. Department of Agriculture

USGS – U.S. Geological Survey

WSR – Wild and Scenic Rivers



LEOPOLD INSTITUTE NEWS

Once again (due to the continuing global pandemic), 2021 was a year of teleworking and Microsoft Teams meetings, except, now, with 18+ months of practice we all have become very proficient with video conferencing. Speaking of being proficient, this year the team collectively made an impressive array of contributions to wilderness stewardship and conservation science, more broadly. The many projects, publications, conference presentations, and manager engagements, and other outreach efforts advanced or completed are described below. Several scientists were formally recognized for their recent contributions and those made over a career. Administratively, we made significant progress in developing our next science charter and strategic plan, which will be submitted for review and approval early in 2022. Development of the charter commenced with a facilitated team training and discussion. In turn, the process was deliberately inclusive of a broad partnership community—an approach that has been recognized and appreciated. As a product of the chartering process, we proposed a revised mission statement for the Institute, a refinement that intends to demonstrate the ultimate purpose for our work: *Advancing wilderness stewardship through transformational science*. Last year was also one of operational adjustments, as we began to understand the consequences of the Forest Service's "budget modernization" process. How the Institute has operated, maybe for decades, has changed. Some of those changes are for the better, but our ability to have a meaningful impact has been diminished. Sadly, we said farewell to a cherished colleague who retired after several decades of service. Fortunately, strong leadership support exists for a continued "renewal" of the Institute. We welcomed a long-term detailer as Acting Deputy Director, a Research Ecologist, and several postdocs to our team; and we completed a hiring process toward welcoming our first research scientist focused on diversity, equity, and inclusion (DEI) in wilderness. The new team has become, you might say, a team. They are a purpose driven, collegial, supportive, constructive, exceptionally talented, team. The research needs we face are many, complex, and wicked, but the team is well suited to advance wilderness stewardship through transformational science in spite of the many aforementioned challenges. Below are a few specific items of note.

- Research Ecologist **Carol Miller** retired in April 2021 after nearly 20 years with ALWRI. Carol's contributions to wilderness fire management cannot be understated. In fact, Carol was recently awarded the Biswell Lifetime Achievement Award from the Association for Fire Ecology! We will miss Carol but wish her a happy retirement.
- Research Ecologist **Sean Parks** was awarded the FY21 Eminent Science Publications Award by the Rocky Mountain Research Station. Sean served as lead investigator for a line of research intended to quantify how previously burned areas influence subsequent fire activity. This research resulted in five peer-reviewed papers and exemplifies the use of wilderness as a natural laboratory from which we can pull lessons to inform and improve management across all land designations.
- **Teresa Hollingsworth**, Research Ecologist at the Pacific Northwest Research Station, joined ALWRI as Acting Deputy Director, in March of 2021, and has been instrumental in development of our new science charter.
- **Kellie Carim** joined ALWRI in September at the end of our fiscal year. Kellie's research experiences are broad and include aspects of using environmental DNA to understand aquatic systems, landscape ecology, invasive species management, population dynamics, and others. Over the last five years, Kellie has also worked as a tribal project coordinator, building collaborations with nearly 20 Native American Tribes and natural resource agencies in the western U.S.

IN SUMMARY (TASKS AND PROJECTS)

Administrative Tasks

Developing a science charter for the ALWRI through partner engagement
Completed hiring process to onboard a scientist focused on DEI in wilderness research
Updated grants/agreements/budget processes to align with Forest Service budget modernization

Projects (sorted by 2008 Science Charter Problem Areas or PAs)

PA1: Recreation experiences and the impacts of recreation on wilderness

Wilderness visitor-use planning for the NPS Park Planning and Special Studies team
Visitor-use management in the high-use Alpine Lakes Wilderness outside of Seattle
Trends in campsite conditions on the Frank Church River of No Return Wilderness
Ranger encounters data to inform future monitoring at Sequoia and Kings Canyon National Parks
Wild and Scenic Rivers user capacity study for the Salmon-Challis National Forest
Public engagement for developing desired conditions for visitor use management
Trail management partnerships research
Recreation ecology and social science in the Rattlesnake Wilderness

PA2: Relationships between people and wilderness lands and management

Public engagement planning for the Wallowa-Whitman National Forest
Visitor use and user information to support planning on the Eleven Point National Scenic River
Scholarly exchange with Yunnan University, China
Relevance, diversity, and inclusion in BLM Wilderness

PA3: Wildland fire and social and ecological values of fire

Forty years of lessons from fire management in large wilderness areas in the Northern Rockies
Improving fire severity mapping in boreal forests in Alaska
Identifying ecological and social resilience in fire-prone landscapes
Landscape fuel management strategies to increase the opportunities to manage wildfire
Ecological characteristics and functions of fire refugia
Contrasting historical and contemporary fire regimes in Arizona and New Mexico
Contrasting historical and contemporary fire regimes in the western U.S.
Ecosystem response to fire in the Selway-Bitterroot Wilderness
Paleo-ecological evaluation of fire and vegetation transformations in western Colorado
High severity fire: trends through time and links to climate
Articulating the benefits and costs of prescribed fire in wilderness
Indigenous fire and fuels management in BLM Wilderness areas: Informing adaptive and collaborative large-scale fire management for the future

PA4: Wilderness stewardship within larger ecological and social systems

Protected area vulnerability under climate change
Effects of management and climate change on biodiversity and connectivity
Contributing to a Landscape Conservation Design for the Crown of the Continent Ecosystem
Ecoregional planning for multiple wildlife species in the Great Basin

Quantify the contribution of wilderness to wildlife population genetics
Economic impacts of wilderness on gateway communities

PA5: Delivery and application of scientific knowledge and tools

Streamline the management and evaluation of scientific research proposals in designated wilderness
Shared stewardship in wilderness: Challenges, components for success, and ideas for improvement

External projects facilitated by Leopold Institute Staff

Economic Benefits of Wilderness Working Group Report
Research to support management of the Pacific Crest National Scenic Trail and related public lands
Wilderness recreation science (at Crater Lake National Park)
Future changes to wilderness areas and surrounding lands linked to land use and climate change

ADMINISTRATIVE TASKS

Developing a science charter for the Aldo Leopold Wilderness Research Institute through partner engagement (Taylor and Hollingsworth (and team)) – Developing a science charter (strategic plan) for ALWRI was a complex task because: (1) science needs relevant to effective stewardship the National Wilderness Preservation System, all 111 million acres and 800+ units, across two Departments and four agencies, are diverse and expansive; (2) identifying priority science needs requires consideration of the science needs of agency and other management and science partners, as well as guiding policy for Forest Service scientists (e.g., the Research Grade Evaluation Guide), and the knowledge and opinions of a diverse range of wilderness stewards and interested parties, both nationally and internationally; and (3) the capacity to address science needs is finite and influenced by the expertise of current ALWRI staff.

We gathered input regarding science priorities for the next ten years of wilderness stewardship research at ALWRI using a process to engage a broad wilderness community of partners. The backbone of our partner engagement was a public engagement process that relied on a social science approach, applying Q-methodology to rigorously distill the opinions of all people in the 'conversation' (i.e., all participating partners) into a limited number of divergent, typified perspectives.

Our science-planning, partner-engagement process had seven key steps:

1. We developed a "universe of potential research questions", called a "research concourse", based on previous science planning efforts, literature, and knowledge of Institute scientists and staff. Our research concourse consisted of 178 research questions.
2. We then shared broadly with partners (nationally and internationally) an opportunity to provide feedback on the research concourse, to add other important research questions that may be missing. This partner-engagement pushed the list of potential research needs to over 200 questions.
3. The next step distilled the concourse into a 'Q-set', which is a tractable set of statements that broadly represent the ideas in the concourse. This effort generated 31 integrated research topics or areas for prioritization.
4. A broad group of partners (again, nationally and internationally) were then invited to prioritize the integrated research topics, based on their own needs, using a web application. Additionally, partners provided demographic information about themselves, including affiliation and identified role.
5. The prioritized needs (Q-sorts), across 175 respondents, were analyzed using factor analysis, which yielded three typified perspectives that captured the broad range of opinions on what the highest research priorities "should be".
6. We conducted five public workshops with partners to share results-to-date, and to understand the nuance and context within the typified perspectives. During the workshops, we presented the three general perspectives and asked partners: (1) do any of the perspectives resonate with you, and if so, which one(s); (2) why do the perspectives resonate with you, and/or what is your reasoning for prioritizing the research topics as you did; and (3) what might you name the three perspectives? In total, 33 people attended the workshops from the BLM, EPA, USFS, NPS, Arthur Carhart National Wilderness Training Center, state governments, universities, and non-governmental organizations (NGOs). Those attending spanned a variety of roles, including science leadership, communications and outreach, wilderness program management, and unit-level oversight (e.g., superintendents).

7. Finally, Institute scientists reviewed research topics not in the top 15 priorities (from the partner engagement effort) to determine if other topics, based on their expertise and current research, should be considered in the new charter.

With the above partner input, we identified that research priorities generally organized into three groups, with little overlap between the groups. That is, there were three primary perspectives (typified responses) that emerged from the input, where everyone within a given perspective responded similarly (with some variation) to one another. The three perspectives were ultimately labeled: societal, ecological, and managerial, since the types of questions that had the highest priority in each group were largely societal, ecological, or managerial, respectively, in nature.

Leveraging the five highest research priorities from each perspective, along with the five highest priorities from each of the National Wilderness Preservation System (NWPS) management agencies and Tribal respondents (based on aggregating the partner input), we identified the 15 highest priority research needs. In turn, ALWRI scientists identified which of the top 15 they could address based on expertise and opportunity. Eleven of the top 15 priorities were integrated to create five research priority areas (RPAs). These RPAs, tied to both perspective and priorities (identified from raw data), provide the foundation upon which the updated ALWRI science charter is developed.

Completed hiring process to onboard a scientist focused on diversity, equity, and inclusion in wilderness research (Taylor and Hollingsworth) - The opening lines of the Wilderness Act state: "An Act to establish a National Wilderness Preservation System for the permanent good of the whole people…". Today, we have yet to meet that ideal. There remain varying opportunities (or lack thereof) to access wilderness for people who were historically excluded from wilderness, for example, Native Americans, people of color, immigrants and new Americans, people with disabilities, and people who identify as LGBTQIA+. The ALWRI has demonstrated a strong commitment to helping the wilderness stewardship community understand and reconcile the past and change the future. In addition to other achievements, the Institute has actively worked to hire a scientist focused on diversity, equity, and inclusion research that will create one pathway toward understanding and managing wilderness for "…the permanent good of the whole people…" The Institute established an interagency team to serve as an advisory panel for hiring the DEI research scientist. We sought guidance from this team (and other leaders in the DEI community) on broadening recruitment to reach candidates with lived experiences different than that of typical forest service demographic groups, successful onboarding, and long-term retention, the latter two concepts with a specific emphasis on supporting potential applicants of color. Hiring a DEI research scientist at ALWRI will, in time, help to ensure that wilderness managers understand: recreational experiences, preferences, barriers, and incentives for underserved communities; "relevancy" of wilderness to all people, in the sense of both what does relevancy mean to different people, and also how we can increase relevancy; value and use of wilderness resources by diverse user groups; proposed and existing wilderness laws and policies, and if they advance equity and inclusion; and most importantly, improve access to wilderness for families of all backgrounds.

Updated grants, agreements, and budget processes to align with Forest Service budget modernization (Taylor and Paige) – The agency underwent a massive budget programming overhaul in FY21 that changed, dramatically in some cases, how we handle/process project funds. Many outcomes of this change remain uncertain; but over the last fiscal year we've had to adapt our efforts and our ability to conduct science on behalf of the National Forest System has been impacted. Fortunately, our ability to engage DOI and other (non-Forest Service) partner funds remains intact. More work remains to understand the path forward and to understand and implement new business practices to adapt to budget modernization.

PROJECTS

PA1: RECREATION EXPERIENCES AND THE IMPACTS OF RECREATION ON WILDERNESS

Visitor-use management (Armatas) – In collaboration with the University of Montana and the National Park Service Park Planning and Special Studies team, a social science project initiated in FY20 to address visitor use management challenges in park wilderness areas continued. An exhaustive literature review of visitor use management in wilderness was submitted to the Journal of Leisure Research, a pilot survey instrument was developed and is ready for implementation in winter 2022/2023 at Everglades National Park, and a qualitative research component of the project is in its design phase. The survey instrument is designed to address issues likely to be shared across park units (e.g., protecting opportunities for solitude), as well as context-specific planning needs (e.g., effective implementation of a visitor permit system). The survey will hopefully be implemented in coming years in multiple park units that are actively engaged in wilderness planning efforts.

A collaborative project with the goal of supporting visitor use management in the high-use Alpine Lakes Wilderness outside of Seattle progressed toward the partner engagement phase. This phase includes development of a governance framework, recruitment of diverse partners, and the establishment of roles. For ALWRI, social science support will include engagement with an Enchantments Wilderness working group, and formal evaluation of the co-production and collaborative process.

Wilderness use monitoring (Armatas) – In collaboration with the University of Montana, two projects to support wilderness use monitoring continued. On the Frank Church – River of No Return Wilderness, a project finalized the compilation and analysis of an exhaustive data set of all campground monitoring reaching back 30-40 years. Analysis of the dataset assessed trends in campsite conditions and will be finalized with spatial representation of campsite conditions. Results have been conveyed to managers through two presentations. Final steps include finishing the report and archiving the data set.

The second project, at Sequoia and Kings Canyon National Parks, included finalizing analysis and reporting writing for of an existing dataset of ranger encounters. The project will inform a future monitoring plan, and ensure that methods of monitoring, and analysis of monitoring data, meets current scientific standards.

Wild and Scenic Rivers user capacity (Armatas) – This ongoing project has two primary objectives: (1) help Salmon River managers on the Salmon-Challis National Forest with their immediate needs to determine user capacity; and (2) develop a framework, or basic process, that could be implemented by other WSR managers that need to integrate user capacity determinations into an existing river plan or

new or revised comprehensive river management plans. Data collection for the monitoring phase of this project, which included camera traps, is complete and an analysis was delivered to managers. The final data collection component of this project, a river-user survey, was partially completed in summer and fall of 2021. Due to low water and an active fire season, inadequate sampling numbers were achieved and, therefore, another field season is planned for summer and fall of 2022. Analysis of current data is planned for the winter of 2022.

Contributed paper on public engagement for developing desired conditions for visitor use management (Armatas) – The Leopold Institute, in collaboration with RMRS and PNW researchers and NOAA scientists and practitioners, is leading the development of a paper that will supplement the desired conditions guidebook, currently being developed by the Interagency Visitor Use Management Council. This high-profile contribution will directly support managers and planners across all land management agencies as they develop 'desired conditions' in a variety of visitor use contexts.

Trail management partnerships research (Armatas) – The Leopold Institute, in collaboration with Virginia Tech and Forest Service and NPS managers, participated in research focused on better understanding indicators of success for trail management partnerships. This work will support land managers at they continue to engage in shared stewardship approaches, whereby diverse partners provide support and expertise in delivering land management missions. This project will include formal social science research of both agency and non-agency partners.

Recreation ecology and social science in the Rattlesnake (Zeller and Armatas) – The Leopold Institute, in collaboration with the University of Montana, Forest Service managers, and the City of Missoula, MT, initiated planning for a project focused on understanding visitor perceptions, interactions with wildlife, and travel patterns in both Forest Service and Missoula open spaces. Project design, and early stages of research, will be completed in FY22.

PA2: Relationships between people and wilderness lands and management

Public engagement in planning (Armatas) – Leopold Institute scientists provided social science, planning support for several management units in FY21.

The *social vulnerability protocol,* published in 2019, was applied at the project level on the Wallowa-Whitman National Forest in FY21. Using an electronic online application, the public engagement approach supported the Forest's 87,000-acre resiliency project. A written report of analysis was recently delivered to managers and, following review, will be finalized. The social vulnerability protocol was also advanced in FY21 with a publication in the peer-reviewed journal Society and Natural Resources, entitled *A Social Science Method for Public Engagement in the Context of Natural Resource Planning in the United States*. Further advancements of this work are planned for FY22, with the integration of the public engagement approach with another social science method (human ecological mapping). This integration will be done in collaboration with PNW researchers, university partners, and Forest Service Regions 5 and 6 managers and planners.

The Leopold Institute and the University of Missouri, School of Natural Resources, collaborated to gather

visitor use and user information for the Eleven Point National Scenic River in Missouri to support its Comprehensive River Management Plan. This project will be completed in FY22, with the archiving of two visitor-use survey data sets and the preparation of a journal article for submission.

Collaborating with Yunnan University, China (Armatas) – Leopold Institute staff collaborated on scholarly exchange toward stewardship and protection of our Earth's wildlands. China, in this specific case, is endowed with a significant portion of the Earth's wild places. Understanding the challenges they face, the approaches taken to stewardship in the West, and the differences between governance systems can provide insights that may lead to more sustainable stewardship of wildlands. This collaboration focused on: (1) contextualizing a study (of a mass closure of lodging around a lake in China) within the environmental justice literature. An article submitted to *Ecology and Society* in FY21 will continue through the peer-review process, and (2) understanding social exclusion within the context of different community types surrounding a large lake in China. An article may be submitted to a peer-reviewed journal focused on different perspectives of social exclusion.

Relevance, diversity, and inclusion in BLM Wilderness (Armatas) – The Leopold Institute, the University of Montana, and BLM managers (at the National level and unit level in California) worked together toward understanding issues related to DEI in wilderness. The project will advance both basic and applied science needs. It will include an on-site survey as well as an off-site component leveraging social media.

PA3: Wildland fire and social and ecological values of fire

Lessons from wilderness fire (Miller) – The practice of allowing naturally ignited fires to burn began over 40 years ago in a handful of wilderness areas and national parks. This ongoing experiment is providing valuable lessons for managers of other areas who seek alternative strategies to aggressive fire suppression. The large wilderness areas in the Northern Rockies region have been leaders in this practice. The National Fire Plan has supported a comprehensive review of modern wilderness fire science and lessons learned since fire management began to adopt the practice of allowing naturally ignited fires to burn (~1970). The synthesis draws on agency fire history records, geospatial fire atlases, published literature, historical and contemporary photos, and interviews with key informant managers. It was published in early FY22 as a Forest Service General Technical Report, entitled *A history of wilderness fire management in the Northern Rockies*.

Improving fire severity mapping in boreal forests (Holsinger and Parks) – Fire severity maps can be produced by comparing differences between pre- and post-fire satellite imagery. The methodology used to produce these fire severity maps is well vetted and validated in the conterminous U.S. However, there was concern that these maps do not well represent fire severity in Alaskan boreal forests. At the urging of resource specialists in Alaska, we evaluated new approaches to mapping fire severity in Alaska and western Canada boreal forests. The process was developed using the Google Earth Engine cloud-computing platform; the relevant code has been published and is publicly available. Most field data used to evaluate our models was collected in protected areas. Partners included the USGS, USFWS, NPS, and the Canadian Forest Service. This project is a continuation of ALWRI's line of work to improve the ability of satellites to measure fire severity. See the paper here: *Improved fire severity mapping in the North American boreal forest using a hybrid composite method*.

Identifying ecological and social resilience in fire-prone landscapes (Miller) – A project funded by the Joint Fire Science Program (JFSP) was completed in FY21. The project developed a framework to better

understand and talk about social-ecological resilience in a way that is compatible with the JFSP National Cohesive Strategy's goals of promoting fire-adapted communities and restoring and maintaining landscapes resilient to fire. A final product is currently in press, a research note entitled *Developing strategies to achieve social-ecological resilience in fire-prone landscapes: A structured approach for natural resource managers, community organizations, and stakeholders*. The research note describes a series of reflective exercises that were developed and used in a 2019 workshop setting. These sequential exercises helped participants clearly identify what resources they and their communities wanted to be resilient, and then helped them outline specific actions that could be taken to support resilience for those resources.

Landscape fuel management strategies to increase the opportunities to manage wildfire for ecological benefits (Miller) – This project funded by the Joint Fire Science Program was completed in FY21. The project addressed the fundamental question of whether landscape fuel treatments can be designed to simultaneously meet resource protection and management objectives. Using state-of the-art spatial fire risk modeling, we evaluated landscape fuel treatment designs in terms of their ability to decrease exposure of homes to fire and their ability to increase opportunities to use wildfire for resource management. Project results revealed guiding principles about landscape fuel treatment strategies that meet the vision of the JFSP National Cohesive Strategy where fire can be accepted as a natural and necessary process, while conflicts between fire-prone landscapes and human uses are reduced. A paper is currently being drafted, entitled *Comparing risk-based fuel treatment prioritization with alternative strategies for enhancing protection and resource management objectives*.

Ecological characteristics and functions of fire refugia (Miller) – Fire refugia are places within high-severity burns that remain unburned or burn with low-severity and can be important for maintaining and regenerating fire-prone forested systems. A project, funded mostly by the National Fire Plan, investigated the formation, persistence, and role of fire refugia in promoting forest recovery and ecosystem resilience. A field study of 13 burns in Arizona, New Mexico, Colorado, Idaho, and Oregon provided a rich dataset and numerous findings from regional analyses of subsets of these data, which has already been published. During FY21, we used the entire dataset to explore relationships between tree seedling abundance and vegetation and determined if and how competition and/or facilitation are at play in post-fire vegetation trajectories. The broad range of climatic conditions covered by our extensive dataset allowed us to explore the influences of climate on those relationships. A *research data archive* entry has been created for this project. One manuscript –a capstone of the project—has been accepted for publication, entitled *Where and why do conifer forests persist in refugia through multiple fire events?*

Contrasting historical and contemporary fire regimes (Parks) – This project's goal is to contrast the contemporary fire severity at select sites (i.e., fire-scarred trees) to the historical inferred fire severity in Arizona and New Mexico. We partnered with USGS and Western Colorado University to recruit a master's student who will collect, analyze, interpret field and satellite-derived fire severity data, and



publish project results. Some of the historical data for this project were collected in wilderness. Field work was conducted in summer 2021 in the Saguaro Wilderness (Arizona); field work in the Gila Wilderness (New Mexico) was cancelled because of the 2021 Johnson Fire. Project completion expected mid-2022.

Contrasting historical and contemporary fire regimes, with lessons learned from wilderness (Parks) – This project's goal is to contrast historical and contemporary fire severity for dry conifer forests in the western U.S. Building off previous products developed by ALWRI scientists (Parks as PI), we will measure contemporary fire severity with satellite data in Google Earth Engine. We will compare our broader results to those in the Gila Wilderness, which serves as model landscape where dry forests remain mostly intact even though the fire regime is quite active. This project was initiated in FY21 and is ongoing.

Ecosystem response to fire in wilderness (Parks) – The overarching objective of this study is to evaluate the ecosystem response to fire across a broad bioclimatic and fire history gradient in the Selway-Bitterroot Wilderness. The field data will be evaluated with appropriate statistics and will enable us to determine how fire history and bioclimatic characteristics influence post-fire ecosystem trajectories, including the potential for enduring conversions to non-forest. We partnered with University of Montana to recruit two graduate students (one master's and one PhD) to conduct this work. We are actively engaging Selway Bitterroot Wilderness personnel to gain insight and coordinate logistics. Field work was conducted in summer 2021 and data are currently being analyzed. We expect the master's degree student will complete analyses in 2022. More field work is expected in summer 2022 (PhD student) and an additional master's student will be recruited in 2022.


Paleo-ecological evaluation of fire and vegetation transformations (Parks) – This pilot project focuses on understanding the potential role of past ecological transformations in creating contemporary vegetation mosaics in western Colorado, characterized today by a patchwork of mixed conifer and deciduous forest stands, intermixed with oak and other shrub-dominated vegetation. The duration of these vegetation types, particularly the iconic and extensive aspen-dominated landscapes of this region, have long been the subject of poorly informed debate within the land management and research communities (with speculated time frames ranging from centuries to millions of years), and which today remains unresolved. Partners include Western Colorado University, University of Montana, and Conservation Science Partners. In FY20, we sampled a shallow lake by extracting a sediment core. In FY21, the sediment core was processed (we counted charcoal and pollen); we now have measures of fire and vegetation starting in about 1350.

High severity fire: trends through time and links to climate (Parks) – Several previous studies have concluded that annual area burned in western states has increased since the mid-1980s, coincident with a warming climate. However, area burned is an imperfect measure of fire impacts because fire burns at various severities: some fire is considered "good" and some "bad". Here, we partnered with UC Merced to evaluate how high severity fire (resulting in ≥95% tree mortality) has changed through time and relates to fire-season climate (with implications under continued climate change). In FY21, we published the results in a peer-reviewed journal, entitled *Warmer and drier fire seasons contribute to increases in area burned at high severity in western US forests from 1985 to 2017* in FY21.

Articulating the benefits and costs of fire in wilderness (Parks) – This project is a collaboration between ALWRI and Western Colorado University and assesses the suitability of prescribed fire use in designated wilderness based on ecological conditions and trajectories, wilderness management guidelines, ethics, and precedence, and perceptions of managers and other stakeholders. Information on the above are being developed through research, interviews, and dialogue. Western Colorado University graduate students and faculty are leading these efforts, intended to produce a peer-reviewed publication and other outreach including web materials and popular media. Findings will inform a workshop including wilderness managers and a range of other stakeholders (advocacy groups, researchers, fire managers, etc.) to engage in dialogue leading to a white paper that synthesizes knowledge and provides policy recommendations. The project was initiated in late FY21; fire management in wilderness was the focus topic of a graduate environmental policy class at Western Colorado University for the fall 2021 semester.

Indigenous fire and fuels management in BLM Wilderness areas: Informing adaptive and collaborative large-scale fire management for the future (Hollingsworth and Parks) – Federally managed wilderness areas often have historical, cultural, and spiritual significance to Indigenous peoples and Tribes, and have a legacy of Indigenous management practices, including fire and fuels management. Exploring and acknowledging historical and current Indigenous land use, the relationship between Indigenous people and wilderness, and considering these practices in the context of untrammeled and natural qualities of wilderness, will help us develop a framework for acknowledging Indigenous use as a key component of wilderness character and appropriate management approaches, and lead to collaborative research programs and management strategies with tribes in Wilderness and other federally managed areas. In FY21, scientists from the AWLRI conducted preliminary field work at the Axolotl Lakes Wilderness Study Area in the Gravelly Range in SW Montana to look for evidence of past fire (e.g. fire-scarred trees) and also evidence of fire suppression (conifer encroachment). Our immediate goal was to identify if we are seeing a signal of fire suppression, with the longer-term goal of better understanding if Indigenous peoples played a role in pre-European fire activity in this region. The area is within the traditional homelands of the Crow Nation. An overarching goal of the work is to coproduce knowledge that could support cultural, ecological, and community health of the Crow Nation, and we have begun conversations with Little Bighorn College in Crow Agency to facilitate this goal.

PA4: Wilderness stewardship within larger ecological and social systems

Protected area vulnerability under climate change (Parks) – Protected areas (PAs) serve as a refuge for plants and animals in a world increasingly modified by human activities. However, protected areas are not immune from the effects of climate change, and moreover, some protected areas are likely to be more vulnerable than others. We evaluated vulnerability of protected areas to climate change across the globe. Several related efforts fall under this theme, all of which involve a partnership with University

of Montana. For example, we evaluated protected areas in the context of ecoregion and biome shifts under climate change and published a paper in FY21, entitled *Protected-area targets could be undermined by climate change-driven shifts in ecoregions and biomes*. In conjunction with this paper, we partnered with Gage Cartographics and developed an online climate change visualization app that was unveiled in FY21 (plus2c.org). Another component of this overarching theme is a study that evaluates the potential for transboundary species movement among PAs under climate change, and another that quantifies protected area vulnerability under climate change through the lens of climate connectivity. We expect to submit another paper to a peer-reviewed journal in FY22.

Effects of management and climate change on biodiversity and connectivity (Zeller) – This work, in cooperation with the Pacific Southwest Research Station, is part of a larger effort to quantify socio-ecological resiliency in the forested landscapes of the Lake Tahoe region of the Sierra Nevada Mountains. Six management and climate scenarios are being assessed with 10 different pillars of resiliency for this area: biodiversity conservation, forest resilience, fire dynamics, carbon sequestration, wetland integrity, air quality, water security, fire-adapted communities, economic diversity, and social and cultural well-being. We are conducting research to assess the biodiversity conservation pillar. We have modeled habitat suitability and connectivity for over 100 terrestrial wildlife species in the region across one climate and two management scenarios. We have brought on a postdoc to the project who is quantifying biodiversity refugia and changes in species composition through time. We and the larger team are beginning to quantify the degree to which wilderness areas contribute to these 10 different pillars compared to the surrounding landscape.

Contributing to a Landscape Conservation Design for the Crown of the Continent Ecosystem (Zeller) – The Crown of the Continent covers nearly 18 million acres and is a patchwork of protected areas, tribal lands, wilderness, and private lands spanning the U.S.-Canada border. To facilitate planning and management across these jurisdictions, the Crown Manager's Partnership—a partnership amongst universities and state, provincial, tribal, and federal agencies in Montana, Alberta and British Columbia—is developing a Landscape Conservation Design for the entire ecosystem. We are working to incorporate connectivity into this Landscape Conservation Design by modeling current and future ecological and species-specific connectivity. Ecological connectivity across the Crown of the Continent has been modeled and presented to the Crown Manager's Partnership Technical Team. This product is currently being updated with new information. We have hired a postdoc for this project, and they have begun developing models for quantifying species-specific connectivity. The many wilderness areas in this ecosystem will be quantified in terms of their contribution to current and future wildlife connectivity.

Ecoregional planning for multiple wildlife species in the Great Basin (Zeller) – In cooperation with other Rocky Mountain Research Station scientists, state, university, and NGO partners, we are assessing important habitat areas and corridors for multiple wildlife species of conservation concern in the Great Basin ecoregion. Planning and management at the ecoregional scale requires landscape scale assessments of species and their habitats. However, to date, these types of analyses have primarily been focused on a single species, the Greater Sage-Grouse. In the last year we completed habitat and connectivity analyses for five bird species of concern in the Great Basin as well as for pronghorn and pygmy rabbit. The work has resulted in two peer reviewed publications *Forecasting habitat and connectivity for pronghorn across the Great Basin ecoregion. Diversity and Distributions* and *Targeting conifer removal to create an even playing field for birds in the Great Basin*, as well as one publication that is in preparation.

Quantifying the contribution of wilderness to wildlife population genetics (Zeller) – Landscape genetics can be used to determine landscape effects on genetic diversity and health of wildlife populations. A

collaboration with the University of Montana has been initiated to assess landscape effects on a suite of wildlife species, project future genetic diversity and allelic variation, and determine the importance of wilderness areas for acting as genetic sources for populations of species. In this past year, we have completed a landscape genetic analysis for cougars in Washington State that identifies population differences, gene flow, source-sink dynamics, and landscape features that facilitate and impede movement.

Economic impacts of wilderness on gateway communities (Armatas) – In collaboration with the Conservation Economics Institute, this project provides an understanding of how wilderness, and the associated migration of people to the area for outdoor amenities, leads to social and economic development in gateway communities. This research, focused on amenity development (e.g., changes per capita income, changes in regional tax revenues), is a continuation of a research collaboration focused on amenity migration (e.g., what types of amenities such as protected areas and climate drive the movement of people). A manuscript on the study was submitted for publication, and after major revisions will be resubmitted to the peer-reviewed journal, *Land Use Policy.*

PA5: Delivery and application of scientific knowledge and tools

Streamlining the management and evaluation of scientific research proposals in designated wilderness to improve consistency and communication (Landres [emeritus] and Armatas) – In collaboration with Forest Service agency wilderness stewards, this project continued toward a streamlined version of a framework developed by ALWRI in 2010. Specifically, several documents were drafted to aid the science in wilderness evaluation process, including requesting a science activity permit, nominal effects determination, a wilderness research guide, and a template for developing proposals to conduct science activities.

Shared stewardship in wilderness: Challenges, components for success, and ideas for improvement (Armatas) – In cooperation with wilderness stewards from federal agencies and non-federal partners, a survey was administered at the 2019 National Wilderness Workshop during a plenary session on shared stewardship. A full report of data analysis was completed in FY20. In FY21, the project concluded with an *International Journal of Wilderness* publication (*Wilderness Shared Stewardship: Exploring Partnerships Through Empathy*), a workshop presentation, a conference presentation, and a webinar.

External projects facilitated by Leopold Institute Staff

Economic Benefits of Wilderness Working Group Report (Taylor) – The Wilderness Economics Working Group, initially convened by the Leopold Institute in 2014, included scientists from the BLM, FWS, NPS, and USGS within the U.S. Department of the Interior, the Forest Service within the U.S. Department of Agriculture, several universities, and private industry. The working group's 10-chapter General Technical Report (*A Perpetual Flow of Nature's Benefits: Wilderness Economics Working Group Report on the Economic, Social, and Tribal Values of Wilderness in America*), was completed and submitted for publication in early FY21. The draft document, after review by the Forest Service's Office of Tribal Relations, required a partial rewrite to address inclusivity concerns. After a lengthy effort, the report will be resubmitted for review and publication in 2022.

Research to support management of the PCT scenic trail and related public lands (Armatas) – Colleagues from Applied Trails Research, LLC, and AWLRI continued to conduct a Pacific Crest National Scenic Trail (PCT) travel pattern analysis and a Yosemite travel pattern and wilderness study.

PCT travel pattern analysis: In 2021 this work supported analyses of use in the Sierra at the high-use Carson Pass Management Area (CPMA) on the Mokelumne Wilderness. Researchers inventoried campsites, deployed visitor use counters, conducted trail encounter monitoring, and conducted a workshop with wilderness and recreation managers of the CPMA from the Eldorado NF, and the Stanislaus NF. Additional support was provided to management partners in the central Sierra via the interagency PCT working group.

Yosemite travel pattern and wilderness study: Field work on this project was delayed from 2020 due to COVID-19. In 2021, researchers studied overnight wilderness use in the park to assess visitors' recreational travel patterns, and understand their perceptions of wilderness character and preferences for camping and campsites. Data were collected from June to October through on-site surveys, field assessments, travel diaries, and with an app via visitors' personal electronic devices. The data collected are currently being analyzed in close collaboration with Yosemite National Park's wilderness managers.

Wilderness recreation science (Armatas) – Colleagues from Virginia Tech are conducting a study of visitor use impacts and campsite/trail sustainability at Crater Lake NP related to PCT hiker use. Fieldwork was completed at Crater Lake NP in July 2021 as part of a larger multi-year study of sustainable camping management on the PCT. All designated campsites in the park were surveyed to document their resource conditions and sustainability. A close-out presentation was given to NPS staff prior to departure. Also in 2021, researchers spent several months writing the final report for a larger project (including the work at Crater Lake NP), and expect to forward a draft final report to the larger PCT community of managers and stewards for peer review in February 2022, after which the report will be revised and finalized.

Future changes to wilderness areas and surrounding lands linked to land use and climate change (Parks) – Colleagues from the University of Idaho have assessed current effects of land use and climate change to evaluate the future effects on wilderness areas and surrounding public lands of land use change and climate change projections. In addition, they evaluated the species occurring within specific wilderness areas and evaluated how species composition could be affected by future land use change and climate change projections. Lastly, they identified the wilderness areas most affected by future land use change, human population change, climate change projections, and changes in species composition. In FY22, a journal article from this previously funded work will be published.

SERVICE AND TECHNOLOGY TRANSFER

Management/Stewardship Community Service

Chris Armatas served on the U.S. Forest Service's Chief's Wilderness Advisory Group. He consulted BLM managers about "The Wave" and ongoing visitor use management issues and their recent application of the limits of acceptable change framework, served on the Interagency Visitor Use Management Council working group for desired conditions, as well as a working group on diverse and equitable public engagement, and served on the NPS Benefits of Wilderness working group.

Carol Miller served as a member of the Regional Science Advisory Team, a group of resource managers from the Northern Region of the Forest Service and RMRS scientists.

Sean Parks, in collaboration with University of Montana, continued to engage with managers of the Selway-Bitterroot Wilderness about ongoing projects involving post-fire vegetation trajectories. Sean gave a virtual lecture at the Arthur Carhart National Wilderness Training Center's regional wilderness course on some of the climate change related threats to wilderness and to the silviculture group at Forest Service Region 1 about fire-catalyzed forest conversions in a warming climate. Sean also published a manager-focused science spotlight entitled, *Area burned at high severity is increasing in western U.S. forests*.

Jason Taylor served as a member of the Interagency Wilderness Steering Committee. He also continued agency-level outreach and engagement activities across the NWPS. He participated in monthly wilderness regional program manager meetings; contributed to the NPS National Wilderness Leadership Council (NWLC, including actively contributing to the NWLC Diversity and Inclusion Working Group); and facilitated quarterly, bureau-level program updates with IWSC and Policy Council representatives. Jason also presented on "The Benefits of Wilderness" at the National Wilderness Leadership for Managers course, Arthur Carhart National Wilderness Training Center.

Kathy Zeller served on the leadership and technical teams of the Crown Managers Partnership, a multi-jurisdictional group of federal, state, provincial, tribal, and First Nation agency managers in Alberta, British Columbia, and Montana. Kathy also published manager-focused science spotlights entitled, *Incorporating dynamics into landscape connectivity models* and *Targeting conifer removal to address habitat needs for multiple species in the Great Basin*.

Science Community Service

Chris Armatas served on the planning committee for the 2021 National Wilderness Workshop. He also served on the planning committee for the Crown of the Continent Recreation Forum, served on the Editorial Board of the International Journal of Wilderness, began serving on two PhD committees (University of Montana and Virginia Tech), and gave two different guest lectures at the University of Montana.

Carol Miller served as Associate Editor for the journal *Fire Ecology*.

Sean Parks continued to serve as a committee member for students at University of Montana and Utah State University.

Jason Taylor served as a member of the IUCN World Commission on Protected Areas, Wilderness, and Science of Management and Biodiversity, Specialist Groups.

Kathy Zeller continued to serve on a thesis committee for a graduate student at the University of Montana and is advising on that research. She also completed duties as guest editor for a special issue on Dynamic Landscape Connectivity in the journal *LAND*, served as the Treasurer for the Spatial Ecology and Telemetry Working Group of The Wildlife Society, and continued to serve as a member of the IUCN World Commission on Protected Areas, Connectivity Conservation Specialist Group.

Conference and Meeting Presentations

Team ALWRI co-presented the America's Keynote, *Past, current and future research at the Aldo Leopold Wilderness Research Institute*, at the European Wilderness Society's, International Wilderness Week (virtual) conference, Oct 2020. We also delivered ALWRI overview presentations at national webinars hosted by the NPS and BLM.

Chris Armatas presented on wilderness shared stewardship during:

- The 2020 National Wilderness Workshop.
- The National Wilderness Stewardship Alliance webinar series.
- A resilience workshop hosted by the Quivira Coalition (with support from the USFS).

He presented on the social vulnerability protocol during:

- The "First Friday All Climate Change Talk" webinar hosted by the Sustainable Forest Management program in USFS Research and Development.
- The Southwest Fire Consortium Webinar Series.
- A Seminar lecture series at Monterey Bay, California State University.
- The River Management Symposium.

Further, Chris presented during a Wild and Scenic Rivers community of practice meeting (Team RAPIDS) on how social science can be integrated into river planning.

Sean Parks (1) presented on the changing prevalence of high severity fire at the American Geophysical Union (AGU) virtual conference, (2) presented on factors that may impede successful range shifts among protected areas at the National Wilderness Workshop, and (3) participated in a webinar science series organized by the Forest Service on the threats posed by climate change.

Jason Taylor presented remarks at the opening session of the (virtual) National Wilderness Workshop, Oct 2020. He also presented on the benefits of wilderness and wilderness research at a Georgian Seminar on Benefits of Wilderness Management in U.S. Protected Areas (hosted by US-DOI ITAP) and the Interagency National Wilderness Skills Institute.

Kathy Zeller presented on climate and land use change impacts on pronghorn habitat suitability and connectivity at the North American Annual Meeting of the International Association of Landscape Ecology.

Publications

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ALWRI-funded Partner Publications (where ALWRI staff are not co-authors)

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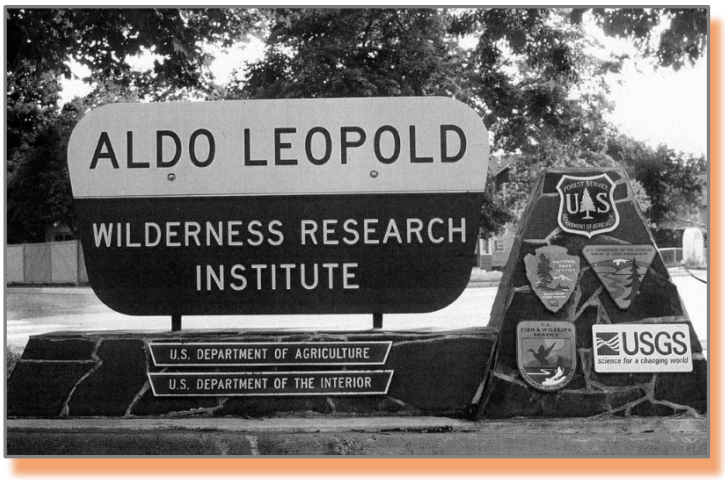
The Aldo Leopold Wilderness Research Institute, part of U.S. Forest Service Rocky Mountain Research Station, is an interagency, national research facility located on campus at the University of Montana. Our mission is "advancing wilderness stewardship through transformational science".



The Leopold Institute is the only Federal research group in the United States dedicated to development and dissemination of knowledge needed to steward the 111-million-acre National Wilderness Preservation System, all 800+ units managed by two Departments and four agencies, from Puerto Rico to Alaska. We have a long history of conducting and sharing science in support of the NWPS, as well as collaborating with management, tribal, academic, non-governmental organizations, community, and other partners within the U.S. and internationally.

The Institute's impact is national and international in scope.

In addition to being administered by the RMRS, the Leopold Institute's work is responsive to an Interagency Wilderness Policy Council and the Institute serves as a member of the Interagency Wilderness Steering Committee. These collaborations help to ensure that our work is relevant to NWPS managers.

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