RESEARCH FOR RESILIENCE: CLIMATE CHANGE,THE CROW TRIBE AND INDIGENOUS KNOWLEDGE, Part II

BY

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ABSTRACT This case illustrates how the interaction between different knowledge systems can make ecosystems and communities more resilient while facing the negative effects of climate change. In the Northern Great Plains, long-term cultural knowledge about adaptation and restoration is missing from agency viewpoints. Opening up communication channels takes place through a framework that incorporates some of the Indigenous knowledge and experience of the Crow Nation whose historic lands and waters form the template for new understandings of ecological practices and principles.

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Looking out from a cave in the Pryor Mountains Photo credit: Aaron Teasdale

This case is based on the idea that incorporation of Indigenous knowledge into post disturbance stream, soil, and vegetation restoration can 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 case also provides a corpus of traditional meanings attached to federal lands of the Upper Missouri River Basin.

THE CULTURAL AND ENVIRONMENTAL SETTING

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.).

Sky prairie grasslands give way to forest with evidence of past fires on the Crow Reservation
Photo credit: Aaron Teasdale

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. High grasslands give way to the mountain range as it 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 Teeth Mountains guard the eastern boundaries of the Crow Indian Reservation, and provide ample grazing lands and excellent habitat for a variety of wildlife . 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 Mountain Range remain sacred to the Crow.

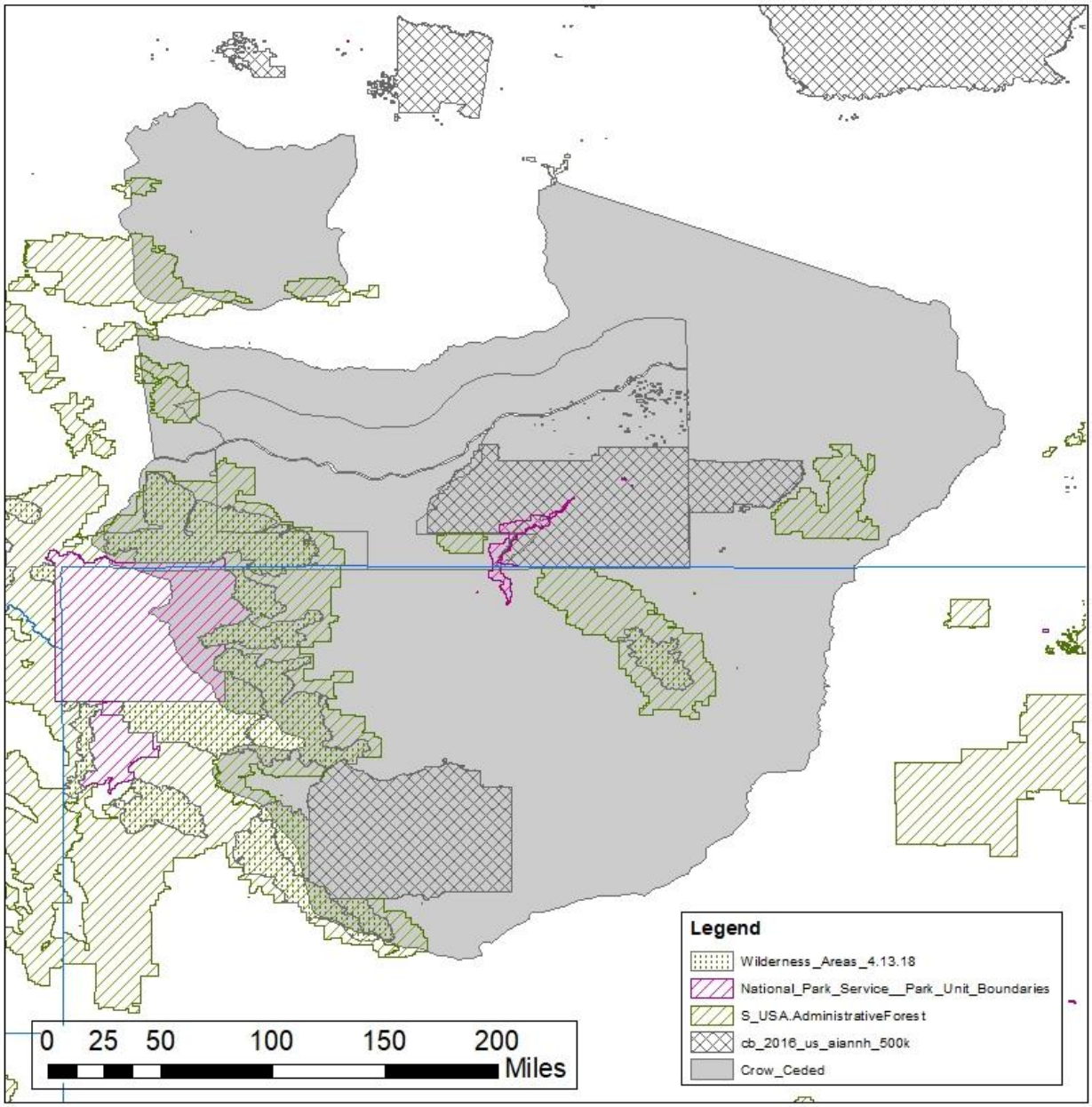

Fig 1: Crow Seated and Federal Lands. Map by Fernando Sanchez Trigueros

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, built on condemned Indian lands, is currently managed by the Bureau of Reclamation.

Little Bighorn River, Crow Reservation Photo credit: Aaron Teasdale

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 carves a dramatic canyon banded by cultural sites 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. 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 (Pomeranz, 2006). 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 narrative, 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. With the equestrian lifestyle, 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.

Wild horse on the Bureau of Land Management Wild Horse Range Photo credit: Aaron Teasdale

Additional treaties and Government policy of forced land cessations 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 led to new economic pursuits including agriculture, ranching, and economic development initiatives such as building a casino, implementing tourism ventures, and coal mining.

Culture and environment co-evolved on the Great Plains. It became a matter of public concern in recent decades due to extreme weather events driven by a warming climate.. Crow tribal 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. In recent years, tourism was added to the economy. Specific cultural practices and traditional ceremonies and rituals, however, remain important and define Crow cultural lifeways. 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 Shield Model

The primary purpose of this case is to understand and promote resilience in mixed-ownership federal lands and tribal lands through the incorporation of Indigenous knowledge into climate change planning and responses. It applies culturally informed restoration principles to achieve environmental and cultural resistance to future impacts. It implements a Protective Shield framework designed to cross-culturally

communicate indigenous-ethnographic knowledge. It rests on a symbolic cognitive model based on the symbol of a shield to derive principles of sustainable management from the existing ethnological knowledge that achieves resilience. The model was developed to employ a culturally appropriate symbol —a circular shield— for informing protective conservation management. Working primarily from archival data from tribal elder interviews, the data relevant to climate change is organized into four categories of continuous actions that analyze adaptation, re-weaving (or two-eyed seeing), restoration and resilience actions in response to climate change impacts. These categories are familiar to government scientists and managers through their academic and managerial backgrounds. 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, the four elements (earth, fire, air and water) and the four stages of life. A sample of such symbolism in Crow culture is included in the next sections. They are used for illustrative purposes only and do not intend to directly symbolize the stages presented in the protective shield framework.

The shield model proceeds through three stages of knowledge building and practice across time — adaptation to changing factors; knowledge reweaving using Indigenous knowledge and contemporary science, restoration of preferred conditions— that fuels a fourth stage of resilience, where *wisdom* informs the formulation of management principles to make ecosystems and their cultures more resistant to climate change-related factors. The cycle is continuous as changing conditions lead to new adaptations.

The outcome of a cognitive sequence that started with the coding of observations (data collection) primarily from interviews with elders across time, proceeded with the synthesis of those observations (information), and eventually allowed the establishment of interconnections between different syntheses (knowledge) (Ackoff 1989; Zeleny 2005). This led to 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 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.

Shield belonging to Chief Eelapuash Smithsonian Museum

Adaptation- Resistance for Survival After Disturbance Impacts

Adaptation is the first stage of resistance to disturbance impacts . 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.

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. They must honor their rights, which encompass their preferences and values. To continue with an 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. Importantly, shortage of the water supply due to drought and elevation of water pollution levels owing to severe flooding (Doyle et al. 2018). The 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). Similarly, the Northwest Tribes, when faced with the prospect of certain extinction of some salmon species, 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. This is a critical bridging step because reservation homeland boundaries make relocation of tribal communities a less nuclear 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 and resist climate change impacts. As pointed out previously, this capacity to respond to change enhances the pathways to resilience, by initiating a renewed cycle of adaptations to and restoration against impacts.

Crow Shield Smithsonian Museum

Reweaving- Research and Two-Eyed Vision as Resistance

Reweaving is grounded in the use of different knowledge systems (inclusive of Western science and Indigenous knowledge) in order to inform restoration from disturbance impacts and assist in the long-term resistance to those impacts. Reweaving extends beyond the dominant paradigm and instead focuses on the interweaving of science with Indigenous knowledge (e.g., the traditional phenological knowledge of SHIELD TWO the seasonal cycles and systems), to create environmentally and culturally sustainable pathways to management action. 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. 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 either “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 worldview 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 trans disciplinary 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.

Tribal natural resource management in the United States retains and reweaves 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. A useful example is the 2000 Flathead Indian Reservation Forest Management Plan (CSKT 2000). Reweaving helps Indigenous knowledge communicate values that may not be well detected with other knowledge systems.

Alaska Natives, 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).

Crow Shield Smithsonian Museum

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 . 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 resilience in relationships between humans and nature. The baseline for restoration gets better defined when it is informed by both science and the extended timeframe of Indigenous knowledge. Reweaving expands the volume of information as it focuses on the place-based scale needed to define restoration goals.

Crow Shield Smithsonian Museum

Resilience- Creating the Connective Vision

The last stage in the cycle of the protective shield framework is resilience . Research shows that as a scientific term, resilience has many definitions within ecological and socio-ecological **sources** (Brand and Jax 2007; Cajete 2000; Carpenter et al. 2001). The shield framework aims to create a resilience-building mechanism by establishing knowledge-based principles that guide future decision-making. These

principles provide a roadmap for selecting and developing 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.

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 Western science-based methods that use systems thinking. 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 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.

The Shield Framework: Collaborating for A Better Strategy

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. 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. 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.

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. 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 resilience to climate change. How Indigenous knowledge can inform the *Shield* pathway for resilient management will be demonstrated in the following 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. Based on her research, three trips to Crow Country and with help and direction from Little Big Horn College (LBHC) and tribal experts and authors, the case study based on the Shield Framework aims to create understanding of the climate change strategy that is ongoing at Crow. Finally, management principles are drawn from the case study in order to communicate the major concepts to external managers and scientists.

The protective shield framework was put into practice with this case study to explore adaptation, reweaving, restoration, and resilience to increase resistance to climate-related disturbance for the Crow Tribe, with a focus on resilience principles that guide future cycles of adaptation, reweaving and restoration. 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 also the accumulation of cultural knowledge that has been transmitted from the previous generations of Elders to her or him. This social-cultural 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: A Meta-Analysis of Crow Elders' Observations Over Time

Through 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 (Sage Encyclopedia, 2017) . Crow scholarly leadership 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). Of key importance was the fact that the collections were curated and shared by Crow authorities. Accessible sources were available such 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 discussions with John T. Doyle in 2010, 2017 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

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 engaged the LBHC, the Crow Tribe, the Apsaalooke Water and Wastewater Authority, the local Indian Health Service Hospital, and other community participants.

Fishing during high water on the Bighorn River- Spring 2017 Photo credit: Aaron Teasdale

The plan for adaptation started with detecting the environmental particulates that are contributing to the water quality crisis and a measurement of its impacts. Current data recently collected was recognized

as pointing to a substantial threat to the health and cultural lifeways of the communities within the Crow Reservation. This prompted 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).

Low water marks at the Bighorn National Recreation Area

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

> "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 was 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.

Drought impacts the Crow Reservation

Reweaving—Traditional phenological knowledge about weather effects on the hydrological cycle lined up with the results contributed by the team of scientists from the university 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 provided 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 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 stream flow 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 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). 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.

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.

Restoration of Montana Ecosystems Wildlife and Grasslands

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).

Moonrise over the remains of ancient tipi rings-Bighorn National Recreation Area Photo:Aaron Teasdale

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 Forest Plan, 2008). Crow Elders and Sundance chiefs 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).

Wolf Mountains—a source of tipi poles and traditional foods Credit: Aaron Teasdale

In addition to plains cottonwood, buffaloberry (*Shepherdia argentea*), chokecherry (*Prunusvirginiana* 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.

Respecting the bison: bison skulls placed together on the prairie

Photo credit: Aaron Teasdale

In recent years, the Crow Tribe 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.

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Wesltern meadowlark, an increasingly uncommon bird on the Crow Reservation Photo credit: Aaron Teasdale

In Doyle et al. (2016) interviewees reported that various fish species 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, cited in The Adventures of Captain Bonneville, U.S.A., in the Rocky Mountains and the Far West, by Washington Irving, 1837, Chief Eelapuash said around 1830 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 words help define seasonal benchmarks that reflect desired ecological conditions for the Crow Tribe, both in the historical past and at present. Such desired conditions were 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 like the photograph of the prescribed burn below.

A much-needed prescribed burn completed by Crow Tribe fire crews in 2017

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 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 was identified as key for wildlife restoration, particularly on the ceded lands that are currently under federal control. Crow interviewees placed a strong emphasis on such geographical features for objectives of cultural subsistence and resilience. Conservation zoning in such ceded areas 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).

Sky prairie in the Wolf Mountains

Members of the Crow Tribe consistently suggested that 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 like 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 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:

Horses roam on extensive grasslands Photo credit: Aaron Teasdale

> "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.

The now-arid landscape blankets the former grasslands and prairies as the fortunes of farmers dry up
Photo credit: Aaron Teasdale

This puts the sustainability of livestock and horse ranching operations that are important to the Crow 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.

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 placed emphasis on restoring wildlands in the federally managed lands that surround the Crow Indian Reservation.

Riparian Ecosystems and Lowlands

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 identified 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*) (Pretty Paint-Small 2013).

Invasive Russian Olive crowds out native cottonwoods along the river

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.

In the face of these threats, Crow Elders drew 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, was observed as well (Doyle et al. 2016; Nabakov 1993–1994; Pretty Paint-

Small 2013; Snell 2006). Altogether, the perception of loss increased among Crow Elders and Knowledge Holders:

> "We are running out of trees, basically" (Pretty Paint-Small 2013, p. 15).
>
> "My father died in late 1985…'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 continued to 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 today they are 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 were 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.

A Crow tribal shield insignia adorns the sign warning of extreme fire danger Credit: Aaron Teasdale

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 including Indigenous knowledge could guide identification of vulnerable sites in the Upper Missouri River Basin, and assist government-to-government partnerships to restore areas with interests shared by the Crow Tribe and the federal government such as ceded lands and reservation borderlands.

Restoration—Riparian restoration is desirable to the Crow, especially 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.

Summary of Shield Pathway Applications

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 principle 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 management of natural and cultural resources to conserve the resilience in human and natural systems.

CONCLUSIONS: REWEAVING INDIGENOUS PRINCIPLES FOR RESTORATION IN THE UPPER MISSOURI RIVER BASIN

The meta-analysis in this case 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 highlight 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 moves in a circular path guided by resilience wisdom addressing 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 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, a series of potential management principles that show meeting points

between Crow Indigenous thinking and systems ecological science have been identified. These principles can be used for restoration of natural and cultural resources in the Upper Missouri River Basin and similar geographies based on the historical role and knowledge of the Crow Tribe in the evolution of ecosystems in the Northern Great Plains.

Looking out from the northern tip of the Bighorn Mountains into the Crow Reservation
Photo credit: Aaron Teasdale

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 continuous co-evolution of environment and cultural.

3. Long-term commitment to adaptive measures and reweaving for restoration practice 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.
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.

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 led 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, and with lands managed by the Bureau of Land Management and the National Park Service. Existing and potential wilderness designation seems 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 take leadership in the design of research projects and 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 rent communities.

Next Steps

Black-tailed prairie dogs, partners in the interconnection of all our relations and an endangered species, build resilience in prairie soils Photto credit: Aaron Teasdale

A useful exercise to achieve the goal of collaboration 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.

What science may categorize as "innovative" may have strong roots within Indigenous knowledge. Some managers may consider some of the resilience principles included in this case in restoration practice and land management planning. These principles may actually reduce risk from lack of long-term knowledge and observations contained in place-based knowledge.