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Grassland, Forest and Riparian Ecosystems on Mixed-Ownership Federal Lands Adjacent to the Crow Indian Reservation: Developing a Protective Shield for Sustainability of the Environment and Culture From the Impacts of Climate-Related Disturbance

Linda M. Stumpff; Fernando Sanchez-Trigueros; Alan E. Watson; Florence Mdodi; Aaron Teasdale



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Abstract

Between 2016 and 2018, the USDA Forest Service, Rocky Mountain Research Station's Aldo Leopold Wilderness Research Institute hosted a team of scholars to reflect on how Federal agencies can best prescribe restoration for conditions associated with climate change-induced disturbance to protect sustainability in mixed-ownership lands, with a focus on the Upper Missouri River Basin. Phase 1 of this project was a review of natural resources and current threats to these resources on mixed-ownership lands adjacent to the Crow Indian Reservation in Montana and Wyoming, USA. Phase 2 was aimed at designing and explaining a model of adaptive environmental management (the *Protective Shield Framework*), based on Indigenous principles to increase resilience, to bolster resistance to climate- and human-related disturbance on fire-adapted ecosystems, and to implement restoration from such impacts in sustainable ways. This effort included specific examples of Crow knowledge to demonstrate the shield framework for management of knowledge related to resistance and restoration. We posit that, in using Indigenous knowledge for the conservation and protection of natural resources in this region of the Upper Missouri River Basin, public land managers can more effectively build a holistic and inclusive resilience regime against the impacts of climate change.

Keywords: sustainability, Indigenous knowledge, traditional knowledge, phenological knowledge, wilderness study areas, wild horses, invasive species, Great Plains, Crow Tribe

Cover: Grasslands give way to forest and the evidence of past wildfires in the Pryor Mountains on the Crow Indian Reservation (photo: A. Teasdale).
Inset: The shield is part of warrior technology and is embedded within spiritual relationships and connections to other circular symbols like the medicine wheel (photo: White Swan (Crow, ca. 1851-1904), Pictographic War Record, 1880, paint on muslin. Snite Museum of Art, University of Notre Dame, Gift of Rev. E.W.J. Lindesmith, 1963.009.005)

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Authors

Linda Moon Stumpff is Professor Emerita at the Evergreen State College in Olympia, Washington. She established a graduate degree program in tribal governance at Evergreen and is co-director of the Native Cases research initiative, specializing in American Indian land, forest, and water issues. She completed a bachelor's degree with a double major in political science and forestry at the University of California, Berkeley. After 24 years of government service, she earned master's and doctoral degrees in regional planning and public administration, natural resource policy at the University of Southern California. She is a member of the San Carlos Apache Tribe of Arizona. Dr. Stumpff contributed the Protective Shield Framework and a synthesis of place-based knowledge shared by the Crow Tribe that can benefit sustainability practices through restoration on adjacent mixed-ownership Federal lands.

Fernando Sanchez-Trigueros is Assistant Professor of Practice in Geographic Information Systems at the University of Arizona in Tucson, Arizona and faculty affiliate in the geography department of the University of Montana, where he coordinated this project and edited this General Technical Report. A scholarly expert on data science, geography, and anthropology, he has worked through the University of Montana to contribute quantitative geographical methods for climate-change vulnerability assessment and adaptive forest management in collaborations with the Confederated Salish and Kootenai Tribes of Montana and the Spokane and Colville Confederated Tribes of Washington. Dr. Sanchez-Trigueros completed a B.A. in history, three master's degrees in human evolution, applied statistics, and geographic information systems, a graduate certificate in operations research, and a Ph.D. in Quaternary sciences.

Alan Watson is Senior Scientist at the Aldo Leopold Wilderness Research Institute, USDA Forest Service, Rocky Mountain Station, on campus at the University of Montana, in Missoula, Montana. He conducts or contributes to research to support stewardship of wilderness and wildlands across the United States and other countries. Dr. Watson has represented the United States through the U.S. State Department's Fulbright Program as a scholar and a senior environmental specialist on sustainability issues in Finland, Brazil, Russia, Taiwan, and China. Since becoming a Forest Service scientist in 1988, Dr. Watson has also provided oversight and continuity for many protected area social science studies, like the one presented here. He completed bachelor's and master's degrees and a Ph.D. in human aspects of natural resources planning and management at the Virginia Polytechnic Institute and State University.

Florence Mdodi is a program officer and social worker for the Save Education and Future Development Foundation. He works to implement social and environmental protective measures through community engagement strategies such as training workshops, seminars, and traditional dances. He was a Visiting Fellow at the Leopold Institute for 3 months in 2017, with his visit arranged by the International Research and Exchanges Board (IREX) for the U.S. Department of State, Community Solutions Program, to study influences on sustainability in the United States. For this General Technical Report, he reviewed Federal lands purposes and sustainability practices on mixed-ownership public lands in the area of Wyoming adjacent to the Crow Indian Reservation. He studied sociology and social work at Mwenge Catholic University in Kilimanjaro, Tanzania, where he obtained his bachelor's degree in 2015. He lives in Ifakara, Tanzania.

Aaron Teasdale is a freelance conservation photographer and award-winning writer based in Missoula, Montana, with notable contributions to public understanding of resource management issues through publications in the popular literature. His photography regularly appears in feature stories and on covers of publications worldwide. He produced most of the photographic content in this project in spring and fall 2017.

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We thank the Snite Museum of Art, University of Notre Dame for permitting us to use a reproduction of White Swan's Pictographic War Record (Rev. E.W.J. Lindesmith's collection, object 1963.009.005) in the cover of this report.

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Executive Summary

Between 2016 and 2018, the USDA Forest Service, Rocky Mountain Research Station's Aldo Leopold Wilderness Research Institute hosted a team of international scholars to reflect on how Federal agencies can best prescribe restoration for conditions associated with climate change-induced disturbance to protect sustainability in mixed-ownership lands, with a focus on the Upper Missouri River Basin. Throughout the world, pressures on the environment from land use, policy and social changes threaten natural resources. In response to such drastic changes, federal land managers, community representatives, scientists and academics are seeking to provide adaptive solutions for natural resource managers and the communities they serve. In rural areas of the world, subsistence-based cultures and community health outcomes are currently threatened due to a reduction of traditionally harvested flora and fauna, which are also intimately tied to the expression of culture. Community responses to drastic changes in the environment due to climate change, however, are often difficult to predict. In our attempt to determine the best way to manage land resources amidst environmental degradation, we divided this project into two separate phases to address the following questions: (1) How is sustainability defined? (2) What are the current threats to sustainability of public land resources? (3) What is the role of Indigenous knowledge (defined herein as accumulated place-based knowledge) and how can it be used in prescribing restoration practices and building resistance to future climate change-related impacts?

Phase 1 of this project was a review of natural resources and current threats to these resources on mixed-ownership lands adjacent to the Crow Indian Reservation in Montana and Wyoming, USA. Phase 1A methodology included research to obtain "foundation documents" from the U.S. government and the Crow Tribe to analyze forest and land management plans from several locations in the Northern Great Plains: Pryor Mountain Wild Horse Range; Bighorn Canyon National Recreation Area; Bighorn National Forest; Shoshone National Forest; Custer Gallatin National Forest; and the Crow Indian Reservation in Southern Montana and Northern Wyoming.

Phase 1B included conducting interviews with managers of some of the areas listed — Pryor Mountain Wild Horse Range, Bighorn Canyon National Recreation Area, and Bighorn National Forest— to identify priority threats to sustainability, public engagement practices, interactions with the Crow Tribe, and other issues that were not deeply addressed in the current "foundation documents".

Phase 2A was aimed at designing and explaining a model (*the Protective Shield Framework*) of adaptive environmental management, based on Indigenous principles of resilience, to bolster resistance to climate- and human-related disturbance on fire-adapted ecosystems, and to implement restoration from such impacts in sustainable ways. Phase 2B provided specific examples of Crow knowledge to demonstrate the *Protective Shield Framework* for management of knowledge related to resistance and restoration.

Lessons learned included how the framework developed in Phase 2A, along with the inclusion of Indigenous knowledge from the Crow Tribe in federal land management planning and practices within the Yellowstone and Bighorn basins, can allow for better-informed decisions for restoration and adaptation. We posit that, in using Indigenous knowledge for the conservation and protection of natural resources in this region of the Upper Missouri River basin, public land managers can more effectively build a holistic and inclusive resistance regime against the impacts of climate change.

Introduction

Purpose and Need

The health and cultural lifeways of rural communities (i.e., with agriculture as a major economic form and dependence on natural ecosystems) are at risk due to a warming planet. This report explores components of such risks and looks at opportunities within the Northern Great Plains. For over 150 years, the Northern Great Plains States (Montana, Wyoming, North Dakota, South Dakota, and Nebraska) have provided key resources to the United States and the rest of the world. The region's livestock and grain production have played a critical role in national food security, and its energy resources (primarily fossil fuels) contribute to national energy self-sufficiency. Tourism is also a stable source of revenue in these States, generating $17 billion in the area in 2017 (Dean Runyan Associates 2017, 2018; Government of North Dakota 2018; Government of South Dakota 2018; Grau 2018). Protection of valuable natural resources and the communities that have coevolved with them, however, has become a matter of public concern in recent decades due to extreme weather events driven by a warming climate (fig. 1). This report explores elements of these risks, but also looks at opportunities within the Northern Great Plains by providing a framework that illustrates how adaptive management that emerges from the interaction between different knowledge systems (e.g., federal law and policy, Western environmental science, and Indigenous knowledge) can make ecosystems and communities more resistant to the ill effects of climate change.

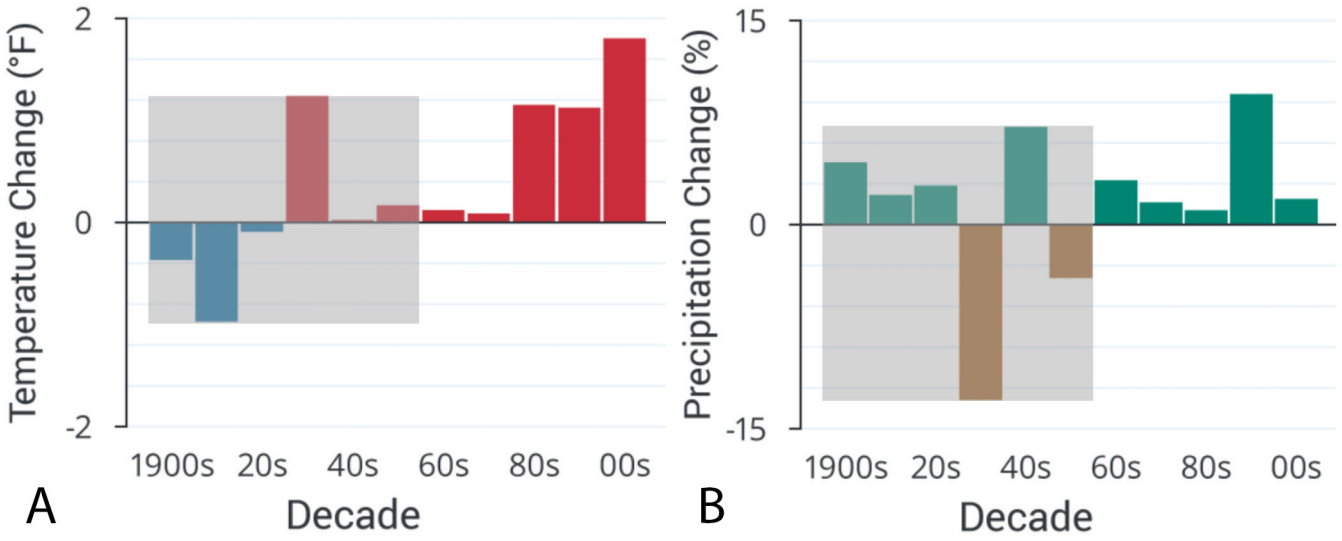


Figure 1—Temperature and precipitation changes in the Northern Great Plains since 1900. A: Temperatures changes. Bars show average temperature changes by decade for 1901–2012, relative to the 1901–1960 average (gray shade). The far-right bar (2000s decade) is for 2001 through 2012. The period from 2001 to 2012 was warmer than any previous decade in the region. B: Precipitation changes. Bars show average precipitation differences by decade for 1901–2012, relative to the 1901–1960 average (gray shade). The far-right bar is 2001 through 2012 (after Peterson et al. 2013).

Vose et al. (2018) suggest that in many locations the relationship between residents and the natural resources they depend on is going to change due to climate change, in some places very slowly and in some very rapidly (fig. 2). In the Northern Great Plains, the scientific consensus within 13 federal agencies is that a continuing trend in rising temperatures is resulting in milder winters, increasingly warmer summer temperatures, declining snowpack totals, and increased variation associated with precipitation events; changes that add to the uncertainty in the sustainability of the hydrological system and the economic structure that defines the region (Conant et al. 2018; Vose et al. 2018).

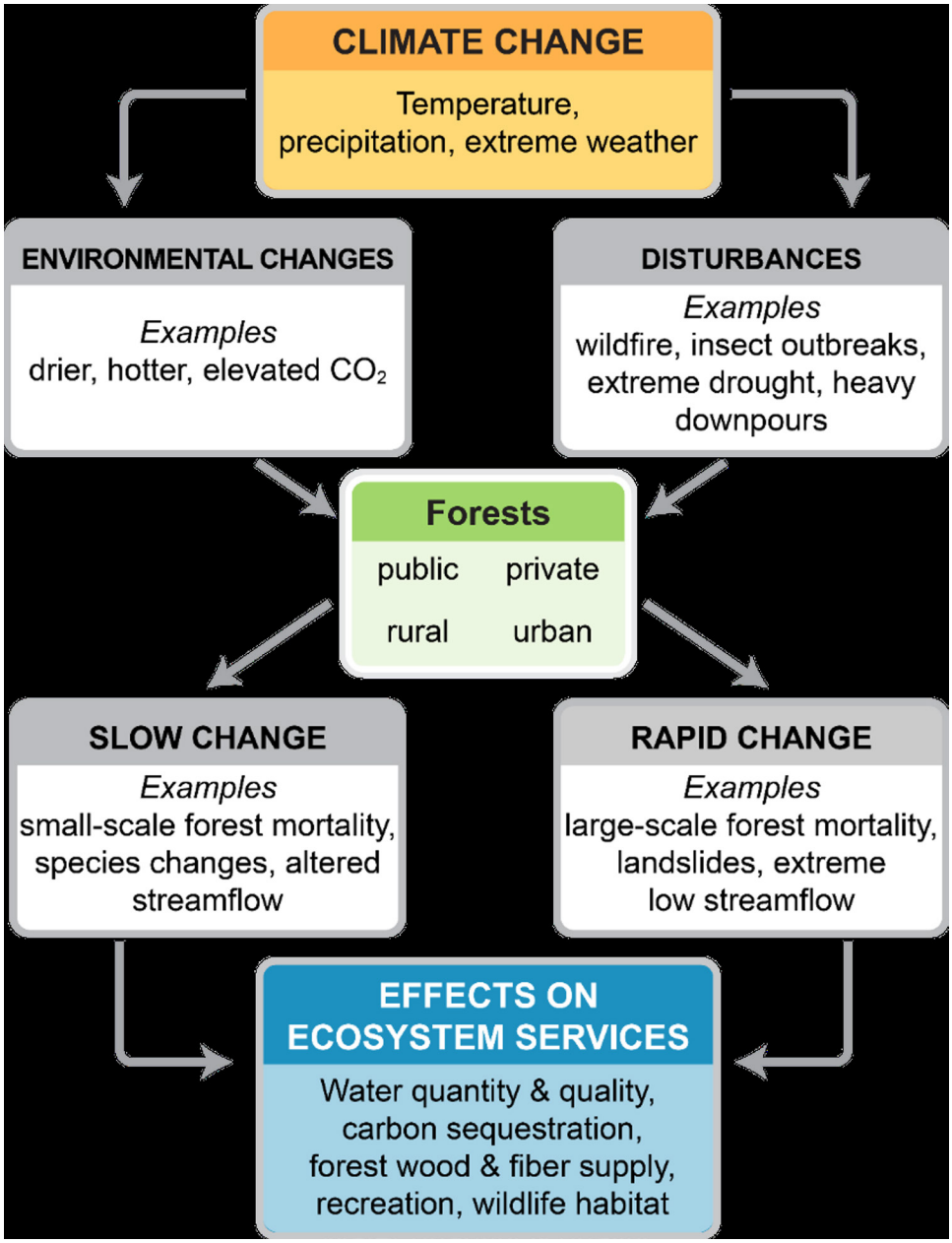


Figure 2—Climate change impacts anticipated on ecosystem services from forest lands (Vose et al. 2018).

In 2011, major flooding across the Missouri River Basin, followed by severe drought the next year, represented a degree of variability that is unprecedented in the historical record of the Upper Missouri River Basin and that is predicted to become more common as global temperatures continue to rise. Additionally, projected warmer and generally wetter conditions are expected to interact with elevated atmospheric carbon dioxide (CO_2) concentrations, increasing the length of the growing season in the Northern Great Plains. Warmer and wetter conditions are also providing a favorable environment for invasive species to proliferate, owing to a reduced period of dormancy. This jeopardizes the viability of native species and may reduce gains in livestock, crop, and forage production (Burke and Emerick 2016). Extreme temperatures and altered plant phenology may affect reproductive growth during pollination and grain maturation, and may also reduce crop production while increasing production costs of crop maintenance and insurance expenditures (Dunnell and Travers 2011; Joyce et al. 2013; Kates et al. 2012; Ko et al. 2012; Mueller et al. 2016; Reeves et al. 2014; Wienhold et al. 2017). Warmer and wetter conditions, coupled with fire suppression and seasonal drought driven by increasing evaporative demand, are already affecting the health of fire-adapted forest ecosystems and making them more susceptible to more frequent and more severe wildfires (Conant et al. 2018; CSKT 2013) (fig. 3). These factors increase forest susceptibility to more common and more destructive pest outbreaks as well (Bentz et al. 1991; Lindner and Kolström 2008; Raffa et al. 2008, 2013; Vose et al. 2018). Reduced snowpack, owing to warmer conditions and variable precipitation, is expected to increase the cost of managing water and snow-dependent ecosystems with present-day technology (Conant et al. 2018).

Extraction and distribution of energy resources is also at risk from a changing climate. Energy resources in the Northern Great Plains region include crude oil, natural gas, coal, wind, and stored water, as well as corn-based ethanol, solar energy, and uranium to a lesser extent. Risk management for the energy sector is closely associated with railroads and pipelines, which are vulnerable to damage or disruption from extreme rainfall events and associated flooding and soil erosion. Increased seasonal drought will make oil production more expensive, given its dependence on water for extractive purposes (U.S. DOE 2015). Extreme heat is also expected to increase energy demands on cooling systems, placing stress on the power grid (U.S. DOE 2015). Increased energy costs may slow energy production, but it will most likely result in those costs being passed on to consumers, particularly affecting rural communities, which may already be facing economic challenges.

The cascading effects of climate change may also impact recreational opportunities, as biophysical conditions of ecosystems could disrupt the spatial distribution of recreational opportunities (e.g., fisheries, game) and limit the seasonality of the recreation industry (e.g., shorter season for winter sports) (Hunt et al. 2016; Rashford et al. 2016; Wobus et al. 2017). Access to and availability of goods and services that support the health and cultural lifeways of local communities are at risk as well (Doyle et al. 2013; Joyce et al. 2013; Kates et al. 2012; Norton-Smith et al. 2016).

In the face of significant change, how do rural communities adapt? Adapting to a warming world, making ecosystems and communities more resistant to future disturbance associated with climate change, and finding sustainable ways to do so have become primary goals for the protection of current ecosystems and the preservation of their values for future generations. In the next sections, sustainability, adaptation, resilience, and knowledge systems are presented as primary concepts to lay the foundations of a framework for adaptive management that emerges from the interaction between different knowledge systems. Such knowledge

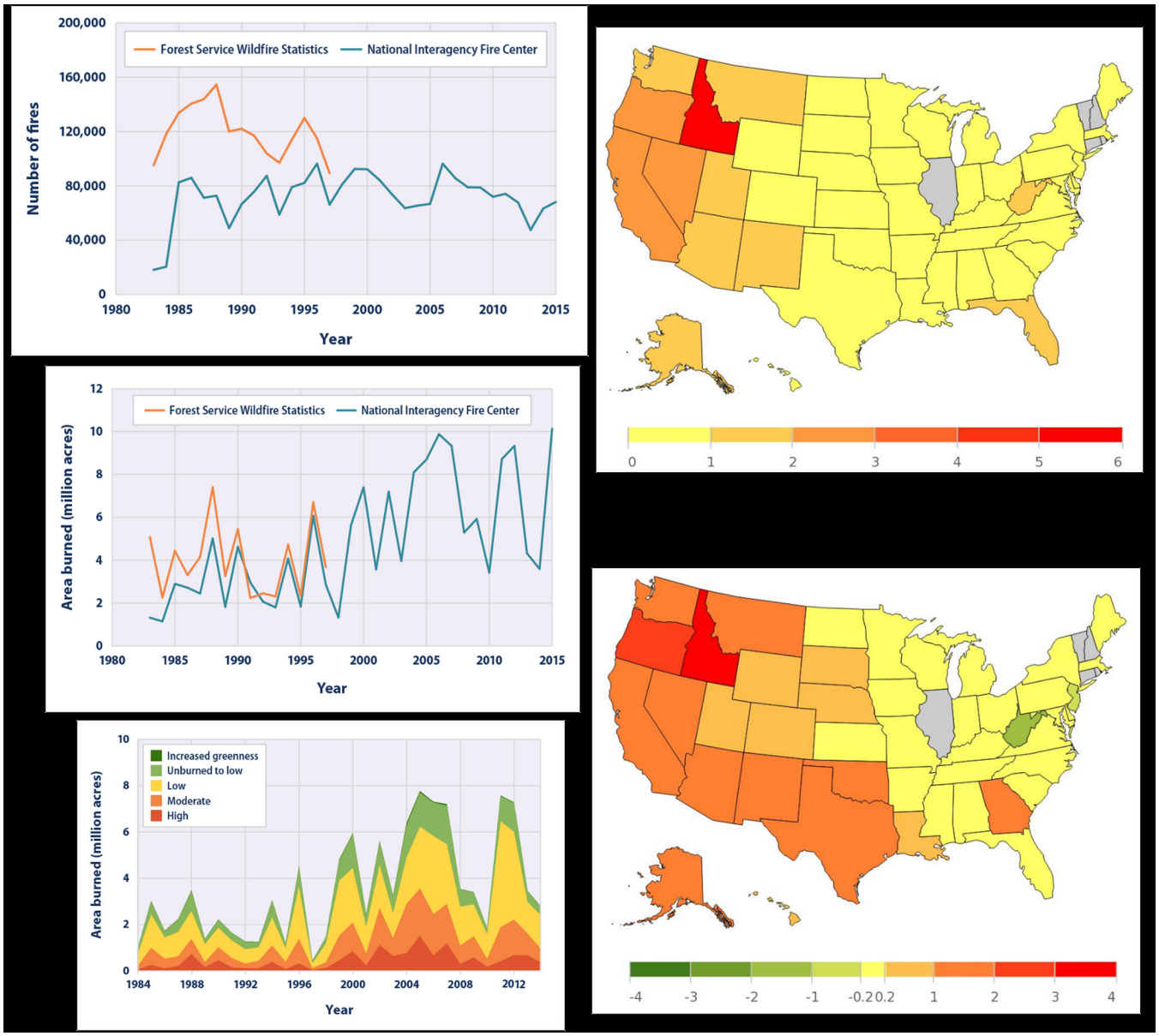


Figure 3—Wildfire in the United States, 1983–2015. A: Wildfire frequency (1983–2015). B: Wildfire extent (1983–2015). C: Wildfire severity (1984–2014). D: Average annual burned acreage (1984–2014), as a percentage of the State's total land area (States colored light gray did not have any fires that were large enough to be included in this analysis). E: Differences in annual burned acreage between 1984–1999 and 2000–2014), as a percentage of the State's total land area (States colored light gray did not have any fires that were large enough to be included in this analysis) (after Short 2015, MTBS 2016, NIFC 2016, U.S. EPA 2016).

systems are, in no order of preference, federal law and policy, Western environmental science, and Indigenous knowledge. The framework and its components will be explained and demonstrated in greater detail, with a case study that is focused on mixed-ownership federal lands of the Upper Missouri River Basin.

Understanding the Pillars of Sustainable Management

There are multiple definitions of sustainability, varying over time and across disciplines. For instance, sustainability is often a desired outcome in development. The World Commission on Environment and Development (1987, p. 41) defined sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainability can also be defined as a desired outcome in development relative to ecological resources. A greater focus on self-discipline and wise use of our natural resources, rather than solely on their potential to generate revenue, may contribute to maintaining the sustainability of ecosystems and thus improve overall well-being. The Ecologically Sustainable Development Steering Committee of Australia (1992) suggested that using, conserving, and enhancing the ecological processes on which all life depends will lead to an increase in quality of life now and secure those benefits well into the future. Decisions to meet our needs today must consider consequences for the future health of ecosystems, in order to sustain those resources for future use. Sustainability often requires transforming ways of living to ensure natural, socioeconomic, and built systems will continue supporting human health, well-being, and security (McMichael et al. 2003). But current human-induced, climate-related disturbances threaten the historical patterns of ecosystem conditions and processes.

Kibert (2016) suggested that sustainability objectives can also be based on moral values and goals, not merely on benefits and effects of economic, social, technological, or environmental nature. Ethical decisionmaking about sustainability identifies values we hold about our ecosystems that can vary owing to culture, individual and community experiences, economic capacity, and social status. Ethical sustainability can guide our decisions towards solving Earth's problems and strengthen our social and economic institutions, practices, and society as a whole. Out of concern for the dangerously high rate of natural resource destruction by global production and consumption patterns, the IUCN (1991) defined sustainability as the capacity to improve the quality of human life while living within the carrying capacity of the Earth's supporting ecosystems. As populations have increased rapidly since the beginning of the industrial era, threats to the sustainability of Earth's natural ecosystems and biodiversity have increased.

Research on sustainable development decision making suggests several "pillars" that guide data collection and model building for sound planning, management, and policymaking. Aylward et al. (1996) and Watson et al. (2009b) focused analysis of sustainable ecotourism development on visitation, financial, ecological, and economic indicators. The study of visitation entailed understanding law and policy related to visitor uses and offsite benefits, as well as motivations for people to visit ecologically and culturally attractive locations. In this approach, financial contributions of expenditures, for both development and delivery of services, are an important element of sustainability planning, as are the economic trends and character of economic sectors in the area of interest. For such operations to be sustainable, however, neither the ecology of the area—in terms of absolute composition, structure, and

function of the ecosystems therein—nor the symbiosis between local communities and that environment should be sacrificed. Research by Nikolaeva et al. (2015) in the Russian Far East expanded this concept of "pillars" to include local communities and their welfare. Similarly, the World Bank suggests three pillars in sustainable development: (1) economic growth, (2) environmental stewardship, and (3) social inclusion. These pillars apply to all sectors of development, from cities to agriculture, and across infrastructure, energy development and use, water, and transportation (World Bank 2012). The question facing public land managers, as well as countries, cities, corporations, and development organizations today is no longer whether to embrace sustainable development, but rather how to establish guidelines that are based on in-depth understanding of the effects of various strategies on sustainability.

The scope of the project presented here is public land management, not development itself, but it follows the assumption that decisions have already been made as to whether to develop, and for what purpose. Building on this assumption, we focus on the sustainability of the resource and pose the following questions:

(1) What are we protecting? (uses, attributes, and values);
(2) What are we protecting it from? (threats);
(3) In serving the public and protecting public lands, how do we obtain commitment of the public for those protection objectives? (engagement); and
(4) How do we evaluate restoration, adaptation, and mitigation actions associated with extreme weather; previous human impacts on sustainability; or pursuit of conflicting goals? (monitoring).

In conclusion, sustainability does not (and perhaps should not) have a rigid definition. Sustainability, for the purposes of this report, emphasizes the importance of identifying behaviors that will allow current societal needs to be met without compromising the ability to fulfill the needs of future generations. In this sense, sustainability is also to be defined in terms of the delicate balance between social equality, cultural conservation, and the benefits and impacts of economic development. Sustainability goes beyond environmentalism.

Relationships Between Perceptions of Climate Change and Adaptation

The reality and severity of climate change, and how it impacts sustainability, have become a matter of controversy among the public, industry, and the political sphere (Chryst et al. 2018; Leiserowitz et al. 2009, 2015; Roser-Renouf et al. 2016). To inform that conversation, the authors of this report emphasize the necessity of establishing long-term, far-reaching mechanisms to let science, environmental education, and community engagement work in synergy for knowledge exchange. A society that understands the close ties between human health and Earth systems is essential to build community consensus for successful adaptation (Bennett 2016).

The study of human perception, whether from qualitative or quantitative approaches, has also become an important paradigm to understand individuals' interpretations of climate change. Such understanding can inform development of policies and adaptation actions as well as improve the effectiveness of interventions. Moser and Ekstrom (2010) and André and Jonsson (2015) have contributed to a growing body of research examining ways to translate high adaptive capacity of cultures into action, recognizing the complexity of decisionmaking

processes and the multiple factors that may hinder or enable adaptation. Adaptation requires some agreement on what ecologically responsible behavior is and engagement from all members of society, rather than a focus solely on economics or personal efficiency. Survival has been a key objective of adaptation over the course of human evolution. Panno et al. (2015) discovered that accurate perceptions of climate change tend to improve ecologically responsible behavior, although there is little information in the literature as to the relationship between climate change perception and responsible behavior. Some evidence does suggest, however, that risk-taking is more common with more accurate perceptions of urgency related to the impacts of climate change (Leiserowitz 2005; Patt and Weber 2014; Zaval et al. 2014). Research on limits to adaptation also highlights the importance of social and cognitive factors in shaping stakeholders' perceptions of climate risks and attitudes toward adaptation measures (Adger et al. 2009; Dow et al. 2013; Grothmann and Patt 2005; Vulturius and Gerger Swarling 2015). Generally, concern for environmental sustainability, along with interest in climate change impacts and hope in the benefits of behavioral adaptations to increase climate change resilience, are typical emotions in people with a tendency to support climate change policy actions, even if such actions involve some risk (e.g., short-term mitigation costs) and lack immediate feedback (Smith and Leiserowitz 2014).

Spence et al. (2012) suggest that strongly held perceptions of climate change are affected by awareness, belief in human causes, feelings of worry, and self-efficiency, and has highlighted the utility of risk communication to reduce the psychological distance of climate change. Results from a study in the United Kingdom indicated that climate change can be both psychologically distant and proximal with regard to four dimensions —temporal, social, geographical, uncertainty. In any case, shorter psychological distance tended to be associated with higher levels of concern.

Beyond Spence et al.'s four dimensions, effects of the cultural dimension on perceptions of climate change should be recognized as well, particularly, those originated from knowledge of the environment but maybe more importantly, from the views that individuals, communities, and peoples have of themselves regarding their position and role in the wider world. Lorenzone et al. (2007, p. 466) concluded that "it is not enough for people to know about climate change in order to be engaged; they also need to care about it, be motivated and able to take action." Grothmann and Patt (2005) emphasized the importance of both risk perception and perceived adaptive capacity as key drivers of adaptation. Risk perception is conceptualized as understanding of the probability of harm and appraisal of its severity in relation to other life problems and challenges. The gradual and long-term nature of climate change can make it difficult to detect signals of climate risk, however (Naustdalslid 2011; Whitmarsh 2008). For instance, Whitmarsh (2008) found that previous flood victims are more concerned about climate change than those who have been unaffected by extreme weather events. The role of direct experience (close psychological distance) therefore plays a crucial role in risk perception and behavioral response based on those experiences. Local risks (closer psychological distance) are also likely to seem more important than global risks in determining the probability of engaging communities in environmentally responsive behaviors (Hinchliffe 1996).

According to Anse et al. (2013), concern about climate change impacts and support for adaptation may be uncorrelated. Rather, adaptation to climate change could largely be conditioned by innovative capacity. In other words, innovativeness could be the quality that favors successful adaptation to climate change. The relationship between perceptions of climate change, risk taking, innovativeness, and Indigenous knowledge is becoming a

well-discussed topic (Nabhan and Martinez 2012; Boelens, Chiba and Nakashima 2006; Baptiste et al. 2017; Karki et al. 2017; Lyver at al. 2015; Nakashima et al. 2012; Roué et al. 2017; Roué and Molnár 2017). Theoretically, accumulated place-based knowledge could increase psychological and social proximity to past environmental changes and phenological events, introducing worry, innovativeness, and risky behavior in efforts to adapt to change. This report takes into account such relationships between types of perception of climate change and the adoption of adaptive and mitigating responses. To this purpose, we next examine Indigenous Peoples' adaptive responses to environmental changes and focus on a case study conducted on the Crow (Apsáalooke) Indian Reservation in south-central Montana.

Embracing Indigenous Knowledge About Climate Change Impacts

Owing to the broad diversity of Indigenous Peoples on Earth, a standard definition of indigeneity has not yet been adopted by the international community. The United Nations recommends a multifaceted understanding of this concept which pivots on

(1) self-identification as indigenous peoples,
(2) historical continuity with pre-colonial regions and societies,
(3) strong link to territories and natural resources,
(4) distinct social, economic or political systems,
(5) distinct language, culture and beliefs,
(6) willingness to perpetuate ancestral environments and systems as distinctive peoples and communities, and
(7) non-dominant presence of these communities in modern societies (UN DESA 2008).

While Indigenous Peoples do not claim to have complete knowledge about how to adapt to climate change (Watson et al. 2012), Indigenous knowledge has been shaped from the systematic observation of phenological cycles across generations and the historical implementation of innovative solutions. In other words, such solutions have not always been infallible under processes of adaptation to change, but they reflect a deep understanding of how ecosystems respond to change, either natural or human-caused. Native American peoples have moved villages, substituted materials (for consumption or ceremonies), traded with others, or reduced dependence on items in short supply due to changes in the environment, (Jantarasami et al. 2018), demonstrating close ("kincentric") sociological distances between each other (Salmon 2000) as well as less psychological distance from the environment, in Spence and others' terms (Spence et al. 2012).

The goal of Indigenous resilience is faced with new challenges today. Native American peoples are among those with the highest rates of poverty and unemployment in the United States and heavily rely on access to ecosystem resources. As a result, Indigenous communities are especially vulnerable to the impacts of climate change. In particular, Indigenous health places Tribes at increased risk of incurring the economic and cultural costs of adapting to a warming world. The negative impacts of climate change on tribal peoples are predicted to disrupt the access to and availability of traditionally harvested flora and fauna that are intimately tied to their expression of cultural identity, threatening places (including sacred sites), customs, and relationships that are central to their lifeways (Jantarasami et al. 2018). In anticipation of such threats, Tribes in the U.S. have been proactively identifying and addressing climate impacts, by initiating planning that aims to protect value-based species within ecosystems and sacred landscapes and waters that are at risk. Solutions include

restoration of fire-adapted ecosystems by replicating natural vegetation density with fuels reduction treatments that are based on prescribed burning, and mitigating climate change impacts through renewable energy programs on tribal lands (Black et al. 2015; Confederated CSKT 2013; McNeeley 2017; Oglala Lakota Nation 2012). Countering the economic and social costs of climate change, Indigenous histories and experience provide important knowledge systems in advancing the understanding of the impacts of climate change in coupled human and natural systems.

Indigenous worldviews on the relatedness and respect for land and water are often reflected in their origin stories, as well as traditional ceremonies, views that contrast starkly with the dominant monetary value systems of non-Indigenous communities. Indigenous viewpoints are unique in their beliefs in the sacredness and living nature of water, rocks, soil, air, celestial bodies, plants, and animals —all of which contain a spirit (Cajete 2000). Sometimes described as a "kincentric" worldview (Salmon 2000), this frequent Indigenous perspective describes human and nonhuman forms as relatives; all are interconnected in their worldview and considered a part of one's community. In similarity with the behavior of feedback loops and flow problems in systems research (Drinkwater et al. 2016) (as opposed to component research), destruction of any one of these forms, within a living and nonliving web, impacts all others (Turner and Clifton 2009). Culturally defined value systems of Native Americans, however, are often misunderstood by non-Indigenous people, and thus require a specific methodology for study. Also needed is illustration of how to include the Indigenous voice and worldviews in management of public lands adjacent to American Indian reservations, following practices that respect and protect this knowledge as Indigenous intellectual property. Although public land management agencies have acknowledged the challenges associated with a general one-size-fits-all approach to public land stewardship, there has been insufficient progress toward collaboratively developing creative stewardship approaches that address the tradeoffs inherent in managing a landscape occupied by people with culturally, politically, and environmentally disparate worldviews.

Recent scientific studies by some members of this combined federal, academic, and tribal research team underscored the importance and relevance of incorporating Indigenous knowledge in a respectful and sensitive manner into vulnerability assessments and adaptive management approaches for forest and fire management planning, including postfire restoration (McBride et al. 2017; Sanchez-Trigueros et al. 2016; Stumpff 2015; Wynecoop et al. 2019). In working with the Santa Clara Pueblo in New Mexico during postfire riparian restoration from recent large-scale fires, several principles were developed from place-based knowledge and prescribed for more successful (as evaluated by a more holistic set of criteria) postfire restoration and increased resistance to future impacts, using both biophysical and cultural perspectives. For instance, using autochthonous (native) materials for reseeding and stabilization of structures, versus nonnative farm straw and cement, and following local prescriptions for placement and design of such structures accomplish restoration purposes but with attention to place-based knowledge and local cultural protocol (Stumpff 2015).

Similarly, collaborative efforts with the Confederated Salish and Kootenai Tribes, Montana discovered different perceptions between tribal resource specialists and tribal residents regarding the need and purpose of restoration, as well as the desired resistance outcomes (McBride et al. 2017). Recent efforts to support the Forest Vision 2020 Collaborative Forest Landscape Restoration Project, engaging the Confederated Colville Tribes, the Spokane Tribe, and the Colville National Forest in Washington, have been aimed at establishing

"communication channels" between Western science and Indigenous knowledge sources for the generation of emergent knowledge in sustainable fuels and fire management. The effects of understory thinning, management-ignited fire, and management of low-intensity natural fires on traditional uses and meanings have provided a baseline for collaborative goal definition in the application of fuels reduction treatments, supporting treatments that are environmentally sustainable and protective of the tangible and intangible meanings that sit on public lands (Sanchez-Trigueros et al. 2016; Wynecoop et al. 2019).

Because Indigenous knowledge is place- and culture-dependent, previous cooperative work with tribal communities in New Mexico, Montana, and Washington should be replicated with other tribal groups to provide a synthesis of knowledge to guide the decisionmaking process in land and resource management. This project could have occurred across a larger geographical area, but to fully demonstrate and document the benefits of the tools employed, focusing on a specific tribal group, the Crow People, and a place, the Upper Missouri River Basin, is highly beneficial to establish important frameworks for future climate change adaptation planning.

Climate Change Vulnerability in the Upper Missouri Basin and the Crow People

As stated in the prior section, comprehensive climate adaptation strategies can be strengthened by informing research and management planning with knowledge systems, such as Indigenous knowledge, that are place-based, holistic, and cognizant of local historical dynamics. Therefore, incorporating place-based Indigenous knowledge into public land management planning and mitigation efforts can become a critical step in understanding community resilience, allowing for local collaborative processes in restoration efforts for resistance to future climate change impacts. Federal land managers in the Northern Great Plains currently lack the ability to implement a formal process and guidance for incorporating Indigenous knowledge into climate-related disturbance adaptive planning, particularly relating to extreme disturbance events such as wildfires (which change carbon sinks to carbon sources), drought (which interrupts water-dependent growth cycles), and flooding (which disrupts land use) (Jay et al. 2018). On the other hand, tribal communities living near public lands in Montana and Wyoming depend on neighboring public lands to access flora and fauna for traditional uses for ceremonial, food source, and medicinal purposes. These Tribes have historical experience in surviving extreme weather and the effects of natural disturbance, such as wildfires, droughts, and floods. They have a unique understanding of climate-related impacts in the region, having overcome disturbance in the past with place-based knowledge. Accumulated experiences of adaptation and resilience to drastic natural and human-caused disturbance can inform current restoration and adaptation planning processes.

The Crow Indian Reservation, at the center-west of the Upper Missouri River Basin, is immediately adjacent to the Bighorn and Custer National Forests (fig. 4). These forest systems are interdependent with the Shoshone National Forest and include the headwaters of the Bighorn River, flowing north from the Montana-Wyoming state line to the Little Bighorn River just outside Hardin, Montana. The reservation is also next to non-Forest Service land management units such as the Bighorn Canyon National Recreation Area, the Pryor Mountain Wild Horse Range, and other U.S. Department of the Interior (DOI), Bureau of Land Management (BLM) lands. These public lands contain a rich history of Native American culturally identified landscapes such as burial grounds, spiritual sites, pictographs, and petroglyphs—a direct reflection of Native Americans' historical association with these lands.

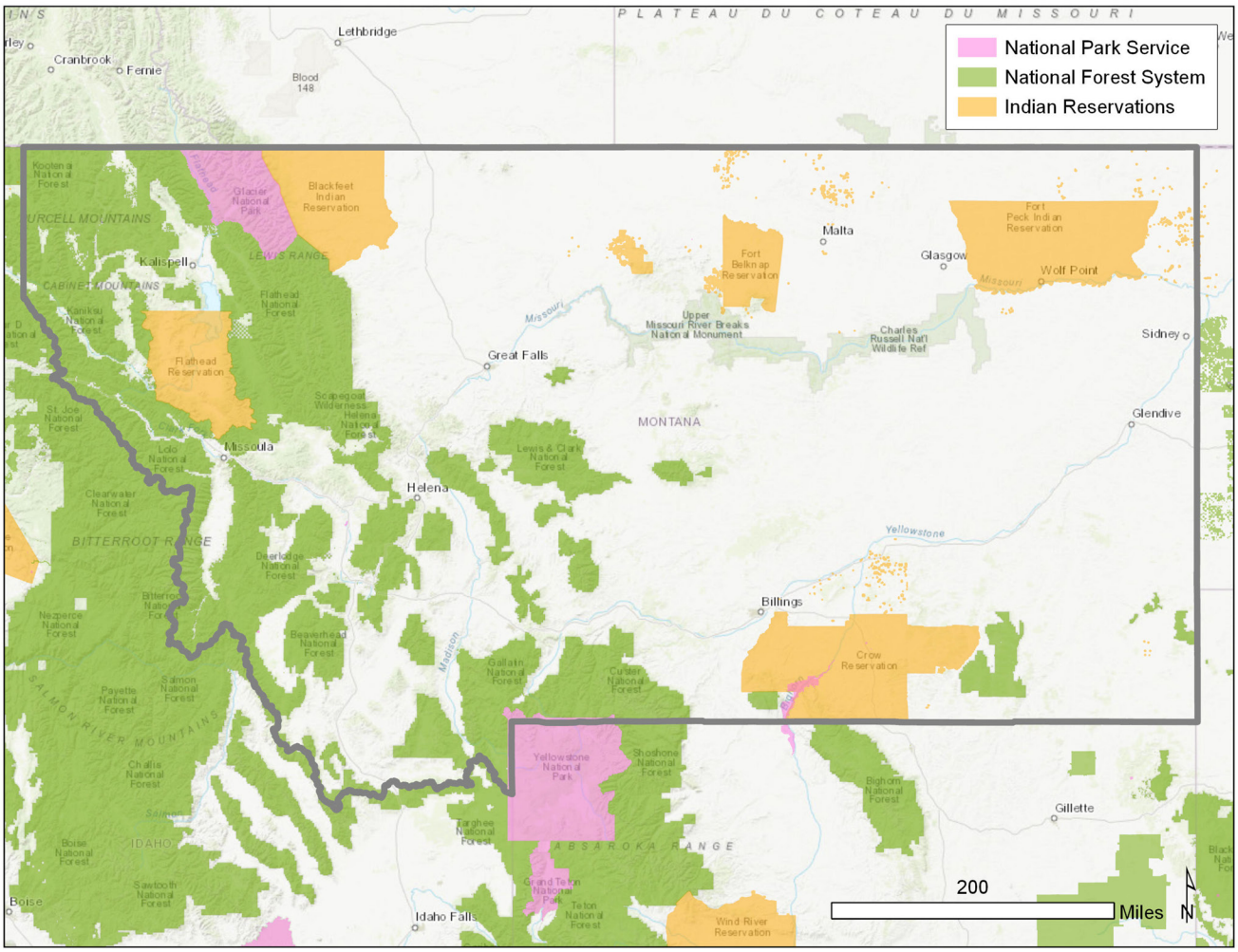


Figure 4—The Crow Reservation, largest of the seven Indian reservations in Montana, is located in south-central Montana, bordered by Wyoming to the south and the Northern Cheyenne Indian Reservation to the east. Sources used are listed in table 1.

The climate on the Crow Indian Reservation varies from humid above 7,000 feet (2,100 m) in the Bighorn Mountains, with 24 inches (610 mm) of annual precipitation, to semiarid around 2,900 feet (900 m) in Crow Agency (the administrative capital of the Crow Indian Reservation), just south of Hardin, with 12 inches (305 mm) of annual precipitation (NOAA 2018). Nestled within the Yellowstone, Bighorn, and Little Bighorn basins, the reservation contains 2,307,506 acres (9,338 km^2). Approximately 10,000 enrolled tribal members reside in the vicinity of Crow Agency and in the communities of Garryowen, Saint Xavier, Lodge Grass, Wyola, and Pryor along the Bighorn and Little Bighorn River valleys, which are located within the exterior boundary of the reservation (Doyle et al. 2013; Montana Governor's Office of Indian Affairs, n.d.). Major highway access is by U.S. Interstate 90 (north/south) and U.S. Highway 212 (east/west).

The current Crow Indian Reservation was established by the Treaty of Fort Laramie (1868) and is only a small part of the ancestral homelands of the Crow people, although knowledge and the use of culturally significant flora and fauna, and knowledge of the importance of water resources, date back centuries, as reflected in their creation stories (Medicine Crow 1992). The

Crow people have lived in the Yellowstone River valley since the late 17th century, following a migration pattern beginning in the mid-1500s, when they split from the Mandan/Hidatsa Tribes (currently located in North Dakota) and eventually settled in the Powder River Basin, located in the current area of Montana and Wyoming (Medicine Crow 1979). In the pretreaty days, the Crow Tribe influence extended over 50 million acres (about 202,000 km²) in the Upper Missouri River Basin from Yellowstone Lake (southwest of the current reservation borders) across the Wind River basin and the grasslands east of the Black Hills, in Wyoming, and across the Bighorn River, the Yellowstone River, and the Musselshell River basins, in northern Wyoming and central Montana (fig. 5). These corners mark the historical boundaries of the Crow Tribe "like four tipi poles" as described by Sits in the Middle of the Land at the Fort Laramie Treaty negotiations (Yarlott n.d.).

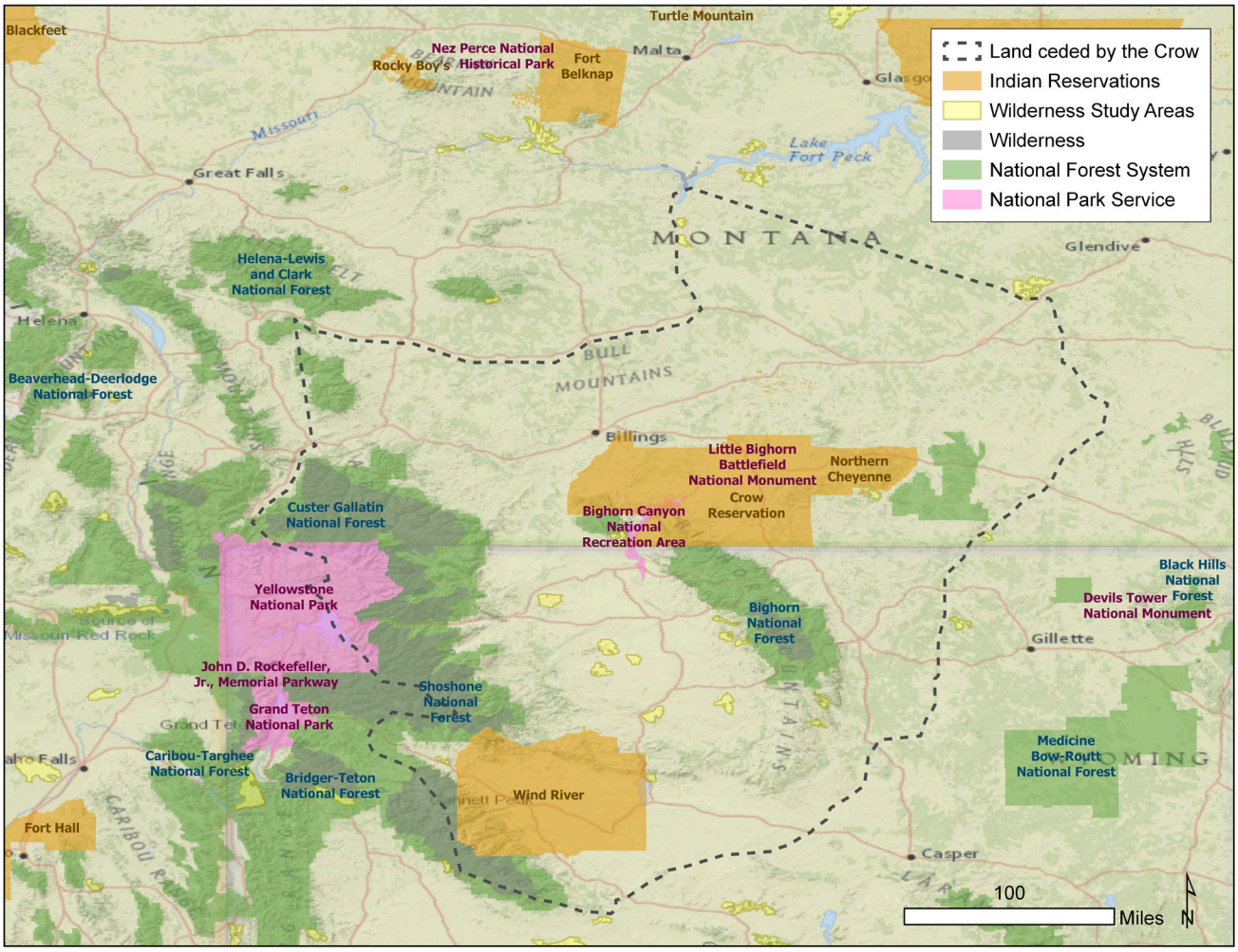


Figure 5—Land cessions affected the Crow Tribe. Source: USDA FS (2018). The extent of lands ceded is based on the catalog "Indian Land Cessions in the United States," compiled by Charles C. Royce and published in the Eighteenth Annual Report of the Bureau of American Ethnology to the Secretary of the Smithsonian Institution, 1896–1897. The catalog has been digitized by the USDA Forest Service and published as "Tribal land cessions in the United States."

The traditional language of the Crow descends from the Siouan language family, and is currently spoken by about 85 percent of the Crow as their first language. The Crow as a synonym for Apsáalooke is actually a mistranslation from French fur traders of the compound word "children of the large-beaked bird," one of several names used by the Apsáalooke to refer to themselves (DeMallie and Sturtevant 2001). There have been multiple spellings of the Apsáalooke, such as the Absaroka, Apsalooke, Apsaroke, and Absarokee. In this report, Apsáalooke and Crow are used interchangeably.

Most of the Crow traditional ceremonies and livelihoods are centered upon the sacredness of water (Lowie 1922, 1970). The DOI, Bureau of Indian Affairs (BIA) began installing floodplain irrigation canals and divergent dams along the Little Bighorn and Bighorn Rivers within the Crow Indian Reservation in 1885. Over time, diversion dams, canals, and floodplain ditches were constructed and the Willow Creek Reservoir was developed to serve 53,000 acres (214 km^2) of farmland. In 1944, construction of a major dam within the Crow Indian Reservation was authorized by the Flood Control Act to potentially serve another 42,600 acres (USDOI NPS 2019). Completed in 1966, the dam was named after Robert Yellowtail, who was chairman of the Crow Tribe from 1934 to 1945. Yellowtail was firmly against the damming of the Bighorn River, and protested and sued in court when the Tribe was forced to sell the dam site to the federal government.

Irrigation within the reservation currently covers only 63,365 acres (256 km^2) in 11 irrigation units along the Bighorn and Little Bighorn Rivers, Pryor Creek, and Lodge Grass Creek. Two of the irrigation units are privately owned and operated, while the remaining nine units are operated and maintained by BIA. The primary irrigated crops are hay and alfalfa, irrigated pasture, sugar beets (fig. 6), and grains. Enabled by the General Allotment Act, or



Figure 6—Sugar beets, an important cash crop in and near the Crow Indian Reservation, are highly dependent on irrigation practices (photo: A. Teasdale).

Dawes Act, of 1887 (with partial title An Act to provide for the allotment of lands in severalty to Indians on the various reservations) and resulting from trade operations that followed—which removed much of the agricultural land on the reservation from tribal ownership (Runyan, 1940)—benefits from these irrigation projects are currently shared by tribal members and other landowners.

Since the end of the 19th century, increased water demands for agricultural purposes have resulted in diversion dams for use in floodplain irrigation. After the Dust Bowl era of the 1930s, increasing need for water from the Bighorn River resulted in significant decreases in water flow. But construction of the Yellowtail Dam in the 1960s was the main factor in removing the natural flood pulse of the river. Additional impacts have also been affecting land and water resources on the reservation more recently. Although Crow Agency has experienced severe flood events approximately every 40 to 50 years since establishment of the reservation, unusual early-season flooding in May 2007 and a severe flood event in spring 2011 have raised community concerns about the increase in frequency and severity of flooding along the Little Bighorn River. Precipitation shifts from winter months to the spring over the last 10 years may be contributing to this higher frequency of spring floods (Doyle et al. 2013). Recently, wildfires have become more frequent and burn hotter as well (fig. 7), resulting in the reduction of populations of deer and elk, which tribal members have traditionally hunted for subsistence purposes.



Figure 7—More frequent and more destructive wildfires are an increasing concern on Crow Tribe lands (photo: A. Teasdale).

A recent climate change vulnerability survey in the Bighorn River basin has found that Native American residents have unique needs and preferences related to management of the regional water resources. Respondents felt the most important water-based values to protect in public lands were water quality and Native American cultural and spiritual values (Armatas et al. 2014). These were followed closely by household and municipal water, instream flow, and non-Native American cultural and spiritual values. Least important were recreational uses, such as nonmotorized and motorized ice recreation and snow-based, commercial land-based, river-based, and commercial water-based activities. As with other residents of the Bighorn River basin, Native Americans expressed concern about future threats to sustainability of their water supply. Many of these concerns were related to environmental impacts of pollution on water resources. Concerns about environmental degradation of water quality and quantity included impacts to drinking water, cloud-seeding impacts on plankton and fish, erosion and flooding, and reduction of mountain snowpack (fig. 8). Survey respondents also indicated concerns about water availability from overcommitment of water allocation for businesses (Armatas et al. 2014).



Figure 8—Snowmelt from the neighboring Beartooth Mountains provides water to lower-elevation lands throughout the summer. Reduction of snowpack is a concern to Crow people (photo: A. Teasdale).

In sum, the perspective of surveyed Crow toward water on public lands can be differentiated from the perspectives of environmentalists, recreationists, and agriculturalists. All of these aforementioned parties depend on the quality and quantity of ecological flow from the national forests of the region (Armatas et al. 2014). The Crow also have unique preferences for management of other resources, including those affected by wildfire, flooding, and drought, or, more generally, disturbance generated by decreasing winter snowfall and warming temperatures over the last two decades. Coupled with increased flood frequency and fire severity, the Crow people have recognized the need for additional research to plan for mitigation of climate change impacts on water quality and quantity. Continued reduced availability of flora and fauna due to an ecologically threatened forest likewise affects the health of the communities within the reservation. Environmental degradation from severe weather events and a continued warming trend reducing streamflows pose a significant economic threat to tribal members engaged in farming and ranching (Gowda et al. 2018; Jantarasami et al. 2018).

Lessons Learned From the Introduction

If our goal is a more holistic approach to the management of national resources in the United States, a full understanding of the benefits flowing from land and water protection, as well as threats to the continuation of these benefits, needs to incorporate Indigenous worldviews for both pragmatic and ethical reasons. On a pragmatic basis, incorporating Indigenous knowledge systems into federal decisionmaking, if such knowledge is freely given and duly protected, will facilitate the production of emergent knowledge through collaborative processes. On ethical grounds, Native American ties with their historical homelands have the right to be honored in federal policymaking and implementation on lands that are often in public holdings (Watson et al. 2012). The federal Indian trust responsibility is a legal mandate under which the federal government "has charged itself with moral obligations of the highest responsibility and trust" toward Tribes (*Seminole Nation v. United States*, 316 U.S. 286, 296-97, 1942). Since 1831, the United States formally recognizes the existence of the federal trust relationship toward Tribes, as firstly discussed by Chief Justice John Marshall (*Cherokee Nation v. Georgia*, 30 U.S. 1, 16, 1831). As a consequence, the federal Indian trust responsibility is a legally enforceable fiduciary obligation on the part of the federal government to protect tribal treaty rights, lands, assets, and resources, and a duty to carry out the mandates of federal law with respect to American Indian and Alaska Native Tribes.

Indigenous worldviews on system restoration after disturbance require attention to the cultural as well as the biophysical elements. Coupled human and natural systems, being understood as a meta-discipline of socioeconomic and Earth systems, also takes a holistic approach to systems vulnerability and restoration (Liu et al. 2007; Turner et al. 2003), so there is potential for developing points of synergy and knowledge exchange with overlapping Indigenous knowledge. The primary purpose of this report is to present a specific Indigenous worldview from the Crow people relative to their perceptions and attitudes toward impacts from climate change. This report includes a review of historical adaptation successes, and prescribes principles to apply Indigenous knowledge (defined herein as an accumulation of place-based knowledge) to postdisturbance restoration planning as a management strategy to increase the resilience of coupled human and natural systems, improve their resistance to climate change impacts, and build sustainable public land practices. More specifically,

incorporation of Indigenous knowledge into postdisturbance stream, soil, and vegetation restoration will help increase the sustainability of these values, and their resistance to disturbance events stemming from the effects of climate change. In presenting Crow perceptions of climate-related change, this report also provides a corpus of traditional meanings attached to federal lands of the Upper Missouri River Basin.

Native American and tribal values, under the provisions of the National Forest System Land Management Planning rule (USDA FS 2012), are a subject for federal protection. However, institutional barriers to land ownership and management capabilities significantly limit the adaptive capacity of Treaty Tribes to take effective action on self-prescribed measures. Barriers to planning and management include limited access to traditional territory and resources, and insufficient capacity of existing laws, programs, and funding within the United States to protect lands and traditional resources of American Indian and Alaska Native Tribes (Black et al. 2015; CSKT 2013; McNeeley 2017; Norton-Smith et al. 2016; Oglala Lakota Nation 2012).

Tsosie (2007, 2009) describes two categories of Indigenous claims for environmental justice that are associated with adaptation to climate change: 1) Native claims for regulating control over reservation lands (sovereignty claims) and 2) claims by Indigenous Peoples that they have unique interests and therefore ought to be represented as "rights holders" in decision making (whether national or international) that impacts their communities, often guaranteed through treaty rights. A lesson from the first category of claims is that, for Indigenous Peoples, equality of status as governments —that is, sovereignty instead of a focus on minority rights— was the key to environmental justice. Claims in the second category relate to multi-stakeholder collaboration and serve as facilitators of knowledge exchange, so they become relevant for comprehensive adaptation planning in questions with multiple perspectives. Because many of the impacts of climate change will fall disproportionately on minority and low-income communities, particularly affecting Indigenous communities (Jantarasami et al. 2018), Native American peoples have the right to be included in environmentally responsible policymaking that counters those impacts, not just by virtue of their rights as a minority population but also because they are key rights holders in outcomes. Tribal sovereignty and the trust responsibility may not always protect American Indian Tribes from external threats, but these legal principles have enabled protective case law (e.g., Womble et al. 2018) and control of policymaking that would otherwise contradict their unalienable and inherent rights (Saavedra Buckley 2019). Building resilience within Indigenous communities, in sum, rests on the proactive efforts of federal, state, and local governments to lift institutional barriers that prevent Tribes from adequately protecting their culturally important relationships with natural resources.

Phase 1A: Protected Resources and Threats to Sustainability on Mixed-Ownership Federal Lands Adjacent to the Crow Indian Reservation

This section examines legislative land designations, forest management planning, comprehensive management plans, and other land planning documents to identify resources, uses, and threats to sustainability for six areas of mixed-land ownership with multiple shared boundaries (tables 1 and 2). We focus on federal lands surrounding the Crow Indian Reservation, and the array of legislatively designated uses across stewardship agencies (fig. 9). These lands were part of the traditional Crow territory prior to forced settlement on the Crow Indian Reservation, as delimited in 1868. The Bighorn Canyon National Recreation Area is managed by NPS and intrudes into the Crow Indian Reservation along its southern boundary (fig. 10). The Custer Gallatin and Bighorn National Forests currently share northern boundaries with the Crow Tribe. The Pryor Mountain Wild Horse Range, managed by BLM (including some NPS and Forest Service lands) likewise share boundaries with the Custer Gallatin National Forest, the Bighorn Canyon National Recreation Area, and the Crow Tribe. The Shoshone National Forest does not share a boundary with the Crow Indian Reservation but does give rise to the Shoshone and Bighorn Rivers, each serving as important water resources to Crow tribally owned lands.

Table 1—Sources for data used to construct figure 4 and other map figures.

Dataset	Curator	Last update	Website
Administrative boundaries of National Park System units	National Park Service	2018	https://irma.nps.gov/Portal/
National Forest System land units	USDA Forest Service	2018	https://data.fs.usda.gov/geodata/edw/datasets.php
National wilderness areas	USDA Forest Service	2018	https://data.fs.usda.gov/geodata/edw/datasets.php
Wilderness study areas	Bureau of Land Management	2011	https://wfdss.usgs.gov/wfdss/WFDSS_Data_Downloads.shtml
BLM wild horse and burro herd area and herd management area	Bureau of Land Management	2018	https://catalog.data.gov/dataset/blm-national-wild-horse-and-burro-herd-area-and-herd-management-area
American Indian and Alaska Native areas, and Hawaiian home lands	U.S. Census Bureau	2017	https://www.census.gov/cgi-bin/geo/shapefiles/index.php
Tribal lands ceded to the United States	USDA Forest Service	1894	https://data.fs.usda.gov/geodata/edw/datasets.php

Table 2—Area of Federal and tribal lands, based on the geospatial data listed in table 1.

Jurisdiction	Acres	Km²	Percent
Bureau of Indian Affairs			
Crow Indian Reservation	2,307,506	9,338	100
National Park Service			
Bighorn Canyon National Recreation Area	119,828	485	100
Bighorn Lake (maximum)	12,700	51	10.6
Bighorn Lake (minimum)	7,000	28	5.8
Forest Service			
Bighorn National Forest	1,112,872	4,504	100
Wilderness	191,913	777	17.2
Shoshone National Forest	2,469,239	9,993	100
Wilderness	1,239,156	5,014	50.2
Custer Gallatin National Forest	3,412,382	13,809	100
Wilderness	941,168	3,809	27.6
Wild Horse and Burro Program			
Pryor Mountain Wild Horse Herd Management Area	40,844	165	100
Bureau of Land Management	28,563	116	69.9
Wilderness Study Areas (within BLM lands)	19,100	77	46.8
National Park Service	7,885	32	19.3
Forest Service	4,396	18	10.7

All of these lands, except the Bighorn Canyon National Recreation Area and the Crow Indian Reservation, contain either wilderness designated areas or wilderness study areas. The Wilderness Act of 1964 enhanced the protection status of remote or undeveloped (or both) lands within federally administered protected areas. Rooted in sustainability principles for the protection of wilderness values, both wilderness designated zones and wilderness study areas prohibit road and building construction, oil and mineral exploration or extraction, logging, and the use of motorized or mechanized equipment, including bicycles.

Pryor Mountain Wild Horse Range

The Pryor Mountain Wild Horse Range is a unique refuge for the wild horse (fig. 11). Many of the wild horses that inhabit the range show primitive striping on their backs, withers and legs, and are believed to be feral descendants of Spanish, Arabian, and English stock brought by European settlers. On December 18, 1971, President Richard M. Nixon signed into law the Wild and Free-Roaming Horses and Burros Act, which made it a crime to harass or kill feral horses or burros on federal land —for the purposes of this act, all unbranded and unclaimed horses and burros on public lands of the United States (fig. 12). This act also required the DOI and the USDA to protect the animals and study their habits and habitats. The act also permitted public land to be set aside for the animals' use. In addition, it required that

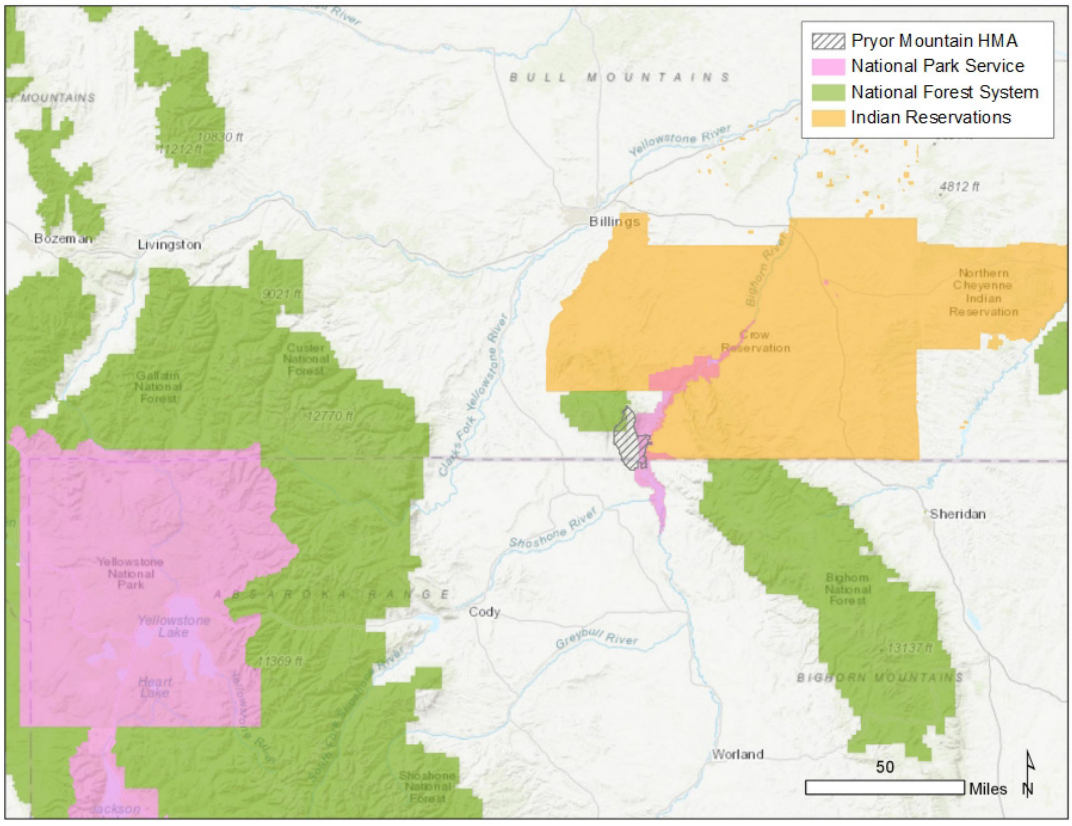


Figure 9—Federal lands surround the Crow Indian Reservation. The Bighorn National Forest is located in the Bighorn Mountain Range, north-central Wyoming. The Shoshone National Forest covers an area from the Montana state line south to Lander, Wyoming, and includes portions of the Absaroka, Wind River, and Beartooth Mountains. The Custer Gallatin National Forest comprises over 10 separate sections, with the Pryor Mountain section and the Pryor Mountain Herd Management Area (HMA) adjacent to the Crow Indian Reservation. Sources used are listed in table 1.



Figure 10—The Bighorn Canyon National Recreation Area includes some lands from the Crow Indian Reservation, but access by the public is restricted (photo: Aldo Leopold Wilderness Research Institute).

wild horses be protected as “living symbols of the historic and pioneer spirit of the West,” and that management plans maintain a natural ecological balance among wild horse populations, wildlife, livestock, and vegetation, and protect the rangelands from the deterioration associated with horse overpopulation. Although wild horse ranges were principally set aside for the protection of the horses, public land management agencies were directed to maintain these lands for multiple uses. The BLM was permitted to close some public land to livestock grazing if needed to protect wild horse and burro habitat. In response to the drastic decrease in wild horse and burro populations, quickly disappearing from America’s public lands in the middle of the 20th century, this act also established a congressional policy that wild free-roaming horses and burros shall be protected from capture, branding, harassment, or death. To accomplish this goal, they are considered an integral part of the natural system of public land in the areas where they currently roam. Sustainability criteria for the Pryor Mountain Wild Horse Range appear in table 3.

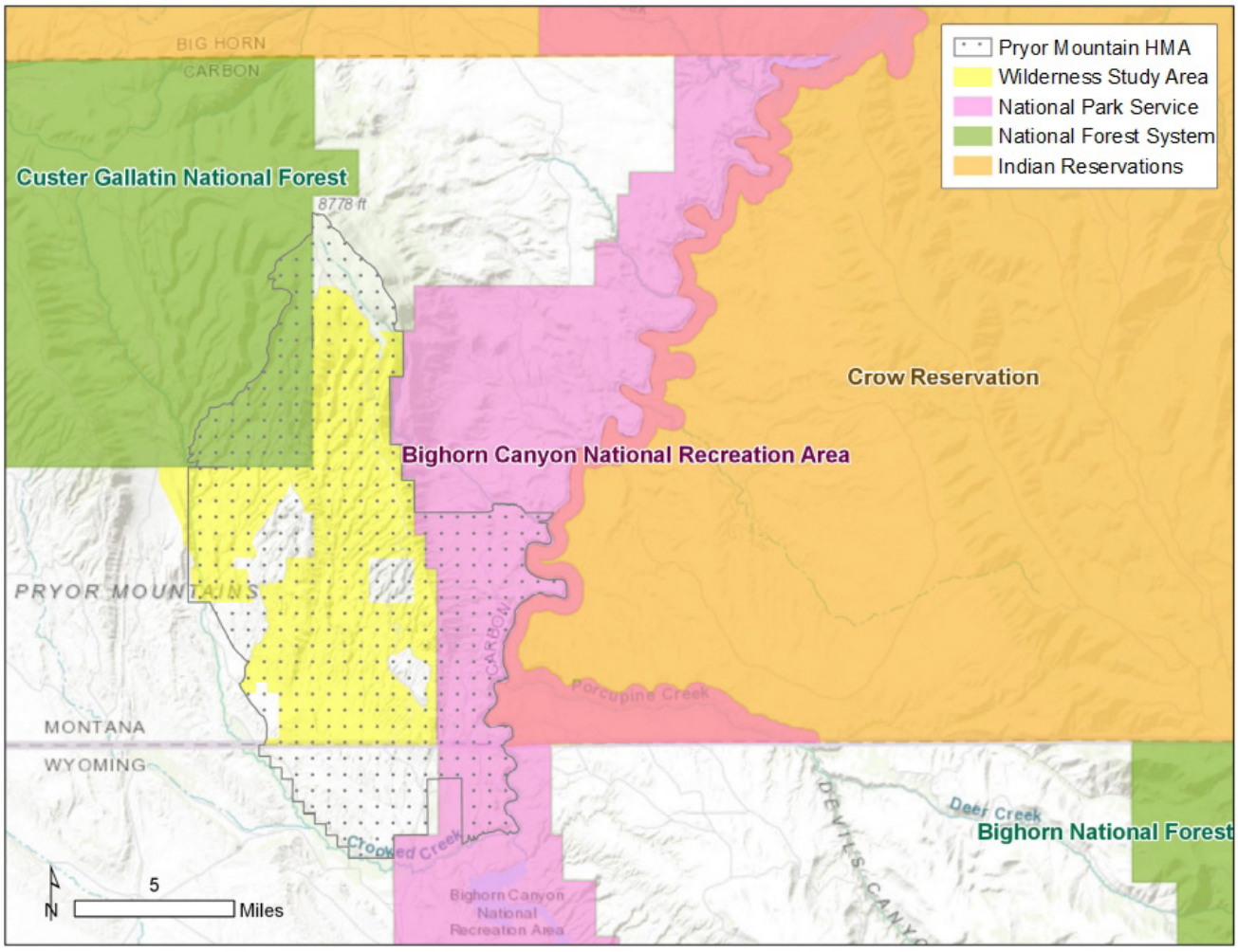


Figure 11—The Pryor Mountain Herd Management Area (HMA) is located within three Federal jurisdictions. Sources used are listed in table 1 (see table 2 for acreage summaries).



Figure 12—The Wild and Free-Roaming Horses and Burros Act protects feral horses and burros on Federal land (photo: A. Teasdale).

The public face of wild horse herds in the Pryor Mountains is the Pryor Mountain Wild Mustang Center in Lovell, Wyoming (fig. 13). This organization performs public outreach and educates visitors on the importance of the wild horses on publicly owned lands. A significant portion of the Wild Horse Range is classified as wilderness study areas on BLM lands (fig. 14), so federal agencies are required to manage them in accordance with the designation of the Wilderness Act, until Congress decides to release acreage or pass legislation that brings them into the National Wilderness Preservation System. In a letter of April 13th, 2017 to the Custer

Table 3—Protected resources and threats to sustainability in the Pryor Mountain Wild Horse Range.

Protected Resources	Threats
• 40,844 acres of wild horse and burro habitat. • Viable populations of wild horses and burros, as living symbols of the historic spirit of the West. • Habitat of other wild animals: mule deer, Rocky Mountain bighorn sheep, elk, black bear. • Mule deer are the most abundant and most widely distributed of these species. • Areas for ecological and environmental research. • Recreational use, mainly: hunting (bear, deer, small game), hiking, snowmobiling. • Outstanding geologic and scenic attributes.	Horses need to be protected from: ○ Harassment and undue harm. ○ Commercial exploitation. ○ Illegal removal. ○ Diseases, sickness and death. The range, forage and water supply need to be protected from: ○ Deterioration associated with horse overpopulation. ○ Overgrazing.



Figure 13—One of the report authors, Florence Mdodi, visited the Pryor Mountain Wild Mustang Center in September 2017. "Wild mustangs" is another name for wild horses and connotes a romantic, adventurous image of them (photo: Aldo Leopold Wilderness Research Institute).



Figure 14—A large proportion of the wild horse range is classified as wilderness study area, to be managed as wilderness (photo: Aldo Leopold Wilderness Research Institute).

Gallatin National Forest, the Pryors Coalition drew attention to the fact that boundaries in the Pryor Mountains between BLM, USFS and NPS "have no correlation with ecological, geological or geographical boundaries. [...] Similarly public recreational uses in the Pryors are not correlated with the areas managed by different agencies." The Pryors Coalition concluded calling for an integral management of the Pryor Mountain landscape based on a common holistic vision of desired future conditions, led by unified, consistent, and coordinated goals and management, and inclusive of the collaboration with the Crow Tribe to that end (Pryors Coalition 2017).

Bighorn Canyon National Recreation Area

The Bighorn Canyon National Recreation Area is located in southeastern Montana and north-central Wyoming (fig. 11). It encompasses approximately 119,828 acres (485 km^2) and includes the 7,000 to 12,700 acres (28–51 km^2) of Bighorn Lake, where water levels vary seasonally (fig. 15). In 1966, the recreation area was established by Public Law 89-664 (with title An Act to provide for the establishment of the Bighorn Canyon National Recreation Area) to manage recreation use in the Bighorn Lake and adjacent lands, and preserve their scenic, scientific, and historic resources. The law also provides for utilizing renewable natural resources and for entering into cooperative agreements with other federal and state agencies



Figure 15—A mountain mahogany (*Cercocarpus* spp.) shrub clings to the cliff edge above Bighorn Lake in the Bighorn National Recreation Area (photo: A. Teasdale).



Figure 16—The ancient remains of a teepee ring are seen in the Bighorn Canyon National Recreation Area, where much archaeological evidence of past activity by Crow and other Tribes can be found (photo: A. Teasdale).

for the joint administration and use of various land and water resources within and adjoining the recreation area. Another provision in the legislation adds the authority to change the boundaries of Bighorn Canyon National Recreation Area through inclusion of Crow tribal lands, as both the recreation area and the dam site were taken by the federal government by condemnation (fig. 16).

This national recreation area consists of an unusual mixture of ownerships and uses. The area was designated to include both NPS lands and approximately 52,000 acres (210 km^2) of the Crow Indian Reservation. Access to lands held in trust for the Crow Tribe by the federal government is restricted from public visitation, requiring nontribal members (including the NPS) to obtain a trespass permit to lawfully enter (fig. 17). Some of the recreation area also doubles as part of the Pryor Mountain Wild Horse Range. The Yellowtail Wildlife Management Area is in the recreation area, at the confluence of the Shoshone and Bighorn Rivers. The current lake extension, created by the construction of the Yellowtail Dam, provides boating and fishing opportunities in the Bighorn Canyon, as well as other river recreation opportunities.

The Bighorn Canyon National Recreation Area Long-Range Interpretive Plan (USDOI NPS 2012) provides a clearer picture of how designation legislation has been translated into what is being protected in the recreation area, while the Foundation Document for the recreation area (USDOI NPS 2016) identifies several major threats to sustainability faced by the area (table 4).

Table 4—Protected resources and threats to sustainability in the Bighorn Canyon National Recreation Area.

Protected Resources	Threats
• 119,828 acres (484 km²) of land and water ecosystems, supporting hundreds of species of plants, birds, fish, and other wildlife. • Vital part of the ancient and living culture of American Indians, including the Crow, Northern Cheyenne, Shoshone, Blackfeet, Arapaho, and Lakota. • Historic value testimony of the 19th- and early 20th-century settlers of European descent in this "wild west" frontier, with legacies that live on in the lifeways of their 21st-century descendants. • The Bighorn River, Bighorn Lake, and watershed represent a vital, life-giving force in a tough, challenging environment. • Geological record of Earth's changes over millions of years, as exposed in the cliffs and rocks of Bighorn Canyon. • Recreational and scenic experiences.	• Wildfire in the dam habitat area. • Climate change-related threats: ○ Changes to precipitation could cause the area to become more arid due to an increase in mean annual temperature. ○ Projected storm intensity and extreme temperature events could result in changes in species composition. ○ New conditions could increase the presence of invasive species. ○ Ongoing siltation of the lake and river will eventually impact the canyon. • Geological record of Earth's changes over millions of years, as exposed in the cliffs and rocks of Bighorn Canyon. • Grazing cattle and other livestock can disturb historic site features • Development projects and road construction can threaten recreation area values. • Vandalism, looting, and graffiti can disturb historic and archaeological sites. • Bureau of Reclamation and National Park Service (NPS) missions do not always align. • Frequent changes to multiagency management staff bring confusion to NPS staff and the public. This can slow down management processes and pose challenges to uninterrupted operations. • NPS contract negotiations with the Crow Tribe regarding access to and management of the Ok-A–Beh Marina are sensitive. • As tribe descendants continue to age, there is potential for a loss of institutional place-based knowledge to sustain cultural connections.



Figure 17—Crow lands within the Bighorn National Recreation Area are restricted from public visitation, and even the National Park Service needs a trespass permit to go onto these lands (photo: A. Teasdale).



Figure 18—The Wolf Mountains on the Crow Indian Reservation, with the Bighorn Mountains in the background (photo: A. Teasdale).

Bighorn National Forest

Created as a U.S. Forest Reserve in 1897, the Bighorn National Forest is one of the oldest federally-protected forest lands in the United States. Located in north-central Wyoming's Bighorn Mountain Range (fig. 9), the forest is east of the Continental Divide. It extends from the Montana border for 80 miles (130 km) along the spine of the Bighorn Mountains (fig. 18), which is an outlying mountain range separated from the rest of the Rocky Mountains by the Bighorn Basin. Elevations range from near 5,000 feet (1,500 m) along the sagebrush and grass-covered lowlands at the foot of the mountains, to 13,189 feet (4,020 m) on top of Cloud Peak, the highest point in the Big Horn Mountains. Approximately 99 percent of the land is above 4,900 feet (1,500 m). The forest is named after the Bighorn River, which is partially fed by streams found in the forest. Limited details on protection and potential threats to sustainability of these forest lands are provided in the Bighorn National Forest Revised Land and Resource Management Plan (USDA FS 2005) (table 5).

The Bighorn National Forest contains the Cloud Peak Wilderness and several wilderness study areas that have been recommended for designation by the Forest Service, as well as four research natural areas. These areas tend to be small but important comparison areas, usually located within riparian zones. The forest also contains the Medicine Wheel, a National Historic Landmark and a sacred historical site culturally important to the people of the Crow Tribe as well as other Tribes. The Medicine Wheel is atop Medicine Mountain at an elevation of 9,642 feet (2,940 m). Both the site and the mountain have been associated with regional Tribes such as Arapaho, Bannock, Blackfeet, Cheyenne, Crow, Kootenai, Salish, Plains Cree, Shoshone, and Sioux (Chapman 2019). The wheel measures about 80 feet (24 m) in diameter and contains 28 alignments of limestone boulders that radiate from a central cairn, connecting it with 6 stone enclosures located around the wheel's perimeter. Researchers believe the wheel

Table 5—Protected resources and threats to sustainability on the Bighorn National Forest.

Protected Resources	Threats

• 1,112,872 acres (4,496 km2) of forest land.
• Animal habitat: mule deer, elk, moose, black bear, and mountain lions.
• The Bighorn River (flowing along the west side of the forest), first named by American Indians due to the great herds of bighorn sheep at its mouth.
• For a few thousands of years, human cultures have inhabited the Bighorn River region, using mountain resources to improve their quality of life.
• Recreational opportunities.
• Economic uses: lumber, and summer grazing for cattle and sheep.
• Subsistence uses: clear and cool water.
	• Development projects and road construction.
	• Climate change-related threats:
	  ○ Rising temperatures.
	  ○ Changes in the length of the growing season.
	  ○ Changes in amounts and timing of precipitation.
	  ○ Increases in water temperature.
	  ○ Other variations that would affect the historical habitats and wildlife.

was constructed over several centuries and predates the arrival of European settlers in the region, though its origin and purpose are still unknown by the archeological community. Tribes have continuously shared concerns about damage to this and other sacred sites from visitors.

Shoshone National Forest

The Shoshone National Forest is located in the northern Rocky Mountains in northwest Wyoming (fig. 9), with its western boundary located south of Yellowstone National Park, the crest of the Continental Divide. Originally a part of the Yellowstone Timberland Reserve, the Shoshone National Forest was created by an act of Congress and signed into law by President Benjamin Harrison in 1891, which makes it one of the first nationally protected land areas in the United States. Native American peoples have lived in the region for at least 10,000 years according to the archaeological record.

The forest currently contains all of the original animal and plant species present when explorers such as John Colter and Jim Bridger first visited the region in the early 1800s. The forest is home to the grizzly bear (*Ursus arctos horribilis*), cougar (*Puma concolor*), moose (*Alces alces shirasi*), and tens of thousands of elk (*Cervus canadensis*) as well as the largest herd of bighorn sheep (*Ovis canadensis*) in the United States. The streams in the forest are considered to have some of the best game species fishing opportunities in the United States, including the Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*). More than 1,300 miles (2,100 km) of hiking trails, 32 campgrounds, and adjacent forests and parklands provide numerous recreational opportunities. There are five wilderness areas within the forest. The North Absaroka (ab-ZORE-kuh) Wilderness and the Absaroka-Beartooth Wilderness (fig. 19) are located in the northern portion of the Shoshone National Forest; the Popo Agie (puh-POE-zhuh), the Fitzpatrick, and the Washakie (WA-shu-kee) Wilderness areas are located to the south. These designated wilderness areas protect half of the managed land from development. According to the forest management plan, Shoshone National Forest has more individual glaciers than any other national forest in the contiguous 48 States, with 16 named and up to 140 unnamed glaciers in the Wind River Range (USDA FS 2015). The Shoshone



Figure 19—The Absaroka-Beartooth Wilderness, which includes Rainbow Lake, shown here, is one of five wilderness areas within the Shoshone National Forest. Wilderness designation protects more than half of the forest with strict intervention guidelines (photo: Wilderness Connect).

Table 6—Protected resources and threats to sustainability on the Shoshone National Forest.

Protected Resources	Threats

• 2,469,239 acres (10,000 km²) of forest land.
• 1,239,156 acres (5,016 km²) of designated wilderness: Absaroka-Beartooth, Fitzpatrick, North Absaroka, Popo Agie, and Washakie.
• Home to over 335 species of wildlife, including the largest population of bighorn sheep and one of the few remaining grizzly bear populations in the lower 48 States.
• Recreation and enjoyment, including hunting and fishing.
• Economic uses: commercial livestock grazing, recreation-related businesses, and a sustainable mix of timber products responsive to existing, new, and changing markets, including local industry.
• Subsistence use: water supplies, wood products, and minerals extraction.
• Cultural uses: sawtimber, small diameter roundwood, chips, pulp, firewood, mushrooms, Christmas trees, pine cones, and greenery.
• Some timber products contribute to carbon sequestration.
	• Development activities such as road construction.
	• Climate change-related threats:
	  ○ Warming trends expected to accelerate in the next century (Rice et al. 2012).
	  ○ Changes in the length of the growing season.
	  ○ Changes in amounts and timing of precipitation.
	  ○ Increases in water temperature.
	• Widespread insect and disease epidemics have affected vegetation on the forest over the last 10 years.

National Forest supports a rich biodiversity rarely matched in any protected area—ranging from sagebrush plains, to dense spruce and fir forests to craggy mountain peaks. The land management plan for the Shoshone National Forest (USDA FS 2015) has identified values for protection and potential threats to sustainability (table 6).

Custer Gallatin National Forest

Custer Gallatin National Forest totals 3,412,382 acres (13,809 km^2), with more than 10 separate sections (figure 9). The Forest lies within the Greater Yellowstone Ecosystem in the westernmost districts, with the easternmost sections consisting of a combination of forest "islands" and grasslands. Over a third of the Absaroka-Beartooth Wilderness lies within this National Forest. South of Red Lodge, Montana, the Beartooth Highway (U.S. 212) passes through the forest en route to Yellowstone National Park (U.S. Department of Agriculture, Forest Service 2017). The eastern habitats are dominated by large stands of ponderosa pine surrounded by mixed grasslands, which are often leased to local ranchers for cattle grazing. Mule deer, pronghorn, elk and a regional type of small falcon, the prairie merlin (*Falco columbarius richardsonii*) are also present within this forest system. *The Monitoring and Evaluation Report* for the Custer National Forest (DeBlander 2001) provides some insight into what forest resources are protected and identifies the forces that threaten sustainability of those resources (table 7).

Table 7—Protected resources and threats to sustainability on the Custer Gallatin National Forest.

Protected Resources	Threats

• 3,412,382 acres (13,820 km^2) of forest land.
• 941,168 acres (3,812 km^2) of wilderness designated land.
• Recreational experiences: wildlife viewing, scenic drives, skiing, snowmobiling, fishing, hiking, and camping.
• Forest ecosystems: high alpine mountain country and small pockets of timbered buttes and grasslands. It is known as the most ecologically diverse forest in the Forest Service's Northern Region.
• Wildlife: Habitats for wild animals are protected, especially Threatened and Endangered species and vegetation.
• Minerals: oil and gas.
	• Extensive rangeland degradation by over-grazing, unregulated grazing, and drought.
	• Insects and plant disease: Grasslands have supported varying populations of grass-hoppers (suborder *Caelifera*) and Mormon crickets (*Anabrus simplex*). These insects are an important source of food for some wildlife species, but they cause serious problems on rangelands.
	• Road construction.
	• Climate change-related threats:
	  o Rising temperatures.
	  o Changes in the length of the growing season.
	  o Changes in amounts and timing of precipitation.
	  o Increases in water temperature.

Crow Indian Reservation

Since the opening of reservation lands for nontribal purchase by the General Allotment Act of 1887, land ownership within the exterior boundaries of the Crow Indian Reservation has turned into a mosaic of mixed ownership, with individually allotted lands (1,166,406 acres; 4712 km^2) that are owned by tribal and nontribal owners, fee patent or privately owned and State lands (709,167 acres; 2,865 km^2), and tribal trust lands (404,172 acres1,633 km^2). Lands within the reservation boundaries held in trust for the Crow Tribe by the federal government comprise approximately 1,135 acres (5 km^2). The Montana Governor's Office of Indian Affairs (n.d.) indicates some aspects of this area and landscape that represent priorities to protect the Tribe's environmental, political, and socioeconomic status as a sovereign nation (table 8, fig. 20).



Figure 20—Climate change influences on water supply for agriculture and domestic uses is a threat to sustainability on the Crow Indian Reservation (photo: A. Teasdale).

Table 8—Protected resources and threats to sustainability on the Crow Indian Reservation.

Protected Resources	Threats

• Native wildlife and vegetation.
• A tribal bison herd of approximately 1,400-1,600 heads (Montana Fish, Wildlife & Parks, 2015).
• Dry land farming and grazing of cattle and horses.
• Recreational experiences.
• Culturally significant sites.
• Culturally significant activities, including raising and riding horses, raising cattle, hunting.
• Extensive coal reserves.
	• Wildfire impacts on communities, natural, and cultural resources.
	• Climate change-related threats:
	  ○ Water supply shortages for agriculture and domestic uses.
	  ○ Drought impacts on economic, social, and environmental attributes.
	• Mining activities and disagreement about mining methods and impacts.
	• Poverty and unemployment.
	• Insufficient access to professional and higher education.
	• Alteration of native conditions by outside influences (e.g. recreation and industry).

Lessons Learned from Phase 1A

Legislative designations and land policy documents that were reviewed in this phase indicate multiple-use/purposes within federal mixed-ownership lands that are adjacent to Tribal trust lands. Across all lands,

(1) recreation and
(2) wildlife values are commonly listed as resources that require protection, closely followed by
(3) water quality, quantity and access.

Some additional unique aspects being protected, and therefore key indicators of sustainability, are

(4) the viability of a wild horse population on the Pryor Mountain Wild Horse Range,
(5) wilderness-designated areas on the three national forests,
(6) research natural areas,
(7) the cultural and historical landscapes associated with regional tribal populations,
(8) a bison herd on tribal lands,
(9) local economies associated with commodities on the three national forests, and
(10) coal reserves on the Crow Indian Reservation.

Specific threats to sustainability include those closely associated with climate change, such as

(1) drought,
(2) wildfire,
(3) pests, and
(4) plant disease.

Other impacts also listed in the corpus are
(5) livestock overgrazing,
(6) land development activities, and
(7) mineral and fossil fuel extraction.

On the Crow Indian Reservation, additional socioeconomic threats are at play and broadly impact factors associated with the quality of the environment and human well-being. Full understanding of resources and values being protected, the threats to them, and how each agency engages the public in controlling or adapting to these threats is the focus of Phase 1B of this report.

Phase 1B: Gaining Insight From Federal Managers on Restoration of Natural and Cultural Resources

To obtain a closer picture of the workflows and personal experiences that currently shape federal management in the study area, in-person interviews were conducted with managers of the Pryor Mountain Wild Horse Range (BLM), managers of the Bighorn Canyon National Recreation Area (NPS), and the forest planner on the Bighorn National Forest (Forest Service) between September 27 and September 30, 2017. The research goal of this phase was to gain insights from these interviews with regard to three questions: (1) How is sustainability defined across mixed-ownership landscapes, and is Indigenous knowledge from the Crow Tribe or another source of place-based knowledge incorporated into the definition of sustainability goals? (2) What evaluation methods are employed to assess whether sustainability objectives are being met, particularly from restoration efforts? (3) How does the public engage in sustainable use of resources flowing from the federal lands under study, with special attention to collaboration between such federal units and the Crow Tribe? A summary of the interviews is available in the Appendix. A synthesis of the findings from the interviews is provided here.

Manager Definitions of Sustainability

As indicated in the Introduction, sustainability has many definitions and applications. What is most important, however, is to understand that sustainability is not a generally applied set of principles. For federal public lands, it is largely determined by the legislation that defined the purpose of and protective directives for those lands, that is, the original organic act of the agency that was placed in charge of the area, and subsequent policy that has been developed to implement legislative or administrative protection.

Within mixed-ownership lands that occupy the same general landscape, sustainability definitions and actions can therefore vary widely. Furthermore, some management objectives may be prioritized over others when legislative directives and uses overlap. This is the case for the wild horse population and current habitat management on the Pryor Mountain Wild Horse Range, which is adjacent to the Crow Indian Reservation and partly within the Bighorn Canyon National Recreation Area. Flood control for the national recreation area or scientific contributions stemming from the research natural areas in national forests, however, have differing threats and therefore require separate applications of sustainability efforts. In the case of the Pryor Mountain Wild Horse Range, if wilderness study areas in it were recommended for wilderness designation, then wilderness management interests potentially could come into conflict with wild horse management interests. Although currently there appears to be little conflict between designation and specific land use in the Pryor Mountain Wild Horse Range, there are some uses within this area that may not be compatible with the designation of this land as an official wilderness. Examples are the building of guzzlers for water supply for horses in an effort to diffuse grazing impacts in concentrated areas, and mechanized aspects of trapping and removing horses to accomplish population control objectives. Indeed, the conflict between wild horse objectives and wilderness objectives has grown in several U.S. western States in recent years, and could easily spread to this wild horse range. Removal from wilderness study area status, however, could open up these areas (more

than they already are now) for development and mechanized management activities (fig. 21). In short, the future of these lands could be very different depending on what decisions are made after recommendations for inclusion in the National Wilderness Preservation System.



Figure 21—A free-range mare and offspring roam the Bighorn Mountains overlooking the Crow Indian Reservation. Removal from wilderness study area status of nearly 47 percent of the Pryor Mountain Wild Horse Range could further open these areas to access for development and mechanized management activities (photo: A. Teasdale).

Sustainability Evaluation Methods

We found little systematic methodology was identified in the federal lands under study. Some quantitative measures of sustainability success are being used. For example, the Appropriate Management Level (AML) that BLM has determined for wild horses in the Pryor Mountain Wild Horse Range is 90 to 120 individuals (USDOI BLM 2019). This AML means that the wild horse population in this area should remain within this interval to be consistent with the land's capacity to support the herds, and to exist in balance with other species, resources, and uses in the rangeland. However, there is little evidence from continual evaluation to determine the level of sustainability, across multiple protected resources, which might be achieved if the local wild horse population is kept within that interval. Public expectations for herd numbers that conflict with sustainability principles, federal budget caps, and lack of horse adoption by the public may lead the Pryor Mountain Wild Horse Range away from its ability to meet broader sustainability goals. Similarly, while overgrazing may be acknowledged as a threat to vegetation within some areas due to horse overpopulation or public grazing of cattle, there appears to be little quantitative assessment of overall vegetation condition or evaluation of success at restoring grazing conditions.

Public Participation

The U.S. Government requires federal agencies to follow a regimented feedback process when developing or updating land management plans, with the goal of broad outreach to obtain public comment. Through the public comment period, organized public and private groups are allowed to comment and hence affect final decisions on planning goals and objectives. Interest groups often form to influence management direction on federal lands. When these groups understand the sustainability goals that determined the management plan proposal for that particular area, they can become instrumental partners with the agencies in assuring those goals will be met in restoration efforts. However, some groups may potentially fail to adequately understand such goals, or have goals that are in conflict with the public purpose of the area in question. In the latter case, their claims can, and sometimes do, pose a threat to achieving the intended sustainability objectives.

Some of the interviewed personnel indicated that, normally, more feedback has been obtained from the public when opposing sides of an issue feel they did not get or may not get what they were expecting from a federal decision. However, none of them mentioned the Crow Tribe often as an important influence in the sustainability practices applied in the Pryor Mountain Wild Horse Range, the Bighorn Canyon National Recreation Area, or the Bighorn National Forest. Their responses did indicate that the Crow Tribe is included in postfire restoration issues and in restoration efforts due to impacts to some spiritual sites. But the interviewees did not identify place-based knowledge that could provide sustainable adaptation measures for postfire wildlife (including wild horses) or vegetation restoration issues on these public lands. The rest of this report aims to fill this void.

Lessons Learned From Phase 1B

In accomplishing sustainability objectives, overlapping management boundaries seem to be less of a problem than overlapping legislated purpose for the public lands under study. Agreeing on sustainability objectives seems possible when jurisdictional boundaries overlap as agencies jointly consider authorizing legislation or policy to develop management protocol. However, agreeing on sustainability purposes and identifying potential threats seem more difficult when legislative measures apply to the same space and conflict with one another, or when historical land practices and uses are not managed for by the overlapping legislation. Moreover, public attitudes are not immutable and, as a result, public opinions on management objectives can, and often do, change over time. Even within a single management agency, a policy can potentially introduce threats to the ability to meet the goals for sustainable land use; an example is when a research natural area becomes a candidate for some timber harvesting.

Phase 2A: Resistance and Resilience: A Protective Shield to Guide Restoration for Sustainability

Indigenous knowledge, particularly traditional phenological knowledge, offers a rich resource of knowledge to understand impacts of climate-related disturbance. This is important because of the breadth of time and depth of local detail that make up climate change science. Indigenous knowledge contributes to the understanding of ecosystem changes as a result of multiple stressors, including climate, and provides information where data are limited, but where existing relationships to the land date back many generations (Doyle et al. 2013). In short, Indigenous knowledge offers the possibility of identifying the effects of recurring disturbance and best practices for adaptation.

Social science, especially ethnological analysis, provides suitable methods for understanding the body of Indigenous knowledge, including its subset traditional phenological knowledge (Gamborg et al. 2012). A unique set of skills is necessary for the development of an Indigenous knowledge base. The validity of this knowledge rests within its own cultural audience and expertise, so use of tribal archives and sources that directly represent the tribal voice should be prioritized whenever possible. While some practices used in Western science are not consistent with the skills necessary to develop and preserve Indigenous knowledge (e.g., controlled experiments for hypothesis testing), practices like systematic observation and trial and error are a common thread in both knowledge systems for problem solving and generation of knowledge. In addition, Indigenous knowledge is a reflection of cultural lifeways, so it may include both scientific methodology and the honoring of cultural identities associated with a particular environment. Moreover, Indigenous knowledge may sometimes be the only source of information about long-term cycles that takes account of human behavior. In sum, Indigenous knowledge presents a holistic perspective that does not dissociate cultural heritage from the earth sciences and vice versa, becoming a natural paradigm for the study of coupled human and natural systems.

Ethnological meta-analysis has proven to be particularly helpful in bridging the gap between science and Indigenous knowledge, given its suitability for synthesizing qualitative research and developing models that interpret findings across multiple studies (Atkins et al. 2008). In ethnographic interviews, data collection and subsequent analysis primarily rely on spoken or written statements to synthesize and interpret information, so it has come to be a key practice for cross-culturally communicating different understandings of natural and cultural resource values. However, ethnological analysis does not diminish the benefits of including quantitative analysis in the application of Indigenous knowledge, as long as accurate quantitative data are available. In fact, both quantitative and qualitative data can be used in culturally appropriate sources such as fire management plans and integrated natural resource plans, and in decisionmaking that extends beyond the current political boundaries of Indian reservations, such as management of larger watersheds and ecosystems in multiownership lands (Walters and Andersen 2013). In any case, scientific research practice should always honor and support tribal decisions regarding the extent of their contributed knowledge base, whether and when to share that knowledge, and the way to use it (Climate Change and Traditional Knowledges Workgroup 2014). Ultimately, Tribes in the U.S. hold the right to develop their own sovereign plans and protocols in planning for climate change impacts.

The Protective Shield Framework

In this section, we present a cognitive model to derive principles of sustainable management from existing ethnological knowledge. The model has been developed for this research project and employs a culturally appropriate symbol —a circular shield— for informing protective and adaptive conservation management. It organizes interview data into four categories of actions with focus on adaptation to, interpretation of, restoration against, and resilience to climate change impacts for more resistant socioecological systems. Stylistically, the model resembles the shield in Native American cultural technology and other circular concepts in Indigenous thought, and symbolizes a warrior or medicine. Four-quarter representations are omnipresent in Native American regalia to symbolize the four directions, the four compass points that define tribal cultural and natural lands (often represented by mountain ranges), the four seasons, and the four stages of life. A sample of such symbolism in Crow culture is included in the next sections (figs. 22–25). They are used for illustrative purposes only and do not intend to symbolize the stages presented in the protective shield framework.

This model allows the representation of an iterative management system across time. It proceeds through three stages of knowledge building and practice —adaptation to changing factors; knowledge reweaving (in the sense of a new weaving of knowledge), restoration of past conditions— to culminate in a fourth stage of resilience, where *wisdom* informs the formulation of management principles to make ecosystems and cultures more resistant to climate change-related factors. The cycle is continuous as changing conditions lead to new adaptations, From a knowledge management perspective, wisdom is to be regarded as the outcome of a cognitive sequence that started with the coding of observations (data collection), has proceeded with the synthesis of those observations (information), and eventually allows establishing interconnections between different syntheses (knowledge) (Ackoff 1989; Zeleny 2005). Wisdom, as the end product of this process, is understood as a deep comprehension of knowledge implications (e.g., prediction of unobserved system states), and the ability to create new knowledge by moving through the sequential stages and adjusting existing knowledge to new situations. In this protective pathway, lessons learned from systems with enhanced resilience inform the next cycle of resistance to disturbances, once again beginning with adaptation to new changes and reweaving of knowledge systems; the management process can thus continue indefinitely. In short, these stages aim to lead to a re-evolution of the shield pathway through restoration practice and the wisdom associated with resilience. The framework has similarities with adaptive management models (compare Armatas et al. 2016), though it strengthens the role of knowledge reweaving and wisdom in managing for resistance. The wisdom that emerges from Indigenous knowledge is a story about traditional, place-based meanings and reaction in the context of environmental disturbance associated with climate change.

Adaptation (Resistance for Survival)

Adaptation is the first stage in this framework toward resistance to disturbance impacts (fig. 22). In this context, it assumes a prior awareness of a particular change in the system, which is perceived as a threat to the viability and health of that system. Adaptation strategies are usually applied to short-term responses, using available materials, technology, and methods to resist

those threats and impacts (Lempert et al. 2018). For example, in instances where the drinking water supply is not accessible (e.g., if severe damage occurs due to an oil spill or a decaying plumbing system) adaptation is immediately necessary to protect the community's health and economy.



Figure 22—Adaptation assumes a prior awareness of a particular change in a system, which is perceived as a threat to its viability and health. Shields like the one illustrated in this figure (USNM ID: E154348-0) are part of Crow warrior technology and symbology (photo: National Museum of Natural History, Smithsonian Institution).

In any case, adaptive measures affecting the lifeways of Indigenous Peoples should honor the concepts and ideas of such communities, whenever possible, or at least be a compromise solution that all parties have freely accepted. To continue our example of water access, the Crow Tribe experienced chemically polluted water stemming from decayed water delivery and plumbing systems, creating cascading effects in combination with climate change impacts on the Upper Missouri River Basin, namely, shortage of the water supply due to drought and elevation of water pollution levels owing to severe flooding (Doyle et al. 2018). First adaptive responses centered on identifying which chemicals were present through scientific testing, replacing water delivery infrastructure, and delivering bottled drinking water to affected users (J.T. Doyle, personal communication in 2018). When faced with the prospect of certain extinction of salmon, the Northwest Tribes conceived the idea of taking excess dead hatchery salmon and dumping them high up in the watershed as organic material, thus activating the process of building up trophic levels to feed the smolts (Stumpff 2013). This action supported the overall cultural values attached to salmon by utilizing native organic materials as the solution, combined with transport by modern vehicles as the means. In other cases, adaptation has included reducing timber harvests or adopting selective managed forest patterns in timber harvesting (BIA and CSKT 1999).

Native American communities use adaptation to resist disturbance impacts, preceded by problem identification and followed by reweaving of potential long-term solutions. This is a critical bridging step because reservation homeland boundaries make relocation of tribal

communities an atomizing option that can cause loss of family and cultural ties to the surrounding lands. Adaptation actions may change as climate and other factors shift, and as human and natural systems themselves respond to such actions. As pointed out previously, this capacity to respond to change enhances the pathways to resilience, by allowing the initiation of a renewed cycle of adaptations to and restoration against impacts.

Reweaving (Research and Two-Eyed Vision as Resistance)

Reweaving is grounded in the use of different knowledge systems (inclusive of science and Indigenous knowledge in our framework) in order to inform restoration from disturbance impacts and assist in the long-term resistance to those impacts (fig. 23). Particularly, reweaving extends beyond the dominant paradigm and instead focuses on the interweaving of science with Indigenous knowledge (e.g., the traditional phenological knowledge of the seasonal cycles and systems), to create environmentally and culturally sustainable pathways to management action.



Figure 23—Reweaving Indigenous knowledge with science can create sustainable pathways to action for resistance. Originally cataloged as Sioux, this shield (USNM ID: E379296-0) has been re-identified as Crow by the American Museum of Natural History, based on stylistic attribution (photo: National Museum of Natural History, Smithsonian Institution).

Reweaving begins with an understanding of the baseline of observations drawn from the set of reference knowledge systems. For climate change research from a human-nature system perspective, it needs to include a comprehensive assessment of the cultural, socioeconomic, and biophysical impacts of a changing environment, followed by communication between knowledge holders and reflection for the harmonization and incorporation of the diverse knowledge sources. All credible sources should be used in this process. However, the protocols and methodology of each knowledge system have been developed to use data with different characteristics, so such systems should be preserved separately.

A key contribution of reweaving to building resistant systems is the rejection of the binary concept of Indigenous knowledge as "traditional" or "contemporary." For a deep reweaving of knowledge, it is fundamental to include all epistemologies held by Indigenous Peoples, "not just those created in the eras of modernity and our actions with an investment in it" (Walters and Andersen 2013, p. 69). An approach that incorporates a continuous stream of growing and interwoven knowledge bases opens the way for the concept of "two-eyed seeing" (Marshall 2017). First articulated by the Indigenous Elder Albert Marshall of the Mi'kmaw Tribe in Canada, "two-eyed seeing" is a form of resistance against domination by one world view and assimilation of alternative knowledge bases. Bartlett (2012) notes that "two-eyed

seeing" challenges those structures of academia where knowledge is divided into disciplines and "the shoals are poorly charted" for transdisciplinary research. "Two-eyed seeing" acknowledges the whole nature and distinct ways of knowing of both Indigenous and Western knowledge, weaving back and forth between epistemologies but allowing them to work together as in binocular vision (Marshall 2017). This interaction holds important advantages because it is always "fine-tuning your mind into different places at once," and "you are always looking for another perspective and better ways of doing things" (Marshall 2017). "Two-eyed seeing" also provides guidance for identifying parallel points of Western and Indigenous-based science that outline long-term cycles or identifies specific phenological patterns. At the nexus points, connections are made to inform the next round of adaptations to changing conditions and resulting disturbance.

Knowledge emerging from "two-eyed seeing" can also build resistance, if it is suitable for adaptation to conditions and restoration against disturbance. Tribal management in the United States retains the knowledge of long-term cycles and practices, while allowing learning systems to evolve by monitoring the results of management actions and reflecting on outcomes and potential adjustments; an example, is the 2000 Flathead Indian Reservation Forest Management Plan (CSKT 2000). As a result, reweaving helps Indigenous knowledge communicate values that may not be well detected with other knowledge systems.

Alaska Native peoples, faced with an imminent ecological crisis, have been particularly adept at reweaving Indigenous knowledge and climate science in tribal education, within a broader strategy to sustain their communities in a warming world (Barnhardt and Kawagley 2010). In keeping with this multidisciplinary approach to education on climate change, approximately one-third of tribal colleges will soon offer a course that compares Indigenous knowledge with Western science to understand climate processes and their effects with the goal of exploring adaptation and mitigation strategies (Weinhold 2010). An expansion of such comparative programs among tribal and nontribal colleges could increasingly change perceptions about the urgency of climate change adaptation, restoration, and mitigation, despite the need to implement policies that might be perceived as involving some risk. Perceptions are changing in the United States toward a sense of urgency in climate change adaptation and mitigation (Leiserowitz 2005; Leiserowitz et al. 2009, 2015), especially in areas affected by catastrophic impacts of climate change (Colorado College 2019).

Restoration (Education and Identification of Positive Practices)

In the third stage of this protective shield framework, practices for ecological restoration and mitigation of disturbance impacts are identified (fig. 24). Through a dual education process that synthesizes the knowledge gained from reweaving Indigenous knowledge and science, restoration actions are implemented with the goal of maintaining sustainable relationships between humans and nature. Sustainable use of resources is a natural idea to Indigenous knowledge, as reflected by Native American narratives on ecological equilibrium, phenological cycles, and ecosystem dynamics in historical times (Watson et al. 2012). Restoration implies the existence of an agreed-upon baseline of environmental conditions that serves as a point of reference to establishing guiding principles for restoration. Again, this baseline for restoration gets better defined when it is informed by both science and Indigenous knowledge. Clearly, reweaving expands the volume of information while both knowledge systems can focus on the place-based scale needed to define restoration goals.



Figure 24—Place-based knowledge accumulated over historical time can inform restoration and mitigation of disturbance impacts to increase resistance. This reproduction (USNM No. E154349A-0) – a Kiowa copy of an original Crow shield – has a sheet metal base covered on the back and the front with light-colored skin, probably cow (photo: National Museum of Natural History, Smithsonian Institution).

Recent collaborative research by federal agencies, universities, and Tribes in the Columbia and Upper Missouri River Basins suggests an interest in actively incorporating Indigenous knowledge into adaptive forest management planning (Armatas et al. 2016; Doyle et al. 2013, 2018; McBride et al. 2017; Watson et al. 2009a, 2011). These studies have addressed long-term objectives through adaptations that aim to strengthen resistance to climate chance disturbance impacts, restore impacted resources in sustainable ways, and build resilience to future impacts. They have also put the emphasis on community engagement for effective communication and consensus building regarding perceptions of climate change. In consultation with the Confederated Salish and Kootenai Tribes, fuzzy mapping technologies illustrated place-based knowledge in a way that led to increased understanding of why tribal residents were opposed to vegetative management through commercial forestry activities within a special zone of the Flathead Indian Reservation in Montana (Watson et al. 2009a, 2013). Community engagement is a more effective method of collective knowledge exchange and education, rather than top-down models, which can be combined with geographic information systems and social science fieldwork for participatory learning and action in spatial planning (McBride et al. 2017; Wynecoop et al. 2019). Strong interest in such collaborations continues to grow amid postfire riparian and forest restoration (undertaken partially in response to the recent large fires that have plagued the western United States) as impacts of climate change present ecological, cultural, and economic restoration challenges (Carver et al. 2009; Watson et al. 2013).

Resilience (From Knowledge to Wisdom)

The last stage in the cycle of the protective shield framework is resilience (fig. 25). As a scientific term, resilience has many definitions within ecological and socioecological sources (Brand and Jax 2007; Cajete 2000; Carpenter et al. 2001). In the context of our management framework, the last stage aims to create a resilience-building mechanism by establishing management principles that guide future decisionmaking. These principles provide a roadmap for selecting and developing sustainable, place-based solutions for adaptation, restoration, and mitigation. A resilience strategy can be developed based on "resilience thinking," where place-based knowledge and practice are linked to the established disciplines of disturbance ecology and adaptive ecosystems management. This idea of resilience thinking does not imply the merging of different knowledge systems. Rather, it provides an epistemological scope where Western science and Indigenous knowledge can coexist as independent knowledge systems contributing to sound land management principles.



Figure 25—Resilience creates a protective shield to guide knowledge development and the wisdom to apply that knowledge. This shield (Catalog No. 11/7680) is associated with Crow Chief Arapooish (photo: National Museum of the American Indian, Smithsonian Institution).

The concept of resilience has gained importance in natural resource management and in cultural studies, particularly under conditions of climate change disturbance, as several nexuses appear that allow environmental sciences, particularly ecology and forestry, to be informed by Indigenous knowledge and vice versa (Armatas et al. 2016; McBride et al. 2017; Wynecoop et al. 2019). Daniel Wildcat's concept of indigenuity, defined as "the ability to solve pressing life issues facing humankind by situating our solutions in Earth-based local indigenous deep spatial knowledge," is another way of advocating for the use of "Western science and indigenous knowledge that resides in deep spatial knowledge" to build resilient human and natural systems (Wildcat 2009, p. 48). Wildcat expresses the need to use Western science and Indigenous knowledge, the latter of which "resides in the land, in the life that constitutes ecologies in which we participate" to create a better understanding of the complex web of life (Wildcat 2009, p. 76).

This emphasis on connecting knowledge systems shares similarities with —though inherently differs from— Western science-based methods that use systems thinking

(particularly, Soft Systems Analysis) as a versatile tool for knowledge exchange (e.g., Checkland and Poulter 2006). While Soft Systems Analysis has historically been used for knowledge management in business and organization contexts, the focus in the protective shield Framework is on sharing knowledge that can assist in resilience building and, more specifically, on the addition of Indigenous knowledge as one of the contributing sources of information. For instance, Seidl et al. (2016) note that measurement of ecosystem resilience is typically based on the range of ecological variability, though resilient systems are also a function of the dynamic nature of the recovery rate and the directionality of recovery. They conclude that some of the gaps to describe such indicators could be filled with place-based knowledge.

Other resilience principles can guide thinning, patch management, diversity in harvest patterns, and responses to natural wildfire, while simultaneously balancing long-term goals and actions with short-term negative effects, and in the process increase species diversity. Resilience principles can also aid in matching planned or existing infrastructure to future adaptation needs. For instance, road design, dams, and drainages can respond to changes in hydrological flows due to extreme weather events from climate change, soil erosion, and the need to conserve water storage through wet storage methods that include holding ponds, netting, and rockwork. Working together across disciplinary and political borders, collaborative knowledge-building is set to increase the spatial and temporal scope of the suite of management principles for ecosystem and community resilience.

Lessons Learned From Phase 2A

Under conditions of high uncertainty associated with climate change impacts, resilience is perhaps a more robust strategy than anticipating and mitigating risks that are imperfectly understood or poorly predictable (or both). An ecological perspective on resource management recognizes the importance of managing for environmental processes that evolve in variable and dynamically shifting ecosystems, because of the conservation risks that are raised by such a changing environment. A social perspective on resource management, in addition, aims to protect the values flowing from this environment that individuals and communities can enjoy by right.

The dynamic process that guides management decisions through ecological and social science, in any case, also fuels Indigenous resilience thinking. When the ecological perspective is combined with Indigenous knowledge practices, together they can illuminate pathways that aid in the discovery of resilience principles to promote sustainable structural diversity and ecological equilibrium. These principles are drawn out by focusing on local and Indigenous solutions in tandem with science rather than building resilience according to a one-size-fits-all plan. Within the context of adaptive management planning, reweaving becomes instrumental in this interconnection because of its capacity to identify the cultural and environmental baselines of resilience, in contrast with grounding this baseline in a single knowledge system.

Communication between knowledge holders and peer-to-peer education both form the foundations for interweaving ways of knowing and, ultimately, knowledge emergence in managing for resistant to climate change. How Indigenous knowledge can inform the *Shield* pathway for resistant management will be demonstrated in Phase 2B, with a case study illustrating contributions of the Crow Tribe for describing climate change disturbance impacts in the Upper Missouri River Basin, as well as Indigenous, placed-based solutions for adaptation, restoration, and resilience in the face of those impacts.

Phase 2B: A Meta-Analysis of Crow Elders' Observations to Draw Out Indigenouse Management Principles

From 2016 to 2018, the protective shield framework was put into practice with a case study to explore adaptation, reweaving, restoration, and resilience to increase resistance to climate-related disturbance for the Crow Tribe, with a focus on restoration principles. In data collection, priority was placed on tribal values and knowledge expressed by Crow members to describe adaptive responses and vulnerabilities to climate change impacts. Within an Indigenous research framework, the knowledge of an Elder is considered to be not only the knowledge of that person, but the accumulation of cultural knowledge that has been transmitted from the previous generations of Elders to her or him. This social approach to compiling Indigenous ecological knowledge, when directed by knowledgeable tribal guidance, can lead to a deeper understanding of how climate change perceptions and tribal values may have varied across time among Crow members, and increase resistance to change in the future, as demonstrated in the following case study.

Methods and Data

By examination of past interviews from 1993 to 2017 and their analysis through the Shield pathway, Crow Knowledge was explored to prescribe resource management principles for sustainable adaptation and restoration in mixed-ownership public lands of the Upper Missouri River Basin. Methods used for the analysis of tribal Elder knowledge included ethnological meta-analysis of themes identified in archived oral history, other culturally related documents on file, and in-person interviews. Crow scholar leadership has expressed the belief that interviews should only be conducted in the Crow language and analyzed by Crow speakers, in order to preserve the holistic nature of their knowledge (Yarlott 1999). Following their guidance, the Crow tribal college, Little Big Horn College (LBHC) generously provided translated interviews of Crow members and supporting materials through the LBHC Archives (http://lib.lbhc.edu/index.php?q=node/28). Accessible sources were available as in-person interviews; books written by knowledgeable tribal members and Crow Elders; journal articles; and unpublished material from the LBHC Archives. Sources that address issues of water resources, flora, fauna, and sacred and cultural resources were selected for meta-analysis. These sources were then coded according to different themes: (1) occurrence of alerts to climate-related environmental change, (2) Indigenous Phenological Knowledge demonstrating benchmarks for Western science and reweaving of multiple knowledge systems, (3) applied restoration practice using both Indigenous knowledge and science, and (4) guiding principles that emerged from intervention actions and reflection. A sample of Crow observations from these sources is included below.

Interviews utilized for the purposes of this research relied on several sources: a study on water resources supported by the Tribal Elders Commission and conducted by John T. Doyle (n = 15) (Doyle et al. 2016); dissertations shared by Dr. David Yarlott, Jr., President of LHBC (n = 13) (Yarlott 1999) and Dr. Valerie Pretty Paint-Small (n = 15) (Pretty Paint-Small 2013); a compilation of unaccessioned interviews with Crow Elders completed by Peter Nabakov (1993–1994) for the NPS (n = 13); the works of Dr. Joseph Medicine Crow (2006), John Eggers et al. (2015, 2018), and Alma Hogan Snell (2006); a thesis by Christopher Armatas (n = 4) (Armatas

2012); and personal interviews with John T. Doyle in 2010 and 2018. These interviews span 23 years (1993 to 2016), though some sources (especially oral history provided by Elders) refer to information that dates back six decades; other materials (archived or historical recollections of Elders' forebears who passed down observations orally) are even older. This temporal depth of the meta-analysis helped to obtain Crow observations of past effects of disturbance and knowledge to guide adaptation, reweaving, restoration, and resilience related to climate change impacts over a long time period in recent history.

Environmental and Cultural Context

The beauty of jagged mountain ranges surrounds the Crow Indian Reservation, with tilting angles that pour snowmelt into the valleys of the Bighorn River Basin. The northern part of the sacred Little Bighorn Range lies within the reservation boundaries and waters flow into the Little Bighorn Canyon. The southern end of the range soars to 13,167 feet (4,014 m) at Cloud Peak, known as *Awaxaawakii* or Extended Mountain (Bauerle et al. 2002-2012). This is the center of the world in the Crow traditional beliefs on the origin, evolution and structure of the universe, where the sacred tobacco plant, at the foot of this mountain range, first appeared to the Crow people during their migration. The seeds from this plant play a prominent role in the Crow origin stories, as they mark the separation of the Crow Nation from the Hidatsa in the late 1500s and are considered seeds of a rare and special tobacco plant (Yarlott n.d.).

The Pryor Mountains on the northern side of Bighorn Canyon contain a bounty of culturally significant resources used for ceremonial, ritual, and subsistence uses within this richly biodiverse ecosystem. The mountain range ascends from the lower northern sections within the boundaries of the reservation, to lands now managed by the Forest Service and BLM. The *Baahpuuo Isawaxaawu* or "Hitting Rock Mountains", as the Crow refer to them (Bauerle et al. 2002-2012), include ice caves, historical and contemporary sites for vision quests, and the Pryor Mountain Wild Horse Range. The southern parts of the range boast elevations of 8,700 feet (2,652 m), which then descend into a desert ecosystem located to the south. The low-lying Wolf Mountains guard the eastern boundaries of the Crow Indian Reservation, and provide ample grazing lands and excellent habitat for a variety of wildlife (fig. 26). In the present day, the Crow Tribe manages the southern Big Horn Mountains while the U.S. Forest Service manages the northern half. Despite management differences, the entire Big Horn Mountains remain sacred to the Crow.

Three national forests create the major boundaries of the contemporary Crow Indian Reservation. Custer Gallatin, Shoshone, and Bighorn National Forests are responsible for management of land ceded by the Crow, where the Tribe retains treaty rights for hunting and gathering of traditional natural resources. The NPS now protects the Custer National Battlefield, which is surrounded by reservation land and lies just outside Crow Agency. The Bighorn Canyon National Recreation Area is surrounded by reservation lands and was removed from the Crow Indian Reservation by federal condemnation. The Yellowtail Dam, also built on condemned lands, is currently managed by the Bureau of Reclamation.

The Little Bighorn River flows directly through the heart of the Crow Indian Reservation, with its headwaters emanating from the Shoshone National Forest located in the south. The Crow call the Little Bighorn River *Lissaxpuatahcheeaashisee*, which means "The Large Bighorn Sheep River"; this river is deeply embedded in Crow cultural narratives (Bauerle et al. 2002–2012). The Little Bighorn River has carved a dramatic canyon banded by cultural sites



Figure 26—The low-lying Wolf Mountains provide abundant grazing lands and native wildlife habitat (photo: A. Teasdale).

on both sides. The Bighorn National Forest contains a portion of the Bighorn Range, including Cloud Peak Wilderness. The beauty of this sacred Crow landscape was early recognized by the U.S. Government as a valuable natural resource, as the Bighorn National Forest has managed the area as a special primitive area since 1932 until it was designated a "wilderness" through the National Wilderness Preservation System in 1984 (Wyoming Wilderness Act of 1984).

The Crow first obtained horses through a war party headed for the Fat River around 1730 to 1735; the party returned to the Wind River Camp with one animal. At about the same time, horses were obtained from the Great Salt Lake area, according to tribal sources (Medicine Crow 1992). In the Crow cultural story, the horse also arrived through a spiritual channel in a dream. The Crow soon became consummate equestrians and herd managers, supporting a rich cultural lifestyle that allowed significant mobility and economic advantages for both trading and raiding.

Arriving early in the area, the Crow created a great dominion, retaining over 35,000,000 acres (about 141,640 km^2) even after the first Fort Laramie Treaty of 1858. Additional treaties and government policy of forced land cessions eventually reduced the total acreage of the reservation to its present size of approximately 2.3 million acres (9,308 km^2). Life on the reservation has led to new economic pursuits including agriculture, ranching, and economic development initiatives such as building a casino, providing tourism ventures, and coal mining.

Crow Tribe members began to adapt their relations with natural and cultural resources more than 150 years ago, when they lost a lifestyle centered on trading, raiding, and hunting bison, as well as a vast land base in exchange for living on a reservation. They adapted to those

changes by adopting an agricultural and ranching economy. Specific cultural practices and traditional ceremonies and rituals, however, remain important and define Crow cultural life-ways. On the Crow Indian Reservation, adaptation efforts combine long-term observed conditions with cultural and spiritual behavior. Although adaptation typically employs a scientific approach and modern technology, cultural and spiritual values are also incorporated into the management of natural and cultural resources on the reservation. Through combining traditional and Western education in practice, restoration actions may be passive, such as in leaving a forest burn area alone to allow native seeds to sprout and regenerate in the area. In other cases, plants or animals that have disappeared from the ecosystem may be restored to achieve ecological balance. For instance, bison and horses are culturally important animals that remain central to Crow belief systems. Consequently, restoration of bison and horse herds holds a broad range of values—ecological, economic, social, and cultural— for the Crow Tribe.

The Crow process for developing Indigenous knowledge is cumulative and entails an intergenerational process where "teaching about the living environment involved, in part, around oral traditions where stories were passed from generation to generation" (Yarlott 1999, p. 27). These values have been taught among the Crow through exposure to the natural world, for example, by vision quests, and by experiencing the intimate connections between nature, traditional medicine, and ceremony:

> "For our whole history, and even today, young Crow men have gone into the wilderness to fast and pray to First Maker, the giver and author of life, in order to obtain visionary power" (Medicine Crow 2006).
>
> "To the Indian, medicine and religion are closely interwoven and knitted together: one is an integral part of the other, one cannot function without the other" (Medicine Crow 2006).

Threats to human and natural systems have also been expressed in Crow cultural terms:

> "Mother Earth is under serious stress these days, and so are her native peoples" (Medicine Crow 2006).

Restoration practices are derived from "two-eyed seeing" and incorporate Crow knowledge and environmental science (Bartlett 2012; Marshall 2017). In Crow Indigenous knowledge, cultural and natural history are woven together, demonstrating dense connections in the coevolution of Indigenous communities and native ecosystems.

> "To the Crow, the cultural landscape emphasizes the interrelationships between the past and the present, the living and the ancestors, people and the environment, and the spiritual and physical aspects of life…Since Crow people today can still recognize these same physical and spiritual qualities of the landscape, there is a continuing tie between the people and the place and the people who created/named the site, and those who view it today" (McCleary 2000).
>
> "From all the interviews conducted with the Apsáalooke Elders, a sense of why there is a need for interrelatedness of all elements within an environment was visualized" (Yarlott 1999).
>
> "In my youth, an Elder told us that the more you seek to understand the essence of the four basic principles of life—earth, water, fire and air—and how they interact, the more power you acquire" (Medicine Crow 2006).

These long-term intimate relationships have led to a land and water ethic for resilience and sustainability in Crow knowledge, especially in regard to ecosystem services flowing from

riparian, grassland, and forest habitats. Riparian systems provide essential habitat for aquatic and terrestrial animal and plant species, which in the Upper Missouri River Basin have coevolved to respond to spring snowmelt-fed flooding followed by a summer drawdown in river flows. These hydrological patterns have established moist banks and sandbars that promote cottonwood propagation. Plains cottonwood (*Populus deltoides* ssp. *monilifera*) is an ecological keystone species within riverine areas on the Crow Indian Reservation, as well as the center for Crow spiritual connection within riparian ecosystems. From in-person interviews with Crow Knowledge Holders, Crow Elders, and community surveys, 23 different uses of plains cottonwood have been identified (Pretty Paint-Small 2013). The most frequently mentioned parts of the tree were branches and saplings, mainly for use in building roof thatch on shade structures and in the construction of the arbor at the Sundance ceremony (V. Pretty Paint-Small, personal communication in 2019). Details of other ceremonial uses are not mentioned in this publication as this information is protected sacred knowledge that is shared only by Crow Elders and Knowledge Holders. In addition to plains cottonwood, buffaloberry (*Shepherdia argentea*), chokecherry (*Prunus virginiana* var. *melanocarpa*), and lodgepole pine (*Pinus contorta*) are culturally significant plant species and central to the cultural identity of the Crow Tribe. Tobacco (*Lobelia inflata L.*) is another essential plant to the Crow culture, historically cultivated in the hills and at the edge of mountainous areas and specifically used in spiritual ceremonies (Nabakov 1993–1994; V. Pretty Paint-Small, personal communication in 2018). Currently, there are no studies on climate change impacts on wild tobacco on the Crow Reservation.

Results

Restoration of Water Resources

Adaptation

A warming climate in the Upper Missouri River Basin is leading to seasonal changes in precipitation, snowmelt, and evapotranspiration, and to increased water temperatures; the resulting decline of water quality affects riparian ecosystems and water consumption within the Crow Indian Reservation. The Crow Tribe has implemented major adaptation solutions to a water quality crisis in response to water quality research conducted by Montana State University scientists (Cummins et al. 2010; Eggers et al. 2018), which has engaged the LBHC, the Crow Tribe, the Apsaalooke Water and Wastewater Authority, the local Indian Health Service Hospital, and other stakeholders.

A plan for adaptation has started with detecting the environmental particulates that are contributing to the water quality crisis and a measurement of its impacts. Data collected have immediately been recognized as a substantial threat to the health and cultural lifeways of the communities within the Crow Reservation, prompting short-term interventions to counteract loss of clean water for drinking, ceremonies, and other cultural uses. This recognition of "red flag" conditions in water resources occurred when Crow Elders observed abnormal location and health of aquatic life. Such observations, along with knowledge of river contamination, have caused families to discontinue traditional uses of freshwater resources (J.T. Doyle, personal communication in 2010; Doyle et al. 2013):

> "Further, Elders have noted freshwater mussel and frog populations have declined and awareness of contamination due to climate change caused some families to give up subsistence fishing" (J.T. Doyle, personal communication in 2010).
>
> "We see fish and turtles under stress in ways we never used to see: the freshwater mussels are disappearing" (Doyle et al. 2016).

Both Crow Elders and tribal members in general have also noted seasonal changes in precipitation and evapotranspiration from reduced snowpack and streamflows:

> "In every District of the Reservation, there isn't nearly as much snow as 50 years ago. The ground used to be snow-covered winter long" (Doyle et al. 2016).
>
> "Spring ice break-up on the rivers used to be a dramatic event, and now the winter river ice is thinner and just melts quietly away" (Doyle et al. 2016).
>
> "Summer heat has changed, became much more intense." (Doyle et al. 2016).
>
> "A locally important mountain stream has been steadily moving down-slope, causing concern that the water table has been dropping due to reduced snowfall (J.T. Doyle, personal communication in 2017).

To address community concerns of reduced water quality and flow, a testing program sponsored by the U.S. Environmental Protection Agency has been implemented to monitor water quality in residential wells on the reservation. Testing results demonstrate that 29 percent of all wells (n = 189) were highly contaminated in 2015 (Eggers et al. 2015). With one-third of the households on the Crow Reservation having incomes below $25,000 that same year (MSU Extension 2017), expensive water cleaning and water softener equipment, along with continuing maintenance, were not a viable adaptive strategy for the reservation. Short-term adaptive measures that were more affordable include placing water coolers in homes for personal drinking water and providing education on the dangers of drinking contaminated water.

Reweaving

Traditional phenological knowledge about weather effects on the hydrological cycle have lined up with the results contributed by the team of scientists, to describe the extent of the impacts from climate change disturbance in the hydric regime of the Bighorn River Basin (Doyle et al. 2016, 2018). Traditional and cultural statements on water quality and accessibility provide supplementary benchmarks for understanding recent changes in this resource. Importantly, comparing past descriptions with current observations helps describe differences between the current state of the environment and the preferred historical conditions in places of the Upper Missouri River Basin. Crow Chief Eelapuash (or Arapooish) provided one such benchmark in the 1830s (italics not in the original):

> "The Crow Country is in exactly the right place. It has snowy mountains and sunny plains: all kinds of climates and good things for every season. When the summer heats scorch the prairies, you can draw up under the mountains, where the air is sweet and cool, and the *grass fresh*, and the bright streams come tumbling out of the *snow banks* … everything good is to be found here" (Yarlott 1999).

Preferred conditions of water resources on the reservation are also demonstrated in recent statements from Crow Elders on the importance and sacredness of water. Doyle et al. (2013) referenced a presentation by Knows His Gun McCormick:

> "Water is one of the most important natural resources to the Crow community and has always been held in high respect among tribal members. River and spring waters are still used in many ceremonies" (p. 2, 3).
>
> Other recent indications of the importance of water to Crow people include:
>
> "Our country is neither too hot in summer, nor too cold in winter. It has beautiful mountains and many lakes and rivers filled with clear, cold water" (Medicine Crow 2006).
>
> "Our way of governing, our way of teaching, our love for each other came from that River corridor…that is our stories, we come out of the water" (Armatas et al. 2014).

These ethnographic observations of reduced snowpack and declining water levels are consistent with the data compiled in the National Climate Assessment (NCA4) (Reidmiller et al. 2018), as well as with decadal water discharge averages measured at the Little Bighorn River gauging stations, U.S. Geological Survey streamflow data, and local data for snowfall and mean temperatures (Doyle et al. 2013). These observations present a broader and culturally richer picture of the current impacts of climate change on the Crow Reservation.

Restoration

Reweaving of scientific results and Indigenous knowledge has served as a guidepost to develop a more socially oriented planning for the restoration of water resources. The Crow tribal government recognized both the scale of addressing this problem and the extent of expenses incurred (Kaljur and Beheler 2017). Eventually, leaking wastewater and pipe infrastructure failures were fixed after contributions from 14 loans and grants (V. Pretty Paint-Small, personal communication in 2018). Such efforts present a challenge to the Crow Tribe due to the multiple federal, state, and local agencies and commissions that are involved in setting policy for water that flows through the Crow Indian Reservation, and the measures implemented should be viewed as a long-term solution. Jurisdictional claims, ongoing litigation on water management, lack of water quality research, and the need for community engagement add to the complexity of adequately prescribing effective restoration strategies (Doyle et al. 2018). In addition, restoration may fail when it lacks social support, its objectives are not well understood by the community, or sectors of the public are not engaged in the preservation of restored actions, factors that can be addressed by providing residents and other users with education in restoration science and opportunities to proactively participate in the restoration strategy. Water diversions for agricultural use must be addressed as well, in order to allow some of the electric plant operations of the Yellowtail Dam to be returned to the Crow Tribe. The future may hold further opportunities for the Crow Tribe to apply restoration actions in the hydrological system at a larger scale, once the tribal administration obtains some measure of control over water flows.

Resilience

Experiences learned in the prior efforts for adaptation, reweaving, and restoration shed light on factors that could help build a more resilient system in the conservation and use of water resources. By a continued monitoring of conditions, collaboration with multiple partners, namely, the Crow Tribe, academia, and federal agencies, and combining Indigenous phenological knowledge with scientific research, resolutions to help solve the problem of

polluted drinking water were implemented. The need to monitor and maintain water quality are critical steps for tribal survival and are clearly stated by Indigenous Knowledge Holders and Crow Elders as a cautionary tale: “Treat water with respect, it gives life. It can also take life” (Grant Bulltail, quoted in Nabakov 1993–1994, p. 64) (fig. 27). The Crow Tribe has lived in the Upper Missouri River Basin and maintained its cultural heritage through intimate relationships with the natural surroundings for many generations. Crow knowledge points to climate change impacts that go beyond evidence from monitoring of biophysical indicators. Doyle et al. (2016) reported that Native American and other communities with substantial subsistence activities and traditional uses of river water are at particular risk from climate change and have greater adaptation challenges.



Figure 27—The Bighorn River flows through the Crow Indian Reservation (photo: A. Teasdale).

The high value placed on water suggests changes in agricultural technology could bring agricultural values closer to tribal values. Encouraging best practices in farming and ranching and improved water delivery systems, low tilling, soil testing and storage, and collection areas for feedlots are needed for good management.

Adaptation

The importance of mountains and forest resources is repeatedly discussed by Crow Elders as a priority to sustain surface water flows, secure the Crow traditional food system, and preserve cultural lifeways:

> "The mountain gave us a good life, protect the waters. When the snow up on the mountain melts, it gives water, down the creek into the valleys, you know, they need the water too (Pius Real Bird, quoted in Nabakov 1993–1994).
>
> "…they reserved these mountains for fasting places…good clean air, clear out the lungs. Fasting places, places to get teepee poles, good water, no pollution…There's endless things from the mountains that serve human beings. We want to preserve the mountains for that purposes…we don't want to commercialize our mountains, we love our mountains" (Pius Real Bird, quoted in Nabakov 1993-1994).

Crow cultural uses of forest resources include the gathering of lodgepole pine tipi poles and the gathering of pine saplings to surround the Sundance arbor when ceremonies are held in the Wolf and Bighorn Mountains. Crow Elders and Sundance chiefs have indicated that they must travel farther now than in earlier times to acquire lodgepole pine wood for tipi poles:

> "…we have to pay to get teepee poles…Crazy Mountains…where there is a Forest Lookout Station" (Grant Bulltail, quoted in Nabakov 1993–1994).

In recent years, the Crow Tribe has built up a bison herd and continued traditional hunting of elk, deer, and other wildlife, complemented with gathering of traditional plant medicines and foods. Tribal members continue to speak out, and have been alerting people of the changing conditions of existing species and impacts of climate change on migration patterns over the last decades.

In Doyle et al. (2016) interviewees reported that various fish species had moved upriver; these interviewees suspected climate change was causing or contributing to this change. Other specific examples include the following:

> "Human activities such as cultivation and industry caused changes in the patterns of the ecosystem and changed the migratory patterns of some animals and plants… animals migrating…raccoons" (Joseph Medicine Crow, quoted in Nabakov 1993–1994, p. 119).
>
> "…strange animals seen…javalinas, kangaroo mouse" (Ty Tenbear, quoted in Nabakov 1993-1994, p. 5).
>
> "Some of the birds are gone. Owls are gone. Some small birds there are no more… these birds spread seed…the birds are gone, the plants are gone" (Bullkill, quoted in Yarlott 1999).

Reweaving

Crow traditional phenological knowledge stretches across generations to interconnect past and present observations of wildlife in the Upper Missouri River Basin. By comparing the current state of wildlife with its historical description, gaps and changes in the present-day structure of ecosystems can be described in tandem with regional research on climate changes impacts on wildlife. This approach helps identify such ecosystem services at risk as those

related to diet, health, religion, and cultural identity. In one of the oldest written sources of Crow Indigenous knowledge, Chief Eelapuash said around 1830 (as cited in The Adventures of Captain Bonneville, U.S.A., in the Rocky Mountains and the Far West, by Washington Irving, 1837) that the Crow country "has snowy mountains and sunny plains…There you can hunt the elk, the deer and the antelope…there you will find plenty of white bears and mountain sheep. In the autumn, when your horses are fat and strong from the mountain pastures, you can go down to the plains and hunt the buffalo, or trap beaver on the streams. And when the winter comes, you can take shelter in the woody bottoms along the rivers" (Bauerle et al. 2002–2012).

Chief Eelapuash's observations help define seasonal benchmarks that reflect desired ecological conditions for the Crow Tribe, both in the historical past and at present. Such desired conditions have been disturbed in industrial times, according to both Elders' Indigenous knowledge and scientific fieldwork. The 2012 fire season was the worst in living memory; it left blistered ground that caused concern for the return of forage for deer and elk important to subsistence hunting (Doyle et al. 2016). Although scientific results are not conclusive on this subject, forest policy has historically favored timber harvest as a fuels treatment, whereas forestry science suggests more nuanced, place-based responses. Indigenous forest management tends to avoid large-scale timber harvests and apply more holistic approaches, which prioritize combinations of management-ignited fire treatments with small-scale mechanical treatments. In a place-based study of preferences for fire management on the Flathead Indian Reservation, Watson et al. (2013) found that many tribal members were fearful of the catastrophic potential for any type of fire from any source and preferred more frequent, less intense fires and labor-intensive forestry practices with minimum impacts to the forest. Efficiency and revenue production were seen as incompatible objectives within a controversial buffer management zone managed by the Confederated Salish and Kootenai Tribes.

Restoration

For the conservation of both flora and fauna, Crow Elders have pointed to mountain formations, foothills, and elevated areas as important biotopes to be included in restoration planning, with a prioritization of areas that include riparian and meadow habitats. Among the restoration programs that the Crow Tribe supports on a permanent basis is a herd of bison (Montana Fish, Wildlife and Parks 2015). The herd is managed on one of the only suitable tribally controlled areas of the Crow Indian Reservation, in a sky prairie (elevated grassland) above two gorges in the Bighorn Mountain Range. Protection of the highest elevations and surrounding hills has been identified as key for wildlife restoration, particularly on the ceded lands that are currently under federal control. Crow interviewees have placed a strong emphasis on such geographical features for objectives of cultural subsistence and resilience. Conservation zoning in such ceded areas has provided high-elevation lands with a greater degree of protection against human overuse:

> "Mountain areas are the only things that are pretty much the way they used to be" (Euna Rose He Does It, 1993, quoted in Reed 2007).

Members of the Crow Tribe have consistently suggested reducing recreational impacts and preserving mountainous and forest habitats are pressing objectives in resisting climate change-induced disturbance. Further, use of off-highway vehicles (OHVs) on federal lands is often in conflict with Crow religious and cultural values. Comments from Crow members on

the recent Custer Gallatin Forest Plan revision indicate the Tribe's concern for the ecological integrity of these higher elevation areas, especially the sky prairies, owing to their importance for grazing livestock and the presence of sacred plant species for cultural uses. The Pryor Mountains are emphasized in a number of interviews with Elders and Knowledge Holders as a special area for ceremonial use (e.g., vision quests), religious practice, and gathering of traditional native foods and medicines (Grant Bulltail, Wilson Lincoln, Carson Walks Over Ice, Ty Ten Bear, Lillian Hogan, quoted in Nabakov 1993–1994; Snell 2006). Use of OHVs is in direct conflict with these traditional uses, as Crow Elders and the Apsáalooke Cultural Committee Chairman George Reed, Jr. have stated in representation of the Crow Tribe for the case of the Pryor Mountains:

> "The whole Pryor, Arrow Shot Into Rock, Mountain is sacred…is a sanctuary for individuals who venture off on fasting quests…Motorized vehicles are threatening the sacredness, solitude and pollution free atmosphere…the last of the sacred places where individuals go for guidance and prayer…" (Reed 2007).

Crow Elder Burton Pretty On Top has suggested a covenant to ensure respectful use of cultural areas, based on placing restrictions on any recreational use in those places, especially on motorized traffic (Pryors Coalition 2014).

Pastures and grasslands are priority ecological systems in adaptation and reweaving efforts. These ecosystems form the foundation for subsistence hunting, ranching, and grazing. For the Crow Tribe, this is particularly significant due to the importance of nutritious grass in supporting horse populations:

> "Once ideal for buffalo pastures, today our pastures nourish horses that remain such an important part of Crow life as well as vast herds of beef cattle that graze where buffalo once roamed…Our country is neither too hot in summer, or too cold in winter. It has beautiful mountains and many lakes and rivers filled with cold, clear water" (Medicine Crow 2006).

Climate-related changes in seasonal growth of C3 grasses (perennial plants adapted to cool seasons) in combination with increased drought frequency, wildfires, and seasonal changes in precipitation have substantially impacted grass species that are key to proper equine health. This puts the sustainability of livestock and horse ranching operations at risk. The wild horses of the Pryor Mountain Wild Horse Range are a living testimony of American history, as descendants of the Barb horses brought to the Great Plains by the Spanish and the historical war and trail horses of the Crow (Pomeranz 2006). The increasing popularity of the Annual Crow Fair (held every third weekend in August) and traditional Plains-style team horse racing helps to maintain continuity with older customs such as parading and the Crow rodeo. These events provide both social and economic benefits (especially for the youth in Crow communities) and underline the importance of the grasslands on which the Tribe's horse populations depend (fig. 28).



Figure 28—The continuance of Crow Fair, parades, and other Crow cultural activities draws attention to the importance of horses and the grasslands that support them. Oglala Sioux artist Colleen Cutschall (alias Sister Wolf) designed this dramatic sculpture for the Indian Memorial at Little Bighorn Battlefield National Monument (photo: A. Teasdale).

Resilience

Several principles emerge from the knowledge shared by Crow Elders about montane ecosystems and grasslands, which follows an ecosystems management approach in the restoration of natural and cultural resources. Most wild berries are highly valued subsistence foods among the Crow people, and yet are likewise important to bears, birds, and small mammals, establishing strong links in the natural food chain of the Upper Missouri River Basin. Likewise, restoring native bird species is intimately connected to spreading the seeds of native plants and vice versa—for example, the mutualistic relationship between Clark's nutcracker (*Nucifraga columbiana*) and whitebark pine (*Pinus albicaulis*). However, because most of the land on the Crow Indian Reservation is used for agricultural production, forest and grassland restoration is limited within Crow tribal jurisdiction. Alternatively, Crow interviewees have placed emphasis on restoring wildlands in the federally managed lands that surround the Crow Indian Reservation, as pointed out previously.

Adaptation

Dependent on wind-blown seeds with low survival rates, successful establishment of plains cottonwood on the Crow Indian Reservation requires moist soil substrates, which get scoured seasonally by spring flooding. Regulation of the Bighorn River since the mid-20th century, however, has removed the natural flood pulse from this hydrological system (Pretty Paint-Small 2013). Many of the native plant species within riparian systems on the Crow Reservation have become scarce owing to this regulation but also to climate-induced factors. Both in earlier and in more recent interviews, Crow Elders have noted a decline of cottonwoods that is connected to both changes in flooding patterns (Doyle et al. 2016; Nabakov 1993–1994) and the spread of the invasive Russian olive (*Elaeagnus angustifolia*) (fig. 29) (Pretty Paint-Small 2013).



Figure 29—A band of invasive Russian olive trees crowds out willow and cottonwood along the Bighorn River on the Crow Indian Reservation (photo: A. Teasdale).

This shrub species was introduced into the United States in the late 19th century for commercial cultivation, but it soon expanded over natural areas as birds dispersed its seeds. Russian olive can grow on poor soils, mortality rates of seedlings are low, and it matures fairly quickly, slowly displacing and replacing less resistant species such as the plains cottonwood and hindering access to berries and roots (Pretty Paint-Small 2013). Russian olive thereby threatens the ecological and cultural integrity of the native ecosystems and the security of the traditional food systems associated with them (fig. 30).



Figure 30—The moon reflects on the Bighorn River which is lined with invasive Russian olive trees. Photo by Aaron Tesdale.

In the face of these threats, Crow Elders have drawn attention to a "continued decline in availability to harvest specific size classes of cottonwood for ceremonial purposes" (Pretty Paint-Small 2013). Declining presence of other culturally significant plants, such as wild carrot (*Daucus carota*), bitterroot (*Lewisia rediviva*), and buffaloberry, has been observed as well (Doyle et al. 2016; Nabakov 1993–1994; Pretty Paint-Small 2013; Snell 2006). Altogether, it has increased the perception of loss among Crow Elders and Knowledge Holders:

> "We are running out of trees, basically" (Pretty Paint-Small 2013, p. 15).
> "My father died at 85…'Today,' he said, 'most of the plants used before are gone… the plants roots like potato black…a plant called footsore…large onion…wolf finger… most plants they use for healing don't grow anymore…' Buffalo don't eat…there is no more around here" (Grant Bulltail, quoted in Yarlott 1999).

Witnessing this loss of native plant species, the Crow people make observations that may support the previously mentioned connection between plant loss and reduced diversity of native birds or a change in seasonality patterns (or both):

> "green grass and flowers are about a month and a half behind" (Joseph Medicine Crow, quoted in Nabakov 1993–1994, p. 93).
>
> "Buffalo berries were traditionally harvested after the first frost, as freezing sweetened the berries. Now buffalo berries are dried out before the first frost hits, so are no longer worth gathering" (L. Medicine Horse, quoted in Doyle et al. 2013).

Decline of buffaloberry and chokecherry could be associated with changes in seasonal temperature trends and surface water flows. Field observations indicate that chokecherry buds are experiencing an early frost due to the disrupted thaw and freeze weather patterns now occurring in early spring, which is resulting in smaller harvests in the late summer and early fall (Snell 2006). Buffaloberries are gathered later in the year after the first fall frost, but have been observed to be too dried out for use as a consequence of increased summer heat. Gooseberries are drying up as well (Snell 2006). Generally, berry species are fruiting earlier, often leading to desiccation due to premature ripening. Moreover, early flowering coupled with later frost in spring kills the flowers, disrupting the regenerative cycle of these berries (Doyle et al. 2016).

Additionally, changes in water policy and management are suggested by the interviewed Crow Elders:

> "If they are going to lower the water, we have less water for the plants and, so, that causes a shortness of growth for our natural plants that we use culturally" (Armatas 2012).

All of the above sources highlight a significant degradation of riparian ecosystems on the Crow Reservation and represent a departure from the desired historical conditions previously observed by Crow Elders.

Reweaving

Up-to-date research on the impacts of climate change on riparian habitats of the Crow Indian Reservation is needed. A tribally informed invasive species management plan could guide identification of vulnerable sites in the Upper Missouri River Basin, and assist Government-to-Tribal-Government partnerships to restore areas with interests shared by the Crow Tribe and the federal government, such as ceded lands and reservation borderlines.

Restoration

Riparian restoration is desirable to the Crow by removal of Russian olive, particularly downstream from dams and at the confluence of the Bighorn and Little Bighorn Rivers. Such mitigation efforts, however, would require extensive treatments to remove large areas of dense thickets along the river basins. Herbicide use is problematic in controlling Russian olive, as glyphosates would directly affect surface water quality. Mechanical removal is the preferred method, but it would be a complicated process due to the fractionated land base of private owners along the river systems. Hand crews would be preferable to prevent seep, although cottonwood restoration could benefit from planting saplings on newly created buffer zones along the rivers. Hand crews consisting of Crow tribal natural resource personnel, college

students and K–12 students could provide an opportunity for environmental youth-in-action education. In addition, identifying Russian olive seedlings that tend to sprout after dredging floodplain irrigation canals could prevent populations downstream from becoming a monocultural ecosystem (Conant et al. 2018; Pretty Paint-Small 2013).

Resilience

Impacts of invasive species on native ecosystems have been well observed in the Bighorn and Little Bighorn River Basins over the last 30 years, as previously described. These impacts, coupled with artificial alteration of the river levels since the early 20th century, are exposing riparian ecosystems and human populations dependent on them to sources of disturbance that are not clearly represented in the place-based knowledge of the Crow Tribe —which has roots in ancestral conditions and natural environmental dynamics. Improving access of riparian ecosystems to suitable water sources, along with restoration of these habitats to historical conditions and implementation of a tribally informed invasive species management plan, could make an effective strategy for long-term protection of health of riparian areas in sustainable ways. In sum, scientific principles and modern technology could be leveraged to replicate the natural processes that evolved under historical conditions. Reconfiguring the current irrigation system to provide river basins with water in suitable conditions for native ecosystems, and eradication of invasive species such as the Russian olive would be large-scale measures pointing in that direction.

Lessons Learned From Phase 2B

Water pollution and loss of access to culturally significant plants and animals due to climate change is affecting tribal health and well-being on the Crow Indian Reservation. Likewise, it is impacting legally protected treaty rights and cultural and religious rights of the Crow Tribe on federal lands. The corollary gained from Crow responses to climate change disturbance effects is that knowledge of desired states, as described by Crow Elders, is a preliminary scoping step to inform building of resilient human and natural systems through adaptation, reweaving, and restoration strategies. All in all, it underlines the value of the role played by Knowledge Holders in guiding these efforts (Pretty Paint-Small 2013). A second corollary forms around the notion that knowledge gained from long-term, intimate relationships between human communities and the wider Earth system can support enduring resistance to climate dynamics and sustainable management of natural and cultural resources.

Conclusions: Reweaving Indigenous Principles for Restoration in the Upper Missouri River Basin

Our meta-analysis suggests culturally important evaluation criteria for restoration of natural and cultural values in the face of increasingly warming conditions. Results of the Crow case study highlights the ethical and scientific need for implementing management policies in the Upper Missouri River Basin that incorporate the traditional values of the Crow Tribe. An examination of Crow sources between 1993 and 2017 reveals a cycle of observation, understanding, and action among Crow Elders and Knowledge Holders, which facilitates moving from resilience to climate change and land-use impacts to resistance to future impacts in a region with multiple overlapping jurisdictions. These impacts have relationships to previous historical vulnerabilities that increase sustainability risks and conservation risks for Crow people. As the Upper Missouri River Basin continues to undergo extreme weather events and a warming long-term trend, place-based knowledge and the cultural context of local communities will be needed in addressing sound land management at the local level. Learning from this meta-analysis of Crow knowledge, we have identified a series of potential management principles that show meeting points between Crow Indigenous thinking and systems ecological science. These principles can be used for restoration of natural and cultural resources in the Upper Missouri River Basin and similar geographies, given the historical role of the Crow Tribe in the evolution of ecosystems in the Northern Great Plains.

Culturally Informed Restoration Principles

1. Long-term intimate relationships with the environment lead to a land ethic that promotes sustainability efforts and resilience. These relationships extend across all jurisdictions and legislative designations.
2. Successful restoration practices take into consideration the connectedness of species and biotopes within the environment and cultural context.
3. Long-term commitment to adaptive measures is needed for resistance to future impacts. These efforts, however, may take longer on reservations due to limited funding sources.
4. Indigenous knowledge is place-based knowledge, and should be taken into account for sound, place-based management of resources. Indigenous Peoples observe the impacts of climate change from cultural and behavioral perspectives, besides scientific monitoring.
5. Indigenous knowledge and environmental science are necessary to understand, anticipate, and plan how Indigenous communities can successfully tackle the impacts of climate change.
6. Two-eyed seeing of Indigenous knowledge and science is required to inform management of issues related to water quality from a holistic and culturally aware perspective.
7. Protection of higher elevation (montane) areas should be prioritized in the Upper Missouri River Basin, including ceded lands under federal control. These lands tend to have a lesser degree of human-caused disturbance and are highly valued due to traditional subsistence and cultural practices.

8. Relevant science and long-term Indigenous knowledge about forests lead to greater insight and provide a useful guide in applying treatments to reduce wildfire severity (fig. 31).
9. Elevated grasslands are important to grazing animals, plant species, and ceremonial use, so recreational use of off-highway vehicles should not be allowed to alter these habitats.
10. On the Crow Indian Reservation, priority should be placed on riparian species, especially on cottonwoods as they are a key species for ecological and cultural function in the riverine woodlands that are adjacent to areas where most of the Crow members reside.
11. Restoration of the cultural landscape is critical to preserving Indigenous knowledge and customs.



Figure 31—Fuel treatments on cultural landscapes should be guided by a combination of science and long-term experiences with the place. A prescribed fire conducted by the Crow Tribe in 2017. Photo by Aaron Teasdale.

Although the findings of the Crow case study are limited to the interviews that were available for analysis, the depth of understanding and knowledge transmitted through the Elders' responses leads to important principles for managing and monitoring the impacts of climate change. In some cases, the tendency of interviewees to stress the need for greater protection, especially in higher elevations and sacred site areas, suggests the possibility of collaboration with the Forest Service through adjacent national forests, the Bureau of Land Management, and the National Park Service. Existing and potential wilderness designation seems highly compatible with these needs due to emphasis in wilderness upon "intact

ecosystems and nature restoration" (Watson et al. 2003). Further research is needed to identify and plan for potential impacts of climate change on culturally significant species and landforms in the Upper Missouri River Basin, particularly plants such as cottonwood in the basin and tobacco in the foothills.

Management of forested watersheds is of critical importance to meet tribal and federal agency goals, such as reduction of high-intensity wildfire risk and the protection of threatened and heavily impacted culturally important species within these areas. The Crow Tribe prefers projects where its members are full partners and share leadership in the gathering of that knowledge for the management of natural and cultural resources. It is hoped that future partnerships will continue knowledge exchange for the benefit of resilient communities.

Final Lessons Learned and Management Implications

The primary purpose of this report was to understand and promote sustainability of mixed-ownership federal lands and tribal lands by applying culturally informed restoration principles to achieve environmental and cultural resistance to future impacts. However, sustainability has multiple meanings, relative to purpose and culture. In reviewing the stated purposes in protecting resources against threats on public lands managed by the Bureau of Land Management, the National Park Service, and the Forest Service, it is apparent that within the same geographical area and ecological landscape, sustainability is defined differently through legislative history and policy. Resistance to impacts on sustainability may require different perspectives for protection and restoration strategies. Through an assessment of Indigenous knowledge of the Crow people who live adjacent to these federally managed lands, it becomes apparent that sustainability can also be defined in terms of a cultural value system. The threat to sustainability from not including this cultural perspective has not been adequately recognized locally or regionally in the Northern Great Plains.

Federal agencies include lands that were formerly ceded by the Crow people to the federal government through treaties or federal condemnation or other federal processes, and should be stewarded in a way that acknowledges and values their inherent knowledge about those land and water resources. This assessment revealed several principles that land managers should consider when planning and before making management decisions. A useful exercise to achieve this goal might be to include these principles, or even a subset of these principles, in personnel performance planning for managers of these land areas. Task-oriented objectives targeting some of these principles in restoration and general management could contribute to positive relations between these agencies and tribal communities and leaders. Such objectives could also contribute substantially to achieving resilience goals on public lands.

Many questions remain unanswered. First, the literature suggests that innovativeness and high-risk behavior connected to climate change adaptation are influenced by proximity of the actor to the effects of climate change. While the research on this topic does not currently identify any specific cultural influences, the postulate of this report is that Indigenous knowledge of past adaptations creates proximity and trust through establishing principles developed from this project (fig. 32). What science may categorize as “innovative” may have strong roots within Indigenous knowledge. Some managers may consider some of the principles of restoration included in this report as risky. They may consider them a greater risk than would people who often rely on accumulated knowledge across generations. However, these principles may actually reduce risk from lack of long-term knowledge and observations contained in place-based knowledge.

While Indigenous knowledge seems to focus heavily on sociological proximity to climate change- related events and tested solutions, psychological proximity may be promoted through trust in this historically place-based accumulated knowledge. Research that includes diverse cultural frameworks shows a range of attitudes as well as behaviors connected to climate change adaptation. Likewise, additional research into the concept of cross-cultural innovativeness and evaluations of risk, and how this concept is related to Indigenous knowledge or the application of that knowledge, is an important question, although unresolved by this report. For instance, if climate change is a threat to environmental and cultural sustainability, how can one shorten psychological distance and therefore heighten concern through applying an Indigenous knowledge framework, such as the protective shield frame-

work? This question can be applied equally to public and tribal lands, and calls for additional research.



Figure 32—If climate change is the largest threat to environmental and cultural sustainability, what are the ways to shorten psychological distance and therefore increase concern through application of Indigenous Knowledge and Western science? In the image, a pile of bison skulls on the Crow Indian Reservation near the Little Bighorn Battlefield National Monument (photo: A. Teasdale).

References

Ackoff, R. 1989. From data to wisdom. Journal of Applied Systems Analysis. 16: 3–9.

An Act to provide for the allotment of lands in severalty to Indians on the various reservations, and to extend the protection of the laws of the United States and the Territories over the Indians, and for other purposes [General Allotment Act]. Pub.L. 49–105. (February 8, 1887)

An Act to provide for the establishment of the Bighorn Canyon National Recreation Area, and for other purposes. Pub.L. 89-664. (Oct. 15, 1966)

Adger, W.N.; Dessai, S.; Goulden, M.; [et al.]. 2009. Are there social limits to adaptation to climate change? Climate Change 93(3–4): 335–354.

André, K.; Jonsson, C.A. 2015. Science-practice interactions linked to climate adaptation in two contexts: Municipal planning and forestry in Sweden. Journal of Environmental Planning and Management. 58(2): 297–314. doi: 10.1080/09640568.2013.854717.

Anse, H.; Sagar Chapagain, P.; Tiwari, P.C. 2013. Innovation as an expression of adaptive capacity to change in Himalayan farming. Mountain Research and Development. 33(1): 4–10.

Armatas, C.A. 2012. The importance of water-based ecosystem services derived from the Shoshone National Forest. Missoula, MT: University of Montana. M.S. thesis. https://scholarworks.umt.edu/etd/1025/ [Accessed December 23, 2018].

Armatas, C.A.; Venn, T.J.; McBride, B.B.; [et al.]. 2016. Opportunities to utilize traditional phenological knowledge to support adaptive management of social-ecological systems vulnerable to changes in climate and fire regimes. Ecology and Society. 21(1): 16. doi: 10.5751/ES-07905-210116.

Armatas, C.A.; Venn, T.J.; Watson, A.E. 2014. Applying Q-methodology to select and define attributes for non-market valuation: A case study from Northwest Wyoming, United States. Ecological Economics. 107: 447–456.

Atkins, S.; Lewin, S.; Smith, H.; [et al.]. 2008. Conducting a meta-ethnography of qualitative literature: Lessons learnt. BMC Medical Research Methodology. 8: 21. doi: 10.1186/1471-2288-8-21

Aylward, B.; Allen, K.; Echeverría, J.; [et al.]. 1996. Sustainable ecotourism in Costa Rica: The Monteverde Cloud Forest Preserve. Biodiversity & Conservation. 5(3): 315–343. doi: 10.1007/BF00051777.

Baptiste, B.; Pacheco, D.; Carneiro da Cunha, M.; [et al.], eds. 2017. Knowing our lands and resources: Indigenous and local knowledge of biodiversity and ecosystem services in the Americas. Knowledges of Nature 11. Paris, France: UNESCO.

Barnhardt, R.; Kawagley, A.O., eds. 2010. Alaska Native education: Views from within. Fairbanks, AK: University of Alaska Fairbanks, Center for Cross-Cultural Studies, Alaska Native Knowledge Network.

Bartlett, C. 2012. The gift of multiple perspectives in scholarship. University Affairs. 53(3): 41. https://www.universityaffairs.ca/opinion/in-my-opinion/the-gift-of-multiple-perspectives-in-scholarship/ [Accessed December 9, 2019].

Bauerle, P.; Bell, C.; Brien, L.; [et al.]. 2002–2012. Apsaaloke Writing Tribal Histories Project. Crow Agency, MT: Little Big Horn College. http://lib.lbhc.edu/index.php?q=node/17 [Accessed December 5, 2018].

Bennett, N.J. 2016. Using perceptions as evidence to improve conservation and environmental management. Conservation Biology. 30: 582–592.

Bentz, B.J.; Logan, J.A; Amman, G.D. 1991. Temperature-dependent development of the mountain pine beetle (Coleoptera: Scolytidae) and simulation of its phenology. The Canadian Entomologist. 123: 1083–1094.
Black, M.; Chief, K.; Jacobs, K.; [et al.]. 2015. Tribal leaders summit on climate change: A focus on climate adaptation planning and implementation; Nov. 12–13, 2015; Tucson, AZ. Tucson, AZ: University of Arizona, Native Nations Climate Adaptation Program. 159 p. https://www.nncap.arizona.edu/sites/default/files/NNCAPSummitFinal.pdf [Accessed December 9, 2019].
Boelens, R.; Chiba, M.; Nakashima, D. 2006. Water and Indigenous Peoples, knowledges of nature 2. Paris, France: UNESCO.
Brand, F.S.; Jax, K. 2007. Focusing the meaning(s) of resilience: Resilience as a descriptive concept and a boundary object. Ecology and Society. 12(1): 23. doi: 10.5751/es-02029-120123.
Bureau of Indian Affairs and Confederated Salish and Kootenai Tribes [BIA and CSKT]. 1999. Flathead Indian Reservation Forest Management Plan: Final Environmental Impact Statement. Pablo, MT: Confederated Salish and Kootenai Tribes.
Burke, M.L.; Emerick, K. 2016. Adaptation to climate change: Evidence from U.S. agriculture. American Economic Journal: Economic Policy. 8(3): 106–140.
Cajete, G., 2000. Native science: Natural laws of interdependence. Santa Fe, NM: Clear Light Publisher. 327 p.
Carpenter, S.; Walker, B.; Anderies, J.M.; [et al.]. 2001. From metaphor to measurement: Resilience of what to what? Ecosystems. 4(8): 765–781.
Carver, S.; Watson, A.; Waters, T.; [et al.]. 2009. Developing computer-based participatory approaches to mapping landscape values for landscape and resource management. In: Geertman, S.; Stillwell, J., eds. Planning support systems: Best practice and new methods. New York, NY: Springer: 431–448.
Chapman, F. 2019. Medicine Wheel/Medicine Mountain: Celebrated and controversial landmark. WyoHistory.org: A project of the Wyoming State Historical Society. https://www.wyohistory.org/encyclopedia/medicine-wheel [Accessed June 12, 2019]
Checkland, P.; Poulter, J. 2006. Learning for action: A short definitive account of Soft Systems Methodology and its use for practitioners. Chichester, UK: John Wiley and Sons.
Chryst, B.; Marlon, J.; van der Linden, S.; [et al.]. 2018. Global warming's "Six Americas Short Survey": Audience segmentation of climate change views using a four question instrument. Environmental Communication. 12(8): 1109–1122. doi: 10.1080/17524032.2018.1508047.
Climate Change and Traditional Knowledges Workgroup. 2014. Guidelines for considering Traditional Knowledges in climate change initiatives. Chartered by the DOI Advisory Committee on Climate Change and Natural Resource Science. http://climatetkw.wordpress.com [Accessed December 12, 2018].
Colorado College. 2019. Conservation in the West poll. Colorado College, State of the Rockies Project. https://www.coloradocollege.edu/stateoftherockies/conservationinthewest/ [Accessed March 24, 2019].
Conant, R.T.; Kluck, D.; Anderson, M.; [et al.]. 2018: Northern Great Plains. In: Reidmiller, D.R.; Avery, C.W.; Easterling, D.R.; [et al.], eds. Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington, DC: U.S. Global Change Research Program. doi: 10.7930/NCA4.2018.CH22.

Confederated Salish and Kootenai Tribes [CSKT]. 2000. Flathead Indian Reservation Forest Management Plan. Pablo, MT: Confederated Salish and Kootenai Tribes.
Confederated Salish and Kootenai Tribes [CSKT]. 2013. Climate change strategic plan. Pablo, MT: Confederated Salish and Kootenai Tribes. http://www.csktribes.org/CSKTClimatePlan.pdf [Accessed December 12, 2019]
Cummins, C.; Doyle, J.; Kindness, L.; [et al.]. 2010. Community-based participatory research in Indian Country: Improving health through water quality research and awareness. Family & Community Health. 33(3): 166–174. doi: 10.1097/FCH.0b013e3181e4bcd8.
Dawes Act. 1887. 24 Stat. 388, ch. 119, 25 USCA 331. (Feb 8, 1887). https://uscode.house.gov/statviewer.htm?volume=24&page=388 [Accessed December 3, 2019].
Dean Runyan Associates. 2017. Nebraska travel impacts, 2003-2016P. Prepared for Nebraska Tourism Commission. http://www.deanrunyan.com/doc_library/NEImp.pdf [Accessed March 24, 2019].
Dean Runyan Associates. 2018. Wyoming Travel Impacts, 2004 - 2017. Wyoming Office of Tourism, Government of Wyoming. https://www.travelwyoming.com/sites/default/files/uploads/industry/State%20and%20County%20Economic%20Impact%20Report%202017.pdf [Accessed March 24, 2019].
DeBlander, L.T. 2001. Forest resources of the Custer National Forest. Washington, DC: U.S. Department of Agriculture, Forest Service. https://www.fs.fed.us/rm/ogden/pdfs/custer.pdf [Accessed October 9, 2018].
DeMallie, R.J.; Sturtevant, W.C. 2001. Handbook of North American Indians. Volume 13: Plains. Washington, DC: Smithsonian Institution.
Dow, K.; Haywood, B.K.; Kettle, N.P.; [et al.]. 2013. The role of ad hoc networks in supporting climate change adaptation: A case study from the Southeastern United Sates. Regional Environmental Change. 13(6): 1235–1244.
Doyle, J.T.; Eggers, M.J.; Camper, A.K.; [et al.]. 2016. Water: Our voice to the future—Climate change adaptation and waterborne disease prevention on the Crow Reservation. Presented at the 2016 EPA Tribal Progress Review Meeting. https://www.epa.gov.files.documents [Accessed October 2017].
Doyle, J.T.; Kindness, L.; Realbird, J.; [et al.]. 2018. Challenges and opportunities for tribal waters: Addressing disparities in safe public drinking water on the Crow Reservation in Montana, USA. International Journal of Environmental Research and Public Health. 15(4): 567. doi: 10.3390/ijerph15040567.
Doyle, J.T.; Redsteer, M.H.; Eggers, M.J. 2013. Exploring effects of climate change on Northern Plains American Indian health. Climate Change. 120(3): 643–655. doi: 10.1007/s10584-013-0799-z.
Drinkwater, L.I.; Friedman, D.; Buck, L. 2016. Systems research for agriculture: Innovative solutions to complex challenges. SARE Handbook Series 13. U.S. Department of Agriculture, Sustainable Agriculture and Research Education. 95 p.
Dunnell, K.L.; Travers, S.E. 2011. Shifts in the flowering phenology of the Northern Great Plains: Patterns over 100 years. American Journal of Botany. 98(6): 935–945. doi: 10.3732/ajb.1000363.

Ecologically Sustainable Development Steering Committee of Australia. 1992. National strategy for ecologically sustainable development—Part 1 Introduction. https://www.environment.gov.au/about-us/esd/publications/national-esd-strategy-part1 [Accessed December 18, 2018].
Eggers, M.J.; Moor-Nail, A.L.; Doyle, J.T.; [et al.]. 2015. Potential health risks from uranium in home well water: An investigation by the Apsaalooke (Crow) tribal research group. Geosciences. 5(1): 67–94.
Eggers, M.J.; Doyle, J.T.; Lefthand, M.J.; [et al.]. 2018. Community engaged cumulative risk assessment of exposure to inorganic well water contaminants, Crow Reservation, Montana. International Journal of Environmental Research and Public Health. 15(1): E76. doi: 10.3390/ijerph15010076.
Flood Control Act of 1944. Pub.L. 78-534. (December 22, 1944)
Gamborg, C.; Parsons, R.; Puri, R.K.; [et al.]. 2012. Ethics and research methodologies for the study of traditional forest-related knowledge. In: Parrotta, J.A.; Trosper, R.L., eds. Traditional forest-related knowledge: Sustaining communities, ecosystems and biocultural diversity. World Forests 12. Berlin, Germany: Springer Science+Business Media B.V.: 535–562.
Gowda, P.; Steiner, J.L.; Olson, C.; [et al.]. 2018. Chapter 10: Agriculture and rural communities. In: Reidmiller, D.R.; Avery, C.W.; Easterling, D.R.; [et al.], eds. Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington, DC: U.S. Global Change Research Program. doi: 10.7930/NCA4.2018.CH10.
Grau, K. 2018. 2017 Economic contribution of nonresident travel spending in Montana regions and counties. Missoula, MT: University of Montana, College of Forestry and Conservation, Institute for Tourism & Recreation Research. https://scholarworks.umt.edu/itrr_pubs/373/ [Accessed March 24, 2019].
Grothmann, T.; Patt, A. 2005. Adaptive capacity and human cognition: The process of individual adaptation to climate change. Global Environmental Change. 15(3): 199–213.
Hinchliffe, S. 1996. Helping the Earth begins at home. The social construction of socio-environmental responsibilities. Global Environmental Change. 6(1): 53–62.
Hunt, L.M.; Fenichel, E.P.; Fulton, D.C.; [et al.]. 2016. Identifying alternate pathways for climate change to impact inland recreational fishers. Fisheries. 41(7): 362–372. doi: 10.1080/03632415.2016.1187015.
International Union for Conservation of Nature [IUCN]. 1991. Caring for the Earth: A strategy for sustainable living. https://portals.iucn.org/library/efiles/documents/CFE-003.pdf [Accessed October 9, 2018].
Irving, W. 1837. The Adventures of Captain Bonneville, U.S.A., in the Rocky Mountains and the Far West. New York, NY: G.P. Putnam's Sons.
Jantarasami, L.C.; Novak, R.; Delgado, R.; [et al.]. 2018. Chapter 15: Tribes and Indigenous Peoples. In: Reidmiller, D.R.; Avery, C.W.; Easterling, D.R.; [et al.], eds. Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington, DC: U.S. Global Change Research Program. doi: 10.7930/NCA4.2018.CH15.
Jay, A.; Reidmiller, D.R.; Avery, C.W.; [et al.]. 2018. Chapter 1: Overview. In: Reidmiller, D.R.; Avery, C.W; Easterling, D.R.; [et al.], eds. Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington, DC: U.S. Global Change Research Program. doi: 10.7930/NCA4.2018.CH1.

Joyce, L.A.; Briske, D.D.; Brown, J.R.; [et al.]. 2013. Climate change and North American rangelands: Assessment of mitigation and adaptation strategies. Rangeland Ecology & Management. 66(5): 512–528. doi:10.2111/REM-D-12-00142.1.
Kaljur, A.; Beheler, M. 2017. Native American tribes fight for clean water and more money. Troubled Water, News21. https://troubledwater.news21.com/native-american-tribes-fight-for-clean-water-and-more-money/ [Accessed January 2, 2019]
Kates, R.W.; Travis, W.R.; Wilbanks, T.J. 2012. Transformational adaptation when incremental adaptations to climate change are insufficient. Proceedings of the National Academy of Sciences of the United States of America. 109(19): 7156–7161. doi:10.1073/pnas.1115521109.
Kibert, C.J. 2016. Sustainable construction: Green building design and delivery, 4th ed. Hoboken, NJ: Wiley. 608 p.
Ko, J.; Ahuja, L.R.; Saseendran, S.A.; [et al.]. 2012. Climate change impacts on dryland cropping systems in the Central Great Plains, USA. Climatic Change. 111(2): 445–472. doi:10.1007/s10584-011-0175-9.
Leiserowitz, A. 2005. American risk perceptions: Is climate change dangerous? Risk Analysis. 25(6): 1433–1442.
Leiserowitz, A.; Maibach, E.; Roser-Renouf, C. 2009. Global Warming's Six Americas 2009: An audience segmentation analysis. New Haven, CT: Yale University. 132 p. http://climatecommunication.yale.edu/publications/global-warmings-six-americas-2009/ [Accessed December 21, 2018].
Leiserowitz, A.; Maibach, E.; Roser-Renouf, C.; [et al.]. 2015. Global Warming's Six Americas. New Haven, CT: Yale University, Program on Climate Change Communication. https://climatecommunication.yale.edu/visualizations-data/six-americas/ [Accessed December 8, 2019].
Lempert, R.; Arnold, J.; Pulwarty, R.; [et al.]. 2018. Chapter 28: Reducing risks through adaptation actions. In: Reidmiller, D.R.; Avery, C.W; Easterling, D.R.; [et al.], eds. Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington, DC: U.S. Global Change Research Program. doi: 10.7930/NCA4.2018.CH28.
Lindner, M.; Garcia-Gonzalo, J.; Kolström, M.; [et al.]. 2008. Impacts of climate change on European forests and options for adaptation. Brussels, Belgium: European Commission Directorate-General for Agriculture and Rural Development.
Liu, J.; Dietz, T.; Carpenter, S.R.; [et al.]. 2007. Complexity of coupled human and natural systems. Science. 317(5844): 1513–1516. doi: 10.1126/Science.1144004.
Lorenzone, I.; Nickolson-Cole, S.; Whitmarsh, L. 2007. Barriers perceived to engaging with climate change among the UK public and their policy implications. Global Environmental Change. 17(3–4): 445–459.
Lowie, R.H. 1922. The religion of the Crow Indians. Anthropological papers of the AMNH 25 (2). http://digitallibrary.amnh.org/handle/2246/208 [Accessed March 24, 2019].
Lowie, R.H. 1970. Primitive religion. [Rev. ed.]. New York, NY: Liveright.
Marshall, A. 2017. Elder Albert Marshall's guiding principle of inter-cultural collaboration. Address at Climate Change Drawdown and the Human Prospect: A Retreat for Empowering our Climate Future in Rural Communities, 28 September–1 October 2017; Pugwash, Nova Scotia. http://www.integrativescience.ca/Principles/TwoEyedSeeing/ [Accessed May 1, 2018].

McBride, B.B.; Sanchez-Trigueros, F.; Carver, S.; [et al.]. 2017. Participatory geographic information systems as an organizational platform for the integration of traditional and scientific knowledge in contemporary fire and fuels management. Journal of Forestry. 115(1): 43–50.
McCleary, T.P. 2000. The valley of the chiefs and the mighty few: The cultural landscape of the Lodge Grass and Wyola districts. Unpublished manuscript on file at the Little Bighorn College Library, Crow Agency, MT.
McMichael, A.J.; Campbell-Lendrum, D.H.; Corvalán, C.F.; [et al.], eds. 2003. Climate change and human health: Risks and responses. Geneva, Switzerland: World Health Organization. 322 p.
McNeeley, S.M. 2017. Sustainable climate change adaptation in Indian Country. Weather, Climate, and Society. 9(3): 393–404. doi:10.1175/wcas-d-16-0121.1.
Medicine Crow, J. 1979. The Crow migration story. Montana Archaeological Society, Archaeology in Montana. 20(3): 63–72.
Medicine Crow, J. 1992. From the heart of the Crow Country: The Crow Indian's own stories. Lincoln, NE: Bison Books and University of Nebraska Press.
Medicine Crow, J. 2006. Counting Coup: Becoming a Crow chief on the Reservation and Beyond. Washington, DC: National Geographic Children's Books. 128 p.
Montana Fish, Wildlife and Parks. 2015. Draft Environmental Impact Statement – Bison Conservation and Management in Montana. Helena, MT: State of Montana, Montana Fish, Wildlife and Parks. http://fwp.mt.gov/fishAndWildlife/management/bison/ [Accessed December 7, 2018].
Montana Governor's Office of Indian Affairs. [n.d.]. Crow Nation. Helena, MT: Office of the Governor. https://tribalnations.mt.gov/crow [Accessed February 7, 2019].
Montana State University Extension [MSU Extension]. 2017. Montana Poverty Report Card - Crow Reservation. Bozeman, MT: Montana State University. http://www.msuextension.org/poverty [Accessed February 22, 2019],
Moser, S.; Ekstrom, J. 2010. A framework to diagnose barriers to climate change adaptation. Proceedings of the National Academy Sciences. 107(51): 1–6.
Monitoring Trends in Burn Severity. [MTBS]. 2016. MTBS data summaries. https://www.mtbs.gov/ [Accessed February 12, 2019].
Mueller, K.E.; Blumenthal, D.M.; Pendall, E.; [et al.]. 2016. Impacts of warming and elevated CO2 on a semi-arid grassland are non-additive, shift with precipitation, and reverse over time. Ecology Letters. 19(8): 956–966. doi: 10.1111/ele.12634.
Nabakov, P. 1993–1994. Big Horn Canyon National Recreation Area ethnographic overview and assessment: Crow oral history interviews. Washington, DC: National Park Service. Un-accessioned volumes stored at the Little Big Horn College Library, Crow Agency, MT.
Nabhan, G. P.; Martinez, D. 2012. Traditional ecological knowledge and endangered species recovery: Is ethnobiology for the birds? Journal of Ethnobiology 32(1): 1–5. https://doi.org/10.2993/0278-0771-32.1.1 [Accessed September 5, 2019].
Nakashima, D.J.; Galloway McLean, K.; Thulstrup, H.D.; [et al.], eds. 2012. Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation. Paris, France: UNESCO.
National Interagency Fire Center [NIFC]. 2016. Total wildland fires and acres (1960–2015). www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html [Accessed February 12, 2019].

National Oceanic and Atmospheric Administration [NOAA]. 2018. Cooperative climatological data summaries. Reno, NV: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Western Regional Climate Center, Desert Research Institute. https://wrcc.dri.edu/Climate/west_coop_summaries.php [Accessed December 9, 2018].
Naustdalslid, J. 2011. Climate change—the challenge of translating scientific knowledge into action. International Journal of Sustainable Development and World Ecology. 18(3): 243–252.
Nikolaeva, E.; Zavadskaya, A.; Sazhina, V.; [et al.]. 2015. Social science in the Russian Far East: Understanding protected area visitors' and local residents' attitudes. International Journal of Wilderness. 21(1): 34–42.
North Dakota Tourism Division. 2018. 2017 Annual report. North Dakota Department of Commerce, Tourism Division. https://www.ndtourism.com/sites/default/master/files/pdf/2017AnnualReport.pdf [Accessed March 24, 2019].
Norton-Smith, K.; Lynn, K.; Chief, K.; [et al.]. 2016. Climate change and Indigenous Peoples: A synthesis of current impacts and experiences. Gen. Tech. Rep. PNW-GTR-944. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 136 p.
Oglala Lakota Nation, 2012: Oyate Omniciyé: Oglala Lakota Plan. The official regional sustainable development plan of the Oglala Sioux Tribe. Pine Ridge, SD: Oyate Omniciye Consortium and Steering Committee.
Panno, A.; Carrus, G.; Maricciolo, F.; Mannetti, L. 2015. Cognitive reappraisal and pro-environmental behavior: The role of global climate change perception. European Journal of Social Psychology. 45(7): 858–867.
Patt, A.G.; Weber, E.U. 2014. Perceptions and communication strategies for the many uncertainties relevant for climate policy. Wiley Interdisciplinary Reviews: Climate Change. 5: 219–232.
Peterson, T.C.; Heim, R.R., Jr.; Hirsch, R.; [et al.]. 2013. Monitoring and understanding changes in heat waves, cold waves, floods and droughts in the United States: State of knowledge. Bulletin of the American Meteorological Society. 94: 821–834. doi: 10.1175/BAMS-D-12-00066.1.
Pomeranz, L. 2006. Among wild horses: A portrait of the Pryor Mountain mustangs. North Adams, MA: Storey Publishing. 144 p.
Pryors Coalition. 2014. The Pryor Mountains Crow Sacred Lands: Baahpuuo Awaxaawé. http://www.pryormountains.org/cultural-history/crow-sacred-landscape [Accessed December 7, 2018]
Pryors Coalition 2017. Letter from the Pryors Coalition to Virginia Kelley, Forest Plan Revision Team Leader et al., April 13, 2017. http://www.pryormountains.org/wp-content/uploads/2017/07/Pryors-Coalition-LTR-Wilderness-Inventory.pdf [Accessed November 1, 2019]
Raffa, K.F.; Aukema, B.H.; Bentz, B.J.; [et al.]. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: The dynamics of bark beetle eruptions. BioScience. 58(6): 501–517. doi: 10.1641/B580607

Raffa, K.F.; Powell, E.N.; Townsend, P.A. 2013. Temperature-driven range expansion of an irruptive insect heightened by weakly coevolved plant defenses. Proceedings of the National Academy of Sciences. 110(6): 2193–2198. doi: 10.1073/pnas.1216666110.
Rashford, B.S.; Adams, R.M.; Wu, J.; [et al.]. 2016. Impacts of climate change on land-use and wetland productivity in the Prairie Pothole Region of North America. Regional Environmental Change. 16(2): 515–526. doi: 10.1007/s10113-015-0768-3.
Reed, G., Jr. 2007. Letter from the Crow Tribe Executive Branch to Steve Williams, Forest Supervisor Custer National Forest, January 4, 2007.
Reeves, M.C.; Moreno, A.L.; Bagne, K.E.; [et al.]. 2014. Estimating climate change effects on net primary production of rangelands in the United States. Climatic Change. 126(3): 429–442. doi: 10.1007/s10584-014-1235-8.
Reidmiller, D.R.; Avery, C.W.; Easterling, D.R.; [et al.], eds. 2018. Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington, DC: U.S. Global Change Research Program. doi: 10.7930/NCA4.2018.
Roser-Renouf, C.; Maibach, E.; Leiserowitz, A.; [et al.]. 2016. Global Warming's Six Americas and the election. New Haven, CT: Yale University, Yale Program on Climate Change Communication.
Roué, M.; Césard, N.; Adou Yao, Y.C.; [et al.], eds. 2017. Knowing our lands and resources: Indigenous and local knowledge of biodiversity and ecosystem services in Africa. Knowledges of Nature 8. Paris, France: UNESCO.
Roué, M.; Molnár, Z., eds. 2017. Knowing our lands and resources: Indigenous and local knowledge of biodiversity and ecosystem services in Europe and Central Asia. Knowledges of Nature 9. Paris, France: UNESCO
Runyan, C.S. 1940. Land utilization on the Crow Indian reservation. Montana State University, Billings, MT. https://scholarworks.montana.edu/xmlui/handle/1/6012/ [Accessed December 9, 2019]
Saavedra Buckley, E. 2019. One tribal nation could decide the fate of Arizona's drought plan. High Country News. January 28. https://www.hcn.org/articles/colorado-river-one-tribal-nation-could-decide-the-fate-of-Arizonas-drought-plan [Accessed February 1, 2019].
Salmon, E. 2000. Kincentric ecology: Indigenous perceptions of the human nature relationship. Ecological Applications. 10(5): 1327–1332. doi: 10.2307/2641288.
Sánchez-Trigueros, F.; Wynecoop, M.; Carver, S. 2016. The value of tribal engagement for monitoring the effects of fire and fuels management on cultural uses of the Colville National Forest, Northeast Washington. Unpublished report to the U.S. Department of Agriculture, Forest Service, Northeastern Washington Collaborative Forest Landscape Restoration Program. On file at the Colville National Forest, Colville, WA.
Seidl, R.; Donato, D.C.; Raffa, K.F.; [et al.]. 2016. Spatial variability in tree regeneration after wildfire delays and dampens future bark beetle outbreaks. Proceedings of the National Academy of Sciences. 113(46): 13075–13080.
Short, K.C. 2015. Sources and implications of bias and uncertainty in a century of U.S. wildfire activity data. International Journal of Wildland Fire. 24(7): 883–891.
Pretty Paint-Small, V. 2013. Linking culture, ecology and policy: The invasion of Russian olive (Elaeagnus augustifolia L.) on the Crow Indian Reservation, South Central Montana, USA. Fort Collins, CO: Colorado State University. Ph.D. dissertation. 94 p. http://hdl.handle.net/10217/78865 [Accessed September 10, 2017].

Smith, N.; Leiserowitz, A. 2014. The role of emotion in global warming policy support and opposition. Risk Analysis. 34(5): 937–948.
Snell, A.H. 2006. A taste of heritage: Crow Indian recipes and herbal medicines. Lincoln, NE: University of Nebraska Press.
Snite Museum of Art, University of Notre Dame 2012. Father Lindesmith's Collection: History into art and anthropology. Notre Dame, IN: University of Notre Dame.
South Dakota Department of Tourism. 2018. 2017 Annual report. Pierre, SD: South Dakota Department of Tourism. https://sdvisit.com/sites/default/files/2018-08/2017annrpt.pdf [Accessed March 24, 2019].
Spence, A.; Poortinga, W.; Pidgeon, N. 2012. The psychological distance of climate change. Risk Analysis. 32(6): 957–972.
Stumpff, L.M. 2013. Living waters: Linking cultural knowledge, ecosystem services, and wilderness. International Journal of Wilderness. 19(1): 20–25.
Stumpff, L.M. 2015. Wildfire in the Valley of the Wild Roses. In: Watson, A.; Carver, S.; Krenova, Z.; McBride, B., comps. 2015. Science and stewardship to protect and sustain wilderness values: Tenth World Wilderness Congress symposium; 2013, October 4-10; Salamanca, Spain. Proc. RMRS-P-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 182–185.
Tsosie, R. 2007. Indigenous people and environmental justice: The impact of climate change. University of Colorado Law Review. 78: 1625–1677.
Tsosie, R. 2009. Climate change, sustainability, and globalization: Charting the future of indigenous environmental self-determination. Environmental Energy Law & Policy Journal. 4(2): 188–255.
Turner, N.J.; Clifton, H. 2009. "It's so different today". Climate change and indigenous life-ways in British Columbia, Canada. Global Environmental Change. 19(2): 180–190.
Turner, B.L.; Matson, P.A.; McCarthy, J.J.; [et al.]. 2003. Illustrating the coupled human–environment system for vulnerability analysis: Three case studies. Proceedings of the National Academy of Sciences. 100(14): 8080–8085. doi: 10.1073/pnas.1231334100.
United Nations Department of Economic and Social Affairs [UN DESA]. 2008. Resource Kit on Indigenous Peoples' Issues. United Nations. http://www.undp.org/content/dam/aplaws/publication/en/publications/environment-energy/www-ee-library/local-development/resource-kit-on-indigenous-peoples-issues/resource_kit_indigenous_2008.pdf [Accessed November 4, 2019]
USDA Forest Service [USDA FS]. 2005. Bighorn National Forest: Revised land and resource management plan. Washington, DC: U.S. Department of Agriculture, Forest Service. https://www.fs.usda.gov/detail/bighorn/landmanagement/planning/?cid=fswdev3_009165 [Accessed October 9, 2018].
USDA Forest Service [USDA FS]. 2012. The National Forest System Land Management Planning Rule. Federal Register. 77(68): 21162–21276. https://www.fs.usda.gov/detail/planningrule/home/?cid=stelprdb5359471 [Accessed December 3, 2019].

USDA Forest Service [USDA FS]. 2015. Shoshone National Forest land management plan: 2015 Revision. Washington, DC: U.S. Department of Agriculture, Forest Service. https://www.fs.usda.gov/detail/shoshone/landmanagement/planning/?cid=stelprdb5199919 [Accessed December 7, 2018].
USDA Forest Service [USDA FS]. 2017. Final assessment report of ecological, social and economic conditions on the Custer Gallatin National Forest. Washington, DC: U.S. Department of Agriculture, Forest Service. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd533598.pdf [Accessed December 9, 2018].
USDA Forest Service [USDA FS]. 2018. Tribal land cessions in the United States. U.S. Department of Agriculture, Forest Service, Geospatial Service and Technology Center. https://data.fs.usda.gov/geodata/edw/edw_resources/meta/S_USA.TRIBALCEDEDLANDS.xml [Accessed October 23, 2019].
U.S. Department of Energy [U.S. DOE]. 2015. Chapter 4: Northern Great Plains. Climate change and the U.S. energy sector: Regional vulnerabilities and resilience solutions. Washington, DC: U.S. Department of Energy, Office of Energy Policy and Systems Analysis. https://www.energy.gov/policy/downloads/climate-change-and-us-energy-sector-regional-vulnerabilities-and-resilience [Accessed February 27, 2018].
USDOI Bureau of Land Management [USDOI BLM]. 2019. Pryor Mountains Wild Horse Range Herd Management Area. Washington, DC: U.S. Department of the Interior, Bureau of Land Management. https://www.blm.gov/programs/wild-horse-and-burro/herd-management/herd-management-area/montana-dakotas/pryor [Accessed February 9, 2019].
USDOI National Park Service [USDOI NPS]. 2012. Bighorn Canyon National Recreation Area: Long-range interpretive plan. Washington, DC: U.S. Department of the Interior, National Park Service. https://www.nps.gov/bica/learn/management/upload/2012-08-27_FinalDocument_Update-StdRes.pdf [Accessed December 6, 2018].
USDOI National Park Service [USDOI NPS]. 2016. Foundation document: Bighorn Canyon National Recreation Area. Washington, DC: U.S. Department of the Interior, National Park Service. https://www.nps.gov/bica/learn/management/upload/BICA_FD_PRINT.pdf [Accessed December 6, 2018].
USDOI National Park Service [USDOI NPS]. 2019. Yellowtail Dam. Bighorn Canyon, National Park Service, U.S. Department of the Interior. https://www.nps.gov/bica/learn/historyculture/yellowtail-dam.htm [Accessed January 20, 2019].
U.S. Environmental Protection Agency [U.S. EPA]. 2016. Climate change indicators in the United States: Wildfires. www.epa.gov/climate-indicators [Accessed March 2, 2019].
Vose, J.M.; Peterson, D.L.; Domke, G.M.; [et al.]. 2018. Chapter 6: Forests. In: Reidmiller, D.R.; Avery, C.W.; Easterling, D.R.; [et al.], eds. Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington, DC: U.S. Global Change Research Program. doi: 10.7930/NCA4.2018.CH6.

Vulturius, G.; Gerger Swarling, A. 2015. Overcoming social barriers to learning and engagement with climate change adaptation: Experiences with Swedish forestry stakeholders. Scandinavian Journal of Forest Research. 30(3): 217–225.
Walters, M.; Andersen, C. 2013. Indigenous statistics: A quantitative research methodology. Oxford, UK and New York, NY: Routledge. 159 p.
Watson, A.; Alessa, L.; Glaspell, B. 2003. The relationship between traditional ecological knowledge, evolving cultures, and wilderness protection in the circumpolar north. Conservation Ecology. 8(1): 2–21.
Watson, A.; Carver, S.; Matt, R.; [et al.]. 2013. Place mapping to protect cultural landscapes on tribal lands. In: Stewart, W.P.; Williams, D.R.; Kruger, L.E., eds. Place-based conservation. Dordrecht, Netherlands: Springer: 212–222.
Watson, A.; Matt, R.; Knotek, K.; [et al.]. 2011. Traditional wisdom: Protecting relationships with wilderness as a cultural landscape. Ecology and Society. 16(1): 36. http://www.ecologyandsociety.org/vol16/iss1/art36/.
Watson, A.; Matt, R.; Waters, T.; [et al.]. 2009a. Mapping trade-offs in values at risk at the interface between wilderness and nonwilderness lands. In: Gonzalez-Caban, A., coord. Proceedings of the Third International Symposium on Fire Economics, Planning, and Policy: Common problems and approaches. Gen. Tech. Rep. PSW-GTR-227. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 375–387.
Watson, A.; Ostergren, D.; Fix, P.; [et al.]. 2009b. Protecting ecotourism resources in a time of rapid economic and environmental transformation in Asia. In: Xiaowen, J.; Xuerming, X.; Schneider, I., eds. Strategic management engineering: Enterprise, environment and crisis. Proc. 2009 International Conference on Strategic Management. Sichuan, China: Sichuan University Press: 185–201.
Watson, A.; Stumpff, L.M.; Meidinger, J. 2012. Traditional wisdom and climate change: Contribution of wilderness stories to adaptation and survival. International Journal of Wilderness. 18(2): 21–25.
Weinhold, B. 2010. Climate change and health: A Native American perspective. Environmental Health Perspectives. 118(2): A64–A65.
Whitmarsh, L. 2008. Are flood victims more concerned about climate change than other people? The role of direct experience in risk perception and behavioural response. Journal of Risk Research. 11(3): 351–374.
Wienhold, B.J.; Vigil, M.F.; Hendrickson, J.R.; [et al.]. 2017. Vulnerability of crops and croplands in the U.S. Northern Plains to predicted climate change. Climatic Change. 146(1–2): 219–230. doi: 10.1007/s10584-017-1989-x.
Wildcat, D.R. 2009. Red alert: Saving the planet with indigenous knowledge. Golden, CO: Fulcrum Publishing. 128 p.
Wild and Free-Roaming Horses and Burros Act of 1971. Pub.L. 92-195. (Dec. 18, 1971).
Wilderness Act of 1964. Pub.L. 88-577. (Sept. 3, 1964).
Wobus, C.; Small, E.E.; Hosterman, H.; [et al.]. 2017. Projected climate change impacts on skiing and snowmobiling: A case study of the United States. Global Environmental Change. 45: 1–14. doi: 10.1016/j.gloenvcha.2017.04.006.
Womble, P.; Perrone, D.; Jasechko, S.; [et al.]. 2018. Indigenous communities, groundwater opportunities. Science 3(6401): 453–455.

The World Bank. 2012. Inclusive green growth: The pathway to sustainable development. Washington, DC: The World Bank. 171 p. https://openknowledge.worldbank.org/bitstream/handle/10986/6058/9780821395516.pdf [Accessed December 6, 2018].
World Commission on Environment and Development. 1987. From one earth to one world: An overview. Oxford, UK: Oxford University Press.
Wynecoop, M.D.; Morgan, P.; Strand, E.; [et al.]. 2019. Getting back to fire sumêŝ: Exploring a multi-disciplinary approach to incorporating traditional knowledge into fuels treatments. Fire Ecology. 15: art. 17. doi: 10.1186/s42408-019-0030-3.
Wyoming Wilderness Act of 1984. Pub.L. 98-550. (Oct. 30, 1984).
Yarlott, D., Jr. [n.d.]. A way of knowing, from the Apsaalooke ancestors. Unpublished manuscript on file at Little Big Horn College Library, Crow Agency, MT.
Yarlott, D., Jr. 1999. Historical uses of natural resources: Transference of knowledge in the Crow Indian environment. Bozeman, MT: Montana State University. Ed.D. thesis. 181 p. https://scholarworks.montana.edu/xmlui/bitstream/handle/1/8588/31762104226772.pdf;sequence=1 [Accessed December 7, 2018].
Zaval, L.; Kennan, E.A.; Johnson, E.J.; [et al.]. 2014. How warm days increase belief in global warming. Nature Climate Change. 4: 143–197. doi: 10.1038/nclimate2093.
Zeleny, M. 2005. Human systems management: Integrating knowledge, management and systems. London, U.K. World Scientific. 484 p.

Appendix: Interviews with Federal Managers, Fall 2017

Note: text below is not a literal transcription of the interviews as they were not recorded, but a synthesis of their original content.

Pryor Mountain Wild Horse Range

Question	How does the designation in 1968 and the1971 Wild and Free-roaming Horses and Burros Act work together? What was the management direction from 1968 to 1971?
Answer	• The Executive Order was in 1971 and mostly set the boundaries. • The specifics for management are in the Act. • From 1968 to 1971 the guidance was that within the area the horses are "wild". The primary things legislation tells them to do is to maintain appropriate herd levels, keep a census, monitor vegetation communities for maintaining ecological balance – there are several amendments to the Wild and Free-roaming Horse and Burro Act.
Q	Where does the legislative direction come from for Pryor Mountain Wild Horse Range?
A	The executive order, Federal Land Policy Management Act and the Public Range Improvement Act, which guides them to maintain a thriving ecological balance of wild horses and livestock in the range.
Q	What are the biggest threats to sustainability of the Pryor Mountains Wild Horse Range? Why?
A	• Finding balance in genetic viability and vegetative capacity – overgrazing; public interest in numbers (ideal is 90 – 120), now 156, 138 was the lowest since management. It is an emotional program – horses are family members to some people; there are tradeoffs – overgrazing and genetic viability; • All-terrain vehicles. • The adoption of horses is down due to economic difficulties of potential adoptive sponsors.
Q	How is the public engaged in controlling these threats? Any involvement with the Crow Tribe? Other tribes?

A	• The Mustang Center in Lovell has a good relationship with the Bureau of Land Management (BLM); they are a partner. It all started with 5th-graders in 1971 writing letters for the act. • Horse "Cloud" of the Arrowhead Mountains – A PBS documentary series with a big influence on public opinion and interest. The Cloud Foundation is active now. • Involve public up front. There is no Crow Tribe involvement or contact at present. Individuals are interested, but are not affiliated with the Crow. Advice is always offered by citizens who visit the range. • International visitors, such as students from Canada, came to learn about wild horses at the range. The range management forms partnerships with other countries for humanitarian resources.
Q	How do you evaluate the success of your public engagement?
A	If we get divergent input – if both groups are a little frustrated – that is good feedback. Always have appeals – groups taking to social media to inform other groups is good. Our decision incorporates both groups' contributions
Q	What kind of restoration activities are occurring or planned for the Pryor Mountains Wild Horse Range?
A	Restoration—prescribed fire—was held up in litigation in forested areas, high elevation. Revegetation around water holes could be undertaken, but there is no point until population is better controlled. Water developments in 2010 opened up some additional areas for the horse use.
Q	What are the roles of the BLM, National Park Service (NPS), and Forest Service (USFS) in management of the Pryor Mountain Wild Horse Range?
A	All of them are the main decision makers especially for the issues which needs BLM, NPS and FS interventions. The BLM is the local decision-maker on matters pertaining to wild horses, FS gives money to finance some projects within the Pryor Mountain Wild Horse Range. National Park Service helps dart horses, horse training and water development – NPS does some of the work
Q	How do the wilderness study areas fit into overall management? How are they managed differently? How do the purposes of wilderness fit with wild horse management objectives?
A	• There are five wilderness study areas, some on NPS, BLM, and National Forest Service lands. They help restrict off-road travel. Two are cultural areas, places people look to find natural conditions. Today, maybe two-thirds of the range is in wilderness study areas. • ATV travel is restricted: They use signs, and people just know some places are off-limits. • They don't know if the 2009 plan addressed wilderness study areas. They do know they need to be careful about water guzzlers and with traps that involve vehicular removal.

Bighorn Canyon National Recreational Area

Question	What was the impact of including tribal land in the original designation?
Answer	• Hunting is important here. There are 52,000 acres (210 km2) of tribal land. • They have an MOU (memorandum of understanding) with the Crow Tribe, 50-year agreement. • The Two Eagle interpretive trail is cooperative with the tribe. • Renegotiating with a sovereign Nation is difficult. They have to get trespass permit to go across Crow land. Studies are done with permission, but they also have to get permission to cross private land, of which there is some. • Administration change in concession. Sometimes it becomes difficult to manage the land since each administration has its priorities.
Q	Is there any subsequent legislation that influences your management goals?
A	• Wilderness study areas – only one? The plan was done in the 1980s. • There is a big power line going through the wilderness study area. • If wilderness study areas are rejected, they would want to develop bike trails. • Bureau of Reclamation is in charge of lake levels, and things are often at conflicting purpose.
Q	What are the biggest threats to sustainability of the Bighorn Canyon National Recreation Area? Why?
A	• Horses and cattle have a big impact on everything else in the area. Their presence overlapping bighorn sheep habitats may impact the sheep herd. • Not overuse from foot traffic, but there are social trails. • Not artifacts getting stolen—probably all gone already. • Climate is affecting vegetation and sheep (they eat mountain mahogany), and cause damage to both historic and prehistoric sites. The Bighorn Canyon National Recreation Area will become more arid in the future. • Water is changing patterns. • Siltation is gradual but monumental. The ongoing siltation of the lake and river will eventually impact the canyon.
Q	How is the public engaged in controlling these threats? Any involvement with the Crow Tribe? Other tribes?
A	• The Friends of Bighorn Lake are pushing to dredge because the lake is silting in. • The Bighorn Alliance. • Outfitter groups.
Q	How do you evaluate success of your public engagement?
A	Youth project feedback comments. Youth outreach, volunteers, arts residency music, newspaper, social media like Facebook and e-mail.

Q	What kind of restoration activities are occurring or planned for the Bighorn Canyon National Recreational Area?
A	Youth Conservation – they do range restoration; horse and cattle impacts; power lines and roads, mine roads; historic ranches and buildings. They protect cultural and historic sites – they preserve. Restoration involves weed control first; cottonwoods and native grasses, willows.

Bighorn National Forest

Question	What challenges do you have in protecting Wilderness and RNAs on the Forest?
Answer	Dispersed camping impacts, soil disturbance; encroachment of motorized use; increase in dispersed recreation; research on the perimeter of the wilderness; gateway (scenic values) concern of wilderness; motorized users' trails coming to the wilderness boundary, there is climbing and mining there now in the RNAs.
Q	What are the values of a research natural area; are they the same as the purposes?
A	• The Bighorn National Forest has five research natural areas. These areas are natural ecosystems as designated by the forest plan. • There is some suitable timber in the resource natural area, according to current plan of 2009. There are not really any advocacy groups. • No vehicles are allowed. These are undisturbed areas with a natural ecosystem, reference areas to understand natural succession, avoided for projects: to look at undisturbed areas as comparison to disturbed areas. Existing research use will continue to occur.
Q	Is there any specific subsequent legislation (Endangered Species Act, Resources Planning Act Assessment [as required by the Forest and Rangeland Renewable Resources Planning Act], and W&SRA) that influences your management goals?
A	The Wilderness Act and the Roadless rule—Council for the Bighorn Range is very engaged. The inventory suggests the suitable timber acres (50 percent inside the roadless inventory). The Roadless area conservation rule of 2001.
Q	What are the biggest threats to sustainability of the Bighorn National Forest? Why?
A	• Historical exclusion of fire owing to lots of recreation residences. Fuel build up brings fire threat. Fuel reduction is needed for Buffalo water supply and watershed protection from catastrophic wildfire. • Insect and disease risk (e.g., beetle infestation); get diversity of structure and age classes to increase; resistance (structural stage diversity).
Q	How is the public engaged in controlling these threats?
A	Public field days – explain the threat and solutions; Forest Plan steering committee – interested agencies, legislators, county commissioners, designed to recommend plan decisions.
Q	How do you evaluate success of your public engagement?
A	• Feedback from steering committee: Did we provide what you needed? Are projects meeting purpose of plan? • Public comments from projects (as mandated by the National Environmental Policy Act). • Bighorn Mountain Coalition survey on dispersed recreation: concerns about recreation use.

Q	What kinds of interaction do you have with Crow Tribe? Other tribes?
A	Post and pole projects – teepee pole collecting; Medicine Wheel – maximize consultation with Crow Tribe – such as too many prayer flags; ceremonial practices; burial sites inventoried and identified.
Q	What kind of restoration activities are occurring or planned for the Bighorn National Forest?
A	Fire; wetlands; off-site mitigation for wetlands – to offset road construction; restoration of willow – not sure of cause of willow decline – possibly elk, cattle, fungus, moose; but there is impact on water temperature.

Legislation Mentioned During the Interviews

Endangered Species Act of 1973 [ESA]. Pub. L. 93–205. (Dec. 28, 1973)

Federal Land Policy and Management Act of 1976 [FLPMA]. Pub. L. 94–579. (Oct. 21, 1976)

National Forest Management Act of 1976 [NFMA]. Pub. L. P.L. 94–588. (October 22, 1976)

National Environmental Policy Act of 1970 [NEPA]. Pub. L. 91–190. (Jan. 1, 1970).

Public Rangelands Improvement Act of 1978 [PRIA]. Pub. L. 95–514. (Oct. 25, 1978).

Wild and Scenic Rivers Act of 1968 [WSR Act]. Pub. L. 90–542. (Oct. 2, 1968)

Wild and Free-Roaming Horses and Burros Act of 1971 [WFRHBA]. Pub. L. 92–195. (Dec. 18, 1971)

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