Exploring effects of climate change on Northern Plains American Indian health

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Abstract

American Indians have unique vulnerabilities to the impacts of climate change because of the links among ecosystems, cultural practices, and public health, but also as a result of limited resources available to address infrastructure needs.OntheCrow Reservationinsouth-central Montana, a Northern Plains American Indian Reservation, there are community concerns about the consequences of climate change impacts for community health and local ecosystems. Observations made by Tribal Elders about decreasing annual snowfall and milder winter temperatures over the 20th century initiated an investigation of local climate and hydrologic data by the Tribal College. The resulting analysis of meteorological data confirmed the decline in annual

snowfall and an increase in frost free days. In addition, the data show a shift in precipitation from winter to early spring. The number of days exceeding 90 ˚F (32 ˚C) has doubled in the past century. Streamflow data show a long-term trend of declining discharge. Elders noted that the changes are affecting fish distribution within local streams and plant species which provide subsistence foods. Concerns about warmer summer temperatures also include heat exposure during outdoor ceremonies that involve days of fasting without food or water. Additional community concerns about the effects of climate change include increasing flood frequency and fire severity, as well as declining water quality. The authors call for local research to understand and document current effects and project future impacts as a basis for planning adaptive strategies.

1 Introduction

Climate change impacts present distinct risks to human health throughout Indian country. Although documented in Alaska (Brubaker et al. 2011a) and the Southwest (Redsteer et al. 2013a, b; Redsteer et al. 2010), these issues are not as well researched for Northern Plains Tribal communities. To address this data gap, observations of Crow Tribal elders in addition to changes in monitored temperature, precipitation and streamflow in the Little Bighorn River valley, Montana are provided. Located in south central Montana, the Crow Reservation encompasses 2.3 million acres, including three mountain ranges and three large river valleys. Approximately 8,000 of the 11,000+ Tribal members reside on the Reservation, primarily along the rivers and creeks. The majority of communities, including the "capital" town of Crow Agency, are situated in the Little Bighorn River valley (Fig. 1). The Crow language is still widely spoken and many cultural traditions continue to be practiced today. Water is one of the most important natural resources to the Crow community and has always

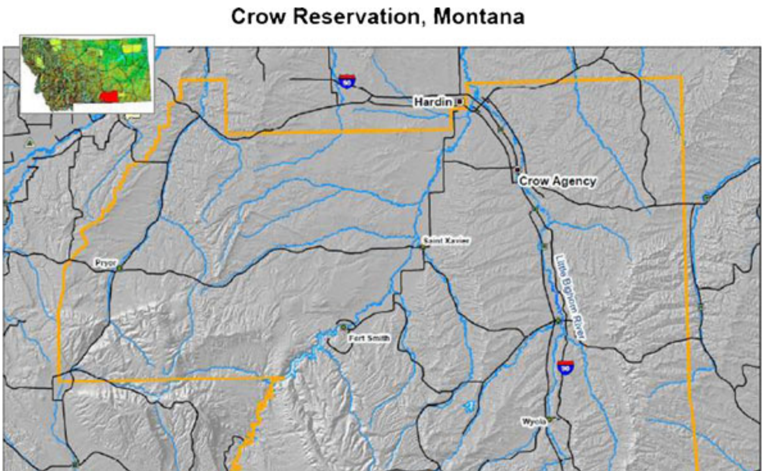

Fig. 1 Map delineating Crow Reservation (in *yellow*) and proximity to Hardin, MT where meteorological data for the study was collected, 15 miles northwest of Crow Agency, MT. The Reservation is southeast of Billings, MT, with the Reservation's southern border on the Montana-Wyoming State boundary. (Map prepared by Eggers; inset courtesy US Department of Agriculture 2013)

been held in high respect among Tribal members. River and spring waters are still used in many ceremonies (Knows His Gun McCormick et al. 2012).

The observations of local climate changes are those made by first author John Doyle, a Tribal Elder, and reflect experiences he and his peers have had over a span of many years. Additionally, other Elders shared their observations with Doyle for this article,[1] or contributed to discussions at meetings of the Crow Environmental Health Steering Committee (Cummins et al. 2010a, b). To compare and integrate the changes observed by the community with existing monitoring data, analyses were conducted of the local National Weather Service records as well as the US Geological Survey discharge data for the Little Bighorn River. Local knowledge and these physical measurements were in agreement, and provided complementary insights. This process has triggered further community discussions about potential impacts on water quality, forest and rangeland resources, subsistence foods and public health. Challenges facing these communities are broad in scope and demonstrate the need for vulnerability assessments and planning to reduce current and future climate-related health impacts.

2 Crow elder observations

Community Elders have observed long-term changes in the local climate, including declining winter snowfall, milder winters and warmer summers. Elders from all Districts of the Reservation remember that the ground used to be covered in deep snow and stayed frozen from November to March—while today the prairies are bare grass for much of the winter (S Young, J Doyle, personal communication, 2007; D Small, MA LaForge, K Red Star, D Yarlott, UJ Bear Don't Walk, personal communications, 2013). Sometimes the snow was so deep that it was a real struggle to feed cattle (D Small, personal communication, 2013). Children could ice skate throughout the winter; now winter days are often above freezing (S Young, personal communication, 2012). Even Tribal members in their thirties note that winters are not as cold as when they were children (W Red Star, V Buffalo, personal communications, 2013). Every spring, massive ice jams on the Little Bighorn River used to break up and scour out the river bottom and banks; today the ice is thin by early spring and what remains melts quietly away (J Doyle, personal communication, 2012). A locally important mountain spring, visited repeatedly over the years, has been steadily moving downslope, causing concern that the water table has been dropping due to reduced snowfall (J Doyle, personal communication, 2013).

Elders note that climate changes are affecting subsistence food plants, especially berries. (See also Lynn et al. 2013). Many species of berries have long been gathered as staple foods, including juneberries, chokecherries, elderberries and buffalo berries. Now these shrubs and trees sometimes bud out sufficiently early in the spring that they are vulnerable to subsequent cold snaps that kill the blossoms, so they never fruit. In years that shrubs bear fruit, the timing has changed: chokecherries used to ripen after the juneberries, and now they ripen at the same time (V Buffalo, personal communication, 2013). Elderberries in the mountains now ripen in July instead of in August (J Doyle, personal communication, 2013). 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, personal communication, 2013). Additionally, some trees now come out of dormancy during mid-winter warm spells, and die when the temperature drops below freezing again. Similar trends in the phenology of lilacs and honeysuckle have been

[1] The eight named Tribal Elders and two younger Tribal members who provided comments specifically for this article all agreed to the use of their names.

observed by the Western Regional Phenological Network: spring bloom dates in the 1980s–1990s were 5 to 10 days earlier than they were in the 1960s–1970s. This shift is attributed to warming spring temperatures in western North America by 2° to 5 °F (1°–3 °C) during the period of observation (Cayan et al. 2001).

Ceremonial practices are being affected by high temperatures. In May and June, sundances are held; these are three- or four-day outdoor events during which the participants fast, dance and pray. One older sundance chief, who for decades has led this ceremony near Crow Agency every Father's Day weekend, notes that the June weather has gotten progressively hotter and therefore the sundance has become increasingly difficult for fasting participants. He remarked that the cattails, which community members bring to participants for relief from the heat, used to average 6 ft in length, and are now only about 3 ft long (L Medicine Horse, personal communication, 2013). Cattail (*Typha latifolia*) vigor, including both root and shoot biomass, has been found to decline with increasing soil dryness (Asamoah and Bork 2010). Other traditional sundancers have concurred that dancing has become tougher with progressively hotter summer weather (L Kindness and anonymous Crow Environmental Health Steering Committee member, personal communications, 2013).

The river ecosystems appear to be warming in parallel with surface temperatures, as has been documented both nationally and globally (NCADAC 2013). Reduced stream flows and warmer summers, in addition to increased agricultural non-point source pollution, is affecting the Little Bighorn River. Apparent impacts to fish and other aquatic species include changes in brown trout location, a species that prefers cooler waters. Although these trout used to be found at the tributary mouth of the Little Bighorn River, near Hardin, they are now more than 35 miles upstream (A Birdinground, personal communication, 2010). Recently, bass have been observed in the lower Little Bighorn River, where they never lived before. Catfish with skin lesions have been caught. Freshwater mussel and frog populations have declined. These observations, along with knowledge of river contamination, have caused some families to give up subsistence fishing (J Doyle, personal communication, 2010). Others note declining fish populations, and believe the changes in climate are a contributing factor (V Buffalo, personal communication, 2013).

3 Confirmation of Elders' observations of recent climate change using monitoring data

The Elders' observations discussed in the previous section were compared to climate and hydrologic data available for the Crow Reservation and vicinity, as well as published regional climate trend information. While observational data are perhaps more subjective and less quantitative than monitored precipitation and streamflow, they have the potential to contribute greatly to understanding what ecosystem changes may be occurring as a result of multiple stressors, including climate change. They also provide information in regions where data are limited. The Reservation is part of the ancestral homelands of the Crow people, and so existing relationships with and uses of plants, game and water resources go back many generations. Parallel observations by Elders from all the Districts of the Reservation, such as of declining snowfall, provide multiple data points and are invaluable in the absence of SnoTel sites on the Reservation. Their observations are also particularly relevant to daily life, illuminating for instance how climate change is impacting food supply, cultural activities and human health.

Climate and hydrologic analyses were focused on the Little Bighorn River valley of the Crow Reservation, which includes the majority of the Reservation's population. Stream flow records for the Little Bighorn River were used because it flows north through the entire Reservation, passing through Crow Agency, before joining the Bighorn River at Hardin (Fig. 1). Weather station data were selected based on station history, completeness and appropriateness of records that would elucidate local changes to the Little Bighorn River valley near Crow Agency, Montana.

Hardin and Crow Agency weather station data were combined in this evaluation in order to provide a more complete history of changes that have occurred over the longest period of time (National Climate Data Center 2013). These data were supplemented by information on trends in precipitation and temperature from Montana's Climate Division 5 (MT CD5), which covers south-central Montana, including all of the Crow Reservation as well as counties to the west and north (Supplement Documents I and II). Other available weather data relevant to the Crow Reservation are limited. There are no other weather stations within the Little Bighorn River valley with sufficiently complete data to be worth analyzing, nor in nearby river valleys within 75 km of Crow Agency, Montana (Supplement Table I). Crow Agency data collection began operation in 1897, has reasonably complete data and is in a small rural community that has had no urban growth (0 %). However, the Crow Agency weather station was discontinued more than 20 years ago, limiting the usefulness of its data for an analysis of recent changes. Hardin, located 15 miles northwest of Crow Agency, began collecting data in 1909. Although the early record is missing much of the 1920s and 1930s, it has a nearly complete record of precipitation, temperature and snowfall from July 1948 to today (March 2013). The town of Hardin has had a negligible urban growth rate (2 %) over the past 75 years, hence urban growth is highly unlikely to have had a substantial impact on the weather data. The site is in an agricultural valley in the NOAA's Climate Division 5, south-central Montana. This weather station is 2905' (881 m) above sea level, and is located on the alluvial plain of the Bighorn River (Fig. 1).

Seasonal temperature variations in the Little Bighorn River valley are extreme, consisting of bitterly cold winters and very hot summers. These variations are reflected in the station data that show temperatures vary from −40 °F (−40 °C) in January and February, to above 100 °F (38 °C) in July and August, with an annual mean of 48.3 °F (9.1 °C). The number of days per year exceeding marked temperature thresholds has increased substantially from 1897 to 2012 (Fig. 2). The number of days per year exceeding 100 °F is highly variable. The

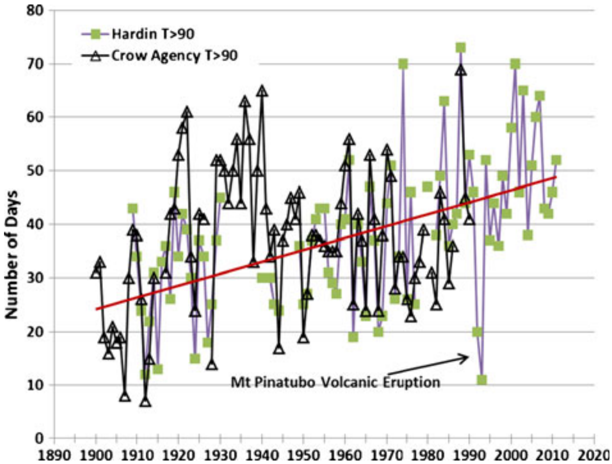

Fig. 2 Number of days per year with temperature exceeding 90 ˚F (32 ˚C) has doubled in the past century in Hardin and Crow Agency, MT. Data from National Weather Service daily records (National Climate Data Center). The *red line* indicates a linear trend of increasing high temperatures based on the data. (A dip in temperature in the early 1990s corresponds to a cold period produced by the volcanic ash from eruption of Mt Pinatubo.)

decadal-average number of days per year exceeding 100 °F has doubled from 1900–1909 to 2000–2009 (Supplement Table II). The increase in high temperatures recorded does not coincide with any changes made to weather station operation, but is consistent with trends in increasing temperatures for Montana Climate Division 5 (CD5) (National Climate Data Center). Montana CD5 data show average monthly temperatures over the past 110+ years have been steadily warming for the summer months of June through September, by 0.1° to 0.2 °F per decade (Supplement Document I). The warming trend observed in monitoring data supports the accounts and observations of the Crow Tribal sundancers.

Additional warming trends in winter temperatures are readily apparent in the number of frost-free days (days exceeding 32 °F), which has increased by about 7.2 days per decade (Fig. 3). In the 1950s there were on average 178 frost-free days per year, whereas since 2000 there have been 213 such days. The number of frost-free days per year has important implications for ecosystems because cold winters are responsible for killing off pests, such as bark beetles (Evangelista et al. 2011). As warm season weather extends in length, pests can have more than one reproductive cycle, further increasing their numbers.

This increase in number of frost-free days is consistent with Montana CD5 data showing that over the past 110+ years, average temperatures for the months of January through March have been steadily increasing (by 0.2 °F, 0.4 °F and 0.5 °F per decade respectively) (Supplement Document I). Elders' accounts that they used to be able to ice skate all winter long as children, and that the river ice was once much thicker in wintertime is consistent with these trends in cold temperatures observed in monitoring data.

Overall, Hardin's average temperature has increased from a mean of 45.6 °F in the 1950s to 50.1 °F since 2000. Average temperatures from the Crow Agency weather station records are nearly identical to the Hardin data for the years that collection occurred at both sites (Supplement Figure I).

These increases in average annual temperature and in the number of hot summer days and frost-free winter days, demonstrates that the climate changes projected by the draft National Climate Assessment (NCA) for the Northern Great Plains are already underway (National Climate Assessment and Development Advisory Committee (NCADAC) 2013).

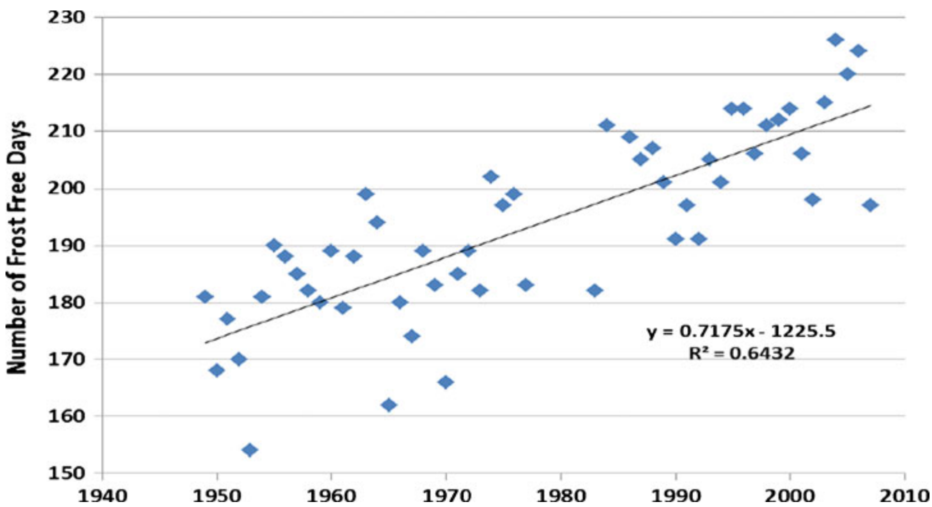

Fig. 3 Number of frost free days per year in Hardin, MT, calculated from historic daily observations. (Data source: National Climate Data Center.)

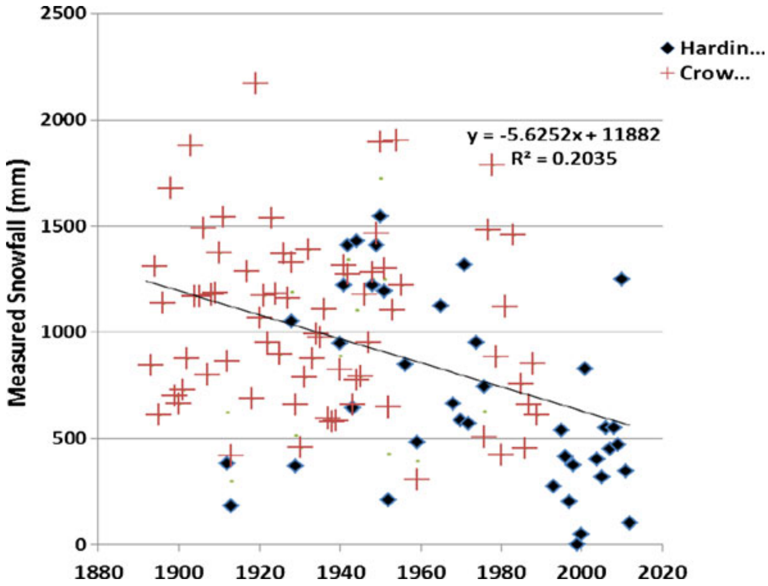

Fig. 4 Plot showing annual snowfall in millimeters from Hardin MT (1912–2012) and Crow Agency MT (1895–1990) observation sites, calculated in water years. The trendline is calculated from the average of measurements when both locations had measurements, and on the single site's measurements when only one station was operating. Years with more than 1 month of missing data were deleted from data plot, except for the earliest records. (Data source: National Climate Data Center.)

As temperatures warm, snowfall is likely to decrease because atmospheric temperatures are warm enough for precipitation to fall in a liquid rather than frozen state for a longer period during the year. Snowfall has decreased significantly in the region surrounding Hardin (Fig. 4). A similar trend in reduced snowpack has been documented for the Northern Great Plains in general, and for other parts of the western U.S. over the past half century (NCADAC 2013). For Montana CD5, including the Crow Reservation, winter precipitation (December through March) has been declining on average 0.05" per decade since 1895 (Supplement Document II). This regional trend has serious implications for local ecosystems, local temperature trends, recharge of aquifers and summer runoff in local streams and river systems, and hence also for Crow Agency, whose municipal water source is the Little Bighorn River. Snow covers the surface with highly reflective water crystals that help keep the surface cool by reflecting the sun's heat back into the atmosphere. Snow melts slowly, and as a result, the moisture delivered as snow infiltrates the substrate more effectively than rain. Also, mountain snowpack melts slowly during spring and summer, reducing the likelihood of flooding and providing riparian areas and communities with a constant fresh water supply during the hot summer months when water is needed most. The decline in winter snow pack is not being made up during other seasons; average annual precipitation in MT CD5 has been declining by 0.11 per decade (Supplement Document II).

The Elders' observations of decreased annual snowfall is confirmed by the research of Stewart et al. (2005) that showed a trend towards an earlier onset of the spring runoff peak throughout western North America. In addition, the Elders' observations were confirmed by an analysis of streamflow data for the Little Bighorn River. The USGS gaging station 06289000 on the Little Bighorn River at State line near Wyola, Montana, measures discharge from a drainage area of 193 square miles in the Big Horn Mountains. The station is located where the river leaves the Big

Horn Mountains and enters the valley floor, documenting flow before any significant withdrawals for agriculture or municipal uses. The river is a critical water source because it provides the municipal water source for Crow Agency and because the majority of the Tribe's population lives in the river valley. A US Geological Survey study of the Valley's groundwater resources found that the water in the Quaternary alluvium had a median total dissolved solids (TDS) concentration of 1,450 mg/L, while the median TDS concentration in the Judith River Formation was 1,000 mg/L (Tuck 2003). The EPA Secondary Standard for TDS is 500 mg/L, hence these levels are considered objectionable for municipal drinking water (EPA 2013). Neither aquifer provides a viable alternative water supply for Crow Agency's municipal use.

To reduce the "noise" from interannual variability in the spring runoff hydrographs, decadal averages of discharge for each day during May and June were calculated for the available data for the Little Bighorn River gaging station (06289000). The 1980s and 2000s had the earliest spring runoff peak of all decades on record (Supplement Figure II) (USGS 2012).

Decadal averages of monthly mean daily discharge from 1940 to 2009 were similarly calculated. Plotting these data show that the 1980s and 2000s had not only the earliest but also the lowest spring runoff of all decades on record (Fig. 5). If this pattern continues, it would be in agreement with research documenting the effects of warmer temperatures on decreased streamflow (Pederson et al. 2010; McCabe and Clark 2005).

Recent devastating spring floods of the town of Crow Agency in 2007 and 2011 warrant examination of flood history to see if their frequency is increasing. The data show that the mean daily discharge for May 2007 was more than 100 cfs higher than any other May on record for the previous 70 years of streamflow data (Supplement Figure III). The USGS data document the well-remembered "epic" June 1978 flood, when the nearest gauging station on the Little Big Horn River (close to Hardin), set an all-time record of 11.78 ft, which was 3.78 ft above flood stage. The devastating 2011 flood, in which more than 200 homes were damaged, set a new gauging station record of 12.32 ft (Olp 2011; Thackeray 2011) (Supplement Figure IV). Local oral history tells of a similarly major flood in the 1920s (Doyle, personal communication, 2012, citing Alice Yarlott Other Medicine). Note that high mean daily discharge of the Little Bighorn

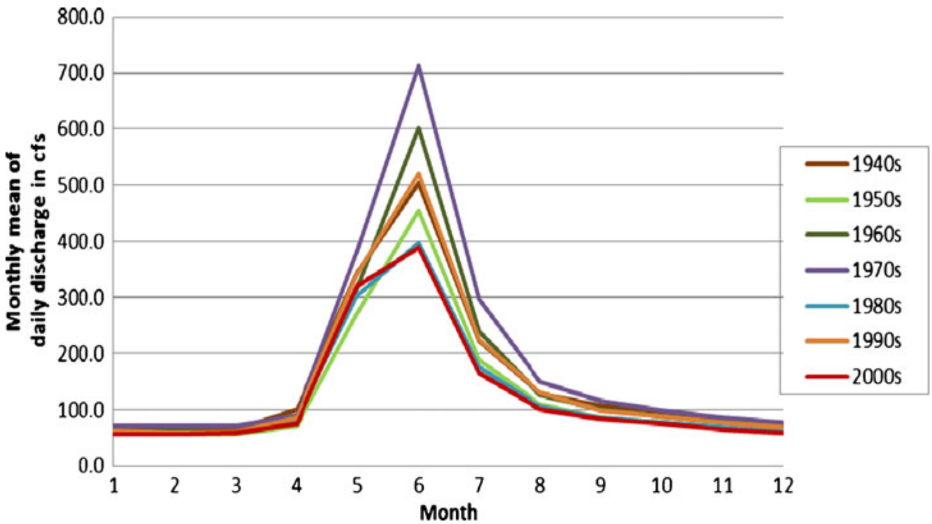

Fig. 5 Monthly averages of daily mean discharge by decade for Little Bighorn River at State Line near Wyola, Montana (station 06289000). (Data source: USGS 2012)

River at State Line near Wyola, Montana (at station 06289000) for the month of June has not always resulted in flooding of Crow Agency. Over the past century, the town of Crow Agency has experienced severe floods about every 40 to 50 years, but the unusual early season flood in May 2007, followed closely by a more damaging flood in 2011, has raised community concerns about increased flood frequency and severity. Trends in CD5 data show a shift in precipitation from winter months to the spring (increasing in April). These trends may also contribute to the probability of spring floods.

The physical data sets available, the descriptions of climate and ecosystem change by Elders, and recent flooding and fire events on the Reservation are almost all in accordance with descriptions of current and predicted climate impacts described in the draft National Climate Assessment (NCA) in the chapters on the Great Plains, Native Lands and Resources, and Water Resources (NCADAC 2013). The additional information contributed by Crow Tribal Elders provides a better understanding of climate impacts and phenological changes experienced by the community, compared to what can only be cautiously surmised from the monitored climate and stream discharge data. These local data are an essential complement to regional predictions, especially when evaluating local ecosystem change and vulnerable communities (e.g. Patz and Olson 2006). The draft NCA's prediction of increased annual precipitation for the Northern Great Plains is contradicted by both the local mountain stream discharge data and the MT CD5 data. The MT CD5 data document an absolute long-term regional decline in annual precipitation for south-central Montana.

4 Anticipated vulnerabilities for the Crow community and local ecosystems

The Apsaalooke [Crow] Water and Wastewater Authority ("the Authority"), which works with the Reservation communities of Crow Agency, Wyola and Pryor on their municipal water and wastewater systems, is particularly concerned about the effects of the apparently declining streamflow, increased agricultural demand and more frequent spring flooding on drinking water availability, water quality and community health. As the Little Bighorn River is the source water for the municipal water treatment plant supplying Crow Agency and the regional Indian Health Service Hospital, and low flows in August already strain the ability of the plant to obtain sufficient water to supply the town, further decreases in streamflow from reduced snowfall could be challenging. The monthly averages of daily mean discharge for the months of June and July were the lowest on record for the 2000s and 1980s (Fig. 5). The demand from agriculture for water for irrigation is already increasing (J. Doyle, personal communication, 2012). Clearly, running out of municipal drinking water for the town and the hospital would have deleterious health impacts.

Research conducted by Little Big Horn College (LBHC) and the Crow Environmental Health Steering Committee, with partners from Montana State University Bozeman and the University of New England, has already found substantial microbial contamination of local rivers during spring and summer months. For instance, *E. coli* levels in the Little Bighorn River exceeded 1,200 colony forming units (CFU)/100 mL during spring 2007 (Ford et al. 2012); surface waters with an *E. coli* geometric mean exceeding 126 CFU/100 mL are considered unsafe for swimming (EPA 2012). Testing initiated by the Crow Agency Water Treatment plant, and conducted at an EPA-certified lab, showed that the *E. coli* concentration in their Little Bighorn River source water exceeded 7,100 CFU/100 mL during spring runoff in 2009 (Bright Wings 2009, cited in Connolly et al. 2010). The documented *E. coli* concentrations mean that under the EPA's Long-Term 2 Enhanced Surface Water Treatment Rule, the Treatment Plant falls into "Bin 4," the highest risk category for *Cryptosporidium* in the source water. *Cryptosporidium* is a protozoan pathogen, which in its oocyst form can survive in the environment for months, and is highly resistant to chlorination (US EPA 2001). The infective dose for humans is low, and an infection can be fatal for immune-compromised individuals (US EPA 2001). *Cryptosporidium* has contaminated public water systems elsewhere in the US, especially after heavy precipitation coinciding with spring snow melt (Patz and Olson 2006). Hence, the Crow Agency Water Treatment Plant is required to meet additional treatment requirements for *Cryptosporidium* removal by October 1, 2014 (Connolly et al. 2010). The Tribe's limited operations and maintenance budget for water treatment strongly constrains technology choices. More frequent spring flooding will only exacerbate these municipal water treatment challenges.

Spring flooding incurs multiple health risks to community members. During the 1978 flood, the sewer clogged and sewage backed up into homes (Thackeray 2011). In 2011, the flood washed wastewater from the Lodge Grass lagoon into the Little Bighorn River, which in turn inundated downstream homes and businesses. Twenty-two homes were destroyed and over 200 were damaged (Olp 2011). There was an increase in complaints about water damage to homes leading to mold infestation (M Eggers, personal communication, 2011). Molds release irritants and allergens, and can cause asthma attacks in some asthmatics (EPA 2010). Many people's wells were flooded; the Tribe's Environmental Protection Department subsequently shock chlorinated many of these wells but could not reach everyone affected. The Federal Emergency Management Administration's Montana Disaster Declaration designated the Crow Reservation as eligible for both Individual Assistance and Public Assistance (FEMA 2011). Experiencing two severe floods within 5 years, there is community concern about the impacts of continued increased flood frequency and severity, possibly driven by climate change.

The Authority, the Crow Tribe, Little Big Horn College and the local Indian Health Service hospital, working together as the Crow Environmental Health Steering Committee, with the support of academic partner Montana State University Bozeman, are working on several mitigation strategies to reduce waterborne microbial health risks (Cummins et al. 2010a, b; Eggers et al. 2012). First, a low cost, high tech home water filtration system was pilot tested for home use. This system is proving to successfully treat river water for microbial contamination such as *E. coli* for only pennies a day, so it can be safely consumed. The filters could provide an option for safer ceremonial consumption of river water, for families who found this culturally acceptable. Second, EPA funding is being sought to work with local ranchers to reduce non-point source pollution from livestock manure. Third, there are collaborations with other researchers to better elucidate the health risks from microbial contamination of river water, especially *Cryptosporidium* and *E. coli*. Finally, there are community education events and partnerships with educators to expand water quality education in the schools.

Warmer summer temperatures are also affecting the Crow Agency municipal water supply's distribution system, with implications for community health. During summer 2012, the soils in Crow Agency became so dry and hard that soil surface impact more readily shattered the older, underground concrete-asbestos drinking water lines. Until breaks are detected and repaired, water lines are vulnerable to contamination, creating health risks for water consumers. This also wastes precious water and increases infrastructure maintenance costs for an already financially strained system. The Water Authority has successfully raised funds to upgrade the distribution system and is replacing these old, fragile water lines.

The effects of decreased snowfall and warmer temperatures on forest health, wildfire severity and hence also human health are another community concern. As mentioned above, drier and warmer weather improve conditions for forest pests such as bark beetles, resulting in more dead timber and greater fire risk (Voggesser et al. 2013). Across the state of Montana, more than 1.2 million acres burned in 2012 (NOAA 2012)—the most acreage burned in recorded history, except for 1910 (Thackeray 2012).

The 2012 Sarpy Creek, Bad Horse, Plum Creek fires and more on the Crow Reservation resulted in the worst fire season in memory for the community. The fires were even worse on the adjoining Northern Cheyenne Reservation, where more than 60 % of their 445,000 acre Reservation burned. Homes and livestock were lost; the town of Lame Deer was evacuated; some areas were burned so badly the soil blistered, creating concern that the pastures and wildlife forage would not recover. If so, ranching and subsistence deer and elk hunting, vital to local families, could be impacted. There were days when the smoke was thick and heavy, but there are no measurements of air quality, so people concerned about the health risks had no way to assess the danger (J. Doyle, personal communication, 2013). This coming spring (2013), erosion is expected to become an issue for both soil and water quality. The full extent of the impacts of the 2012 fire season on land, water and human health are still unfolding.

5 Conclusion

Meteorological data from Hardin and Crow Agency, the USGS streamflow-gauging station on the Little Bighorn River and MT CD5 exhibit trends predicted and observed to be the result of the Earth's average warming by 0.7 °C this last century due to the greenhouse effect, with one exception: annual precipitation and apparently streamflow are declining, in contradiction to the prediction for increased precipitation in the Northern Great Plains (NCADAC 2013). Observations from Tribal Elders and the small amount of meteorological data available are in agreement. In addition, Elder observations suggest that the data trends are representative of the Little Bighorn River valley. Further investigation of these trends is needed to provide an account of when changes to ecosystems began, the magnitude of ecosystem changes that could be occurring, and any underlying mechanisms and stressors that may contribute to observed changes to plant and animal species.

The ecological effects of less snowfall, warmer temperatures, recently reduced streamflow, increasing flood frequency and fire severity are already being experienced by Crow Tribal members and other residents of Big Horn County. Additional research to understand and document the full extent of the consequent human health impacts has yet to be conducted. A "Climate Change Health Assessment," to include the steps of "scoping… surveying… analysis… and planning," as was conducted in northwest Alaskan villages (Brubaker et al. 2011b) would be invaluable. Such an assessment would be essential for the Crow Reservation community to plan for mitigation of the impacts on water and subsistence food resources, forest health, agriculture, ranching and community health. Other Northern Plains communities are encouraged to examine their local climate data and consider and plan for current and future impacts of climate change on their local ecosystems, water resources and public health.

While changes in climate and health impacts have been researched and documented for Alaskan Native and Southwestern Tribal communities, much less has been published about impacts on Tribes in the Northern Great Plains (NCADAC 2013). Recent publications documenting how climate change is affecting snowmelt hydrology and streamflow timing in the northern Rocky Mountains (Pederson et al. 2010; Hamlet et al. 2001), as well as the draft National Climate Assessment (NCA) (NCADAC 2013), suggest that Crow Reservation climate changes and concerns might be relevant to other communities in the region. Additionally, as local changes in climate shown in the NOAA record are not completely in agreement with the changes projected for the Northern Great Plains by the draft NCA (NCADAC 2013), there is a need for analyses at both local and regional scales. The addition of local data to regional projections is resulting in more engaged community discussions and will provide a better basis for community policy development and long range planning (Brubaker et al. 2011b). Therefore, this article describes how the local weather and discharge data has been analyzed, and the potential public health impacts, as an example that could be useful for other communities.

Acknowledgments Thank you to the many Crow Tribal members who contributed their personal observations of changes to the Reservation's climate, water resources and phenology over the recent decades, and particularly to Sara Young, whose initial observations inspired this work. Anne Camper (Montana State University Bozeman), David Anning (Arizona Water Science Center, US Geological Survey) and anonymous reviewers provided useful suggestions.

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