MONTANA CLIMATE ASSESSMENT

CLIMATE CHANGE AND HUMAN HEALTH IN MONTANA

A Special Report of the Montana Climate Assessment

January 2021

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Fire in the Bridger Mountains, September 2020
Photo courtesy of Bruce Maxwell

CLIMATE CHANGE AND HUMAN HEALTH IN MONTANA

A Special Report of the Montana Climate Assessment

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Wildfire smoke, September 2020, East Wind Creek near Crow Agency
Photo courtesy of John Doyle

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Photo courtesy of John Doyle

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LIST OF ACRONYMS

CDC—Centers for Disease Control and Prevention

ENSO—El Niño-South Oscillation

GCM—general circulation model

GHG—greenhouse gas

HEPA—high-efficiency particulate air (filters)

HVAC—heating, ventilation, and air conditioning (systems)

IPCC—Intergovernmental Panel on Climate Change

MCA—Montana Climate Assessment

MSU—Montana State University

MTDPHHS—Montana Department of Public Health and Human Services

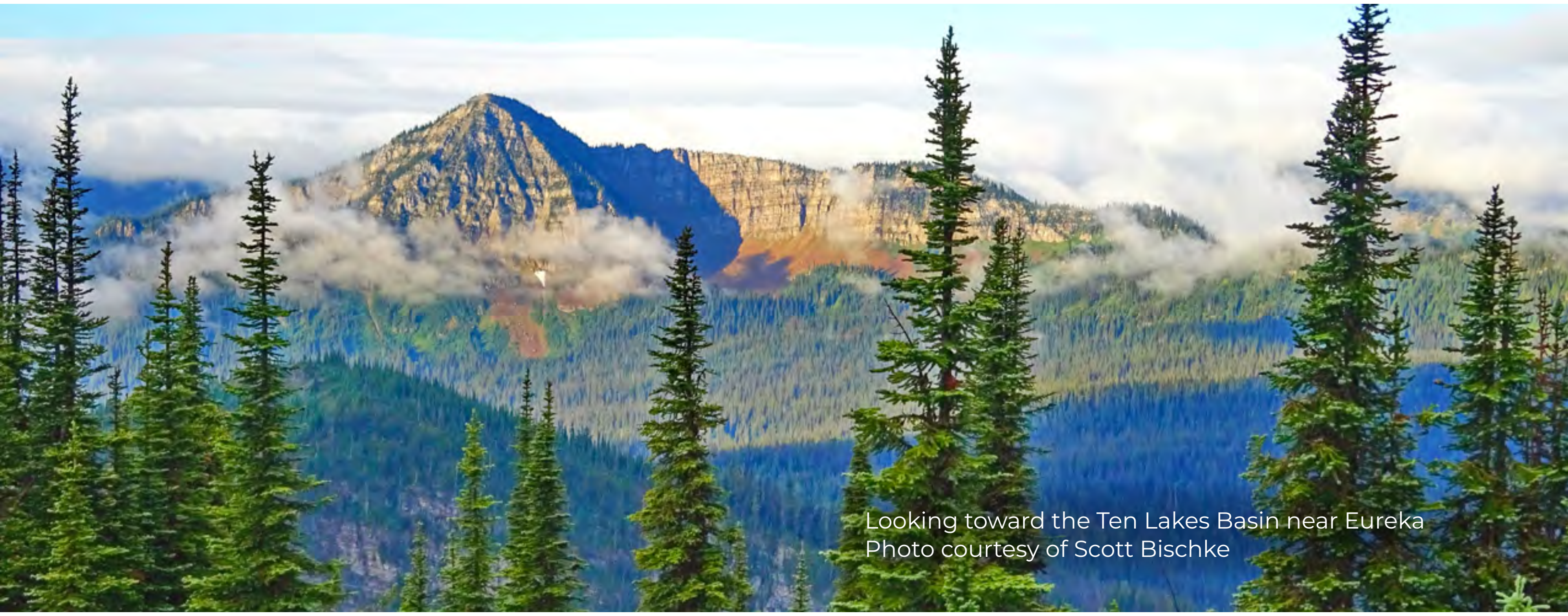
NOAA—National Oceanic and Atmospheric Administration

NWS—National Weather Service

PM—particulate matter (most often seen as PM2.5 and PM10, describing particulates under 2.5 μm and 10 μm, respectively)

PTSD—post-traumatic stress disorder

RCPs—representative concentration pathways



Looking toward the Ten Lakes Basin near Eureka
Photo courtesy of Scott Bischke

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Nighttime fire glow near Roundup
Photo credit: Casey Page, Billings Gazette

FOREWORD

Aaron Wernham MD, MS

Dr. Wernham is Chief Executive Officer of the Montana Healthcare Foundation (2014-present). He is also a family physician with experience in both public health and medical practice. Dr. Wernham developed and led the Health Impact Project, a major national initiative of the Robert Wood Johnson Foundation and served on several National Academy of Sciences committees.

January 2021

In recent years, Montanans have seen record-breaking heatwaves and intense fire seasons. The *Montana Climate Assessment* (MCA)[1] indicates that the state will continue to experience rising temperatures through the end of the century, along with increased smoke from wildfires and extreme climate events ranging from flood to drought. These conditions have the potential to threaten our health, particularly for the growing share of Montanans who are over the age of 65, and for those who are more vulnerable due to disabilities, chronic health conditions, or the lack of health insurance and limited access to healthcare. This Special Report of the MCA, *Climate Change and Human Health in Montana*, focuses on climate change issues that impact Montanans. Its key messages and recommendations highlight the challenges facing communities and healthcare professionals, as well as provide important guidelines for better monitoring, preparedness, and action.

In 2016, under a mandate from the United States Congress, the US Global Change Research Program released a foundational report titled *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*[2] . The report offered a view of climate-related health

1 Whitlock C, Cross W, Maxwell B, Silverman N, Wade AA. 2017. 2017 Montana Climate Assessment. Bozeman and Missoula MT: Montana State University and University of Montana, Montana Institute on Ecosystems. 318 p. Available online http://montanaclimate.org. Accessed 9 May 2020. doi:10.15788/m2ww82.

2 [USCGRP] US Global Change Research Program. 2016. The impacts of climate change on human health in the United States: a scientific assessment. Crimmins A, Balbus J, Gamble JL, Beard CB, Bell JE, Dodgen D, Eisen RJ, Fann N, Hawkins MD, Herring SC, Jantarasami L, Mills DM, Saha S, Sarofim MC, Trtanj J, Ziska L (eds). Washington DC: US Global Change Research Program. 332 p. Available online https://health2016.globalchange.gov/low/ClimateHealth2016_FullReport_small.pdf. Accessed 14 May 2020.

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impacts at the national level, such as increases in heat-related illness, sea-level rise and displacement of coastal communities, changing patterns in insect-borne diseases, and threatened water supplies. No report to date, though, has examined climate-related health risks in Montana.

After publication of the MCA, public health and healthcare professionals made the point that, although its coverage of water, forests, and agriculture was a good start, there was a need for information on the state's most valuable resource: its people. They saw an urgent need for a state-specific health assessment and, most importantly, for practical ways to help communities address the health risks. To this end, in July 2018 a workshop was convened to discuss preparing a new special report to the MCA on health challenges related to climate change in Montana. That workshop, attended by 23 climate scientists, health professionals, and other stakeholders, laid the foundation for this assessment, which is the result of more than two years of work by members of that group, with robust peer review and input from Montana citizens.

Even though many face workforce shortages and limited funding, local public health agencies and healthcare providers lead the response to a long list of health challenges—from mental illness and substance use disorders, to seasonal flu, to the current COVID-19 pandemic. In this context, the need for this report is evident: clear, practical recommendations will make it easier to respond effectively and reduce the health risks of climate change given that staff and time are limited in many public health and healthcare centers in Montana.

Climate Change and Human Health in Montana aims to provide up-to-date information and to explain the impacts and potential solutions in a way that can be understood by everyone. Groups that seldom work together—climate scientists, healthcare and public health professionals, and leaders from non-governmental organizations—came together to contribute to the report.

The report reflects the proactive leadership of our state's healthcare and public health communities, who came together to advocate for the topic and contribute to the report. Many of the contributors have worked for years to educate peers about the health risks of climate change. Moreover, some tribes and rural communities are in the process of conducting, or have already conducted, climate and health assessments, and these efforts contributed to and helped pave the way for this report.

The last section of the report provides practical recommendations for healthcare providers, public health officials, communities, and individuals on how to prepare for the future. These guidelines can serve as a template for planning and identifying areas of vulnerability and for assisting communities in preparing for and reducing the impacts of climate change on public health.

Climate Change and Human Health in Montana is a first step in preparing for our changing climate, and it deserves to be updated as new information becomes available and unforeseen situations arise. I hope the report is widely studied and becomes the go-to reference for public health officials, healthcare professionals, and communities as we work together to mitigate the effects of climate change in Montana.

Air quality can be tracked via AirNow.gov, as described in Section 5

Flooding of Little Bighorn River, 2011
Photo courtesy of John Doyle

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SUMMARY OF KEY MESSAGES AND RECOMMENDATIONS

During the preparation of *Climate Change and Human Health in Montana*, we developed key messages and recommendations about how climate change will impact the health of Montanans. *Key messages* refer to evidence-supported projections of those impacts. *Recommendations* are proposed behavioral and policy changes for coping with those impacts.

For each key message, we provide a statement of confidence in our findings. We rate the certainty of key messages based on agreement and evidence following the approach used by the Intergovernmental Panel on Climate Change's (IPCC's) Fifth Assessment Report (IPCC 2014) (Figure Key Messages-1).

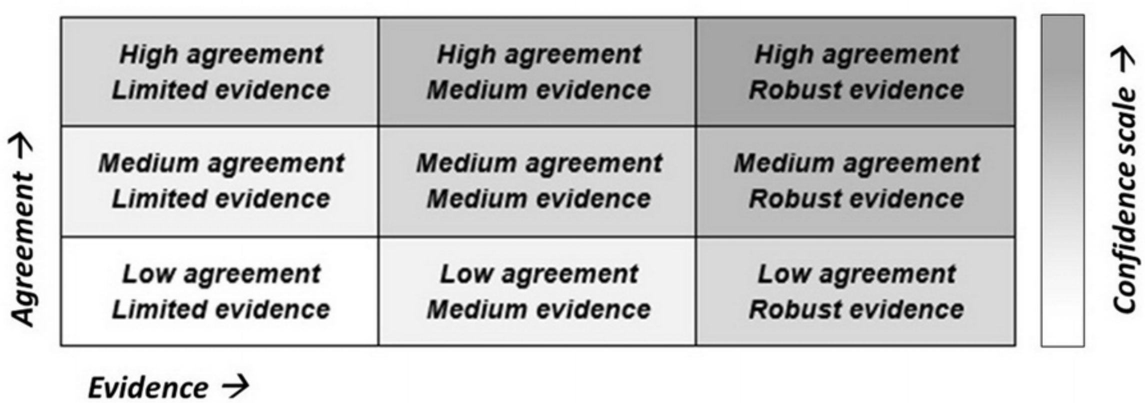

Figure Key Messages-1. A depiction of evidence and agreement statements and their relationship to confidence. Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent, and independent lines of high-quality evidence (figure and caption following that presented in the IPCC Fifth Assessment Report [IPCC 2014]).

For each key message, authors of the relevant section rate agreement—the consistency of the evidence among scientific reports—as "low," "medium," or "high." Authors also rate the evidence as "limited," "medium," or "robust," depending on the type, amount, and quality of the scientific information supporting the message. The authors offer their expert judgment in these assignments based on the level of evidence and agreement, and provide details in the text to support their ratings. The higher the level of author confidence in the key message, the greater the evidence and agreement.

This assessment draws from, and is an extension to, the *2017 Montana Climate Assessment* (MCA) (Whitlock et al. 2017), which provides the first detailed analysis of expected impacts to Montana's water, forests, and agriculture from climate change. MCA presents 35 key messages, seven of which serve as important foundations to the work of this report:

- Annual temperatures have risen 2-3°F (1.1-1.7°C) since 1950, and our growing season is now 12 days longer. Montana has experienced an increase in warm days and nights, both in summer and winter. There is no trend in precipitation since 1950. [*high agreement, robust evidence*]
- Climate models project that temperatures will continue to increase and by the end of the century average annual temperature may be 9.8°F (5.4°C) higher than those recorded between 1971-2000, given our present rate of greenhouse gas emissions. [*high agreement, robust evidence*]
- Precipitation received at a state level may increase slightly in the future, but these gains will be offset by evaporation and transpiration due to higher temperatures. More precipitation will be received in winter, spring, and fall; summers will become drier than at present. [*moderate agreement, moderate evidence*]
- Rising temperatures will result in a shift from snow to rain earlier in the year than at present. In turn, this shift will result in earlier dates for the onset of snowmelt and associated peak stream runoff by the end of the century. [*high agreement, robust evidence*]
- The number of days >90°F (>32°C) will increase significantly by the end of the century, with the greatest warming in eastern Montana. The eastern part of the state will also experience more extreme heat (i.e., days when the heat index[1] exceeds 105°F [41°C]). [*high agreement, moderate evidence*]
- Increased wildfires are expected as wetter springs result in increased fuel accumulation, and drier summers lead to fuel desiccation. The size of fires and the length of the fire season will increase in both forest and grassland. [*high agreement, robust evidence*]
- Unforeseen climate-related weather events will occur with projected increases in temperature and drought in the coming decades, including greater likelihood of spring flooding, severe summer drought, and extreme storm events. [*high agreement, moderate evidence*]

Following, then, is a summary of key messages and recommendations as developed in this report, *Climate Change and Human Health in Montana*.

1 A glossary is provided at the end of this report for unfamiliar terms. *Heat index*, for example, is defined in the glossary as a measure of perceived heat when humidity, which can make it feel much hotter, is factored in with the actual measured air temperature.

Key Messages

- Three aspects of projected climate change are of greatest concern for human health in Montana: 1) increased summer temperatures and periods of extreme heat, with many days over 90°F (32°C); 2) reduced air quality from smoke, as wildfires will increase in size and frequency in the coming decades; and 3) more unexpected climate-related weather events (i.e., *climate surprises*), including rapid spring snowmelt and flooding, severe summer drought, and more extreme storms. [*high agreement, robust evidence*]
- The most vulnerable individuals to the combined effects of heat, smoke, and climate surprises will be those with existing chronic physical and mental health conditions, as well as individuals who are very young, very old, or pregnant. Montana's at-risk populations include those exposed to prolonged heat and smoke, living in poverty, having limited access to health services, and/or lacking adequate health insurance. [*high agreement, robust evidence*]
- Projected increased summer temperatures and wildfire occurrence will worsen heat- and smoke-related health problems such as respiratory and cardiopulmonary illness, and these potential problems are of most immediate concern. [*high agreement, robust evidence*]
- Earlier snowmelt, more intense precipitation events, and projected increases in floods will endanger lives and lead to more gastrointestinal disease due to contaminated water supplies, as well as increased opportunities for other water-borne, food-borne, and mold-related diseases. [*high agreement, moderate evidence*]
- Increased summer drought will likely increase cases of West Nile virus in Montana, but the impact of climate change on other vector-borne diseases is less clear. [*high agreement, moderate evidence*]
- Longer growing seasons, warmer temperatures and elevated carbon dioxide (CO_2) levels are leading to increased pollen levels, worsening allergies and asthma. [*high agreement, moderate evidence*]
- Summer drought poses challenges to local agriculture, resulting in decreased food availability and nutritional quality, and to the safety and availability of public and private water supplies, especially for individuals and communities relying on surface water and shallow groundwater. [*high agreement, robust evidence*]
- Climate changes, acting alone or in combination, are reducing the availability of wild game, fish, and many subsistence, ceremonial, and medicinal plants, which threatens food security, community health, and cultural well-being, particularly for tribal communities. [*high agreement, moderate evidence*]
- Increased stress and increased mental illness are under recognized but serious health consequences of climate change. [*high agreement, robust evidence*]

Recommendations

- o Address the health and economic impacts of climate change by creating an adequately funded and coordinated statewide public health network that engages public health and emergency and environmental management professionals, clinicians, climate scientists, elected leaders, and stakeholders in planning and implementing climate mitigation and adaptation strategies.
- o Improve information collected and shared at the state and local levels on climate and health to facilitate this public health network and medical decision-making by:
  - working with government agencies to expand heat, smoke, air-quality, and water-quality monitoring, and improve data accessibility, especially for underreported and underserved areas; and
  - supporting efforts in the healthcare community to establish mechanisms for capturing and analyzing physical and mental health impacts related to heat, smoke and air quality, and water quality in Montana.
- o Boost statewide technical expertise in implementing climate change adaptation by funding trainings for diverse stakeholders, landowners, professionals, and leadership.
- o Continue the work of the MCA to update the information in this report and expand the understanding of climate change impacts on other sectors of importance in Montana.
- o Get involved and be part of the solution! Use the information in this report to help yourself, your community, and Montana address climate change. Everyone has a role to play!

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Whitlock C, Cross W, Maxwell B, Silverman N, Wade AA. 2017. 2017 Montana Climate Assessment. Bozeman and Missoula MT: Montana State University and University of Montana, Montana Institute on Ecosystems. 318 p. Available online http://montanaclimate.org. Accessed 9 May 2020. doi:10.15788/m2ww82.

Smith River country near White Sulphur Springs
Photo courtesy of Scott Bischke

Ennis, Montana
Photo courtesy of Scott Bischke

01. INTRODUCTION

Cathy Whitlock and Alexandra Adams

The purpose of this assessment is to a) present understandable, science-based, Montana-specific information about the impacts of climate change on the health of Montanans; and b) describe how our healthcare providers, state leaders, communities, and individuals can best prepare for and reduce those impacts in the coming decades. This assessment draws from, and is an extension to, the *2017 Montana Climate Assessment* (MCA[1]) (Whitlock et al. 2017), which provides the first detailed analysis of expected impacts to Montana's water, forests, and agriculture from climate change. MCA explains historical, current, and prospective climate trends for the state based on the best-available science.

The *2017 Montana Climate Assessment* did not address the impact of climate change on the health of Montanans. This special report of the MCA fills that important knowledge gap; it represents a collaboration between climate scientists and Montana's healthcare community and is intended to help Montanans minimize the impacts of climate on their health. The report is broken into five additional sections:

- Section 2 summarizes key findings about climate change in Montana, drawing on information from the *2017 Montana Climate Assessment*.
- Section 3 details the consequences of climate change on human health, globally and in Montana.
- Section 4 explains the health effects of climate change on our state's most vulnerable populations, such as the very young and very old, people with chronic disease, pregnant individuals, and those living remotely and in poverty.
- Section 5 provides recommendations and resources for planning, policy changes, adaptations, and actions to ensure positive health outcomes for Montanans in the face of climate change.
- Section 6 provides important concluding remarks.

Both Sections 4 and 5, which are less technical than previous sections, may be read as stand-alone resources. Throughout the report, we provide sidebars with stories specific to Montana.

1 This report uses "MCA" in discussing the Montana Climate Assessment program. We provide the reference (Whitlock et al. 2017) only when speaking of specific results published in the 2017 Montana Climate Assessment, not the overall program.

> *The purpose of this assessment is to a) present understandable, science-based, Montana-specific information about the impacts of climate change on the health of Montanans; and b) describe how our state can best prepare for and reduce those impacts in the coming decades.*

Concerns for the Vulnerable

Climate change is a global phenomenon, and the anticipated impacts to health and well-being affect all humankind to some degree. Given its northern and interior location in the US, Montana will avoid some of the health impacts of climate change facing other parts of the country and the world. Nonetheless, some of the health consequences experienced here will likely be *more* serious than elsewhere. Projected temperature increases in Montana, as described in the MCA (Whitlock et al. 2017), are of foremost concern to climate scientists and health practitioners alike. For example:

- Average temperatures in Montana have increased across the state by 0.42°F (0.23°C) per decade since 1950, which is faster than the US average (0.26°F [0.14°C]).
- Climate projections indicate continued warming in the coming decades with temperature increases of 4.5-6.0°F (2.5-3.3°C) by mid century.[2]
- Days above 90°F (32°C) are anticipated to increase by 5-35 days by mid century, with greatest increases occurring in the southeastern part of the state.

Along with increased temperature, four other climate change projections in the *2017 Montana Climate Assessment* are issues that threaten the health of Montanans. Those issues are increased occurrence of wildfire and its impact on smoke and air quality; early snowmelt and intense precipitation events; projected changes in water availability and quality; and extreme and unexpected climate-related weather events. MCA finds that although there has been no significant change in statewide average annual precipitation since 1950, summer precipitation has decreased, while spring and fall precipitation have increased slightly. Projections indicate more year-to-year and season-to-season variability in precipitation, earlier loss of snow, and more summer drought (Whitlock et al. 2017).

Montana is a rural state with widely spaced urban centers. Its population of 1,062,305 in 2018 included 5.9% under five years old, 17.6% over 65 years old, and 2% over 80 years old. Older age groups—that is, people over 65—are increasing in number across the state. The state's economy has become more diversified in recent decades, with one-third of the workforce now in the service sector (e.g., health care, trade, leisure activities), while goods-based industries

2 The increase depends on the scenario of global greenhouse gas emissions, as described in Section 2.

(e.g., manufacturing, construction, mining, agriculture) collectively account for about 24% of the economy (Montana Department of Labor and Industry undated). Montana ranked 39th in median household income in 2018, but poverty is a problem in several parts of the state, especially on Indian reservations (US Census Bureau 2019). About 14% of Montanans live in poverty; of those 6% live in deep poverty, earning <50% of the federal poverty level.

Montanans will experience both benefits and harm to human health from climate change, depending on location and individual. While warmer winters may help some Montanans, for example, a number of negative consequences are foreseeable for others. Added heat stress and other climate changes may cause or exacerbate cardiovascular and respiratory infirmities, gastrointestinal ailments, infectious diseases, premature births, and morbidity. Vulnerability to such impacts will vary depending on where individuals live, as well as on their age, gender, occupation, residence, socioeconomic status, and underlying medical conditions (see sidebar).

Populations Most Vulnerable to Climate Change in Montana

Multiple sectors of Montana's population are at special risk of having their health impacted by our warming climate, including people...

- ...threatened by increased heat
- ...living in proximity to wildfire and smoke
- ...facing food and water insecurity
- ...who are very young, very old, or pregnant
- ...having limited access to healthcare services
- ...living in poverty
- ...lacking adequate health insurance
- ...with existing chronic conditions
- ...with mental health issues
- ...whose livelihoods or traditional ways are closely tied to the land or environment, including those working outdoors in construction, agriculture, recreation, and resource-extraction industries

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Report Purpose and Genesis

To date there has been no single source of information about how climate change will affect the health of Montanans. *Climate Change and Human Health in Montana* seeks to fill this gap in our knowledge, drawing on the best available, current information. Scientific assessments are essential tools for linking knowledge to decision-making, by surveying and synthesizing peer-reviewed scientific information across disciplines, sectors, and regions. Assessments highlight key information that can improve understanding of complex issues and identify topics where study is needed. The work presented here on climate change and human health should be a sustained effort, updated and expanded on a regular basis as part of the overall MCA program.

Climate Change and Human Health in Montana is intended to help communities, healthcare professionals, and other decision makers understand the climate-health connection and evaluate different strategies for response. The flow of information should also go in the opposite direction, with this report helping decision makers identify critical information gaps that require new scientific investigation, tool development, and future assessment. Along with its statewide focus, *Climate Change and Human Health in Montana* contributes to the larger flow of information on this topic that occurs between national, regional, state, and local levels.

Climate Change and Human Health in Montana is the product of a diverse partnership of over 40 scientists and healthcare professionals who first met in August 2018 to discuss the issue and plan the assessment. Before its release, the report received public comment and rigorous scientific review by health and climate experts at state and national levels (see Acknowledgments section).

This report makes it clear that Montana's changing climate will have measurable impacts on our state's human health and well-being in the future. We hope that this information motivates much-needed discussion on this topic, one that leads to greater awareness, considers multiple sources of knowledge, and helps planning efforts and action in this important area. During the 2020 COVID-19 pandemic, we have had to acknowledge how much we are all connected, and now more than ever realize how clearly our health and economic well-being are tied to the health of the planet. It is our hope that this report will motivate our collective action towards innovative mitigation and adaptation strategies for improving health in the face of climate change.

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The Montana Climate Solutions Plan

In 2019, Governor Bullock issued an executive order creating the Montana Climate Solutions Council, tasked with developing a plan of recommendations and strategies to prepare Montanans for climate impacts, reduce greenhouse gas emissions (GHG) to achieve net GHG neutrality by mid century, and advance new technologies and other innovations to meet these goals. The Council was composed of members from state agencies, the universities, businesses, tribal communities, and non-governmental organizations; and during its deliberations received input from experts and the public. The Montana Climate Solutions Plan[a] was released in September 2020 with a broad list of recommendations, many of which are relevant and align with this report on climate change and human health:

- Develop a Montana Climate Solutions Network to share climate information and resources and build capacity in communities so that climate solutions connect at state, local, regional, and tribal nation levels
- Build community resilience to climate change through better coordination with existing planning efforts
- Adapt buildings, homes, and other infrastructure to better withstand climate change
- Maintain a diverse and healthy economy, positive mental and physical health outcomes, and a resilient high quality of life for Montanans and visitors
- Safeguard Montana's water quality and quantity from climate change
- Enhance local air quality monitoring and support indoor air quality needs for vulnerable communities during intense periods of wildfire smoke

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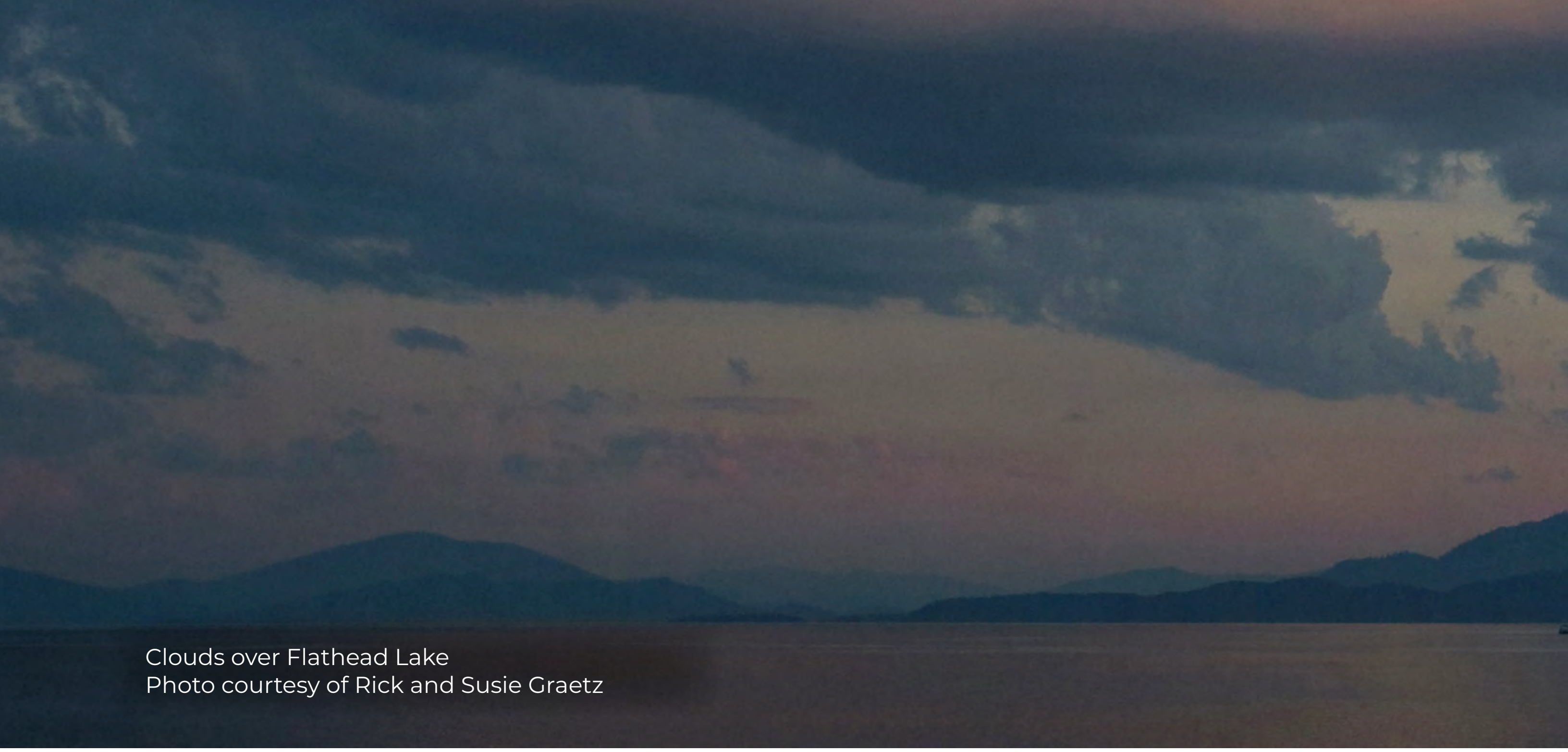
[a] State of Montana. 2020. Montana Climate Solutions Plan: a report by the Montana Climate Solutions Council. Helena MT. 73 p. Available online https://deq.mt.gov/Portals/112/DEQAdmin/Climate/2020-09-09_MontanaClimateSolutions_Final.pdf. Accessed 4 Nov 2020.


Clouds over Flathead Lake
Photo courtesy of Rick and Susie Graetz

02. CLIMATE CHANGE AND HUMAN HEALTH IN MONTANA

Cathy Whitlock[1]

As noted in the Introduction, this assessment brings scientific information about the impacts of climate change on human health to the people of Montana in an organized and understandable manner. In this section, we begin with a short description of Montana's geography. We then describe how climate and weather differ, as well as past trends and future projections for temperature and precipitation in the state. We next review the climate changes that pose the greatest threat to the physical and mental health of Montanans.

1 With grateful acknowledgment to the contributions of Kelsey Jencso and Nick Silverman for their work on the climate chapter of the *2017 Montana Climate Assessment* (Whitlock et al. 2017).

Montana's Unique Geography

Montana's climate is as diverse as its landscapes, which vary from high plains grasslands to alpine rock and ice. As the nation's fourth largest state, and given our location in the interior of North America, Montana is exposed to diverse weather systems that arise from air masses in the Arctic, Pacific, and Gulf of Mexico. The strength and location of these air masses shift seasonally, creating differences in climate and weather across the state and throughout the year. Montana's complex topography modifies weather systems as they travel over our western mountain ranges and onto the Great Plains. Montana tends to be wetter in the west because of the proximity to Pacific moisture sources and the cooling and condensing effects that result as air masses rise to cross the Continental Divide. The state is generally drier in the east where heating is stronger and elevations are lower.

Montana's mountains are headwaters to three of the continent's major river systems: the Missouri, Columbia, and Saskatchewan. As such, snow levels in our region affect water availability far beyond the state's border. Our mountain snowpack comes largely from Pacific storms. This winter precipitation is the primary water supply serving our state's waterways, ecosystems, municipalities, farms and ranches, and recreational and tourism industries.

Climate Differs from Weather

Climate change is a description of a region's average weather conditions as they vary over at least decades. Weather, in contrast, refers to the short-term changes, occurring over minutes to months in the atmosphere, as measured by temperature, humidity, precipitation, atmospheric pressure, and other variables (NASA undated). While Montana's climate has become warmer in recent decades, weather patterns have shown considerable variability on a day-to-day and month-to-month basis.

In addition to relatively rapid changes in weather, Montana has also experienced year-to-year variability in climate that relates to global-scale fluctuations in ocean circulation and their influence on the atmosphere. The El Niño-Southern Oscillation (ENSO) is an example of a climate pattern in our region that varies from year to year depending on ocean-atmosphere patterns in the tropical Pacific Ocean and their influence on storm tracks and pressure systems at higher latitudes. Montana experiences different phases of ENSO, each leading to short-term climate conditions:

> *Climate change is a description of a region's average weather conditions as they vary over at least decades. Weather, in contrast, refers to the short-term changes, occurring over minutes to months in the atmosphere, as measured by temperature, humidity, precipitation, atmospheric pressure, and other variables (NASA undated). ... The important point is not to confuse weather and year-to-year climate variability with long-term climate trends.*

- *El Niño phase.*—During an El Niño phase, the tropical Pacific Ocean is warmer than normal and Montana, especially the northwestern region, tends to experience warmer winters.
- *La Niña phase.*—During the opposite La Niña phase, the tropical ocean is cooler than normal and Montana tends to experience cool, often wet winters.
- *ENSO neutral phase.*—When the tropical Pacific Ocean experiences near-average temperatures, circulation conditions in Montana are less predictable.

The important point is not to confuse weather and year-to-year climate variability with long-term climate trends. The former two describe short-term, continually shifting conditions observed over days and years; the latter refers to climate conditions as summarized over decades, or longer. When we discuss climate change, we usually refer to a baseline or *normal period* for comparison. In the *2017 Montana Climate Assessment* (Whitlock et al. 2017) and in this report, that normal period is a 30-year time span from 1971-2000.

The Science of Projecting Montana's Future Climate: An Overview

Montana is made up of 56 counties, with climate issues ranging widely—including drought, floods, wildfires, extreme heat, and unexpected weather events—depending on location (Figure 2-1). Each county, likewise, has its own unique history, economy, and level of community connection and, thus, access to healthcare is highly variable.

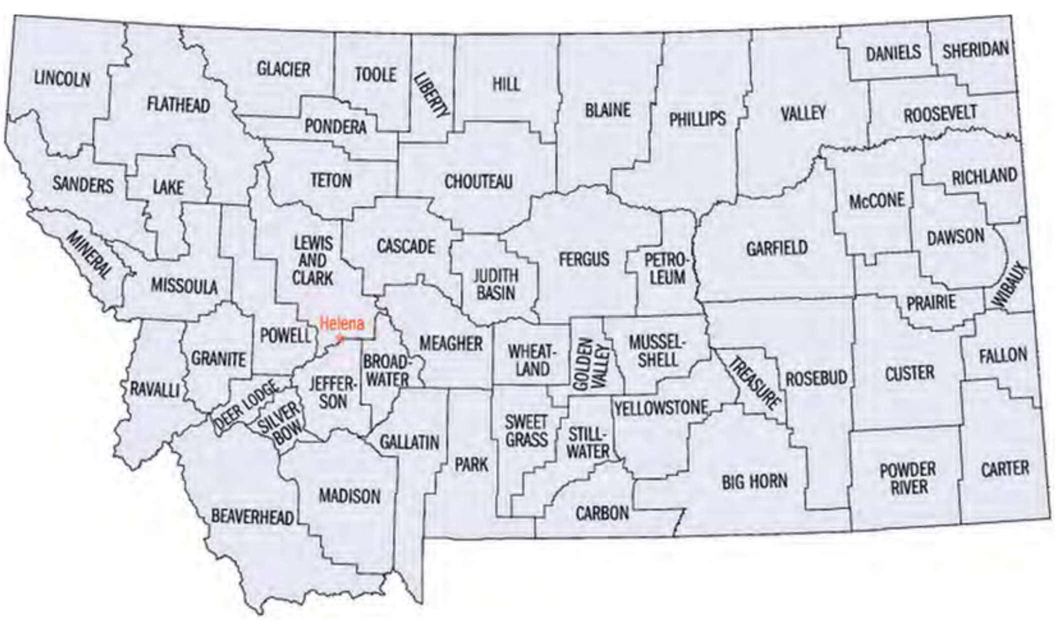


Figure 2-1. Montana consists of 56 counties.

To more readily understand climate change across our state, the *2017 Montana Climate Assessment* (Whitlock et al. 2017) aggregates the 56 counties into seven climate divisions, then describes recent climate trends and future projections for those seven divisions. These climate divisions are the Montana subset of the 344 divisions identified by the National Oceanic and Atmospheric Administration (NOAA) to report climate for the US (NOAAa undated). NOAA established the divisions based on climatic, political, agricultural, and watershed boundaries. For Montana, the MCA identifies the seven NOAA divisions as the northwestern, southwestern, north central, central, south central, northeastern, and southeastern climate divisions (Figure 2-2).

MCA analysis of *historical* climate trends started with the mid-20th century and drew on direct measurements of temperature and precipitation from weather stations across the state. Using statistical methods, these observations were used to derive a single temperature or precipitation value to represent each of the seven climate divisions.

MCA *future projections* were based on a set of 20 climate models, selected from a larger suite of general circulation models (GCMs) developed by scientists to simulate global climate. GCMs are complex mathematical depictions of the global circulation of the atmosphere and oceans (including the Earth's frozen waters). These models provide ten-day weather forecasts, as well as projections of future climate. The 20 GCMs included in the MCA were independently developed at research laboratories around the world—as part of the fifth phase of the Coupled Model Intercomparison Project (WCRP undated)—and chosen for their ability to accurately provide daily outputs of climate variables important in Montana. The Montana Climate Office statistically downscaled the coarse-scale GCM output to a finer scale that incorporated the influence of topography on regional climate (Abatzoglou and Brown 2012). The result was projections of future climate for each Montana climate division.

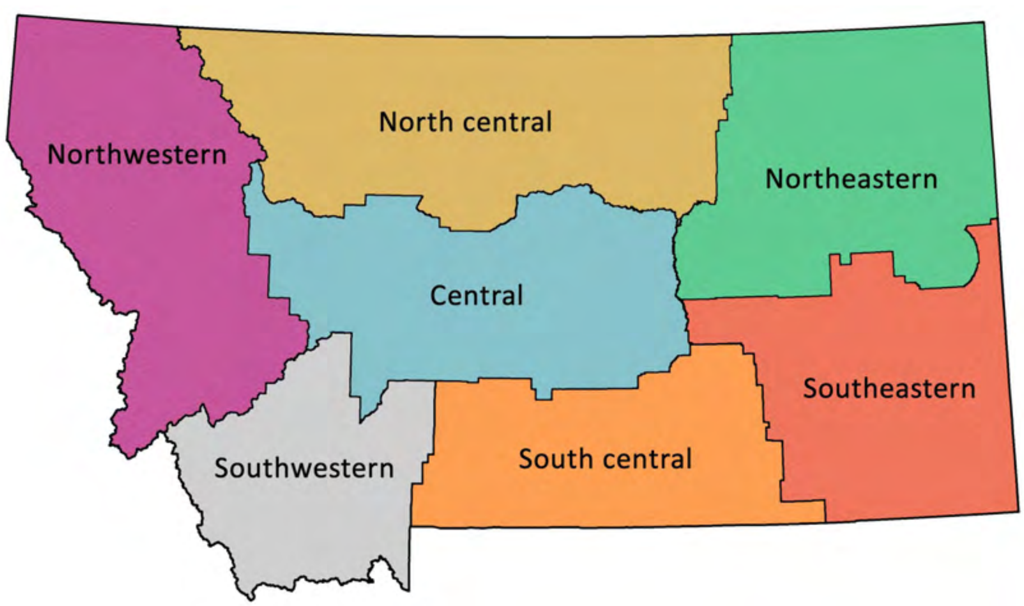


Figure 2-2. Montana's seven climate divisions. Note that NOAA officially names the *northwestern* division on this map as the *western* division. We use *northwestern* for geographic clarity.

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We all wonder about the current trajectory of warming and how it will develop in the future—will it be rapid or gradual? In climate assessments, it is common to see graphs with multiple curves showing different trends in projected climate change through the end of the century. Each curve results from different assumptions regarding future greenhouse gas emissions; the assumptions are based on a range of possible decisions that humankind makes globally from today forward. Those decisions, called *scenarios* by modelers, include such factors as changing energy sources (fossil fuel or renewable), technological advancements, economic trajectories, and population growth.

The current set of scenarios behind each curve are known as *Representative Concentration Pathways* (RCPs), and their plausibility is continually re-evaluated as new information comes to light. Again, RCPs describe decisions society *might* make from today forward. Each scenario-driven pathway results in a particular level of greenhouse gas (CO_2, CH_4, and others) emission in the coming decades and, as a result, a different amount of temperature increase, precipitation change, and more. While multiple RCPs have been investigated, MCA (Whitlock et al. 2017) focuses on two scenarios for Montana's future climate, RCP4.5 and RCP8.5[2], as described below:

- RCP4.5, often termed the *stabilization* scenario of expected carbon use, describes a future trajectory that involves some level of greenhouse gas mitigation (i.e., slowing use because of decisions society makes). The curve shows a near-term rise in the rate of greenhouse gas emissions, with maximum levels reached at about 2040, and a decline in the rate of emissions in the last half of the century (Clarke et al. 2007).
- RCP8.5, which currently represents the *upper bound* of expected carbon use, describes a future trajectory where greenhouse gas emissions rise at a high rate through the century. The scenario presents a future where humankind does not curb fossil fuel use and the release of greenhouse gases increases without mitigation. RCP8.5 is more extreme than RCP4.5 in its projections of climate change after the mid century, including higher temperatures.

A key goal of this assessment is to identify those aspects of changing temperature and precipitation most likely to have consequences on the physical well-being and mental health of Montanans. In the following subsections, we provide a short review of projections for those two climate variables, which serves as the basis for understanding the impacts of climate change on human health in our state.

A key goal of this assessment is to identify those aspects of changing temperature and precipitation most likely to have consequences on the physical well-being and mental health of Montanans.

2 The RCP number (i.e., 4.5 or 8.5) refers to the resulting watts/m^2 of greenhouse-gas-derived heating by the year 2100 if this scenario plays out.

Temperature

Increasing temperatures, the most direct consequence of rising greenhouse gases, are a major health concern for Montana, the nation, and the globe. Air temperature has increased in recent decades and that warming will continue in the future. MCA shows that the rate of change per decade in average annual temperature for the period from 1950-2015 was about 0.4°F (0.2°C) statewide, which equates to 2-3°F (1.1-1.7°C) warming in the last 65 yr (Whitlock et al. 2017). More recently, the years 2015 and 2016 were the first and third warmest since 1950, with average annual temperatures 3.2 and 2.9°F (1.8 and 1.6°C) above the base period of 1971-2000 (NOAA b). Likewise, 2017 had average annual temperatures 1.5°F (0.8°C) above this base period, although average annual temperatures for 2018 and 2019 were average or slightly below average (NOAAb undated).

A 70-yr warming trend since 1950 is evident across the state, with greatest warming in the south central climate division (Figure 2-2). Since 1895, Montana's rate of warming (0.20°F/decade [0.1°C/decade]) has been greater than that of the US (0.15°F/decade [0.08°C/decade]), and this condition reflects the state's location far from the moderating effects of an ocean. Average maximum and minimum temperatures have also risen across the state since 1950 by 0.3-0.6°F/decade (0.2-0.3°C/decade), amounting to an increase of approximately 3.3°F (1.8°C) for the hottest and coldest conditions (Whitlock et al. 2017).

MCA temperature projections for 2040-2069 (mid century) and 2070-2099 (end of century) indicate that current warming trends will continue (Whitlock et al. 2017) (Figure 2-3). By mid century, annual average temperatures are 4.5°F (2.5°C) higher under the RCP4.5 scenario and 6°F (3.3°C) higher under RCP8.5 than the base period (1971-2000). All models agree on the direction of this trend. End-of-century average annual temperatures for the state are more dramatic: increases of 5.6°F (3.1°C) in RCP4.5 and 9.8°F (5.4°C) in RCP8.5, again with full model agreement. Temperature projections show small differences across climate divisions, but overall warming is evident across the state. Projections of average monthly temperatures show temperature increases in all seasons and for all divisions, with summer and winter experiencing the greatest warming. August, in particular, has the greatest monthly change for all divisions.

> *The upper-bound emission scenario (RCP8.5) shows approximately 34 additional days exceeding 90°F (32°C) in the northwestern, southwestern, and north central divisions and 54 additional extreme-heat days in the south central, northeastern, and southeastern divisions. The significant increase in the number of extremely warm days in summer and the loss of cold days in winter by the end of the century are important projections in the MCA (Whitlock et al. 2017).*

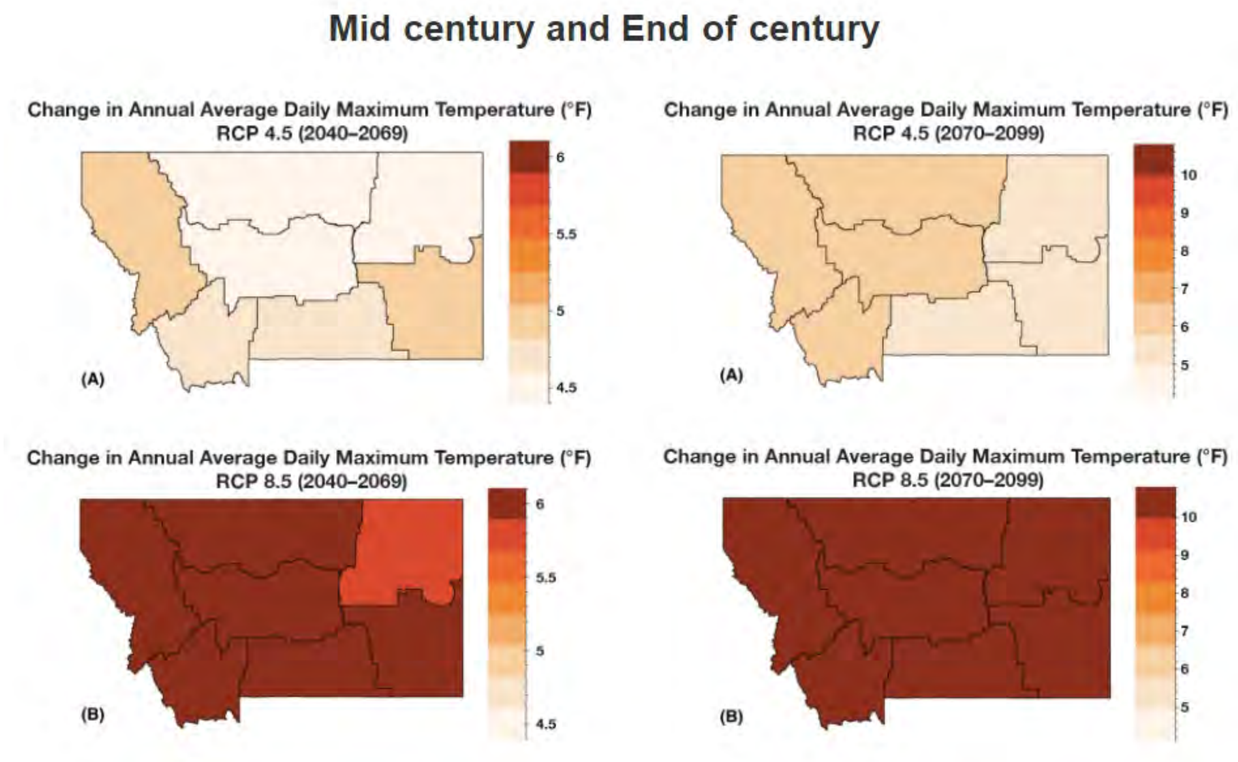

Figure 2-3. The projected increase in annual average daily maximum temperature (°F) for each climate division in Montana for the periods 2049-2069 and 2070-2099 for (A) stabilization (RCP4.5) and (B) upper-bound (RCP8.5) emission scenarios (Whitlock et al. 2017).

Daily minimum and maximum temperatures also show a similar magnitude of increase in the coming decades. The number of frost-free days (days where the temperature does not drop below 32°F [0°C]) is conservatively projected to increase by 24-30 days by mid century (RCP4.5 stabilization scenario), particularly in the western division. Extreme-heat days (where the daily temperature exceeds 90°F [32°C]) also increase in the model projections. In the stabilization scenario (RCP4.5), the western and north central climate divisions experience an additional five extreme-heat days, and the northeastern, southeastern, and south central divisions have an increase of 25 extreme-heat days by mid century as compared to the base period (1971-2000).

The upper-bound scenario (RCP8.5) elevates the number of days above 90°F (32°C) days by mid century: 11 additional extreme-heat days in the northwest and north central divisions and 33 additional extreme-heat days in the northeastern, southeastern, and south central divisions. These numbers increase further by the end of the century, where the stabilization scenario (RCP4.5) indicates 9-29 additional days. The upper-bound emission scenario (RCP8.5) shows approximately 34 additional days exceeding 90°F (32°C) in the northwestern, southwestern, and north central divisions, and 54 additional extreme-heat days in the south central, northeastern, and southeastern divisions. The significant increase in the number of extremely warm days in summer and the loss of cold days in winter by the end of the century are important projections in the MCA (Whitlock et al. 2017).

Precipitation

Montana is a semi-arid region. Thus, the availability and quality of water are critical for the health of the state's communities and ecosystems. The amount of precipitation varies widely across the state, with elevation, topography, and distance from the Pacific Ocean determining the timing and form of precipitation received. Generally, the western part of the state receives the highest levels of precipitation (average of 22-30 inches [56-76 cm]), and most of it falls in the form of winter and early-spring snow from Pacific storms. The eastern part of the state receives only half the level of precipitation (average of 12-14 inches [30-36 cm]), with moisture sources coming from a combination of Pacific storms in winter and convective storms in late spring and summer. These convective storms are associated with hail, lightning, and sometimes tornados in eastern and central Montana.

Annual precipitation levels for the state have not changed significantly since 1950, although there is considerable variability among regions in the amount received each year. In general, since 1950 northwestern Montana has become slightly drier in winter, while eastern Montana has become slightly wetter in spring. The year-to-year variation reflects the influence of topography on individual storm tracks, as well as large-scale climate patterns that vary year to year (e.g., ENSO), and creates particular weather conditions. In the winter of 2017-2018, for example, Pacific storms were directed to our region (a La Niña condition), resulting in record-high snow accumulation in Montana. Places in western and central Montana received from 111-152% of normal snowpack, as measured by the April 1 snow water equivalent (Figure 2-4). These high levels of snowpack are likely to be rare in the future, as warmer temperatures force earlier melting and runoff.

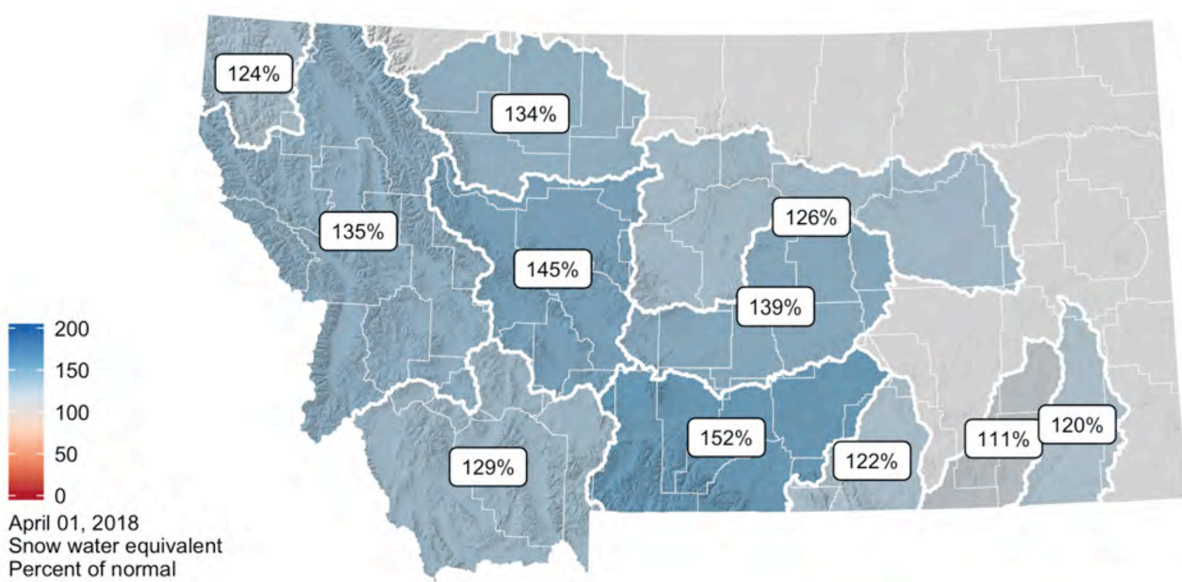

Figure 2-4. The Montana Drought and Climate report from the Montana Climate Office showing snowpack in 2018 as measured by the April 1 snow water equivalent (MCO 2019). This high snowpack was the result of interannual climate variability, which set up a strong La Niña-type climate pattern in the western US. With projected warming in the future, snowpack will be greatly reduced by April 1, making these high-snow years increasingly rare.

Precipitation is a complex phenomenon to simulate in climate models because a number of interactive components in the atmosphere, land, and ocean govern where, when, and how much precipitation falls. These components must be incorporated correctly for general circulation models to accurately portray current conditions and provide credible projections for the future. As a result, GCM projections show less agreement about future precipitation levels than they do for future temperature; this is true at a global scale and also for Montana. MCA suggests that by mid century, precipitation will increase slightly across the state, with 1.3 inch/yr (3.3 cm/yr) more in the northwestern and north central regions and 0.9 inch/ yr (2.3 cm/yr) more in the southwestern, central, and eastern climate divisions, as compared to the base period (1971-2000) (Whitlock et al. 2017). The upper-bound scenario (RCP8.5) for mid-century projections suggests an increase of 2.0 inch/yr (5.1 cm/yr) in the western half of the state and 1.8 inch/yr (4.6 cm/yr) in the eastern half. For this scenario, model agreement ranges from 65% for the mid-century summer projections to 95% for the spring projections.

It is important to caution that projected increases in precipitation will likely be more than offset by the coincident rise in temperature. Warming will increase rates of evaporation from soils and water bodies, and transpiration (water loss) from plants (Collins et al. 2013). While we may receive more precipitation, especially in the form of rain, effective moisture (that which remains on the surface and in the ground) will be reduced by the consequences of heat.

Seasonal differences in the projected changes in precipitation are striking, as analyzed in the MCA (Figure 2-5). In all regions and under both scenarios for the mid century and end of century, precipitation increases markedly in spring (March-May), and less markedly in winter (December-February) and fall (September-October). In contrast, summers (June-August, and in some regions, September) receive less precipitation in the future. The combination of slightly wetter conditions in winter, spring, and fall, coupled with drier summers, both as compared with the base period (1971-2000), is especially striking in the upper-bound emission scenario (RCP8.5) (Figure 2-5). In the end-of-the-century projection, for example, increases in winter and spring precipitation of 0.4 inch/month (1 cm/month) and decreases in summer precipitation of -0.2 inch/month (-0.5 cm/ month) are indicated, with 75% model agreement. MCA projections thus indicate that winter, spring, and fall will get wetter and summer will get drier in the coming decades, with the likelihood of effective moisture (that which remains on the surface and in the ground) decreasing in all seasons because of rising temperatures (Whitlock et al. 2017).

> *MCA projections indicate that winter, spring, and fall will get wetter and summer will get drier in the coming decades, with the likelihood of effective moisture (that which remains on the surface and in the ground) decreasing in all seasons because of rising temperatures.*

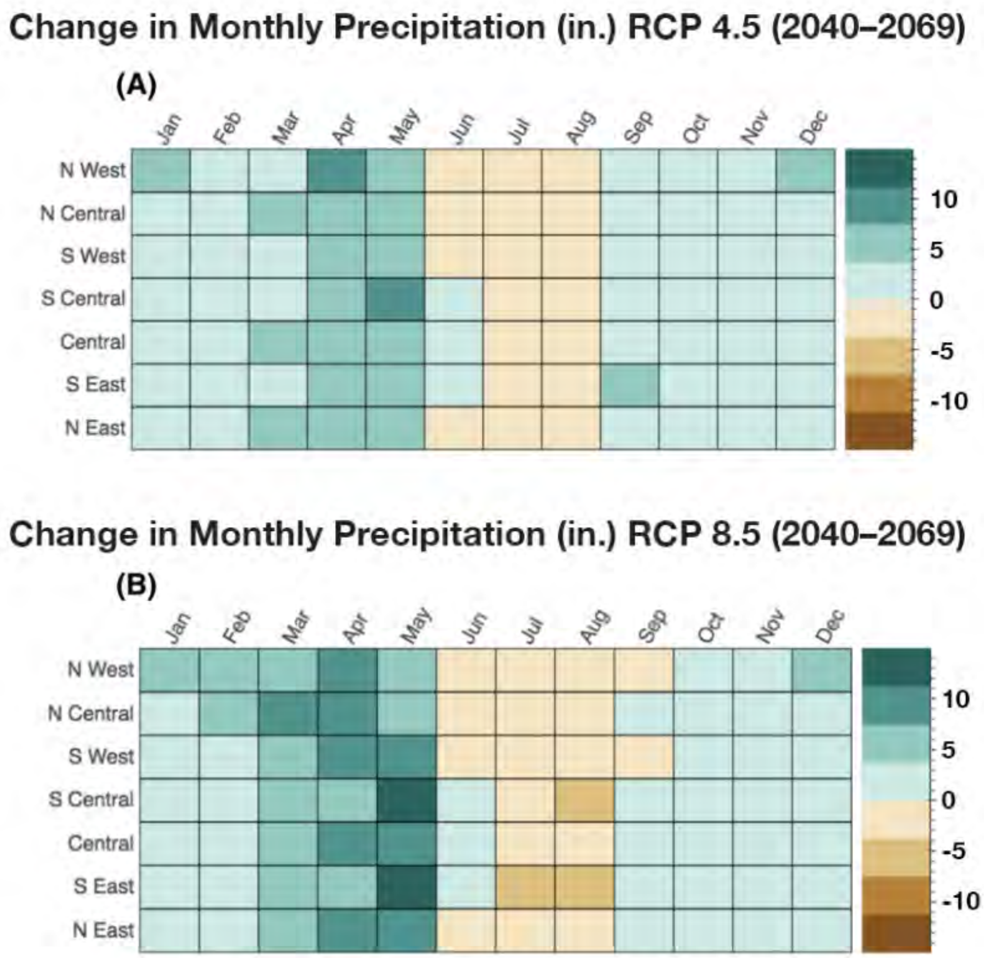

Figure 2-5. Projected monthly change in average precipitation (inches; color scale to the right) for each climate division in Montana in the mid-century projection (2040-2069) for (A) stabilization (RCP4.5) and (B) upper-bound (RCP8.5) emission scenarios (Whitlock et al. 2017).

Climate Concerns for Human Health

Given this background of current climate trends and future climate projections for Montana, we turn to an overview of how those changes may affect the health and well-being of Montanans. Three elements of projected climate change are of particular concern in our state and deserve close attention from the health community. In subsequent sections of this report, we address the health consequences directly, but first the nature of the climate threats themselves deserves a brief explanation.

Extreme heat

Extreme heat is the most pervasive issue of health concern, with statewide increases in annual temperature of potentially 4-6°F (2.2-3.3°C) by mid century and possibly as great as 9.8°F (5.4°C) by the end of the century, based on RCP8.5 (upper-bound) emission scenario.[3] This rise in temperature continues a warming trend that the state has already experienced during most of the last 120 yr, and especially since 1950. The coldest temperatures during winter will become warmer in the future, which may have positive consequences for some communities and livelihoods. However, the number of extremely warm days in summer will also increase, by over a month in most places and with rural areas of eastern Montana projected to experience the greatest heat stress (Whitlock et al. 2017). Across the US and world, populations living in areas that have experienced extreme heat have suffered from a variety of heat-related health illnesses, and even death.

Given the state's northerly location, Montanans have not lived through the summer heat experienced in other regions, but this situation will likely change in the future. Some areas of the world have already experienced the heat-index levels that the MCA projects for Montana. People living in those areas have suffered from heat stress and worse. In France, for example, heatwaves are blamed for the deaths of 1500 people in the summer of 2019 (Guardian 2019). Montanans, likewise, are at risk as we expect as many as 2.5 weeks of 105°F (41°C) in the northeastern and southeastern climate divisions by the end of the century (Figure 2-2). These two areas include a large sector of the population that works outdoors in agriculture. Most of the rest of the state is projected to experience up to 10 days reaching 105°F (41°C) by the end of the century.

Smoke and air quality

Smoke is likely to become a persistent seasonal feature of our climate, as wildfires become ever larger and more severe across the western US. Smoke fills our valleys from local wildfires, as well as those burning in other western states and Canada. Particulate matter from these fires traps heat, reduces visibility, and creates dangerous air quality conditions. Since the 1970s, the US fire season has lengthened from 5 to over 7 months/yr (see Section 3), and parts of the country now experience wildfires year-round. The link between rising temperature and fire activity is clear: warming summers dry vegetation, and increasing fuels set the stage for fires to ignite and spread. Learning to live with fire has become a priority for Montanans, as increased fire management will not return us to fire frequencies and sizes of the past. Likewise, making our communities better adapted and more resilient to fire and smoke is now a priority in planning efforts (Schoennagel et al. 2017; McWethy et al. 2019).

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3 The frequency and severity of these extreme heat events in the future depends on the level of greenhouse gases (CO_2, CH_4, and others) in the atmosphere, and our ability and willingness to reduce those levels.

Climate "surprises"

Climate "surprises" are extreme or unexpected events that can cause great damage to human health and property. The list of events includes abrupt and marked changes in average temperature and altered patterns of storms, floods, droughts, and wildfire. These events take place so rapidly and unexpectedly that human and natural systems often have difficulty adapting.

Rising spring temperatures, for example, have led to a shift from snow to rain in early spring. In addition, snowpack melts more rapidly in spring, resulting in ice jams and streams overflowing their banks, with sometimes disastrous consequences. Severe spring floods have occurred in snow-fed streams in Montana throughout history (NOAAc undated), but recent years have seen unusually large floods on the Clark Fork, Little Big Horn, Missouri, Musselshell, Poplar, Powder, and Yellowstone rivers. These events have led to extensive property and infrastructure damage, as well as loss of human lives. Although it is difficult to predict spring flood events with certainty, they are likely to increase in frequency and severity in the future. Climate projections suggest that the seasonal shift from snow to rain will occur earlier, as will the date of peak spring runoff. Peak runoff on most headwater streams in Montana now occurs 10-20 days earlier than in 1948, and by the end of the century the date of peak runoff is projected to occur 5-35 days earlier than during the period from 1951-1980 (Whitlock et al. 2017).

Another consequence of earlier snowmelt is less water available in late summer, increasing the risk of drought. Some droughts start abruptly; some can last a long time. In the former category are *flash droughts*, a recently coined phrase that describes a rapid shift from wet to dry conditions following just a few weeks of hot, dry weather (see sidebar). As an example of the latter category, Montana suffered a 307-week drought starting May 2000 (NIDIS undated).

Regardless of length of drought, the impacts to human health range from respiratory issues due to poor air quality from fires or dust storms; to gastrointestinal strife due to declining drinking water quality and/or sanitation services; to increased disease carried by vectors such as mosquitoes that breed in stagnant waters (CDC undated). Drought also negatively impacts communities that rely in part on wild foods for sustenance (Smith et al. 2019; Martin et al. 2020).

Reduced streamflow in late summer has led to high temperatures in some waterways, stressing the region's water supplies and ecosystems. Reduced late-season water availability threatens irrigation and community water sources, plus sets the stage for a host of health issues, including vector-borne diseases and mental health concerns (see Section 3). In 2016, Montana Fish, Wildlife, and Parks closed a 184-mile (296-km) stretch of the Yellowstone River because increased water temperatures led to a massive fish kill. The die-off was attributed to a proliferative kidney disease caused by the warmer temperatures (MTFWP 2016).

The 2017 Northern Great Plains Drought

The 2017 Northern Plains drought sparked wildfires, destroyed livestock, and reduced agricultural production. It was the worst drought to impact North Dakota, South Dakota, eastern Montana, and the Canadian prairies in decades.

Neither the drought's rapid onset—sometimes called a *flash drought*—nor its severity was forecast. In May 2017, the northern Great Plains region was mostly drought free, and at least average summer precipitation was forecast. By July 2017, the region was experiencing severe to extreme drought, resulting in fires that burned 4.8 million acres (1.9 million hectares) across both countries. US agricultural losses alone exceeded $2.6 billion dollars.

Firefighters battle the Bridge Coulee Fire, part of the Lodgepole Complex, east of the Musselshell River, north of Mosby. 21 July 2017. (Photo courtesy of Jonathan Moor / Bureau of Land Management)

The unique circumstances of this drought provided an opportunity to evaluate the evolution of this type of climate event, as well as improve the effectiveness of drought-related coordination, communication, and management in preparation for future droughts. The National Integrated Drought Information System and partners published two reports that examine the evolution and impacts of the 2017 drought, as well as lessons learned, data needs, and information gaps (Jencso et al. 2019).

Droughts of this type will likely be more frequent in the future, with rising temperatures, reduced snowpack and earlier snowmelt leading to warm dry summer conditions. The seasonal shift from warm and wet to warm and dry could be very rapid, as in 2017.

Other climate surprises are likely but tougher to predict. Tornado and severe thunderstorm events currently cause significant property damage and loss of life every year. Of the US weather disasters that have inflicted more than $1 billion in damage costs in the last 25 yr, over one-third were due to severe storms (NOAAd undated). In Montana, a 2010 tornado in Billings, which caused city officials to declare a state of emergency, resulted in millions of dollars of property damage, including ripping the roof off the 12,000-seat Metra Park Arena (CBS News 2010; NOAA 2010). In May 2016, severe thunderstorms, tornados, and high winds in the Great Plains and Rockies, including Montana, cost over $1.1 billion (NOAAd undated).

The link between severe storms (e.g., tornados, hailstorms, severe thunderstorms) and climate change is not well understood or easily predicted, in part because their documented record is relatively short, going back only to the 1950s. Nonetheless, there is a clear physics-based linkage: as temperatures increase, convection and atmospheric circulation patterns become more extreme and less stable. Weather and extreme events are becoming more frequent and extreme, and their variability is increasing. Past events have been responsible for lives lost and serious and costly property damage, especially for those living in substandard housing. The uncertainty of such events also creates enormous mental stress. Evidence exists that the number of days with tornados is increasing, and it is likely that a warmer world with more atmospheric instability will shift both the timing and extent of severe storm conditions (Kossin et al. 2017). The mechanisms that create these storms, however, are complex and difficult to model (Diffenbaugh et al. 2013; Seeley and Romps 2015).

Summary

In summary, extreme heat, early snowmelt, large wildfires, spring flooding, late-season drought, and climate surprises challenge all aspects of our economy, infrastructure, and well-being. The health effects of these climate extremes include direct injury and loss of life, as well as indirect consequences related to disease, illness, and stress. Human health issues derived from or exacerbated by climate change are now taken seriously by health professionals around the world, and likewise require serious attention in Montana. In the sections that follow, we discuss the physical and mental health issues associated with climate change in Montana, and offer possible actions needed to improve health outcomes.

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Montanans and Climate Concerns

A 2019 statewide survey of Montana public health and environmental health professionals asked about climate change concerns (Byron 2019). Of the 222 responses, 89% accepted that global warming is occurring and 69% accepted human causation. They expressed stronger perceptions of climate change risk than the public in recent surveys and US health professionals in most previous surveys. Risk perception evaluates a person's personal concern about risks—whether or not an issue will affect their community or themselves. Risks seen as distant (affecting Africa, for example) do not translate into taking action, whereas risks that are close and personal result in more concern and cause for response.

Most of the health professionals surveyed felt that their own health was already being affected by climate change. They also felt that the mental health effects from climate change would be a concern in the future for their community. Seventy-two percent of the professionals (160 out of 222) felt that health departments should prepare to deal with the public and environmental health effects of climate change, although only 29% of the departments were currently doing so. Nearly all wanted multiple entities to work together to address climate change, including governments (federal, state, local, tribal), elected officials, non-governmental organizations, businesses, individuals, and healthcare providers.

Analysis done in conjunction with the 2019 Yale Climate Opinion Maps for Montana estimated that 60% of Montanans accept that global warming is happening, 45% believe it is mostly human caused, and 30% feel that global warming will hurt them personally in the future (Marlon et al. 2019). In a study to assess Montanans' opinions on energy and conservation, Metz and Weigel (2016) found that 51% of respondents felt that climate change needs to be addressed now, including taking actions to mitigate greenhouse gases and adapt to changing conditions.

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Walking along the Rimrocks above Billings
Photo courtesy of Scott Bischke

P-0008237

03. CLIMATE-RELATED HEALTH IMPACTS

Robert Byron, Bruce Maxwell, Nick Silverman, Philip Higuera, Madison Boone, and Dave McWethy

The consequences of climate change in Montana—including more frequent and intense heat waves; and increases in spring flooding, late-summer drought, extreme weather events, and wildfires—have recognized potential to impact human health (Ebi et al. 2018). Though little studied for Montana to date, climate change is known to be adversely impacting global health, including some Americans, now. For example, an increase in climate-related extreme events has led to increased emergency room visits and hospital admissions in the US (Ebi et al. 2018). Those adverse impacts are expected to increase over coming decades (Wuebbles et al. 2017).

Figure 3-1 depicts how climate pressures (also called *stressors*), following multiple exposure pathways, can lead to specific health outcomes for people. Those outcomes, discussed in this section, include heat-related illness; vector-borne diseases; mental health impacts; physical trauma, injuries, and death; respiratory, cardiovascular, and gastrointestinal conditions; and adverse effects on pregnancies and birth outcomes.

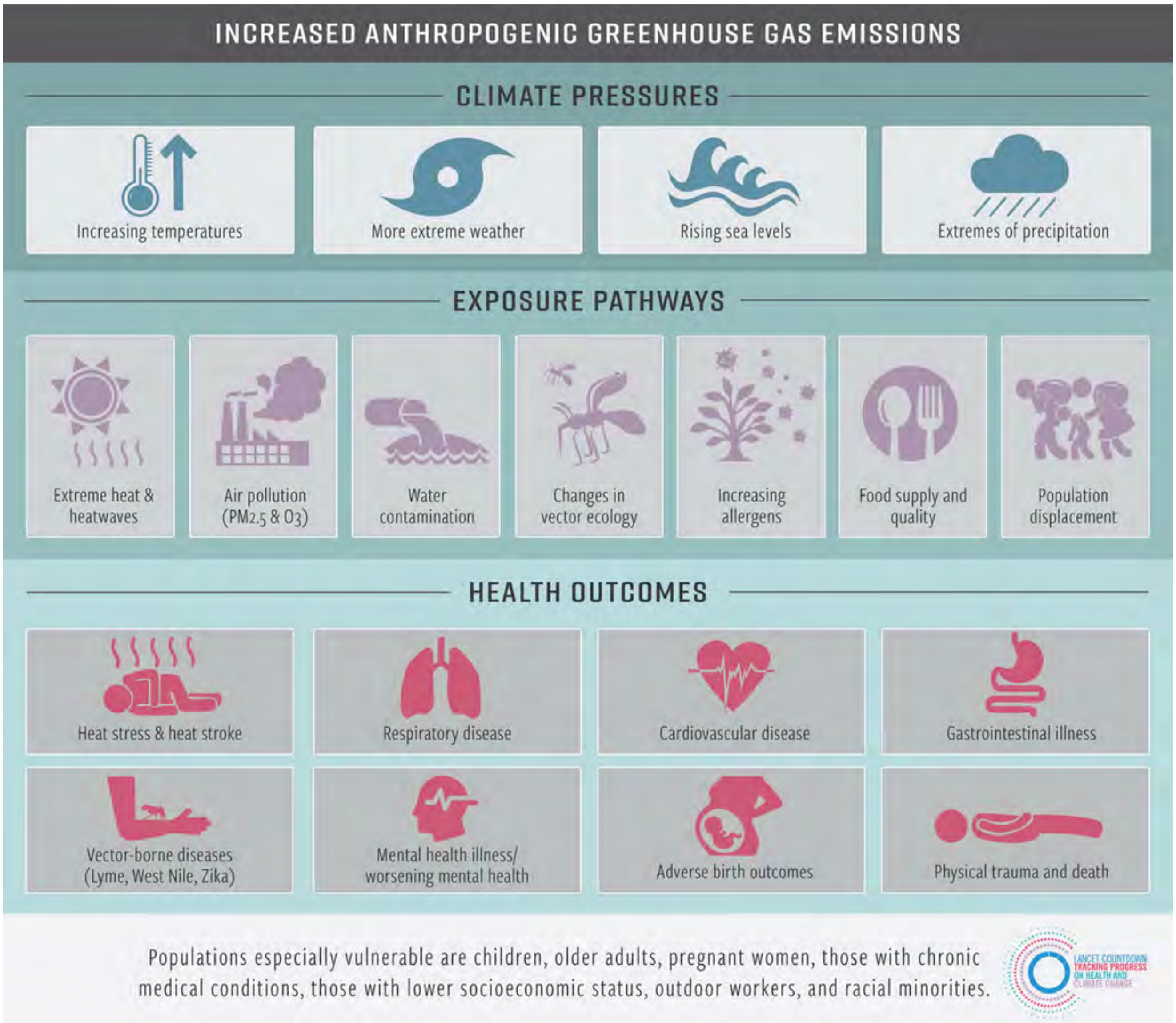


Figure 3-1. Ways climate change is harming, and will increasingly harm, human health (Salas et al. 2018).

While climate change affects all parts of the world, the severity of specific health impacts will vary by the specific climate pressure, as well as by location. Coastal regions, for example, will endure the most damage from sea-level rise, whereas inland states like Montana will be impacted most by the adverse effects of heat waves and reduced air and water quality (from wildfire smoke, desertification, land degradation, and other factors [Hughes and Diaz 2008; Sharratt et al. 2017]).[1] In the subsections that follow, we describe some of the exposure pathways and health outcomes resulting from climate change as shown in Figure 3-1. Some of the discussion may apply globally, but we emphasize those pathways and outcomes more likely to impact Montanans.

1 Montanans could feel indirect influences of sea-level rise, for example if coastal populations are forced to relocate inland or coastal grain export terminals important to the Montana economy must be moved.

Extreme Heat

Climate change is increasing the intensity and frequency of heat waves (Meehi and Tebaldi 2004; Reid et al. 2009). Globally, 157 million more people were exposed to extreme heat in 2017 than in 2000 (Watts et al. 2018). Assuming no changes in the current trend of emissions, the Union of Concerned Scientists projects that by mid century "the number of people [in the United States] experiencing 30 or more days with a heat index above 105°F in an average year will increase from just under 900,000 to more than 90 million—nearly one-third of the US population" (UCS 2019). Similarly, by the end of the century parts of Montana could see as many as 54 additional days over 90°F (32°C) (Whitlock et al. 2017; Section 2).

Multiple studies have demonstrated increased mortality associated with heat waves (Knowlton et al. 2009; Ostro et al. 2009; Isaksen et al. 2016), which is the major cause of weather-related deaths in the United States (NWS undated) (see next page). Gubernot et al. (2015) find that people who work in agriculture or construction jobs have the highest risk for heat-related death; that risk may be even higher for employees of Montana businesses such as farms and small construction firms that have no backup personnel. This finding should concern Montanans given that agriculture and construction are integral to our state's economy.

In addition, American Indian ceremonial practices (e.g., sundances) become more difficult during extreme heat and expose participants to risk for heat-related conditions (Doyle et al. 2013).

Late summer sun in south central Montana
Photo courtesy of Scott Bischke

Which is More Deadly—
Extreme Heat or Extreme Cold?

This seemingly simple question actually has no clear answer. Temperature extremes in both directions kill hundreds of people in the US each year, but determining the actual death toll is subject to large errors. Two US agencies, using different methods and datasets, came to opposite conclusions about which is more deadly:

- NOAA's monthly publication Storm Data (NOAA-NCEIa) regularly reports many more deaths per year as heat-related than as cold-related (NOAA-NCEIb). For example, their annual summary for 2011 indicates 206 deaths from extreme heat versus 29 from extreme cold.

- The Centers for Disease Control and Prevention's National Center for Health Statistics analyzed death certificates in the US and came to the opposite conclusion, finding roughly twice as many people die of "excessive cold" conditions than of "excessive heat" (Berko et al. 2014). About 1300 deaths per year from 2006-2010 were coded as resulting from extreme cold exposure, whereas 670 deaths per year were attributed to extreme heat.

The different findings depend, at least in part, on whether the focus is on acute or short-term responses to extreme weather or, alternatively, seasonal differences in estimates of daily mortality. Abnormally cold conditions may have little effect on estimates of daily mortality; rather deaths in winter increase as a result of non-weather-related diseases, like influenza. In addition, a recent study noted that a large majority of cold-related deaths occur under moderately cold conditions, so a reduction in extreme cold due to global warming is not expected to cause a large reduction in cold-related deaths (Gasparrini et al. 2015). It is also widely accepted that direct attribution (in medical records) of cause of death underestimates the number of people who die from temperature extremes (Sarofim et al. 2016). For example, a person who dies from a heart attack that resulted from heat or cold exposure is listed only as having died from a heart attack, even though extreme temperature exposure may have hastened or triggered the attack.

Looking to the future, the Fourth National Climate Assessment found that under an upper-bound (RCP8.5) emissions scenario we should expect a large increase in US extreme temperature deaths. In 49 large US cities, representing one-third of the nation's population, the report projected that changes in extreme hot and extreme cold temperatures would result in 9300 additional premature deaths per year by 2090, at a cost of $140 billion per year in 2015 dollars (Ebi et al. 2018). Since the study only covered populations in large cities, Montana was not included. These mortality estimates may be reduced through adaptation efforts such as acclimatization programs (e.g., ensuring adequate heating and cooling systems, and improved insulation). The report also considered the reduction in extreme cold deaths expected in a warmer climate; approximately 100 fewer cold deaths per year were expected in the US by 2050, with no further reduction in cold deaths between 2050 and 2090 (Ebi et al. 2018)

The bottom line is that high and low temperature extremes affect vulnerable populations, such as the unwell, the poor, the young, and the elderly, among others. Understanding the extreme-temperature risk for the future requires additional in-depth study of the interaction between temperature-related deaths and socioeconomic factors. With additional information, we can avoid adverse policy outcomes and achieve effective adaptation strategies.

Human impacts from excessive heat

Heat affects humans in a variety of ways, impinging on multiple body systems. As depicted in Figure 3-2, elevated temperatures directly cause heat-related conditions ranging from muscle cramps to heat exhaustion to heat stroke, the latter of which is deadly if not treated promptly (Becker and Stewart 2011; Epstein and Yanovich 2019). In addition, elevated temperatures have been associated with increases in respiratory disease (Anderson et al. 2013; Ho et al. 2015); heart disease and strokes (Knowlton et al. 2009; Wang et al. 2016; Achebak et al. 2018); and fluid and electrolyte disorders, kidney disease, and kidney failure (Bobb et al. 2014; Ross et al. 2018; Sorensen and Garcia-Trabanino 2019). A study by Li et al. (2012) found evidence of a potential high-temperature threshold for several age groups (15–64 yr, 75–84 yr, and >85 yr) and specific heat-related causes for hospital admissions that included endocrine, genitourinary, and renal morbidities, as well as accidental injuries and intentional self-harm.

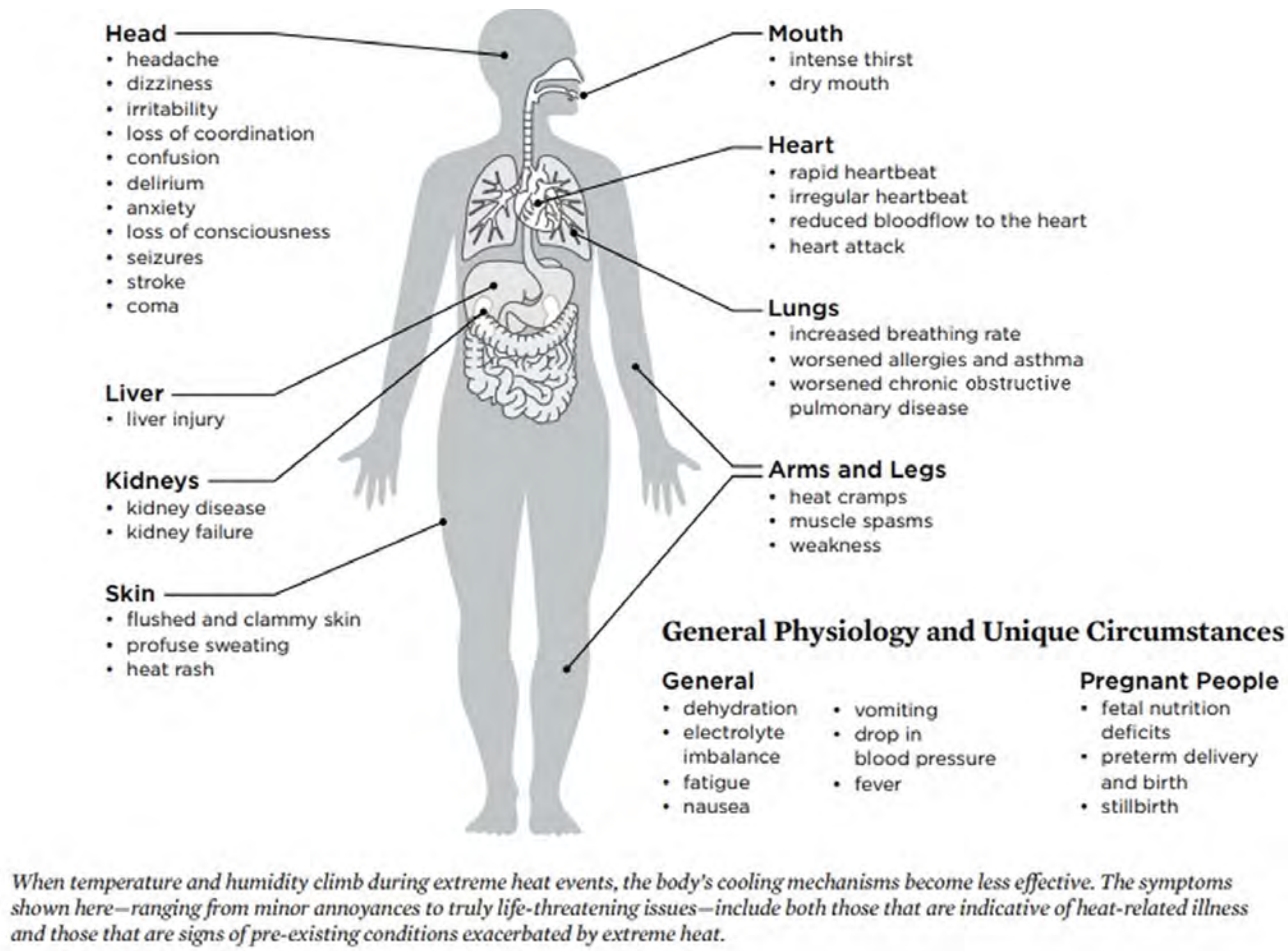


Figure 3-2. How heat affects our bodies. When temperature and humidity climb during extreme heat events, the body's cooling mechanisms become less effective. The symptoms shown here—ranging from minor annoyances to truly life-threatening issues—include both those that are indicative of heat-related illness and those that are signs of preexisting conditions exacerbated by extreme heat. Figure and caption used with permission from The Union of Concerned Scientists (UCS 2019).

Elevated temperatures are also associated with increased risk of preterm labor (Auger et al. 2014; Ha et al. 2016; Avalos et al. 2017), as well as sudden infant death/sudden unexpected infant death syndromes (SIDS/SUID) (Jhun et al. 2017). Elevated temperatures also cause worsening mental health, as described in the Mental Health subsection later in Section 3.

The severity and duration of high temperatures influence the health impacts resulting from extreme heat. In addition, air pollution and population vulnerability (Basu 2009) compound these impacts. Vulnerability is also a function of the typical temperatures to which a population is exposed, plus the extent to which a population adapts (Curriero et al. 2002; Baccini et al. 2008; Ho et al. 2015).

Workers, especially those who work outdoors or in hot indoor environments, are at increased risk of heat stress and other heat-related disorders, occupational injuries, and reduced productivity at work (Levy and Roelofs 2019). Workers in the agricultural sector face increased risk of heat strain and dehydration[2] due to repeated exposures to high air temperatures, arduous physical exertion, and limited fluid intake. These risk factors may result in acute kidney injury (Moyce et al. 2017), as well as increased heat-related traumatic injuries (Spector et al. 2016). Spector et al. (2016) suggest that efforts should be made to address heat-related illness and prevent occupational injury for high-risk populations exposed to high temperatures and high physical exertion.

The impacts of increased air temperature may increase workers' exposure to hazardous chemicals and, thus, the adverse health effects of those chemicals (Spector et al. 2016). Global warming is also increasing ground-level ozone concentrations with adverse effects on outdoor workers (Levy and Roelofs 2019).

Assessing heat impacts specific to Montana

Multiple studies—covering wide ranges of temperature, time, and geographic area—have sought to assess the health impacts of extreme heat (e.g., Morabito et al. 2014; Zhang et al. 2014). Some studies estimate how heat-related mortality differs between rural and urban landscapes (reviewed by Ho et al. 2015). Other studies develop indices to identify heat-vulnerable populations (Vescovi et al. 2005; Reid et al. 2009; Reid et al. 2012; Chuang and Gober 2015).

Human health vulnerability to heat is most often expressed as a combination of three factors: adaptive capacity, exposure to heat, and sensitivity to heat (Smit and Wandel 2006; Füssel 2010; Inostroza et al. 2016) (see sidebar). In our analysis, heat vulnerability was calculated as a combination of a) the historical land-surface temperature and future projections of heat to describe exposure; and b) county-level[3] socioeconomic factors to describe sensitivity and adaptive capacity (see Appendix A for details). We will refer to the climate impacts as exposure, and the socioeconomic factors as sensitivity, with sensitivity inclusive of adaptive capacity, but no health factors were directly included due to incomplete county health factor data.

2 Dehydration, or the excessive loss of body water, can have many causes, including heat exposure, kidney disease, and diseases of the gastrointestinal tract that cause vomiting or diarrhea.

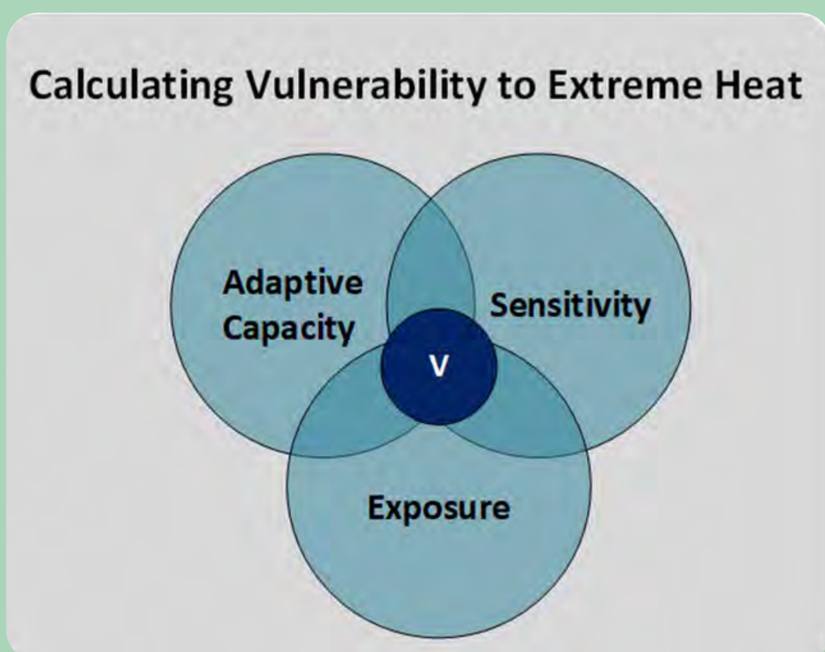
3 Figure 2-1 provides a map showing and naming Montana's 56 counties.

Factors Considered in Determining Vulnerability to Extreme Heat

Vulnerability, in the present context, is the extent to which a person is susceptible to the impacts of climate change. As described in the text and below, many factors go into calculating a person's vulnerability to extreme heat. Three key terms bear definition:

- *adaptive capacity.*—The ability of a person (or society) to cope with climate change.
- *exposure.*—The type and magnitude of a climate change.
- *sensitivity.*—How easily affected a person is by climate change.

Vulnerability (the "V" in the diagram below) is assumed to be the intersection of adaptive capacity, exposure, and sensitivity (Smit and Wandel 2006; Füssel 2010; Inostroza et al. 2016). We combine adaptive capacity and sensitivity into one group, which is based on socioeconomic factors (see Appendix A for details). We continue to use the intersection of the three areas to determine vulnerability, and asssume adaptive capacity is simply implicit in the socioeconomic layers that comprise our sensitivity factor.



P-0008244

Heat exposure

Heat exposure is modeled as the combination of historical land-surface temperatures and projected heat. To determine the county average land-surface temperature on days of extreme heat, we use the 95th percentile of daily average land-surface temperatures from 2000-2019 (Figure 3-3). For future projected heat, we use the heat index of each county (UCS 2019) generated from an ensemble of general circulation models.[4] The heat index includes a combination of temperature and humidity to create a "feels-like" heat rating.

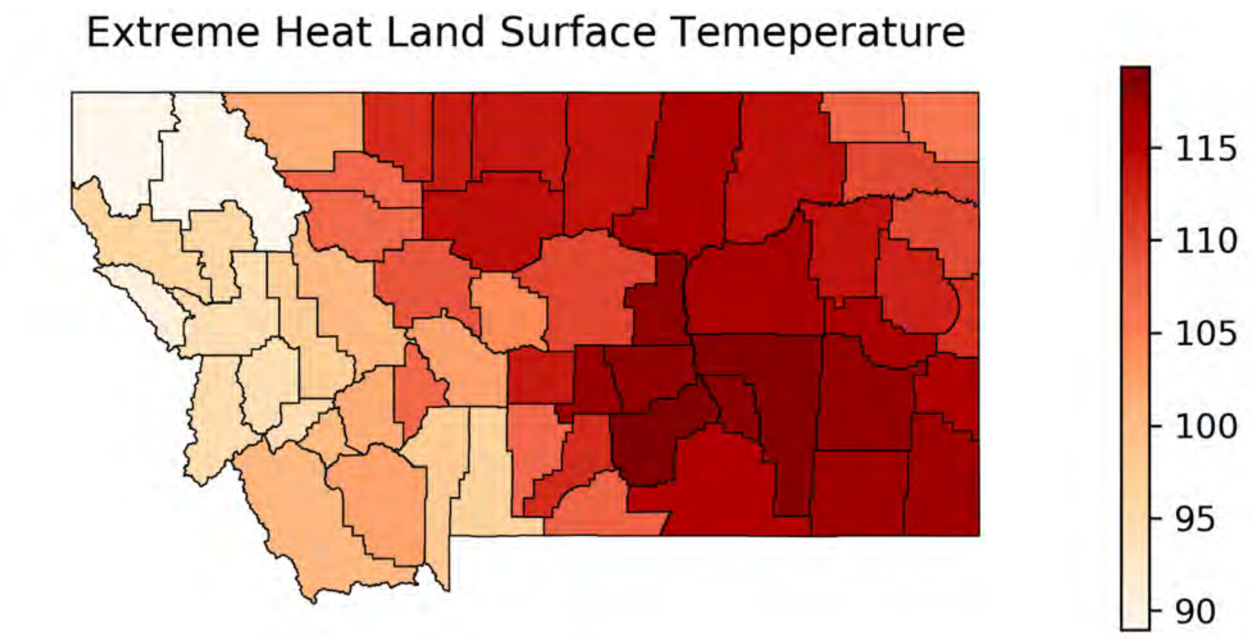


Figure 3-3. The county average land-surface temperature on days with extreme heat from 2000-2019. Note: Land-surface temperatures are higher than air temperatures measured at weather stations. The scale to the right shows color-coding for temperature in °F.

Sensitivity

We base our calculation of sensitivity to heat on socioeconomic variables from the US Census Bureau, 2013-2017 American Community Survey 5-Year Estimates (US Census Bureau undated).[5] Socioeconomic factors include age, the average income for people in the county, the percent of county population under the poverty line, the percent of poverty households with children, the percent of population employed in construction and production (implying predominantly outdoor workers with greatest exposure to heat), the percent of population unemployed, and type of housing (see further details in Appendix A).

4 Both heat index and general circulation models are described in Section 2.

5 See Appendix A for a complete explanation of socioeconomic variables and their weighting to derive a heat vulnerability index.

P-0008245

Heat vulnerability

Human exposure to heat has been quantified and mapped, although only a few studies have combined socioeconomic sensitivity with heat exposure data to evaluate human vulnerability to the health risks associated with extreme heat (Buscail et al. 2012; Ho et al. 2015). Most studies that examine health vulnerability to heat use aggregate data that matches the spatial units from which sensitivity information is derived by the US Census Bureau (Ho et al. 2015). For example, most socioeconomic factors are measured at the county scale so exposure measurements (i.e., land-surface temperature and change in future heat) must be averaged across a county. Despite this complication, heat vulnerability is a useful measure to relate climate to human health impacts (see further details in Appendix A). Municipalities can use heat vulnerability information to guide heat mitigation interventions, such as establishment of green or reflective roofs, urban parks, and water features (see Section 5).

Little Bighorn River swimming hole at Crow Agency
Photo courtesy of John Doyle

P-0008246

By combining exposure and sensitivity data, we identified counties with populations most vulnerable to extreme temperatures. Vulnerability was split into four main categories represented in Figure 3-4. The darker the color the higher the vulnerability to heat.

Of Montana's 56 counties, one county has a high vulnerability rating, while 17 have a medium-high rating, 12 have a medium-low rating, and 26 have a low rating. A strong west-to-east increasing trend in vulnerability exists. That trend largely represents the patterns of exposure (i.e., land surface temperatures and projected heat). Roosevelt County ranked 29th for historical extreme heat and 51st for future predicted heat (higher rankings indicate higher exposure), making it one of the top five counties for projected extreme heat in Montana. Along with its high heat ranking, other factors make the population of Roosevelt County vulnerable to the negative health impacts of heat. Those include relatively high unemployment, low median income, high poverty levels, and many production jobs (agriculture and energy sectors).

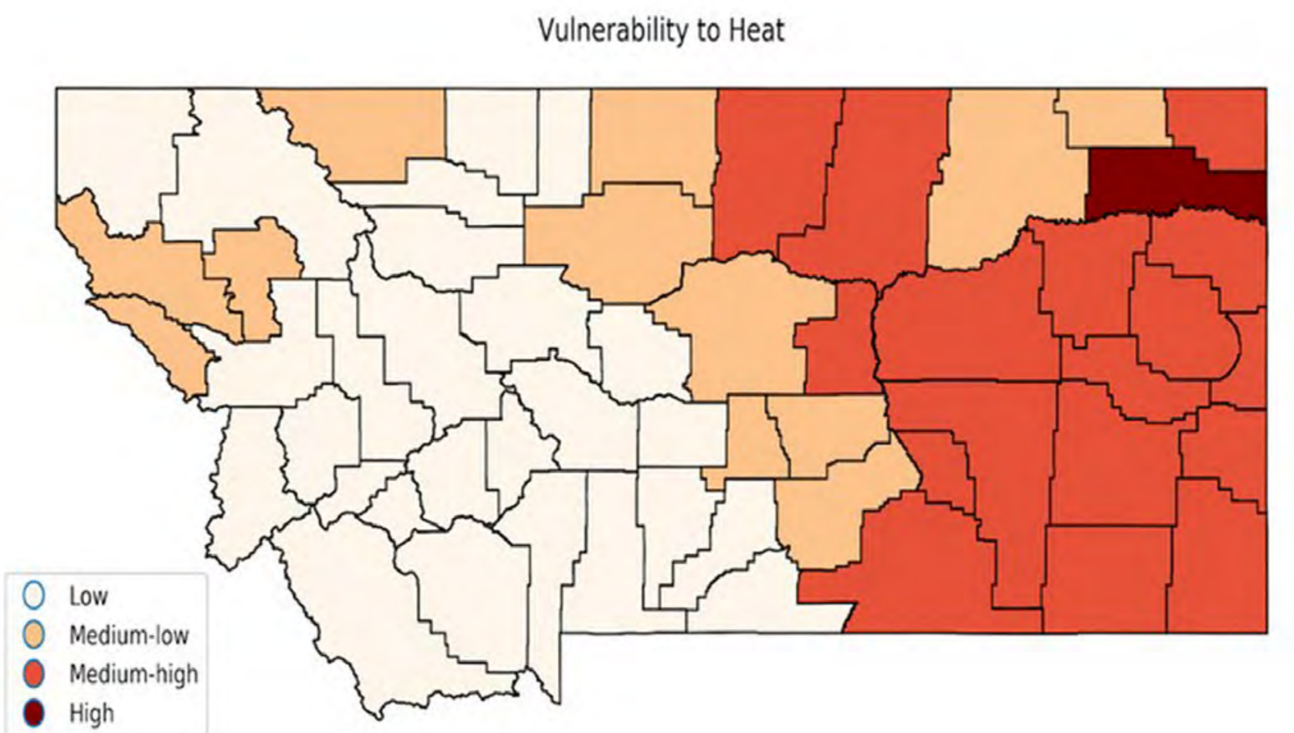


Figure 3-4. Montana heat vulnerability ratings for mid century, using multi-criteria decision analysis and the RCP8.5 emission scenario (explained in Section 2). Darker shading indicates higher vulnerability. See text and Appendix A for details.

P-0008247

Local temperature trends

To understand the local effects of extreme temperatures, we examined daily temperature data from 38 NOAA weather stations across Montana. We determined the maximum and minimum temperature trends in summer months (June, July and August) at each station. The temperature records at individual stations may not coincide or reveal the same patterns as the Montana climate region results indicated in the MCA, which were averaged (Whitlock et al. 2017). Our intent was to examine recent temperatures and their trends at a scale where human health may be monitored and impacted in the future. Our findings are:

- *Summer maximum temperature.*—Fifteen out of the 38 stations across Montana indicate an increasing trend in summer (June, July, August) maximum temperatures over the last 30 yr. The easternmost stations show no trend in maximum temperatures. No stations have a negative trend in maximum summer temperatures (i.e., cooling) over the last 30 yr (1990-2019).

- *Summer minimum temperature.*—From 1990-2019 minimum summer night temperature has an increasing trend at 15 of the 38 stations across Montana, and a decreasing trend at four stations. All of the decreasing trends in summer night temperature (i.e., cooling) are in western Montana. Five of the 15 stations with increasing summer maximum temperature also show increasing trends in summer night temperature; three are in urban centers. In other words, stations that show a trend towards increasing temperature during the day also experience a trend towards warming night conditions. Warm nights represent a burden on the human thermoregulatory system, particularly for the elderly and those who rely on natural ventilation (e.g., open windows) to reduce body temperature (Mills et al. 2015).

  The number of continuous days and nights at high temperature results in cumulative, negative heat impacts on people. In a study that looked at large cities at sea level, human mortality increased when extremely hot nights followed hot days (Xu and Tong 2017). While a different scenario than faced by Montanans, increased human mortality has the potential to become a concern here given projected increased extreme temperatures.

- *Winter minimum temperature.*—Winter (December, January, February) minimum temperatures indicate an increasing trend (i.e., winter progressively getting warmer) at only two of 38 stations, both in southwestern Montana, and four stations indicate decreasing trends in winter minimum temperature from 1990-2019. Over the longer period of 1970-2019 (50 yr), 11 out of 35 stations show winters warming while no stations indicate decreasing winter temperature. Thus, the time span for analysis influences the trend, as do the months included in a season. For example, when winter is expanded to include November and March in a different study (not published), 13 out of 15 weather stations show winters getting warmer.

Increasing temperature trends over the last 30 yr at individual weather stations are not limited to the larger cities in Montana where heat islands[6] might exist. Small rural towns are also vulnerable to increasing heat and, based on limited healthcare facilities and other factors (see Section 4), may include citizens who are already vulnerable to extreme conditions. The number of summer days with maximum temperatures over 90°F (32°C) is projected to increase 11-33 days by mid century (Whitlock et al. 2017).

Air Quality Issues

Overview

Degraded air quality, or air pollution, refers to myriad substances, both human-made and naturally occurring, including tobacco smoke, carbon dioxide, nitrous oxides, sulfur dioxide, particulate matter, ground-level ozone, and volatile organic compounds. *Outdoor* air pollution, some forms of which are also global warming gases, is estimated to contribute to 64,200 premature deaths in the US annually (Watts et al. 2019). Outdoor air pollution is expected to worsen with climate change (Orru et al. 2014).

Across the US, human health concerns related to air quality are dominated by particulate matter and ground-level ozone (American Lung Association undated; Ward and Smith 2001; Tao et al. 2005).

Particulate matter (PM)—especially $PM_{2.5}$ and PM_{10}, describing particulates under 2.5 μm and 10 μm diameter, respectively—has been associated with multiple health effects. Those effects include cardiovascular, respiratory, and immunological problems, the latter manifesting as increased risk for pneumonia (Rappold et al. 2011; Reid et al. 2016b; Tinling et al. 2016), and neurological issues, in the form of greater risk for dementia (reviewed by Peters et al. 2019). Particulate matter has been found to penetrate the blood-brain barrier—i.e., move into the human brain—and cross the placenta in pregnant women (Bové et al. 2019). It has also been associated with possible increased risk of preterm birth (DeFranco et al. 2016; Trasande et al. 2016), low birth weight (Fleischer et al. 2014), and increased medication use in children with asthma (Gielen et al. 1997).

6 According to the US Environmental Protection Agency (USEPA undated): "Heat islands occur on the surface and in the atmosphere. On a hot, sunny summer day, the sun can heat dry, exposed urban surfaces, such as roofs and pavement, to temperatures 50–90°F (27–50°C) hotter than the air, while shaded or moist surfaces—often in more rural surroundings—remain close to air temperatures. Surface urban heat islands are typically present day and night, but tend to be strongest during the day when the sun is shining."

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Ground-level ozone forms when sunlight and heat act on nitrous oxides and volatile organic compounds (Rani et al. 2011). It has been associated with asthma exacerbations, increased hospitalizations, and premature mortality (Bell et al. 2004; Zanobetti and Schwartz 2008; Di et al. 2017), as well as with preterm birth (Olsson et al. 2013). Ground-level ozone is expected to increase with warming temperatures (Melillo et al. 2014).

In Montana, ozone levels are generally rated low (<50) on the USEPA air quality index (AQI), but particulate matter levels are seasonally elevated (>100 AQI) in some areas (AirNow undated).[7] Ten counties in Montana, for example, received grades of “F” for particulate matter in the American Lung Association *State of the Air 2020* report card (American Lung Association 2020).[8] Some local areas have elevated particulate-matter levels during winter months due to inversion layers and high woodstove usage. In eastern Montana, particulate matter is expected to increase as summer drought increases dust emissions in agricultural areas where land gets tilled for crops (Gage et al. 2016) and tillage is employed as a common summer fallow practice (Cook et al. 2014; Dawson et al. 2014). Wildfires also contribute significantly to high levels of particulate matter, as we discuss in the next subsection.

Separately, but related to air quality concerns, pollen counts in the United States are increasing with projections for doubling by 2040 (Zhang et al. 2015) due to warming temperatures with longer growing seasons (Ziska et al. 2019), and higher atmospheric carbon dioxide levels (Ziska and Caulfield 2000). In addition to worsening seasonal allergies, this increase in pollen poses risks of triggering exacerbations of asthma, which affects 9.1% and 6.8% of Montana adults and children, respectively (MTDPHHS 2013).

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7 The USEPA developed the AQI scale as a simple way to convey how clean or polluted air is. The AQI scale has six levels: 0-50 good; 51-100 Moderate; 101-150 Unhealthy for sensitive groups; 151-200 Unhealthy; 201-300 Very unhealthy; 301-500 Hazardous.

8 The report is based on data collected from 2016-2018. The ten Montana counties are Fergus, Flathead, Gallatin, Lewis and Clark, Lincoln, Missoula, Powder River, Ravalli, Rosebud, and Silver Bow.

Smoky skies near Missoula, from Mount Sentinel
Photo courtesy of Philip HIguera

Wildfires and wildfire smoke

Between 1997 and 2006, 339,000 human deaths per year globally were attributed to smoke from landscape fires, which includes forest fires, peat fires, grass fires, prescribed burns, agricultural burns, and tropical deforestation burning (Johnston et al. 2012). Deaths and injuries occur to people caught in fast-moving fires, as well as to firefighters, emergency response personnel, and others assisting with fire management. Wildfires can result in large-scale, temporary evacuations, or permanent displacement following the destruction of homes or even entire towns (Insurance Information Institute undated). The 2019/2020 fires in Australia, for example, killed 33 people across the country; in New South Wales alone over 2000 homes were destroyed (BBC News 2020). Closer to home, the November 2018 Paradise Fire in California killed 85 people, displaced hundreds, and destroyed over 18,000 buildings (Vox 2019). Large fires with adverse impacts on communities throughout the western US, including Montana, are increasing as measured in numbers of acres burned (Figure 3-5) because a) climate warming produces longer, drier fire seasons and extensive burning; and b) patterns of human development are increasing human exposure to wildfires (Abotzoglou and Williams 2016; Radeloff et al. 2018).

In Montana, increased fire activity in recent decades has impacted people through an increase in hazardous air quality from wildfire smoke, originating locally or from distant sources (see, for example, Figure 3-6). For the western US, including Montana, warmer and drier conditions during summer have contributed to longer fire seasons and more area burned by wildfires, producing more and longer smoke events (Dennison et al. 2014; Westerling 2016; Dalton et al. 2017). Smoke events in the western US from 2004–2009 were associated with a 7.2% increase in respiratory hospital admissions among adults over 65 yr of age (Liu et al. 2017).

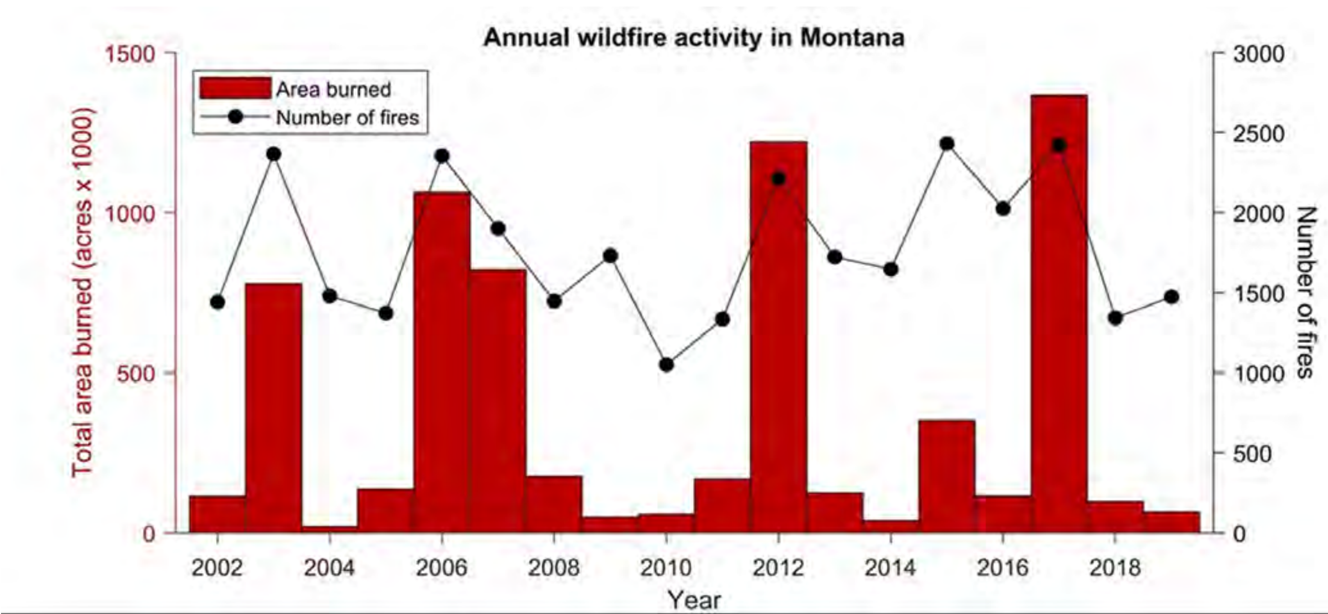

Figure 3-5. Annual area burned by, and number of, wildfires in Montana 2001-2019.

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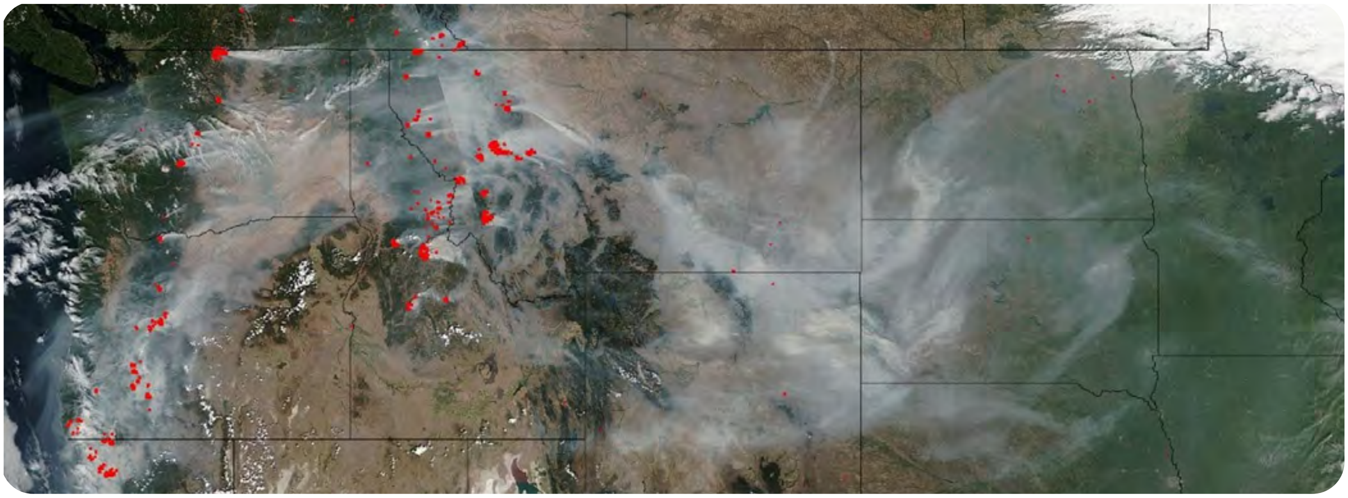

Figure 3-6. NASA composite satellite image from 11 September 2017, showing fires in the Cascades and Rockies and smoke as far east as the Great Lakes. (Image source Wikipedia; used under Creative Commons attribution-share alike 4.0 international license [user "Bri"]. https://commons.wikimedia.org/wiki/File:2017_September_5_MODIS_Pacific_to_Minnesota.jpg.)

Human response data connecting heat and smoke to human health are limited for Montana. In nearby Boise, Idaho, however, seven of the last ten years have included smoke levels considered "unhealthy for sensitive groups" for at least a week during the fire season (IDDEQ 2013), causing cancellation of some school-related sports activities (Nolte et al. 2018). In 2020, large fast-moving fires in California, Colorado, Oregon, and Wyoming resulted in days with the air quality index rated "hazardous" in locations across the western US.

Air quality hazards from wildfire

Wildfire smoke worsens local air quality (Navarro et al. 2016), with substantial public health impacts in regions with large populations near heavily forested areas (Liu et al. 2015; Reid et al. 2016a; Fann et al. 2018). Smoke decreases visibility causing hazardous conditions (Yue et al. 2013), and can be transported hundreds of miles downwind (Dreessen et al. 2016; Kollanus et al. 2016).

Wildfire smoke contains many components that are hazardous to human health, including particulate matter (more below), polyaromatic hydrocarbons, carbon monoxide, nitrous oxide, aldehydes, benzene, among other components (Reisen et al. 2015; Adetona et al. 2016; Liu et al. 2016).

Exposure to wildfire smoke can result in emergency room visits for a variety of conditions, newly caused or aggravated, including asthma and chronic obstructive pulmonary disease (Rappold et al. 2011; Tinling et al. 2016; Cascio 2018); and cardiovascular conditions, including stroke, heart attack, and heart failure (Dennekamp et al. 2015; Haikerwal et al. 2015; Hutchinson et al. 2018; Wettstein et al. 2018). Additionally, wildfires can lead to rapid ozone formation and increased frequency of ozone pollution levels that exceed air quality standards (Jaffe et al. 2008; Jaffe and Widger 2012). Increased ozone pollution harms human health, as described previously.

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Particulate matter

Wildfires are estimated to have contributed about 18% of the total atmospheric particulate matter emissions in the US from 2004-2009 (Liu et al. 2015). Wildfires are projected to become the principal driver of summer particulate-matter concentrations in the western US (Ebi et al. 2018).

A study by Liu et al. (2016) shows that on days in the US exceeding regulatory particulate matter ($PM_{2.5}$) standards, wildfires contributed an average of 71% of total particulate matter ($PM_{2.5}$). Under future climate change, they estimate that more than 82 million individuals will experience a 57% increase in frequency and a 31% increase in intensity of *smoke waves*, defined as two or more consecutive days with high, wildfire-associated increases in particulate matter. They additionally project that wildfire-associated particulate matter will increase 160% by mid century under the RCP4.5 scenario (see Section 2).

Airborne particulate matter is expected to increase in Montana croplands with more soil-exposed fallow periods (Pi and Sharratt 2017). Wind erosion of soil in wheat production is likely to increase due to increased summer drought and changing precipitation patterns favoring winter wheat over spring wheat. Climate change is also likely to create more cropland abandonment leading to desertification and land degradation (Hughes and Diaz 2008).

Exposure to particulate matter results in numerous negative health outcomes (described above), as well as reduced life expectancy or death (Schwartz et al. 1996; Dominici et al. 2006; Pope et al. 2009; Puett et al. 2009).

New fire projections for Montana

Warmer spring and summer temperatures in Montana and reduced summer precipitation (see Section 2 regarding drought) create conditions conducive to wildfires. In grassland regions, wet spring conditions favor wildfire activity by promoting growth of understory vegetation, which is subsequently flammable during warm, dry summers and even into the fall and following winter (McKenzie and Littell 2017; Holden et al. 2018). When fires ignite under unusually warm, dry conditions—whether caused by humans or lightning—they spread faster, are harder to suppress, and end up burning larger areas than in summers with average climate conditions. Fire danger ratings—a five-class system widely used in wildfire management (low, moderate, high, very high, and extreme)—summarize the ways weather and climate conditions influence the likelihood and spread of wildfires (Dennison et al. 2014).

We compare the average number of summer days having extreme fire danger (the highest classification in the system) between a reference period (1971-2000) and mid century (2040-2069), the latter based on climate projections (Whitlock et al. 2017). The most extensive wildfire activity in Montana correlates well with extreme fire danger, and thus the latter provides a suitable representation of extensive wildfire activity and resultant smoke in the future.

Under RCP8.5 climate projections, the number of summer days having extreme fire danger increases across all counties, relative to the 1971-2000 reference period. In many counties, particularly in northwestern and south central Montana, the number of days with extreme fire danger increases by 10 days by mid century, doubling (100% increase) from the 1971-2000 benchmark (Figure 3-7). More days with extreme fire danger implies a longer, more active fire season, which ultimately results in more area burned per year, and increased atmospheric particulate matter and smoke (Norby et al. 2010; Jenkins et al. 2014; Jolly et al. 2015). Wildfire smoke is and will be most common in western Montana, primarily because wildfires in forested areas produce large amounts of smoke (Westerling et al. 2006; IDDEQ 2013) (Figure 3-7).

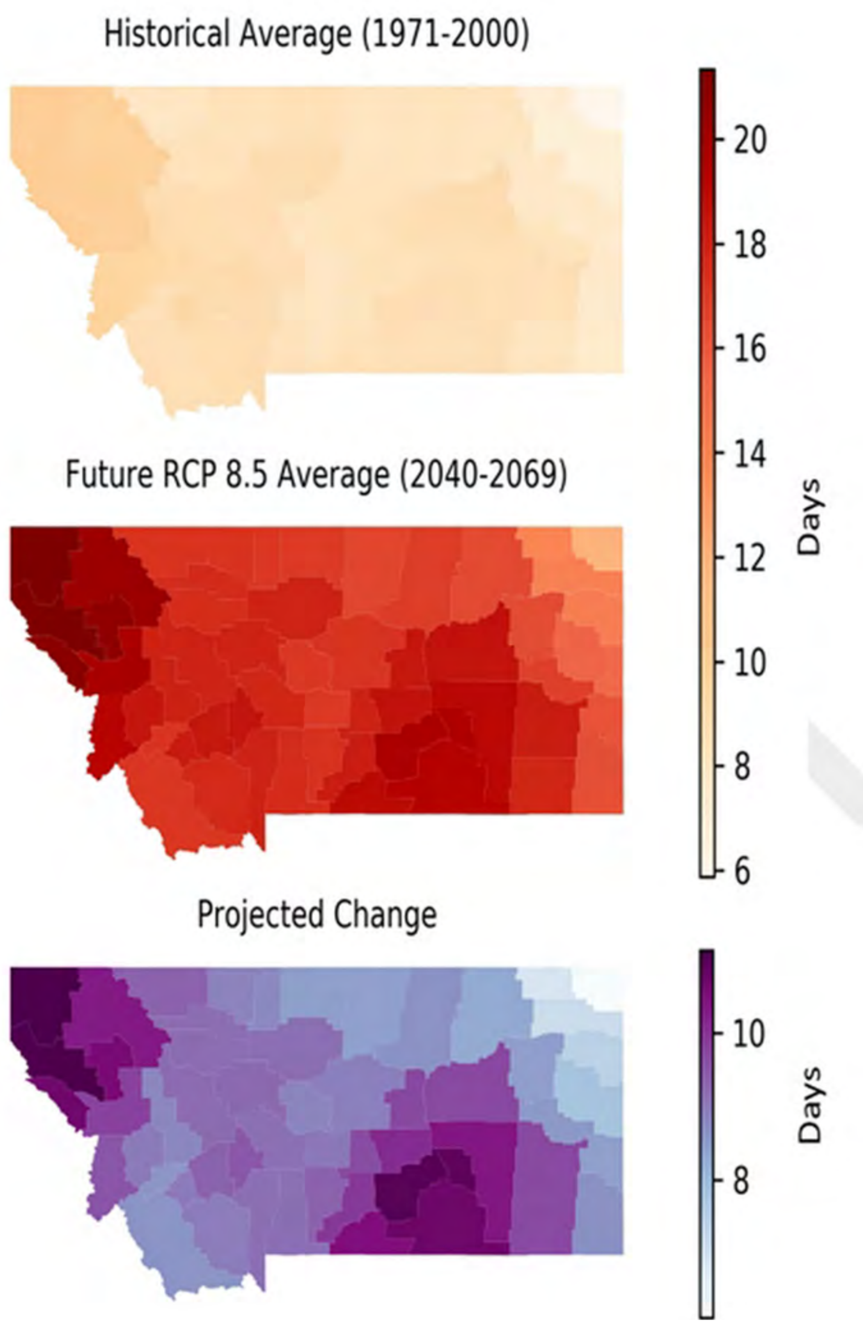

Figure 3-7. Number of days with extreme fire danger over time in Montana. From top to bottom we show the historical pattern, the mid-century projection under RCP8.5 (upper-bound emission scenario), and the projected change in number of extreme fire days from 1971-2000 to mid century.

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In Montana, Department of Environmental Quality reports show that the number of communities or counties whose air quality rated as *moderate*, *unhealthy*, *very unhealthy*, or *hazardous* generally increased from 2010-2017 (Figure 3-8), as a result of increased acres burned by wildfires. However, these trends were followed by declining smoke in the below-average fire seasons of 2018 and 2019 but on track in 2020 to be similar to or exceed 2017. The number of smoke events in each health category shows similar trends, with western Montana valleys receiving the most unhealthy smoke days followed by the southeastern region of Montana. In 2017, the most recent year with regionally extensive wildfire activity, Seeley Lake, Lolo, Superior, and Frenchtown all had ten or more days where air quality was rated unhealthy, very unhealthy, or hazardous, with Seeley Lake experiencing 38 days with unhealthy and worse smoke conditions (see a) Section 2, b) sidebar Section 4 titled *The 2017 Seeley Lake fires and lung function*). Assuming that projected increases in extreme fire danger result in increased wildfire activity, Montana could expect an increase in summers exceeding moderate air quality standards, with more communities affected, especially in western Montana.

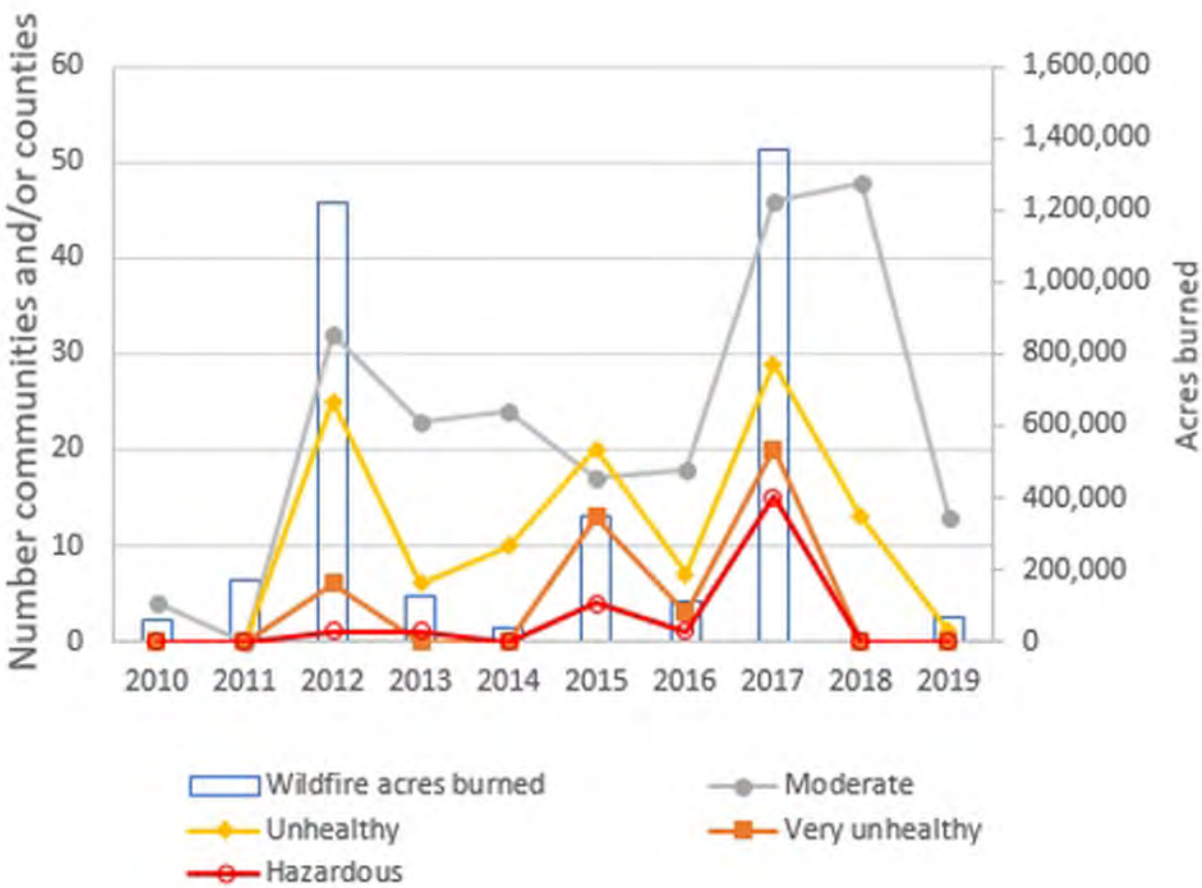

Figure 3-8. The number of communities, counties, and regions in Montana where wildfire smoke led to varying air quality ratings (MTDEQ undated), and number of acres burned by wildfire each year.

Increased fire danger for Montana in coming decades will likely result in decreased air quality in years with widespread wildfire activity, like 2017. Such years will be interspersed with years having average or below-average fire activity. Communities can adopt a suite of actions to mitigate adverse effects on citizens from poor air quality (McWethy et al. 2019; also, such actions are described in Section 5).

Water-related Illnesses

Climate change is affecting Montana's water quantity and quality (Whitlock et al. 2017; MTDEQ 2019), each of which may, in turn, impact human health[9]. For example, spring floods, which are expected to increase because of earlier snowmelt or extreme precipitation events (see Section 2), affect people's health in a variety of ways. Immediate impacts include injury, hypothermia, death from drowning, exposure to toxic substances and pathogens released by flood waters, and exacerbation of underlying conditions such as cardiovascular or pulmonary disease (due the flood itself or cleaning up afterwards). Later complications include respiratory and skin infections, vector-borne illnesses, and mental health conditions (Du et al. 2010; Ryan et al. 2015; Paterson et al. 2018).

Floods also increase the risk of mold formation in homes (Bell et al. 2017), an environmental stressor that can impact anyone but particularly American Indian/Alaska Native children (Barros et al. 2018). Even in the absence of flooding, elevated rates of gastrointestinal disease have been associated with precipitation events (Carlton et al. 2016; Levy et al. 2016), as well as with dry conditions (Alexander et al. 2013; Friedrich 2013; Fouladkhah et al. 2019), though the latter association is weaker.

Water quality issues resulting from climate change may also come about because of changes to precipitation runoff, land use, and the way agricultural lands are managed (MTDEQ undated). Changes to the timing and amount of runoff can impact stream turbidity and sediment deposition, plus non-point pollution runoff and subsequent increased stream concentrations of undesirable compounds. Late season droughts may result in higher concentrations of pollutants—including fertilizers and pesticides—in warmer waters, potentially leading to decreased levels of dissolved oxygen and/or increased algal blooms.

Harmful algal blooms, often caused by cyanobacteria[10], are special cause for concern. Cyanobacteria have increased across the US from under 100 incidents in 2013 to over 500 in 2019 (EWG undated), and are becoming increasingly common in Montana (MTDPHHSa undated). Many factors influence harmful algal blooms, including increased nutrients from agricultural runoff or sewage, changes in water circulation, and increased water temperatures (Paerl and Huisman 2009;

9 Ecological health may also be impacted, but here we focus on human health.

10 Although commonly referred to as blue-green algae, cyanobacteria are a group of photosynthetic bacteria.

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Moore et al. 2011; Davidson et al. 2014). Based on climate model projections, Chapra et al. (2017) indicate that concentrations of cyanobacteria are likely to increase across the US, primarily due to water temperature increases and increased nutrient inputs. They predict that the mean number of days of harmful algal bloom occurrence, which is about 7 days/year per water body under current conditions, will increase to 16−23 days in 2050 and 18−39 days in 2090.

Harmful algal blooms can harm human health. Depending on the causative organism and type of exposure, maladies include gastrointestinal symptoms, muscle cramps, skin rashes, liver damage, and even death. In addition, harmful algal blooms can impair municipal water supplies, hamper recreational activity, and cause significant economic hardships (e.g., if tourism declines in the affected areas).

Food Security and Nutrition Concerns

Climate change threatens human health through its effects on agriculture. For Montana, the MCA describes that global warming will influence the distribution of weeds, pathogens, and insect pests and introduce *new* pests (Whitlock et al. 2017) . These changes may alter the types and amount of pesticides used, potentially affecting the health of agricultural workers and others.

In addition, food quantity and quality, including nutrition, are directly and indirectly impacted by climate change (Gowda et al. 2018b) (see facing page). Grains, for example, provide almost half the calories humans eat and wheat is a major crop in Montana. With increasing atmospheric CO_2 levels, plants grow larger and store more carbohydrates (sugars), yet they contain less protein, zinc, iron, and other nutrient concentrations (Myers 2014).[11] Reduced nutrient quality leads to a number of health problems, including:

- Inadequate nutrition can permanently affect the physical and mental development of children. In the US, low iron levels are experienced by one of out of every five children for part of their childhood (Irwin and Jeffrey 2001).
- Low iron levels have been associated with decreased cognitive function (Jáuregui-Lobera 2014), reduced work capacity (Haas and Brownlie 2001), decreased quality of life, and reduced life expectancy (Shander et al. 2014).
- Reduced protein decreases muscle mass.
- Undernourished people have greater difficulty fighting infections.
- Severe zinc deficiency can cause diarrhea, weight loss, skin lesions, and decreased immunity (NCHS undated).

11 Conversely, in some cases drought can increase the concentration of nutrients (Balla et al. 2011; Gooding et al. 2008).

Climate Impacts on Food Availability and Nutrition

Food and nutrition concerns resulting from a warming world could outweigh all other human health impacts brought on by climate change (Springmann et al. 2016). Examples include:

- Elevated CO_2 levels can reduce the protein and micronutrient concentration in grains, putting larger swaths of the global population at risk for malnutrition and anemia (Medek et al. 2017; Smith and Myers 2018; Uddling et al. 2018).
- Increased temperatures, both modest and extreme, can lower crop yields (Zhao et al. 2017; Vogel et al. 2019), as can drought (Lesk et al. 2016) and extreme weather events (Nelson et al. 2014).

- Increased food prices are an economic result of lower crop yields, making some foods less available to those who may already be undernourished. Increased food prices disproportionately affect lower income people (Lake et al. 2012).
- Given the interconnected food supply, global crop failures or shortages in distant locations can impact food prices and availability in Montana.
- Montana has seen longer growing seasons, offset by summers becoming hotter and drier. Hence, it is hard to project whether local food production will increase.

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Cattle in Valley County
Photo courtesy of Erik Adams

Climate change can also lower the overall quantity of food produced, resulting in multiple impacts including to traditional sources for American Indians (Zhao et al. 2017; Gowda et al. 2018b; see Section 4 sidebar: *Changes Rippling Through Our Lives and Waters*). The salt content of underground water sources (aquifers) and coastal lands globally is increasing due to greater withdrawal of groundwater and sea-level rise, making these regions less productive or non-productive. Some pests and weeds that lower the productivity of food crops can thrive better in a CO_2-enriched atmosphere (Deutsch et al. 2018; Ziska et al. 2019). Increasing extreme weather (e.g., flood and precipitation events), growing season drought, and increasing fire severity can also be a detriment to food production.

Food and nutrition concerns resulting from a warming world could outweigh all other human health impacts brought on by climate change (Springmann et al. 2016).

Livestock, not just plants, are impacted by climate change. Milk production decreases as dairy cows are exposed to increased heat (reviewed in Whitlock et al. 2017; Summer et al. 2018). Deaths in all animals, including livestock, increase with excessive heat, and animals with dark coats are more sensitive to extreme heat. Heat waves make livestock less fertile (Takahashi 2012). Extreme weather events, such as flash floods and drought, also lead to increased animal mortality.

Vector-borne Disease

Vectors—primarily arthropods such as ticks, mosquitoes and fleas—are organisms that transmit diseases from one host to another. Globally, vector-borne diseases include Zika, plague, dengue, malaria, yellow fever, Chagas disease, and Chikungunya, among others. In the US, Rocky Mountain spotted fever, Lyme disease, and anaplasmosis, all carried by ticks, and West Nile virus, transmitted by mosquitoes, are most prominent. Zika, dengue, Chikungunya, and Eastern Equine Encephalitis are also of concern.

Overall, climate change is expected to increase the range of vectors, primarily ticks and mosquitoes in the US, thereby increasing the number of people exposed to the diseases that these arthropods transmit (Beard et al. 2016; Sonenshine 2018). Recent work by Rosenberg et al. (2018) shows that the number of vector-borne diseases tripled in the US between 2004 and 2016, with over 100,000 cases reported in 2016. Whereas the marked increase is unlikely to be fully attributable to climate change given the complexities of vector life cycles, disease prevalence, and human interactions (well discussed by Ogden 2017), neither can the contribution of climate change be discounted. Thus, concern is reasonable.

The interactions between climate, vectors, and pathogens are complex. For example, for certain mosquitoes increased temperatures boost the rate of reproduction and feeding, lengthen the breeding season, and shorten the maturation time for the pathogens they carry (Patz et al. 1996; Epstein et al. 1998; Epstein 2005). However, such complex relationships vary by locale and species. Temperatures that benefit mosquitoes may be detrimental to ticks; flooding may wash away larval stages of mosquitoes; drought may contribute to a decline in tick numbers. Rodent vectors, such as deer mice that carry Hantavirus, demonstrate equally variable relationships (Mordecai et al. 2012, 2017, 2019).

Lyme disease.—According to the Centers for Disease Control and Prevention (CDC), Lyme disease is the most common vector-borne illness in the US, with approximately 300,000 total cases diagnosed annually (CDCa undated). Lyme disease is most prevalent in the Northeast, but has been spreading westward and northward into the Midwestern states and farther into Canada. The main vector, the deer or blacklegged tick, is not found in arid parts of the West, requiring more moisture to thrive. Although Lyme disease is the most common tick-borne disease in Montana—averaging 10 cases per year—all cases reported through 2018 came from people infected outside of Montana (MTDPHHSb undated).

West Nile virus.—West Nile virus, first reported in the United States in 1999, is found in nearly every country and is the most common mosquito-borne illness in the United States, with 2647 cases and 167 deaths reported in 2018 (CDCb undated). West Nile virus is considered the most important cause of viral encephalitis globally (Chancey et al. 2015; Paz 2015), with increased spread projected with climate change (Paz 2015). Drier weather, especially drought, leads to higher rates of West Nile virus infection in people (Wang et al. 2010; Paull et al. 2016).

In the last several years, the northwest region of the US has seen an increase in some infectious diseases, including West Nile virus. The Washington Department of Health's vector surveillance program observed earlier arrival of West Nile virus-carrying mosquitoes than some other states (likely associated with higher temperatures), and an increasing number of human infections, including some resulting in fatalities (WSDOH 2018).

Photo: James Gathany / Wikimedia

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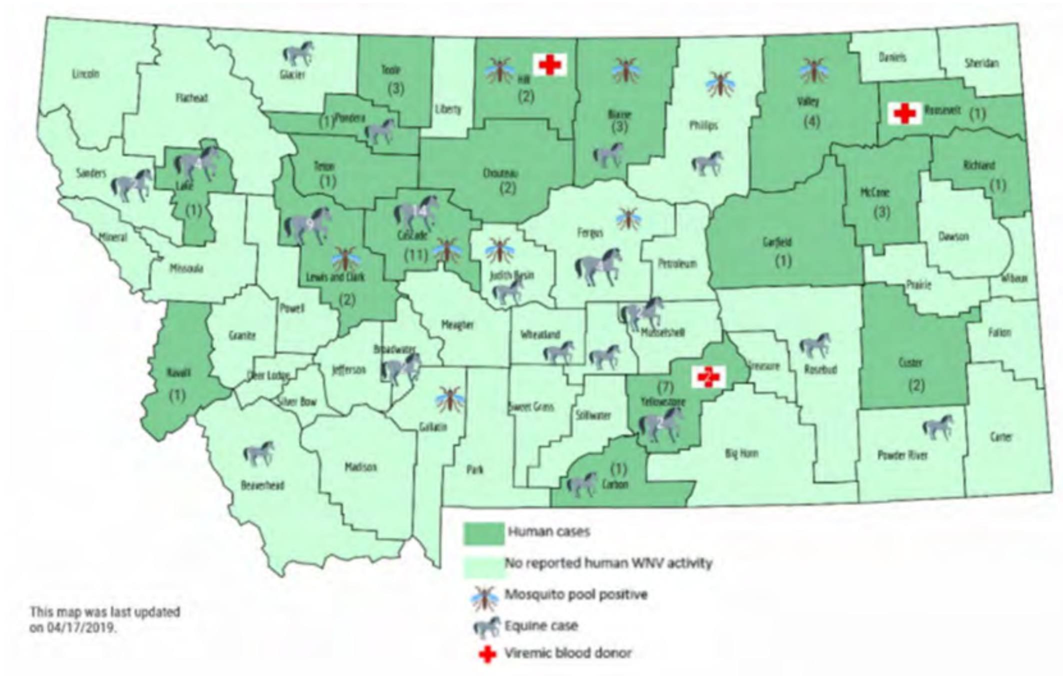

Figure 3-9. Map showing 2018 detections of West Nile virus in humans and horses, by county (MTDPHHSc undated).

Montana had no cases of West Nile virus until 2002. By 2018, the Montana Department of Public Health and Human Services (MTDPHHS) reported 51 cases across 18 counties. Nine counties reported mosquito pools[12] that tested positive for West Nile virus out of 30 counties tested (Figure 3-9). Three people have died from West Nile virus in Montana since it was first detected (MTDPHHSc undated). MCA projects longer droughts, warmer temperatures, and minimal change in average annual precipitation, likely concentrated in fewer precipitation events (Whitlock et al. 2017; also see Section 2), factors that favor both the virus and the primary vector, the *Culex* spp. mosquito (Epstein 2001; Harrigan et al. 2014; Paull et al. 2017). Thus, concern exists for climate change resulting in increased numbers of West Nile virus infections in Montana.

12 A mosquito pool is described by the West Umatilla Mosquito Control District as a collection of mosquitoes (usually about 50) of any given species or group (e.g., *Culex* spp. mosquitoes) that are likely to carry and potentially transmit a virus (WUMCD undated).

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Climate Change and Mental Well-being—Perspectives from Montana Farmers and Ranchers

Meredith Howard, Selena Ahmed, Paul Lachapelle, and Mark B. Schure

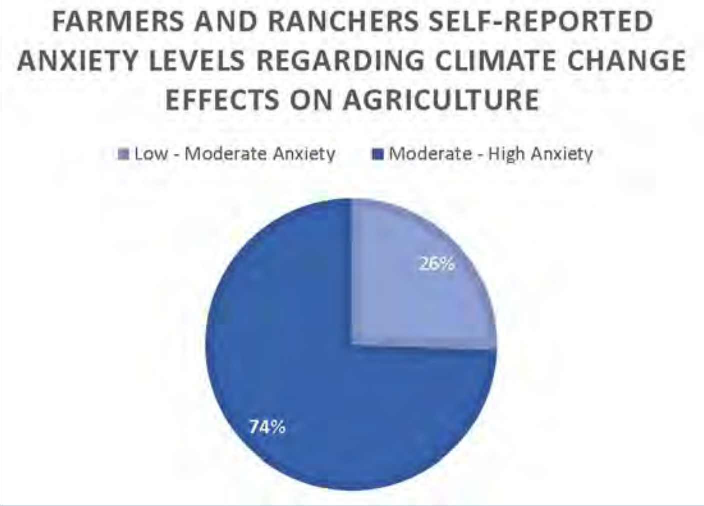
While the physical and economic implications of climate change have been studied widely, including effects on agricultural systems, the mental health implications have been largely overlooked. Farmers and ranchers—who contribute to local, national, and global food security—represent an especially vulnerable and critical population for consideration. Montana State University researchers surveyed farmers and ranchers (n=125) in Montana using a mixed-method approach to investigate the relationship between climate change perceptions and mental well-being (Howard et al. 2020). Survey results revealed the following:

- The majority of respondents (72%) agreed that climate change is having an adverse effect on their farm or ranch.
- Nearly three quarters of respondents reported feeling moderate to high levels of anxiety when thinking about climate effects on their agricultural business.
- The greater the reported perceived risk regarding climate change, the greater the level of reported anxiety.
- The impact of climate change on farm/ranch profitability was perceived as a main cause of distress.

One Montana producer commented, "[I am] worried about crop losses of current and future years, and about where funds will come for dealing with climate change on the farm. As with most, my worries generally stem from financial stress."

Another respondent shared, "Climate change contributes to my distress because it makes planning for long-term crops more difficult and predicting weather patterns less predictable."

Public-health preparedness efforts are warranted to provide mental health support for the agricultural sector. Research and outreach efforts are further called for to promote the adoption of practices that mitigate climate risk and enhance personal and food-system resilience. Linkages between climate-induced anxiety and an increasingly aging and female farm and ranch population should also be studied. Policy discussions at various scales should be considered to address financial risk to agricultural enterprises in the face of increased climate variability.



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Mental Health Concerns

The mental health impacts of climate change are profound and varied. Elevated temperatures have been related to worsening a) mental health status (Obradovich et al. 2018); b) diminished cognitive function (Laurent et al. 2018); c) increased violence (Clayton et al. 2017); d) increased interpersonal aggression in the form of domestic violence, abuse, and rapes (Hsiang et al. 2013); and e) suicide (Page et al. 2007). Even small increases in temperature, in one case comparing average monthly temperatures between 25-30°C (77-86°F) with those over 30°C (86°F), can lead to significant increases in mental illness (Obradovich et al. 2018).

People with preexisting mental illness are at increased risk following weather-related events (Trombley et al. 2017), as are youth (Paulson et al. 2015; Orengo-Aguayo et al. 2019). Likewise, climate "surprises" (see Section 2) such as flooding (Lamond et al. 2015), wildfires, or storms have been shown to impact mental health. Those impacts include increases in post-traumatic stress disorder (PTSD), anxiety, depression, substance abuse, and suicidal thoughts. A sense of community loss and, in many cases, displacement can also result following sudden extreme events, or they may occur over time with slower, sustained climate change impacts (e.g., persistent drought or sea-level rise) (Hayes et al. 2018; Palinkas and Wong 2019).

Montana has one of the highest per capita suicide rates in the country (CDC 2018; AAS 2020a,b). This unfortunate reality, coupled with limited access to mental health professionals in most rural areas of the state, greatly heightens the importance of preparedness planning in Montana to address anxiety, stress, and other mental health issues exacerbated by climate change.

Montana has one of the highest per capita suicide rates in the country (CDC 2018; AAS 2020a,b). This unfortunate reality, coupled with limited access to mental health professionals in most rural areas of the state, greatly heightens the importance of preparedness planning in Montana to address anxiety, stress, and other mental health issues exacerbated by climate change (see facing page). The Montana health workforce does *not* have widely available access to training on how to address climate anxiety and post-disaster trauma; nor does it have information on the tracking of climate stressors (Doppelt 2016).

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Helena at -15°F (-26°C)
Photo courtesy of Scott Bischke

Photos (left to right): Engin Akyurt / Pexels, Lori Byron; John Turner / US Air Force; Vlad Chețan / Pexels

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04. WHOSE HEALTH IS MOST VULNERABLE TO CLIMATE CHANGE IMPACTS?

Susan Higgins, Alexandra Adams, and Margaret Eggers, with contributing authors Lori Byron, Paul Lachapelle, Sally Moyce, Richard Ready, Lisa Richidt, Jennifer Robohm, and Eliza Webber

Some people are more vulnerable to climate change impacts than others. When considering all Americans, Gamble et al. (2016) identify those at higher risk to include children, older adults, pregnant females, tribal communities, communities of color, people with lower incomes, and people living in rural or remote regions. People with disabilities or mental health conditions, as well as people who are displaced, suffer from social isolation, or live without insurance are also more likely to suffer adverse consequences from climate change (Forman et al. 2016). Montanans fit into a number of the categories just noted, as we describe below.

We recognize that some people in Montana are *already* health-challenged with issues like chronic disease, poor diet and nutrition, and/or limited access to food and healthcare, regardless of climate change impacts. Such challenges are depicted annually for nearly every county in the United States in the *County Health Rankings and Roadmaps* report (Givens et al. 2019). Figure 4-1 shows how Montana's 56 counties rank with respect to a set of *health factors* that determine how long and how well we live. Those factors—e.g., personal behavior, socioeconomic status, and the physical environment—strongly influence health concerns resulting from climate change.

We find ten sectors of Montana's population are at particular risk of having their health impacted by Montana's warming climate. We base that assessment on an understanding of our state's warming climate (Whitlock et al. 2017; also see Section 2), known climate impacts on human health (see Section 3), and Montana's health profile, as follows.

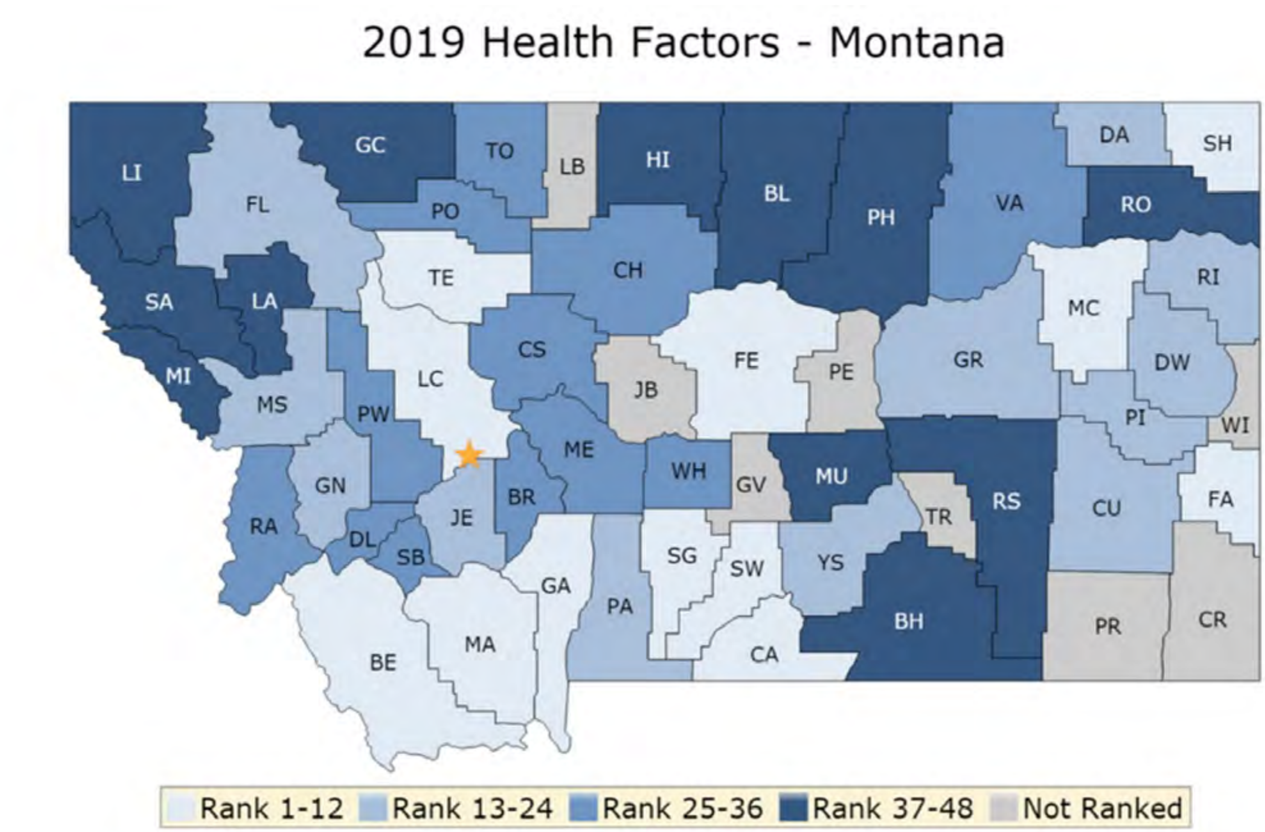

Figure 4-1. Montana's 56 counties ranked with respect to *health factors* (factors that drive how long and how well we live including, for example, personal behaviors, socioeconomic factors, and the physical environment). The higher the number, the greater the health challenges (Givens et al. 2019). Note: Figure 2-1 provides a map showing and naming Montana's 56 counties. Note that some counties are not ranked due to low population numbers and/or lack of data.

Photo facing page: iStock by Getty Images

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Montana's Health Profile

Before describing Montanans who are most vulnerable to climate-related health concerns, we acknowledge our state's current health profile. A health profile describes access to and availability of health resources, social and demographic characteristics, current health status, health risk factors, and quality of life (Durch et al. 1997). Montana has many health-related inequities and complexities, as described below, even before adding climate-related complications.

Montana is a rural state

The most important aspect of Montana's health profile is that *Montana is a rural state*. As such, many Montanans live in frontier areas[1] that lack essential services like healthcare, and thus must travel long distances for such vital needs. Figure 4-2 shows the population status of Montana's 56 counties, and the boundaries of tribal reservations (OMB 2010).

1 A *frontier area* is defined as having fewer than 7 people/mile^2 (2.7 people/km^2) (RHIhuba 2020).

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Montana averages just 6.9 people/mile^2 (2.7 people/km^2), making it the third most sparsely populated state in the country (US Census Bureau 2010). The 2018 census estimates show that 33.1% of Montana's 1,062,305 residents live in rural areas, as defined by Office of Management and Budget's Core-Based Statistical Areas (OMB 2010; US Census Bureau 2018b). In comparison, just 5.6% of the total US population resides in a rural area (US Census Bureau 2018b). Montana's population is 88.9% White. American Indians comprise 6.6% of Montana's population, one of the highest percentages of any state (US Census Bureau 2018c). Other ethnic and racial groups represent 4.6% of the population.

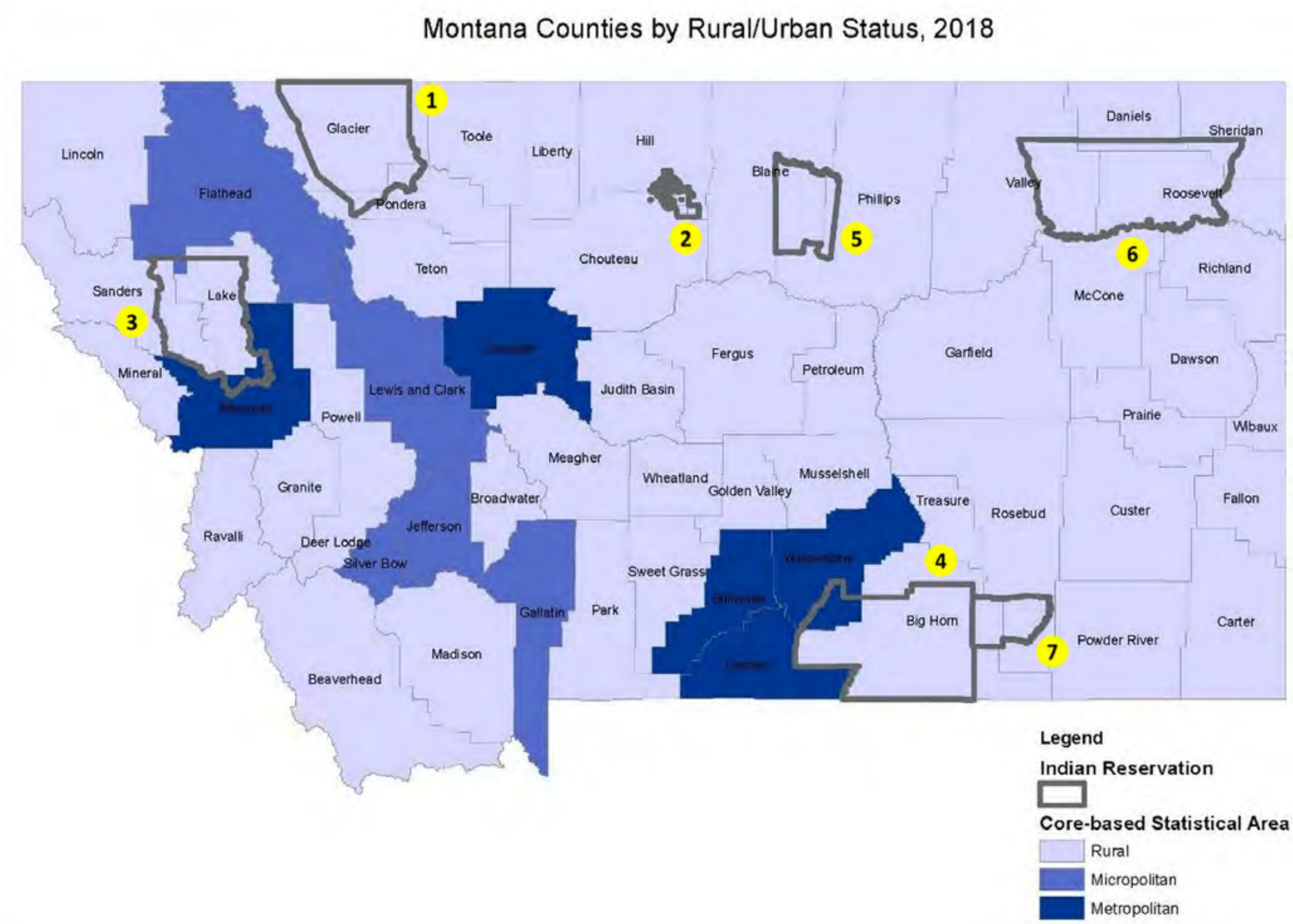

Figure 4-2. Population status of Montana's 56 counties. The three statistical areas shown are defined as follows: *Rural* areas are counties with an urban cluster having less than 10,000 people. *Micropolitan* areas have at least one urban cluster of at least 10,000 but less than 50,000 population, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties. *Metropolitan* areas have at least one urbanized area of 50,000 or more population, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties. The analysis here was created from OMB (2010) and US Census Bureau (2018a) data. Montana's tribal reservations, numbered, are outlined in gray: 1) Blackfeet Tribe of the Blackfeet Reservation; 2) Chippewa Cree Tribe of the Rocky Boy's Reservation; 3) Confederated Salish and Kootenai Tribes of the Flathead Reservation; 4) Crow Tribe of the Crow Reservation; 5) Assiniboine (Nakoda) and Gros Ventre (Aaniiih) Tribes of the Fort Belknap Reservation; 6) Assiniboine and Sioux Tribes of the Fort Peck Reservation; and 7) Northern Cheyenne Tribe of the Northern Cheyenne Reservation.

Between 2010 and 2018, Montana's population grew 7.4%, faster than the average national growth rate of 5.9% during the same period. Yet, even though Montana as a whole is growing quickly, its rural areas continue to lose numbers: 18 of 56 counties *lost* population (US Census Bureau 2018d). Growth has been concentrated in Montana's most highly populated counties, with urban county growth in Gallatin, Yellowstone, Flathead, Missoula, and Lewis and Clark counties accounting for 83% of the state's total population increase (US Census Bureau 2018d) (Table 4-1; Figure 4-3).

The most important aspect of Montana's health profile is that ***Montana is a rural state****. As such, many Montanans live in frontier areas that lack essential services like healthcare, and thus must travel long distances for such vital needs.*

Table 4-1. Distribution of Montana population growth, 2010-2018[a]

Location	Net growth	Growth share (%)	Urban/rural status
MT net growth, statewide	72,890		
Growth share by county			
Gallatin County	22,363	30.7%	Urban
Yellowstone County	12,165	16.7%	Urban
Flathead County	11,178	15.3%	Urban
Missoula County	9492	13.0%	Urban
Lewis and Clark County	5305	7.3%	Urban
Other counties[b]—rural (n=46)	3903	5.4%	Rural
Other counties[c]—urban (n=5)	2853	3.9%	Urban

[a] Data sources: US Census Bureau 2018b,d

[b] Combined net growth of the following rural counties: Beaverhead, Big Horn, Blaine, Broadwater, Carter, Chouteau, Custer, Daniels, Dawson, Deer Lodge, Fallon, Fergus, Garfield, Glacier, Golden Valley, Granite, Hill, Judith Basin, Lake, Liberty, Lincoln, Madison, McCone, Meagher, Mineral, Musselshell, Park, Petroleum, Phillips, Pondera, Powder River, Powell, Prairie, Ravalli, Richland, Roosevelt, Rosebud, Sanders, Sheridan, Sweet Grass, Teton, Toole, Treasure, Valley, Wheatland, and Wibaux

[c] Combined net growth of the following urban counties: Carbon, Cascade, Jefferson, Silver Bow, and Stillwater

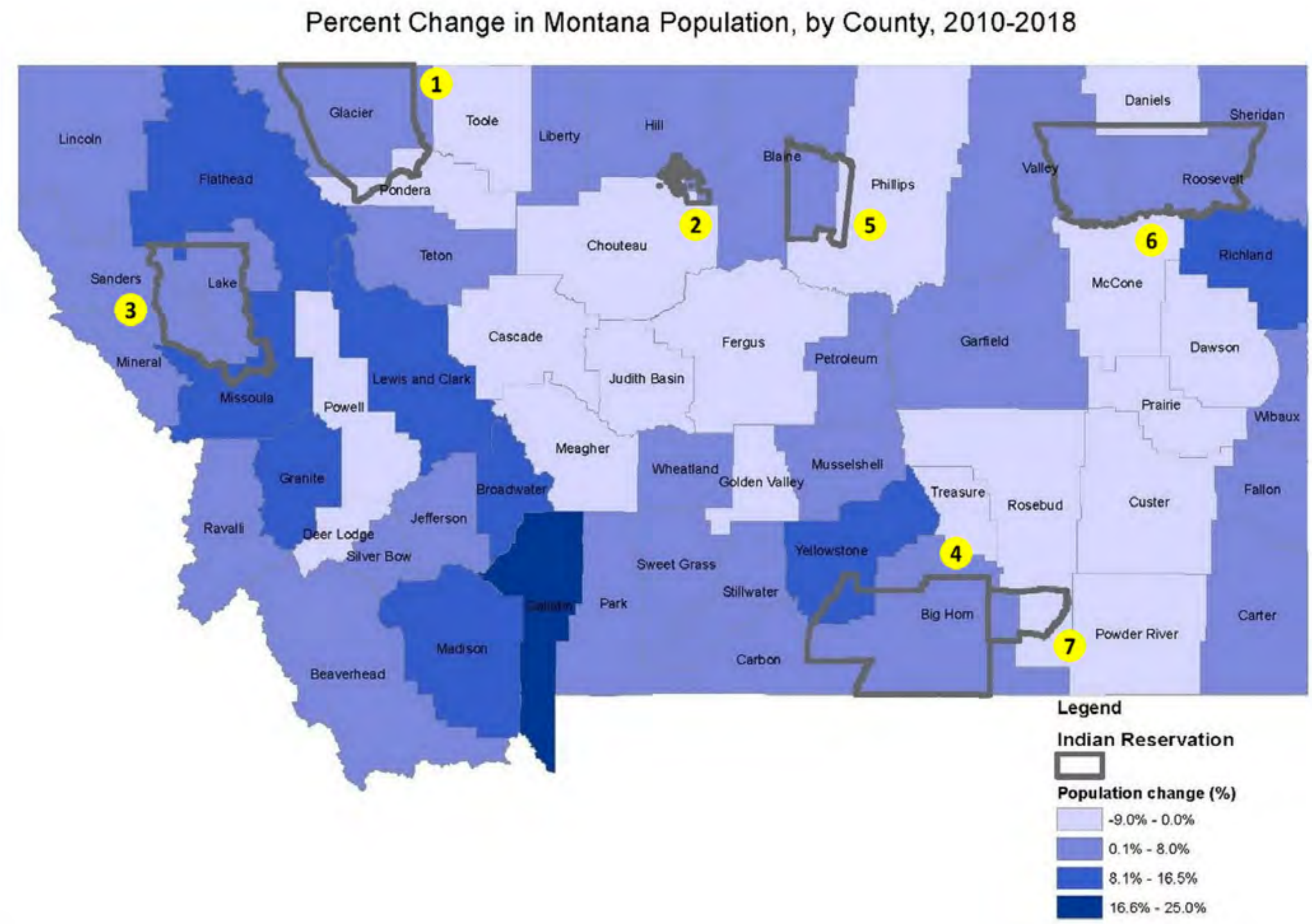

Figure 4-3. Range of percent change in population for Montana's 56 counties from 2010-2018 (US Census Bureau 2018d). Montana's tribal reservations, numbered, are outlined in gray: 1) Blackfeet Tribe of the Blackfeet Reservation; 2) Chippewa Cree Tribe of the Rocky Boy's Reservation; 3) Confederated Salish and Kootenai Tribes of the Flathead Reservation; 4) Crow Tribe of the Crow Reservation; 5) Assiniboine (Nakoda) and Gros Ventre (Aaniiih) Tribes of the Fort Belknap Reservation; 6) Assiniboine and Sioux Tribes of the Fort Peck Reservation; and 7) Northern Cheyenne Tribe of the Northern Cheyenne Reservation.

Health-wise, where you live matters

It is not surprising that healthcare access is a challenge to Montanans in low-population counties and— combined with other risk factors described below—translates into poorer health outcomes when compared to those living in high-population counties. Montana ranks higher than the national average in percentages of people over the age of 65, housed in mobile homes, without health insurance, or with disabilities (Headwaters Economics 2019). Thirty-three percent of adults in Montana report having two or more chronic health conditions, and the prevalence of multiple chronic conditions is significantly higher among adults living in low-population counties (MTDPHHSa undated).

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Health outcomes for Montana's American Indian communities are worse than for its non-American Indian communities. For example, the rate of premature death in Montana is much higher for American Indians than for non-Native residents (MTDPHHS 2019a). The life expectancy for Montana American Indians is nearly 20 yr less, and their rates of death from cancer, injury, cirrhosis, diabetes, and heart disease are higher than for non-Native residents (MTHCF undated). Table 4-2 compares the differences in health outcomes for Montana's different ethnic and racial groups (Givens et al. 2019). These inequities stem from systemic, long-standing issues such as racism, historical trauma, and rural isolation; and/or lack of access to healthy foods and healthcare, inadequate water and wastewater infrastructure, problems of safety or crime, loss of tribal connections, high stress levels, and poverty. In addition, funding disparities for education, housing, healthcare, and food have perpetuated this vulnerability (US Commission on Civil Rights 2003, 2018).

Table 4-2. Differences in health outcome measures among counties and racial/ethnic groups in Montana (Givens et al. 2019)

	Healthiest MT county	Least healthy MT county	AI / AN [a]	Asian / PI [a]	Black	Hispanic	White
Premature death (yr lost/100,000)[b]	4900	21,000	19,400	2900	10,000	6800	6600
Poor or fair health (%)	11%	26%	25%	NA*	NA*	18%	13%
Poor physical health (days/month)[c]	3.0	5.4	5.1	NA*	NA*	3.4	3.3
Poor mental health (days/month)[c]	2.9	4.5	5.3	NA*	NA*	4.6	3.4
Low birth weight (%)	5%	7%	9%	10%	12%	8%	7%

[a] AI = American Indian; AN = Alaska Native; PI = Pacific Islander; NA = not applicable (data for all racial/ethnic groups may not be available due to small numbers)

[b] *Premature* death is defined in the Montana State Health Assessment (MTDPHHS 2019a) as: "A death which occurs before a person's life expectancy. In the US, premature death is dying before the age of 75."

[c] Past 30 days at time of survey

Key health issues in Montana

The CDC (2017) identified the leading causes of death in Montana as respiratory disease, heart disease, accidents, suicide, cancer, and stroke. Building from that knowledge, Montana's State Health Improvement Plan identified five priority areas for healthcare focus (MTDPHHS 2020a). We summarize each of the priority areas below, plus compare Montana to the national averages in Table 4-3. All declarations in the bullets that follow, unless otherwise credited, are derived from Montana's State Health Improvement Plan (MTDPHHS 2020a).

- *Behavioral health, including suicide prevention, depression, substance abuse, and opioid misuse.*—Suicide-related deaths in Montana are the fourth highest per capita in the US, and almost twice the national average (CDC 2018). This rate is significantly higher in rural counties and in American Indian populations. Precursors to suicide often include depression and/or substance abuse. The number of adults treated with mental illnesses in Montana between 2009 and 2013 was higher than the national average, and nearly 64,000 Montana adults struggle with substance abuse. Alcohol is the most commonly abused substance in Montana, but opioids are the leading cause of drug-overdose deaths in Montana, accounting for 44% of such deaths.
- *Chronic disease.*—Chronic diseases are long-term conditions lasting one or more years that require ongoing medical attention or limit activities of daily living (NCCDPHP 2019). Chronic disease in Montana is attributable in large part to smoking, obesity, poor nutrition, and physical inactivity. Tobacco use is the leading cause of preventable death, with 1600 tobacco-related deaths each year. Per capita, these deaths strike Montana's American Indian population disproportionately (Campaign for Tobacco-free Kids 2017). Two factors adding to chronic disease in our state are a) 75% of Montana adults and 72% of youth do not meet the national physical activity recommendations (MTOPI 2019); and b) only 62% of Montanans are up-to-date with colorectal cancer screening (MTDPHHS 2016).
- *Maternal health and newborns.*—Approximately 12,000 live births occur each year in Montana. Infant mortality in Montana is 5.7 per 1000 births for White populations, closely matching the rate for all races nationally of 5.8 per 1000 births. In great contrast, infant mortality for American Indians in Montana is 10 per 1000 births (MTDPHHS 2017).
- *Motor vehicle crashes.*—Motor vehicle crashes are one of the most common causes of fatal and non-fatal injuries in Montana. In 2014, the rate of death due to crashes was 19.4 per 100,000 in Montana, approaching twice the national figure of 10.3 per 100,000 in the same year (MTPHIS undated). The rate is higher among American Indians and for those living in rural versus urban areas (MTDPHHSb undated). From 2011–2016, 60% of all crash-related fatalities involved a driver impaired by alcohol or drugs (MTDPHHS 2020a).
- *Adverse childhood experiences.*—The Centers for Disease Control defines adverse childhood experiences as (CDCb undated):

...potentially traumatic events that occur in childhood (0-17 years) such as experiencing violence, abuse, or neglect; witnessing violence in the home; and having a family member attempt or die by suicide. Also included are aspects of the child's environment that can undermine their sense of safety, stability, and bonding such as growing up in a household with substance misuse, mental health problems, or instability due to parental separation or incarceration of a parent, sibling, or other member of the household.

Adverse childhood experiences are directly related to negative outcomes in chronic disease, substance abuse, and mental health. In 2011, 60% of Montana adults reported having one or more adverse childhood experiences (CDCb undated). Due to the established links between adverse childhood experiences and negative behavioral and health outcomes, this is an important area for health improvement in our state (CDCc undated). People with higher probability of chronic disease and mental health issues related to adverse childhood experiences are also more vulnerable to climate-related health impacts.

Table 4-3. Comparisons of Montana and US rates for incidence of five priority health issues. See text for a description of each issue.

Priority health issue in Montana	Unit of measure	Montana	US
Suicide mortality[a]	per 100,000 population	28.9	14.0
Chronic disease[b]	% of adults with multiple (two or more) chronic conditions	33.2%	25.7%
Infant mortality[c]	per 1000 live births	5.4	5.8
Motor vehicle crash mortality[d]	per 100,000 population	17.1	11.2
Adverse childhood experiences[e]	% of adults experiencing one or more such experiences	60%	61.5%

Data sources (all accessed 4 April 2020)

[a] https://www.cdc.gov/nchs/pressroom/sosmap/suicide-mortality/suicide.htm

[b] https://www.cdc.gov/mmwr/volumes/65/wr/mm6529a3.htm#T1_down

[c] https://www.cdc.gov/nchs/pressroom/states/montana/montana.htm

[d] https://www.cdc.gov/nchs/pressroom/states/montana/montana.htm

[e] https://dphhs.mt.gov/ahealthiermontana/ACEs; https://www.cdc.gov/violenceprevention/childabuseandneglect/acestudy/ace-brfss.html

Populations Vulnerable to Climate Change

Review of Montana's health profile reveals that our state's rural nature—including limited access to healthcare facilities—has a wide-reaching impact on our citizens' well-being. Montanans suffer from chronic disease, inadequate maternal and childhood healthcare, a high rate of vehicular deaths, and mental illness, suicide, alcoholism, and substance use disorders. We next consider what concerns result when climate-related impacts are added to these existing health conditions. The remainder of this section describes ten groups in Montana having particular health vulnerabilities to climate change.

People with existing chronic conditions

Why it matters.—People living with chronic conditions (e.g., asthma, obesity, heart disease, pulmonary disease) are more vulnerable to the risks of climate change (Gamble et al. 2106). Extreme heat and degraded air quality that result from wildfires greatly aggravate these existing health problems (USEPA 2016).

What we know in Montana.— Rural Montanans, regardless of race or ethnicity, have higher mortality rates for six of the ten leading causes of death, including heart disease, diabetes, and chronic liver disease, compared to residents of more urban counties. Rural risk factors for health disparities in Montana include geographic isolation, fewer healthcare providers, more health risk behaviors (e.g., binge drinking and unhealthy diets), lower socioeconomic status, and limited employment opportunities. The story becomes even more stark when considering Montana's American Indian communities. From 2011 to 2015, for example, the median age at death in Montana was 16 and 19 yr younger for American Indian men and women, respectively, when compared to their non-Native counterparts (MTDPHHS 2019a).

People threatened by increased heat

Why it matters.—National data show that increasing heat negatively impacts mental health and risk of heat stroke (see Section 3). People without access to shade, air conditioning, and cooling places are at much greater risk than those having adequate protection from heat. In addition, heat exposure during pregnancy carries with it the risk of premature births and birth defects (Ravanelli et al. 2019; Section 3).

What we know in Montana.—Increased heat poses the greatest risk for migrant agricultural workers and others working outdoors, as well as those living in inadequate housing (without, for example, adequate insulation or air conditioning).

- *Those working in the outdoors.*—Over 62% of Montana lands are in farm and ranch production (NASS 2019). In summer, farmers, ranchers, and workers labor outside on these lands through the heat of the day. Researchers are exploring the impacts of heat on agricultural and other outdoor occupations. For example, migrant and seasonal

Photo facing page: M. Thivierge / Wikimedia workers come to Montana to work in agriculture, construction, and other industries involving outdoor labor. These workers are at increased risk due to inadequate or substandard housing facilities, cultural and linguistic isolation, lack of health insurance, and poverty. As depicted in Figure 4-4, fatalities are highest in the occupational sector that includes agriculture and forestry (North American Industry Classification Sector 111). An analysis of workers' compensation data revealed that workers in these industries are at particular risk of injuries on high heat days (Moyce and Nealy 2019).

- o *Housing and air conditioning.*—Inhabitants of mobile homes may be more susceptible to higher heat days.[2] Some mobile homes may be unbearably hot in summer if they lack adequate air conditioning and/or insulation. In 2017, there were 45,496 mobile homes in Montana, or 10.8% of the total housing units, which is nearly double the national average of 5.7% (Headwaters Economics 2019). In addition, mobile homes are more likely to be damaged during extreme storms, which poses a risk for both the structure and its occupants.

  Data on air conditioning in Montana are sparse. Based on a small-sample survey, NEEA (2012) estimates that 19% of rural Montana households and 35% of urban households have some type of air conditioning (NEEA 2014). People living in urban areas tend to have central air conditioning systems, while those in rural areas tend to have window or roof units.

2 Mobile homes are defined by the Montana Department of Revenue as any trailer, house trailer, or trailer coach that is over 8 ft wide or 45 ft long and designed to be moved by connecting to another vehicle, or under 8 ft wide or 45 ft long and used as a principal residence (Montana Department of Revenue undated).

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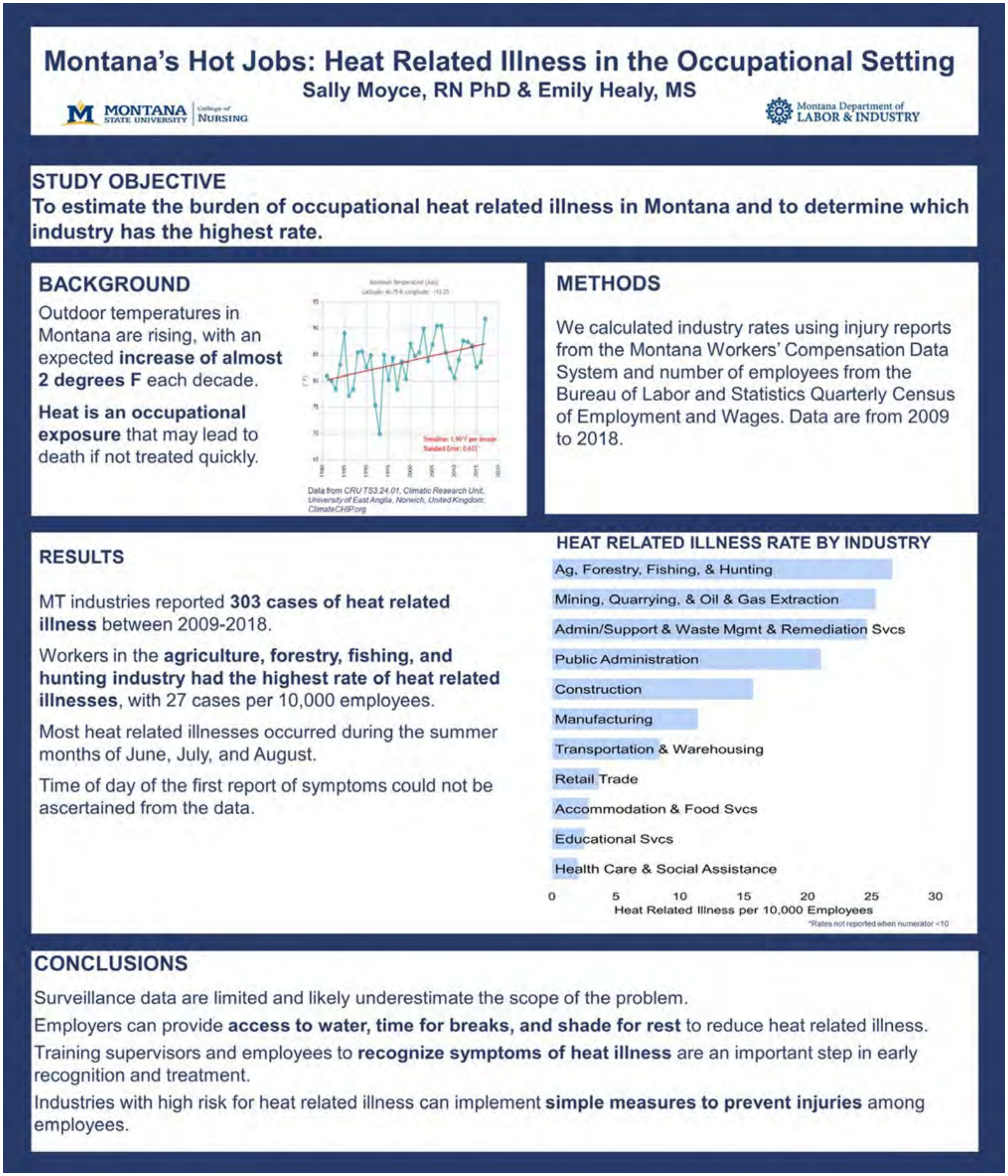

Figure 4-4. Heat-related illness rate by industry (used with permission from Moyce and Nealy 2019).

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People living in proximity to wildfire and smoke

Why it matters.—Particulate matter from wildfire smoke impacts incidence of lung disease and asthma (see next page). Smoke and fire damage can also cause or accentuate depression and anxiety. Montanans living in or near areas prone to wildfire are most vulnerable, although smoke travels great distances. Section 3 provides more information on health effects of wildfire and smoke.

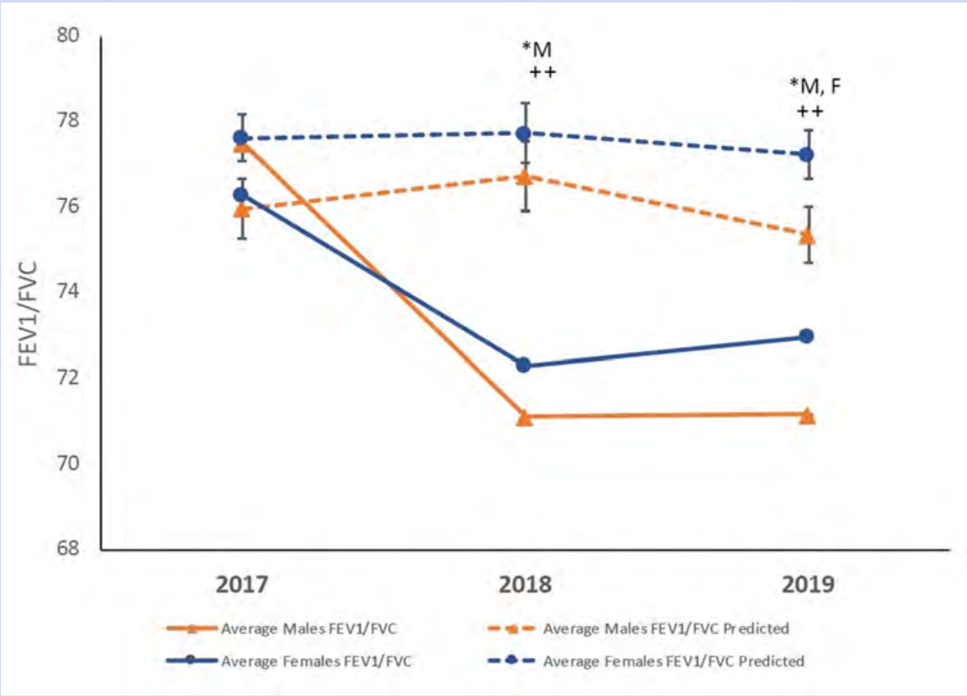
What we know in Montana.—The wildland-urban interface is where human development and wildlands meet or intermingle, placing houses or other structures near or within fire-prone forests. In 2010, 64.1% of Montana houses were located in the wildland-urban interface (Martinuzzi et al. 2015), the second highest percentage of all western states behind Wyoming. In Montana's 25 western counties, located in forested areas and for which contiguous fire hazard data are available, over 10% of homes are in high fire hazard, forest interface areas (Headwaters Economics 2018). Houses and structures in such areas are at highest risk of burning, with the risk decreasing the more distant houses are from the wildland-urban interface.

Lolo Peak Fire south of Missoula, 2017
Photo courtesy of Philip Higuera

The 2017 Seeley Lake Fires and Lung Function

Higher incidence of wildfire due to climate change is resulting in more large wildfires (Whitlock et al. 2017). Emergency room visits and hospitalizations for cardiovascular and respiratory complaints have increased due to wildfire smoke exposures. As exposures to wildfire increase in number and intensity, research on the resulting health impacts becomes more vital (Reid et al. 2016; Black et al. 2017).

In a local example, Orr et al. (2020) found long-term respiratory complications resulting from wildfires around the town of Seeley Lake, Montana. For 49 days in 2017, Seeley Lake was exposed to smoke from multiple nearby wildfires (NPR 2019). A group of 95 participants from Seeley Lake (average age 63 yr) was administered spirometry, a test used to assess how well the lungs work by measuring



Pulmonary function changes from predicted values. The graph depicts the changes to lung function (FEV1/FVC) in 2018 and 2019 following the Rice Ridge fire in Seeley Lake, Montana. In both years following the exposure the observed (solid lines) was significantly lower than predicted (dashed lines) for males (*M), while significantly lower in 2019 for females (*F). In addition, the male values were significantly lower as compared to the observed values in 2017. (* $P<0.05$ observed vs predicted within sex; ++ $P<0.01$ Significant compared to 2017 for corresponding group)

amount and rate of air inhaled and exhaled.

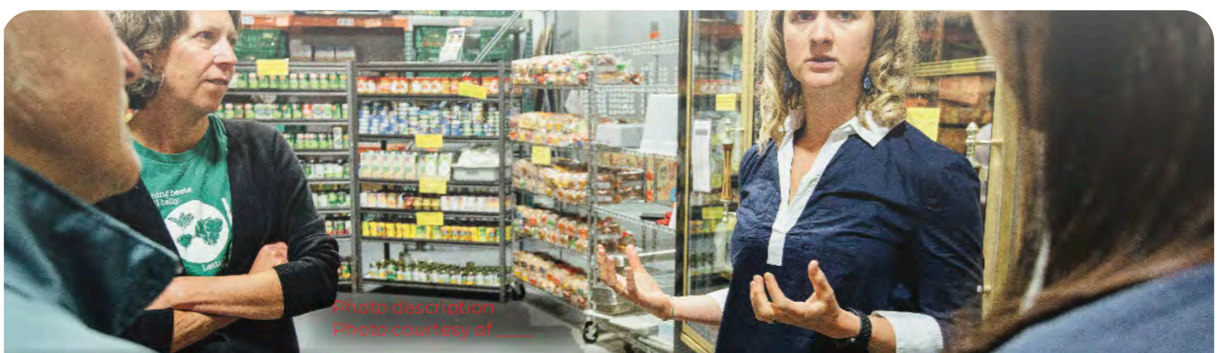
A decrease in lung function[a] was observed over time. Specifically, measured lung capacity decreased significantly compared with predicted values (age and sex matched), with a greater effect on males. The effect appears to continue at least two years post exposure. These observed decreases highlight the need for longitudinal studies to assess the health effects of smoke exposures.

[a] The ratio of FEV1/FVC, shown as the y-axis in the plot, is a measure of the amount of air a person can forcefully exhale from their lungs.

People facing food and water insecurity

Why it matters.—Montanans face the stark reality of losing nutritious—and for some, indigenous—foods due to wildfires, drought, and flood events resulting from climate change. Drought and flood can diminish local crop yields and floods can carry and distribute crop diseases. Drinking water supplies, likewise, can be threatened, first due to diminished water availability during drought, and second due to public water and wastewater disruption and potential for water-borne pathogen spread during flooding. Home wells that are inundated can become contaminated, thereby posing a health risk. Aging water infrastructure is also an issue. For example, one of the five 100-year-old concrete drop structures in the St. Mary Canal failed in 2020 flooding, making it impossible to divert water from the canal into the Milk River (Havre Daily News 2020). This canal supplies up to 80% of the water to communities along the Hi-line and northeastern Montana, and this loss of conveyance greatly threatens irrigation and municipal water supplies.

Regarding food security, only about 10% of the food we consume in Montana is grown here (Montana Department of Agriculture 2013), Thus, our food security is threatened by climate changes *outside* of Montana, a fact that strengthens the need for increasing local food production and processing. The USDA's Federal-State Marketing Improvement Program (USDA undated) and many instate partners (e.g., agriculture departments , agricultural experiment stations, universities) are working to improve Montana's food supply chains among producers, processors, food services, grocers, pantries, and distributors to assure food availability and improve instate production to support local needs.



Disussing healthy foods at Galatin Valley Food Bank, Bozeman
Photo courtesy of Adrian Sanchez-Gonzalez, Montana State University

What we know in Montana.—In 2017, 42,745 (10.2% of total) households received food stamps from the Supplemental Nutrition Assistance Program[3]; 19,564 (4.7% of total) received Supplemental Security Income[4]; and 8696 (2.1% of total) received cash public assistance income (Headwaters Economics 2019).

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3 The Supplemental Nutrition Assistance Program (SNAP) provides benefits to people who are elderly, homeless, unemployed, have low or no income, or are disabled with low incomes. Recipients can purchase groceries with SNAP benefits.

4 Supplemental Security Income (SSI) gives financial assistance to people who are disabled, aged, or blind and of limited income. Unlike Social Security benefits, SSI benefits are not determined by the recipient's lifetime earnings.

Nearly 10 percent of Montanans struggle with hunger, and 37,000 children live in food-insecure homes. Thirty of Montana's 56 counties have areas considered *food deserts*, i.e., low-income areas where at least 500 people and/or 33% of the residents must travel more than 10 miles (16 km) to the nearest supermarket (or 1 mile [1.6 km] in urban areas). This equates to nearly 72,000 Montanans without fresh, affordable food on a daily basis (Montana Food Bank Network undated).

Most Montanans (86%) get their drinking water from public water supplies and most public water systems meet the Environmental Protection Agency's Safe Drinking Water Standards (MTDEQ undated). Still, the MCA (Whitlock et al. 2017; also see Section 2) describes multiple threats to Montana's domestic water supply, including drought, flooding, and extreme storm events; and also to Montanans using domestic wells susceptible to contamination from flood events. MCA also states that Montana will experience reduced snowpack and diminished late-season flows with changing climate. Both are critical to public and private water supplies, as well as agricultural production and, hence, food security[5].

Tribal members in Montana are observing impacts from climate change on traditional foods and water sources. For the Crow Tribe, warming streams are affecting the distribution and health of fish species. Multiple berry shrub species and other traditionally harvested plants are also impacted (Doyle et al. 2013; Martin et al. 2020). Devastating spring floods inundated the Crow Reservation in 2007 and 2011, the latter of which set a gaging station record and damaged more than 200 homes (Billings Gazette 2011a,b). Lacking the resources to remediate the problems caused by the floods, many families had to move back into damaged and now mold-infested homes, in spite of health risks (Martin et al. 2020).

> *Nearly 10 percent of Montanans struggle with hunger, and 37,000 children live in food insecure homes. ... [N]early 72,000 Montanans [go] without fresh, affordable food on a daily basis (Montana Food Bank Network undated).*

Interviews with both Native and non-Native low-income residents of the Flathead Indian Reservation in northwestern Montana found that half reported being food insecure or having inconsistent access to adequate food. About 28% of those interviewed hunt, fish, and/or gather wild foods such as berries, and on average were more food secure than those who did not. Fish, game, and wild plants were valued for their taste, freshness, nutritional value, and traditional significance, as well as for promoting self-sufficiency. These residents perceive that their local wild foods are being adversely impacted by climate change, particularly by wildfires and increased seasonal variability in precipitation and temperature (Smith et al. 2019).

5 *Food security*, as defined in the glossary of this report, describes an individual or community's ability to reliably access a sufficient quantity of affordable, nutritious food.

People who are very young, very old, or pregnant

Why it matters.—Beginning at the fetal development stage, exposures to air or water pollution can increase the risk of impaired brain development (Clifford et al. 2016), stillbirth (Siddika 2016), and preterm births (Peterson et al. 2015; Sun et al. 2015). Infants and children are disproportionately affected by toxic exposures because they eat, drink, and breathe more in proportion to their body size (Heindel et al. 2016; Anderko et al. 2020). In addition, children spend more time outdoors, putting them at greater risk for respiratory problems from airborne particulates, wildfire smoke, and allergens. Children are also more sensitive to infectious diseases brought on by natural disasters that compromise water sanitation (Balbus and Malina 2009; Cooley et al. 2012).

Mental and developmental health issues also impact the young. For example, Clayton et al. (2014) suggest that young people may face increased risk of anxiety, depression, and post-traumatic stress disorder from extreme climate-driven weather events. Studies have shown that early-childhood health status also influences health and socioeconomic well-being later in life (Anda and Brown 2010; Currie et al. 2014).

Photo: Lindsay Richards

Advanced age is a top risk factor related to illness or death from extreme heat (CDCa undated) due to hormonal changes and health issues that make thermoregulation and hydration more difficult (Brennan et al. 2019). In addition, the likelihood of chronic disease increases with age (Prasad et al. 2013). The elderly are more likely to have preexisting medical conditions such as diabetes, pulmonary disease, and congestive heart failure, all of which will be exacerbated by the higher temperatures expected with climate change. For example, the elderly often have compromised mobility that reduces their ability to respond to natural disasters. Given chronic obstructive pulmonary disease (and other chronic diseases), the elderly are also highly susceptible to air pollution, such as ground-level ozone, particulate matter, or dust associated with drought, wildfires, and high-wind events (Bell et al. 2014).

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When faced with extreme heat, pregnant women can be subject to preterm labor, and their babies may be smaller and/or more prone to Sudden Infant Death Syndrome/Sudden Unexpected Infant Death Syndrome (SIDS/SUIDS; also see Section 3). Women are less tolerant of extreme heat during pregnancy. They are more sensitive to dehydration and acute kidney damage.

What we know in Montana.—In 2018, according to the Montana Public Health Information System, Montana had 11,515 births (MPHIS undated). In the same year. 5.9% of children in Montana were younger than 5 yr old, similar to the US average. Montanans 65 yr and older made up 18.7% of the population, compared to 16.0% nationwide. The proportion of people 65 yr and older is even higher in rural counties, where they are at risk due to limited access to healthcare (see below). In the six most populous counties, 16.8% of residents are 65 yr and older, while in rural counties, 21.7% are 65 and older (US Census Bureau 2019).

People with limited access to healthcare services

Why it matters.—Extreme weather events and natural disasters limit access to medical care. It is all too common for Montanans to be snowed in at their rural homes, with days passing before plows can get through. In February 2018, for example, 20-ft snow drifts were reported on the Blackfeet Reservation, and a state of emergency was declared by the Tribal Council and Montana Governor Bullock (Great Falls Tribune 2018; Spokesman-Review 2018). Likewise, rapid spring flooding, sometimes combined with major precipitation events, can cut communication lines, block access to roads, and limit availability of medical services to those in remote areas. The town of Roundup experienced such flooding of the Musselshell River in the spring of 2011, resulting in closed roads and disruptions to potable water supply (City of Roundup undated).

The inability to access medical providers following such extreme events is particularly consequential for those who already have compromised health (MTDPHHS 2020a). In rural Montana, assistance can be greatly delayed, given lack of nearby community health services and/or the transportation infrastructure needed to reach medical attention.

Choteau County Public Health in Fort Benton
Photo courtesy of Scott Bischke

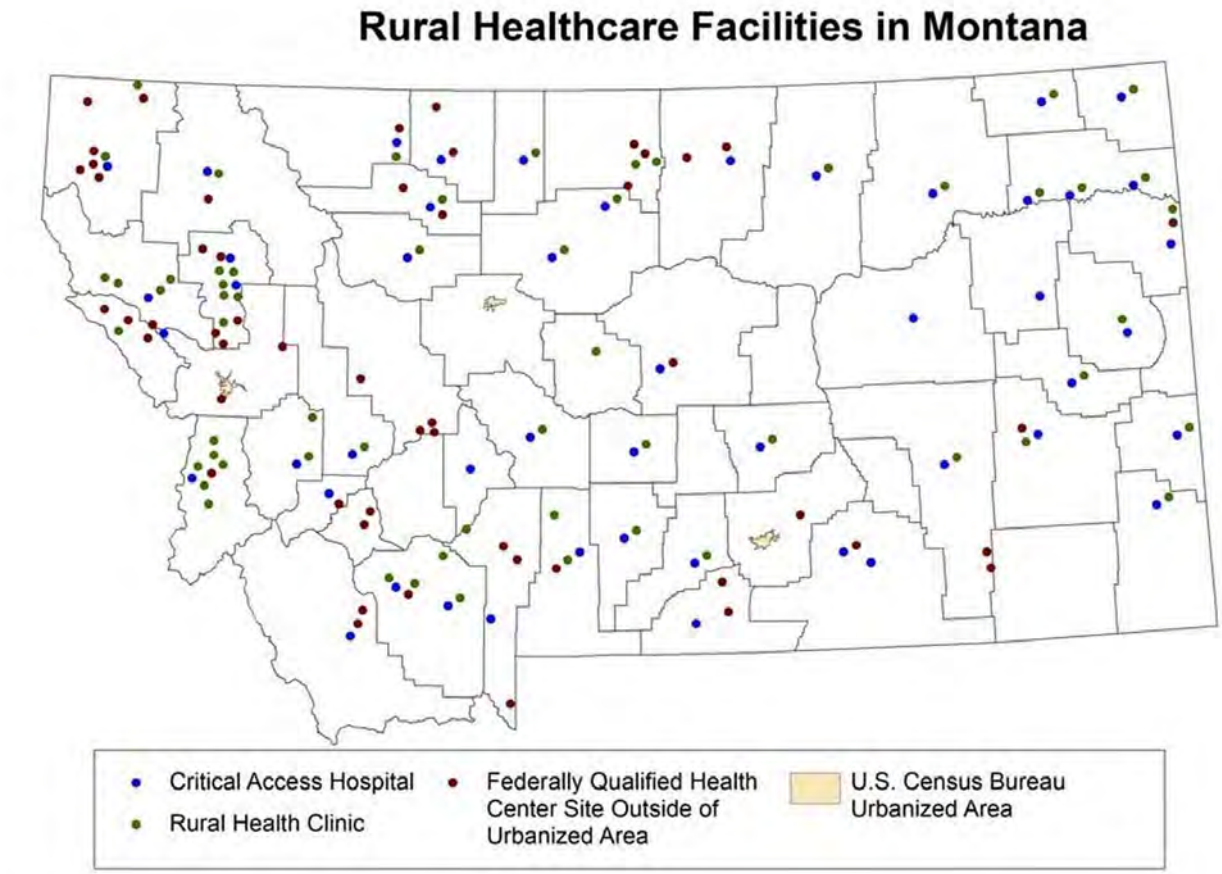

Figure 4-5. Location and type of healthcare facilities in Montana (RHIhubb 2018).

What we know in Montana.—As of January 2020, Montana had 49 critical-access hospitals, 58 rural health clinics, and 52 federally qualified health centers located outside of urban areas (Figure 4-5) (RHIhubb 2018). Even with these facilities, annual survey studies of Montana community members by the Montana Office of Rural Health show that access to healthcare is a major concern (MORHAHEC 2017). The Federal Health Resources and Services Administration designates 23 of Montana's 56 counties as Health Provider Shortage Areas, meaning residents have limited access to primary care providers (HRSA undated). Such a designation is based on provider-to-patient ratio, percentage of the population living in poverty, and travel time to the nearest health facility.

In 2019, residents of rural counties had a mortality rate 1.5 times higher due to unintentional injury compared with residents of more urban counties. Rural-county residents also had higher death rates due to chronic liver disease and cirrhosis, heart disease, diabetes, and suicide compared with residents of more urban counties, in part due to lack of immediate access to healthcare providers (MTDPHHS 2020a). The impact of climate change—whether on disease outcomes or transportation infrastructure—will only exacerbate the existing challenge of providing adequate access to health services for rural Montanans.

People living in poverty

Why it matters.—To save money, families with low incomes often must make lifestyle choices that subject them to impacts of climate change. These tough choices can result in poor diet, inadequate shelter, delayed medical care, unhealthy housing with leaks and mold, and no funds for electric fans or air conditioners. People in poverty often live in substandard housing or in mobile homes and are more vulnerable to heat-related illnesses and extreme weather events (Headwaters Economics 2019). Displaced communities are also at risk. Planning is especially critical for counties and communities already suffering from the loss of coal jobs and coal tax revenue, who need to diversify their economies in addition to planning for impacts described in this report.

What we know in Montana.—The poverty rate in Montana is similar to the US average. In 2017, 14.4% of Montana residents lived below the federally defined poverty level compared to 14.6% nationally. However, a mean of 17.6% of young Montana residents under 18 yr lived in poverty, with highest percentages in more rural and reservation regions. The poverty rate for Montana residents 65 yr and older was 8.3% (US Census Bureau 2018e; Givens et al. 2019), and 9.2% for the US residents over 65 (CRS 2019).

Crossing the Little Bighorn River in August
Photo courtesy of John Doyle

American Indians

Why it matters.—American Indians are among the most vulnerable groups to climate change (Ford 2012; Bennett et al. 2014; Gamble et al. 2016; Ebi 2018). As the Third National Climate Assessment's section on Indigenous Peoples explains (Bennett et al. 2014):

> *Native cultures are directly tied to Native places and homelands, and many indigenous peoples regard all people, plants, and animals that share our world as relatives rather than resources. Language, ceremonies, cultures, practices, and food sources evolved in concert with the inhabitants, human and non-human, of specific homelands.*

Hence, in addition to coping with long-standing economic, social, and political inequities, tribes are stressed by climate changes that threaten ways of life they have practiced for thousands of years. Native communities' cultural and spiritual reliance on local ecosystems, water sources, and subsistence foods contributes to an increased vulnerability during extreme climate events (Cozetto et al. 2013; Gamble et al. 2016). The US Global Change Research Program's 2016 report summarizes climate impacts to the health of Native peoples under the themes of loss of cultural identity, water insecurity, decreased food safety and security, and degraded infrastructure (Gamble et al. 2016).

What we know in Montana.—Interviews with Crow Tribal Elders reveal that climate change impacts to wild foods, water quality, and traditional spiritual practices are already being observed (Doyle et al. 2013; Doyle and Eggers 2017; also see sidebar next page). Crow Elders express a widespread sense of environmental-cultural-health loss, along with despair at their inability to address root causes of these local impacts of climate change (Martin et al. 2020). On the Flathead Indian Reservation, more than a quarter of low-income residents surveyed (both Native and non-Native) increase their food security by harvesting wild foods. They perceive that these wild foods are already adversely impacted by climate changes, such as increased wildfires, increased drought, and weather variability (Smith et al. 2019).

Communities nationwide face threats to water security from droughts, floods, and other extreme climate events. Those threats are uniquely serious for tribes as many aquatic species are culturally and nutritionally vital to their well-being (Donatuto et al. 2011; Cozetto et al. 2013; Doyle et al. 2013). As an example, for many Crow families, increased microbial contamination means that rivers have been lost as a source of trusted water for ceremonial drinking and bathing (Doyle et al. 2013). Addressing degraded water and wastewater infrastructure is always challenging (Ferguson et al. 2011; Ojima et al. 2013; Redsteer et al. 2011), but the maze of jurisdictional and legal complexities—for example, the lack of authority to create water districts as described by the Apsaalooke Water and Wastewater Authority (Crow Reservation, Montana)—makes it more difficult for tribes (Doyle et al. 2018). In response, several Montana tribes are proactively assessing current and projected climate change impacts, developing resiliency plans, and implementing adaptation strategies (see sidebar in Section 5).

Changes Rippling Through Our Waters and Our Lives

C. Martin, J. Doyle, J. LaFrance, M.J. Lefthand, S.L. Young, E. Three Irons, and M. Eggers

The Crow Reservation is located in south central Montana, in the heart of our traditional homelands. As we live in a wide-open landscape and are tied to a different time than the fast pace of western life, our understanding of nature and observations of the seasons comes from the eye instead of a calendar or watch.

Climate change is already impacting our lands, our waters, our health and well-being. To better understand these impacts, we interviewed 26 Crow Elders about their perceptions of changes in local weather patterns and ecosystems throughout their lifetime, and how they are being affected. We conducted a thematic analysis of the interviews.

Interviewees' observations paralleled and elaborated on instrumental climate data: we are experiencing far less snowfall and milder winters, increased spring flooding, hotter summers, and more severe wildfire seasons. Additionally, many Elders commented on extreme, unusual, and unpredictable weather events, compared to earlier times when the seasons were consistent year after year.

Interviews notably identified declines in wild foods, which have not been recorded by scientists; wild game, fish, berries, and medicinal plants are being detrimentally affected in diverse ways (Martin 2020). Our homes and infrastructure have been hit time after time by high floods; we have few resources to repair the damage, so this is taking a toll on families, including on our health and well-being.

Bill Lincoln picking chokecherries on the Crow Reservation. Photo courtesy of John Doyle.

In addition to ecosystem resource losses and changes, we are devastated by the loss of coal jobs and coal tax revenue. More than 1200 coal mining and tax-funded jobs have been lost in the past couple years, in a community of about 8000 people. Without that income and lacking any other tax structure, we cannot adequately fund our government nor maintain our infrastructure.

Through the research we have been conducting on climate change and with our Tribal Elders, we are able to better understand what has been happening and anticipate what is to come. Although we are enduring unprecedented environmental change and extreme economic conditions, we are looking for solutions we can implement ourselves.

(For more detail, see Martin et al. [2020])

People lacking adequate health insurance

Why it matters.—Access to health insurance is directly related to a person's ability to respond to health emergencies. People with chronic health conditions but no health insurance are less likely to be able to manage their illnesses, putting them at greater risk should an emergency arise (Sommers et al. 2017). Those without health insurance, for example, suffer more consequences from air pollution compared to those with health insurance (Cooley et al. 2012). Likewise, other climate-related concerns such as water-borne disease will be more difficult to treat for those without health insurance.

What we know in Montana.—In 2017, 91.5% of Montana residents had either private or public health insurance, close to the national average of 93.1% (Table 4-4). However, the proportion of Montana residents with health insurance varies both by age and between rural and urban places. Almost all residents old enough to qualify for Medicare have health insurance. The percent of residents with health insurance is higher in urban counties than in rural counties. However, private insurance prices vary, and coverage may be costly with plans paying for 60-90% of medical expenses. This variability may leave some individuals and families with substantial out-of-pocket costs depending on their plan (HealthCareInsider 2020).

Table 4-4. Percentage of Montana residents with health insurance in 2017 (US Census Bureau undated)

Residency	Age Group			
	18 yr and under	*19-64 yr*	*65 yr and older*	*All*
All counties	94.2%	88.1%	99.4%	91.5%
Six most populous counties	96.1%	90.0%	99.4%	92.9%
All other counties	91.5%	84.9%	99.4%	89.5%

People with mental health issues

Why it matters.—People living with and learning about the consequences of climate change can experience stress, anxiety, and deep feelings of loss (Clayton et al. 2017). A 2019 Yale report found that 62% of Americans were "somewhat worried" and 23% were "very worried" about global warming (Leiserowitz et al. 2019). The Yale Program on Climate Change Communications (YPCCC 2019) estimates that 60% of Montanans worry about climate change.

Chronic conditions like depression and anxiety can be worsened by climate change, with consequences ranging from minimal stress to clinical conditions such as post-traumatic stress disorder and suicidal thoughts (USGCRP 2016). Feelings of hopelessness, helplessness, fatalism, apathy, and denial associated with environmental change have become so prevalent as to have earned their own descriptive terms, including *climate grief*, *eco-anxiety*, and *solastalgia* (Albrecht et al. 2007; Clayton et al. 2017; NBC News 2018; Time 2019).

Such mental strife can be heightened further for those whose economic livelihoods or traditional ways are closely tied to the land or environment, as well as those who hunt, fish, and gather wild foods. That group includes people working in natural resource-related industries, for example agriculture, forestry, and tourism, as well as coal, oil, or natural gas extraction (Clayton et al. 2017; also see sidebars—below and Section 3 sidebar titled *Climate Change and Mental Well-being—Perspectives from Montana Farmers and Ranchers*).

Mental Health Impacts on Resource-dependent Communities

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Decarbonizing at national and global scales has profound social, economic, and, by extension, health implications for local places that have developed as key nodes in the current energy system. In Montana, these sites include the communities in which energy extraction, processing, and/or distribution constitute the area's primary source of public revenue and private income.

Photo: Adrian Swancar / Upsplash

Resource-dependent communities are at risk of acute mental-health concerns in the event of mass layoffs associated with plant closures and other events in the contraction of energy economies. Research shows that negative psychological outcomes associated with such events derive primarily through economic hardship (Broman et al. 1990), and secondarily through the loss of occupational identity (Carley et al. 2018). Given that Montana's remote and rural areas are chronically underserved across a variety of critical healthcare services, available resources may prove inadequate in the face of abrupt economic transitions.

Where local government revenue depends heavily on fossil fuel extraction—as in the case of several American Indian reservations as well as some rural communities—the very services necessary to build community resilience in the face of economic shocks are at risk (Besser 2013; Haggerty et al. 2018). In the very worst cases in recent history in the US, abandonment of resource-dependent regions can create a host of chronic health issues associated with the compounding effects of persistent rural poverty, environmental contamination, and the legacy of hazardous work conditions (Hendryx 2009).

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What we know in Montana.—From 2011–2015, Montana's suicide rate, at 240 suicides each year, was nearly twice the US average (MTDPHHS 2019b). Alarmingly, the suicide rate in Montana rose 38 percent from 1999 to 2016. In 2017, Montana had the highest suicide rate in the US, but in 2018 the state dropped to the fourth highest (AAS 2020a,b). Montana regularly registers one of the highest suicide rates in the country, with an age-adjusted suicide rate of 25.9 per 100,000 people in 2016 compared to almost half that rate for the US. Males are 3.5 times more likely to die by suicide than females. Others at risk are veterans, American Indians, and residents of rural counties.

Substance use is a risk factor for suicide, with toxicology screenings revealing that over 40% of suicides involve alcohol use.

Attempted suicide in Montana is also alarming. One in 10 of all Montana high school students attempted suicide in 2019. For American Indian high school students alone, 1.5 in 10 attempted suicide in 2019 (MOPI 2019). Governor Bullock of Montana, reacting at least in part to these grave realities, invested $80 million over five years to address mental health services (MTDPHHS 2020b).

Along with the mental health issues shared by many across Montana, tribal members may suffer a unique type of personal anguish, one tied to tribal history, which changes brought by climate change can exacerbate. In a study conducted primarily by Crow tribal members, 26 Tribal Elders were interviewed about the impacts of climate change on local ecosystems and community health. Nearly all participants described a sense of loss in relation to the impacts from changing climate and environmental conditions on their land. They write (Martin et al. 2020):

> *For us, and perhaps for many other indigenous people, the changes aren't simply unfamiliar alterations in our home environment causing discomfort—they are direct threats to our ability to carry on the traditional practices which define us as a people. It is history repeating itself in an even more insidious way. We lost the majority of our lands through treaties and Congressional acts. We lost generations of raising and educating our own children through federal boarding schools starting in the 1880s. We have since lost the upper Bighorn River to Yellowtail Dam, agricultural and recreational lands to non-tribal members, much of our traditional diet—the list goes on. Now, even though we live in our traditional territory, the changes in climate are changing our homelands all around us, and this time there is no single enemy to fight.*

What Conclusions Can We Draw?

As described in Section 2, Montana will experience more 90°F+ (32°C+) heat days, increased wildfires, more spring flooding, and less water available with more drought during the late growing season (Whitlock et al. 2017). Given this knowledge, communities need to take action now to protect the health of Montana residents most vulnerable to impacts of climate change. Climate change will amplify vulnerability, exacerbating pre-existing health disparities. The next section provides recommendations for how Montana communities (including city, state, and tribal governments), healthcare practitioners and facilities, and individual community members can respond today to address the impacts of climate change on our most vulnerable populations.

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Fort Peck Lake
Photo courtesy of Rick and Susie Graetz

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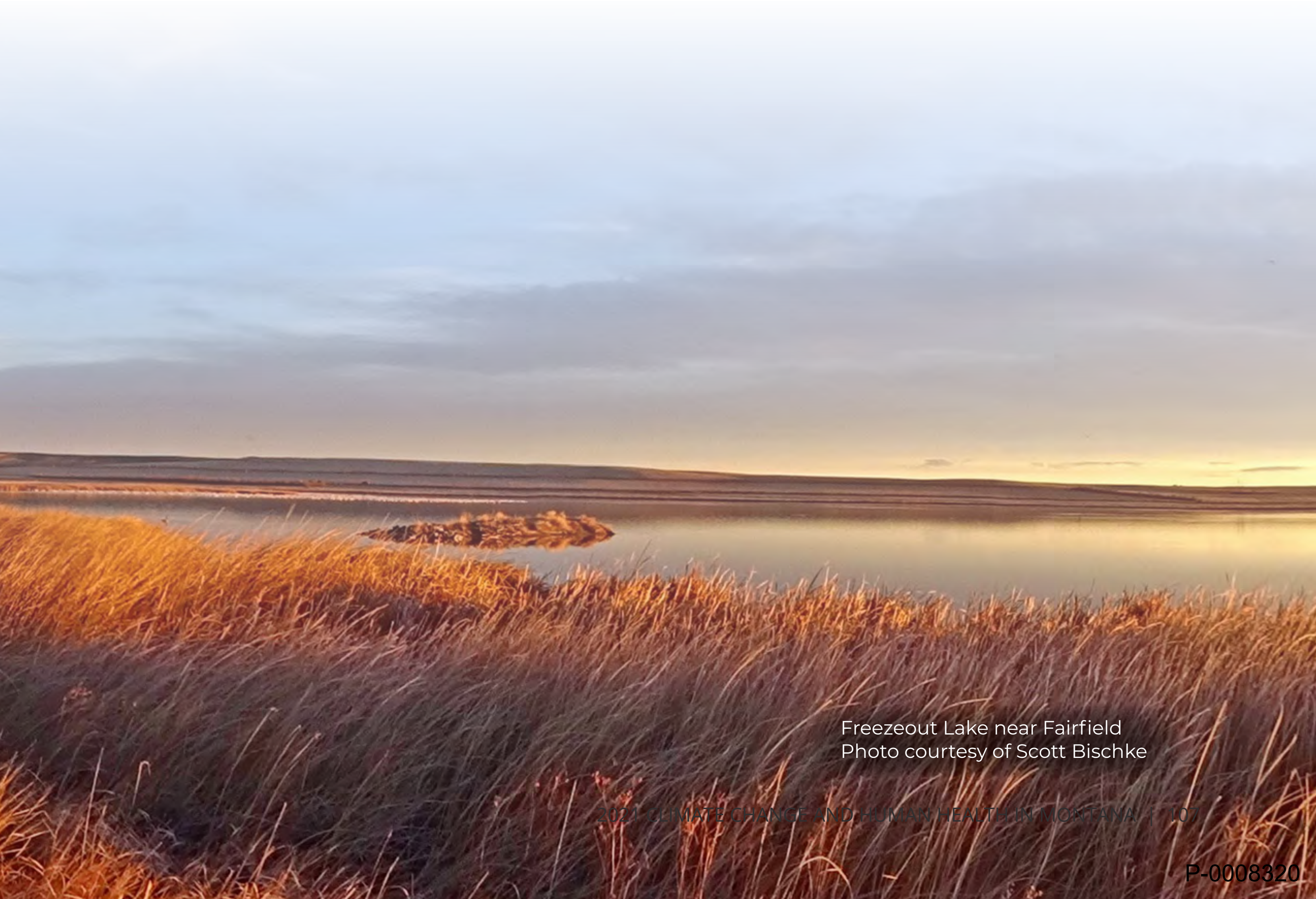


Freezeout Lake near Fairfield
Photo courtesy of Scott Bischke

Learning about water on the Crow Reservation
Photo courtesy of Adrian Sanchez-Gonzalez, Montana State University

05. CLIMATE HEALTH ACTIONS

Margaret Eggers, Alexandra Adams, and Susan Higgins, with contributing authors Robert Byron, Amy Cilimburg, Angelina Gonzalez-Aller, Paul Lachapelle, Miranda Margetts, Jennifer Robohm, and Nick Silverman

Planning, preparation, and collaboration across all sectors, both at the state and community levels, are critical to reducing the broad impacts of climate change on public health. This section describes planning guides, action strategies, and information sources[1] for 1) communities, 2) healthcare practitioners and institutions, and 3) individuals, organized for each sector by the key health issues described in Section 3. These tools help communities and individuals access local climate and health data, assess the greatest threats to local well-being, prioritize goals and objectives, and prepare accordingly.

1 The authors recognize that the recommendations herein are not exhaustive, and that some of the actions and/or resources described are not available to every person. Similarly, some of the actions we describe may require local and/or statewide policy change, which is beyond the scope of this document, but is detailed in the recently released Governor's Climate Solutions Plan (State of Montana 2020).

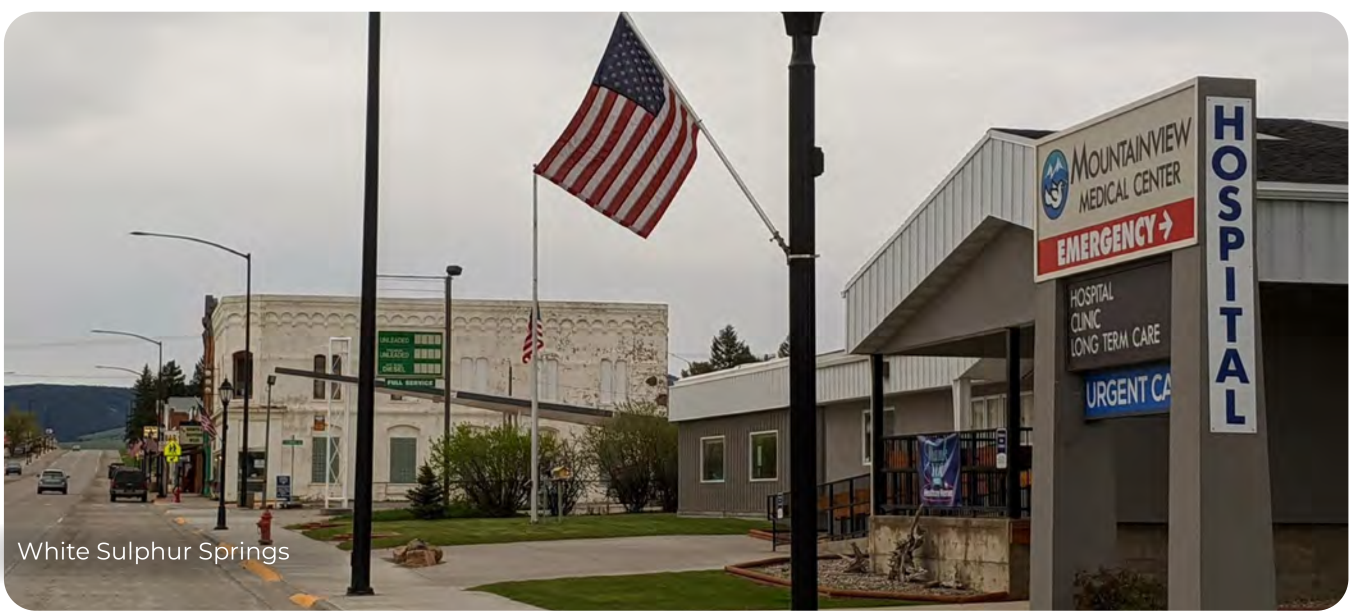
Planning, preparation, and collaboration across all sectors, both at the state and community levels, are critical to reducing the broad impacts of climate change on public health.

While the risks and outcomes of climate change may seem beyond anyone's direct control, many manageable actions exist for protecting our communities, our families, and ourselves. The goal of this section is to provide information that helps Montanans maintain optimal health in the face of climate change.

Tackling problems of climate-induced environmental issues—e.g., warmer temperatures, increased forest disease and fire, or changing water quality and availability—often involves discussions of *mitigation* and *adaptation*. Mitigation is the work to reduce or stabilize the climate changes already taking place. Adaptation involves efforts to adjust to life in a changing climate. Mitigation and adaptation efforts also apply to tackling climate-induced human health issues. Citizen involvement in climate change adaptation and mitigation planning and action is already underway in some Montana counties, and several case studies are provided below.

For some, tackling climate change may seem like too great a challenge, but even small efforts to improve health, well-being, and resilience make a difference for climate change mitigation and adaptation. It is time to work on building relationships, developing collaborations, and understanding who around you are most vulnerable to climate change, and who are best positioned to provide support.

Mitigation is the work to reduce or stabilize the climate changes already taking place. Adaptation involves efforts to adjust to life in a changing climate.



White Sulphur Springs

P-0008323

Community Actions: Teaming Up for Success

A fall 2019 statewide survey of 222 Montana public-health and environmental-health professionals asked their concern regarding climate change. Almost three-fourths of respondents said that health departments should be preparing to deal with the public and environmental health effects of climate change, although less than 30% of the departments were currently doing so (Byron 2019; see sidebar *Montanans and Climate Concerns* in Section 2). Almost all respondents indicated that multiple entities should work together in this effort.

Building resilience to climate change impacts on public health requires collaboration across all sectors: state, tribal, county, and municipal governments. It includes elected leadership; emergency management teams; public healthcare systems and practitioners; and local organizations, businesses, and community members (UNDRR and WHO 2020). A wealth of online materials is available to help build our resilience to climate change impacts. Developed by federal agencies and professional and non-profit organizations, these materials provide many examples from successful communities. In addition, many useful tools can be found in the Institute on Ecosystems' Climate Smart Montana Program[2] and in the subsections that follow. Our list of top actions for communities is presented below.

Top Actions for Communities

Join or create a broad community coalition, optimally including your local health department, and start working together across sectors to create and implement a community resilience plan that includes climate change mitigation and adaptation.

- Identify human, organizational, financial, and other resources for conducting your work.
- Assess local climate change concerns such as extreme heat, poor air quality, drought/floods, food and water insecurity, vector borne diseases, and more.
- Gather the local/county epidemiological (health) and climate data needed for your work.
- Recognize that public health and economic well-being are inseparable—planning for climate change impacts will protect both.
- Assure that more vulnerable groups, including those with mental health, concerns, are incorporated into all planning efforts.

2 http://www.msucommunitydevelopment.org/ClimateSmartMontana.html

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Steps to create a community climate action plan

The Centers for Disease Control's Climate and Health's *Building Resilience Against Climate Effects* (BRACE) plan provides an excellent guide for creating a community climate action plan. This plan describes a five-step program to assist health officials and communities in preparing for health effects resulting from, or worsened by, climate change (Figure 5-1) (CDC 2019).

Figure 5-1. The CDC's Climate-Ready States and Cities Initiative (see https://www.cdc.gov/climateandhealth/climate_ready.htm) competitively funds states and large cities to implement the five-step BRACE framework shown here and described in the text.

Initiating the BRACE (or other) planning framework requires broad community engagement and one or more government agencies, citizen groups, or organizations committed to leading the effort. Join with others in your community who are already addressing or are beginning to address the impacts of climate change on local health. As a team, carefully consider the support of your citizens and leaders. Assess your community's capacity to develop a health and climate action plan. Is the CDC's BRACE framework, or some other process, best suited to address your community's capacity and needs?

It is possible, and perhaps likely, that a community's first step will be to implement a well-thought-out engagement and education campaign or initiate some actions that will excite and galvanize a multi-sector coalition. As the National League of Cities advises in its multi-faceted guide to local actions to address climate change, "Start with people, stay with people: build an inclusive, broad public engagement program with local partners to grow public support and political will for climate action" (NLCI undated). Including the public in initial planning leads to more public participation in plan implementation, and better understanding of community vulnerabilities (van Aalst et. al 2008; IPCC 2014; Di Matteo et al 2018).

> *As the National League of Cities advises…, "Start with people, stay with people: build an inclusive, broad public engagement program with local partners to grow public support and political will for climate action."*

Implementing a BRACE plan in Montana ideally requires access to county-level climate and air quality data, updated climate projections, and current and projected disease burden related to climate, as well as a better understanding of climate-vulnerable populations. With these data and the BRACE framework, state, tribal, and local leaders can collaborate across sectors more effectively to prepare for, manage, and reduce the health and economic impacts of climate changes (UNDDR 2020; UNDDR and WHO 2020). Data availability and access challenges—some of which are detailed below—exist in every community but should not impede planning and taking action. Data gaps and missing analyses that are consistently identified can become work mandates for state agencies and academic institutions.

The next step in creating a climate action plan is to assess sensitivity, exposure, and risk for your community. This assessment will form the basis for your community's plan, and outline how it will address human health issues that result from climate change. Include local leaders, health professionals, a diverse stakeholder group representing your community, and people experienced in creating climate change plans. Explore the following questions:

- What are the major climate- and health-related risks facing your community now and expected in the coming decades? The impacts of climate change on health may also vary widely among community members (Islam and Winkel 2017; National Geographic 2019). Develop a climate action plan that is equitable, feasible, and tailored to community demographics (e.g., age and income distributions), exposures (e.g., climate components like increasing temperatures), and risks (e.g., the likelihood that exposure events like major wildfires or flooding will occur).
- Carefully consider the needs of each community's unique vulnerable populations, as described in Section 4. Who are the most vulnerable? Why? What can be done to increase their resilience?
- Are any stakeholder groups underrepresented on your team? If so, how can you engage them?

- Beyond applying to the CDC's Climate-Ready States and Cities Initiative[3] for funding, what financial resources are available for this process and for outside facilitation to help guide discussions and actions?
- What kind of community outreach will your team need to implement before, during, and after development of your climate action plan?
- Could first-step targeted activities be initiated in your community *before* conducting a full climate and health assessment plan? If so, what steps? Getting started is one way to build support for further action, plus it can help develop climate and health literacy.

With persistence and patience, capable facilitation, and access to health- and climate-science expertise, your community can assess its health vulnerabilities to climate change, identify the most suitable and highest priority interventions, and then create and continuously improve your community climate action plan. That plan will describe mitigation or adaptation actions that fit your local conditions. For example, the Blackfeet Tribe, the Confederated Salish and Kootenai Tribes, and the community of Missoula have actively responded to climate-related changes faced by their people and landscapes (see sidebars, coming pages).

3 https://www.cdc.gov/climateandhealth/climate_ready.htm

Missoula, in fine air
Photo courtesy of Philip Higuera

Act on climate change not only for public health, but also economic well-being

As we are learning during the current COVID-19 pandemic, public health and economic well-being are inseparable. The same concept applies to climate-driven increases in wildfire, flood, and drought, which not only directly affect our health and our economy, but are also starting to influence state and local government credit ratings. Broad collaboration and planning will reduce the intertwined health and economic impacts of climate change.

Climate surprises—such as heat waves, drought, flooding, or other disasters—can trigger an exodus of residents, resulting in declining tax revenue, or bring a flood of new immigrants to the state from regions that are experiencing worse conditions. Damage to municipal infrastructure from severe storms, floods, wildfires, or other disasters can incur major expenses for communities. For instance, a major wildfire may result in runoff water of such poor quality that a community's current water plant can no longer adequately treat it. Such occurrences add to the risks that rating agencies assess. As a result, they might lower a government's credit rating and ultimately increase its cost of borrowing money via bonds (Fitch Ratings 2018; Pew 2019; DeFries et al. 2019; Janney Investment Strategy Group 2019; New York Times 2019).

Moody's Analytics: "Cities and counties with plans for reducing their exposure to climate risks... could see their credit ratings improve as a result, or at least not deteriorate."

To better assess climate change risks, the rating agency Moody's recently bought a controlling share of a company that specializes in climate change risk assessment. According to the New York Times, several major rating agencies, including S&P Global and Moody's (Moody's Investor Services 2017), have issued reports "...warning state and local governments that their exposure to climate risk could affect their credit rating. Moody's has said that cities and counties with plans for reducing their exposure to climate risks, by updating their infrastructure for example, could see their ratings improve as a result, or at least not deteriorate" (New York Times 2019).

Communities need climate and health data for planning and action

One challenge facing Montana's communities is that the climate and epidemiologic data necessary for planning are not currently collected for and shared with all counties in Montana. The coverage of NOAA/National Weather Service (NWS) meteorological stations is uneven in Montana, such that some parts of the state have limited direct information (NOAA-NCEIa undated). Additionally, only a small number of the meteorological stations have operated long enough to characterize long-term trends in climate variables (NOAA-NCEIb undated). Several programs seek to fill the gap. First, NOAA/NWS improves the coverage of recording sites by using participating cooperative observer information (NWSb undated) to provide a network of minimum/maximum temperatures, precipitation, snowfall, and snow depth. However, parts of Montana have relatively few of these sites and the time span of records is variable. Second, the Montana Climate Office is a partner in NOAA's Mesonet program, set up to deploy automated weather and environmental monitoring stations at 74 sites across the state, and thus increase the spatial coverage of weather data and improve services (MCO 2020).

Stories of Climate Change, Health, and Indigenous Ways

Blackfeet Nation
Gerald Wagner and Termaine Edmo, Blackfeet Environmental Office

In 2018, Blackfeet Nation released a climate adaptation plan that works to protect our diverse ecosystems from the impacts of a rapidly changing climate. Underlying this plan is the Blackfeet understanding that people and nature are one, and that people can only be healthy if we ensure the health of the environment we depend on. Blackfeet Nation borders Glacier National Park to the east and Canada to the north. The Blackfeet Nation is not only our home, it's our place of origin. From the soil we walk on, to the water and land we protect, the Amskapii Pikunii people have worked hard to preserve our language, customs, traditions, and practices throughout the 10,000 years we have called this region home. We understand deeply that what happens to the Earth happens to us, and that we protect ourselves by honoring our traditional principles and values of stewardship.

Climate change threatens all we hold sacred, and the impacts of a changing climate are visible everywhere. For example, more extreme weather events are starting to disrupt power and water supplies, communication systems, and transportation, making it difficult to maintain critical services. During winter storm emergencies, people have become stranded in their homes with insufficient food or medicine, jeopardizing their health and well-being. Similarly, more intense flooding can negatively impact services.

In 2019 alone, we experienced several winter storm emergencies and a flood disaster. During such events our communities demonstrate exceptional resilience, compassion, and creativity. Neighbors help each other free vehicles from mud or snow, we drive miles out of our way to check on Elders, and we continue to work on ways to be better prepared for the next emergency.

Our climate adaptation plan[a] works to protect the health and well-being of our people. We want our people to understand the connection between climate change and health, so our adaptation plan is the foundation from which we *iikakimaat* (try hard) to care for the environment and thereby our people, and our ways of life.



Photos, courtesy of Jacob LeVitus, from September 29 and 30, 2019.

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[a] blackfeetclimatechange.com

P-0008329

Confederated Salish and Kootenai Tribes (CSKT) of the Flathead Indian Reservation

Mike Durglo, Jr., Environmental Director, CSKT Natural Resources

The Flathead Indian Reservation is home to approximately 28,000 people, of which about 9000 identify as Native American. CSKT has approximately 6800 enrolled tribal members, 4000 of whom live on the reservation. On the Flathead Indian Reservation, climate change threatens our treasured landscapes, our people, and the traditional customs and practices that sustain our way of life. Climate change is the result of the worldwide establishment of a way of life that is fundamentally at odds with the traditional ways of tribal people here. This establishment, and its disregard for the environment, pose serious risks to the S'elish, Qlispe, and Ktunaxa peoples[b] that call the reservation home.

Climate change is already impacting the health and well-being of our people. Wildfires have caused hazardous air quality conditions, and extreme weather events create dangerous conditions and limit access to healthcare and other critical services. The climate crisis and the ecological changes that it brings threaten traditional customs, including our access to first foods through hunting, fishing, and gathering, and our ability to conduct ceremonies and spiritual practices. Many foods and medicinal plants grow on the reservation and aboriginal lands. As a result, climate change threatens our cultural survival, which directly affects both our physical and mental health. To address these risks, CSKT released our first Climate Change Strategic Plan[c] in 2013 and is taking deliberate actions to address climate impacts wherever possible. Our tribal values affirm that everything is connected and that human beings have a responsibility to care for the things that were placed here, before the human beings.

Graphic design by Ron Oden of Ron Oden Designs and the Native Waters on Arid Lands Project

As with all things, the CSKT follow the circle pathway worldview. Our Elders teach that all things are connected and that any impact or action on one resource will impact all. The diagram shown illustrates a tribal way of thinking as also expressed during our recent climate planning session. Climate-related disturbances including flood, drought, wind events, and wildfires impact our tribal resources, and will therefore impact our culture, traditions, and our foods and spirituality—without which our lifeways cannot survive. Impacts are also expected to be place-based. Impacts in the high-elevation region will be different from impacts to resources in the dry-grass and sage-steppe ecoregions of the reservation. The climate crisis requires immediate and sustained action to protect human health and well-being. For the people of CSKT, this requires protecting the ways of life that define us as a people.

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[b] The Tribes which in English are called the Salish, Pend d'Oreille, and Kootenai.

[c] http://csktclimate.org/

** We understand deeply that what happens to the Earth happens to us, and that we protect ourselves by honoring our traditional principles and values of stewardship.*

** Climate change is the result of the worldwide establishment of a way of life that is fundamentally at odds with the traditional ways of tribal people here. This establishment, and its disregard for the environment, poses serious risks ....*

Further, the Montana Climate Office is working with US Army Corp of Engineers and NOAA to establish and maintain upwards of 220 additional monitoring stations across the state over the next 5-7 yr.[4] The US Army Corp of Engineers and NOAA federal funding will support better soil moisture and snowpack monitoring for flood forecasts and drought assessment. However, little funding exists for updating and analyzing historical and recent climate trends, or local climate projections. Other funding will be necessary to add air-quality monitoring sensors to these stations, as presently there are only 20 air-quality monitoring stations managed by the Montana Department of Environmental Quality. Although the department posts current air quality conditions online, 20 stations provide only limited coverage and historical data are not provided.[5]

MCA provides climate projections for Montana, focused on the seven NOAA climate divisions in the state (Whitlock et al. 2017; Section 2). However, projections at the climate division level are too coarse to assess climate trends for particular counties or communities. Each division covers a large area and their boundaries are not defined by physical geography. Local experience suggests this may be particularly true for changes in precipitation patterns (Doyle et al. 2013; Martin et al. 2020). The spatial resolution of climate projections will improve in future Montana climate assessments, with a scale that will be even more useful for community-level planning.

Installing a weather station
Photo courtesy of John Doyle

4 Jencso K, Montana Climate Office, personal communication, 3 May 3 2020; unreferenced. Also see https://www.nwo.usace.army.mil/Media/News-Releases/Article/2369091/contracts-awarded-for-establishment-of-upper-missouri-basin-monitoring-network/.

5 https://svc.mt.gov/deq/todaysair/

County-level epidemiologic data are also required for the CDC's BRACE framework (CDC 2019), reviewed above. Statewide epidemiological data are collected by the Montana Department of Public Health and Human Services, but for a variety of reasons are not easily accessible at the county or commmunity level. We need shared, statewide monitoring of health-facility visits related to climate change, especially county-level data about visits related to smoke, heat, or home-mold exposure; vector- or water-borne illnesses; and mental health concerns.[6] In sum, data are a critical need for climate monitoring agencies and communities—particularly for state and county public health departments and their collaborators—to address the impacts of climate change on health. To meet that need the state of Montana, in collaboration with relevant federal agencies, should:

- increase the network of meteorological stations in the state to fill in geographic gaps;
- add to the network of air quality stations monitoring for particulate matter to fill in geographic gaps;
- increase funding to the Montana Climate Office for historical and current analysis of climate and human health trends and patterns at the state, county, and community scales;
- improve the spatial resolution of climate projections to provide county-level information; and
- create a shared, statewide monitoring process of health-facility visits related to climate change, with county-level data available to communities.

6 The authors recognize that privacy issues might exist if county-level data on rarer health conditions were released.

Medical lab work in Glasgow
Photo courtesy of Alexandra Adams

P-0008332

Strategies and actions for communities

The remainder of this section highlights some strategies your community will want to consider in planning and preparing for health-related impacts from climate change. How you prioritize these categories will depend on your review of the data and discussions across your multi-sector collaboration. Appendix B provides a tabularized list of resources for communities, including public and environmental health agencies and organizations, to develop climate change assessments and action plans.

> *Appendix B provides a tabularized list of resources for communities, including public and environmental health agencies and organizations, to develop climate change assessments and action plans.*

Heat

Two strategies communities can use to address heat-related impacts to health are to: 1) inform citizens about dangers of overheating in extreme temperatures; and 2) provide cool or cooler spaces both inside and outside. Examples include:

- Encourage employers to improve the workplace environment and policies to reduce heat exposure. During extremely hot weather employers should, for example, provide outdoor workers ready access to shade, drinking water, and restroom facilities, plus allow break time for workers to cool off.
- Inform those working, playing, or otherwise spending extended time outdoors about the importance of resting, hydrating, and seeking shade to avoid potentially life threatening, heat-related health issues.
- Designate (or create) a cooling facility for your community or workplace where people can go during a heat emergency. Such a facility might be an air-conditioned school or community center, or a deeply shaded park, perhaps near a community swimming pool, lake, or river.
- Ensure vulnerable populations (see Section 4) understand heat-related health issues and have a plan for staying cool. For example, develop programs to ensure access to cool community spaces. Likewise, ensure that those most vulnerable to extreme heat have window fans or air conditioners.
- Create incentives and programs to address the rising urban heat-island effect (USEPAd undated). Examples include substituting lighter colored materials in place of black asphalt and tar on roads and driveways, and encouraging more environmentally friendly building practices, including cool roofs, constructed with light colors and heat-reflecting materials.
- Create incentives, programs, and/or campaigns to plant and care for trees and other vegetation to create shade (USEPAe undated).

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Community Climate Action Planning for Health Resilience—Tips from Missoula

Amy Cilimburg, Executive Director, Climate Smart Missoula

More wildfire smoke combined with extreme heat is a challenge to physical and mental health—what can we possibly do? That was a question our newly formed non-profit, Climate Smart Missoula, asked a few years back as we recognized Missoulians were not prepared to "weather the changing weather." Via our Summer Smart program, we started working on a handful of initiatives, from planting shade trees to donating indoor high-efficiency particulate air (HEPA) filters to homebound seniors. Because we were already working with our City-County Health Department, in 2017, when hazardous smoke filled our valley, we were able to rapidly grow this program, providing HEPA filters—and thus clean indoor air—to those most at risk, from babies to people with asthma to the elderly.

This early effort helped us learn that although it may be difficult to address the intersection of health and climate change, it can be done. And there's more to do!

Our Summer Smart efforts gave us the confidence and motivation to broaden this work. We are now partnering with Missoula County and the City to craft and implement Missoula's first-ever resiliency plan: Climate Ready Missoula[a]. We first partnered with scientists to understand climate projections and then, given these, worked with hundreds of county residents to identify who and what is most at risk and what adaptation goals and strategies would best address these risks. We highly recommend the *Climate Ready Communities* guide[b] or other similar (and free) planning resources available to help any Montana community get started.

By bringing people together to understand how we can best look ahead to the challenges coming our way and "bounce forward," we can build social equity and strengthen a can-do attitude in the face of change. And community members will no doubt be healthier as a result of these efforts. A few things we've learned along the way:

- Partner with community health professionals—they are trusted community members.
- Initiate conversations about who is most at risk in your area.
- Consider starting with a focused initiative, then expand as capacity and buy-in grows.
- Connect with neighboring communities when and where you can.
- Take care of your own personal health and go forth armed with compassion and hope.

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[a] https://www.climatereadymissoula.org/

[b] https://climatereadycommunities.org/learn-more/about-guidebook/

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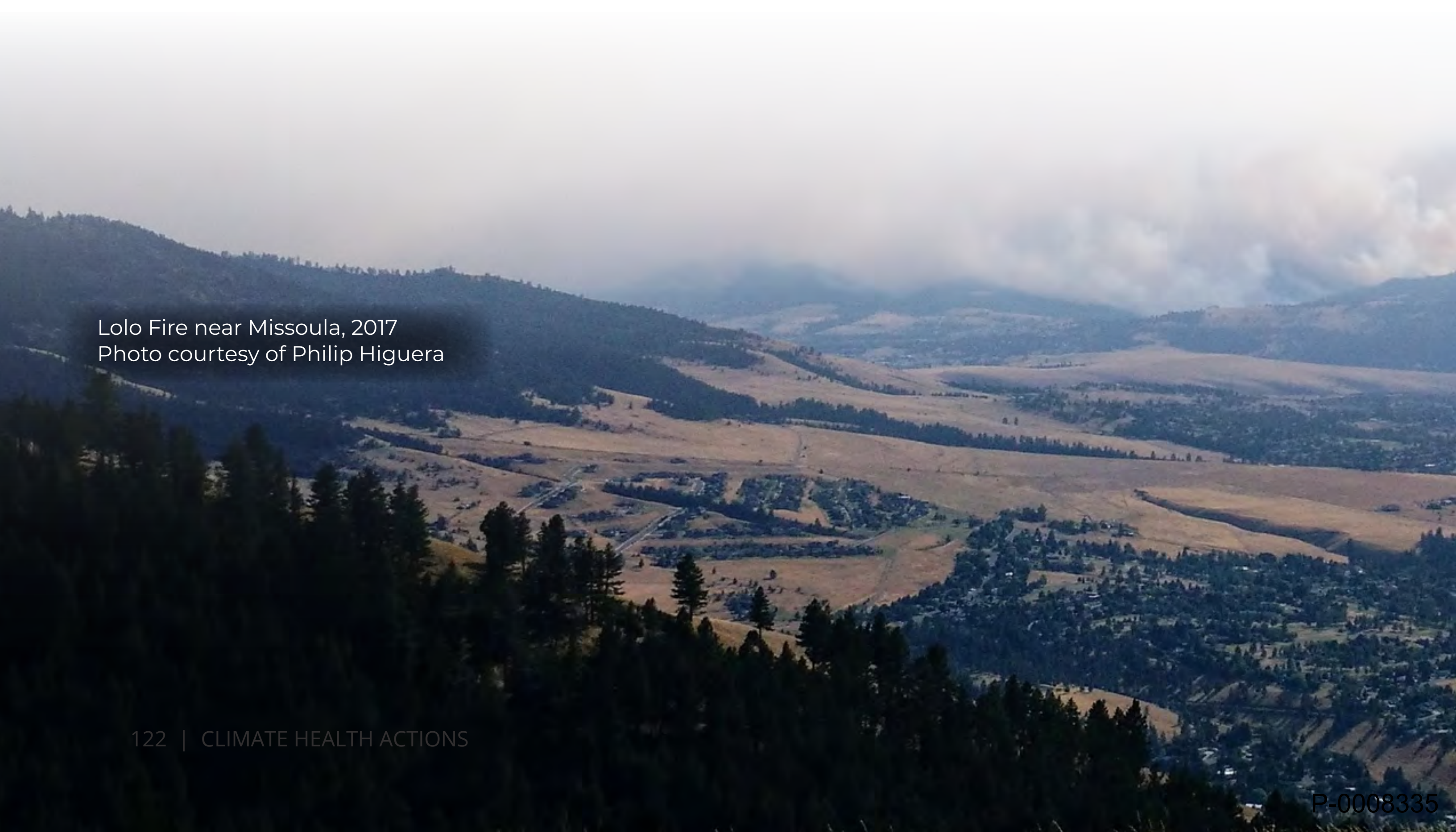
Air quality

While it might be possible to mitigate some of the health effects of wildfire and smoke through forest management practices, local communities do not generally carry out such efforts. However, every Montana community can focus on adaptation strategies for dealing with wildfire by increasing their community's fire resilience and, during wildfire season, improving air quality indoors and outside.

Actions your community can take include:

- Implement sustainable construction and encourage new housing in more sustainable and fire-safe areas (Zakaria 2020). Learn more about building fire resilience in your community through an excellent online resource titled "The science of firescapes: achieving fire-resilient communities."[7] The Federal Emergency Management Administration provides relevant checklists for homeowners (FEMAb undated) and communities (FEMAc undated).
- Educate homeowners about assessing fire risks to their homes, checking with their insurance company on the terms of their homeowner's wildfire coverage, and, if needed, reducing fuels around their home.
- Develop or enhance emergency response plans for forest and grassland wildfires. Create a community database of people who would need physical assistance to evacuate if required, and determine who will help those people in such emergencies.

7 https://www.fs.fed.us/rm/pubs_journals/2016/rmrs_2016_smith_a001.pdf



Lolo Fire near Missoula, 2017
Photo courtesy of Philip Higuera

- o Inform homeowners about options to create safe indoor air using HEPA portable air cleaners, MERV 13 air filters, or HVAC (heating, ventilation, and air conditioning) systems. See the Personal/Air Quality/Indoor Air subsection below and the Climate Smart Missoula guide to filtration systems.[8]
- o Consider funding air filtration in public spaces, for example in schools, daycare centers, senior centers, municipal buildings, evacuation shelters, houses of worship, and gyms and recreational facilities. Such work is underway in Montana: the team at Climate Smart Missoula donated portable HEPA air cleaners to those who were most vulnerable.
- o Encourage employers to reduce workers' exposure to smoke and particulate matter. For example, employers could halt or limit outdoor work during periods of poor air quality, schedule (if possible) employees to work at alternative sites having less hazardous air quality, or provide protective breathing masks appropriate to the conditions.
- o Encourage schools, organizations and employers to implement the federal Air Quality Flag Program.[9]
- o Work with the Montana Climate Office and Department of Environmental Quality to ensure a) your community has a weather station with added sensors for particulate matter ($PM_{2.5}$ and PM_{10}); and b) that the public has online access to both real-time and historical data.

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8 https://www.missoulaclimate.org/hepa-air-filtration.html

9 https://www.airnow.gov/air-quality-flag-program/

Flooding and water-related illness

Flooding can impact human health in a number of ways, including by increasing exposure to vector-borne diseases.

Actions to counteract or minimize exposure include:

- Protect wetlands and restrict new development in flood-prone areas in and adjacent to your community. Wetlands retain water, slowly filtering and releasing it to surface waters, thereby improving surface water quality. Wetlands also serve as recharge areas for groundwater. Hence, wetlands protection and open space planning not only conserve habitat and local amenities, they also help protect water quality and quantity. For these reasons, identify and protect wetlands and other such groundwater recharge areas from development. If impermeable parking lots are built, design adjacent landscaping to capture and filter runoff. Note that if wetlands are destroyed by development, Montana law requires that alternate wetlands be created nearby.[10]
- One major way floods can impact health is by contaminating lakes and ponds with nutrient and sediment runoff. Excessive nutrient enrichment, termed *eutrophication*, can result in deaths of fish and other aquatic organisms from depleted oxygen levels (National Ocean Service, NOAA undated), and trigger hazardous algal blooms (MTDPHHS 2019). During hazardous algal blooms, algae release toxins—poisonous

10 https://www.blr.com/Environmental/Water/Wetlands-in-Montana

Horses in a flooded pasture
Photo courtesy of Larry Mayer, Billings Gazette

to humans and other animals—into the water (see Section 3, Water-Related Illnesses subsection). Best management practices such as creating vegetative buffers for water bodies and limiting excessive use of fertilizers are effective mitigation measures (USEPA 2020).

- o Assess water and wastewater infrastructure needs and vulnerabilities to flooding, drought, and sediment runoff following wildfire. Does your infrastructure need upgrading to handle such events? Assure that an emergency response plan is in place in the event of an extreme weather event. The Montana Department of Environmental Quality provides a useful two-page flier[11] that includes guidelines on training, development of local emergency planning committees, core elements of an Emergency Response Plan, and compliance with the National Incident Management System.

- o Ensure that emergency service providers have appropriate training, adequate supplies, and tested plans and systems ready to help those in need during flooding (and other emergency) events. Three critical items to prepare in advance are methods and logistics a) for emergency communications and outreach; b) for evacuation, including strategies, routes, and safety zones; and c) for accessing medical care. The Montana Primary Care Association[12] and two Montana Department of Public Health and Human Services programs—Ready and Safe[13] and EMS and Trauma Systems[14]—are good resources to consult.

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11 https://deq.mt.gov/Portals/112/Water/PWSUB/Documents/docs/EmergencyResponseFactSheet.pdf

12 https://www.mtpca.org/programs-and-services/emergency-preparedness/

13 http://readyandsafe.mt.gov

14 https://dphhs.mt.gov/publichealth/emsts

Flood near Crow Agengy, 2011
Photo courtesy of Larry Mayer, Billings Gazette

Food security

Drought and extreme weather events impact local food security (see related sidebar in Section 3), for example, when hail damages crops. But while some Montanans source their food close to home, most rely heavily on food produced long distances away and trucked to grocery stores. Climate change in other parts of the world can impact *our* food security. Crop destruction or failure and transportation interruption—potential outcomes from climate "surprises" (see Section 2) or pandemics—may result in pricing increases or interruptions to Montana's food supply. A vibrant local food system can build resilience in the face of such challenges, as well as support local economies (State of Montana 2020).

A few examples of community actions that can help protect food security in the face of climate change are:

- Incorporate the complexities of food security into community climate action plans. Identify those who most rely on food from outside sources, with particular attention to vulnerable people.
- Develop forums to discuss how much and what kinds of foods can be stored for emergencies. Information on types and amounts of foods, as well as sanitation, cooking without power, and more can be found in the Federal Emergency Management Act[15] and Ready.gov[16].
- Encourage personal, small-scale agriculture, local farmers' markets, and farm-share programs to support and diversify local food supply and empower individuals with the knowledge and skills to grow their own food.
- Tap resources offered by County Extension and Natural Resources Conservation Service offices to understand sustainable practices, irrigation efficiencies, and integrated pest management.
- Enhance and incentivize more effective, multi-stakeholder approaches to drought response planning through local watershed groups and public works departments.

> *Climate change in other parts of the world can impact our food security. .... [Thus] encourage personal, small-scale agriculture, local farmers' markets, and farm-share programs to support and diversify local food supply and empower individuals with the knowledge and skills to grow their own food.*

15 https://www.fema.gov/pdf/library/f&web.pdf

16 https://www.ready.gov/food

Vector-borne and zoonotic diseases

Paying attention to outbreaks of vector-borne, zoonotic, and other infectious diseases belongs on a community's planning radar. Climate change is a key contributor to the emergence of these diseases (see Section 3), and warming temperatures promote mosquito, tick, and other arthropod reproduction and range extension. Having good drainage near homes and mosquito control programs (e.g., municipalities that spray for mosquitoes) are two ways to reduce vectors at the community level. Community education on vector-borne diseases is essential (see Actions for Individuals subsection below). Medical practitioners and those involved in public health should stay current on issues of vector-borne disease epidemiology and symptoms, as provided by the Centers for Disease Control[17], the US Department of Agriculture Animal and Plant Health Inspection Service[18], and Montana's Department of Public Health and Human Services[19].

Mental health

Extreme weather events, prolonged heat and smoke, and environmental and societal change all affect mental health, including increasing feelings of disconnectedness and despair. Build a plan for community well-being. Actions include:

- Plan for increased mental health impacts of climate change by working with local hospitals, clinics, health departments, schools, and faith and service organizations to build mental health services that connect across jurisdictions in your county and community.

> *Extreme weather events, prolonged heat and smoke, and environmental and societal change all affect mental health, including increasing feelings of disconnectedness and despair.*

- Inform healthcare providers and the public about the mental health impacts related to climate-induced extreme weather events, poor air quality, rising heat, flooding, drought, and more. Discuss and plan for the potential community disruption (e.g., to healthcare access and food and water availability) that can be caused by extreme events, and how that disruption can impact the mental health of individuals and communities.

- Build in-school capacity to address mental health issues in youth related to climate change. Acknowledge the anxiety some students feel around mounting climate change impacts (Burke et al. 2018), by opening discussion among teachers, students, parents, and friends. Consider also setting up mentoring programs with community members like the Child Advancement Project established by Thrive.[20]

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17 https://www.cdc.gov/nceh/information/state_factsheets/montana.htm

18 https://www.aphis.usda.gov/aphis/home/

19 https://dphhs.mt.gov/HealthInThe406/HealthInThe406Archive/CommunicableDisease

20 https://allthrive.org/programs/child-advancement-project/

Top Actions for Practitioners

- Get informed about the effects of climate change on health, including mental health, so you can recognize concerns and treat your patients accordingly. Be especially vigilant during climate-related extreme-events, including droughts, floods, wildfires, and other disasters.
- Educate your patients about the effects of climate change on health.
- Provide educational materials about the effects of climate change on physical and mental health in your clinic and on your organizations websites.
- Become involved with professional or public organizations advocating for climate action based on health impacts (Table 5-1).
- Provide primary care, behavioral health, and crisis treatments that ameliorate the physical and mental health impacts of climate change (Anderson et al. 2017). The resources provided in Community Actions subsection above include checklists for health-related impacts, such as those from mold, overheating, wildfire smoke, vector-borne disease, lack of nourishing foods, and the mental health distresses from major storm and other climate-induced weather events.
- Consider providing patient-specific information related to climate change and ways to protect yourself, both in your clinic and on your organization's websites.
- Be an advocate in your community providing trusted guidance and information. Become involved with professional or public organizations advocating for climate action based on health impacts (Table 5-1).

Strategies and Actions for Healthcare Practitioners and Institutions

Medical practitioners, clinics, and hospitals have critical roles to play in preparing for and coping with health issues resulting from climate change. All in the medical field must become fluent in the language of climate change and its health impacts, and knowledgeable of the treatment methods they will be required to apply—be those currently used methods or new skills they can obtain.

This subsection describes strategies and actions applicable to individual practitioners and healthcare facilities. We also recognize the many online resources on the intersection of human health and climate change available for both groups. Table 5-1 provides a number of these resources, with an emphasis on information for Montana providers.

Practitioners

Clinicians—primary care, subspecialty, or mental health professionals—are generally trusted by their patients. Thus, healthcare practitioners trained to detect potential health impacts of climate change can not only assess and treat those health impacts, they can also inform their patients. Groups like the American College of Physicians, American Academy of Pediatrics, and Climate Psychiatry Alliance provide tools and guidelines for integrating climate- and health-related questions and discussions into routine patient visits (Table 5-1). Providers have many opportunities for productive, climate-related actions when interacting with patients, the medical community, or the community-at-large, as enumerated here.

Dr. Lori Byron
Photo courtesy of Dr. Robert Byron

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Table 5-1. Information sources useful for healthcare providers, be they individuals or facilities.[a]

Source	Resource description	Website
American College of Physicians	Climate change toolkit for physicians, including ACP position paper, educational materials, greening the healthcare sector documents and other resources	https://www.acponline.org/advocacy/advocacy-in-action/climate-change-toolkit
American Academy of Pediatrics	AAP policy statement on Global Climate Change and Children's Health	https://pediatrics.aappublications.org/content/136/5/992
Climate Psychiatry Alliance	What psychiatrists can do about impacts of climate change on mental health, in terms of patient care, systems of care and public health advocacy.	https://www.climatepsychiatry.org/what-to-do
American Psychological Association	APA 2017 Publication "Mental health and our changing climate: Impacts, implications and guidance," 69 pp.	http://ecoamerica.org/wp-content/uploads/2017/03/ea-apa-psych-report-web.pdf
American Public Health Association (APHA)	APHA's declared mission is to "Improve the health of the public and achieve equity in health status," including improving mental healthcare. This brief publication referenced describes immediate, gradual and indirect impacts of climate change on mental health.	https://www.apha.org/~/media/files/pdf/topics/climate/climate_changes_mental_health.ashx
Medical Society Consortium for Climate and Health	Groups that, among many functions, advocate for climate change action based on health impacts. MTHPHC welcomes all health professionals and health profession students to join as members.	https://medsocietiesforclimatehealth.org/
Montana Health Professionals for a Healthy Climate (MTHPHC)		https://www.montanahphc.org
American Lung Association	The ALA advocates for climate action and preparedness by elected officials as well as professional and public organizations. Resources on climate change impacts on air pollution and lung health, as well as ways to fight climate change.	https://www.lung.org/clean-air/climate-change
MyGreenDoctor	An evidence-based practice management tool for individual practitioners, clinics, and hospitals to save money by becoming environmentally sustainable.	https://www.mygreendoctor.org
Health Care Without Harm	Works to transform healthcare worldwide. Their Climate and Health program supports the healthcare sector in reducing its carbon footprint, building climate-smart and resilient hospitals and communities, and mobilizing healthcare's ethical, economic, and political influence to advance the transition to a low-carbon future that supports healthy people living on a healthy planet.	https://noharm-uscanada.org/climateandhealth
Alliance of Nurses for Healthy Environments	The Mission of ANHE: Promoting healthy people and healthy environments by educating and leading the nursing profession, advancing research, incorporating evidence-based practice, and influencing policy.	https://envirn.org/

[a] Websites shown were active as of December 2020. For the latest resources and web links, go online to the Climate Change and Human Health link at the Montana Climate Assessment website (montanaclimate.org).

Healthcare institutions

In addition to the actions of individual practitioners, hospitals, clinics, and other healthcare facilities can make a substantial difference to their patients and communities dealing with climate-related health issues, as enumerated below.

Top Actions for Healthcare Institutions

- Work on mitigation efforts, for example instituting energy savings programs, upgrades to HVAC systems, development or improvement of recycling programs, and more. Choose one and start!
- Work within your organization and with community public health, community, academic leaders, and other groups to create a community plan for management of climate surprises, disasters, and pandemics.
- Add climate health effects to electronic records for both physical and mental health.
- Contribute to climate and health trainings for health professionals, including psychological first aid.

Here are additional actions for healthcare institutions:

- Improve and model sustainable practices and processes, including capturing anesthesia gases, decreasing use of disposables, shifting to renewable energy, and sourcing food locally. Tell your community that you are taking such steps, and hence helping mitigate climate change. Table 5-1 provides links to two programs—Health Care Without Harm and MyGreenDoctor.org—scoped to meet such goals (also see next page).
- Conduct climate adaptation and resilience planning with communities and local and state public health systems.
    - Consider addressing HVAC/HEPA retrofits to maintain facility indoor air quality, particularly for hospital inpatients.
    - Develop defined steps for meeting the needs of distressed communities, including not only physical ailments and distress, but also the needs of those who are mentally traumatized or have severe mental illness (Rao 2006). The Centers for Disease Control and Prevention has created a five-step plan titled *Building Resilience Against Climate Effects* that health officials can follow to help your community prepare for the health effects from or exacerbated by climate change (see the Community Actions subsection above for more information).
    - Assess impacts on the public health, medical, and mental healthcare systems due to shifting priorities, budget cuts, and budget diversion (e.g., to fire suppression) related to climate change.

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Greener Healthcare Ideas

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According to the World Health Organization, the US healthcare system contributes 8% of our greenhouse gas emissions (WHO undated). Climate change is a threat to human health, and hospitals especially must do all they can to model best-available environmental practices.

To reduce energy usage, a healthcare facility must first know how much natural gas and fuel it uses, energy and water it consumes, and waste it produces. Once familiar with these measures, a facility can set goals to reduce them. Programs such as Practice Green Health and Health Care Without Harm help hospitals set goals and lead the way in sustainability. For example, healthcare facilities can:

- improve local air quality by creating no idling zones on their campuses;
- reduce toxic emissions from incinerators with clear guidelines and education for all employees regarding materials that can and cannot be processed in biohazard waste dispensers;
- reduce laundry energy requirements by reducing the use of hot water and electricity;
- switch to LED light bulbs (which also saves a hospital thousands of dollars); and
- update and improve maintenance of HVAC systems that consume an enormous amount of energy.

Proper waste distribution and management must be demonstrated on every level in the hospital. The average hospital creates 29 lb (13.2 kg) of waste per patient bed per day (Eckelman and Sherman 2016). Accessibility to well-placed recycling, compost, and trash bins is important; they should be placed anywhere food is offered. To assist patients and staff, clear signage and instructions should be placed near every bin to ensure people properly segregate their waste.

Above all, if a healthcare facility wants to reduce its carbon footprint, it must build a culture of awareness by encouraging employees to turn off lights, shut down computers, utilize natural lighting, and not open materials until needed. It can reward employees who walk, bike, or carpool to work, and offer online meeting options rather than having employees drive to work for short time frames.

A hospital can also help patients become healthier by offering more vegetable-based, locally sourced meals in the cafeteria, and cooking classes on how to prepare these foods at home. Last of all, hospitals can invest in growing trees and other plants around campus. Such efforts not only improve air quality, but also provide shade and emotional support for patients and families.

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[a] More information at https://www.montanahphc.org/index.php

- o Work with universities, insurance providers, other healthcare systems, and local and state public health agencies to acquire critical data on the mental health consequences of climate-related extreme weather events and disasters. Those data should include prevalence and severity of climate-related health conditions, hospital admissions, suicide attempts, and episodes of violence.
    - Recognize that overarching psychosocial consequences of global climate change, termed *climate anxiety*, stem from awareness of the looming threats and current risks of climate change.
    - Prepare for disruptions to mental healthcare (including availability of psychotropic medications) due to climate-related weather events and unexpected disasters that may interrupt supplies.
    - Educate decision makers—be they in public health, healthcare systems, emergency response, the medical insurance industry, or local or state government—to increase understanding of where and how to invest in medical and public health infrastructure and resources.
- o Implement, support, or participate in training programs for clinicians, as well as healthcare, public health, and environmental health students and professionals on the health effects of climate change. (Healthcare training is a component of healthcare systems.)
    - *Curriculum development.*—Address the physical and mental health impacts of climate change in educational curricula for graduate and professional students in clinical health and social work training programs in Montana. Review availability of pre-professional courses and course components on a) the physical and mental health impacts of climate change; and b) community-level climate change adaptation planning. Such courses are scoped for undergraduates in healthcare, public health, and environmental health degree programs at institutions of higher education across Montana.
    - *Continuing education.*—Provide climate health certification/training programs, continuing medical education credits, continuing education workshops, and online medical training modules for primary care, nursing, pharmacy, mental health, and public health professionals that highlight potential health and mental health impacts of climate change, and interventions to address those impacts. Examples of such efforts include the Climate Change and Health Certificate offered at the Yale School of Public Health[21], and the Climate Change and Health Training Module Series offered by the Minnesota Department of Health[22].

21 https://publichealth.yale.edu/cchcert/

22 https://www.health.state.mn.us/communities/environment/climate/resources.html

- *Psychological First Aid.*—Ensure that first responders in Montana have training to respond to the psychological impacts of climate-related weather events and disasters. Psychological First Aid is an evidence-informed modular approach to help children, adolescents, adults, and families in the immediate aftermath of disaster and terrorism.[23]

o Join local, regional and national networks of health professionals working on climate change and health.

- Encourage members to become involved in climate change mitigation and adaptation efforts through Montana Health Professionals for a Healthy Climate (Table 5-1).

23 https://www.nctsn.org/treatments-and-practices/psychological-first-aid-and-skills-for-psychological-recovery/about-pfa

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Strategies and Actions for Individuals

Protecting your health in a changing climate takes work, but many actions are possible for individuals to prepare for and minimize health risks associated with climate change. The recommendations that follow are broken into climate concerns similar to those addressed in Section 3 (Climate-related Health Impacts).

Top Actions for Individuals

- Be familiar with your own (and your children's) medical conditions and have regular checkups with a trusted healthcare professional.
- Stay informed about climate change impacts on health.
- Explore what you can do to become involved in community climate change and public health initiatives.
- Become aware of local sources of mental health counseling.
- Prepare your home now for extreme weather events. Have extras of essential medications, blankets, potable water, respiratory masks, and cleaning and food supplies on hand, and check your home insurance policies for flood and wildfire coverage.
- Learn the signs of and remedies for heat exhaustion and heat stroke; and learn how to help yourself in extreme heat with adequate water, shade, home insulation, and salt replacements.
- Consider installing high-efficiency particulate air (HEPA) filters or activated carbon filters in your home or business to remove dust, pollen, and smoke particles, especially for those living in areas threatened by wildfire.
- Check current air quality at http://airnow.gov, or go directly to https://fire.airnow.gov for fire, wildfire smoke, and air quality data. Historical, current, and forecast air-quality data are available from a national to regional (if not local) scale. Where monitors in Montana exist, clicking on the small circles on the map retrieves data from those particular locations.
- Become aware of, utilize, and support local foods and renewable energy resources.

Photo facing page: Anna Shvets / Pexel

Extreme events and disaster planning

Montana is expected to experience more climate-driven weather extremes, from intense heat waves to spring flooding to late-summer drought to, potentially, more intense and more frequent storms (Whitlock et al. 2017; Section 2).

Here's what you can do:

- Create a family emergency plan to encompass issues that are relevant to your region. Resources are available from the US Department of Homeland Security[24] and the National Safety Council[25]. Consider installing the Federal Emergency Management app on your phone.[26] Plan so that you can comfortably stay in your home during extreme events, including, for example, being snowed-in for extended periods. Have at least three days of medications, water, and food safely stored in the home. The rule of thumb is one gallon of water per person per day for three days. Make sure you have adequate blankets or sleeping bags to stay warm during low temperatures and/or power outages.
- Install a functional carbon monoxide (CO) detector in your home, especially important during cold temperatures. If you use a furnace system, check and change the furnace filter regularly.
- Seek support from a healthcare professional should you experience a traumatic, climate-driven weather event, like flooding, drought, wildfires, and severe winter storms. Such events pose serious risks to mental health, particularly if they result in displacement, or loss of property or life. They can bring increased risk of anxiety, depression, post-traumatic stress disorder, suicidal thoughts, and suicide (USGCRP 2016; Guardian 2019).
- Check with your insurance provider if your home is prone to flooding and/or mud slides, as you may need to purchase separate coverage from the National Flood Insurance Program (FEMAa undated) or elsewhere. Also, check flood risk for your home address at https://floodfactor.com/, a website created by First Street Foundation, a group of independent experts who have modelled flood risk to include climate change impacts.

Heat

MCA notes that with climate change the number of days when temperature exceeds 90°F (32°C) in Montana is increasing (Whitlock et al. 2017). The National Integrated Heat Health Information System[27] is a good resource on heat and health-related issues.

24 https://www.ready.gov/plan

25 https://www.nsc.org/home-safety/safety-topics/emergency-preparedness

26 https://www.fema.gov/mobile-app

27 https://nihhis.cpo.noaa.gov

Here's what you can do:

- o Ensure that you have curtains or shades on windows during the summer, as well as adequate ventilation or air conditioning, to help keep your living space cool during high temperatures. If wildfire is not a risk where you live, consider planting trees near your home to provide shade.
- o Explore retrofit options to help keep your home cooler, including white roofing and added insulation and ventilation. Resources are available to help finance retrofits, including those from Northwestern Energy[28], the Montana's electric cooperatives[29], the Montana Department of Health and Human Services[30], the US Department of Energy[31], and the US Department of Housing and Urban Development[32].
- o Know the locations of cooling centers—e.g., malls, libraries, movie theaters, civic centers, and shaded parks—in your community where you can seek shelter in extreme heat events.
- o Never leave infants, children, or pets unattended in a hot car, even with the windows cracked.
- o Limit your outdoor exposure on hot days, and follow these recommendations (CDC 2017; NSC 2020; NIOSH undated):
    - Air conditioning, if available, is the best way to cool down.
    - Stay well hydrated (drink *before* your get thirsty) and avoid alcohol.
    - Wear loose, lightweight clothing and a hat.
    - Replace water or salt lost from sweating by drinking fruit juices or sports drinks.
    - Avoid spending time outdoors during the hottest part of the day (11 AM to 3 PM).
    - Wear sunscreen; sunburn affects the body's ability to cool itself.
    - Pace yourself when you work, run, or otherwise exert yourself. Take breaks to rest and cool down.
- o Avoid losing too much water and salt, typically from excessive sweating, which can lead to heat exhaustion, rhabdomyolysis (breakdown and death of muscles), health syncope (fainting), heat cramps, heat rash, or life-threatening heat stroke. Learn the signs of these conditions[33] and pay attention to your own and your colleagues' condition in hot weather.

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28 https://www.northwesternenergy.com/docs/default-source/documents/e-programs/3490_energyassistance
29 https://www.montanaco-ops.com/
30 https://dphhs.mt.gov/hcsd/energyassistance.aspx
31 https://www.energy.gov/eere/wipo/weatherization-assistance-program
32 https://www.hud.gov/states/montana/renting
33 https://www.cdc.gov/niosh/topics/heatstress/heatrelillness.html

Air quality

Climate change can affect respiratory health through increased air pollution, including wildfire smoke and longer dust and pollen seasons (see Section 3). People with pollen sensitivities may experience more severe reactions, and those with respiratory conditions, such as asthma, may be especially at risk of their symptoms intensifying (e.g., coughing, shortness of breath) (Wellbery and Sarfaty 2017).

Here's what you can do:

Outdoor air quality

- Learn more about health risks from wildfire smoke, as well as how to reduce those risks, on the Montana Wildfire Smoke website (montanawildfiresmoke.org). See also the Centers for Disease Control's website on protecting yourself from wildfire smoke.[34]

- Check current air quality anywhere in the country, including Montana, at AirNow.gov. The website was created by the US Environmental Protection Agency, National Oceanic and Atmospheric Administration, National Park Service, and tribal, state, and local agencies to provide the public understandable, easy-to-access national air quality information. The website color coding system, from green to dark red, shows what level of health risk exists for your region. An Airnow app is available for iOS and Android mobile devices.

- Montana data on particulate matter ($PM_{2.5}$) air pollution is available at https://www.montanawildfiresmoke.org/todays-air.html, which also provides information on how to estimate air quality based on visibility. On a clear day, establish pre-determined landmarks visible at various distances (1, 2, 5, 9, 13 and >13 miles), standing with your back to the sun. When there is smoke in the air, check for the visibility of these landmarks again. The more limited your visibility, the greater the $PM_{2.5}$ levels. Consult http://deq.mt.gov/Air/SF/breakpointsrevised to translate your visibility numbers into health risks.

- Remove trees, dead brush, or other flammable materials near your home's exterior to protect against wildfire. The National Fire Protection Agency provides a set of guidelines for protecting your home[35], plus check with your local fire department for advice applicable to your local conditions.

- As mentioned previously, check your home insurance to understand—and establish or increase if needed—your wildfire coverage.

- Carefully monitor the status of wildfires in your region. If you live in a high-fire-risk area, have an evacuation plan and be prepared to leave your home quickly.

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34 https://www.cdc.gov/air/wildfire-smoke/default.htm

35 https://www.nfpa.org/Public-Education/Fire-causes-and-risks/Wildfire/Preparing-homes-for-wildfire

- Avoid extended periods outside when smoke is present. Wildfire smoke creates a fine particulate matter that cannot be filtered by dust masks or bandanas. Those with respiratory conditions and children under 18 are especially vulnerable to wildfire smoke. Those over 65 yr are at increased risk of heart attack or stroke (Wettstein et al. 2018) (also see Section 3).
- Do not hold or participate in outdoor activities, especially rigorous outdoor activities like running and other sports, when wildfire smoke or haze is visible. Check with your local health department for air quality advisories for outdoor sports events. Ask your children's schools if they receive air quality advisories and if so, if they abide by them. (Health departments can only provide advice; schools decide whether to cancel sports events).
- Monitor pollen conditions, develop a treatment plan with your doctor, and have the necessary medications on hand. The ragweed pollen season in central North America is increasing in length as temperatures increase (Ziska et al. 2011). Periods of drought may also increase irritants, so limit your time outside during times of high pollen and/or dust. Consider downloading one of the many phone apps—some free—for displaying and forecasting pollen counts and other allergens.

Indoor air quality

- Protect air quality inside your home by using air filters and keeping doors and windows closed when outdoor air quality is poor. If you have central air, improve your indoor air quality by upgrading your system's air filter. Filters are rated using the Minimum Efficiency Reporting Value (MERV), ranging from 1-20. The higher the MERV, the more effective the filter at removing small particles (USEPAa undated). The minimum MERV rating for removing the fine particulate in smoke is MERV 13. The more times air passes through the MERV 13 filter, the cleaner the air becomes. Note that a higher-rated MERV filter will likely need to be changed more frequently due to the amount of material it accumulates.

Photo: CDC / Upsplash

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Not all central air systems can handle the pressure drop associated with higher MERV filters. Check with the manufacturer to find out what filters will work with your furnace, or have an HVAC technician check your system before installing. Note that your air is cleaned only while it is moving through the filter, so keep your furnace fan running when air quality is poor. You may wish to upgrade to a higher MERV filter only during poor air quality events; discuss the wear and tear on your furnace and the potential for higher utility bills with your furnace manufacturer's local representative.

Another option is portable air cleaners with true HEPA filtration, which can dramatically improve indoor air quality. These standalone units use a fan to pull air through a true HEPA filter (MERV rating 17-20), which mechanically removes the fine particles in smoke. Costs for portable air cleaners increase with room size. However, you should be able to find a good portable air cleaner with a true HEPA filter for under $200, suitable for most living rooms or bedrooms. Use the portable air cleaners in the room where you spend the most time; it is a good idea to run one in your bedroom while you sleep. Try to keep windows and doors to the room with the portable air cleaners closed to allow the machine to recirculate air through its filter. Make sure the portable air cleaner is sized appropriately for the room. Caution: *mechanical* portable air cleaners are reliable, while some that are *electronic* produce hazardous ozone (a gas) and/or other hazardous chemicals, and hence should be avoided (USEPAa undated, 2018a, 2018b, 2019).

For a lower-cost solution, you can put together a do-it-yourself fan/filter. Use a newer box fan (manufactured in the past five years), and a MERV 13 furnace filter attached to the back of the fan with the airflow arrow pointing toward the fan. Duct tape or a bungee cord will do the trick. Do not leave such a set up unattended, and change the filter when it becomes visibly dirty. These do-it-yourself air cleaners can be quite effective in rooms around 250 square feet. More information, including how-to videos, is available at montanawildfiresmoke.org.

- o Reduce sources of air pollution indoors when poor outdoor air quality requires staying inside. For example, avoid burning candles, smoking tobacco, using aerosol sprays, or burning your woodstove or fireplace.
- o Upgrade your woodstove or fireplace, as needed and if possible, to one that is tighter and cleaner burning, thereby helping improve both indoor and outdoor air quality. See the US EPA's *Burn Wise* website[36] for tips on woodstove use and for links to the US EPA's database of certified woodstoves.
- o Support transitioning to clean, renewable sources of energy. As the American Lung Association states in its *Lung Health Brief* (American Lung Association 2016): "Switching to clean, renewable energy will allow the US to generate electricity without adding pollution that harms Americans' health… Decades of research shows that these pollutants trigger asthma attacks and heart attacks, cause cancer, and shorten lives, among many other health impacts."

36 https://www.epa.gov/burnwise

Flood and drought

Flooding can contaminate surface water and groundwater, and harmful algal and bacterial blooms are expected to become more frequent in a warming climate. The trends of early-season runoff and late-season drought described in the MCA (Whitlock et al. 2017) can also impact food security and the incidence of vector-borne disease (also see Section 2).

Here’s what you can do:

- Protect your home from the risk of mold by checking for piping leaks or water accumulation under sinks, crawl spaces, attics and basements. Install drainage systems to prevent rainwater or saturated grounds from damaging your home, including providing a foothold for mold and rot.
- Act quickly if you find mold in your home. Along with the health effects that result from mold exposure—e.g., allergies, stuffy nose, wheezing—the longer mold grows the more damage it will cause to your home. You must both eliminate the water source and remove the mold. EPA’s *A Brief Guide to Mold, Moisture, and Your Home* provides a useful guide, including the tradeoffs between cleaning your home yourself versus employing a professional (USEPA 2012).
- Monitor your water supply if you have a well, and make your home as water-efficient as possible. These are good practices anytime, and potentially critical during times of drought. Store spare water in case of an emergency.

Flood of 2007, I-90 bridges at Crow Agency
Photo courtesy of John Doyle

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- o Ensure your wellhead has a watertight sanitary cap, rather than an old-style cap with no gasket. The casing for a well must extend at least 18 inches (46 cm) above the natural ground surface; casing extensions can be added if needed (USEPAb undated). These features protect your home well water from contamination year-round, and especially in the event of a flood.

- o Be prepared to boil, filter, or chemically purify your water before drinking in the event of flood contamination. Such treatments can eliminate most organic contaminants and microbes (USEPAc undated). Organic compounds can be the biggest concern during a flood due to sewage (human and/or livestock) runoff. However, those with wells should know—in advance via testing—if their water contains such inorganic contaminants as uranium, arsenic, manganese, or other hazardous metals or nitrates. In the case of flood, such contaminants might make boiling your water a poor idea as boiling will likely concentrate these inorganic contaminants, resulting in increased health danger. Uranium, arsenic, and some other hazardous contaminants have no taste, smell, or color—thus, you won't know they are present until you have your water tested. Montana State University's Montana Well Educated Program[37] is an excellent resource for accessing discounted, EPA-certified, well-water testing for microbial, organic and inorganic contaminants, plus for learning more about drinking water quality and safety.

- o Never swim in, nor drink from, water where blue-green algae (cyanobacteria) are visible or where harmful algal blooms have been reported (MTDPHHS undated). Similarly, keep pets and livestock away from waters where such hazards are present. If you are camping, understand that boiling, filtering, or adding purifying tablets to water will not remove these toxins. Public drinking water supplies in Montana are not required to monitor or test for cyanobacterial toxins (MTDPHHS undated). For further information, see Section 3 and the *Harmful Algal Bloom Guidance Document for Montana* (MTDPHHS 2019).

- o Conserve water and reduce your water bill by upgrading to high efficiency showerheads, toilets, and washing machines, plus fixing faucet and shower leaks. Keep your grass at least 3 inches (7.6 cm) high, mulch your plants, landscape with drought-tolerant plants, and learn best watering practices. Know how to operate and maintain your in-ground sprinkler system most efficiently. You can find great tips and water conservation resources on the city of Bozeman website.[38]

37 http://waterquality.montana.edu/well-ed/

38 https://www.bozeman.net/government/water-conservation/resources

Food security

The growing-season drought and limitation on agricultural irrigation water projected in MCA (Whitlock et al. 2017) will likely result in crop losses, lower yields, higher anxiety among producers, higher food prices, and higher risk of food-borne disease. Commodity crop and livestock producers can be challenged by a wide range of climate change factors, many of which are not local, but impact global food security. On a local scale, community food enterprises are taking an active role in growing, marketing, processing, distributing, and retailing food to decrease reliance on food vulnerability of global food systems. Building local food availability creates local jobs, improves the community economy, in some cases lowers emissions from transportation and storage, and benefits human health by providing more fresh and nutritious food (Norberg-Hodge et al. 2002; Borelli et al. 2020).

Here's what you can do:

- Buy from local sources whenever possible, including farmers markets, community supported agriculture (often called "CSAs"), food hubs[39], and growers' coops.[40,41]
- Diversify food supplies and crop types. Plant and eat from a variety of food sources and eat more seasonal foods.
- Purchase less processed and highly packaged food.
- Learn how to prepare and store more foods for later use. Store non-perishable foods in a location expected to be safe and accessible in emergencies. MSU Extension is an excellent resource for helpful guides on food preservation and storage.[42]
- Plant and grow your own vegetables using organic fertilizer and an efficient irrigation system.
- Advocate for local foods—fruits, vegetables, grains, legumes, or meat—sourced and processed in Montana.
- Decrease waste, both your own and your community's, by supporting community compost collection.
- Support farm-to-table restaurants that use locally grown foods and ask others (including hospital cafeterias) to do so, as well.
- Encourage Montana's farm-to-school program[43] and the FoodCorps program[44] to inform our teachers and youth about local food sources.

39 The US Department of Agriculture defines a food hub as, "A centrally located facility with a business management structure facilitating the aggregation, storage, processing, distribution, and/or marketing of locally/regionally produced food products" (USDA undated).

40 https://www.farmersmarketplaces.com/

41 https://www.wmgcoop.com/about.us

42 https://store.msuextension.org/Departments/MontGuides-by-Category/HR/Nutrition-and-Health.aspx

43 http://www.farmtoschool.org/our-network/Montana

44 htpps://foodcorps.org/apply/where-youll-serve/montana/

Photo facing page: Charl van Rooy / Upsplash

Vector-borne disease

Changing temperatures and water regimes are expected to expand the range of illnesses spread by vectors such as mosquitoes, ticks, and fleas (see Section 3).

Here's what you can do:

- Mount (or repair) screens on windows and doors to prevent mosquitoes from entering your home. Limit pools of water around your home, where mosquitoes breed.[45] To protect yourself outside use insect repellent and wear long-sleeved shirts and pants. Stay inside or take extra precautions especially at dusk and dawn, when mosquitoes are most active.
- Monitor outbreaks of vector-borne illnesses—e.g., West Nile virus, Rocky Mountain Spotted Fever, and Q fever—through your local health department or the Montana Department of Public Health and Human Services website[46] (Figure 5-2).
- Tuck your pants into your socks when walking through grasses or areas where ticks are common. Check yourself for ticks when you return home. Visit the Centers for Disease Control and Prevention website for further information on preventing tick bites, removing ticks, what to do after a tick bite, where different types of ticks live, and more.[47]
- Watch for potential emergence of zoonotic disease by monitoring the Montana Department of Public Health and Human Services website (also see Section 3).[48] Although there are many illnesses that can potentially be transferred from animals to people, there is currently no research showing that climate changes are directly increasing these health risks in Montana. Still, new zoonotic diseases that emerge in other parts of the world can reach Montana, as COVID-19, from the SARS-CoV-2 virus, demonstrated (see facing page).

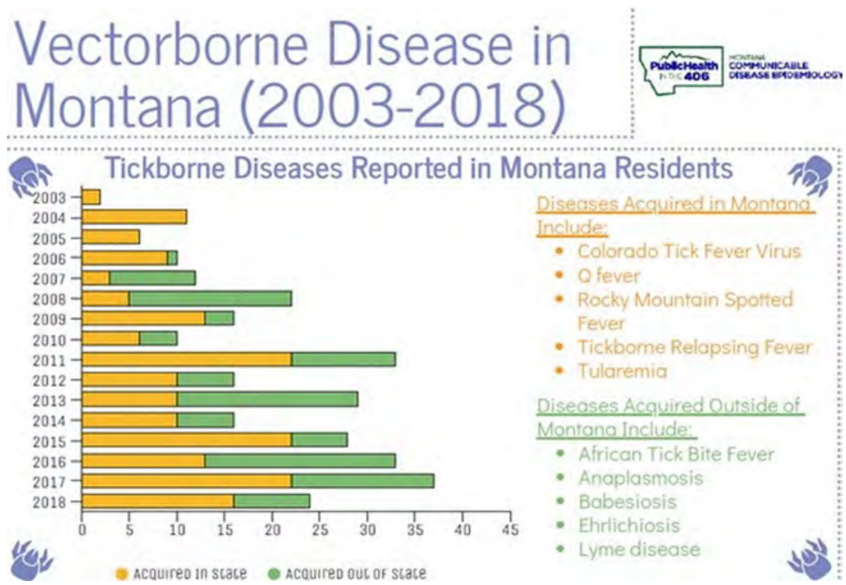

Figure 5-2. An example of vector-borne disease tracking that citizens can access from the Montana Department of Public Health and Human Services website (start at https://dphhs.mt.gov/publichealth/cdepi/surveillance).

45 https://dphhs.mt.gov/aboutus/news/2019/preventwestnilevirus

46 https://dphhs.mt.gov/publichealth/cdepi/surveillance

47 https://www.cdc.gov/ticks/index.html

48 https://dphhs.mt.gov/publichealth/cdepi/diseases/zoonotic

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Epidemics, Pandemics, and Climate Change

Epidemics and pandemics have ravaged human societies throughout history. However, studies suggest that the number of infectious disease outbreaks from all causes has increased significantly since 1980 (Smith et al. 2014). Up to 75% of newly emerging diseases originate in animals (referred to as *zoonotic* diseases) (USAID undated).

As the world combats the ongoing COVID-19 pandemic, questions arise about the contribution of climate change to the emergence of new infectious diseases and pandemics, in general. Many of the same factors contributing to climate change also increase the risk of new diseases. Deforestation—for agriculture, urbanization, and mining—is a leading contributor to climate change due to the burning of trees and subsequent loss of carbon sequestration from photosynthesis, which further increases atmospheric carbon dioxide. In addition, deforestation forces humans and wild animals into more frequent and closer interactions through loss of habitat and increased numbers of people living at the forest edge (Faust et al. 2018; Bloomfield et al. 2020). This proximity increases the opportunities for disease transmission to humans. Deforestation, coupled with economic disparities and food insecurity, can also lead to more people hunting wild animals for food in many parts of the world. It also forces animal species that would normally occupy different habitats into close proximity to each other, yielding yet another opportunity for disease pathogens to cross species boundaries.

Warmer temperatures globally drive animals and plants to shift their range from unsuitable areas to places with conditions more conducive to their survival. This report discusses such shifts relative to disease vectors such as mosquitoes and ticks, but research suggests that similar movement is occurring with mammals, such as bats, bringing them into new areas and increasing risk of disease transmission to humans (Plowright et al. 2015).

Along with potentially contributing to the emergence of infectious diseases, the burning of fossil fuels also causes air pollution, which worsens the effects of certain epidemics and pandemics among people with chronic medical conditions. During the 2003 SARS outbreak (Cui et al. 2003) and recent SARS-CoV-2 outbreak and resultant COVID-19 pandemic (Wu et al. 2020), virus-related mortality was highest in areas with high levels of air pollution.

Thus, climate change does not cause the diseases that result in epidemics or pandemics. Climate change can, however, amplify the impacts on human health, and even some of the factors that make pandemics more likely. Further, many of the drivers of climate change also contribute to emergence of new zoonotic diseases in humans. By addressing those forces, we not only lessen the chances of new diseases, but mitigate climate change, as well.

Mental health: getting involved and finding support

The stress of climate change can greatly influence our mental health. Recognizing that you need help and taking the first steps to process hard times are often the most difficult. Approaches to protecting mental health include crisis counseling, primary care intervention, individual and group therapy, and practices that increase emotional coping abilities (Hayes et al. 2018).

Here's what you can do:

- Learn more about coping skills. If you can, seek advice from a mental health counselor, therapist, or another trusted support person.
- Get involved with art, literature, nature, and spirituality; spend time with friends; get outside; exercise; garden—all will increase emotional resilience (Koger et al. 2011; Hayes et al. 2018; Guardian 2019) (Figure 5-3).

Figure 5-3. Creating art of all kinds—painting, drawing, sculpture, poetry, literature, photography, and more—can help increase emotional resilience during times of stress, including that related to climate change. Art provides anyone, young or old, a place to express his or her fears or hopes, or to encapsulate an idea or a moment in time. Here, for example, environmental engineer and painter Katie Lindberg has captured the essence of this report on climate change and human health in Montana.

- Build a sense of community and become involved in civic action, such as volunteering, polling, voting, or advocacy. Working on climate change adaptation or mitigation has been shown to have mental health benefits (Reser et al. 2012), so find a group or organization that is active on climate change issues and get involved (see Table 5-1 and sidebars in this section).
- Foster optimism by maintaining connectedness to family, place, culture, and community (Clayton et al. 2017).
- Talk with others about climate-related distress (NBC News 2018; Ozy 2019). Consider involvement in such groups as The Good Grief Network[49], who describe themselves as "…a nonprofit dedicated to bringing people together to help metabolize collective grief. Using a 10-step approach, we help build personal resilience while strengthening community ties to help combat despair, inaction, eco-anxiety, and other heavy emotions in the face of daunting systemic predicaments."
- Seek solace in nature as a way help overcome feelings of anxiety, hopelessness, and powerlessness over the future (Koger et al. 2011).
- Finally, realize that we all have a role to play in the mitigation and adaptation to climate change and we *can* be inspired by the many communities, healthcare settings, and individuals in Montana who are working for a better future.

What Professional Organizations are Saying

A number of professional organizations, health-focused and otherwise, have developed policies or position statements regarding the impacts of climate change on human health. Following is a collection of quotes from a number of these trusted resources.

- *Montana Farmer's Union.*—"As the impacts of climate change mount, producers will need to be armed with the latest research, information and tools to mitigate the adverse effects, adapt to the changing conditions and continue providing a safe, reliable and healthy food source for the world." [50]
- *Montana Climate Change Advisory Committee.*—"Explicitly articulated public education and outreach can support GHG emissions reduction efforts at all levels in the context of emissions reduction programs, policies, or goals. Public education and outreach is vital to fostering a broad awareness of climate change issues and effects (including co-benefits, such as clean air and public health) among the state's citizens." [51]
- *US Department of Health and Human Services.*—"The US Department of Health and Human Services considers climate change to be one of the top public health challenges of our time." [52]

49 https://www.goodgriefnetwork.org/

50 https://montanafarmersunion.com/wp-content/uploads/2016/01/MFU_Climate_Final.pdf

51 https://deq.mt.gov/Portals/112/Energy/ClimateChange/Documents/FinalReportChapters.pdf

52 https://www.hhs.gov/climate/index.html

Younger Montanans Taking Action for Their Health

Protecting the health of Montana youth, one of the most vulnerable populations to climate change, is a major action motivator for young people across Montana. Supporting this idea, a recent study of 47 students in the health field in Montana showed 100% agreement in the science of climate change, and 89% felt their health was at stake due to climate change (Byron 2019).

Sarah Lorch, a 21-year-old honors nursing student at Montana State University, is one such active participant in the climate and health conversation. Sarah says,

> *Understanding how climate change affects my health and the health of my generation is a deep passion as I pursue a profession in public health nursing. I often find it puzzling that climate change has become such a political issue. I think many youth are confused by this phenomenon. I want people from all walks of life to feel that climate change is relatable and to understand that their own personal well-being is affected by it. Widespread hesitations around climate change place us in a pressure cooker, and addressing climate change needs to be an emergency response accomplished through powerful and personal storytelling that sparks immediate action. We also need to assure that climate change and human health studies are integrated into every medical curriculum as a required standard.*

To move forward in this work, Sarah has contributed to several blogs and newsletters, completed leadership training with the Sunrise Movement, is an active member of the Alliance of Nurses for Healthy Environments, and is the newest board member of the Montana Health Professionals for a Healthy Climate. These and other climate action and health groups, described below, draw on the innovation and leadership of Montana's young people:

- The Sunrise Movement[a] is a global connection, with chapters in Montana, of "ordinary young people who are scared about what the climate crisis means for the people and places we love. We are gathering in classrooms, living rooms, and worship halls across the country … We are not looking to the right or left. We look forward. Together, we will change this country and this world, sure as the sun rises each morning." Montana Sunrise helped organize the Global Climate Strike marches on September 20, 2019, in many cities across Montana for an historic call-to-action and strike for a livable future. The Sunrise Movement offers national trainings in leadership and action.
- Alliance of Nurses for Healthy Environments[b] believes that "changes to climate patterns lead to current and imminent threats to public and environmental health with growing evidence and concern about impacts on human health noted if action is not taken."
- Student chapters in high schools and university campuses of 350.org[c], Citizens' Climate Lobby[d], and Protect Our Winters[e] are active throughout Montana.
- 4-H, the USDA Extension Service's youth development program, has a new national climate curriculum, initiated at Montana State University.[f]
- On March 13th, 2020, a group of Montana's youth filed a complaint in the First Judicial District Court against the State of Montana arguing they are harmed by the "dangerous impacts of fossil fuels and the climate crisis." The law firms representing the youth maintain that Montana's fossil-fuel based energy system and the Climate Change Exception within the Montana's Environmental Policy Act violates their state constitutional rights.

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[a] https://www.sunrisemovement.org; [b] https://envirn.org/; [c] https://350.org/; [d] https://citizensclimatelobby.org/; [e] https://protectourwinters.org/; [f] https://shop4-h.org/products/4-h-weather-and-climate-learning-lab-leader-s-guide

- *National Institute of Environmental Health Sciences.*—"While climate change is a global process, it has very local impacts that can profoundly affect communities. It can affect people's health and well-being in many ways, some of which are already occurring." [53]
- *National Indian Health Board.*—"Tribal communities can be particularly vulnerable to the health effects associated with climate change for a variety of reasons. There are already existing and pronounced health disparities in Native communities that can lead to the health impacts from environmental damage being much more severe." [54]
- *Medical Society Consortium on Climate and Health's Climate, Health, and Equity Policy Action Agenda.*—"Climate change is a public health emergency. We call on our nation's leaders to act now by mobilizing climate actions for our health, and health actions for our climate. With the right policies and investments today, we have the opportunity to realize our vision of healthy people in healthy places on a healthy planet." [55] (Note: This statement was signed by over 100 health organizations.)
- *National Academy of Medicine.*—"The negative impacts of climate change disproportionately affect the very young and the very old, people who are ill, impoverished or homeless individuals, and populations that depend on the natural environment for survival. Urgent action is needed to mitigate the health consequences of climate change for these populations, among others. … Climate change represents one of the most significant threats to human health in the 21st century." [56]
- *Lancet Commission Report on Health and Climate Change: Policy Responses to Protect Public Health, 2015.*—"Climate change…threatens to undermine the last half century of gains in development and global health. … Tackling climate change could be the greatest global health opportunity of the 21st century." [57]

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53 https://www.niehs.nih.gov/health/topics/agents/climate-change/index.cfm
54 https://www.nihb.org/docs/10102019/Climate%20Change%20&%20Tribes%20Article.pdf
55 https://climatehealthaction.org/cta/climate-health-equity-policy/
56 https://nam.edu/programs/climate-change-and-human-health/
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Paradise Valley south of Livingston
Photo courtesy of Violeta Corpron

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Foraging horse
Photo courtesy of Alexandra Adams

06. MOVING FORWARD

Alexandra Adams

This is the first report produced specifically for Montanans and Montana that focuses on human health impacts from climate change. As a special report of the *2017 Montana Climate Assessment*, it is intended to foster greater awareness of public health impacts from climate change in communities across Montana, and thus spur action.

The authors and their organizations—Montana Institute on Ecosystems, Center for American Indian and Rural Health Equity, and Montana Health Professionals for a Healthy Climate—support implementation of the key messages and recommendations herein to mitigate significant climate-related human health impacts in Montana. They extend their gratitude to many contributing experts, as noted in the Acknowledgments section, for their input to the development of this report.

The recommendations promote establishment of a key climate action network that ensures the impacts of climate change on public health can be assessed, prepared for, and mitigated in Montana. Given the many efforts related to climate and health already occurring in Montana, the current lack of a collaborative network connecting these organizations and issues must be addressed. The creation of a statewide public health-climate science network comprising key stakeholders will improve climate and health data collection and sharing across Montana. Easier access to relevant data and capacity building will better inform and strengthen collective climate change adaptation planning, decision-making, and implementation, from state-level to personal health.

This report presents the best available science and resources at the time of publication. Many interconnections exist between climate change and human health, and these relationships are likely to evolve in the coming years. As access to better data becomes available on the climate impacts on Montanans' health, new knowledge will inevitably expand the foundation this report offers. Thus, while this effort fills a key gap, this work will need to be sustained, updated, and expanded on a regular basis as part of the overall MCA program. Continuing focus and collaborations on these issues will assure Montanans are informed about the impacts of climate change on their health, and are also prepared to respond to those impacts in the coming decades.

This report provides an important and valuable first step in raising awareness of the topic of climate change and its impacts on human health in Montana. We hope that everyone will recognize their role to mitigate and adapt to climate change, both for our own health and for those most vulnerable among us.

Happiness in the Clark Fork River!
Photo courtesy of Nick Silverman

APPENDIX A. ANALYSIS OF VULNERABILITY TO HEAT BASED ON HISTORIC AND FUTURE TEMPERATURE, AS WELL AS SOCIOECONOMIC FACTORS

Nick Silverman, Bruce Maxwell, and Robert Byron

Multi-criteria Decision Analysis

We used Multi-criteria decision analysis (MCDA) to categorize vulnerability to heat across the state of Montana. MCDA is a statistical method of weighting different layers of contributing information to provide a qualitative description of risk. The method has been applied to a wide range of topics in risk analysis (Chi 2010, Ho et al. 2014). Several studies have used MCDA to better understand the relationship between land surface temperature (heat) and human health (Ho et al. 2015, Reid et al. 2009, Morabito et al. 2015). More locally, MCDA was used to map heat vulnerability across the city of Missoula, Montana (Thompkins 2018). The term *decision analysis* in the name comes from the original intent of the method to help inform decision-making by allowing decision makers with local knowledge to weigh different factors based on their intuitive sense of which factors may be most strongly associated with a response. In our case, how heat may associate with socioeconomic factors with different weightings to determine human health impact. We used this method to determine which counties in Montana may be most vulnerable to heat effects from climate change.

Exposure Calculations

In our analysis, we define vulnerability as having three main components: 1) heat exposure; 2) heat sensitivity; and 3) adaptive capacity. Exposure is the direct effect of heat based on temperature and humidity; sensitivity and adaptive capacity are combined through socioeconomic factors that make humans more susceptible to heat-related illness. We refer to these socioeconomic factors as *sensitivity* for this analysis. Exposure is further broken down into historical conditions and future change. Historical heat conditions for each county[1] were estimated using the Moderate Resolution Imaging Spectroradiometer (MODIS) Land Surface Temperature (daily average) and Emissivity (MOD11) approximately 1-km resolution satellite product (Wan et al. 2015). We calculated the 95th percentile land surface temperatures from 2000-2019 for each grid-cell and then averaged those by county creating an estimate of the historical land surface temperature for each county during the hottest climate events (i.e., falling within the top 95th quantile) during the study period. For future changes in heat projections, we used the heat index values by UCS (2019) for the 100°F threshold at mid century with the RCP8.5 scenario. The heat indices for each county were generated based on an ensemble of general circulation models and include a combination of temperature and humidity estimates to create a "feels like" temperature rating commonly used when estimating heat impacts on humans.

Sensitivity Calculations

We based our calculation of sensitivity on socioeconomic factors from the US Census Bureau, 2013-2017 American Community Survey 5-Year Estimates. We used county estimates of median household income assuming that if income was low the county population would have less ability to mitigate extreme heat. Percent of the county in poverty, percent of children in poverty, and percent of population unemployed for a county were assumed to increase the likelihood of negative health impacts from heat. The percent of construction and production (those employed in production, transportation, and material movement) jobs were assumed to be related to increased exposure to heat because most of these jobs are outside or have little access to air conditioning. Percent of professional jobs, like household income, is thought to increase the potential for the population to survive extreme heat. In the cases of median household income and percent of professional jobs, the inverse ranking was used to associate with heat vulnerability. These mapped layers of information were selected by a panel of Montana healthcare experts as best indicators of heat vulnerability from the list available (Table A-1).[2]

1 See Figure 2-1 for a map naming Montana's 56 counties.

2 It is important to recognize that data and discussion on percent employment, as presented in this analysis, are from well before the 2020 COVID-19 pandemic.

Table A-1. County rankings based on socioeconomic variables that are sensitive to heat using 2013-2017 data (closeness not used for ranking, but ranking associated with vulnerability so median income and percent professional jobs are ranked high if values are low and all other variables ranked from low to high). Two notes associated with the socioeconomic column: a) If average median household income was low for a county relative to the other counties in Montana then the rank would be high (i.e., more sensitive to heat); b) If the percentage of professional jobs in the county was low relative to other Montana counties then the rank would be high (i.e., more sensitive to heat).

Socio-economic variable	Counties with low sensitivity rank (1-14)	Counties with medium-low sensitivity rank (15-28)	Counties with medium-high sensitivity rank (29-43)	Counties with high sensitivity rank (44-56)
Median household income	Rosebud, Broadwater, Custer, Richland, Valley, Daniels, Fallon, Stillwater, Dawson, Yellowstone, Carbon, Gallatin, Lewis and Clark, Jefferson	Sweet Grass, Garfield, Fergus, Big Horn, Granite, Wibaux, Sheridan, Prairie, Madison, Teton, Powder River, Cascade, Flathead, Missoula	Pondera, Carter, Liberty, Ravalli, Petroleum, Beaverhead, Toole, Judith Basin, Powell, Park, McCone, Lake, Hill, Treasure, Golden Valley	Musselshell, Chouteau, Meagher, Sanders, Lincoln, Wheatland, Phillips, Blaine, Roosevelt, Glacier, Mineral, Deer Lodge, Silver Bow
% poverty	Broadwater, Custer, Richland, Valley, Daniels, Fallon, Stillwater, Carbon, Jefferson, Garfield, Granite, Teton, Powder River, McCone	Dawson, Yellowstone, Gallatin, Lewis and Clark, Sweet Grass, Wibaux, Sheridan, Prairie, Madison, Cascade, Flathead, Carter, Petroleum, Park	Fergus, Missoula, Liberty, Ravalli, Beaverhead, Toole, Judith Basin, Powell, Treasure, Golden Valley, Musselshell, Meagher, Lincoln, Phillips, Deer Lodge	Rosebud, Big Horn, Pondera, Lake, Hill, Chouteau, Sanders, Wheatland, Blaine, Roosevelt, Glacier, Mineral, Silver Bow
% child poverty	Broadwater, Custer, Richland, Valley, Daniels, Fallon, Stillwater, Garfield, Teton, Powder River, McCone, Gallatin, Wibaux, Beaverhead	Carbon, Jefferson, Granite, Yellowstone, Lewis and Clark, Sweet Grass, Sheridan, Prairie, Madison, Cascade, Petroleum, Park, Missoula, Judith Basin	Dawson, Flathead, Carter, Fergus, Liberty, Ravalli, Toole, Powell, Treasure, Musselshell, Meagher, Lincoln, Phillips, Deer Lodge, Silver Bow	Golden Valley, Rosebud, Big Horn, Pondera, Lake, Hill, Chouteau, Sanders, Wheatland, Blaine, Roosevelt, Glacier, Mineral
% construction jobs	Custer, Gallatin, Jefferson, Granite, Yellowstone, Lewis and Clark, Cascade, Missoula, Flathead, Fergus, Silver Bow, Hill, Chouteau, Mineral	Valley, Daniels, Beaverhead, Carbon, Sheridan, Park, Ravalli, Toole, Deer Lodge, Big Horn, Pondera, Lake, Roosevelt, Glacier	Broadwater, Stillwater, Garfield, Teton, McCone, Wibaux, Prairie, Madison, Dawson, Carter, Powell, Musselshell, Meagher, Lincoln, Sanders, Blaine	Richland, Fallon, Powder River, Sweet Grass, Petroleum, Judith Basin, Liberty, Treasure, Phillips, Golden Valley, Rosebud, Wheatland
% production jobs	Jefferson, Lewis and Clark, Missoula, Daniels, Carbon, Sheridan, Big Horn, Glacier, Garfield, McCone, Prairie, Madison, Carter, Petroleum, Judith Basin, Liberty, Treasure	Custer, Gallatin, Cascade, Flathead, Fergus, Valley, Park, Toole, Powell, Blaine, Powder River, Wheatland	Yellowstone, Chouteau, Beaverhead, Ravalli, Deer Lodge, Pondera, Lake, Broadwater, Teton, Wibaux, Lincoln, Phillips, Golden Valley, Rosebud	Granite, Silver Bow, Hill, Mineral, Roosevelt, Stillwater, Dawson, Musselshell, Meagher, Sanders, Richland, Fallon, Sweet Grass
% unemployment	Daniels, Garfield, McCone, Liberty, Treasure, Custer, Toole, Powell, Deer Lodge, Teton, Wibaux, Dawson, Fallon, Sweet Grass	Lewis and Clark, Sheridan, Prairie, Madison, Carter, Judith Basin, Fergus, Park, Powder River, Wheatland, Yellowstone, Chouteau, Meagher, Richland	Jefferson, Missoula, Carbon, Petroleum, Gallatin, Cascade, Flathead, Valley, Beaverhead, Pondera, Broadwater, Golden Valley, Silver Bow, Stillwater, Musselshell	Big Horn, Glacier, Blaine, Ravalli, Lake, Lincoln, Phillips, Rosebud, Granite, Hill, Mineral, Roosevelt, Sanders
% professional jobs	Garfield, Carter, Wibaux, Petroleum, Daniels, Prairie, Judith Basin, Powell, McCone, Powder River, Gallatin, Lewis and Clark, Jefferson, Missoula	Chouteau, Meagher, Fergus, Broadwater, Valley, Sheridan, Blaine, Teton, Glacier, Hill, Treasure, Golden Valley, Carbon, Cascade	Rosebud, Pondera, Big Horn, Granite, Custer, Ravalli, Phillips, Madison, Beaverhead, Park, Dawson, Lake, Yellowstone, Flathead, Silver Bow	Musselshell, Sweet Grass, Liberty, Sanders, Lincoln, Richland, Wheatland, Toole, Roosevelt, Fallon, Stillwater, Mineral, Deer Lodge

Weighting Scheme

We weighted historical land surface temperatures and projected heat index by 0.255 and each socioeconomic factor by 0.07 so that the cumulative exposure layers and cumulative sensitivity layers were equally weighted (0.255 + 0.255 + 7*0.07 = 1.0). Income and percent of professional jobs were maximized while all other layers were minimized in the MCDA algorithm to minimize vulnerability. We used the *closeness* values calculated from the "skcriteria" Python library to calculate county vulnerability using the Technique for Order of Preference by Similarity to Ideal Solutions (TOPSIS) method (Sevachandran et al. 2018). Closeness represents how far each county's subset of socioeconomic variables, chosen to represent vulnerability, depart from the ideal set (Hwang and Yoon, 1981). Closeness values are normalized to be between 0 and 1. We grouped counties with closeness values below 0.25, between 0.25 and 0.50, above 0.50 and below 0.75 and above 0.75 into low, medium-low, medium-high and high vulnerability ratings, respectively.

In the absence of additional information, we assumed that each of the socioeconomic factors were equally weighted to represent sensitivity to heat. We know that certain factors are likely to have a stronger influence in some counties, but equal weighting was the best assumption without a detailed investigation into the variation in epidemiology of heat-related illness in Montana. To assess the uncertainty in our assumption, we performed a Monte-Carlo analysis on our weighting scheme for the different variables. We ran 10,000 simulations where socioeconomic variables were randomly assigned a weight using a Dirichlet distribution (a family of continuous multivariate probability distributions representing the socioeconomic variables) and then forced the sum of the weights corresponding to the 7 socioeconomic variables to equal 0.49. We kept the exposure weights constant at 0.255 for both historical and future predicted heat.

Results

The higher the rank values the more vulnerable a county's population is to heat. One county in Montana has a high vulnerability rating, while 17 have a medium-high rating, 12 have a medium-low rating, and 26 have a low rating (Figure A-1). There is a strong west-to-east increasing trend in vulnerability that mostly results from the patterns of exposure (i.e., land surface temperatures and projected heat are highest in eastern Montana). Roosevelt County ranked 29 for historical heat and 51 for future predicted heat relative to the other 56 counties, making it one of the top five counties for projected extreme heat in Montana. Roosevelt's high heat ranking coupled with a number of other factors—a) relatively high unemployment; b) low median income; c) low number of professional jobs; d) high poverty levels; and e) high number of agricultural production jobs—make it highly vulnerable to human health impacts from heat. While Roosevelt County is the only county with a "high" vulnerability rating, it is important to remember the uncertainty in the socioeconomic weight assignments when evaluating these results.

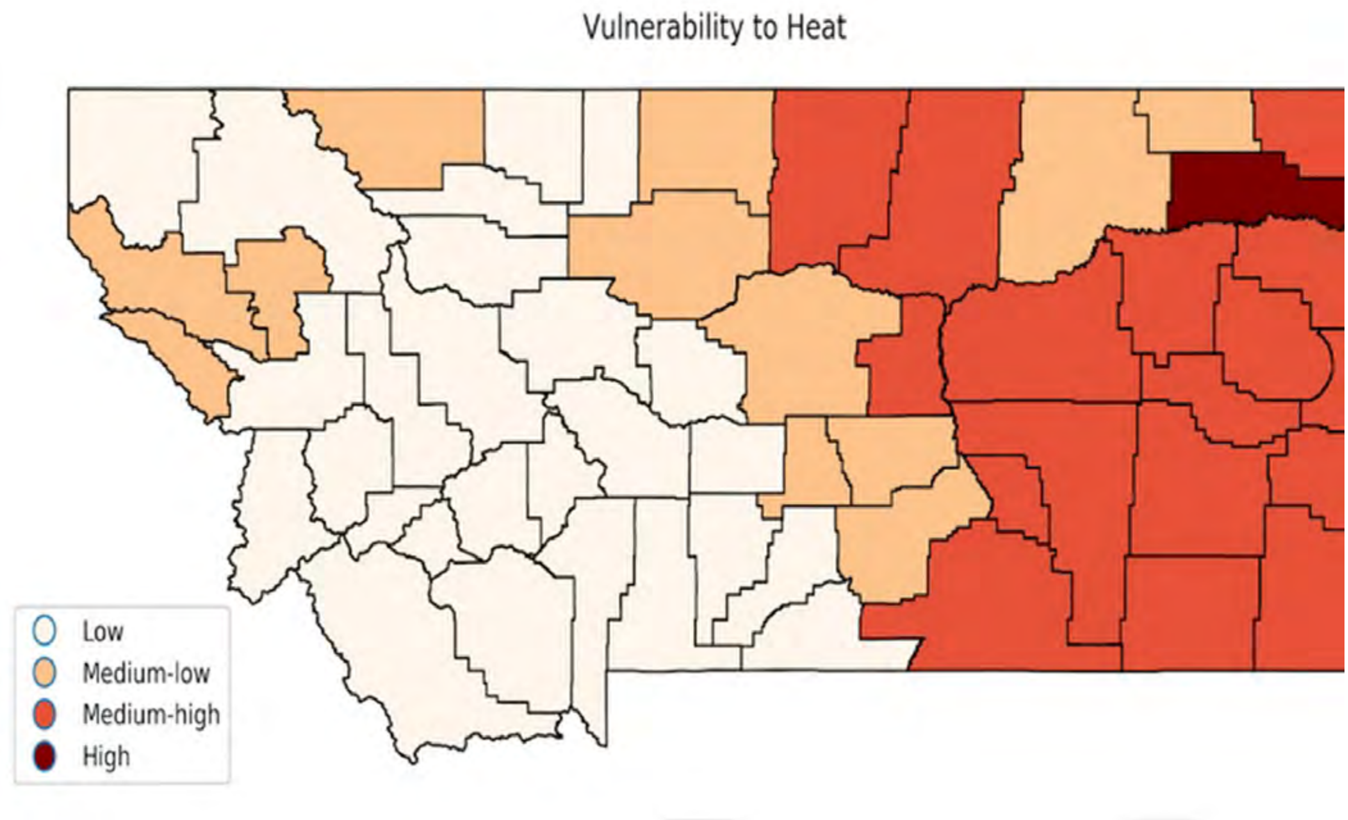

Figure A-1. Montana heat vulnerability ratings from the multi-criteria decision analysis.

The uncertainty analysis shows that there is variability in the sensitivity of the county ratings to the socioeconomic weights (Figure A-2). In some counties, such as Madison and Carbon, the closeness values were less sensitive to the weights, while in other counties, such as Richland and Fallon, there was larger variability. In general, the uncertainty results suggest that when clumped into the four categories (low, medium-low, medium-high, and high) the results are robust and that most of the ratings are stay the same irrespective of the weighting scheme. This finding increases our confidence in the general relative vulnerability prediction.

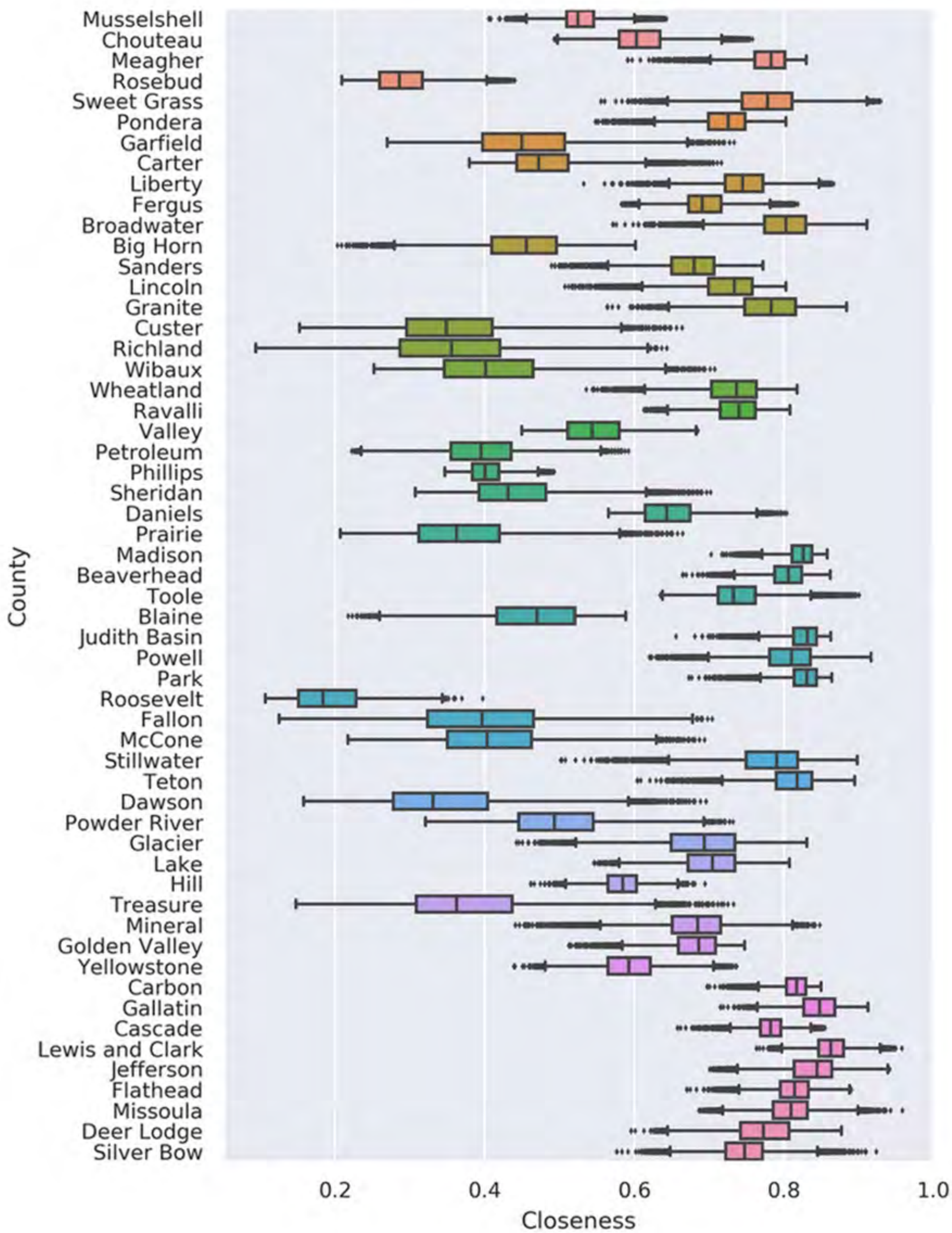

Figure A-2. Monte-Carlo analysis of socioeconomic weights to predict closeness to ideal (not vulnerable) is used as the metric of human health vulnerability.

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APPENDIX B. COMMUNITY TOOLS AND RESOURCES

Table B-1 provides a list of resources for communities, including public and environmental health agencies and organizations, to develop climate change assessments and action plans.

Table B-1. Resources for state and local governments, communities, tribes, faith organizations, and teachers to help plan for, address, and inform about climate change impacts.[a]

Source	Resource description
NATIONAL: Comprehensive Planning for Climate Change Resilience and Adaptation	
National Oceanic and Atmospheric Administration, US	A comprehensive, nationwide, online climate toolkit to help communities a) explore hazards; b) assess vulnerability and risks; c) investigate options to reduce risks and protect assets; d) prioritize and plan; e) take actions to build resilience. At this site: find climate projections for every US county, funding opportunities to plan for climate impacts and training options. See https://toolkit.climate.gov/.
National League of Cities, Climate for Health and many other partner organizations	Moving Forward: A Guide to Building Momentum on Climate Solutions in Your Community. A guide for civic leaders in smaller and mid-size communities who want to lead on climate and sustainability but may lack full-time sustainability staff. Provides resources and ideas to embed local climate solutions into planning and management activities, to achieve benefits with little or no additional costs. Create healthier communities, protect vulnerable residents, save money by reducing waste, spur economic development, build property values, improve public safety and restore natural assets. Engage residents using clear, positive, inclusive and relevant messages. See https://www.nlc.org/topics/environment-sustainability/climate; https://www.nlc.org/resource/moving-forward-a-guide-to-building-momentum-on-climate-solutions-in-your-community.
	Local Actions to Mitigate and Build Resilience to Climate Change: A list of some of the many steps you can take locally to prepare your community, help mitigate impacts, and build a cleaner future for your residents. See https://pathtopositive.org/wp-content/uploads/2019/09/P2P-checklist-Sep13-Final.pdf.
	Additional resources from National League of Cities and ecoAmerica are available. See https://www.nlc.org/program-initiative/nlc-ecoamerica-elevating-local-climate-action; https://www.neha.org/eh-topics/climate-change-0.
Climate Adaptation Knowledge Exchange	Widely used source of climate adaptation case studies, resources and opportunities, to support managers, planners and practitioners in preparing for and responding to climate change. Resources can be searched by adaptation phase, region and topic. See www.cakex.org.
ASTHOs Climate Change Collaborative	Association of State and Territorial Health Officials' (ASTHO) Extreme Weather and Climate Readiness: Toolkit for State and Territorial Health Departments. Developed by the US Association of State and Territorial Health Officers for state-level health departments in the US. It provides some practical steps, forms, and guidance for climate readiness planning within your public health agency. The toolkit describes a comprehensive approach to integrating climate readiness into seven key public health programs. See https://www.astho.org/Programs/Environmental-Health/Natural-Environment/Climate-Change/Extreme-Weather-and-Climate-Readiness-Toolkit-for-State-and-Territorial-Health-Departments/.

Table B-1. Resources for state and local governments, communities, tribes, faith organizations, and teachers to help plan for, address, and inform about climate change impacts.[a]

Source	Resource description
National Center for Appropriate Technology (NCAT)	NCAT aims to help people to build resilient communities through local and sustainable solutions that reduce poverty, strengthen self-reliance, and protect natural resources. See https://www.ncat.org/.
Geos Institute's Climate Ready Communities	The Geos Institute helps small to mid-sized communities plan for and build climate resilience. Climate Ready Communities is an affordable "assisted do-it-yourself" program, which includes: a) A free, downloadable, comprehensive Practical Guide to Building Climate Resilience; b) Annual support for assistance utilizing the Guide; c) Other services. See www.climatereadycommunities.org; https://climatereadycommunities.org/learn-more/about-guidebook/.
	Geos' Climate Wise Initiative: The Geos team supports community leaders in understanding likely future conditions, building resilience in ways that are effective and beneficial over the long term for people and nature, and developing locally appropriate solutions. See climatewise.org.
Geos Institute's Working Waters	Working Waters: A science-based initiative to ensure safe water for ecosystems, including people. Helps water managers and other stakeholders to research, plan, incentivize, and implement actionable strategies to heal damaged habitat and protect healthy landscapes. See https://www.workingwatersgeos.org/.
United Nations Office for Disaster Risk Reduction (UNDRR) and the World Health Organization (WHO)	UNDRR/WHO training webinar available: Resilience of local governments: A multi-sectoral approach to integrate public health and disaster risk management. The UNDRR's Public Health Addendum to the Disaster Resilience Scorecard for Cities is a useful tool for integrating relevant aspects of public health with disaster planning, mitigation and response. Examples include sanitation, disease prevention, nutrition, care for those who are already sick or disabled as a disaster happens, those who are injured or become sick as a result of the disaster, mental health issues, health logistics, more. Training webinar and links to many resources for disaster resilience are available online. See https://www.unisdr.org/campaign/resilientcities/toolkit/article/public-health-system-resilience-scorecard.
NATIONAL: Planning for Climate Change and Health	
National Integrated Heat Health Information System	The NIHHIS is an integrated system that builds understanding of the problem of extreme heat, defines demand for climate services that enhance societal resilience, develops science-based products and services from a sustained climate-science research program, and improves capacity, communication, and societal understanding of the problem in order to reduce morbidity and mortality due to extreme heat. The NIHHIS is a jointly developed system by the Centers for Disease Control and Prevention (CDC) and the National Oceanic and Atmospheric Administration. See https://nihhis.cpo.noaa.gov.
National League of Cities, Climate for Health, et al.	Moving Forward: A Guide for Health Professionals to Building Momentum on Climate Action. Guidance and tools to reduce energy use, build resilient clinics and health departments, and support policies, which better integrate health into climate solutions. See https://climateforhealth.org/wp-content/uploads/sites/2/2020/01/CFHMFG-web.pdf.
US Global Change Research Program	The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. Climate change is a significant threat to the health of the American people. This scientific assessment examines how climate change is already affecting human health and the changes that may occur in the future. See https://health2016.globalchange.gov/.

Table B-1. Resources for state and local governments, communities, tribes, faith organizations, and teachers to help plan for, address, and inform about climate change impacts.[a]

Source	Resource description
American Public Health Association	Climate Changes Health. A wealth of resources, including their Climate Change and Health Needs Assessment and their Climate Change and Health Strategic Plan. Understand and plan for the effects of climate change on health. See https://www.apha.org/topics-and-issues/climate-change.
Public Health Institute (PHI)	PHI's Center for Climate Change and Health's report explores the many ways in which climate change, health, and equity are connected. Presents a conceptual framework to show how these issues are linked, and to identify opportunities and recommendations for action. See https://www.phi.org/resources/?resource=climate-change-health-and-equity-opportunities-for-action.
Neighborhoods at Risk Tool	See where flooding, urban heat, and hurricanes impact the most vulnerable people. Map and explore information at the neighborhood level for every community in the US. See https://headwaterseconomics.org/tools/neighborhoods-at-risk/tool-about/
Centers for Disease Control and Prevention (CDC)	Climate and Health: Resources for Public Health Professionals. Resources include guidance, trainings, webinars, data, tools and videos for the range of essential public health services around climate and health. See https://www.cdc.gov/climateandhealth/default.htm; https://www.cdc.gov/climateandhealth/climate_ready.htm.
	Assessing Health Vulnerability to Climate Change: A Guide for Health Departments. Provides a suggested sequence of steps that health departments can undertake to assess local health vulnerabilities associated with climate change. See https://stacks.cdc.gov/view/cdc/24906.
	Climate and Health Intervention Assessment. Outlines evidence of effectiveness of various interventions for reducing the negative health impacts of climate change. Ninety pages of thoroughly cited, very helpful information. See https://www.cdc.gov/climateandhealth/docs/ClimateAndHealthInterventionAssessment_508.pdf.
	Information on the health effects of climate change, excerpted from the Third National Climate Assessment. Some existing health threats will intensify and new health threats will emerge. See https://www.cdc.gov/climateandhealth/effects/default.htm.
	The Building Resilience Against Climate Effects (BRACE) framework is a five-step process that allows health officials to develop strategies and programs to help communities prepare for the health effects of climate change. Combining atmospheric data and climate projections with epidemiologic analysis allows health officials to more effectively anticipate, prepare for, and respond to a range of climate sensitive health impacts. See https://www.cdc.gov/climateandhealth/BRACE.htm.
	CDC's Climate-Ready States and Cities Initiative (CRSCI) funds states and cities to use the five-step Building Resilience Against Climate Effects (BRACE) framework (described above). See https://www.cdc.gov/climateandhealth/climate_ready.htm.
National Academies Press	Protecting the Health and Well-Being of Communities in a Changing Climate: Proceedings of a Workshop. Presentations and discussions about regional, state, and local efforts to mitigate and adapt to health challenges arising from climate change. See https://www.nap.edu/download/24797.
US Government Accountability Office	Water infrastructure: Technical Assistance and Climate Resilience Planning Could Help Utilities Prepare for Potential Climate Change Impacts. This report examines federal technical and financial assistance to utilities for enhancing climate resilience, and options experts identified for providing additional assistance, among other things. See https://www.gao.gov/products/gao-20-24.

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Table B-1. Resources for state and local governments, communities, tribes, faith organizations, and teachers to help plan for, address, and inform about climate change impacts.[a]

Source	Resource description
ECONOMICS	
Moody's Investor Services	Moody's Report: Environmental Risks—Evaluating the impact of climate change on US state and local issuers. "Climate change is forecast to heighten US exposure to economic loss... This will be a growing negative credit factor for issuers without sufficient adaptation and mitigation strategies." See http://www.moodys.com/researchdocumentcontentpage.aspx?docid=PBM_1071949.
New York Times	"Moody's Buys Climate Data Firm, Signaling New Scrutiny of Climate Risks." See https://www.nytimes.com/2019/07/24/climate/moodys-ratings-climate-change-data.html.
Janney Investment Strategy Group	Muni Report, 10/22/19: Climate Change and Potential Impact on State and Local Government Credit Analysis. See https://www.janney.com/docs/default-source/latest-articles-insights/isg/municipal-market-monthly/climate-change-and-munis-(oct-22).pdf.
Pew Trust	"Climate Change Could Make Borrowing Costlier for States and Cities... now is the time for communities to make serious investments in climate resilience — or risk being punished by the financial sector in the future." See https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2019/10/01/climate-change-could-make-borrowing-costlier-for-states-and-cities.
London School of Economics and Political Science	2019 Report: The Missing Economic Risks in Assessments of Climate Change Impacts. Additional sponsors: Potsdam Institute for Climate Impact Research; Earth Institute at Columbia University. See http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2019/09/The-missing-economic-risks-in-assessments-of-climate-change-impacts-2.pdf.
Fitch Ratings	Environmental Risks in US State and Local Government Ratings (report available to Fitch Ratings Research subscribers). See https://www.fitchratings.com/site/re/10031874.
MONTANA	
MT Climate Solutions Council	This Governor's Council developed a Montana Climate Solutions Plan (June 2020), which provides recommendations and strategies aimed at preparing Montanans for climate impacts. See https://deq.mt.gov/DEQAdmin/dir/Climate.
MT Dept. of Environ. Quality	Daily air quality updates for Montana. See svc.mt.gov/deq/todaysair/smokereport/mostrecentupdate.aspx.
Climate Smart Montana	A non-partisan, non-profit network sharing information and resources to better coordinate community-based climate solutions and resiliency efforts in Montana. Access existing and proposed community resiliency plans in Montana. Join their listserve. See http://www.msucommunitydevelopment.org/ClimateSmartMontana.html.
Montana State University Extension	A listserve for Montana citizens and educators who want to share information on climate science and policy. See https://www.montana.edu/communitydevelopment/csm/index.html.
City of Bozeman	Bozeman's Climate Planning Framework provides summaries of 17 separate Bozeman plans related to climate and climate change impacts. See https://www.bozeman.net/home/showdocument?id=9681.

Table B-1. Resources for state and local governments, communities, tribes, faith organizations, and teachers to help plan for, address, and inform about climate change impacts.[a]

Source	Resource description
TRIBAL	
The Institute for Tribal Environmental Professionals	Northern Arizona University's ITEP's Tribal Climate Change Program offers training, technical assistance, educational resources, and tools to build the capacity of tribes to address climate change impacts. Resources include the ITEP Adaptation Planning Toolkit. See http://toolkit.climate.gov/tool/tribal-climate-change-adaptation-planning-toolkit.
Bureau of Indian Affairs: Tribal Resilience Program	BIA Tribal Resilience Program. Provides resources to tribes to build capacity and resilience through leadership engagement, delivery of data and tools, training and tribal capacity building. Competitive funding supports tribes and authorized tribal organizations to build resilience through tribally designed resilience training, adaptation planning, vulnerability assessments, supplemental monitoring, capacity building, and youth engagement. See https://www.bia.gov/bia/ots/tribal-resilience-program.
	US Climate Resilience Toolkit: Tribal Nations. Tribal Nations often integrate traditional knowledges with technology and diverse research methods to effectively address climate change and related impacts in a culturally appropriate community context. See https://toolkit.climate.gov/topics/tribal-nations.
	Tribal Resilience Resource Guide: Training. A wealth of training resources listed by the six strategies/subtopics described in the US Resilience Toolkit, Tribal Nations Topic. See https://biamaps.doi.gov/tribalresilience/resourceguide/training/index.html
National Indian Health Board	The Climate Ready Tribes Initiative: 1) Funds tribes to conduct local climate health work or research; 2) Hosts an Environmental Health and Climate Track at the Annual National Tribal Public Health Summit; 3) Shares materials including resources, information and opportunities, largely through the Climate and Health Learning Community. See https://www.nihb.org/public_health/climate_ready_tribes.php; https://www.nihb.org/public_health/climate_resources.php.
Blackfeet Nation	The Blackfeet Nation is building resilience to climate change. They are planning ahead, engaging young people, and sharing information about climate change and: air quality, extreme weather events, cancer, food safety and nutrition, heat-related illnesses, pregnant women, mental health and well-being, vector-borne diseases and water-related illnesses. Check out their Blackfeet Climate Change Adaptation Plan. See https://blackfeetclimatechange.com; https://bcapwebsite.files.wordpress.com/2018/04/bcap_final_4-11.pdf.
TEACHERS	
National Oceanic and Atmospheric Administration, US	Toolbox for Teaching Climate and Energy. Downloadable scientifically and pedagogically reviewed digital resources for teaching about climate's influence on us and our influence on climate. Prepare to teach the science and engineering called for in the new standards, which address major world challenges and opportunities, such as generating sufficient clean energy, building climate resilience for businesses and communities, maintaining supplies of food and clean water, and solving the problems of global environmental change. See https://www.climate.gov/teaching.

Table B-1. Resources for state and local governments, communities, tribes, faith organizations, and teachers to help plan for, address, and inform about climate change impacts.[a]

Source	Resource description
FAITH COMMUNITIES	
The Center for Large Landscape Conservation	Healthy Landscapes, Healthy People: A Guidebook for Montana Communities Preparing for a Changing Climate. A guide for people who are concerned about human health and climate change, with a specific focus on faith communities. Addresses impacts of climate change to landscapes and human health; how to protect landscapes to protect human health; things our communities can do; tools for planning and acting now to protect our future. See https://largelandscapes.org/wp-content/uploads/2019/03/Climate_Landscapes__Health_Guidebook_10.9.18.pdf.
Faith and Climate Action Montana	Educates individuals in faith communities about climate change and creates space for spiritual reflection on social and environmental issues. See faithandclimateactionmontana.weebly.com.
Faith, Science and Climate Action MT	The FSCA Conferences provide a supportive community learning environment for participants to discuss climate change and our moral obligations to families, neighbors, future generations, and vulnerable populations, and, fundamentally, to our planet. See fscaconference.org.
MT Interfaith Power and Light	Seeks to deepen the connection between ecology and faith. IPL has mobilized religious communities to be faithful stewards of creation through the promotion of energy conservation, energy efficiency, and renewable energy. See http://blessedtrinitymissoula.org/outreach/social-concerns-parish-team/interfaith-power-and-light/.
ecoAmerica	Blessed Tomorrow: Caring for Creation Today. Blessed Tomorrow is a coalition of diverse religious partners working to advance climate solutions in faithful service to God. Living our faith means leading on climate change as stewards of God's creation. See https://blessedtomorrow.org/.
LOCAL FOOD SYSTEMS AND AGRICULTURE	
Northern Plains Resource Council	Northern Plains is a grassroots conservation and family agriculture group that organizes Montanans to protect our water quality, family farms and ranches, and unique quality of life. See https://northernplains.org/about-us/.
Montana Farmers Union	Montana Farmers Union is a statewide grassroots organization working for family farmers, ranchers and rural communities through conferences, scholarships and other educational opportunities as well as legislative representation and support for producer-owned co-ops. See https://montanafarmersunion.com/.
Montana Organic Association	The MOA brings together people, businesses, organizations, and agencies working to develop Montana's organic sector and building its community. See https://montanaorganicassociation.org/.
Western Sustainability Exchange (WSE)	WSE conserves the abundance of the Northern Rockies including its open spaces; wildlife habitats; soil, air, and water resources; rural communities; and agricultural land and heritage. WSE consists of local, regional, national, and international partners working cooperatively to resolve problems facing the rural West. See https://www.westernsustainabilityexchange.org/about-wse.
There are many communities and county based groups as well – look into what is happening in your area.	

[a] Websites shown were active as of December 2020. For the latest resources and web links, go online to the Climate Change and Human Health link at the Montana Climate Assessment website (montanaclimate.org).

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Montana State University, Bozeman
Photo courtesy of Scott Bischke

GLOSSARY

adaptation — Actions taken to help communities and ecosystems better cope with potential negative effects of climate change or take advantage of potential opportunities.

adaptive capacity — Ability of a person (or society) to cope with climate change. Used to calculate vulnerability.

adverse childhood experiences — Potentially traumatic events that occur in childhood. Sometimes referred to as *ACEs*. These events can include violence, abuse, neglect, separation, substance abuse, mental health problems, or witnessing a family suicide. ACEs are linked to chronic health problems, mental illness, and substance misuse in adulthood. ACEs can also negatively impact education and job opportunities. ACEs can be prevented.

anthropogenic — Originating in human activity; human caused.

aquifer — A body of permeable rock that can contain or transmit groundwater.

atmospheric carbon dioxide (CO2) — The amount of carbon dioxide in Earth's atmosphere. Although the proportion of Earth's atmosphere made up by CO_2 is small, CO_2 is one of the most potent greenhouse gases and directly related to the burning of fossil fuels. Atmospheric carbon dioxide levels in Earth's atmosphere are at the highest levels in an estimated 3 million yr and these levels are projected to increase global average temperatures through the greenhouse effect.

attribution — Identifies a source or cause of something.

basin — A drainage basin or catchment basin is an extent or an area of land where all surface water from rain, melting snow, or ice converges to a single point at a lower elevation, usually the exit of the basin, where the waters join another body of water, such as a river, lake, reservoir, estuary, wetland, sea, or ocean.

biodiversity — The variety of all native living organisms and their various forms and interrelationships.

chronic disease — A disease or health condition lasting for a long time, usually more than 3 months. Examples include high blood pressure, chronic obstructive lung/pulmonary disease (COLD/COPD), cancer and diabetes.

climate change — Changes in average weather conditions that persist over multiple decades or longer. Climate change encompasses both increases and decreases in temperature, as well as shifts in precipitation, changing risk of certain types of severe weather events, and changes to other features of the climate system.

climate pressures — Events or processes either caused by or made more frequent due to climate change, including increased temperatures, sea-level rise, extreme precipitation events, and more extreme weather, such as storms.

climate variables — Essential information for understanding the Earth's climate, including average annual and season temperature and precipitation.

climate versus weather — The difference between weather and climate is a measure of time. Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time (i.e., multiple decades).

commodity futures — Buying or selling of a set amount of a commodity at a predetermined price and date.

COVID-19 — Respiratory illness and associated complications caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV2) that was first detected in humans in late 2019.

direct effect — A primary impact to a system from shifts in climate conditions (e.g., temperature and precipitation), such as direct mortality to species from increased heat extremes.

displacement — Forced migration due to conditions that prevent individuals, families, or communities from sustaining themselves in traditional locations. Those conditions might result from climate change—e.g., sea-level rise, floods, or drought—or social upheaval such as violence, persecution, or economic distress.

downscaling — A general term for procedures that take information known at large scales to make predictions at local scales.

drought — Drought is generally categorized in three ways: 1) *meteorological drought*, defined as a deficit in precipitation, 2) *agricultural drought*, commonly understood as a deficit in soil moisture, and 3) *hydrological drought*, characterized by reduced water levels in streams, lakes, and aquifers.

El Niño-Southern Oscillation (ENSO) — A periodic variation in wind and sea-surface temperature patterns that affects global weather; El Niño (warming phase where sea-surface temperatures in the eastern Pacific Ocean warm) generally means warmer (and sometimes slightly drier) winter conditions in Montana. In contrast, La Niña (cooling phase) generally means cooler (and sometimes wetter) winters for Montanans. The two phases each last approximately 6-18 months, and oscillate between the two phases approximately every 3-4 yr.

ensemble of general circulation models (GCMs) — *Succinctly:* When many different forecast models are used to generate a projection, and outputs are synthesized into a single score or average. This type of forecast significantly reduces errors in model output and enables a level of certainty to be placed on the projections. *More broadly:* Rather than relying on the outcome of a single climate model, scientists run ensembles of many models. Each model in the ensemble plausibly represents the real world, but as the models differ somewhat they produce different outcomes. Scientists analyze the outputs (e.g., projected average daily temperature at mid century) over the entire ensemble. Those analyses provide both the projection of the future resulting from the ensemble of models, and define the level of certainty that should be placed on that projection.

evaporation — The change of a liquid into a vapor at a temperature below the boiling point. Evaporation takes place at the surface of a liquid, where molecules with the highest kinetic energy are able to escape. When this happens, the average kinetic energy of the liquid is lowered and its temperature decreases.

exposure — The type and magnitude of a climate change. Used to calculate vulnerability.

fire regime — The frequency, severity, and pattern of wildfire.

fire risk — The likelihood of a fire ignition.

fire severity — The magnitude of effects from a fire, usually measured by the level of vegetation or biomass mortality or the area burned.

flood — An overflowing of a large amount of water beyond its normal confines, especially over what is normally dry land.

flood plain — An area of low-lying ground adjacent to a river, formed mainly of river sediments and subject to flooding.

food security / insecurity — Describes an individual's or community's ability to reliably access a sufficient quantity of affordable, nutritious food. The USDA defines *food security* into four categories: 1) *high* food security means having no food-access problems or limitations; 2) *marginal* food security means having some anxiety over food sufficiency, but little change in diets or food intake; 3) *low* food security (i.e., *food insecurity*) means reduced quality, variety, or desirability of diet, though little or no reduction in food intake; and 4) *very low* food security (again, *food insecurity*) means disrupted eating patterns and reduced food intake.

frost days — The annual count of days where daily minimum temperature drops below 32°F (0°C).

general circulation models (GCMs) — Numerical models representing physical processes in the atmosphere, ocean, cryosphere, and land surface. They are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations.

greenhouse gas — A gas in Earth's atmosphere that absorbs and then re-radiates heat from the Earth and thereby raises global average temperatures. The primary greenhouse gases in Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Earth relies on the warming effect of greenhouse gases to sustain life, but increases in greenhouse gases, particularly carbon dioxide from the burning of fossil fuels, can increase average global temperatures over historical norms.

greenhouse gas emissions — The discharge of greenhouse gases, such as carbon dioxide, methane, nitrous oxide and various halogenated hydrocarbons, into the atmosphere. Combustion of fossil fuels, agricultural activities, and industrial practices contribute to the emissions of greenhouse gases.

global warming — The increase in Earth's surface air temperatures, on average, across the globe and over decades. Because climate systems are complex, increases in global average temperatures do not mean increased temperatures everywhere on Earth, nor that temperatures in a given year will be warmer than the year before (which represents weather, not climate). More simply: *Gobal warming* is used to describe a gradual increase in the average temperature of the Earth's atmosphere and its oceans, a change that is believed to be permanently changing the Earth's climate.

groundwater — Water held underground in the soil or in pores and crevices in rock.

health factors — Factors that drive how long and how well people live including, for example, personal behaviors, socioeconomic factors, and the physical environment.

heat index — A measure of perceived heat when humidity, which can make it feel much hotter, is factored in with the actual measured air temperature. (A similar and more familiar term is *wind chill factor*, a measure of how cold it feels when wind, which can make it feel much colder, is factored in with the actual measured air temperature.)

heat stress — A buildup of body heat generated either internally by muscle use or externally by the environment. Heat exhaustion and heat stroke result when the body is overwhelmed by heat . As the heat increases, body temperature and the heart rate rise.

HEPA — high-efficiency particulate air (filters)

hydrograph — A hydrograph is a graph showing the rate of flow (discharge) versus time past a specific point in a river, or other channel or conduit carrying flow. The rate of flow is typically expressed as cubic feet per second, CFS, or ft^3/s (the metric unit is m^3/s).

hydrologic cycle — The sequence of conditions through which water passes from vapor in the atmosphere through precipitation upon land or water surfaces and ultimately back into the atmosphere as a result of evaporation and transpiration.

hydrology — The study of water. Hydrology generally focuses on the distribution of water and interaction with the land surface and underlying soils and rocks.

interpolation — The process of using points with known values to estimate values at other unknown points.

intervention — The act of interfering or interceding with the intent of modifying the outcome. In medicine, an intervention is generally undertaken to help treat or cure a condition.

irrigation — Application of water to soil for the purpose of plant production.

legume — Any of a large family (Leguminsoae syn. Fabaceae, the legume family) of dicotyledonous herbs, shrubs, and trees having fruits that are legumes or loments, bearing nodules on the roots that contain nitrogen-fixing bacteria, and including important food and forage plants (as peas, beans, or clovers).

mental health — The condition of being sound mentally and emotionally that is characterized by the absence of mental illness and by adequate adjustment, especially as reflected in feeling comfortable about oneself, positive feelings about others, and the ability to meet the demands of daily life.

metrics — Quantifiable measures of observed or projected climate conditions, including both primary metrics (for example, temperature and precipitation) and derived metrics (e.g., projected days over 90°F [32°C] or number of consecutive dry days).

metropolitan areas — Areas having at least one urbanized area of 50,000 or more population, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties.

microclimate — The local climate of a given site or habitat varying in size from a tiny crevice to a large land area. Microclimate is usually, however, characterized by considerable uniformity of climate over the site involved and relatively local when compared to its enveloping macroclimate. The differences generally stem from local climate factors such as elevation and exposure.

micropolitan areas — Areas having at least one urban cluster of at least 10,000 but less than 50,000 population, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties.

mitigation — Efforts to reduce greenhouse gas emissions to, or increase carbon storage from, the atmosphere as a means to reduce the magnitude and speed of onset of climate change

model — A physical or mathematical representation of a process that can be used to predict some aspect of the process.

organic — A crop that is produced without: antibiotics; growth hormones; most conventional pesticides; petroleum-based fertilizers or sewage sludge-based fertilizers; bioengineering; or ionizing radiation. USDA certification is required before a product can be labeled *organic*.

oscillation — A recurring cyclical pattern in global or regional climate that often occurs on decadal to sub-decadal timescales. Climate oscillations that have a particularly strong influence on Montana's climate are the El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO).

Pacific Decadal Oscillation (PDO) — A periodic variation in sea-surface temperatures that is similar to El Niño-Southern Oscillation, but has a much longer duration (approximately 20-30 yr). When the PDO is in the same phase as El Niño-Southern Oscillation, weather effects are more pronounced. For example, when both are in the warming phase, Montanans may experience an extremely warm winter, whereas if PDO is in a cooling phase, a warm phase El Niño-Southern Oscillation may have a reduced impact.

pandemic — An epidemic of a disease that has spread across a wide geographic region, either multiple continents or worldwide. (Contrast with an epidemic, which is a disease that is actively spreading. Thus, a pandemic is a specific type of epidemic that has spread more widely.)

parameter — A variable, in a general model, whose value is adjusted to make the model specific to a given situation.

pathogen — Microorganisms, viruses, and parasites that can cause disease.

peak flow — The point of the hydrograph that has the highest flow.

permeability — A measure of the ability of a porous material (often, a rock or an unconsolidated material) to allow fluids to pass through it.

pulse crop — Annual leguminous crops yielding from 1-12 grains or seeds of variable size, shape, and color within a pod. Limited to crops harvested solely for dry grain, thereby excluding crops harvested green for food, oil extraction, and those that are used exclusively for sowing purposes.

RCP (representative concentration pathways) — Imagined plausible trends in greenhouse gas emissions and resulting concentrations in the atmosphere used in climate projection models. This analysis uses the relatively moderate and more severe scenarios of RCP4.5 and 8.5. These scenarios represent a future with an increase in radiative forcing of 4.5 or 8.5 watts/m2, respectively. The RCP4.5 scenario assumes greenhouse gas emissions peak mid century, and then decline, while the RCP8.5 scenario assumes continued high greenhouse gas emissions through the end of the century.

resilience — In ecology, the capacity of an ecosystem to respond to a disturbance or perturbation by resisting damage and recovering quickly.

resistance — In ecology, the property of populations or communities to remain essentially unchanged when subject to disturbance. Sensitivity is the inverse of resistance.

runoff — Surface runoff (also known as *overland flow*) is the flow of water that occurs when excess stormwater, meltwater, or other sources flows over the Earth's surface.

scenario — Climate change scenarios are based on projections of future greenhouse gas (particularly carbon dioxide) emissions and resulting atmospheric concentrations given various plausible but imagined combinations of how governments, societies, economies, and technologies will change in the future. This analysis considers two plausible greenhouse gas concentration scenarios: a moderate (*stabilized*) and more severe (*upper-bound*) scenario, referred to as RCP4.5 and RCP8.5, respectively.

sensitivity — How sensitive a person is to climate change. Used to calculate vulnerability.

Snow Water Equivalent (SWE) — A common snowpack measurement that is the amount of water contained within the snowpack. It can be thought of as the depth of water that would theoretically result if you melted the entire snowpack instantaneously.

soil moisture — A measure of the quantity of water contained in soil. Soil moisture is a key variable in controlling the exchange of water and energy between the land surface and the atmosphere through evaporation and plant transpiration.

Sudden Infant Death / Sudden Unexpected Infant Death syndromes (SIDS / SUIDS) — unexplained death, usually during sleep, of a seemingly healthy baby less than a year old.

transpiration — The passage of water through a plant from the roots through the vascular system to the atmosphere.

vulnerability — The extent to which a person is susceptible to the impacts of climate change.

warm days — Percentage of time when daily maximum temperature >90^{th} percentile.

warm nights — Percentage of time when daily minimum temperature >90^{th} percentile.

water quality — The chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and/or to any human need or purpose.

watershed — An area characterized by all direct runoff being conveyed to the same outlet. Similar terms include basin, sub-watershed, drainage basin, catchment, and catch basin.

weather versus climate — See climate versus weather.

zoonosis (plural, zoonoses) — An infectious disease caused by a bacterium, virus, fungus, or other agent that has moved from non-human animals to humans. Recent examples include Ebola, HIV, and SARS-CoV2.

Pelicans on the Jefferson River
Photo courtesy of Scott Bischke

LIST OF CONTRIBUTORS

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Madison Boone is the Program and Communications Manager for the Montana Institute on Ecosystems (IoE) at Montana State University, a position she has held since 2017. Prior to joining the IoE, she served for two years with the non-profit One Montana and MSU-Extension Service in Gallatin County through the Big Sky Watershed Corps program, during which she worked on projects related to climate, agriculture, and water. Boone graduated magna cum laude in 2014 from Hendrix College with a BA in Biology and a BA in Environmental Studies.

Lori G. Byron MD, MS, of Hardin Montana, received a BS and BA from Kentucky Wesleyan College, her MD from University of Louisville, and completed a pediatric residency. She practiced pediatrics for 27 years on the Crow Indian Reservation. She is a past-president of the Montana Academy of Pediatrics. She co-chairs the Citizen's Climate Lobby Health Team and chairs Montana Health Professionals for a Healthy Climate. Lori is on the Children's Health Advisory Committee to USEPA and the Executive Committee of the Environmental Health Council at the American Academy of Pediatrics. She recently earned a MS in Energy Policy and Climate from Johns Hopkins.

Robert Byron MD, MPH, is an internist from Hardin, Montana. After receiving his undergraduate degree from Vanderbilt University, he served in the US Navy. Obtaining his medical degree from the University of Louisville School of Medicine, he then completed an internal medicine residency, later earning a master's in public health through the University of Washington. Dr. Byron worked on the Crow Indian Reservation for over 20 years, then later helped start Bighorn Valley Health Center in Hardin. A former governor of the Montana Chapter of the American College of Physicians, he also served on the Montana Board of Environmental Review. He is vice-chair of the Montana Health Professionals for a Healthy Climate and co-chairs the Citizen's Climate Lobby Health Team.

Amy Cilimburg is the Executive Director of Climate Smart Missoula where she develops local climate solutions and works to build networks and community resiliency. Amy helped launch Climate Smart in 2015 following efforts to develop Missoula's municipal and community Climate Action Plans. Based in Missoula, she has worked on climate and energy policy and conservation for over a decade. Amy has a MS degree in Wildlife Biology from the University of Montana. She is on the Board of the Missoula's Mountain Line Transit System and is a member of the Governor's Climate Solutions Council.

Margaret (Mari) Eggers PhD is a research assistant professor in environmental health at Montana State University Bozeman (MSU). She previously lived in Crow and taught science at Little Big Horn College for a decade. Since 2005 Eggers has been working with Crow colleagues and others on community-engaged research and mitigation to reduce exposure to waterborne contaminants, improve access to safe drinking water and understand the impacts of climate change on water resources and community health. Eggers teaches environmental and global health, is the Associate Director for MSU's accredited Environmental Heath degree program and serves on the local Board of Health. Eggers has a BA and MA (Stanford), an MS in Ecology and a PhD in environmental health (MSU).

Angelina Gonzalez-Aller PhD is a researcher, educator, and organizer working at the intersections of health, climate change, and social justice. Angelina holds a PhD in political science, specializing in racial and ethnic studies, health disparities, and US policymaking. Angelina currently works at the Center for Large Landscape Conservation as the Community Resilience Program Manager where she strives to support communities in their efforts to achieve conservation goals and prepare for a changing world.

Philip Higuera PhD is an Associate Professor of fire ecology in the Department of Ecosystem and Conservation Sciences at the University of Montana. He directs the PaleoEcology and Fire Ecology Lab, funded largely from the National Science Foundation and Joint Fire Science Program, and he teaches undergraduate and graduate courses in fire and disturbance ecology. Work from his lab spans western North America and reveals how fire activity and forest ecosystems vary with climate change, in recent decades and the distant past.

Susan Higgins MS is an Associate with the Center for American Indian and Rural Health Equity and Montana INBRE at MSU. Prior, Sue was water planner for the State of Montana, and facilitated research exchanges for The Tributary Fund in Mongolia and Montana. She was also director for water research communications at MUS Water Center and a founding director for the Montana Watercourse. A trained facilitator, Sue has authored guides on topics such as streambank stabilization and wetlands management. She was consultant for the Roundtable on the Crown of the Continent and the National Drought Resiliency Project and has co-developed best practices for scientists engaging globally with faith and indigenous communities.

Paul Lachapelle PhD is Professor in the Department of Political Science at Montana State University-Bozeman. His teaching and research spans many disciplines and practices, including community climate-change resiliency, diversity and inclusion, and social justice topics. His publications include the edited book, *Addressing Climate Change at the Community Level* (Routledge 2019), as well as journal articles on energy impacts in communities, democratic practice, and local governance. He earned a PhD (Forestry) at the University of Montana's College of Forestry and Conservation and serves as a member of the Board of Directors (and past-President) of the International Association for Community Development.

Miranda Margetts PhD is an instructor (Department of Land Resources and Environmental Science) and research assistant (Center for American Indian and Rural Health Equity) at Montana State University. She received her legal qualifications and worked as a health lawyer in Australia before moving into health research in the US. Miranda also holds a research affiliate position with the Department of Obstetrics, Gynecology and Reproductive Sciences at Yale University, for her role on an international women's reproductive health study. She also serves as a member of the Board of Trustees for the Community Memorial Health System in Ventura County, California.

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Jennifer Robohm PhD is a clinical psychologist on the faculty of the University of Montana Family Medicine Residency of Western Montana. She is part of the 2020 class for the Bloomberg Fellowship Program at the Bloomberg Johns Hopkins School of Public Health, where she will be working on the physical and mental health impacts of climate change in Montana. Dr. Robohm and Hayley Blackburn, PharmD, recently received a planning grant from the Montana Healthcare Foundation to develop "climate change and health" curriculum and continuing education programming for health care trainees and practicing health professionals in our state.

Nick Silverman PhD, PE is a Faculty Affiliate and Adjunct Professor at the University of Montana in Geosciences and the College of Forestry. His academic research focuses on identifying hydroclimatic trends in mountainous landscapes and the interactions between water, climate, and vegetation. Nick has a background in Physics and Engineering and is a licensed Civil and Water Resources Engineer in the State of Montana. He received a PhD in Hydroclimatology from the University of Montana in 2014 and led the climate analysis for the *2017 Montana State Climate Assessment*. Currently, Nick works around Montana and the greater Pacific Northwest on projects that help land managers build adaptive capacity to solve food, water, and energy challenges related to climate change.

Eliza Webber MPH is a Research Project Manager at the Center for American Indian and Rural Health Equity at Montana State University. She graduated with an MPH from Yale School of Public Health in 2015, specializing in chronic disease epidemiology and social and behavioral science. Since then, she has worked in program evaluation, assessing community-wide diabetes prevention interventions, and in clinical health outcomes research, using state and nation-wide datasets to explore indicators and trends in pediatric cardiac disease. Eliza's work is driven by her passion for eliminating health disparities.

Cathy Whitlock PhD is a Regents Professor in Earth Sciences and Fellow of the Montana Institute on Ecosystems at Montana State University. She is recognized nationally and internationally for her scholarly contributions and leadership activities in the area of long-term environmental and climate change, with much of her research focused on Montana. Whitlock has published over 200 scientific papers on this topic. She is a member of the National Academy of Sciences, a Fellow of the American Association for the Advancement of Science, and a Fellow of the Geological Society of America. Whitlock is lead author of the *2017 Montana Climate Assessment*.

Get involved and be part of the solution!

Use the information in this report to help yourself, your community, and Montana address climate change.

Everyone has a role to play!

Two views from Wild Horse Island in Flathead Lake:
* Smoke-covered Melita Island, August 2020
* Normal view of Mission Mountains, inset

Photos courtesy of Bruce Maxwell

Back cover: Tipi, mountain fires, and the Milky Way
Photo courtesy of Chema Domenech (copyright 2018)

What Professional Organizations are Saying

A number of professional organizations, health-focused and otherwise, have developed policies or position statements regarding the impacts of climate change on human health. Following are a collection of quotes from a number of these trusted resources.

- *Montana Farmer's Union.*—"As the impacts of climate change mount, producers will need to be armed with the latest research, information and tools to mitigate the adverse effects, adapt to the changing conditions and continue providing a safe, reliable and healthy food source for the world." [1]

- *Montana Climate Change Advisory Committee.*—"Explicitly articulated public education and outreach can support GHG emissions reduction efforts at all levels in the context of emissions reduction programs, policies, or goals. Public education and outreach is vital to fostering a broad awareness of climate change issues and effects (including co-benefits, such as clean air and public health) among the state's citizens." [2]

- *US Department of Health and Human Services.*—"The US Department of Health and Human Services considers climate change to be one of the top public health challenges of our time." [3]

- *National Institute of Environmental Health Sciences.*—"While climate change is a global process, it has very local impacts that can profoundly affect communities. It can affect people's health and well-being in many ways, some of which are already occurring." [4]

- *National Indian Health Board.*—"Tribal communities can be particularly vulnerable to the health effects associated with climate change for a variety of reasons. There are already existing and pronounced health disparities in Native communities that can lead to the health impacts from environmental damage being much more severe." [5]

- *Medical Society Consortium on Climate and Health's Climate, Health, and Equity Policy Action Agenda.*—"Climate change is a public health emergency. We call on our nation's leaders to act now by mobilizing climate actions for our health, and health actions for our climate. With the right policies and investments today, we have the opportunity to realize our vision of healthy people in healthy places on a healthy planet." [6] (Note: This statement was signed by over 100 health organizations.)

- *National Academy of Medicine.*—"The negative impacts of climate change disproportionately affect the very young and the very old, people who are ill, impoverished or homeless individuals, and populations that depend on the natural environment for survival. Urgent action is needed to mitigate the health consequences of climate change for these populations, among others. ... Climate change represents one of the most significant threats to human health in the 21st century." [7]

- *Lancet Commission Report on Health and Climate Change: Policy Responses to Protect Public Health, 2015.*—"Climate change...threatens to undermine the last half century of gains in development and global health. ... Tackling climate change could be the greatest global health opportunity of the 21st century." [8]

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1 https://montanafarmersunion.com/wp-content/uploads/2016/01/MFU_Climate_Final.pdf
2 https://deq.mt.gov/Portals/112/Energy/ClimateChange/Documents/FinalReportChapters.pdf
3 https://www.hhs.gov/climate/index.html
4 https://www.niehs.nih.gov/health/topics/agents/climate-change/index.cfm
5 https://www.nihb.org/docs/10102019/Climate%20Change%20&%20Tribes%20Article.pdf
6 https://climatehealthaction.org/cta/climate-health-equity-policy/
7 https://nam.edu/programs/climate-change-and-human-health/
8 https://www.ncbi.nlm.nih.gov/pubmed/26111439

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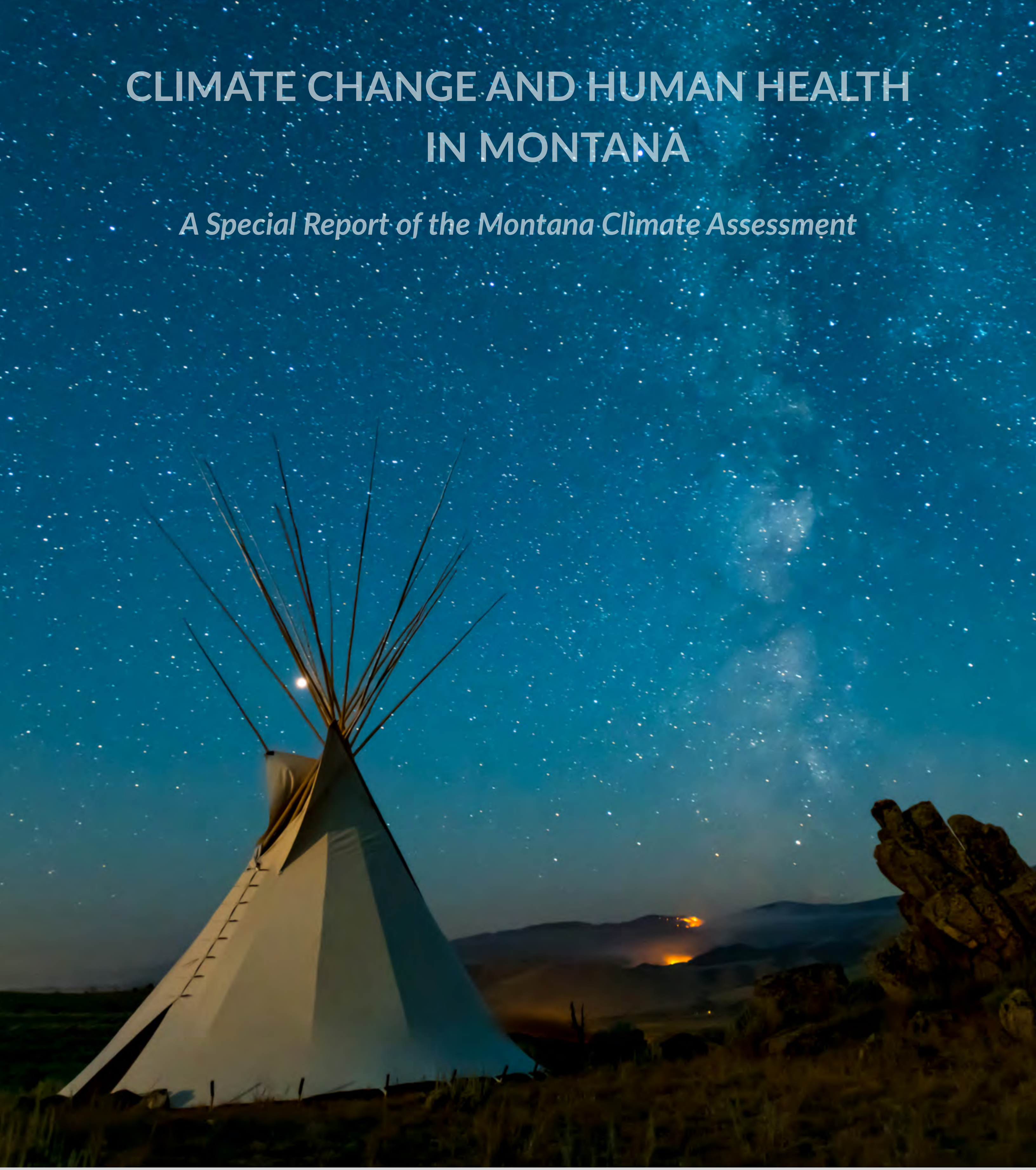
A Special Report of the Montana Climate Assessment



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