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Climate Change and Human Health in Montana

A Special Report of the Montana Climate Assessment

Alexandra Adams, Rob Byron, Bruce Maxwell, Lori Byron, Susan Higgins, Margaret Eggers, Cathy Whitlock

ON THIS PAGE
Bridger Mountains near Bozeman.
Photograph courtesy of Scott Bischke.

ON THE COVER
Hailstorm, Pioneer Mountains in southwest Montana.
Photograph courtesy of Scott Bischke.

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Contents

Figures and Sidebars

Tables

Missouri River near Loma, Montana. Photograph courtesy Scott Bischke.

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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)
IPCC—Intergovernmental Panel on Climate Change
MCA—Montana Climate Assessment
MTDPHHS—Montana Department of Public Health and Human Services
NOAA—National Oceanic and Atmospheric Administration
NWS—National Weather Service
PM—particulate matter
PTSD—post-traumatic stress disorder
RCPs—representative concentration pathways

Looking south from the M Trail near Bozeman, Montana. Photograph courtesy Scott Bischke.

Foreword

Author—affiliation

Text to come…

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* refers 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).

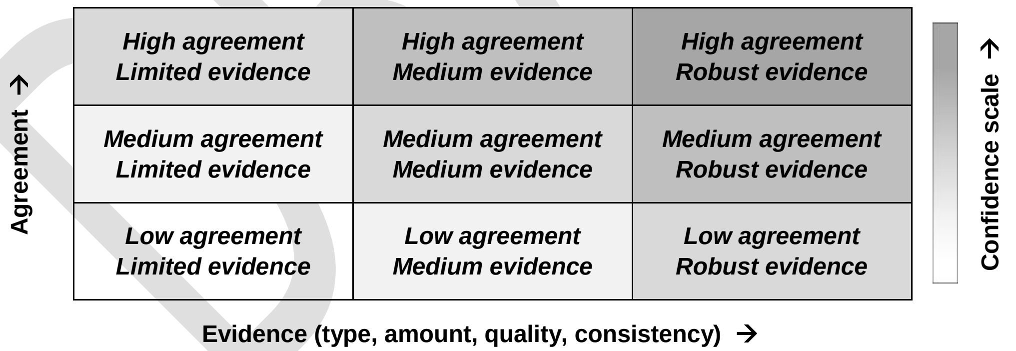


Figure Key Messages-1. A depiction of evidence and agreement statements and their relationship to confidence. Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent, and independent lines 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. The 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 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 in the coming decades and average annual temperature may be 9.8°F 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; and 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 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). [*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,

[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 how hot it feels when humidity, which can make it feel much hotter, is factored in with the actual measured air temperature.

Climate Change and Human Health in Montana.

Key Messages

- Increased summer temperatures and wildfire occurrence will worsen heat- and smoke-related health problems, such as asthma and cardiopulmonary illness, and are of most immediate concern. [*high agreement, robust evidence*]
- Early snowmelt, intense precipitation events, and projected increases in floods will lead to more gastrointestinal disease due to contamination of water supplies, as well as increased opportunities for food-, water-, and vector-borne diseases. Allergies and asthma associated with mold contamination of homes will increase. [*high agreement, moderate evidence*]
- Summer drought poses challenges to food security, and to the safety and availability of public water supplies, especially for individuals and communities relying on surface water. [*high agreement, robust evidence*]
- Projected changes in climate will impact the availability of many traditional subsistence, ceremonial, and medicinal plants, which in turn threaten food security, community health, and cultural well-being for tribal communities. [*high agreement, moderate evidence*]
- Extreme weather, higher temperatures, and uncertainty in livelihoods related to agriculture, forestry, and tourism may cause or exacerbate stress and/or mental illness. [*high agreement, robust evidence*]
- Climate change contributes to rapid emergence of new infectious diseases, as with the 2020 coronavirus pandemic (SARS-CoV2/COVID-19), and can impact Montanans even though the disease may originate elsewhere. [*high agreement, robust evidence*]

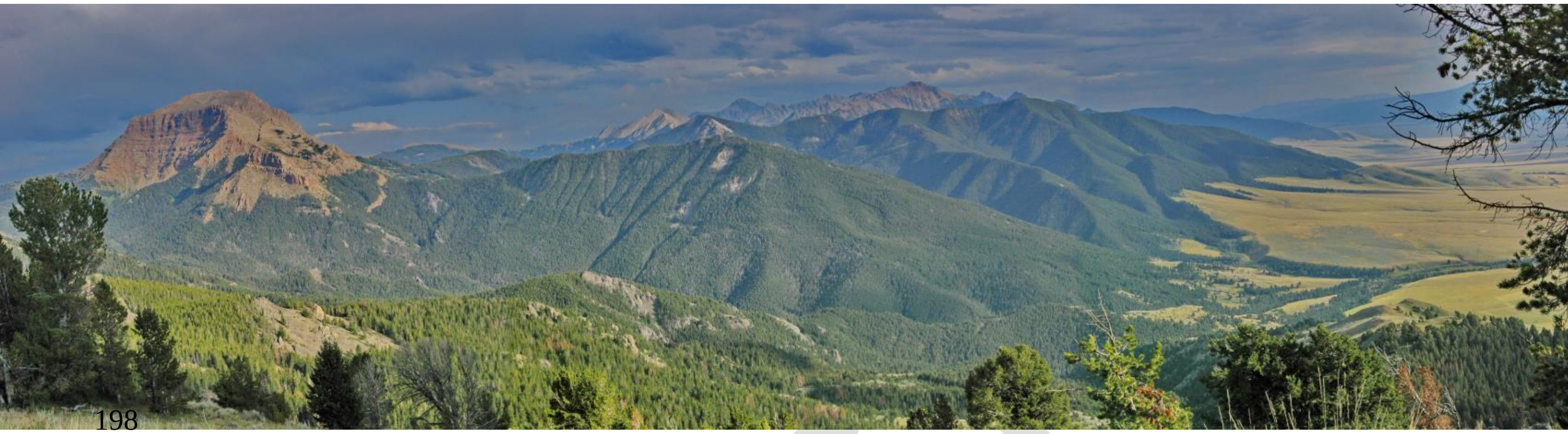
Recommendations

- To understand and mitigate health effects, we need better information at the statewide and local levels on climate and health to facilitate public health and medical decision-making.
    - We need to increase a) the network of meteorological stations in the state; b) the spatial resolution of climate projections to provide county-level information; and c) monitoring of air quality (smoke as particulate matter) across Montana.
    - We need a shared, statewide monitoring process of health-facility visits related to climate change. Of special importance are visits related to smoke, heat or mold exposure, waterborne disease, or mental health concerns.
- Improve public health capacity to foster increased collaboration and data sharing among health and climate scientists, public health practitioners, emergency service professionals, and clinicians. This collaborative network will assure appropriate decision-making, from state-level to individual-patient focus.
- To improve both their public health and economies, communities need funding and technical support to utilize the proposed collaborative network to plan and prepare for climate change and its impacts on human health, with special attention to Montana's most vulnerable populations.

LITERATURE CITED

[IPCC] Intergovernmental Panel on Climate Change. 2014. Climate change 2014: synthesis report: contribution of working groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. Pachauri RK, Meyer LA, eds. Intergovernmental Panel on Climate Change, Geneva Switzerland. 151 p.

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.



Section 1. Introduction

— Cathy Whitlock, Alexandra Adams, Robert Byron, Bruce Maxwell, Lori Byron, Susan Higgins, Margaret Eggers

The purpose of this assessment is a) to present understandable, science-based, Montana-specific information about the impacts of climate change on the health of Montanans; and b) to describe how our state can best prepare for and respond to those impacts in the coming decades. This assessment draws from, and is an extension to, the *2017 Montana Climate Assessment* (MCA[2]) (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 void; it is intended to serve as a foundation for collaboration between climate scientists and the healthcare community. The report is broken into four 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 effects of climate change on human health, globally and in Montana.

[2] 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.

- 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, and those living remotely.
- 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.

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 information and relevant stories specific to Montana.

> "*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 respond to those impacts in the coming decades. ... [It] is intended to serve as a foundation for collaboration between climate scientists and the healthcare community.*"

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 per decade since 1950, which is faster than the US average (0.26°F).
- Climate projections indicate continued warming in the coming decades with temperature increases of 4.5-6.0°F by mid century.[3]
- Days above 90°F 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 wildfire occurrence 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

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

weather events. MCA finds that although there has been no significant change in statewide mean annual precipitation since 1950, summer precipitation has decreased, while spring and fall precipitation have slightly increased. Projections indicate more year-to-year and season-to-season variability in precipitation, early loss of snow, and summer drought (Whitlock et al. 2017).

Montana, a rural state with widely spaced urban centers, 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).

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 in resource-extraction industries

Report Purpose and Genesis

To date we have limited specific understanding 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 will 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 in 2020, 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 impact 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 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.

LITERATURE CITED

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.

Section 2. Climate Change and Human Health in Montana

— Cathy Whitlock [4]

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.

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 and evaporation are 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.

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[4] 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*.

CLIMATE DIFFERS FROM WEATHER

Climate change is a description of a region's average weather conditions as they vary over multiple 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.

> *Climate change is a description of a region's average weather conditions as they vary over multiple 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.*

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-South Oscillation (ENSO) is an example of a climate pattern in our region that varies from year to year depending on ocean-atmospheric 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:

- *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.

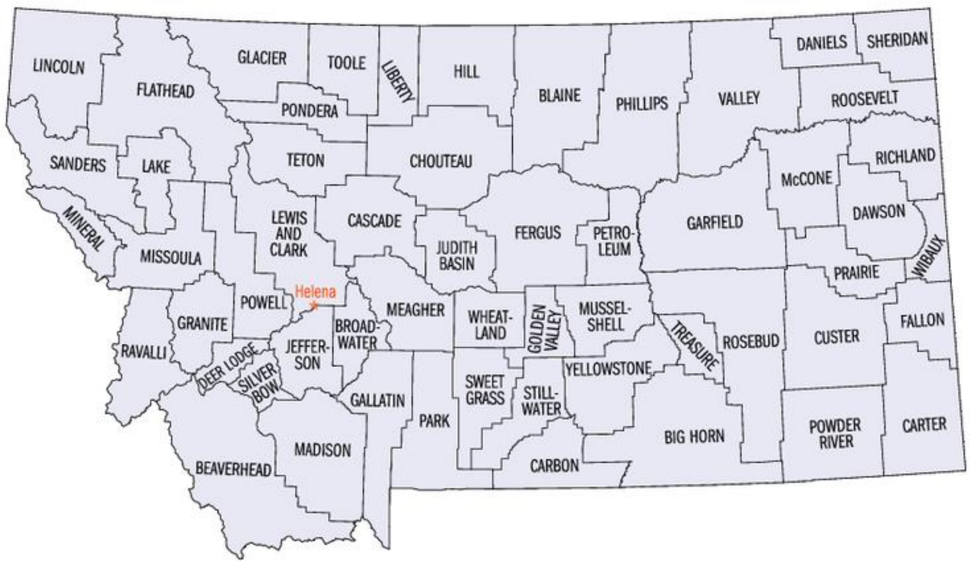


Figure 2-1. Montana consists of 56 counties.

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).

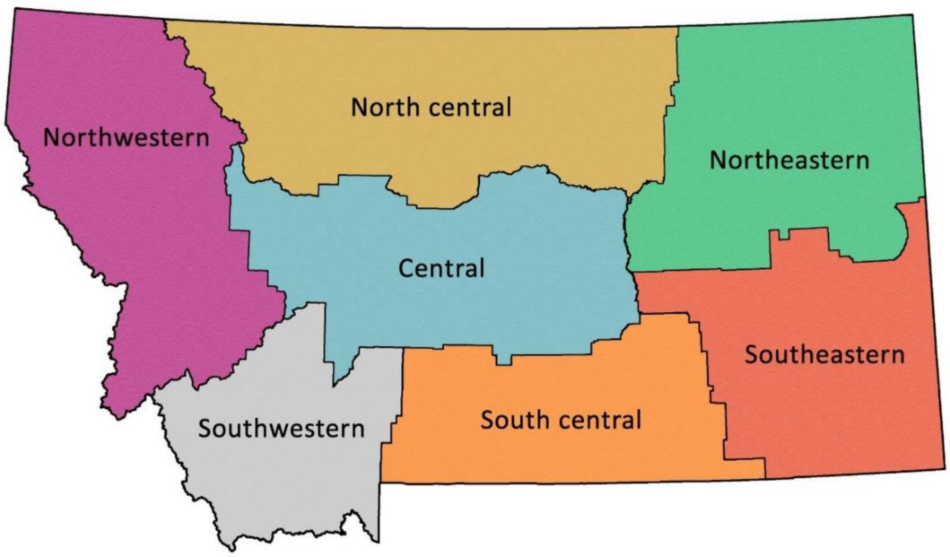


Figure 2-2. Montana's seven climate divisions. Note that NOAA officially names the northwestern division on this map as the *western* division. We use *northwestern* for geographic clarity.

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. The result was projections of future climate for each Montana climate division.

We all wonder about the trajectory of warming 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[5], as decribed 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.*

Temperature

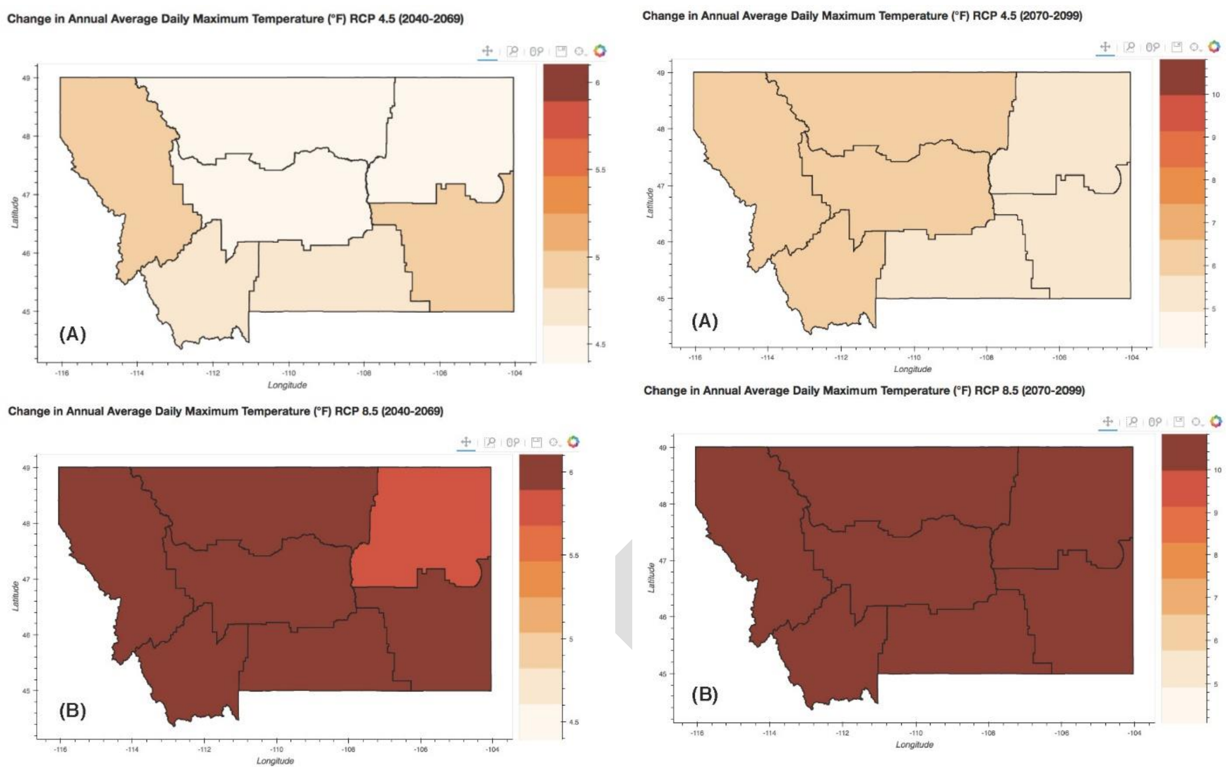
Increasing temperatures, the most direct consequence of rising greenhouse gases, are a major health concern for Montana, the nation, and the globe. Air temperature has increased in recent decades and that warming will continue in the future. MCA shows that the rate of change per decade in average annual temperature for the period from 1950-2015 was about 0.4^{o}F statewide, which equates to 2-3^{o}F warming in the last 65 yr (Whitlock et al. 2017). More recently, the years 2015 and 2016 were the second and third warmest of the last 70 yr, with average annual temperatures 3.2 and 2.9^{o}F above the base period of 1971-2000. Likewise, 2017 had average annual temperatures 1.5^{o}F above this base

[5] 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.

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^{o}F/decade) has been greater than that of the US (0.15^{o}F/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^{o}F/decade, amounting to an increase of approximately 3.3^{o}F 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^{o}F higher under the RCP4.5 scenario and 6^{o}F higher under RCP8.5 than the base period (1971-2000). All models show these general projections. End-of-century average annual temperatures for the state are more dramatic: increases of 5.6^{o}F in RCP4.5 and 9.8^{o}F 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.



Mid century ***End of century***

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) 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) 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 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 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 absence of cold days in winter by the end of the century is an important projection in the MCA (Whitlock et al. 2017).

> *The upper-bound emission scenario (RCP8.5) shows approximately 34 additional days exceeding 90^{o}F 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 absence of cold days in winter by the end of the century is an important projection 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), 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), with moisture sources coming from a combination of Pacific storms in winter and convective storms from the Gulf of Mexico 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 anomalies in the future, as warmer temperatures force earlier melting and runoff.

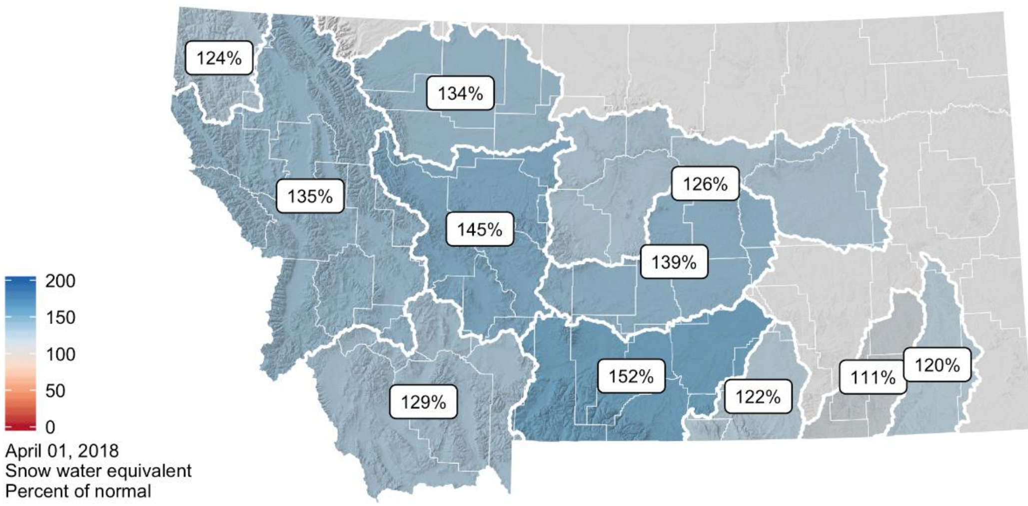


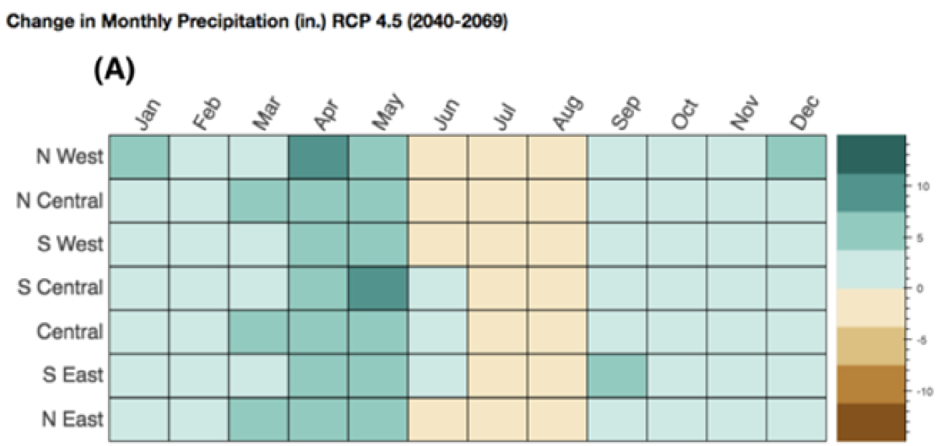
Figure 2-4. The Montana Drought and Climate report from the Montana Climate Office showing snowpack in 2018 as measured by the April 1 snow water equivalent (MCO 2019). The Upper Missouri River Basin above Fort Peck Reservoir was 127% of normal in 2018, and unusually high snowpack contributed to soil moisture recharge and good growing conditions in summer.

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 the 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 more in the northwestern and north central regions and 0.9 inch/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 in the western half of the state and 1.8 inch/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.

> “ *MCA projections indicate that winters, springs, and fall will get wetter and summers will get drier in the coming decades, with the likelihood of effective moisture decreasing in all seasons because of rising temperatures.*

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 is actually experienced) 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 and decreases in summer precipitation of -0.2 inch/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 decreasing in all seasons because of rising temperatures (Whitlock et al. 2017).



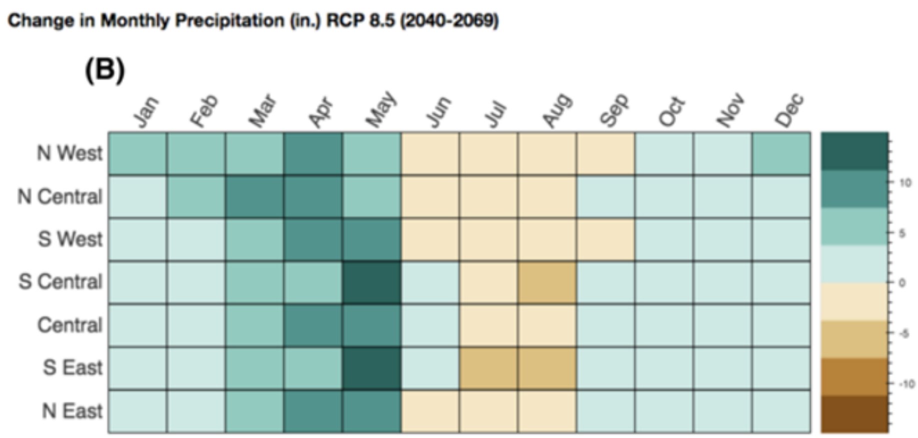


Figure 2-5. Projected monthly change in average precipitation (inches; color scale to the right) for each climate division in Montana in the mid-century projection (2040-2069) for (A) stabilization (RCP4.5) and (B) upper-bound (RCP8.5) emission scenarios (Whitlock et al. 2017).

CLIMATE CONCERNS FOR HUMAN HEALTH

Given this background in how climate change has impacted, and is expected to impact, Montana, we turn to an overview of how those impacts 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^{o}F by mid century and possibly as great as 9.8^{o}F by the end of the century, based on RCP8.5 (upper-bound) emission scenario[6]. 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[7] 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 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 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 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 trap heat, reduce transparency, and create 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: warmer summers dry vegetation and increase fuels, setting 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 is now a local priority in planning efforts (Schoennagel et al. 2017; McWethy et al. 2019).

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

[6] 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.

[7] Heat index is a measure of how hot it feels when humidity, which can make it feel much hotter, is factored in with the actual measured air temperature.

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. Droughts are abrupt or gradual. In the first 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). In contrast, 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 mosquitos that are better able to 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).

Sidebar: 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 across both countries. US agricultural losses alone exceeded $2.6 billion dollars.

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 (Jensco et al. 2019).

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

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). Montana Fish, Wildlife, and Parks closed a 184-mile stretch of the Yellowstone River in 2016 because of a massive fish kill attributed to the warm temperatures leading to a proliferative kidney disease (MFWP 2016).

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, in part because their documented record is relatively short, going back only to the 1950s. 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, early snowmelt, large wildfires, spring flooding, late-season drought, and extreme weather events 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.

Sidebar: 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 much stronger climate change risk perceptions compared to the public in recent surveys and in most previous surveys of US health professionals. Risk perception evaluates a person's personal concern about risks—if 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 action.

Of these health professionals, most felt that their own health was already being affected by climate change. Most felt that mental health effects from climate change would be a concern in the future for their community. Three-fourths felt that health departments should be preparing to deal with the public and environmental health effects of climate change, although only 29% of the departments were currently doing so. Almost all felt that multiple entities should be working to address climate change: governments (federal, state, local, tribal), elected officials, non-profits, businesses, individuals, and healthcare providers.

Analysis done in conjunction with the 2019 Yale Climate Opinion Maps for Montana estimates 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 2019). In a study to assess Montanan's opinions on energy and conservation, Metz (2016) finds that 51% of respondents felt action should be taken on climate change.

LITERATURE CITED

Byron L. 2019. Significant concern about climate among Montana public health and environmental health professionals [masters' thesis]. Baltimore MD: Johns Hopkins University. 48 p. Available online https://jscholarship.library.jhu.edu/handle/1774.2/62338. Accessed 31 Mar 2020.

CBS News. 2010 (Jun 1). Montana tornado rips roof off sports arena [news report]. Available online https://www.cbsnews.com/news/montana-tornado-rips-roof-off-sports-arena/. Accessed 1 Mar 2020.

[CDC] Centers for Disease Control and Prevention. [undated]. Drought and health [website]. Available online https://www.cdc.gov/nceh/drought/default.htm. Accessed 1 Mar 2020.

Clarke L, Edmonds J, Jacoby H, Pitcher H, Reilly J, Richels R. 2007 (Jul). Scenarios of greenhouse gas emissions and atmospheric concentrations. Sub-report 2.1a of synthesis and assessment product 2.1 by the US Global Change Science Program and the Subcommittee on Global Change Research. Washington DC: Department of Energy, Office of Biological & Environmental Research. 164 p. Available online https://globalchange.mit.edu/sites/default/files/CCSP_SAP2-1a-FullReport.pdf. Accessed 22 May 2020.

Collins M, Knutti R, Arblaster J, Dufresne J-L, Fichefet T, Friedlingstein P, Gao X, Gutowski WJ, Johns T, Krinner G, Shongwe M, Tebaldi C, Weaver AJ, Wehner M. 2013. Long-term climate change: projections, commitments and irreversibility [chapter]. In: Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds). Climate change 2013: the physical science basis; contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge UK: Cambridge University Press. p. 1136.

Diffenbaugh NS, Scherer M, Trapp RJ. 2013. Global warming and severe thunderstorms. Proceedings of the National Academy of Sciences 110:16361-6. doi:10.1073/pnas.1307758110.

Guardian. 2019. Summer heatwaves in France killed 1500, says health minister [article]. Available online https://www.theguardian.com/world/2019/sep/09/summer-heatwaves-in-france-killed-1500-says-health-minister. Accessed 1 Mar 2020.

Jensco K, Parker B, Downey M, Hadwen T, Howell A, Rattling Leaf J, Edwards L, Akyuz A, Kluck D, Peck D, Rath M, Syner M, Umphlett N, Wilmer H, Barnes V, Clabo D, Fuchs B, He M, Johnson S, Kimball J, Longknife D, Martin D, Nickerson N, Sage J, Fransen T. 2019. Flash drought: lessons learned from the 2017 drought across the US northern plains and Canadian prairies [report]. Boulder CO: NOAA, National Integrated Drought Information System. 76 p. Available online https://www.drought.gov/drought/sites/drought.gov.drought/files/NIDIS_LL_FlashDrought_2017_low-res_Final.pdf. Accessed 15 Sep 2019.

Kossin JP, Hall T, Knutson T, Kunkel KE, Trapp RJ, Waliser DE, Wehner MF. 2017: Extreme storms [chapter 9]. In: Wuebbles DJ, Fahey DW, Hibbard, DJ, Dokken DJ, Stewart BC, Maycock TK (eds). Climate Science Special Report: Fourth National Climate Assessment, Volume I. Washington DC: US Global Change Research Program. p 257-76. Available online https://science2017.globalchange.gov/downloads/CSSR2017_FullReport.pdf. Accessed 12 May 2020.

Marlon J, Howe P, Mildenberger M, Leiserowitz A, Wang X. 2019 (Sep 17). Yale Program on Climate Change Communication; Yale climate opinion maps 2019 [website]. Available online https://climatecommunication.yale.edu/visualizations-data/ycom-us/. Accessed 25 Nov 2019.

Martin C, Doyle J, LaFrance J, Lefthand MJ, Young SL, Three Irons E, Eggers M. 2020. Change rippling through our waters and culture. Journal of Contemporary Water Research and Education 169:61-78.

[MCO] Montana Climate Office. 2019 (April). Montana drought and climate [newsletter]. Available online https://climate.umt.edu/mtdrought/mtdrought-2019-april.pdf. Accessed 15 Sep 2019.

McWethy DB, Schoennagel T, Higuera PB, Krawchuk M, Harvey BJ, Metcalf EC, Schultz C, Miller C, Metcalf AL, Buma B, Virapongse A, Kulig JC, Stedman RC, Ratajczak Z, Nelson CR, Kolden C. 2019. Rethinking resilience to fire. Nature Sustainability 2:797-804. doi:10.1038/s41893-019-0353-8.

Metz D, Weigel L. 2016. Montana voter attitudes on energy and conservation in 2016 [slide presentation]. Available online https://climateadvocacylab.org/system/files/57ec4f056ad44.pdf.pdf. Accessed 12 May 2020.

[MFWP] Montana Fish, Wildlife, and Parks. 2016 (Aug 19). Yellowstone River closed in response to ongoing fish kill [press release]. Available online http://fwp.mt.gov/news/newsReleases/headlines/nr_4277.html. Accessed 1 Mar 2020.

[NASA] National Aeronautics and Space Administration. [undated]. NASA—What's the difference between weather and climate? Available online https://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html. Accessed 15 Sep 2019.

[NIDIS] National Integrated Drought Information System. [undated]. Drought.gov: drought in Montana [website]. Available online https://www.drought.gov/drought/states/montana. Accessed 12 May 2020.

[NOAAa] National Oceanic and Atmospheric Administration. [undated]. NOAA, National Centers for Environmental Information: US climate divisions. Available online https://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php. Accessed 15 Sep 2019.

[NOAAb] National Oceanic and Atmospheric Administration. [undated]. NOAA, National Centers for Environmental Information: climate at a glance. Available online https://www.ncdc.noaa.gov/cag/statewide/time-series. Accessed 15 Sep 2019.

[NOAAc] National Oceanic and Atmospheric Administration. [undated]. NOAA, National Weather Service: flooding in Montana. Available online https://www.weather.gov/safety/flood-states-mt. Accessed 15 Sep 2019.

[NOAAd] National Oceanic and Atmospheric Administration. [undated]. NOAA, National Centers for Environmental Information: billion-dollar weather and climate disasters: overview. Available online https://www.ncdc.noaa.gov/billions/. Accessed 15 Sep 2019.

[NOAA] National Oceanic and Atmospheric Administration. 2010. Billings tornado of June 20, 2010: overview [internal report]. 3 p. Available online https://www.wrh.noaa.gov/byz/local_news/2010/BillingsTornado10.pdf. Accessed 1 Mar 2020.

Schoennagel T, Balch J, Brenkert-Smith H, Dennison P, Harvey B, Krawchuk M, Morgan P, Moritz M, Rasker R, Turner GG, Whitlock C. 2017. Adapt to more wildfires in western North American forests as climate changes. Proceedings of the National Academy of Sciences 114:4582-90.

Seeley JT, Romps DM. 2015. The effect of global warming on severe thunderstorms in the United States. Journal of Climate 28:2443-58.

Smith E, Ahmed S, Dupuis V, Running Crane M, Eggers M, Pierre M, Flagg K, Byker Shanks C. 2019. Contribution of wild foods to diet, food security, and cultural values amidst climate change. Journal of

Agriculture, Food Systems, and Community Development 9(B):191-214. https://doi.org/10.5304/jafscd.2019.09B.011.

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.

[WCRP] World Climate Research Program. [undated]. WCRP climate model intercomparison project [website]. Available online https://www.wcrp-climate.org/wgcm-cmip. Accessed 12 May 2020.

Section 3. Climate-Change-Related Health Impacts

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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. 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.

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.

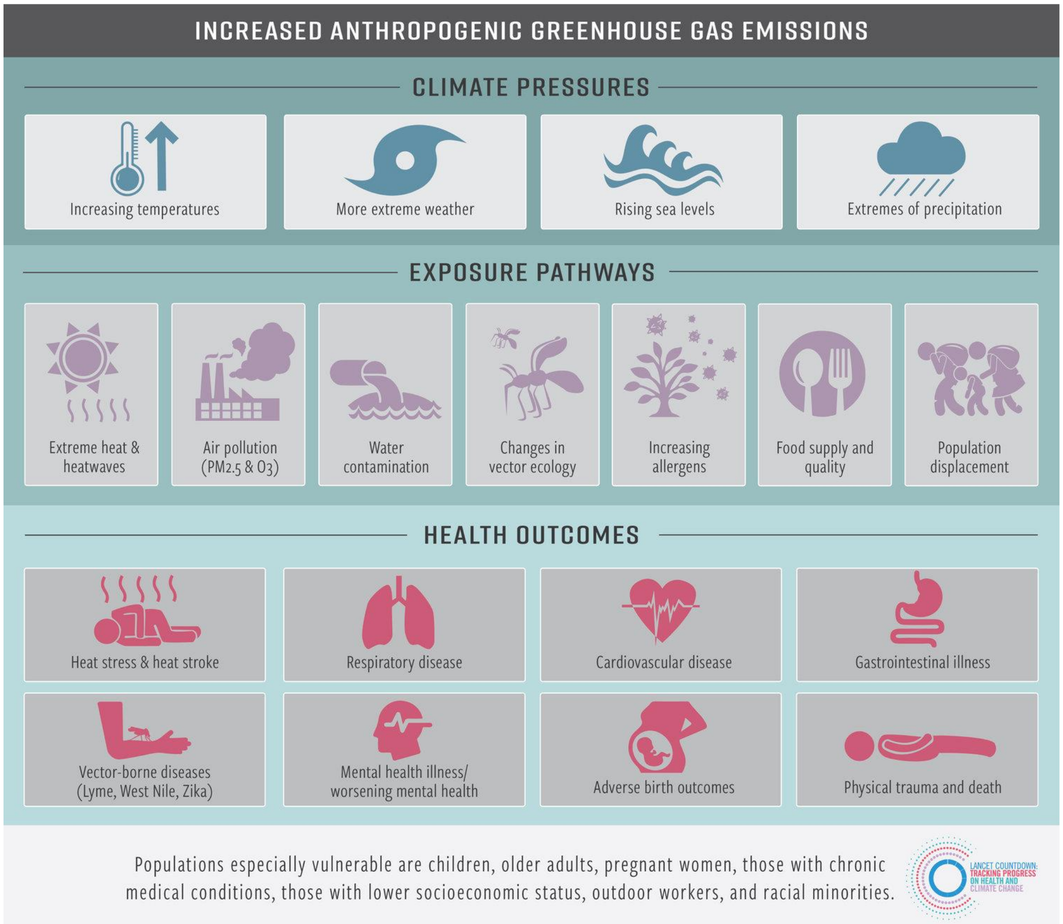

Figure 3-1. Ways climate change is harming, and will increasingly harm, human health (Salas et al. 2018).

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 likely be impacted most by the adverse effects of heat waves and reduced air quality (from wildfire smoke and other factors).[8] 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.

[8] 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 current 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 (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 sidebar). 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 small businesses that have no backup personnel. This finding should concern Montanans given that agriculture and construction are integral to our state's economy.

Sidebar: 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 result, 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, 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). 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 status, as described in the Mental Health subsection below.

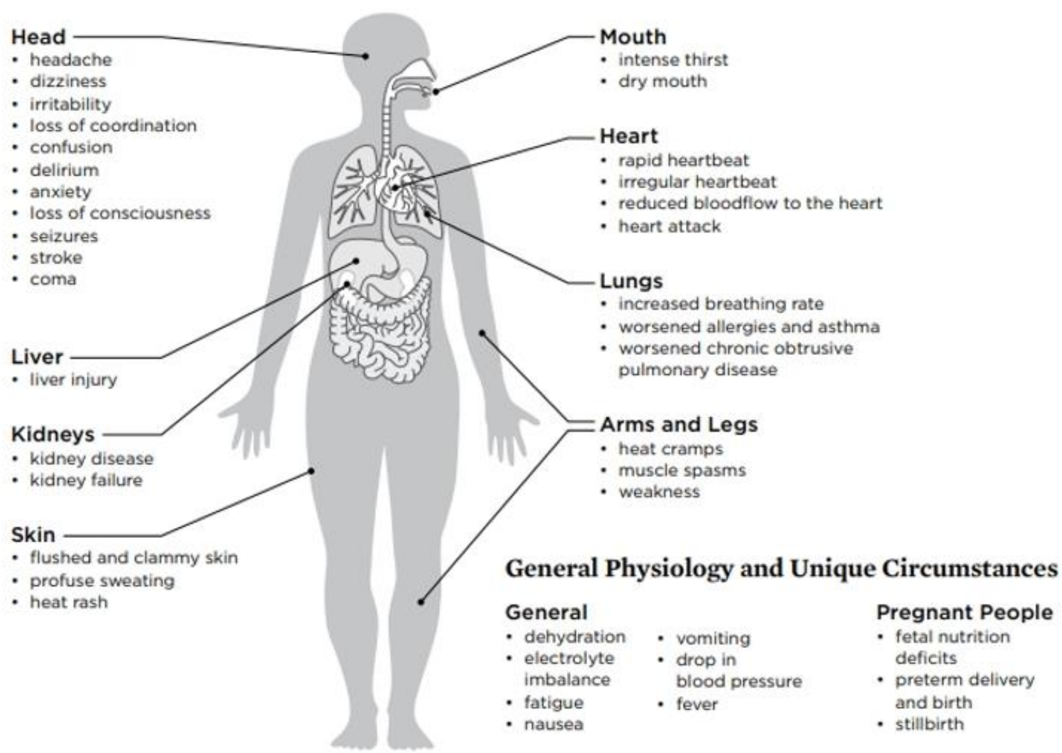

Figure 3-2. How heat affects our bodies. When temperature and humidity climb during extreme heat events, the body's cooling mechanisms become less effective. The symptoms shown here—ranging from minor annoyances to truly life-threatening issues—include both those that are indicative of heat-related illness 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).

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[9] 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 both 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). Likewise, global warming is increasing ground-level ozone concentrations with adverse effects on outdoor workers (Levy and Roelofs 2019). For Montana, Whitlock et al. (2017) describe that global warming will influence the distribution of weeds, pathogens, and insect pests and introduce *new* pests. These changes may alter the types and amounts of pesticides used, potentially affecting the health of agricultural workers and others.

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[10] socioeconomic factors to describe sensitivity and adaptive capacity. We will refer to the climate impacts as exposure, and the socioeconomic factors as sensitivity, with sensitivity inclusive of adaptive capacity.

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[9] 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.

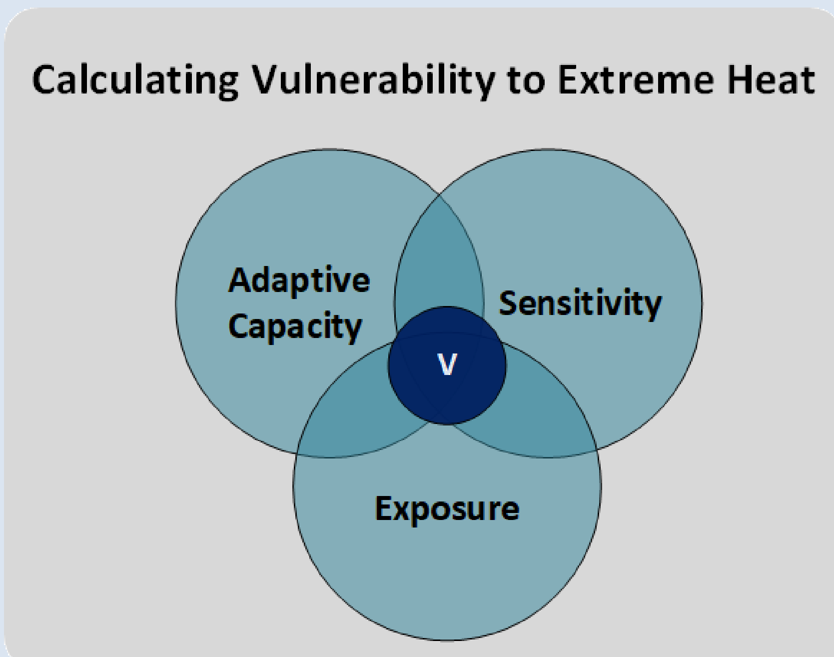
[10] Figure 2-1 provides a map showing and naming Montana's 56 counties.

Sidebar: 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, 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 typically modeled as the intersection of adaptive capacity, exposure, and sensitivity (Smit and Wandel 2006; Füssel 2010; Inostroza et al. 2016). As described in the text, here we instead combine adaptive capacity and sensitivity into one group, which is based on socioeconomic factors. We continue to use the intersection of the three areas to determine vulnerability; adaptive capacity is simply implicit in the socioeconomic layers that comprise our sensitivity factor.



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 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 circulations models.[11] The heat index includes a combination of temperature and humidity to create a “feels-like” heat rating.

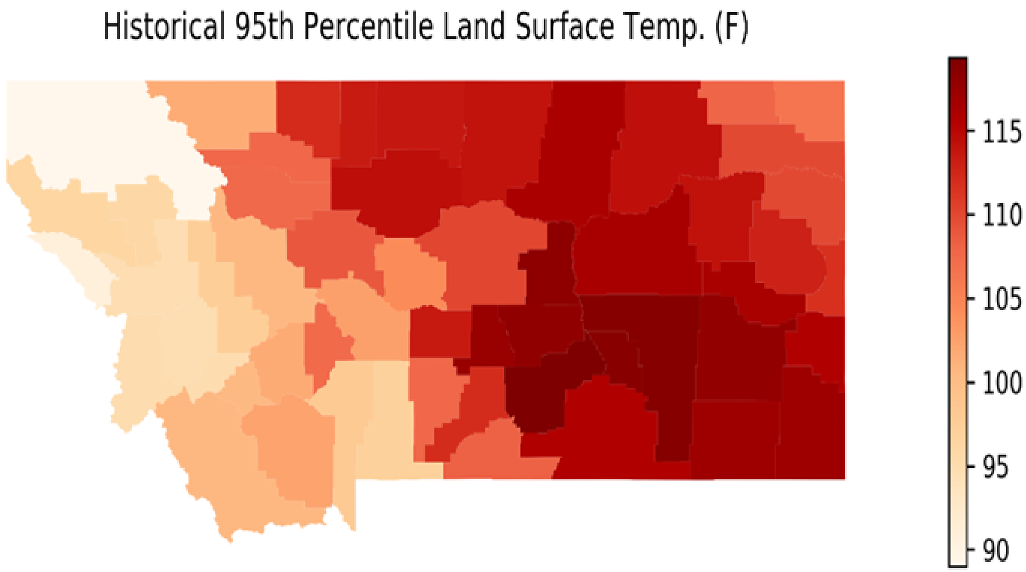


Figure 3-3. The county average land-surface temperature on days with extreme heat from 2000-2019. Note: Land-surface temperatures are higher than air temperatures measured at weather stations. The scale to the right shows color-coding for temperature in °F.

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).[12] Socioeconomic factors include age, the average income for people in the county, the percent of county population under a 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.

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

[11] Both heat index and general circulation models are described in Section 2.

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

vulnerability to heat have 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. Municipalities can use heat vulnerability information to guide heat mitigation interventions, such as establishment of green or reflective roofs, urban parks, and water features (Section 5).

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.

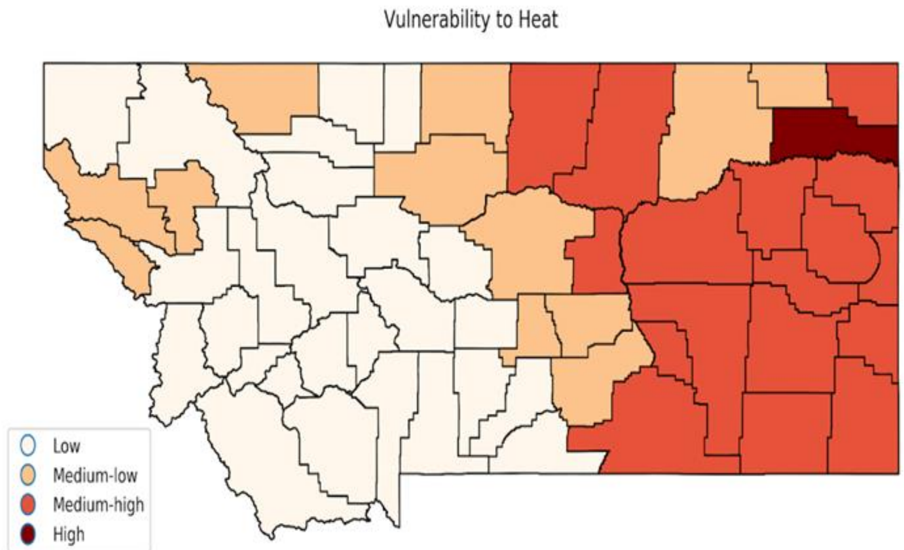


Figure 3-4. Montana counties ranked by heat vulnerability index for humans. Darker shading indicates higher vulnerability. See text for details.

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 production jobs.

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 over diverse geography (Whitlock e 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 follow:

- *Summer maximum temperatures.*—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 temperatures.*—Minimum summer night temperature have an increasing trend at 15 of the 38 stations across Montana and a decreasing trend at four stations from 1990-2019. All of the decreasing trends in summer night temperatures (i.e., cooling) are in western Montana. Five of the 15 increasing summer maximum temperatures are also stations indicating increasing trends in summer night temperatures and three of those five are in urban centers that are more likely to hold heat at night following hot days. In other words, stations that show a trend towards increasing temperatures during the day also experience a trend towards warming night conditions.

  The trend in summer minimum temperatures relates to nighttime 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 temperatures results in cumulative, negative heat impacts on people.

- *Winter minimum temperatures.*—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 temperatures 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 temperatures. 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[13] might exist. Small rural towns are also vulnerable to increasing heat and, based on limited healthcare facilities and other factors (Section 4), may include citizens who are already vulnerable to extreme conditions. The number of summer days with maximum temperatures over 90^{o}F is projected to increase by up to 35 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 United States annually (Watts et al. 2019). Outdoor air pollution is expected to worsen with climate change (Orru et al. 2014).

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[13] 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."

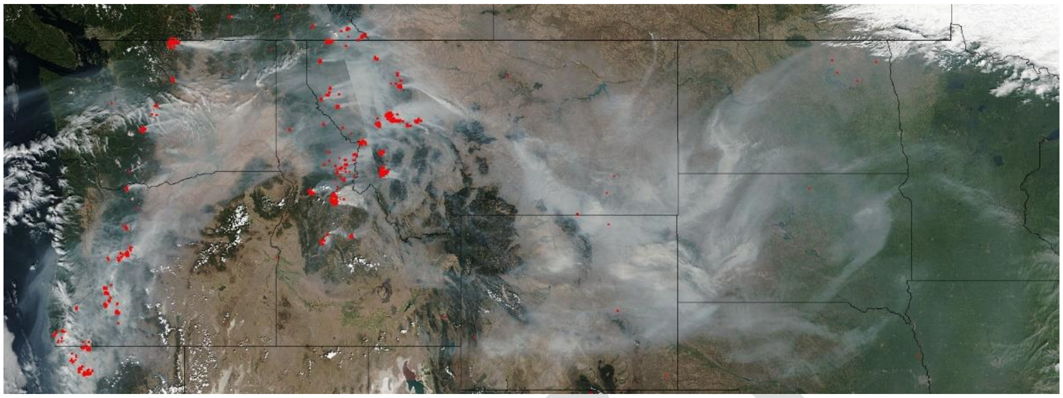

Figure 3-5. NASA composite satellite image from 11 September 2017, showing fires in the Cascades and Rockies and smoke as far east as the Great Lakes.[14]

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 $PM_{2.5}$, defined as particulates under 2.5 µm—has been associated with multiple health effects. Those effects include cardiovascular, respiratory, and immunological issues, 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).

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.

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).[15] Ten counties in Montana, for example, received grades of "F" for particulate matter in the American Lung

[14] 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.

[15] 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.

Association *State of the Air 2020* report card (American Lung Association 2020).[16] 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).

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). The incidence of large fires with adverse impacts on communities throughout the western US is increasing because climate warming produces longer, drier fire seasons and extensive burning, and 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. For the western US, including Montana, warmer and drier conditions during summer have contributed to longer fire seasons and more area burned by wildfires (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).

Human response data connecting heat and smoke to human health are limited for Montana. In nearby Boise Idaho, however, seven of the last 10 yr have included smoke levels considered “unhealthy for

[16] 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.

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).

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 agitated, 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; 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.

Particulate matter

Wildfires are estimated to contribute 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 (Section 2).

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 (i.e., drought, Section 2) 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 (McKenzie and Littell 2017; Holden et al. 2018). When fires ignite under usually 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.

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. 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 in summer with 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 3-6). More days with extreme fire danger imply 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).

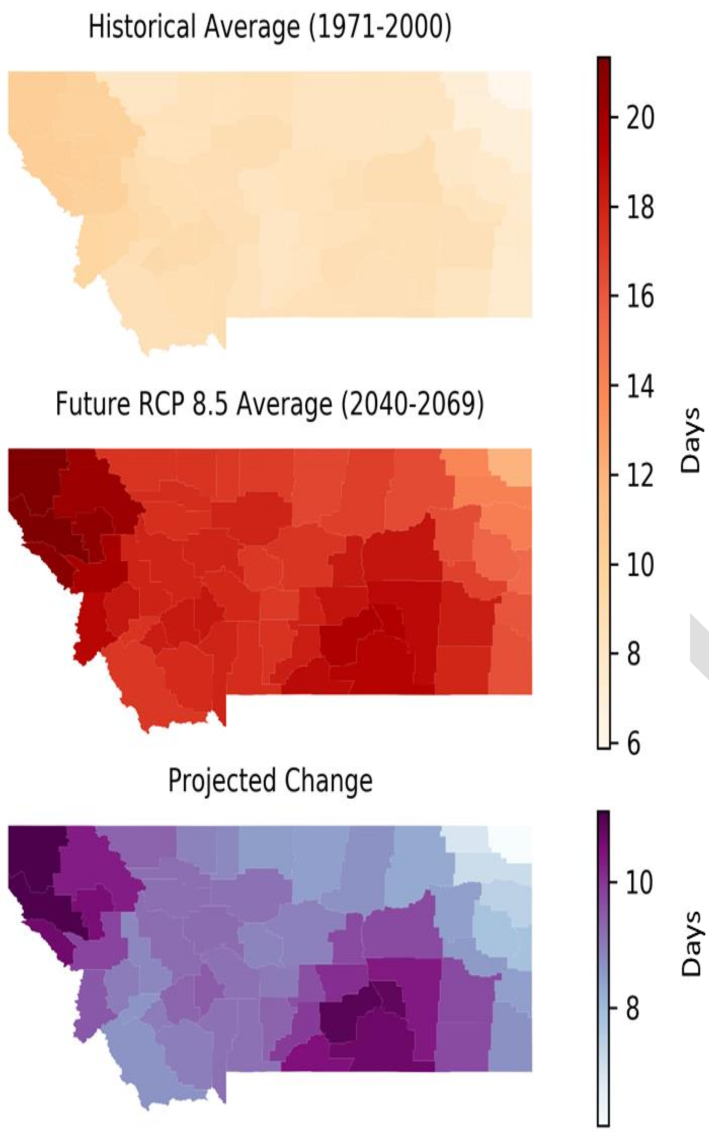

Figure 3-6. Number of days with extreme fire danger over time in Montana. From top to bottom we show the historic pattern, the mid-century projection under RCP8.5 (upper-bound emission scenario), and the change in number of extreme fire days from the 1971-2000 to the mid-century projection.

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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 3-6). 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 3-7), 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. The number of smoke events in each health category showed 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 (Section 2; sidebar Section 4). 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.

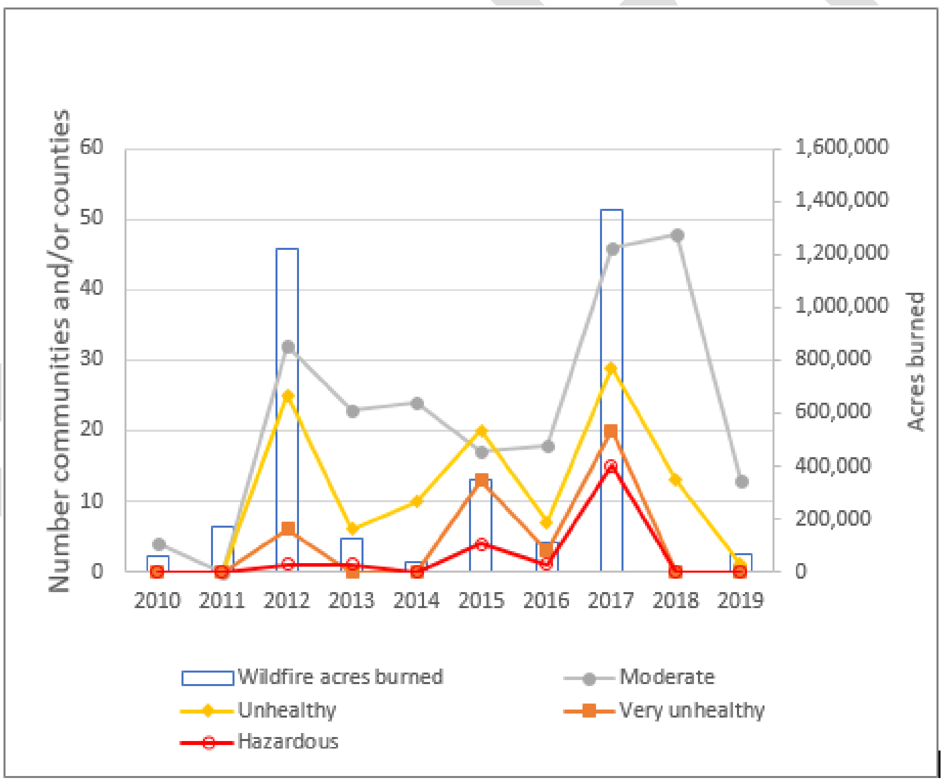


Figure 3-7. The number of communities, counties, and regions in Montana where wildfire smoke led to varying air quality ratings (MTDEQ undated), and number of acres burned by wildfire each year.

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. Such actions include delivery of air filters to community members most at risk, providing access to public buildings and spaces with clean air (e.g., libraries, courthouses, community centers), and assisting those with mobility issues to move from residences having insufficient air filtration (McWethy et al. 2019; such actions are discussed in detail in Section 5).

WATER-RELATED ILLNESSES

Spring floods, which are expected to increase with earlier snowmelt or extreme precipitation events (Section 2), affect people's health in a variety of ways. Immediate impacts include injury, hypothermia, death from drowning, exposure to toxic substances 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), which is an environmental stressor known to impact American Indian/Alaskan 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), and with dry conditions (Alexander et al. 2013; Friedrich 2013), though the latter association is weaker.

Hazardous algal blooms, often caused by cyanobacteria[17], are another 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; Moore et al. 2011; Davidson et al. 2014). 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. Food quantity and quality, including nutrition, are directly and indirectly impacted (Gowda et al. 2018b).

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

[17] Although commonly referred to as *blue-green algae*, cyanobacteria are a group of photosynthetic bacteria.

they contain less protein, zinc, iron, and other nutrients (Myers 2014).[18] 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 is 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.
- Inadequate intake of zinc in one out of four adults causes diarrhea, weight loss, skin lesions, and decreased immunity (NCHS undated).

Climate change can also lower the overall quantity of food produced, via multiple impacts (Zhao et al. 2017; Gowda et al. 2018b). The salt content of underground water sources (aquifers) and coastal lands 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.

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. Heat waves make livestock less fertile (Takahashi 2012). Extreme weather events, such as flash floods and drought, also lead to increased animal mortality.

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

Sidebar: 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 content of 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.

> *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).*

VECTOR-BORNE DISEASE

Vectors—primarily arthropod organisms 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 United States, 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 insects 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 lifecycles, 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 further 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 triggers higher rates of West Nile virus infection in people (Wang et al. 2010).

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).

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[19] that tested positive for West Nile virus out of 30 counties tested (Figure 3-8). Three people have died from West Nile virus in Montana since it was first detected (MTDPHHSc undated).

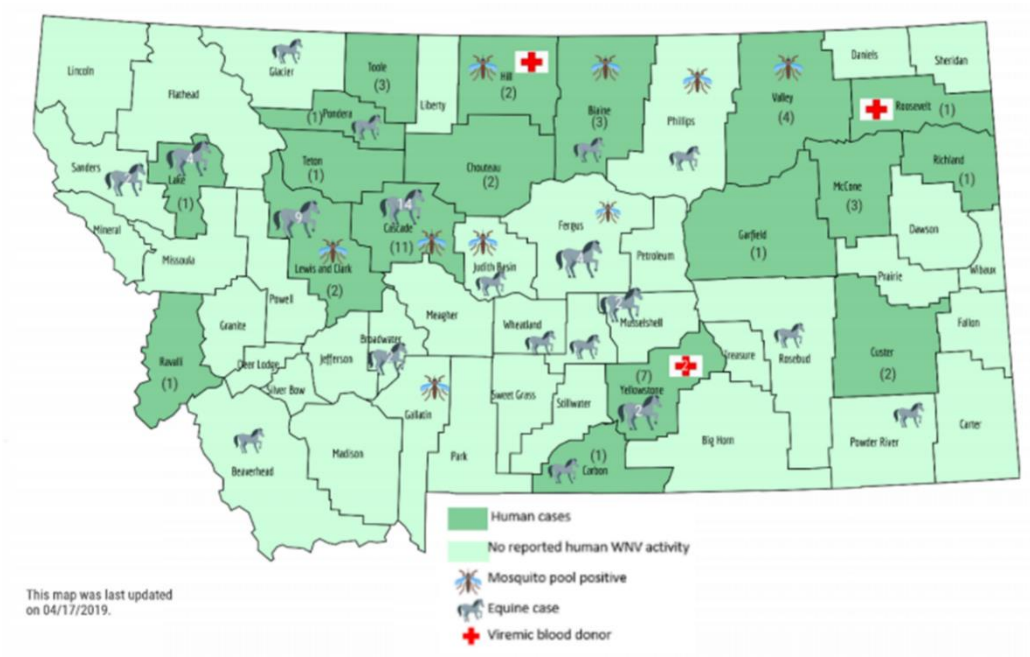


Figure 3-8. Map showing 2019 (last update 10/3/19) detections of West Nile virus in humans and horses, by county (MTDPHHSc undated).

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 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" (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 (often

[19] A mosquito pool is s a collection of mosquitoes (usually about 50) of any given species or group (e.g., *Culex mosquitoes*) that are likely to carry and potentially transmit a virus.

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 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 issues exacerbated by climate change (see sidebar). 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).

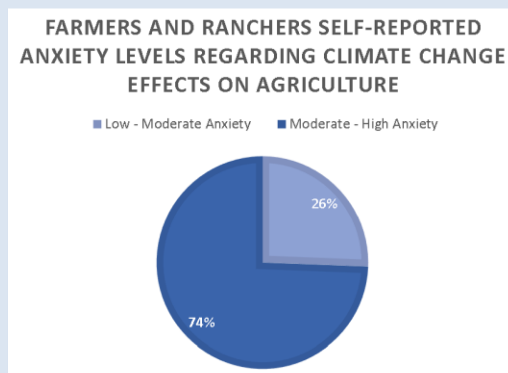
Sidebar: Climate Change and Mental Well-being—Perspectives from Montana Farmers and Ranchers

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.

LITERATURE CITED

[AAS] American Association of Suicidology. 2020a. Annual ranking of USA states by crude suicide rates (rates per 100,000 population), 1990-2018 [report]. Available online https://suicidology.org/wp-content/uploads/2020/02/StateRankings1990to2018TABLE.pdf. Accessed 28 Apr 2020.

[AAS] American Association of Suicidology. 2020b. USA suicide: 2018 official final data [report]. Available online https://suicidology.org/wp-content/uploads/2020/02/2018datapgsv2_Final.pdf. Accessed 24 Apr 2020.

Achebak H, Devolder D, Ballester J. 2018. Heat-related mortality trends under recent climate warming in Spain: a 36-year observational study. PLOS Medicine 15(7):e1002617. doi:10.1371/journal.pmed.1002617.

Adetona O, Reinhardt TE, Domitrovich J, Broyles G, Adetona AM, Kleinman MT, Ottmar RD, Naeher LP. 2016. Review of the health effects of wildland fire smoke on wildland firefighters and the public. Inhalation Toxicology 28(3): 95-139.

AirNow [undated]. AQI calculations overview—ozone, $PM_{2.5}$, and PM_{10} [website]. Available online https://forum.airnowtech.org/t/aqi-calculations-overview-ozone-pm2-5-and-pm10/168. Accessed 27 Apr 2020.

Alexander KA, Carzolio M, Goodin D, Vance E. 2013. Climate change is likely to worsen the public health threat of diarrheal disease in Botswana. International Journal of Environmental Research and Public Health 10(4):1202–30. doi:10.3390/ijerph10041202.

American Lung Association. [undated]. State of the air: health effects of ozone and particle pollution [website]. Available online http://www.stateoftheair.org/health-risks/. Accessed 27 Apr 2020.

American Lung Association. 2020. State of the air 2020: report card Montana [website]. Available online http://www.stateoftheair.org/city-rankings/states/montana/. Accessed 28 Apr 2020.

Anderson BG, Dominici F, Wang Y, McCormack MC, Bell ML, Peng RD. 2013. Heat-related emergency hospitalizations for respiratory diseases in the Medicare population. American Journal of Respiratory and Critical Care Medicine 187(10):1098–103. doi:10.1164/rccm.201211-1969oc.

Auger N, Naimi AI, Smargiassi A, Lo E, Kosatsky T. 2014. Extreme heat and risk of early delivery among preterm and term pregnancies. Epidemiology 25(3):344–50. doi:10.1097/EDE.0000000000000074.

Avalos LA, Chen H, Li D-K, Basu R. 2017. The impact of high apparent temperature on spontaneous preterm delivery: a case-crossover study. Environmental Health 16(1):5. doi:10.1186/s12940-017-0209-5.

Baccini M, Biggeri A, Accetta G, Kosatsky T, Katsouyanni K, Analitis A, Anderson HR, Bisanti L, D'Ippoliti D, Danova J. 2008. Heat effects on mortality in 15 European cities. Epidemiology 19:711-9.

Balla K, Rakszegi M, Li Z, Békés F, Bencze S, Veisz O. 2011. Quality of winter wheat in relation to heat and drought shock after anthesis. Czech Journal of Food Sciences 29(2):117–28. doi:10.17221/227/2010-cjfs.

Barbero R, Abatzoglou JT, Steel EA, Larkin NK. 2014. Modeling very large-fire occurrences over the continental United States from weather and climate forcing. Environmental Research Letters 9(12):124009. http://dx.doi.org/10.1088/1748-9326/9/12/124009.

Barros N, Tulve NS, Heggem DT, Bailey K. 2018. Review of built and natural environment stressors impacting American-Indian/Alaska-Native children. Reviews on Environmental Health. 33(4):349–81. doi:10.1515/reveh-2018-0034.

Basu R. 2009. High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. Environmental Health 8:40. doi:10.1186/1476-069X-8-40.

[BBC News] British Broadcasting Corporation 2020 (31 Jan). Australia fires: a visual guide to the bushfire crisis [article]. Available online https://www.bbc.com/news/world-australia-50951043. Accessed 24 Apr 2020.

Beard CB, Eisen RJ, Barker CM, Garofalo JF, Hahn M, Hayden M, Monaghan AJ, Ogden NH, Schramm PJ. 2016. Vector-borne diseases [chapter 5]. In: 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). The impacts of climate change on human health in the United States: a scientific assessment. Washington DC: US Global Change Research Program. p 129-156. Available online https://s3.amazonaws.com/climatehealth2016/low/ClimateHealth2016_05_Vector_small.pdf. Accessed 3 Mar 2020.

Becker JA, Stewart LK. 2011. Heat-related illness. American Family Physician 83(11):1325–30.

Bell JE, Brown C, Conlon K, Herring S, Kunkel KE, Lawrimore J, Luber G, Schreck C, Smith A, Uejio C. 2017. Changes in extreme events and the potential impacts on human health. Journal of the Air and Waste Management Association 68(4):265–87. doi:10.1080/10962247.2017.1401017.

Bell ML, MacDermott A, Zeger SL, Samet JM, Dominici F. 2004. Ozone and short-term mortality in 95 US urban communities, 1987-2000. Journal of the American Medical Association 292(19):2372–8. doi:10.1001/jama.292.19.2372.

Berko J, Ingram DD, Saha S, Parker JD. 2014. Deaths attributed to heat, cold, and other weather events in the United States, 2006-2010. National Health Statistics Report July 30(76):1-15.

Bobb JF, Obermeyer Z, Wang Y, Dominici F. 2014. Cause-specific risk of hospital admission related to extreme heat in older adults. Journal of the American Medical Association 312(24):2659–67. doi:10.1001/jama.2014.15715.

Bové H, Bongaerts E, Slenders E, Bijnens EM, Saenen ND, Gyselaers W, Eyken P, Plusquin M, Roeffaers MB, Ameloot M, Nawrot TS. 2019. Ambient black carbon particles reach the fetal side of human placenta. Nature Communications 10(1):3866. doi:10.1038/s41467-019-11654-3.

Buscail CE, Upegui E, Viel J-F. 2012. Mapping heatwave health risk at the community level for public health action. International Journal of Health Geographics 11(38). https://doi.org/10.1186/1476-072X-11-38.

Carlton EJ, Woster AP, DeWitt P, Goldstein RS, Levy K. 2016. A systematic review and meta-analysis of ambient temperature and diarrhoeal diseases. International Journal of Epidemiology 45(1):117–30. doi:10.1093/ije/dyv296.

Cascio WE. 2018. Wildland fire smoke and human health. Science of the Total Environment 624:586-95. http://dx.doi.org/10.1016/j.scitoenv.2017.12.086.

[CDCa] Centers for Disease Control and Prevention. [undated]. How many people get Lyme disease? [website]. Available https://www.cdc.gov/lyme/stats/humancases.html. Accessed 3 Mar 2020.

[CDCb] Centers for Disease Control and Prevention. [undated]. West Nile virus disease cases and presumptive viremic blood donors by state—United States, 2018 [report]. 2 p. Available online https://www.cdc.gov/westnile/resources/pdfs/data/WNV-Disease-Cases-PVDs-by-State-2018-P.pdf. Accessed 3 Mar 2020.

[CDC] Centers for Disease Control and Prevention. 2018. National Center for Health Statistics: suicide mortality by state [website]. Available online https://www.cdc.gov/nchs/pressroom/sosmap/suicide-mortality/suicide.htm. Accessed 26 Mar 2020.

Chancey C, Grinev A, Volkova E, Rios M. 2015. The global ecology and epidemiology of West Nile virus. Biomedical Research International 2015:376230. doi:10.1155/2015/376230.

Chuang WC, Gober P. 2015. Predicting hospitalization for heat-related illness at the census tract level: accuracy of a generic heat vulnerability index in Phoenix, Arizona (USA). Environmental Health Perspectives 123(6):606–12. doi:10.1289/ehp.1307868

Clayton S, Manning C, Krygsman K, Speiser M. 2017. Mental health and our changing climate: impacts, implications, and guidance [report]. Washington, D.C.: American Psychological Association, and ecoAmerica. 70 p. Available online https://www.apa.org/news/press/releases/2017/03/mental-health-climate.pdf. Accessed 22 May 2020.

Cook BI, Smerdon JE, Seager R, Coats S. 2014. Global warming and 21st century drying. Climate Dynamics 43(9):2607-27. http://dx.doi.org/10.1007/s00382-014-2075-7

Curriero FC, Heiner KS, Samet JM, Zeger SL, Strug L, Patz JA. 2002. Temperature and mortality in 11 cities of the eastern United States. American Journal of Epidemiology 155:80-7.

Dalton MM, Dello KD, Hawkins L, Mote PW, Rupp DE. 2017. Third Oregon climate assessment report. Corvallis OR: Oregon State University, Oregon Climate Change Research Institute. 106 p. Available online http://www.occri.net/media/1055/ocar3_final_all_01-30-2017_compressed.pdf. Accessed 3 Mar 2020.

Davidson K, Gowen RJ, Harrison PJ, Fleming LE, Hoagland P, Moschonas G. 2014. Anthropogenic nutrients and harmful algae in coastal waters. Journal of Environmental Management 146:206–16. doi:10.1016/j.jenvman.2014.07.002.

Dawson JP, Bloomer BJ, Winner DA, Weaver CP. 2014. Understanding the meteorological drivers of US particulate matter concentrations in a changing climate. Bulletin of the American Meteorological Society 95(4):521-32. http://dx.doi.org/10.1175/BAMS-D-12-00181.1

DeFranco E, Moravec W, Xu F, Hall E, Hossain M, Haynes EN, Muglia L, Chen A. 2016. Exposure to airborne particulate matter during pregnancy is associated with preterm birth: a population-based cohort study. Environmental Health-UK 15(1):6. doi:10.1186/s12940-016-0094-3.

Dennekamp M, Straney LD, Erbas B, Abramson MJ, Keywood M, Smith K, Sim MR, Glass DC, Del Monaco A, Haikerwal A, Tonkin A. 2015. Forest fire smoke exposures and out-of-hospital cardiac arrests in Melbourne, Australia: a case-crossover study. Environmental Health Perspectives 123(10):959–64. doi:10.1289/ehp.1408436.

Dennison PE, Brewer SC, Arnold JD, Moritz MA. 2014. Large wildfire trends in the western United States, 1984-2011. Geophysical Research Letters 41(8):2928-33. http://dx.doi.org/10.1002/2014GL059576.

Deutsch CA, Tewksbury JJ, Tigchelaar M, Battisti DS, Merrill SC, Huey RB, Naylor RL. 2018. Increase in crop losses to insect pests in a warming climate. Science 361(6405):916–9. doi:10.1126/science.aat3466.

Di Q, Wang Yan, Zanobetti A, Wang Yun, Koutrakis P, Choirat C, Dominici F, Schwartz JD. 2017. Air pollution and mortality in the Medicare population. New England Journal of Medicine 376(26):2513–22. doi:10.1056/nejmoa1702747.

Dominici F, Peng RD, Bell ML, Pham L, McDermott A, Zeger SL, Samet JM. 2006. Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. Journal of the American Medical Association 295(10):1127–34. doi:10.1001/jama.295.10.1127.

Doppelt B. 2016. Transformational resilience: how building human resilience to climate disruption can safeguard society and increase well-being. New York: Greenleaf Publishing. 368 p.

Dreessen J, Sullivan J, Delgado R. 2016. Observations and impacts of transported Canadian wildfire smoke on ozone and aerosol air quality in the Maryland region on June 9-12, 2015. Journal of the Air and Waste Management Association 66(9):842-62. http://dx.doi.org/10.1080/10962247.2016.1161674.

Du W, FitzGerald G, Clark M, Hou X-Y. 2010. Health impacts of floods. Prehospital Disaster Medicine 25(3):265–72. doi:10.1017/s1049023x00008141.

Ebi KL, Balbus JM, Luber G, Bole A, Crimmins A, Glass G, Saha S, Shimamoto MM, Trtanj J, White-Newsome JL. 2018. Human health [chapter 14]. In: Reidmiller DR, Avery CW, Easterling DR, Kunkel KE, Lewis KLM, Maycock TK, Stewart BC (eds). Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, vol II. Washington DC: US Global Change Research Program. p 539–71. Available online https://nca2018.globalchange.gov/chapter/health. Accessed 3 Mar 2020.

Epstein PR, Diaz HF, Elias S, Grabherr G, Graham NE, Martens WJ, Mosley-Thompson E, Susskind J. 1998. Biological and physical signs of climate change: focus on mosquito-borne diseases. Bulletin of the American Meteorological Society 79(3):409–17.

Epstein PR. 2005. Perspective: climate change and human health. New England Journal of Medicine 353(14):1433-6. doi:10.1056/nejmp058079.

Epstein Y, Yanovich R. 2019. Heatstroke. New England Journal of Medicine 380(25):2449–59. doi:10.1056/nejmra1810762.

[EWG] Environmental Working Group. [undated]. News reports on algal blooms, 2010 to present [website]. Available online https://www.ewg.org/interactive-maps/2019_algal_blooms/map/. Accessed 3 Mar 2020.

Fann N, Alman B, Broome RA, Morgan GG, Johnston FH, Pouliot G, Rappold AG. 2018. The health impacts and economic value of wildland fire episodes in the US: 2008-2012. Science of the Total Environment 610-611:802-9.

Fleischer NL, Merialdi M, van Donkelaar A, Vadillo-Ortega F, Martin RV, Betran A, Souza J, O'Neill MS. 2014. Outdoor air pollution, preterm birth, and low birth weight: analysis of the World Health Organization global survey on maternal and perinatal health. Environmental Health Perspectives 122(4):425–30. doi:10.1289/ehp.1306837.

Friedrich M. 2013. Climate change linked with increase in diarrheal disease. Journal of the American Medical Association 309(19):1985. doi:10.1001/jama.2013.5879.

Füssel HM. 2010. World development report 2010: development and climate change, background note—review and quantitative analysis of indices of climate change exposure, adaptive capacity, sensitivity, and impacts [report]. Potsdam Germany: Potsdam Institute for Climate Impact Research. 35 p. Available online https://openknowledge.worldbank.org/bitstream/handle/10986/9193/WDR2010_0004.pdf?sequence=1. Accessed 7 May 2020.

Gage AM, Olimb SK, Nelson J. 2016. Plowprint: tracking cumulative cropland expansion to target grassland conservation. Great Plains Research 26:107-16.

Gasparrini A, Guo Y, Hashizume M, Lavigne E, Zanobetti A, Schwartz J, Tobias A, Tong S, Rocklöv J, Forsberg B, Leone M, De Sario M, Bell ML, Leon Guo YL, Wu C-F, Kan H, Yi S-M, de Sousa Zanotti Stagliorio Coelho M, Hilario Nascimento Saldiva P, Honda Y, Kim H, Armstrong B. 2015. Mortality risk attributable to high and low ambient temperature: a multi-country observational study. Lancet 386:369-75. doi:10.1016/S0140-6736(14)62114-0.

Gielen MH, van der Zee SC, van Wijnen JH, van Steen CJ, Brunekreef B. 1997. Acute effects of summer air pollution on respiratory health of asthmatic children. American Journal of Respiratory and Critical Care Medicine 155(6):2105-8. doi:10.1164/ajrccm.155.6.9196122.

Gooding MJ, Ellis RH, Shewry PR, Schofield JD. 2003. Effects of restricted water availability and increased temperature on the grain filling, drying, and quality of winter wheat. Journal of Cereal Science 37(3):295–309. doi:10.1006/jcrs.2002.0501.

Gowda P, Steiner JL, Olson C, Boggess M, Farrigan T, Grusak MA. 2018. Agriculture and rural communities [chapter 10]. In: Reidmiller DR, Avery CW, Easterling DR, Kunkel KE, Lewis KLM, Maycock TK, Stewart BC (eds). Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington DC: US Global Change Research Program. p 391–437. Available online https://nca2018.globalchange.gov/downloads/NCA4_Ch10_Agriculture_Full.pdf. Accessed 8 May 2020.

Gubernot DM, Anderson BG, Hunting KL. 2015. Characterizing occupational heat-related mortality in the United States, 2000–2010: an analysis using the census of fatal occupational injuries database. American Journal of Industrial Medicine 58(2):203–11. doi:10.1002/ajim.22381.

Ha S, Liu D, Zhu Y, Kim S, Sherman S, Mendola P. 2016. Ambient temperature and early delivery of singleton pregnancies. Environmental Health Perspectives 125(3):453–9. doi:10.1289/ehp97.

Haas JD, Brownlie T. 2001. Iron deficiency and reduced work capacity: a critical review of the research to determine a causal relationship. Journal of Nutrition 131(2):676S-90S. doi:10.1093/jn/131.2.676s.

Haikerwal A, Akram M, Monaco A, Smith K, Sim MR, Meyer M, Tonkin AM, Abramson MJ, Dennekamp M. 2015. Impact of fine particulate matter ($PM_{2.5}$) exposure during wildfires on cardiovascular health outcomes. Journal of the American Heart Association 4(7):e001653. doi:10.1161/jaha.114.001653.

Hayes K, Blashki G, Wiseman J, Burke S, Reifels L. 2018. Climate change and mental health: risks, impacts and priority actions. International Journal of Mental Health Systems 12(1):28. doi:10.1186/s13033-018-0210-6.

Ho HC, Knudby A, Huang W. 2015. A spatial framework to map heat health risks at multiple scales. International Journal of Environmental Research and Public Health 12:16110–23. doi:10.3390/ijerph121215046.

Holden ZA, Swanson A, Luce CH, Jolly WM, Maneta M, Oyler JW, Warren DA, Parsons R, Affleck D. 2018. Decreasing fire season precipitation increased recent western US forest wildfire activity. Proceedings of the National Academy of Sciences 115(36):E8349-E8357. https://doi.org/10.1073/pnas.1802316115.

Howard M, Ahmed S, Lachapelle P, Schure MB. 2020. Farmer and rancher perceptions of climate change and their relationships with mental health. Journal of Rural Mental Health 44(2):87-95. https://doi.org/10.1037/rmh0000131.

Hsiang SM, Burke M, Miguel E. 2013. Quantifying the influence of climate on human conflict. Science 341(6151):1235367. doi:10.1126/science.1235367.

[IDDEQ] Idaho Department of Environmental Quality. 2013 (Dec 6). Request for EPA concurrence as exceptional events for 2012 wildfire impacts on $PM_{2.5}$ monitor values at Salmon and Pinehurst Idaho [report]. 275 p. Available online http://www.deq.idaho.gov/media/1187/exceptional-events-request-pinehurst-salmon-final.pdf. Accessed 13 May 2020.

Inostroza L, Palme M, de la Barrera F. 2016. A heat vulnerability index: spatial patterns of exposure, sensitivity, and adaptive capacity for Santiago de Chile. PLOS ONE 11(9):e0162464. doi:10.1371/journal.pone.0162464.

Insurance Information Institute [undated]. Facts + statistics: wildfires [website]. Available online https://www.iii.org/fact-statistic/facts-statistics-wildfires. Accessed 25 Apr 2020.

[IPCC] Intergovernmental Panel on Climate Change. 2019. Summary for policymakers [chapter]. In: Pörtner H-O, Roberts DC, Masson-Delmotte V, Zhai P, Tignor M, Poloczanska E, Mintenbeck K, Nicolai M, Okem A, Petzold J, Rama B, Weyer N (eds.). IPCC special report on the ocean and cryosphere in a changing climate. Available online https://www.ipcc.ch/srocc/chapter/summary-for-policymakers/. Accessed 3 Mar 2020.

Irwin J, Jeffrey K. 2001. Anemia in children. American Family Physician 64(8):1379-87.

Isaksen T, Fenske RA, Hom EK, Ren Y, Lyons H, Yost MG. 2016. Increased mortality associated with extreme-heat exposure in King County, Washington, 1980–2010. International Journal of Biometeorology 60(1):85–98. doi:10.1007/s00484-015-1007-9.

Jaffe D, Chand D, Haffner W, Westerling A, Spracklen D. 2008. Influences of fire on O3 concentrations in the western US. Environmental Science and Technology 42(16):5885-91. http://dx.doi.org/10.1021/es800084k.

Jaffe DA, Widger NL. 2012. Ozone production from wildfires: a critical review. Atmospheric Environment 51:1-10. http://dx.doi.org/10.1016/j.atmosenv.2011.11.063.

Jáuregui-Lobera I. 2014. Iron deficiency and cognitive functions. Neuropsychiatric Disease and Treatment 10:2087–95. doi:10.2147/ndt.s72491.

Jenkins MJ, Runyon JB, Fettig CJ, Page WG, Bentz BJ. 2014. Interactions among the mountain pine beetle, fires, and fuels. Forest Science 60(3):489-501. http://dx.doi.org/10.5849/forsci.13-017

Jhun I, Mata DA, Nordio F, Lee M, Schwartz J, Zanobetti A. 2017. Ambient temperature and sudden infant death syndrome in the United States. Epidemiology 28(5):728. doi:10.1097/ede.0000000000000703.

Johnston FH, Henderson SB, Chen Y, Randerson JT, Marlier M, DeFries RS, Kinney P, Bowman D, Brauer M. 2012. Estimated global mortality attributable to smoke from landscape fires. Environmental Health Perspectives 120(5):695–701. doi:10.1289/ehp.1104422.

Jolly WM, Cochrane MA, Freeborn PH, Holden ZA, Brown TJ, Williamson GJ, Bowman DM. 2015. Climate-induced variations in global wildfire danger from 1979 to 2013. Nature Communications 6:7537.

Knowlton K, Rotkin-Ellman M, King G, Margolis HG, Smith D, Solomon G, Trent R, English P. 2009. The 2006 California heat wave: impacts on hospitalizations and emergency department visits. Environmental Health Perspectives 117(1):61–7. doi:10.1289/ehp.11594.

Kollanus V, Tittanen P, Niemi JV, Lanki T. 2016. Effects of long-range transported air pollution from vegetation fires on daily mortality and hospital admissions in the Helsinki metropolitan area, Finland. Environmental Research 151:351-8. doi:10.1016/j.envres.2016.08.003

Lake IR, Hooper L, Abdelhamid A, Bentham G, Boxall ABA, Draper A, Fairweather-Tait S, Hulme M, Hunter PR, Nichols G, Waldron KW. 2012. Climate change and food security: health impacts in developed countries. Environmental Health Perspectives 120(11):1520–6. doi:10.1289/ehp.1104424.

Lamond J, Joseph RD, Proverbs DG. 2015. An exploration of factors affecting the long-term psychological impact and deterioration of mental health in flooded households. Environmental Research 140:325–34. doi:10.1016/j.envres.2015.04.008.

Laurent J, Williams A, Oulhote Y, Zanobetti A, Allen JG, Spengler JD. 2018. Reduced cognitive function during a heat wave among residents of non-air-conditioned buildings: an observational study of young adults in the summer of 2016. PLOS Medicine 15(7):e1002605. doi:10.1371/journal.pmed.1002605.

Lesk C, Rowhani P, Ramankutty N. 2016. Influence of extreme weather disasters on global crop production. Nature 529(7584):84–8. doi:10.1038/nature16467.

Levy K, Woster AP, Goldstein RS, Carlton EJ. 2016. Untangling the impacts of climate change on waterborne diseases: a systematic review of relationships between diarrheal diseases and temperature, rainfall, flooding, and drought. Environmental Science and Technology 50(10):4905–22. doi:10.1021/acs.est.5b06186.

Levy BS, Roelofs C. 2019. Impacts of climate change on workers' health and safety [report]. In Oxford Research Encyclopedias: global public health. doi:10.1093/acrefore/9780190632366.013.39.

Liu JC, Pereira G, Uhl SA, Bravo MA, Bell ML. 2015. A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke. Environmental Research 136:120-32. http://dx.doi.org/10.1016/j.envres.2014.10.015.

Liu J, Mickley LJ, Sulprizio MP, Dominici F, Yue X, Ebisu K, Anderson G, Khan RF, Bravo MA, Bell ML. 2016. Particulate air pollution from wildfires in the western US under climate change. Climatic Change 138(3):655–66. doi:10.1007/s10584-016-1762-6.

Liu JC, Wilson A, Mickley LJ, Ebisu K, Sulprizio MP, Wang Y, Peng RD, Yue X, Dominici F, Bell ML. 2017. Who among the elderly is most vulnerable to exposure to and health risks of fine particulate matter from wildfire smoke? American Journal of Epidemiology 186(6):730-5. http://dx.doi.org/10.1093/aje/kwx141.

McKenzie D, Littell JS. 2017. Climate change and the eco-hydrology of fire: will area burned increase in a warming western USA? Ecological Applications 27:26-36. doi:10.1002/eap.1420.

McWethy DB, Schoennagel T, Higuera PB, Krawchuk M, Harvey BJ, Metcalf EC, Schultz C, Miller C, Metcalf AL, Buma B, Virapongse A, Kulig JC, Stedman RC, Ratajczak Z, Nelson CR, Kolden C. 2019. Rethinking resilience to fire. Nature Sustainability 2:797-804. doi:10.1038/s41893-019-0353-8.

Medek DE, Schwartz J, Myers SS. 2017. Estimated effects of future atmospheric CO_2 concentrations on protein intake and the risk of protein deficiency by country and region. Environmental Health Perspectives 125(8). doi:10.1289/ehp41.

Meehi GA, Tebaldi C. 2004. More intense, more frequent, and longer lasting heat waves in the 21st century. Science 305:994-7.

Mills D, Schwartz J, Lee M, Sarofim M, Jones R, Lawson M, Duckworth M, Deck L. 2015. Climate change impacts on extreme temperature mortality in select metropolitan areas in the United States. Climatic Change 131:83-95. doi:10.1007/s10584-014-1154-8.

Moore SK, Mantua NJ, Salathé EP. 2011. Past trends and future scenarios for environmental conditions favoring the accumulation of paralytic shellfish toxins in Puget Sound shellfish. Harmful Algae 10(5):521–9. doi:10.1016/j.hal.2011.04.004.

Morabito MA, Crisci A, Messeri A, Capecchi V, Modesti PA, Gensini GF, Orlandini S. 2014. Environmental temperature and thermal indices: what is the most effective predictor of heat-related mortality in different geographical contexts? Scientific World Journal 2014(ID 961750). doi:10.1155/2014/961750.

Mordecai EA, Paaijmans KP, Johnson LR, Balzer C, Ben-Horin T, de Moor E, McNally A, Pawar S, Ryan SJ, Smith TC, Lafferty KD. 2012. Optimal temperature for malaria transmission is dramatically lower than previously predicted. Ecology Letters 16(1):22–30. doi:10.1111/ele.12015.

Mordecai EA, Cohen JM, Evans MV, Gudapati P, Johnson LR, Lippi CA, Miazgowicz K, Murdock CC, Rohr JR, Ryan SJ, Savage V, Shocket MS, Ibarra AS, Thomas MB, Weikel DP. 2017. Detecting the impact of temperature on transmission of Zika, dengue, and chikungunya using mechanistic models. PLOS Neglected Tropical Diseases 11(4):e0005568. doi:10.1371/journal.pntd.0005568.

Mordecai EA, Caldwell JM, Grossman MK, Lippi CA, Johnson LR, Neira M, Rohr JR, Ryan SJ, Savage V, Shocket MS, Sippy R, Ibarra AMS, Thomas MB, Villena O. 2019. Thermal biology of mosquito-borne disease. Ecology Letters 22(10):1690–708. doi:10.1111/ele.13335.

Moyce S, Mitchell D, Armitage T, Tancredi D, Joseph J, Schenker M. 2017. Heat strain, volume depletion, and kidney function in California agricultural workers. Occupational and Environmental Medicine 74(6):402-9.

[MTDEQ] Montana Department of Environmental Quality. [undated]. Archived wildfire smoke updates [website]. Available online http://svc.mt.gov/deq/todaysair/smokereport/SmokeList.aspx?smokeYear=2012. Accessed 8 May 2020.

[MTDPHHSa] Montana Department of Health and Human Safet. [undated]. Public health and safety: harmful algal blooms [website]. Available online https://dphhs.mt.gov/publichealth/Epidemiology/hab. Accessed 24 Apr 2020.

[MTDPHHSb] Montana Department of Public Health and Human Services. [undated]. Tick-borne illnesses [website]. Available online https://dphhs.mt.gov/publichealth/cdepi/diseases/ticks. Accessed 3 Mar 2020.

[MTDPHHSc] Montana Department of Public Health and Human Services. [undated]. West Nile virus [website]. Available online https://dphhs.mt.gov/publichealth/cdepi/diseases/westnilevirus. Accessed 3 Mar 2020.

[MTDPHHS] Montana Department of Public Health and Human Services. 2013. The burden of asthma in Montana Report, 2013 [internal report]. 33 p. Available online https://dphhs.mt.gov/Portals/85/publichealth/documents/Asthma/AsthmaBurdenReportAugust2018.pdf. Accessed 20 May 2020.

Myers SS, Zanobetti A, Kloog I, Huybers P, Leakey ADB, Bloom AJ, Carlisle E, Dietterich LH, Fitzgerald G, Hasegawa T, Holbrook NM, Nelson RL, Ottman MJ, Raboy V, Sakai H, Sartor KA, Schwartz J, Seneweera S, Tausz M, Usui Y. 2014. Increasing CO_2 threatens human nutrition. Nature 510:139–42.

Navarro KM, Cisneros R, O'Neill SM, Schweizer D, Larkin NK, Balmes JR. 2016. Air-quality impacts and intake fraction of $PM_{2.5}$ during the 2013 Rim Megafire. Environmental Science and Technology 50 (21):11965-73. http://dx.doi.org/10.1021/acs.est.6b02252.

[NCHS] National Center for Health Statistics. [undated]. National health and nutrition survey [website]. Available online https://www.cdc.gov/nchs/nhanes/index.htm. Accessed 2019 Dec 20.

Nelson GC, Valin H, Sands RD, Havlík P, Ahammad H, Deryng D, Elliott J, Fujimori S, Hasegawa T, Heyhoe E, plus 14 more. 2014. Climate change effects on agriculture: economic responses to biophysical shocks. Proceedings of the National Academy of Sciences 111(9):3274–9. doi:10.1073/pnas.1222465110.

[NOAA-NCEIa] National Oceanic and Atmospheric Administration—National Centers for Environmental Information. Storm data [website]. Available online https://www.ncdc.noaa.gov/IPS/sd/sd.html. Accessed 13 May 2020.

[NOAA-NCEIb] National Oceanic and Atmospheric Administration—National Centers for Environmental Information. National climate report—annual 2011 [website]. Available online https://www.ncdc.noaa.gov/sotc/national/201113. Accessed 13 May 2020.

Nolte CG, Dolwick PD, Fann N, Horowitz LW, Naik V, Pinder RW, Spero TL, Winner DA, Ziska LH. 2018. Air quality [chapter 13]. In: Reidmiller DR, Avery CW, Easterling DR, Kunkel KE, Lewis KLM, Maycock TK, Stewart BC (eds). Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington DC: US Global Change Research Program. p 512-38. Available online https://nca2018.globalchange.gov/downloads/NCA4_Ch13_Air-Quality_Full.pdf. Accessed 14 May 2020.

Norby RJ, Warren JM, Iversen CM, Medlyn BE, McMurtrie RE. 2010. CO_2 enhancement of forest productivity constrained by limited nitrogen availability. Proceedings of the National Academy of Sciences USA 107(45):19368-73. http://dx.doi.org/10.1073/pnas.1006463107

[NWS] National Weather Service [undated]. Weather-related fatality and injury statistics [website]. Available online https://www.weather.gov/hazstat/. Accessed 19 Feb 2020.

Obradovich N, Migliorini R, Paulus MP, Rahwan I. 2018. Empirical evidence of mental health risks posed by climate change. Proceedings of the National Academy of Sciences 115(43):201801528. doi:10.1073/pnas.1801528115.

Ogden NH. 2017. Climate change and vector-borne diseases of public health significance. FEMS Microbiology Letters 364(19). doi:10.1093/femsle/fnx186.

Olsson D, Mogren I, Forsberg B. 2013. Air pollution exposure in early pregnancy and adverse pregnancy outcomes: a register-based cohort study. Bmj Open. 3(2):e001955. doi:10.1136/bmjopen-2012-001955.

Orengo-Aguayo R, Stewart RW, de Arellano MA, Suárez-Kindy J, Young J. 2019. Disaster exposure and mental health among Puerto Rican youths after Hurricane Maria. Journal of the American Medical Association Network Open 2(4):e192619. doi:10.1001/jamanetworkopen.2019.2619.

Orru H, Ebi KL, Forsberg B. 2017. The interplay of climate change and air pollution on health. Current Environmental Health Reports 4(4):504-13.

Ostro BD, Roth LA, Green RS, Basu R. 2009. Estimating the mortality effect of the July 2006 California heat wave. Environmental Research 109(5):614–9. doi:10.1016/j.envres.2009.03.010.

Paerl HW, Huisman J. 2009. Climate change: a catalyst for global expansion of harmful cyanobacterial blooms. Environmental Microbiology Reports 1(1):27-37. doi:10.1111/j.1758-2229.2008.00004.x.

Page LA, Hajat S, Kovats SR. 2007. Relationship between daily suicide counts and temperature in England and Wales. British Journal of Psychiatry 191(2):106–12. doi:10.1192/bjp.bp.106.031948.

Palinkas LA, Wong M. 2019. Global climate change and mental health. Current Opinion in Psychology 32:12–6. doi:10.1016/j.copsyc.2019.06.023.

Paterson DL, Wright H, Harris PN. 2018. Health risks of flood disasters. Clinical Infectious Diseases 67(9):1450–4. doi:10.1093/cid/ciy227.

Patz JA, Epstein PR, Burke TA, Balbus JM. 1996. Global climate change and emerging infectious diseases. Journal of the American Medical Association 275(3):217–23. doi:10.1001/jama.1996.03530270057032.

Paulson JA, Ahdoot S, Baum CR, Bole A, Brumberg HL, Campbell CC, Lanphear BP, Lowry JA, Pacheco SE, Spanier AJ, Trasande L. 2015. Global climate change and children's health. Pediatrics 136(5):992–7. doi:10.1542/peds.2015-3232.

Paz S. 2015. Climate change impacts on West Nile virus transmission in a global context. Philosophical Transactions Royal Society B Biological Sciences 370(1665):20130561. doi:10.1098/rstb.2013.0561.

Peters R, Ee N, Peters J, Booth A, Mudway I, Anstey KJ. 2019. Air pollution and dementia: a systematic review. Journal of Alzheimer's Disease 70(s1):S145–63. doi:10.3233/jad-180631.

Pope CA III, Ezzati M, Dockery DW. 2009. Fine-particulate air pollution and life expectancy in the United States. New England Journal of Medicine 360(4):376-86. doi:10.1056/NEJMsa0805646.

Puett RC, Hart JE, Yanosky JD, Paciorek C, Schwartz J, Suh H, Speizer FE, Laden F. 2009. Chronic fine and coarse particulate exposure, mortality, and coronary heart disease in the nurses' health study. Environmental Health Perspectives 117(11)1697–701. doi:10.1289/ehp.0900572.

Radeloff VC, Helmers DP, Kramer HA, Mockrin MH, Alexandre PM, Bar-Massada A, Butsic V, Hawbaker TJ, Martinuzzi S, Syphard AD, Stewart SI. 2018. Rapid growth of the US wildland-urban interface raises wildfire risk. Proceedings of the National Academy of Sciences USA 115:3314–9. doi:10.1073/pnas.1718850115.

Rani B, Singh U, Chuhan AK, Sharma D, Maheshwari R. 2011. Photochemical smog pollution and its mitigation measures. Journal of Advanced Scientific Research 2(4):28-33.

Rappold AG, Stone SL, Cascio WE, Neas LM, Kilaru VJ, Carraway M, Szykman JJ, Ising A, Cleve WE, Meredith JT, Vaughan-Batten H, Deyneka L, Devlin RB. 2011. Peat bog wildfire smoke exposure in rural North Carolina is associated with cardiopulmonary emergency department visits assessed through syndromic surveillance. Environmental Health Perspectives 119(10):1415–20. doi:10.1289/ehp.1003206.

Reid CE, O'Neill MS, Gronlund CJ, Brines SJ, Brown DG, Diez-Roux AV, Schwartz J. 2009. Mapping community determinants of heat vulnerability. Environmental Health Perspectives 117:1730-6.

Reid CE, Mann J, Alfasso R, English PB, King GC, Lincoln RA, Margolis HG, Rubado DJ, Sabato JE, West NL. 2012. Evaluation of a heat vulnerability index on abnormally hot days: an environmental public health tracking study. Environmental Health Perspectives 120:715-20.

Reid CE, Brauer M, Johnston FH, Jerrett M, Balmes JR, Elliott CT. 2016a. Critical review of health impacts of wildfire smoke exposure. Environmental Health Perspectives 124:1334-43. http://dx.doi.org/10.1289/ehp.1409277.

Reid C, Jerrett M, Tager I, Petersen M, Mann J, Balmes J. 2016b. Differential respiratory health effects from the 2008 northern California wildfires: a spatiotemporal approach. Environmental Research 150:227-35. https://dx.doi.org/10.1016/j.envres.2016.06.012.

Reisen F, Duran SM, Flannigan M, Elliott C, Rideout K. 2015. Wildfire smoke and public health risk. International Journal of Wildland Fire 24(8):1029–44. doi:10.1071/WF15034.

Rosenberg R, Lindsey NP, Fischer M, Gregory CJ, Hinckley AF, Mead PS, Paz-Bailey G, Waterman SH, Drexler NA, Kersh GJ, Hooks H, Partridge SK, Visser SN, Beard CB, Petersen LR. 2018. Vital signs: trends in reported vector-borne disease cases—United States and territories, 2004–2016. Morbidity Mortal Weekly Report 67(17):496–501. doi:10.15585/mmwr.mm6717e1.

Ross ME, Vicedo-Cabrera AM, Kopp RE, Song L, Goldfarb DS, Pulido J, Warner S, Furth SL, Tasian GE. 2018. Assessment of the combination of temperature and relative humidity on kidney stone presentations. Environmental Research 162:97–105. doi:10.1016/j.envres.2017.12.020.

Ryan B, Franklin RC, Burkle FM, Aitken P, Smith E, Watt K, Leggat P. 2015 (Sep 28). Identifying and describing the impact of cyclone-, storm-, and flood-related disasters on treatment management, care, and exacerbations of non-communicable diseases and the implications for public health. PLOS Current Disasters (edition 1). doi:10.1371/currents.dis.62e9286d152de04799644dcca47d9288.

Salas RN, Knappenberger P, Hess J. 2018. 2018 Lancet countdown on health and climate change brief for the United States of America [report]. London UK: Lancet Countdown. 32 p. Available online https://storage.googleapis.com/lancet-countdown/2019/10/2018-lancet-countdown-policy-brief-usa.pdf. Accessed 13 May 2020.

Sarofim MC, Saha S, Hawkins MD, Mills DM, Hess J, Horton R, Kinney P, Schwartz J, St. Juliana A. 2016. Temperature-related death and illness [chapter 2]. In: 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). The impacts of climate change on human health in the United States: a scientific assessment. Washington DC: US Global Change Research Program. p 43–68. Available online https://s3.amazonaws.com/climatehealth2016/low/ClimateHealth2016_02_Temperature_small.pdf. Accessed 22 Apr 2020.

Schwartz J, Dockery DW, Neas LM. 1996. Is daily mortality associated specifically with fine particles? Journal of Air and Waste Management Association 46(10)927-39. doi:10.1080/10473289.1996.10467528.

Shander A, Goodnough LT, Javidroozi M, Auerbach M, Carson J, Ershler WB, Ghiglione M, Glaspy J, Lew I. 2014. Iron deficiency anemia—bridging the knowledge and practice gap. Transfusion Medicine Reviews 28(3):156–66. doi:10.1016/j.tmrv.2014.05.001.

Smit B, Wandel J. 2006. Adaptation, adaptive capacity, and vulnerability. Global Environmental Change 16(2006)282–92. Available online https://www.parc.ca/mcri/pdfs/papers/iacc023.pdf. Accessed 7 May 2020.

Smith MR, Myers SS. 2018. Impact of anthropogenic CO_2 emissions on global human nutrition. Nature Climate Change 8:834–9. doi:10.1038/s41558-018-0253-3.

Sonenshine DE. 2018. Range expansion of tick disease vectors in North America: implications for spread of tick-borne disease. International Journal of Environmental Research and Public Health 15(3):478. doi:10.3390/ijerph15030478.

Sorensen C, Garcia-Trabanino R. 2019. A new era of climate medicine—addressing heat-triggered renal disease. New England Journal of Medicine 381(8):693–6. doi:10.1056/nejmp1907859.

Spector JT, Bonauto DK, Sheppard L, Busch-Isaksen T, Calkins M, Adams D, Lieblich M, Fenske RA. 2016. A case-crossover study of heat exposure and injury risk in outdoor agricultural workers. PLOS ONE 11(10):e0164498. http://dx.doi.org/10.1371/journal.pone.0164498.

Springmann M, Mason-D'Croz D, Robinson S, Garnett T, Godfray CH, Gollin D, Rayner M, Ballon P, Scarborough P. 2016. Global and regional health effects of future food production under climate change: a modeling study. Lancet 387(10031):1937–46. doi:10.1016/s0140-6736(15)01156-3.

Summer A, Lora I, Formaggioni P, Gottardo F. 2018. Impact of heat stress on milk and meat production. Animal Frontiers 9(1):39-46. doi:10.1093/af/vfy026.

Takahashi M. 2012. Heat stress on reproductive function and fertility in mammals. Reproductive Medicine and Biology 11:37–47. https://doi.org/10.1007/s12522-011-0105-6.

Tao Z, Larson SM, Williams A, Caughey M, Wuebbles DJ. 2005. Area, mobile, and point source contributions to ground-level ozone: a summer simulation across the continental USA. Atmospheric Environment 39(10):1869-77.

Tinling MA, West JJ, Cascio WE, Kilaru V, Rappold AG. 2016. Repeating cardiopulmonary health effects in rural North Carolina population during a second large peat wildfire. Environmental Health 15(1):12. doi:10.1186/s12940-016-0093-4.

Trasande L, Malecha P, Attina TM. 2016. Particulate matter exposure and preterm birth: estimates of US attributable burden and economic costs. Environmental Health Perspectives 124(12):1913–8. doi:10.1289/ehp.1510810.

Trombley J, Chalupka S, Anderko L. 2017. Climate change and mental health. American Journal of Nursing 117(4):44–52. doi:10.1097/01.naj.0000515232.51795.fa.

[UCS] Union of Concerned Scientists. 2019. Killer heat in the United States; climate choices and the future of dangerously hot days [report]. Dahl K, Spanger-Siegfried E, Licker R, Caldas A, Abatzoglou J, Mailloux N, Cleetus R, Udvardy S, Declet-Barreto J, Worth P, authors. Available online https://www.ucsusa.org/sites/default/files/attach/2019/07/killer-heat-analysis-full-report.pdf. Accessed 15 Sep 2019.

Uddling J, Broberg MC, Feng Z, Pleijel H. 2018. Crop quality under rising atmospheric CO_2. Current Opinion in Plant Biology 45(B):262–7. doi:10.1016/j.pbi.2018.06.001.

US Census Bureau. [undated]. 2013-2017 American community survey 5-year estimates [website]. Available online https://www.census.gov/newsroom/press-kits/2018/acs-5year.html. Accessed 25 Apr 2020.

[USEPA] US Environmental Protection Agency. [undated]. Learn about heat islands [website]. Available online https://www.epa.gov/heat-islands/learn-about-heat-islands. Accessed 10 May 2020.

Vescovi L, Rebetez M, Rong F. 2005. Assessing public health risk due to extremely high temperature events: climate and social parameters. Climate Resilience 30:71-8.

Vogel E, Donat MG, Alexander LV, Meinshausen M, Ray DK, Karoly D, Meinshausen N, Frieler K. 2019. The effects of climate extremes on global agricultural yields. Environmental Research Letters 14(5):054010. doi:10.1088/1748-9326/ab154b.

Vox. 2019. The survivors: a year after the Camp Fire nearly leveled Paradise, California, the money is drying up and a lawsuit rages. Can recovery efforts ever return a community to its old self? [article]. Available online https://www.vox.com/the-highlight/2019/10/16/20908291/camp-fire-wildfire-california-paradise-survivors. Accessed 3 Mar 2020.

Wang Yan, Bobb JF, Papi B, Wang Yun, Kosheleva A, Di Q, Schwartz JD, Dominici F. 2016. Heat stroke admissions during heat waves in 1916 US counties for the period from 1999 to 2010 and their effect modifiers. Environmental Health-UK 15(1):83. doi:10.1186/s12940-016-0167-3.

Wang G, Minnis RB, Belant JL, Wax CL. 2010. Dry weather induces outbreaks of human West Nile virus infections. BMC Infectious Disease 10(38). https://doi.org/10.1186/1471-2334-10-38.

Ward TJ, Smith GC. 2001. Air sampling study of the 2000 Montana wildfire season [report]. Missoula MT: University of Montana. 13 p. Available online https://nanopdf.com/download/air-sampling-study-of-the-2000-montana-wildfire-season_pdf#. Accessed 8 May 2020.

Watts N, Amann M, Arnell N, and 65 more. 2018 (Dec 8). 2018 report of the Lancet Countdown on health and climate change: shaping the health of nations for centuries to come. Lancet 392(Lancet 386 2015):2479–514. doi:10.1016/s0140-6736(18)32594-7.

Watts N, Amann M, Arnell N, and 66 more. 2019. The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. Lancet 394(10211):1836-78. doi:10.1016/S0140-6736(19)32596-6.

Westerling A, Hidalgo H, Cayan D, Swetnam T. 2006. Warming and earlier spring increase western US forest wildfire activity. Science 313(5789):940–3. doi:10.1126/science.1128834.

Westerling A. 2016. Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring. Philosophical Transactions of the Royal Society B: Biological Sciences 371(1696):20150178. doi:10.1098/rstb.2015.0178.

Wettstein ZS, Hoshiko S, Fahimi J, Harrison RJ, Cascio WE, Rappold AG. 2018. Cardiovascular and cerebrovascular emergency department visits associated with wildfire smoke exposure in California in 2015. Journal of the American Heart Association 7(8). doi:10.1161/jaha.117.007492.

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.

[WSDOH] Washington State Department of Health. 2018. Washington tracking network: a source for environmental public health data [web tool]. Available online https://fortress.wa.gov/doh/wtn/WTNIBL/. Accessed 3 Mar 2020.

Yue X, Mickley LJ, Logan JA, Kaplan JO. 2013. Ensemble projections of wildfire activity and carbonaceous aerosol concentrations over the western United States in the mid-21st century. Atmospheric Environment 77:767-80. doi:10.1016/j.atmosenv.2013.06.003.

Zanobetti A, Schwartz J. 2008. Is there adaptation in the ozone mortality relationship: a multi-city case-crossover analysis. Environmental Health-UK 7(1):22. doi:10.1186/1476-069x-7-22.

Zhang K, Li Y, Schwartz J, O'Neill M. 2014. What weather variables are important in predicting heat-related mortality? A new application of statistical learning methods. Environmental Research 132:350-9.

Zhang Y, Bielory L, Cai T, Mi Z, Georgopoulos P. 2015. Predicting onset and duration of airborne allergenic pollen season in the United States. Atmospheric Environment 103:297–306. doi:10.1016/j.atmosenv.2014.12.019.

Zhao C, Liu B, Piao S, Wang X, Lobell DB, Huang Y, Huang M, Yao Y, Bassu S, Ciais P, plus 19 others. 2017. Temperature increase reduces global yields of major crops in four independent estimates. Proceedings of the National Academy of Sciences 114(35):9326–31. doi:10.1073/pnas.1701762114.

Ziska LH, Blumenthal DM, Franks SJ. 2019. Understanding the nexus of rising CO_2, climate change, and evolution in weed biology. Invasive Plant Science and Management 12(02):79–88. doi:10.1017/inp.2019.12.

Ziska LH, Caulfield FA. 2000. Rising CO_2 and pollen production of common ragweed (*Ambrosia artemisiifolia* L.), a known allergy-inducing species: implications for public health. Functional Plant Biology 27(10):893. doi:10.1071/pp00032.

Ziska LH, Makra L, Harry SK, Bruffaerts N, Hendrickx M, Coates F, Saarto A, Thibaudon M, Oliver G, Damialis A, plus 16 others. 2019. Temperature-related changes in airborne allergenic pollen abundance and seasonality across the northern hemisphere: a retrospective data analysis. Lancet Planetary Health 3(3):e124–31. doi:10.1016/s2542-5196(19)30015-4.

Section 4. Who is Most Vulnerable to Climate-Change Impacts?

—Susan Higgins, Alexandra Adams[20]

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. In addition, 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 these categories, as we describe below. First, however, it is important to recognize that some people in Montana are already health-challenged with issues like poor diet and nutrition, limited access to healthcare, and/or chronic disease, 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.

[20] Other contributors to this section: Eliza Webber, Rich Ready, Sally Moyce, Paul LaChapelle, Angelina Gonzales-Aller, Jennifer Robohm, Lisa Richidt, Greg Holzman, Margaret Eggers

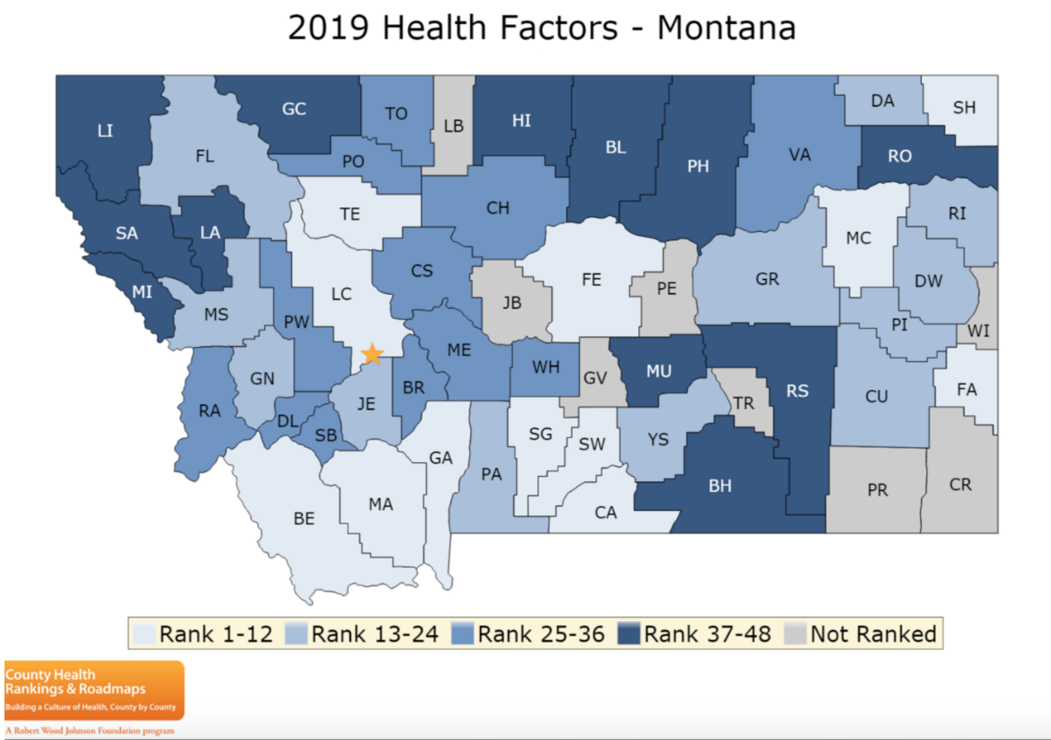


Figure 4-1. Montana's 56 counties ranked with respect to health factors (factors that drive how long and how well we live including, for example, personal behaviors, socioeconomic factors, and the physical environment). The higher the number, the greater the health challenges (Givens et al. 2019). Note: Figure 2-1 provides a map showing and naming Montana's 56 counties.

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

Montana's Health Profile

Before describing Montanans most vulnerable to climate-change-related health concerns, it is important to understand our state's 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). The review of Montana's health profile that follows highlights that our state has existing health-related concerns and complexities, even before adding climate-change-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[21] that lack essential services like healthcare, and thus must travel long distances for such services. Figure 4-2 shows the population status of Montana's 56 counties, and the boundaries of tribal reservations (OMB 2010).

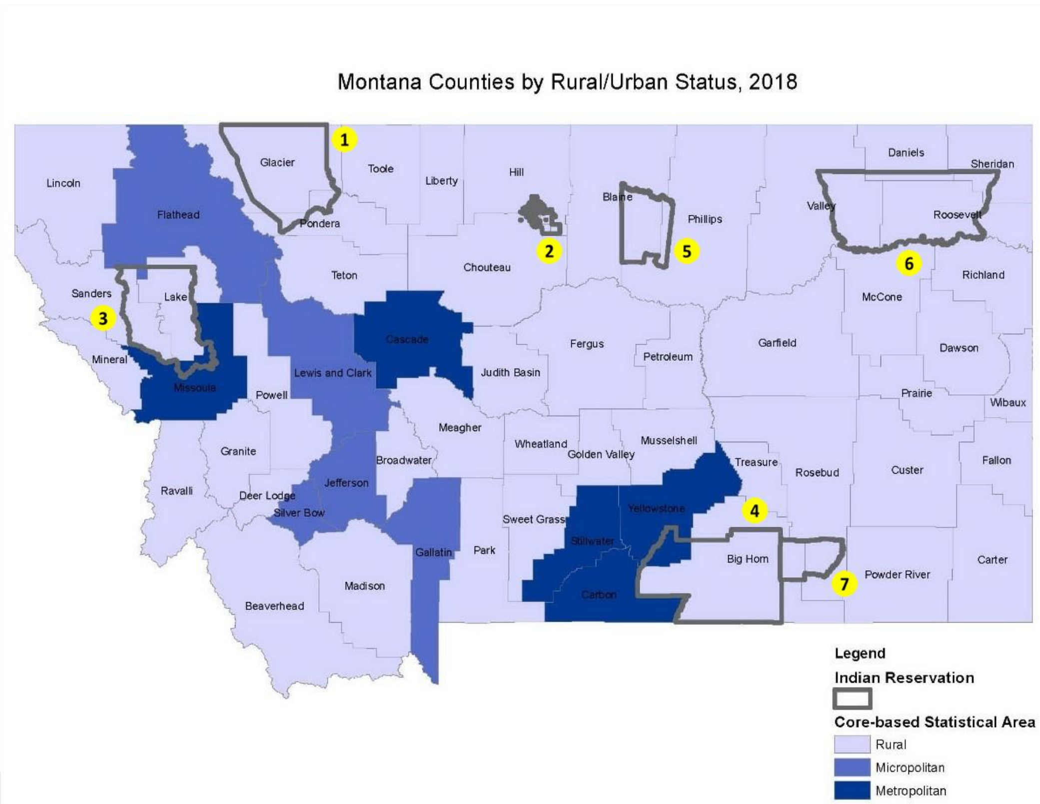


Figure 4-2. Population status of Montana's 56 counties. The three statistical areas shown are defined as follows: *Rural* areas are counties with an urban cluster having less than 10,000 people. *Micropolitan* areas have at least one urban cluster of at least 10,000 but less than 50,000 population, plus 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) Fort Belknap Tribes of the Fort Belknap Reservation; 6) Fort Peck Tribes of the Fort Peck Reservation; 7) Northern Cheyenne Tribe of the Northern Cheyenne Reservation.

Montana averages just 6.9 people/mile^2, making it the third most sparsely populated state in the country (US Census Bureau 2010). The 2018 census population 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

[21] A *frontier area* is defined as having fewer than 7 people/mile^2 (RHIhuba undated).

population resides in a rural area (US Census Bureau 2018b). American Indians make up 6.6% of Montana's population, one of the highest percentages of any state (US Census Bureau 2018c).

> *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 services.*

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 accounting for 83% of the state's total population increase (US Census Bureau 2018d) (Table 4-1; Figure 4-3).

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

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-eight 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.

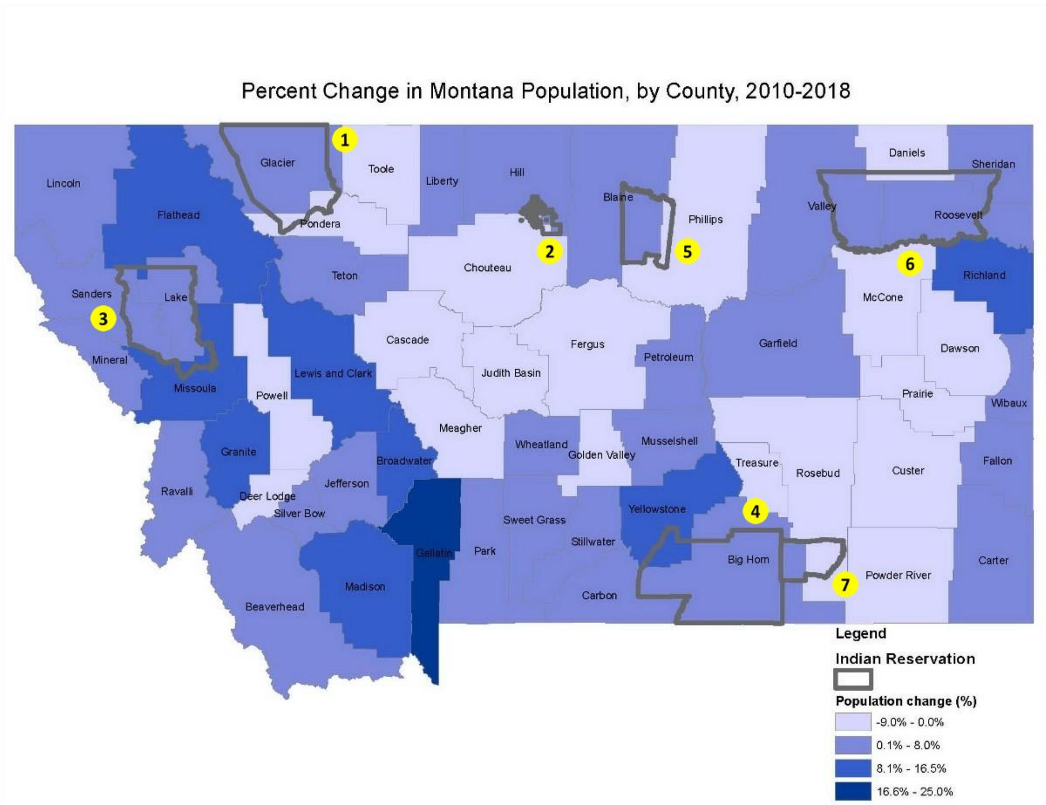


Figure 4-3. Range of percent change in population for Montana's 56 counties from 2010-2018 (US Census Bureau 2018d). Montana's tribal reservations, numbered, are outlined in gray: 1) Blackfeet Tribe of the Blackfeet Reservation; 2) Chippewa Cree Tribe of the Rocky Boy's Reservation; 3) Confederated Salish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

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 substantially higher than for non-Native residents (MTHCF undated). Table 4-2 compares the discrepancies in health outcomes for Montana's different ethnic and racial groups (Givens et al. 2019).

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 [b] (yr lost/100,000)	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 birthweight (%)	5%	7%	9%	10%	12%	8%	7%

[a] AI = American Indian; AN = Alaskan 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

Leading causes of death in Montana, in order of decreasing severity, are heart disease, cancer, respiratory disease, accidents, stroke, and suicide (CDC 2017). Building on this knowledge, Montana’s State Health Improvement Plan identified five priority areas for 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 third highest per capita in the US—24.9 per 100,000 people—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 health 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, physical inactivity, and poor nutrition. 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 1) 75% of Montana adults and 72% of youth do not meet the national physical activity recommendations (MTOPI 2019); and 2) 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. Multiple causes are at play: 1) From 2011–2016, 60% of all crash-related fatalities involved a driver impaired by alcohol or drugs (MTDPHHS 2020a). In addition, the non-governmental group Mothers Against Drunk Driving declared Montana as having the worst driving-under-the-influence laws in the nation (MADD 2019). 2) Some young people living in rural Montana falsely believe that drinking and driving is less dangerous in rural areas because there are fewer drivers on the road (Greene et al. undated). 3) Crashes associated with distracted driving—texting is a top cause—are also common. 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 (MTDPHHS undated).

- *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 encountering chronic disease and mental health issues 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

Summary

Review of Montana's health profile reveals that our state's rural nature—including poor access to healthcare facilities—has a wide-reaching impact on our citizens' well-being. Montanans suffer from chronic disease and illness, inadequate maternal and childhood healthcare, a high percentage of vehicular deaths, and mental illness, suicide, alcoholism, and drug abuse.

We next layer climate-change-related impacts atop these existing health concerns. The remainder of this section describes ten groups having particular health vulnerabilities to such impacts.

PEOPLE THREATENED BY INCREASED HEAT

Why it matters.—National data indicate impacts of increasing heat on mental health and risk of heat stroke (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, insulation or air conditioning).

- *Those working in the outdoors.*—During the summer, migrant and seasonal workers, a mostly immigrant workforce from Mexico, 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).

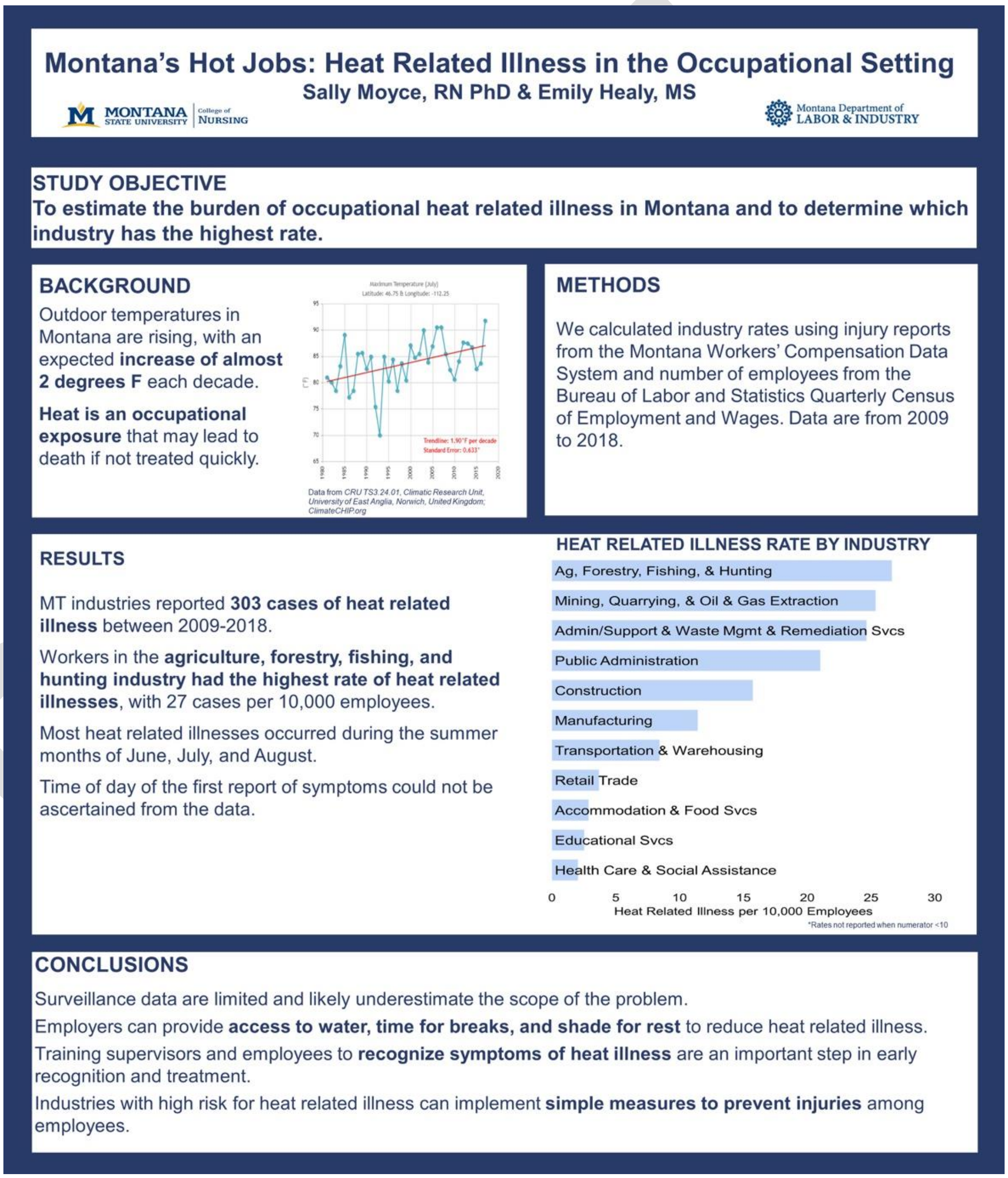


Figure 4-4. Heat-related illness rate by industry (used with permission from Moyce and Nealy 2019).

- *Housing and air conditioning.*—Mobile homes may be particularly susceptible to higher heat days.[22] 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 favor central air conditioning systems, while those in rural areas favor window units. Regionally, the proportion of homes with air conditioning has been increasing. In 2009, 61% of homes in the Northern Mountain Census Division (CO, ID, MT, UT, WY) had air conditioning, while in 2015 the percentage increased to 71% (USEIA undated).

PEOPLE LIVING IN PROXIMITY TO WILDFIRE AND SMOKE

Why it matters.—Particulate matter from wildfire smoke impacts incidence of lung disease and asthma (see sidebar). 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).

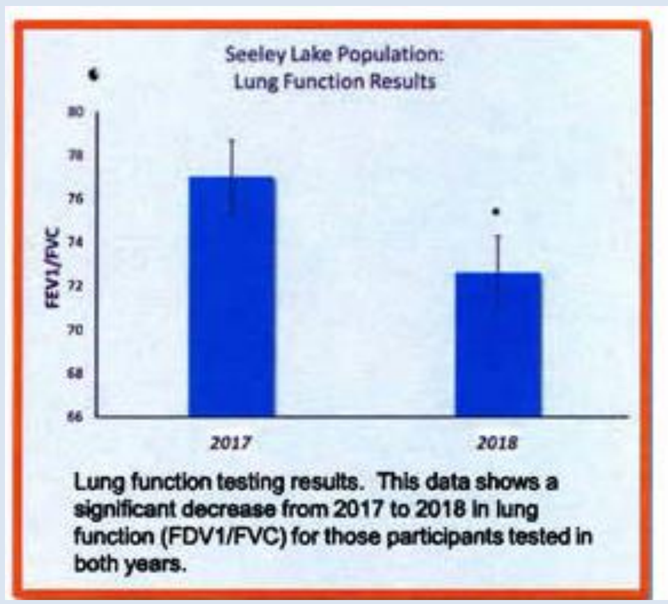
What we know in Montana.—The wildland-urban interface is where human development and wildlands meet or intermingle, placing houses or other structures near or within fire-prone forests. In 2010, 64.1% of Montana houses were located in the wildland-urban interface (Martinuzzi et al. 2015), the second 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 located in high hazard, fire-prone 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.

[22] 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 (MDR undated).

Sidebar: The 2017 Seeley Lake fires and lung function

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

In a local example, Migliaccio 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 amount and rate of air inhaled and exhaled.



Lung function testing results. This data shows a significant decrease from 2017 to 2018 in lung function (FDV1/FVC) for those participants tested in both years.

A decrease in lung function[a] was observed over time. Specifically, measured lung capacity decreased significantly compared with predicted values, with a greater effect on males. In addition, at least half of the participants evaluated in 2018 and 2019 continued to have significant decreases in lung capacity. Observed decreases over the two years following exposure highlight the need for long-term studies to assess the health effects of smoke exposures.

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[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 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.

What we know in Montana.—In 2017, 42,745 (10.2% of total) households received food stamps from the Supplemental Nutrition Assistance Program[23]; 19,564 (4.7% of total) received Supplemental Security Income[24]; and 8696 (2.1% of total) received cash public assistance income (Headwaters Economics 2019).

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 to the nearest supermarket (or 1 mile in urban areas). This equates to nearly 72,000 Montanans without fresh, affordable food on a daily basis (MFBN undated).

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Most Montanans (86%) get their drinking water from public water supplies and most public water supply systems meet the Environmental Protection Agency's Safe Drinking Water Standards (MTDEQ undated). Still, the MCA (Whitlock et al. 2017) 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. The MCA also states that Montana will experience reduced snowpack and diminished late-season flows with changing climate. Both are

[23] 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.

[24] 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.

critical to public and private water supplies, as well as agriculture production and, hence, food security[25].

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. The availability of 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 gauging 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).

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).

People Who are Very Young, Very Old, or Pregnant

Why it matters.—Beginning at the fetal development stage, environmental 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, they 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. Clayton et al. (2014), for example, 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 influences health and socioeconomic well-being later in life, as well (Anda and Brown 2010; Currie et al. 2014).

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

[25] 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.

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. The elderly often have compromised mobility that reduces, as one example, their ability to respond to natural disasters. Given chronic obstructive pulmonary disease (and more), 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).

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 or Sudden Unexpected Infant Death Syndrome (see also Section 3). Women are less tolerant of extreme heat during pregnancy. They are more sensitive to dehydration and acute kidney damage. As with the elderly, pregnant women have reduced mobility that may hinder their ability to respond to natural disasters.

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 into 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.

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 (RHIhubb undated). 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 (Healthinfo 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 to 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 sometimes live in mobile homes and are more vulnerable to heat-related illnesses and extreme weather events (Headwaters Economics 2019).

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).

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 problems, 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 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 observed (Doyle et al. 2013; Doyle and Eggers 2017; see sidebar). 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 these wild food as already adversely impacted by climate changes, such as increased wildfires 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 as 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, as well 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).

Sidebar: Changes Rippling Through Our Waters and 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. 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 the urban counties than in rural counties.

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 Existing Chronic Conditions

Why it matters.—People living with existing 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 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). For Montana, 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 diagnostic 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; see sidebars—adjacent and in Section 3).

Sidebar: 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.

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 Native American 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 United States, 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).

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 fact, 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 United States. Males are 3.5 times more likely to die by suicide than females. Others at risk are veterans over non-veterans, American Indians over other groups, and residents of rural counties compared to micropolitan counties. In 2017, Montana had the highest suicide rate in the United States, but in 2018 the state dropped to fourth highest (AAS 2020a,b).

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).

The Governor 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?

The MCA (Whitlock et al. 2017) finds that Montana will experience more 90ºF+ heat days, increased wildfires, more spring flooding, and less water available with more drought during the late growing season. Given this knowledge, communities need to take action now to protect the health of Montana residents most vulnerable to impacts of climate change. The next section provides recommendations for how individual community members, healthcare practitioners and facilities, and Montana communities (including city, state, and tribal governments) can respond today to address these vulnerabilities.

LITERATURE CITED

Albrecht G, Sartore G-M, Connor L, Higginbotham N, Freeman S, Kelly B, Stain H, Tonna A, Pollard G. 2007. Solastalgia: the distress caused by environmental change. Australasian Psychiatry 15(Suppl 1):S95-8. doi:10.1080/10398560701701288.

[AAS] American Association of Suicidology. 2020a. Annual ranking of USA states by crude suicide rates (rates per 100,000 population), 1990-2018 [report]. Available online https://suicidology.org/wp-content/uploads/2020/02/StateRankings1990to2018TABLE.pdf. Accessed 28 Apr 2020.

[AAS] American Association of Suicidology. 2020b. USA suicide: 2018 official final data [report]. Available online https://suicidology.org/wp-content/uploads/2020/02/2018datapgsv2_Final.pdf. Accessed 24 Apr 2020.

Anda RF, Brown DW. 2010. Adverse childhood experiences and population health in Washington: the face of a chronic public health disaster. Results from the 2009 Behavioral Risk Factor Surveillance System (BRFSS) [report prepared for the Washington State Family Policy Council]. 131 p. Available online http://www.wvlegislature.gov/senate1/majority/poverty/ACEsinWashington2009BRFSSFinalReport%20-%20Crittenton.pdf. Accessed 3 Mar 2020.

Anderko L, Chalupka S, Du M, Hauptman M. 2020. Climate changes reproductive and children's health: a review of risks, exposures, and impacts. Pediatric Research 87:414–9. https://doi.org/10.1038/s41390-019-0654-7.

Balbus JM, Malina C. 2009. Identifying vulnerable subpopulations for climate change health effects in the United States. Journal of Occupational and Environmental Medicine 51(1):33-7. doi:10.1097/JOM.0b013e318193e12e.

Bell ML, Zanobetti A, Dominici F. 2014. Who is more affected by ozone pollution? A systematic review and meta-analysis. American Journal of Epidemiology 180(1):15–28.

Bennett TMB, Maynard NG, Cochran P, Gough R, Lynn K, Maldonado J, Voggesser G, Wotkyns S, Cozzetto K. 2014. Indigenous Peoples, Lands, and Resources [chapter 12]. In: Melillo JM, Richmond TC, Yohe GW (eds). 2014: Climate change impacts in the United States: the Third National Climate Assessment. Washington DC: US Global Change Research Program. p 297-317. Available online https://nca2014.globalchange.gov/highlights/report-findings/indigenous-peoples. Accessed 29 Feb 2020.

Besser TL. 2013. Resilient small rural towns and community shocks. Journal of Rural and Community Development 8(1). Available online https://journals.brandonu.ca/jrcd/article/view/725/163. Accessed 28 May 2020.

Billings Gazette. 2011a (Jun 4). Historic floods: old-timers make comparisons with epic 1978 flood [article]. Available online https://billingsgazette.com/news/state-and-regional/montana/old-timers-make-comparisons-with-epic-flood/article_b64fc028-1c1b-599e-bfe0-69fa33156eaa.html. Accessed 11 May 2020.

Billings Gazette. 2011b (Jun 15). Crow flooding: more than 200 Crow Reservation homes damaged, destroyed from flooding [article]. Available online https://rapidcityjournal.com/news/more-than-crow-reservation-homes-damaged-destroyed-from-flooding/article_74023f48-9837-11e0-b2c0-001cc4c002e0.html. Accessed 28 Apr 2020.

Billings Gazette. 2012 (Nov 1). Montana wildfires burn most acreage since 1910; $113M spent to battle blazes [article]. Available online https://billingsgazette.com/news/state-and-regional/montana/montana-wildfires-burn-most-acreage-since-m-spent-to-battle/article_88b22157-7b4b-5b0b-9951-9732801e7fe7.html. Accessed 28 Apr 2020.

Brennan M, O'Keeffe ST, Mulkerrin EC. 2019. Dehydration and renal failure in older persons during heatwaves-predictable, hard to identify but preventable? Age and Ageing 48(5)615–8.

Broman CL, Hamilton VL, Hoffman WS. 1990. Unemployment and its effects on families: evidence from a plant closing study. American Journal of Community Psychology 18(5):643-59.

Campaign for Tobacco-Free Kids. 2017. The toll of tobacco in Montana [website]. Available online https://www.tobaccofreekids.org/problem/toll-us/montana. Accessed 13 May 2020.

Carley S, Evans TP, Konisky DM. 2018 (Mar). Adaptation, culture, and the energy transition in American coal country. Energy Research and Social Science 37:133-9.

[CDCa] Centers for Disease Control and Prevention. undated. Frequently asked questions about extreme heat [website]. Available online https://www.cdc.gov/disasters/extremeheat/faq.html. Accessed 23 Mar 2020.

[CDCb] Centers for Disease Control and Prevention. [undated]. Violence prevention: preventing adverse childhood experiences [website]. Available online https://www.cdc.gov/violenceprevention/childabuseandneglect/acestudy/index.html. Accessed 1 Mar 2020.

[CDCc] Centers for Disease Control and Prevention. [undated]. Violence prevention: behavioral risk factor surveillance system ACE data [website]. Available online https://www.cdc.gov/violenceprevention/childabuseandneglect/acestudy/ace-brfss.html. Accessed 1 Mar 2020.

[CDC] Centers for Disease Control and Prevention. 2017. National Center for Health Statistics: stats of the state of Montana [website]. Available online https://www.cdc.gov/nchs/pressroom/states/montana/montana.htm. Accessed 18 Mar 2020.

[CDC] Centers for Disease Control and Prevention. 2018. National Center for Health Statistics: Suicide mortality by state [website]. Available online https://www.cdc.gov/nchs/pressroom/sosmap/suicide-mortality/suicide.htm. Accessed 26 Mar 2020.

City of Roundup. [undated]. Floods of 2011 [website]. Available online http://www.roundupmontana.net/flood-2011.html. Accessed 28 Feb 2020.

Clayton S, Manning C, Krygsman K, Speiser M. 2017. Mental health and our changing climate: impacts, implications, and guidance [report]. Washington DC: American Psychological Association and ecoAmerica. 70 p. Available online https://www.apa.org/images/mental-health-climate_tcm7-215704.pdf. Accessed 29 Feb 2020.

Clayton S, Manning CM, Hodge C. 2014. Beyond storms and droughts: the psychological impacts of climate change [report]. Washington DC: American Psychological Association and ecoAmerica. 51 p. http://ecoamerica.org/wp-content/uploads/2014/06/eA_Beyond_Storms_and_Droughts_Psych_Impacts_of_Climate_Change.pdf. Accessed 3 Mar 2020.

Clifford A, Lang L, Chen R, Anstey KJ, Seaton A. 2016. Exposure to air pollution and cognitive functioning across the life course—a systematic literature review. Environmental Research 147:383-98. http://dx.doi.org/10.1016/j.envres.2016.01.018.

Cooley H, Moore E, Heberger M, Allen L. 2012 (Jul). Social vulnerability to climate change in California [report]. Prepared for the California Energy Commission Pub; report #CEC-500-2012-013. 77 p. Available online https://ww2.energy.ca.gov/2012publications/CEC-500-2012-013/CEC-500-2012-013.pdf. Accessed 13 May 2020.

Cozetto K, Chief K, Dittmer K, Brubaker M, Fough R, Souza K, Ettawageshik F, Wotkyns S, Opitz-Stapleton S, Duren S, Chavan P. 2013. Climate change impacts on the water resources of American Indians and Alaska Natives in the US. Climatic Change 120:569–84. doi:10.1007/s10584-013-0852-y.

Currie J, Zivin JG, Mullins J, Neidell M. 2014. What do we know about short- and long-term effects of early-life exposure to pollution? Annual Review of Resource Economics 6(1):217-47. http://dx.doi.org/10.1146/annurev-resource-100913-012610.

Donatuto JL, Satterfield TA, Gregory R. 2011. Poisoning the body to nourish the soul: prioritizing health risks and impacts in a Native American community. Health, Risk, and Society 13(2):103-27. doi:10.1080/13698575.2011.556186.

Doyle JT, Redsteer MH, Eggers MJ. 2013. Exploring effects of climate change on Northern Plains American Indian health. Climatic Change 120(3):643–55. doi:10.1007/s10584-013-0799-z.

Doyle JT, Eggers MJ. 2017. Crow climate observations [sieebar]. In: Whitlock C, Cross WF, Maxwell B, Silverman N, Wade AA. 2017 Montana Climate Assessment. Bozeman and Missoula MT: Montana State University and University of Montana, Montana Institute on Ecosystems. P 23-26. Available online http://montanaclimate.org/. Accessed 13 May 2020.

Doyle JT, Kindness L, Realbird J, Eggers MJ, Camper AK. 2018. Challenges and opportunities for tribal waters: addressing disparities in safe public drinking water on the Crow Reservation in Montana, USA. International Journal of Environmental Research in Public Health 15(4):E567. doi:10.3390/ijerph15040567.

Durch JS, Bailey LA, Stoto MA, eds. 1997. Measurement tools for community health improvement process [chapter 5]. In: Improving health in the community: a role for performance monitoring. Washington DC: National Academies Press, Institute of Medicine, Committee on Using Performance Monitoring to Improve Community Health. Available online https://www.ncbi.nlm.nih.gov/books/NBK233011/#ddd00101. Accessed 14 Apr 2020.

Ebi KL, Balbus JM, Luber G, Bole A, Crimmins A, Glass G, Saha S, Shimamoto MM, Trtanj J, White-Newsome JL. 2018. Tribes and indigenous people [chapter 15]. In: Reidmiller DR, Avery CW, Easterling DR, Kunkel KE, Lewis KLM, Maycock TK, Stewart BC (eds). Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, vol II. Washington DC: US Global Change Research Program. p 572–603. Available online https://nca2018.globalchange.gov/downloads/NCA4_Ch15_Tribes-and-Indigenous-Peoples_Full.pdf. Accessed 3 Mar 2020

Ferguson DB, Alvord C, Crimmins M, Redsteer HM, Hayes M, McNutt C, Pulwarty R,Svoboda M. 2011. Drought preparedness for tribes in the Four Corners region [report from April 8-9 2010 workshop]. Tucson AZ: University of Arizona, The Institute of the Environment, Climate Assessment for the Southwest. 42 p. Available online https://www.drought.gov/drought/sites/drought.gov.drought/files/media/resources/tribal/wksp_Drought%20Preparedness%20for%20Tribes%20in%20the%20Four%20Corners%20Region_Workshop%20Report_04-08-10.pdf. Accessed 13 May 2020.

Ford JD. 2012. Indigenous health and climate change. American Journal of Public Health 102(7):1260-6.

Forman F, Solomon G, Morello-Frosch R, Pezzoli K. 2016. Chapter 8—Bending the curve and closing the gap: climate justice and public health [online special collections report]. Oakland CA: University of California Press. Collabra 2(1):22. http://doi.org/10.1525/collabra.67.

Gamble J, Balbus J, Berger M, Bouye K, Campbell V, Chief K, Conlon K, Crimmins A, Flanagan B, Gonzalez-Maddux C, Hallisey E, Hutchins S, Jantarasami L, Khoury S, Kiefer M, Kolling J, Lynn K, Manangan A, McDonald M, Morello-Frosch R, Hiza M, Sheffield P, Thigpen Tart K, Watson J, Whyte KP, Wolkin AF. 2016. Populations of concern [chapter 9]. In: 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). The impacts of climate change on human health in the United States: a scientific assessment. Washington DC: US Global Change Research Program. p 247-86. Available online https://health2016.globalchange.gov/high/ClimateHealth2016_09_Populations.pdf. Accessed 13 May 2020.

Givens M, Jovaag A, Roubal A. 2019. Montana: 2019 county health rankings report. Madison WI: University of Wisconsin Population Health Institute. 16 p. Available online https://www.countyhealthrankings.org/sites/default/files/media/document/state/downloads/CHR2019_MT.pdf. Accessed 28 Feb 2020.

Great Falls Tribune. 2018 (Feb 21). Critical human needs rise as Blackfeet endure unrelenting winter storms. Available online https://www.greatfallstribune.com/story/news/2018/02/21/critical-human-needs-rise-blackfeet-endure-unrelenting-winter-storms/359300002/. Accessed 28 Feb 2020.

Greene KM, Rossheim ME, Murphy ST. [undated]. Drinking and driving in the Big Sky state: key insights from young adults [report]. Bozeman MT: Montana State University, Center for American Indian and Rural Health Equity. 8 p. Available online http://www.montana.edu/cairhe/other-investigators/greene/Drinking%20and%20Driving%20in%20the%20Big%20Sky%20State.pdf. Accessed 9 May 2020.

Haggerty JH, Haggerty MN, Roemer K, Rose J. 2018. Planning for the local impacts of coal facility closure: emerging strategies in the US West. Resources Policy 57:69-80.

Headwaters Economics. 2018 (Jun). New Montana homes increase wildfire risks [online report]. Available online https://headwaterseconomics.org/wildfire/homes-risk/new-montana-homes-increase-wildfire-risks/. Accessed 2 May 2020.

Headwaters Economics. 2019. Populations at risk [website]. Available online https://headwaterseconomics.org/tools/populations-at-risk/. Accessed 28 Feb 2020.

Healthinfo. 2017. Addressing health needs in rural Montana: an aggregate summary of community health needs assessments and implementation plans of Montana critical access and rural hospitals 2015-2017 [internal report]. Available online via http://healthinfo.montana.edu/morh/chsd/about.html (navigate to “View addressing health needs report”). Accessed 15 Apr 2020.

Heindel JJ, Balbus J, Birnbaum L, Brune-Drisse MN, Grandjean P, Gray K, Landrigan PJ, Sly PD, Suk W, Slechta DC, Thompson C, Hanson M. 2016. Developmental origins of health and disease: integrating environmental influences. Endocrinology 156(10):3416-21. http://dx.doi.org/10.1210/en.2015-1394.

Hendryx M. 2009 (Jan). Mortality from heart, respiratory, and kidney disease in coal mining areas of Appalachia. International Archives of Occupational and Environmental Health 82(2):243-9. doi:10.1007/s00420-008-0328-y.

[HRSA] Health Resources and Services Administration. [undated]. Health workforce: shortage designation scoring criteria [website]. Available online https://bhw.hrsa.gov/shortage-designation/hpsa-criteria. Accessed 29 Feb 2020.

Leiserowitz A, Maibach E, Rosenthal S, Kotcher J, Bergquist P, Ballew M, Goldberg M, Gustafson A. 2019. Climate change in the American mind: April 2019. New Haven CT: Yale University and George Mason University, Yale Program on Climate Change Communication. 71 p. Available online https://osf.io/296be/. Accessed 13 May 2020.

[MADD] Mothers Against Drunk Driving. 2019. MADD report rates every state on drunk driving laws [website]. Available online https://www.madd.org/press-release/madd-report-rates-every-state-on-drunk-driving-laws/. Accessed 1 Mar 2019.

Martin C, Doyle J, LaFrance J, Lefthand MJ, Young SL, Three Irons E, Eggers M. 2020. Change rippling through our waters and culture. Journal of Contemporary Water Research and Education. Forthcoming.

Martin C, Doyle J, LaFrance J, Lefthand MJ, Young SL, Three Irons E, Eggers M. 2020. Change rippling through our waters and culture. Journal of Contemporary Water Research and Education. Forthcoming.

Martinuzzi S, Steward SI, Helmers DP, Mockrin MH, Hammer RB, Radeloff VC. 2015. The 2010 wildland-urban interface of the conterminous United States. Research Map NRS-8. Research map NRS-8. Newtown Square PA: US Department of Agriculture, Forest Service, Northern Research Station. 124 p. Available online https://www.nrs.fs.fed.us/pubs/48642. Accessed 13 May 2020.

[MDR] Montana Department of Revenue. [undated]. Montana and manufactured homes [website]. Available online https://mtrevenue.gov/property/property-types/mobile-manufactured-homes/. Accessed 28 Feb 2020.

[MFBN] Montana Food Bank Network. [undated]. Hunger in Montana [website]. Available online https://mfbn.org/hunger-in-montana/. Accessed 28 Feb 2020.

[MOPI] Montana Office of Public Instruction. 2019. 2019 Montana youth risk behavior survey: high school results [internal report]. Helena MT: Montana Office of Public Instruction. p 29. Accessible online http://opi.mt.gov/Portals/182/Page%20Files/YRBS/2019YRBS/2019_MT_YRBS_FullReport.pdf?ver=2019-08-23-083248-820. Accessed 27 May 2019.

Moyce S, Nealy E. 2019. Montana's hot jobs: heat-related illness in the occupational setting. Presented at: Montana Environmental Health Association/Montana Public Health Association Annual Conference and Meeting. 17-18 Sep 1919. Bozeman MT.

[MPHIS] Montana Public Health Information System . [undated]. Query results for Montana birth data, years 1999 to 2018—average number of prenatal visits [website]. Available online http://ibis.mt.gov/query/result/birth/BirthBirthCnty/AvgPNCVisit.html. Accessed 5 May 2020.

[MTDEQ] Montana Department of Environmental Quality. [undated]. Drinking water rules and monitoring [website]. Available online https://deq.mt.gov/Water/DrinkingWater/Monitoring. Accessed 28 Apr 2020.

[MTDPHHS] Montana Department of Public Health and Human Services. [undated]. Priority area 3: motor vehicle crashes [website]. Available online https://dphhs.mt.gov/ahealthiermontana/mvcs. Accessed 1 Mar 2020.

[MTDPHHS] Montana Department of Public Health and Human Services. 2016. 2016 Montana behavioral risk factor surveillance system annual report [report]. Helena MT: Montana DPHHS, Office of Epidemiology and Scientific Support. 46 p. Available online https://dphhs.mt.gov/Portals/85/publichealth/documents/BRFSS/Annual%20Reports/BRFSS_Annual_Report_2016.pdf. Accessed 1 Mar 2020.

[MTDPHHS] Montana Department of Public Health and Human Services. 2017 (Oct). Trends in infant mortality, Montana 2006-2015 [report]. Helena MT: Montana DPHHS, Office of Epidemiology and Scientific Support. 4 p. https://dphhs.mt.gov/Portals/85/publichealth/documents/Epidemiology/VSU/VSU_InfantMortality_2006_2017.pdf. Accessed 1 Mar 2020.

[MTDPHHS] Montana Department of Public Health and Human Services. 2019a (Feb). Montana state health assessment 2017—a report on the health of Montanans. Available online: https://dphhs.mt.gov/Portals/85/ahealthiermontana/2017SHAFinal.pdf. Accessed 18 Mar 2020.

[MTDPHHS] Montana Department of Public Health and Human Services. 2019b. Suicide prevention strategic plan 2019 [report]. p 2. Available online https://dphhs.mt.gov/Portals/85/suicideprevention/StateSuicidePlan2019.pdf. Accessed 28 Apr 2020.

[MTDPHHS] Montana Department of Public Health and Human Services. 2020a (Jan). Montana state health improvement plan 2109-2023 [internal report]. 35 p. Available online https://dphhs.mt.gov/Portals/85/ahealthiermontana/2019SHIPFinal.pdf. Accessed 1 Mar 2020.

[MTDPHHS] Montana Department of Public Health and Human Services. 2020b. Governor Bullock announces plan to invest $80 million in community mental health services over five years [press release]. Available online https://dphhs.mt.gov/aboutus/news/2020/investmentalhealthservices. Accessed 28 Apr 2020.

[MTHCF] Montana Healthcare Foundation. [undated]. Improving the health and well-being and reducing disparities in health and life expectancy among American Indian people in Montana [website]. Available online https://mthcf.org/focus-areas/american-indian-health-2/health-disparities/. Accessed 1 Mar 2020.

[MTOPI] Montana Office of Public Instruction. 2019. Montana youth risk behavior survey. Available online https://opi.mt.gov/Portals/182/Page%20Files/YRBS/2019YRBS/2019_MT_YRBS_FullReport.pdf?ver=2019-08-23-083248-820. Accessed 14 May 2020.

[MTPHIS] Montana Public Health Information System. [undated]. MT-IBIS [health] indictor reports [website]. Available online http://ibis.mt.gov/indicator/view/InjuryMVCDeath.Year.MT_US.html. Accessed 13 May 2020.

NBC News. 2018 (Dec 24). Climate grief: the growing emotional toll of climate change [article]. Available online https://www.nbcnews.com/health/mental-health/climate-grief-growing-emotional-toll-climate-change-n946751. Accessed 4 May 2020.

[NCCDPHP] National Center for Chronic Disease Prevention and Health Promotion. 2019. About chronic diseases [website]. Available online https://www.cdc.gov/chronicdisease/about/index.htm. Accessed 25 Mar 2020.

[NEAA] Northwest Energy Efficiency Alliance. 2012. 2011 Residential building stock assessment: single-family characteristics and energy use. A report to NEAA from Ecotope Inc, Seattle WA. 231 p. Available online https://neea.org/img/documents/residential-building-stock-assessment-single-family-characteristics-and-energy-use.pdf. Accessed 28 Feb 2020.

[NEAA] Northwest Energy Efficiency Alliance. 2014. Montana single-family homes—state summary statistics [internal report]. 21 p. Available online https://neea.org/img/documents/montana-state-report-final.pdf. Accessed 28 Feb 2020.

[NPR] National Public Radio. 2019 (Feb 12). Lung function decline continued one year after Rice Ridge Fire, research finds [report]. Available online https://www.mtpr.org/post/lung-function-decline-continued-one-year-after-rice-ridge-fire-research-shows. Accessed 4 May 2020.

Ojima D, Steiner J, McNeeley S, Cozetto K, Childress A. 2013. Great Plains Regional Climate Assessment Technical Report, National Climate Assessment 2013. Washington DC: Island Press. 224 p.

[OMB] Office of Management and Budget. 2010. 2010 standards for delineating metropolitan and micropolitan statistical areas. Federal Register/ Vol. 75, No. 123 / Monday, June 28, 2010 / Notices. p 37246. Available online https://obamawhitehouse.archives.gov/sites/default/files/omb/assets/fedreg_2010/06282010_metro_standards-Complete.pdf. Accessed 10 Feb 2020.

Peterson W, Bond N, Robert M. 2015. The warm blob—conditions in the northeastern Pacific Ocean [article]. PICES Press 23(1):36-8. Available online https://www.pices.int/publications/pices_press/volume23/PPJanuary2015.pdf. Accessed 3 Mar 2020.

Prasad S, Sung B, Aggarwal BB. 2013. Age-associated chronic diseases require age-old medicine: role of chronic inflammation. Preventative Medicine 54(1):S29-37. doi:10.1016/j.ypmed.2011.11.011.

Ravanelli N, Casasola W, English T, Edwards K M, Jay O. 2019. Heat stress and fetal risk. Environmental limits for exercise and passive heat stress during pregnancy: a systematic review with best evidence synthesis. British Journal of Sports Medicine 53(13):799-805.

Redsteer MH, Kelley KB, Francis H, Block D. 2011. Disaster risk assessment case study: recent drought on the Navajo Nation, southwestern United States. Contributing paper for the Global Assessment Report on Disaster Risk Reduction. Reston VA: United Nations Office for Disaster Risk Reduction and US Geological Survey. 19 p. Available online https://www.researchgate.net/publication/260710023_Disaster_Risk_Assessment_Case_Study_Recent_Drought_on_the_Navajo_Nation_southwestern_United_States/citation/download. Accessed 14 May 2020.

[RHIhuba] Rural Health Information Hub. [undated]. Health and healthcare in frontier areas [website]. Available online https://www.ruralhealthinfo.org/topics/frontier. Accessed 14 Apr 2020.

[RHIhubb] Rural Health Information Hub. [undated]. Montana [website]. Available online https://www.ruralhealthinfo.org/states/montana. Accessed 28 Apr 2020.

Siddika N, Balogun HA, Amegah AK, Jaakkola JJK. 2016. Prenatal ambient air pollution exposure and the risk of stillbirth: systematic review and meta-analysis of the empirical evidence. Occupational and Environmental Medicine 73(9):573-81. doi:10.1136/oemed-2015-103086.

Sommers BD, Gawande AA, Baicker K. 2017. Health insurance coverage and health—what the recent evidence tells us. New England Journal of Medicine 377(6):586-93. doi:10.1056/NEJMsb1706645.

Smith E, Ahmed S, Dupuis V, Running Crane M, Eggers M, Pierre M, Flagg K, Byker Shanks C. 2019. Contribution of wild foods to diet, food security, and cultural values amidst climate change. Journal of Agriculture, Food Systems, and Community Development 9(B):191-214. https://doi.org/10.5304/jafscd.2019.09B.011.

Spokesman-Review. 2018 (Feb 27). Relentless winter brings state of emergency to Montana reservations [article]. Available online https://www.spokesman.com/stories/2018/feb/27/relentless-winter-brings-state-of-emergency-to-mon/). Accessed 28 Feb 2020.

Sun X, Luo X, Zhao C, Chung Ng RW, Lim CED, Zhang B, Liu T. 2015. The association between fine particulate matter exposure during pregnancy and preterm birth: a meta-analysis. BMC Pregnancy and Childbirth 15:300. http://dx.doi.org/10.1186/s12884-015-0738-2.

Time. 2019 (Nov 21). Terrified of climate change? You might have eco-anxiety [article]. Available online https://time.com/5735388/climate-change-eco-anxiety/. Accessed 28 Apr 2020.

US Census Bureau. [undated]. 2017 ACS 1-year estimates [website data source]. Available online https://www.census.gov/programs-surveys/acs/technical-documentation/table-and-geography-changes/2017/1-year.html. Accessed 28 Apr 2020.

US Census Bureau. 2010. 2010 census: population density data [website data source. Available online https://www.census.gov/data/tables/2010/dec/density-data-text.html. Accessed 18 Mar 2020.

US Census Bureau. 2018a. Delineation files [website data source]. Available online https://www.census.gov/geographies/reference-files/time-series/demo/metro-micro/delineation-files.html. Accessed 10 Feb 2020.

US Census Bureau. 2018b. Metropolitan and micropolitan statistical areas population totals: 2010-2018 [website data source]. Available online https://www.census.gov/data/tables/time-series/demo/popest/2010s-total-metro-and-micro-statistical-areas.html#par_textimage. Accessed 28 Feb 2020.

US Census Bureau. 2018c. Quick facts Montana [website data source]. Available online https://www.census.gov/quickfacts/fact/table/MT/RHI325218#qf-headnote-a. Accessed 28 Feb 2020.

US Census Bureau. 2018d. County population totals and components of change: 2010-2018 [website data source]. Available online https://www.census.gov/data/tables/time-series/demo/popest/2010s-counties-total.html. Accessed 28 Feb 2020.

US Census Bureau. 2018e. US Census American community survey 2013-2017 5-year data release [website data source]. Available online https://www.census.gov/newsroom/press-kits/2018/acs-5year.html. Accessed 29 Feb 2020.

US Census Bureau. 2019. State population by characteristics: 2010-2019 [website data source]. Available online https://www.census.gov/data/tables/time-series/demo/popest/2010s-state-detail.html#par_textimage_785300169 gov. Accessed 29 Feb 2020.

[USEIA] US Energy Information Administration. [undated]. Residential energy consumption survey [website]. Available online https://www.eia.gov/consumption/residential/. Accessed 28 Feb 2020.

[USEPA] US Environmental Protection Agency. 2016. Climate change and the health of people with existing medical conditions [report]. US EPA report 430-F-16-059. 2 p. Available online https://www.cmu.edu/steinbrenner/EPA%20Factsheets/existing-conditions-health-climate-change.pdf. Accessed 28 Apr 2020.

[USGCRP] 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.

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.

[YPCCC] Yale Program on Climate Change Communication. 2019. Yale climate opinion maps 2019 [website]. Available online https://climatecommunication.yale.edu/visualizations-data/ycom-us/. Accessed 30 Apr 2020.

Section 5. Climate Health Actions for Individuals, Healthcare Practitioners and Facilities, and Communities

— Alexandra Adams, Susan Higgins, Margaret Eggers[26]

Opportunities abound for Montana individuals, healthcare practitioners (be they single providers, clinics, or larger facilities), and communities to address climate-change-induced health concerns. In this section, we catalog ways each of these groups can prepare for, respond to, or adapt to our state's warming climate. For some it may seem like the challenge is too great, but even small efforts to improve our health, well-being, and personal resilience make a difference. We describe actions and resources[27] for dealing with the key health issues described in Sections 3 and 4, with a goal of providing 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 wilting crops—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-change-induced human health issues. Such efforts can be simple, yet collectively make a big difference. For example, growing a nutritious and shared community garden, creating green space by planting trees, taking walks with a friend, buying an electric car, eating more local foods, installing solar panels, recycling and re-using, driving less, biking, and more; all play a part in strengthening individual and community health (Khumalo and Stoneciper 2018).

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[27] 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.

> *While the risks and outcomes of climate change may seem beyond anyone's direct control, there are many actions possible for protecting your health, your family's health, and your community's health.*

While the risks and outcomes of climate change may seem beyond anyone's direct control, there are many actions possible for protecting your health, your family's health, and your community's health. The remainder of this section details those actions, as well as key information sources, for individuals, for healthcare practitioners and facilities, and for communities. Now is the right time to explore these healthcare options, create goals and action plans, and build relationships to understand who around you are most vulnerable to climate health impacts, and who are best positioned to provide support.

INDIVIDUAL ACTIONS: PREPARING YOURSELF FOR HEALTH RISKS

Below we recommend actions that individuals can take to prepare for or minimize health risks associated with climate change. The recommendations are broken into climate concerns similar to those addressed in Section 3 (global and national health concerns in a changing climate) and Section 4 (Montana sectors vulnerable to climate change).

Protecting your health in a changing climate takes work. While we provide many actions and information sources for climate-change-induced health concerns, there are two simple steps every individual can take now. First, have regular checkups with a healthcare professional; and second, stay informed regarding expected and ongoing climate-change impacts.

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, increased intense storms (Whitlock et al. 2017; Section 2).

Here's what you can do:

- Plan ahead so that you can comfortably stay in your home during extreme events, including, for example, being snowed-in for extended periods. Have several days of medications, water, and food safely stored in the home. Make sure you have adequate blankets or sleeping bags to stay warm during low temperatures and/or power outages.

- Install a functional carbon monoxide 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 weather event, for example floods, drought, wildfires, and severe winter storms. Such events pose serious risks to mental health, particularly if these events are accompanied by 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 slides (mud, rocks, foundation), as you may need to purchase separate coverage from the National Flood Insurance Program (FEMAa undated) or elsewhere.

Heat

MCA (Whitlock et al. 2017) notes that with climate change the number of days when temperature exceeds 90^{o}F in Montana is increasing. A good resource is on changing heat information and health-related issues is the National Integrated Heat Health Information System.[28]

Here's what you can do:

- 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.
- 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 from Northwestern Energy[29], the Montana's electric cooperatives[30], the Montana Department of Health and Human Services[31], the US Department of Energy[32], and the US Department of Housing and Urban Development[33].
- Know the locations of cooling centers—e.g., malls, libraries, movie theaters, civic centers, shaded parks—in your community where you can seek shelter in extreme heat events.
- Never leave infants, children, or pets unattended in a hot car, even with the windows cracked.
- Limit your outdoor exposure on hot days, and follow these recommendations (CDC 2017; NSC 2020):
    - Air conditioning, if available, is the best way to cool down.
    - Drink fluids, even if you don't feel thirsty, and avoid alcohol.
    - Wear loose, lightweight clothing and a hat.
    - Replace salt lost from sweating by drinking fruit juices or sports drinks.
    - Avoid spending time outdoors during the hottest part of the day, from 11 AM to 3 PM.
    - Wear sunscreen; sunburn affects the body's ability to cool itself.

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[28] https://nihhis.cpo.noaa.gov

[29] https://www.northwesternenergy.com/docs/default-source/documents/e-programs/3490_energyassistance

[30] https://www.montanaco-ops.com/

[31] https://dphhs.mt.gov/hcsd/energyassistance.aspx

[32] https://www.energy.gov/eere/wipo/weatherization-assistance-program

[33] https://www.hud.gov/states/montana/renting

  - Pace yourself when you run or otherwise exert yourself.

- Manage outdoor work efforts—be it for yourself or those you supervise—by following the recommendations of the National Institute for Occupational Safety and Health (NIOSH undated):

  - Work shorter shifts until your body adjusts to the heat.
  - Stay well hydrated (drink before you get thirsty).
  - Watch yourself and your co-workers for signs of heat-related illness.
  - Take breaks to rest and cool down.

- Avoid losing too much water and salt, typically from excessive sweating, which can lead to heat exhaustion, or to life-threatening heat stroke. Learn the signs of these conditions (Figure 5-1). If you experience heat exhaustion, take immediate multiple measures to cool off, as described in Figure 5-1. Heat exhaustion can progress to heat stroke. If a colleague has heat stroke, call 911 and take these immediate actions to cool them down (NSC 2020):

  <u>DO:</u>

  - Move the victim to a cool place.
  - Remove unnecessary clothing.
  - Cool the victim immediately, preferably by immersing up to the neck in cold water (with the help of a second rescuer). If immersion in cold water is not possible, place the victim in a cold shower or move to a cool area and cover as much of the body as possible with cold, wet towels.
  - Keep cooling until body temperature drops to 101°F degrees.
  - Monitor the victim's breathing and be ready to give CPR (cardiopulmonary resuscitation), if needed.

  <u>DO NOT:</u>

  - Force the victim to drink liquids.
  - Apply rubbing alcohol to the skin.
  - Allow victims to take pain relievers or salt tablets.

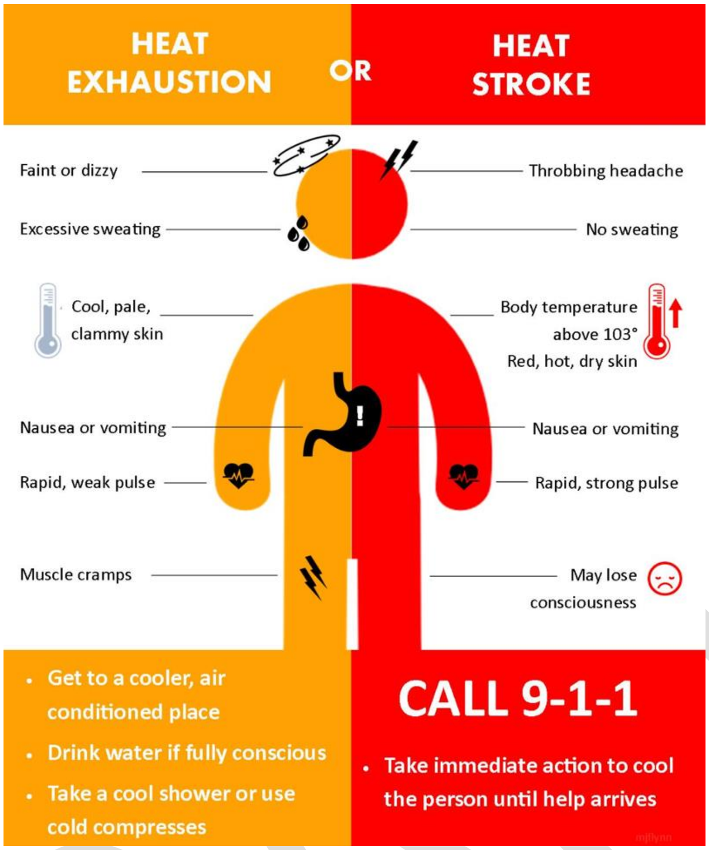

Figure 5-1. Recognize the difference between heat exhaustion and heat stroke, and respond quickly. Note that heat stroke requires immediate medical attention (image courtesy NWSa undated).

Air quality

Climate change can affect respiratory health through increased air pollution, including wildfire smoke and a longer dust season (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 being exacerbated (e.g., coughing, shortness of breath) (Wellbery and Sarfaty 2017).

Here's what you can do:

<u>Protecting indoor air quality</u>

- 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.

- 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 for tips in woodstove use and for links to the US EPA's database of certified woodstoves.[34]

- Protect air quality inside your home by using air filters and keeping doors and windows closed when outdoor air quality is poor. Consider installing High Efficiency Particulate Air (HEPA) filters and/or activated carbon filters in your home or business to remove dust, pollen, and smoke particles. Filter efficiency is rated by the Minimum Efficiency Reporting Value (MERV) system on a scale of 1-20, the higher the number the better the filter (USEPAa undated). HEPA filters are the best, with a MERV rating of 17-20. Check with the manufacturer or their local representative to find out what filters will work with your furnace. You may wish to upgrade to a HEPA filter only during poor air quality events. If you use a portable air cleaner instead, know that the less expensive ones (under $200) may not filter out wildfire smoke. Mechanical cleaners are reliable, while some electronic cleaners produce hazardous ozone and/or other hazardous chemicals (USEPAa undated, 2018a, 2018b, 2019).

- Limit your time outside during periods of high air-borne dust, which may result from drought.

- Check current air quality anywhere in the country, including Montana, at http://airnow.gov[35]. The website color coding system, from green to dark red, makes it easy to tell what level of health risk currently exists for your location. There is also an Airnow app for iOS and Android mobile devices.

- Support transitioning to clean, renewable sources of energy. As the American Lung Association states in their *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."

<u>Wildfire smoke</u>[36]

- Remove trees, dead brush, or other flammable materials near the home exterior to protect against wildfire. The National Fire Protection Agency[37] provides a set of guidelines for

[34] https://www.epa.gov/burnwise

[35] According to the airnow.gov website, "The US Environmental Protection Agency, National Oceanic and Atmospheric Administration, National Park Service, tribal, state, and local agencies developed the AirNow system to provide the public with easy access to national air quality information."

[36] An excellent review from the CDC's National Center for Environmental Health, titled "Protect yourself from wildfire smoke" can be found at https://www.cdc.gov/nceh/features/wildfires/index.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Ffeatures%2Fwildfires%2Findex.html

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

protecting your home, plus check with your local fire department for advice applicable to your local conditions.

- Check your home insurance to understand your coverage. Some home insurance policies do *not* cover wildfire damage; some cover wildfire damage *only* if the area around your house has been cleared appropriately. Add or increase coverage as needed and possible.

- Keep your windows closed when smoke is present and 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 on a moment's notice, if necessary.

- Avoid extended periods outside when smoke is present. Keep inside air clean by closing windows and doors. Wildfire smoke creates a fine particulate matter that cannot be filtered by dust masks or bandanas. Those with respiratory conditions and the young are especially vulnerable to wildfire smoke. Those over 65 yr are at increased risk of heart attack or stroke (Wettstein et al. 2018).

- 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).

<u>Pollen</u>

- Monitor pollen conditions, develop a treatment plan with your allergist, 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.

Flood and drought

Flooding can contaminate surface water and groundwater sources, 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.

Here's what you can do:

- Protect your home from the risk of mold by checking for piping leaks or water accumulation under sinks, in crawl spaces, or in 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 that interrupts water supplies.

- 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 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.

- Be prepared to boil, filter, or chemically purify your own 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, 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.

- Never swim in, nor drink from, water where blue-green algae (cyanobacteria) are visible or where hazardous algal blooms have been reported (MTDPHHS undated). Similarly, keep pets and livestock away from waters where such hazards are present. Cyanobacteria occur throughout Montana in lakes, reservoirs, and any other standing body of water exposed to the sun, and all species have the potential to produce toxins. 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 the *Harmful Algal Bloom Guidance Document for Montana* (MTDPHHS 2019).

Food security

The growing-season drought projected in the MCA (Whitlock et al. 2017) will likely result in crop losses, lower yields, higher food prices, and higher risk of food-borne disease.

Here's what you can do:

- Buy from local food sources whenever possible. Plant and grow your own vegetables using organic fertilizer and an efficient irrigation system.
- Diversify food supplies and crop types. Plant and eat from a variety of food sources.
- Learn how to prepare and store more foods for later use.
- Store non-perishable foods in a location expected to be safe and accessible during foreseeable climate-change-related events.
- Consider new strategies for small farming, such as growing pulse crops like lentils, which consume less water and adapt to hot summer temperatures, or early detection and aggressive management of weeds (MSU Extension 2017).
- Learn from—and possibly help create your own—community project that focuses on local food and agriculture. Such a project is underway in Missoula, where participants envision "… a vibrant, affordable, and resilient local food and agriculture economy in the Missoula community with an educated consumer base that creates sufficient demand for local food" (Climate Smart Missoula undated). Such programs can help people become engaged in local healthy foods policies that assure nutritious foods in schools, learn to grow their own fruit and vegetable gardens, and capture and reuse water.

Vector-borne disease

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

Here's what you can do:

- Mount (or repair) screens on windows and doors to prevent mosquitos from entering your home. Limit pools of water around your home, where mosquitos could breed.[38] To protect yourself outside use insect repellent (e.g., DEET) and wear long-sleeved shirts and pants. Stay inside or take extra precautions especially at dusk and dawn, when mosquitos 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 through the Montana Department of Public Health and Human Services website[39] (Figure 5-2).

[38] https://dphhs.mt.gov/aboutus/news/2019/preventwestnilevirus

[39] https://dphhs.mt.gov/publichealth/cdepi/surveillance

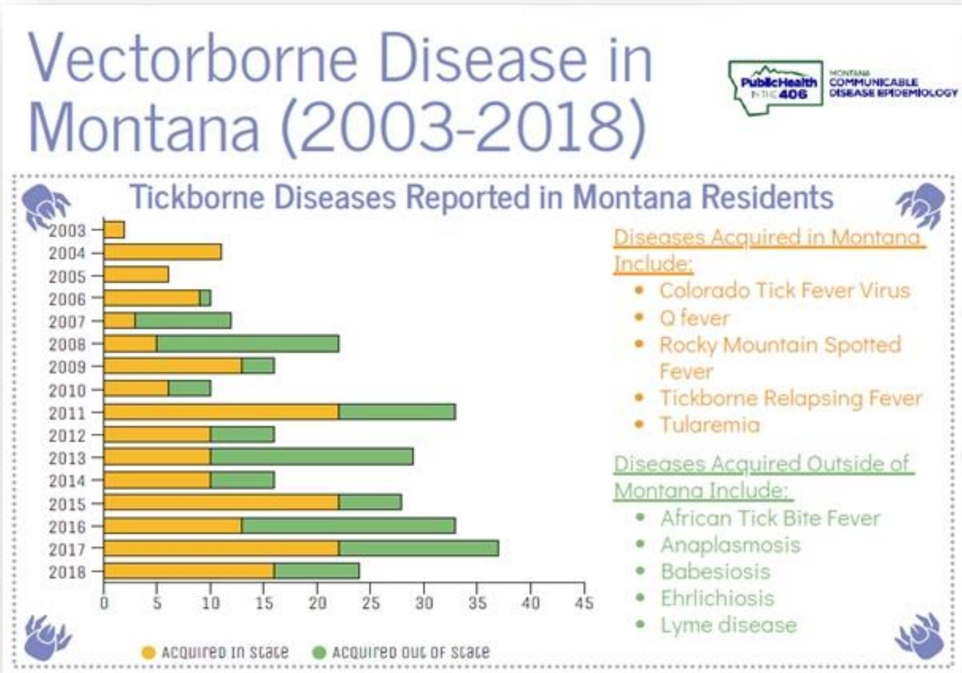

Figure 5-2. Summary of vector-borne diseases reported by Montana residents in 2003-2018. The figure is an example of vector-borne disease tracking that citizens can access from the Montana Department of Public Health and Human Services website (start at https://dphhs.mt.gov/publichealth/cdepi/surveillance).

- 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.[40]

- Watch for potential emergence of zoonotic disease by monitoring the Montana Department of Public Health and Human Services website.[41] Unlike vector-borne disease, zoonotic disease transfer results from human contact with infected animals, including pets, livestock, and wildlife. 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, emergence of new zoonotic diseases elsewhere in the world can reach Montana, as SARS-CoV2 demonstrated (see sidebar).

[40] https://www.cdc.gov/ticks/index.html

[41] https://dphhs.mt.gov/publichealth/cdepi/diseases/zoonotic

Sidebar: 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).

Even as the world recovers from the recent coronavirus 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 loss of standing carbon. 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, termed *bush meat*, 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 mosquitos 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 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 will have a major influence on our mental health. Recognizing that you need help and taking the first steps to process hard times is often the most difficult. General 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, and spirituality; spend time with friends; get outside; exercise; garden—all to increase emotional resilience (Koger et al. 2011; Hayes et al. 2018; Guardian 2019).
- Build a sense of community and be proactive by becoming involved in civic action, such as volunteering, polling, voting, or advocacy. Working on climate change adaptation or mitigation efforts 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 sidebar).
- 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 Network42, who describes itself 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).

[42] https://www.goodgriefnetwork.org/

Sidebar: 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 L 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 Heathy Environments 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 [b], Citizens' Climate Lobby [c], and Protect Our Winters [d] 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. [e]
- 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://350.org/
[c] https://citizensclimatelobby.org/
[d] https://protectourwinters.org/
[e] https://shop4-h.org/products/4-h-weather-and-climate-learning-lab-leader-s-guide

Strategies and Actions for Healthcare Practitioners and Facilities

Medical practitioners, clinics, and hospitals have big 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 causes, and aware of the treatment methods they might be required to apply—be those methods their training already covers, or new skills they can obtain.

This subsection describes strategies and actions applicable to individual practitioners and healthcare facilities. First, however, we 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.

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 the September 2020 publication of this report. For the latest resources and web links, go online to the Climate Change and Human Health in Montana website (ref).*

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 act as information resources for their patients. Groups like the American College of Physicians, American Academy of Pediatrics, and Climate Psychiatry Alliance provide tools and guidelines for integrating screens and discussions into routine patient visits (Table 5-1). Providers have many opportunities for productive, climate-change-related actions when interacting with patients, the medical community, or the community-at-large, including:

- Provide educational materials about climate change and human health in your clinic. Along with physical health concerns, assure that patient materials about the health impacts of climate change include attention to the mental health impacts.
- Become involved with professional or public organizations advocating for climate action based on health impacts (Table 5-1).
- Conduct vulnerability and adaptation assessments that include risks, impacts, and adaptations related to mental health in all climate change and health vulnerability assessments (Hayes et al. 2018; Hayes and Poland 2018).
- Pay particular attention to health concerns *during* extreme climate-related weather events, such as drought, flood, and wildfires.
- 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 below include detailed medical 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.
- Apply a stepped-care approach to treating patient mental health concerns, especially following climate-related disasters or extreme weather events. Such an approach specifies different levels of intervention depending on the timing of the disaster and the level of distress (Bower and Gilbody 2005; Tworney and Byrne 2012).

Healthcare facilities

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-change-related health issues (see sidebar). Here are a number of suggestions:

- Improve and model sustainable practices and processes, including capturing anesthesia gases, decreasing use of disposables, shifting to renewable energy, and sourcing food locally. Tell our 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.
- Be prepared for climate-related weather surprises. Collaborate with community leaders, including those in rural and ethnic communities, to develop preparedness plans for extreme and unexpected events such as heat waves, wildfires, and flooding.

- 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 below for more information.

- Assess impacts on the public health, medical, and mental healthcare systems due to shifting priorities, budget cuts, budget diversion (e.g., to fire suppression) related to climate change.

 Work with universities, insurance providers, healthcare systems, and local and state public health agencies to acquire critical data on the mental health consequences of 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.

 Evaluate the indirect mental health consequences of climate change (e.g., loss of community cohesion, loss of identity, threats to a sense of continuity and sense of belonging) resulting from disruption of social, economic, and environmental services that promote mental health. Those disruptions might include damage to physical and social infrastructure, physical health effects, food and water shortages, displacement, and conflict.

- Recognize that overarching psychosocial consequences of global climate change, or *climate anxiety*, stem from awareness of the looming threats and current risks of climate change.

 Conduct climate adaptation and resilience planning with communities and local and state public health systems.

- Prepare for disruptions to the mental health system (including availability of psychotropic medications) due to climate-related weather events and unexpected disasters that may interrupt supplies.

- Provide decision makers—be they in public health, healthcare systems, emergency response, the medical insurance industry, or local or state government—with a better understanding of where and how to invest in medical and public health infrastructure and resources.

 Develop training programs for clinicians and healthcare professionals on the health effects of climate change.

- *Curriculum development.*—Address the physical and mental health impacts of climate change in educational curricula for graduate and professional students in clinical health training programs in Montana (e.g., medical residency, clinical psychology, counselor's education, nursing and pharmacy programs, and graduate programs in social work).

- *Continuing education.*—Develop 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 a) potential health and mental health impacts of climate change; and b) interventions to address them. Examples of such efforts include the Climate Change and Health Certificate offered at the Yale School of Public Health[43], and the Climate Change and Health Training Module Series offered by the Minnesota Department of Health[44].

- *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.[45]

- Create a network of health professionals working on climate change and health.

    - Collect contact information for medical, mental health, emergency responder, and public health professionals in Montana who are interested in working on these issues.

    - Mobilize members of the medical and mental-health community to become involved in climate change mitigation and adaptation efforts through Montana Health Professionals for a Healthy Climate (Table 5-1).

[43] https://publichealth.yale.edu/cchcert/

[44] https://www.health.state.mn.us/communities/environment/climate/resources.html

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

Sidebar: Greener Healthcare Ideas

Julia Ryder BSN, RN, CEN
(Founding Board Member of Montana Health Professionals for a Healthy Climate[a])

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 hospital. The average hospital creates 29 lb 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 lightening, and not open materials until needed. It can reward employees who bike, walk, 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 vegetation around campus. This not only improves air quality, but also provides shade and emotional support for patients and families.

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

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.

- *Centers for Disease Control and Prevention.*—"Climate change, together with other natural and human-made health stressors, influences human health and disease in numerous ways. Some existing health threats will intensify and new health threats will emerge. Not everyone is equally at risk. Important considerations include age, economic resources, and location."[46]
- *World Health Organization.*—"Climate change is impacting human lives and health in a variety of ways. It threatens the essential ingredients of good health—clean air, safe drinking water, nutritious food supply, and safe shelter—and has the potential to undermine decades of progress in global health. … Between 2030 and 2050, climate change is expected to cause approximately 250,000 additional deaths per year, from malnutrition, malaria, diarrhea and heat stress alone. The direct damage costs to health is estimated to be between USD 2-4 billion per year by 2030."[47]
- *United Nations Climate Change.*—"Climate change is expected to exacerbate health problems that already pose a major burden to vulnerable populations."[48]
- *Environmental Protection Agency.*—"Every American is vulnerable to climate-change impacts on their health at some point in their lives."[49]
- *National Institute of Health.*—"Changes in the greenhouse gas concentrations and other drivers alter the global climate and bring about myriad human health consequences. … Certain adverse health effects can be minimized or avoided with sound mitigation and adaptation strategies. Strategies for mitigating and adapting to climate change can prevent illness and death in people now, while also protecting the environment and health of future generations."[50]
- *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."[51]
- *Department of Health and Human Services.*—"The US Department of Health and Human Services (HHS) considers climate change to be one of the top public health challenges of our time."[52]
- *American Public Health Association.*—"We need national attention focused on the environmental injustices and lack of health equity that affect American Indian/Alaska Native

[46] https://www.cdc.gov/climateandhealth/effects/default.htm

[47] https://www.who.int/health-topics/climate-change#tab=tab_1

[48] https://unfccc.int/news/climate-change-impacts-human-health

[49] https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-human-health_.html

[50] https://www.niehs.nih.gov/research/programs/geh/climatechange/health_impacts/index.cfm

[51] https://www.nihb.org/docs/10102019/Climate%20Change%20&%20Tribes%20Article.pdf

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

communities. … Working in partnership with Native communities, including the 567 federally recognized tribes in the US, is essential to moving forward."[53]

- *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."[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, including the American Medical Association, National Medical Association, and the American Public Health Association.)

- *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."[56]

- *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."[57]

- *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."[58]

- *Montana Department of Environmental Quality*.—"According to the IPCC, possible effects of climate change for our general region include: A change in disease vectors, an increase in mortality due to heat waves, floods, and droughts, and other health problems."[59]

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[53] https://www.apha.org/topics-and-issues/climate-change/tribal-and-indigenous

[54] https://www.niehs.nih.gov/health/topics/agents/climate-change/index.cfm

[55] https://climatehealthaction.org/cta/climate-health-equity-policy/

[56] https://www.ncbi.nlm.nih.gov/pubmed/26111439

[57] https://deq.mt.gov/Portals/112/Energy/ClimateChange/Documents/FinalReportChapters.pdf

[58] https://montanafarmersunion.com/wp-content/uploads/2016/01/MFU_Climate_Final.pdf

[59] http://deq.mt.gov/Energy/climatechange/data/ClimateChangeInMontana

- *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."[60]

Community Actions: Teaming Up for Success

Communities need to plan and prepare for climate change to create resiliency for protecting public health and their economies. This process of building resilience will require multi-sectoral collaboration, as well as access to and use of local climate and health data, and there is excellent free guidance available, as we describe below.

Montana communities vary widely in the financial and human resources they have available to develop climate change plans and solutions. Funding and technical support for such planning and preparation is sorely needed, including 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. Yet, no matter the level of community resources and support currently available, it is always possible to make progress and implement strategies that best "fit" a community.

The impacts of climate change on health may also vary widely among community members (Islam and Winkel 2017; National Geographic 2019). It is important to develop climate action plans that are equitable, feasible, and tailored in each community to the demographics (e.g., age and income distributions), exposures (e.g., climate components like increasing temperatures), and risks (e.g., the likelihood that the exposure events like major wildfires or flooding will occur). Likewise, it is critical in planning to consider the needs of each community's unique vulnerable populations, as described in Section 4.

Planning Ahead

Credit ratings

Climate-change impacts are starting to threaten state and local government credit ratings. Adaptation planning can reduce this threat.

Governments are assessed by rating agencies for their ability to repay loans, yet climate changes can threaten that capacity in multiple ways. Climate surprises—such as heat waves, drought, flooding, or other disasters—can trigger an exodus of residents, resulting in declining tax revenue, or bring 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 in the watershed of a community's public water supply

[60] https://nam.edu/programs/climate-change-and-human-health/

could result in raw water of such poor quality that the treatment plant cannot clean it. These 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).

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).

Therefore, it is vital to the economic future of Montana communities that our state and local governments implement climate mitigation and adaptation action planning. A wealth of online guides, toolkits, and outreach materials is available to help build our resilience to climate-change impacts. Those resources, developed by various federal agencies and professional and non-profit organizations, provide myriad examples from successful communities.

One source of such materials is the Centers for Disease Control's Climate and Health Program, which provides comprehensive guides and funding sources for health departments and public health professionals. That program's *Building Resilience Against Climate Effects* (BRACE) plan offers a five-step program to assist health officials in developing strategies that will help communities prepare for health effects resulting from, or exacerbated by, climate change (Figure 5-3) (CDC 2019).

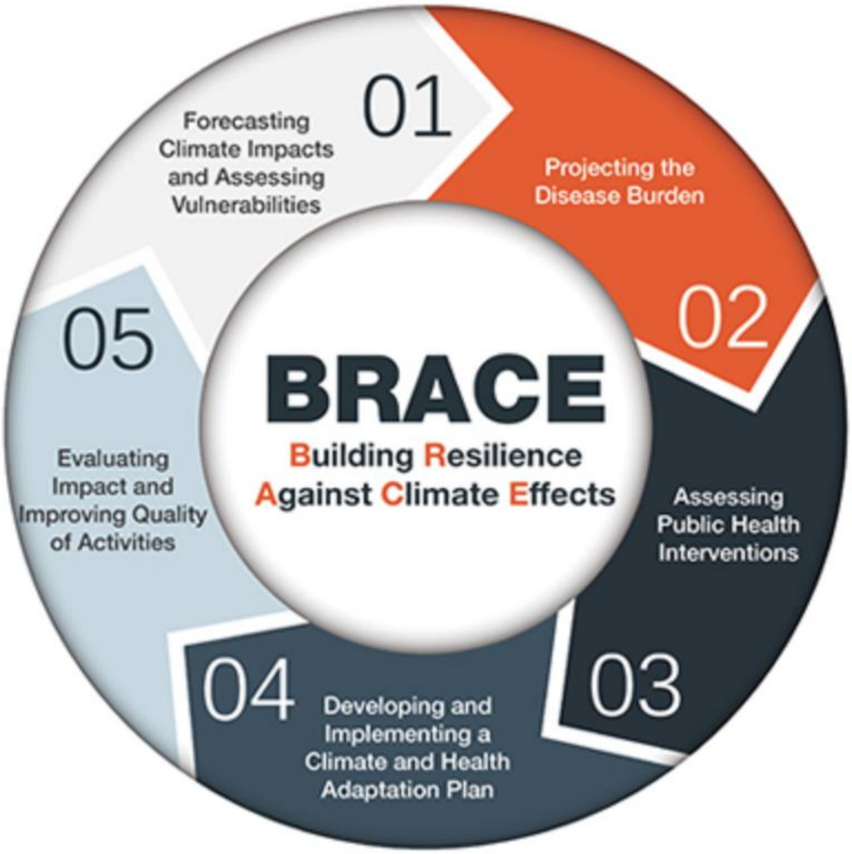


Figure 5-3. The CDC's Climate-Ready States and Cities Initiative[61] competitively funds states and large cities to implement the five-step BRACE framework shown here and described in the text.

Implementing a BRACE plan in Montana to build resilience requires access to *local* (county level) climate and air quality data, updated climate projections, and current and projected disease burden, as well as a better understanding of vulnerable populations. With these data and the BRACE framework, state and county 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).

<u>The data challenge</u>

The challenge is that these data—atmospheric, climatic, epidemiologic—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-

[61] https://www.cdc.gov/climateandhealth/climate_ready.htm

NCEIb undated). Two 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. Still, parts of Montana have relatively few of these sites and again 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).

The Montana Climate Office is working with US Army Corp of Engineers and NOAA to establish and maintain upwards of 200 additional monitoring stations across the state over the next 5-10 yr.[62] The US Army Corp of Engineers and NOAA federal funding will support better soil moisture and snowpack monitoring. Other sources of funding will be necessary to add air-quality monitoring sensors to these stations. Currently, there are only 20 air-quality monitoring stations managed by the Montana Department of Environmental Quality. Current air quality conditions are provided online[63], but not historical data. Broader climate and air quality monitoring across Montana, and online data accessibility, are vital to provide the information necessary for climate-change planning and adaptation.

The 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. The spatial resolution of climate projections will improve in future Montana climate assessments, with a scale that will be more useful for community-level planning.

Local- (county-) level epidemiologic data are also required for the CDC's framework for Building Resilience Against Climate Effects (CDC 2019). Statewide epidemiological data are collected by the Montana Department of Public Health and Human Services, but are not currently shared at the county level. The need exists for a shared, statewide monitoring process of health-facility visits related to climate change. Of special importance are county-level data about visits related to smoke, heat, or home-mold exposure; vector- or water-borne illnesses; and mental health concerns.[64]

Further, multi-sectoral collaboration is essential (UNDDR 2020; UNDDR and WHO 2020). As we are learning from addressing the COVID-19 pandemic in Montana, state and local leadership, public health and emergency management professionals, clinicians, and health and climate scientists must work together to plan for, adapt to, and help mitigate climate change. City/county public health departments can take a leadership role. A fall 2019 statewide survey of 222 Montana public health and

[62] Jensco K, Montana Climate Office, personal communication, 3 May 3 2020; unreferenced.

[63] https://svc.mt.gov/deq/todaysair/

[64] The authors recognize that privacy issues might exist if county-level data on rarer health conditions were released. Perhaps any data on rare conditions could be compiled by Montana Climate Divisions, rather than by counties.

environmental health professionals asked their concern about 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 Section 2). Almost all indicated that multiple entities should work to address climate change: governments (federal, state, local, tribal), elected officials, non-profits, businesses, individuals, and healthcare providers.

In sum, data are a critical need for communities—particularly for state and county public health departments—to address the impacts of climate change on the health of their citizens. To meet that need, Montana needs to:

- increase the network of meteorological stations in the state to fill in geographic gaps,
- increase air quality monitoring (smoke as particulate matter),
- 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.

<u>Community-level steps to develop a BRACE planning framework</u>

Along with finding, developing, and implementing methods to collect critical data, initiating the BRACE (or other) planning framework requires broad community engagement. Carefully consider the support of your citizens and leaders. It is possible, and perhaps likely, that a community's first step will be to implement a well-thought-out engagement and education campaign. As the National League of Cities advises in its multi-faceted (over 100 concepts presented) 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).

> *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."*

The next step in creating a climate action plan is to do an assessment of sensitivity, exposure, and risk for your community. That assessment will form the basis for creating your community's plan, describing how it will prepare for and react to human health issues that result from climate change. Include local leaders, health professionals, citizens, and a diverse stakeholder group broadly 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 in the coming decades? Who are most vulnerable to health impacts from climate change in your town or region, and why (e.g., limited medical services)?
- What is your community's capacity to develop a health and climate assessment or action plan, and is the BRACE framework, or some other process, best suited to address your capacity and needs?
- Are funding sources available for this process, including for outside facilitation to help guide discussions as you develop your climate and health assessments, and eventually an action plan for your town?
- Are any stakeholder groups underrepresented on your team? If so, how can you engage them? What kind of community outreach will your team need to accomplish 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 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 communities of the Blackfeet Tribe and the Confederated Salish and Kootenai Tribes have actively responded to climate-related changes faced by their people and landscapes (see sidebar).

Sidebar: 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 yr 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. More intense flooding can spread and impact services.

In 2019 alone we experienced several winter storm emergencies and a flood disaster. During these 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 (blackfeetclimatechange.com) 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.

Confederated Salish and Kootenai Tribes (CSKT) of the Flathead Indian Reservation
Mike Durglo, Jr., Environmental Director, CSKT Natural Resources

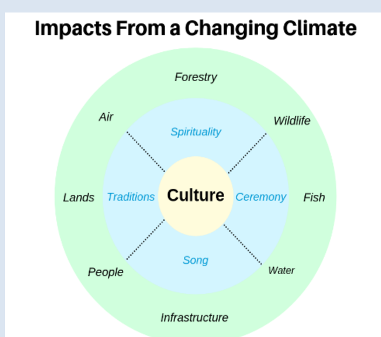
The Flathead Indian Reservation is home to approximately 28,000 people, of which about 9000 identify as Native American. CSKT has approximately 6800 enrolled tribal members, 4000 of whom live on the reservation. On the Flathead Indian Reservation climate change threatens our treasured landscapes, our 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, poses serious risks to the S'elish, Qlispe, and Ktunaxa peoples 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 in 2013 (http://csktclimate.org/) and has taken 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.

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 illustrates a tribal way of thinking as also expressed during our recent climate planning session. Climate-change-related disturbances including flood, drought, wind events, 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.

CSKT Lifeways Diagram

Spirit Mind Body



Places
Timberline/Alpine Forest
Mixed Conifer (stand replacement/mixed fire regime)
Pine/grass (non-lethal fire regime)

Individual <<>> Family <<>> Community <<>> Tribe <<>> Nation <<>> World <<<< *Temporal* >>>>

> “
>
> *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….*

The remainder of this section highlights some strategies your community will want to consider to plan for and mitigate health-related impacts from climate change.

Heat

Two strategies that communities can use to address heat-related impacts to health are 1) to educate citizens about the importance of not overheating in extreme temperatures; and 2) to provide cool or cooler spaces both inside and outside.

Here are some examples centered on these strategies:

- Inform those working, playing, or otherwise spending extended time in the outdoors about the importance of resting, hydrating, and seeking shade.
- Encourage employers to change workplace environment and policies to reduce heat exposure. For example, employers could provide access to shade and drinking water for outdoor workers and allow breaks to cool off during extremely hot weather.
- Consider designating (or creating) a cooling facility for your community or workplace that people know to go to during a heat emergency. This might be an air-conditioned school or community center, or a deeply shaded park, perhaps near a community swimming pool.
- Ensure vulnerable populations (Section 4) understand heat-related health issues and have a plan for staying cool. For example, develop programs to ensure vulnerable people have access to the cool community spaces just noted. Likewise, assure 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). Example efforts include minimizing the use 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—to reflect sunlight.

- Create incentives, programs, and/or campaigns to plant and care for trees and other vegetation to create shade (USEPAe undated).

Air quality

While it is possible to mitigate some of the health effects of wildfire and smoke through forest management practices, these efforts are generally not done at the local community level. However, every Montana community can focus on adaptation strategies for dealing with wildfire by increasing the fire resilience of homes and, during wildfire season, improving air quality indoors and outside.

Actions your community can take include:

- Review fire risks of homes and increase fire resilience in your community by reducing fuels (e.g., pruning shrubs and trees and removing dead plant matter). The Federal Emergency Management Administration provides checklists for homeowners (FEMAb undated) and communities (FeEMAc undated).
- 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. Determine who will help those people needing evacuation or other assistance.
- Inform homeowners about effective options to create safe indoor air using HEPA portable air cleaners, MERV 13 air filters, or HVAC (heating, ventilation, and air conditioning) systems. These filters remove harmful particulate matter from the smoke that infiltrates your space. See the Personal/Air Quality/Indoor Air subsection above. Also, Climate Smart Missoula (see sidebar) has developed a great resource to guide you in selecting a filter system.[65]
- Consider funding air filtration in public spaces, such as 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 promoted safe, filtered, indoor air during fire season by donating portable HEPA air cleaners to those who were most vulnerable.
- Encourage employers to change workplace environment and policies 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.
- Work with the Montana Climate Office to ensure your community has a weather station with added sensors for $PM_{2.5}$ and PM_{10}, and that the public has real-time online access to these data.

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[65] https://www.missoulaclimate.org/hepa-air-filtration.html

Sidebar: Community Climate Action Planning for Health Resilience—Tips from Missoula

Amy Cilimburg

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 HEPA air 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 those with asthma to the elderly.

This early effort helped us learn that although it can 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 all around.

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/

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. In rural Montana, 39% of the public water supply and 94% of the domestic water supply comes from groundwater (MTGIC undated), some of which permeates from wetlands above. 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, such as the creation of impervious parking lots, when possible. Note that if wetlands are destroyed by development, Montana law requires that alternate wetlands be created nearby.[66]

- Assess water and wastewater infrastructure needs and vulnerabilities and 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[67] 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.

- 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[68] and two Montana Department of Public Health and Human Services programs—Ready and Safe[69] and EMS and Trauma Systems[70]—are good resources to consult.

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[66] https://www.blr.com/Environmental/Water/Wetlands-in-Montana

[67] https://deq.mt.gov/Portals/112/Water/PWSUB/Documents/docs/EmergencyResponseFactSheet.pdf

[68] https://www.mtpca.org/programs-and-services/emergency-preparedness/

[69] http://readyandsafe.mt.gov

[70] https://dphhs.mt.gov/publichealth/emsts

Food security

Drought and extreme weather events impact local food security, 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 our grocery stores. Climate change in other parts of the world impacts *our* food security. Crop destruction or failure and transportation interruption—potential outcomes from climate "surprises" (Section 2) or pandemics—may result in pricing increases or supply interruption to Montana's food supply.

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.
- Develop educational forums to discuss how much and what kinds of foods citizens might store in case of emergencies. Excellent discussions on the types and amounts of foods, as well as sanitation, cooking without power, and more, can be found from the Federal Emergency Management Act[71] and Ready.gov[72].
- Encourage personal, small-scale agriculture, and local farmers' markets to diversify local food supply and empower individuals with the knowledge and skills to grow their own food.
- Tap resources offered by County Extension offices to understand irrigation efficiencies and pest control.
- Enhance and incentivize more effective, multi-stakeholder approaches to drought response planning through local watershed groups and public works departments.

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 (Section 3), and mountain states are becoming more susceptible to vector-borne disease with warming temperatures that 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 mosquitos) are two ways to reduce vectors at the community level. Community education on vector-borne diseases is essential (see Individual Actions section above). 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[73], the US Department of Agriculture Animal

[71] https://www.fema.gov/pdf/library/f&web.pdf

[72] https://www.ready.gov/food

[73] https://www.cdc.gov/nceh/information/state_factsheets/montana.htm

and Plant Health Inspection Service[74], Montana's Department of Public Health and Human Services[75], and through periodic workshops and symposiums (see, for example, Lemon et al. 2008).

Mental health

Extreme weather events, prolonged heat and smoke, and environmental and societal change all affect mental health, including feelings of disconnectedness and despair. Building capacity to plan is critical to community well-being. Actions include:

- Support your community's local resources, including health departments, faith leaders, service organizations, chambers of commerce, watershed groups, and extension agents. With all groups, and with local citizens, work to eliminate the stigma sometimes associated with mental health issues.
- Help in planning for increased mental health response by working with local hospitals, clinics, and health departments to learn how to build mental health services that connect across jurisdictions in your community.
- Inform healthcare providers and the public about the mental health impacts related to climate-change-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 availability) that can be caused by such events, and how that disruption can impact both the mental health of individuals and the community.
- Build in-school capacity to address mental health issues in youth related to climate change. As part of existing programs like Individual Education Plans and other assessments (MHAM 2009), acknowledge the anxiety some feel around mounting climate-change impacts (Burke et al. 2018) to assure proactive interaction among teachers, students, parents, and friends. Consider also setting up mentoring programs with community members like the Child Advancement Project established by Thrive.[76]

Community tools and resources

Table 5-2 provides a list of resources for communities, including public and environmental health agencies and organizations, to develop climate change assessments and action plans.

[74] https://www.aphis.usda.gov/aphis/home/
[75] https://dphhs.mt.gov/HealthInThe406/HealthInThe406Archive/CommunicableDisease
[76] https://allthrive.org/programs/child-advancement-project/

Table 5-2. Resources for state and local governments, communities, tribes, faith organizations, and teachers to help plan for, address, and inform about climate-change impacts. Note: websites associated with each numbered description can be found at the end of the table.

Source	Resource description
NATIONAL: Comprehensive Planning for Climate Change Resilience and Adaptation	
National Oceanic and Atmospheric Administration, US	1) 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.
National League of Cities, Climate for Health and many other partner organizations	2) 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.
	3) 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.
	4) Additional resources from National League of Cities and ecoAmerica are available.
Geos Institute's Climate Ready Communities	5) 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
	6) 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.
Geos Institute's Working Waters	7) 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.
Climate Adaptation Knowledge Exchange	8) 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.
ASTHOs Climate Change Collaborative	9) ASTHO's 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.
United Nations Office for Disaster Risk Reduction (UNDRR) and the World Health Organization (WHO)	10) 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.
NATIONAL: Planning for Climate Change and Health	
Centers for Disease Control and Prevention (CDC)	11) 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.
	12) 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.
	13) 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.
	14) 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.
	15) 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

Table 5-2. Resources for state and local governments, communities, tribes, faith organizations, and teachers to help plan for, address, and inform about climate-change impacts. Note: websites associated with each numbered description can be found at the end of the table.

Source	Resource description
	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.
	16) 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).
National Integrated Heat Health Information System	17) 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. https://nihhis.cpo.noaa.gov
National League of Cities, Climate for Health, et al.	18) 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.
US Global Change Research Program	19) 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.
American Public Health Association	20) #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.
Public Health Institute (PHI)	21) 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.
National Academies Press	22) 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.
US Government Accountability Office	23) 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.
ECONOMICS	
Moody's Investor Services	24) 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.*"*
New York Times	25) "Moody's Buys Climate Data Firm, Signaling New Scrutiny of Climate Risks"
Janney Investment Strategy Group	26) Muni Report, 10/22/19: Climate Change and Potential Impact on State and Local Government Credit Analysis.
Pew Trust	27) "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."
London School of Economics and Political Science	28) 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
Fitch Ratings	29) Environmental Risks in US State and Local Government Ratings (report available to Fitch Ratings Research subscribers)
MONTANA	
MT Climate Solutions Council	30) This Governor's Council developed a Montana Climate Solutions Plan (June 2020), which provides recommendations and strategies aimed at preparing Montanans for climate impacts.
MT Dept. of Environ. Quality	31) Daily air quality updates for Montana

Table 5-2. Resources for state and local governments, communities, tribes, faith organizations, and teachers to help plan for, address, and inform about climate-change impacts. Note: websites associated with each numbered description can be found at the end of the table.

Source	Resource description
Climate Smart Montana	32) 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.
MSU Extension	33) A listserve for Montana citizens and educators who want to share information on climate science and policy. To subscribe, email paul.lachapelle@montana.edu with a request to join.
City of Bozeman	34) Bozeman's Climate Planning Framework provides summaries of 17 separate Bozeman plans related to climate and climate-change impacts
TRIBAL	
ITEP: Inst. for Tribal Enviro. Professionals	35) 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.
Bureau of Indian Affairs: Tribal Resilience Program	36) 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.
	37) 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.
	38) 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.
National Indian Health Board	39) 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.
Blackfeet Nation	40) 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.
FAITH COMMUNITIES	
The Center for Large Landscape Conservation	41) 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.
Faith and Climate Action Montana	42) Educates individuals in faith communities about climate change and creates space for spiritual reflection on social and environmental issues.
Faith, Science and Climate Action MT	43) 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.
MT Interfaith Power and Light	44) 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.
ecoAmerica	45) 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.
TEACHERS	
National Oceanic and Atmospheric Administration, US	46) 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.

Table 5-2. Resources for state and local governments, communities, tribes, faith organizations, and teachers to help plan for, address, and inform about climate-change impacts. Note: websites associated with each numbered description can be found at the end of the table.

Source	Resource description

Websites associated with numbered descriptions in table above. Website shown here were active as of the September 2020 publication of this report. For the latest resources and web links, go online to Climate Change and Human Health in Montana website (ref).

1) https://toolkit.climate.gov/
2) 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
3) https://pathtopositive.org/wp-content/uploads/2019/09/P2P-checklist-Sep13-Final.pdf
4) https://www.nlc.org/program-initiative/nlc-ecoamerica-elevating-local-climate-action; https://www.neha.org/eh-topics/climate-change-0
5) www.climatereadycommunities.org; https://climatereadycommunities.org/learn-more/about-guidebook/
6) climatewise.org
7) https://www.workingwatersgeos.org/
8) www.cakex.org
9) https://www.astho.org/Programs/Environmental-Health/Natural-Environment/Climate-Change/Extreme-Weather-and-Climate-Readiness-Toolkit-for-State-and-Territorial-Health-Departments/
10) Training webinar and links to many resources for disaster resilience are available at: https://www.unisdr.org/campaign/resilientcities/toolkit/article/public-health-system-resilience-scorecard
11) https://www.cdc.gov/climateandhealth/default.htm; https://www.cdc.gov/climateandhealth/climate_ready.htm
12) https://stacks.cdc.gov/view/cdc/24906
13) https://www.cdc.gov/climateandhealth/docs/ClimateAndHealthInterventionAssessment_508.pdf
14) https://www.cdc.gov/climateandhealth/effects/default.htm
15) https://www.cdc.gov/climateandhealth/BRACE.htm
16) https://www.cdc.gov/climateandhealth/climate_ready.htm
17) https://nihhis.cpo.noaa.gov
18 https://climateforhealth.org/wp-content/uploads/sites/2/2020/01/CFHMFG-web.pdf
19) https://health2016.globalchange.gov/
20) https://www.apha.org/topics-and-issues/climate-change
21) https://www.phi.org/resources/?resource=climate-change-health-and-equity-opportunities-for-action
22) https://www.nap.edu/download/24797
23) https://www.gao.gov/products/gao-20-24
24) http://www.moodys.com/researchdocumentcontentpage.aspx?docid=PBM_1071949
25) https://www.nytimes.com/2019/07/24/climate/moodys-ratings-climate-change-data.html
26) https://www.janney.com/docs/default-source/latest-articles-insights/isg/municipal-market-monthly/climate-change-and-munis-(oct-22).pdf
27) https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2019/10/01/climate-change-could-make-borrowing-costlier-for-states-and-cities
28) http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2019/09/The-missing-economic-risks-in-assessments-of-climate-change-impacts-2.pdf
29) https://www.fitchratings.com/site/re/10031874
30) https://deq.mt.gov/DEQAdmin/dir/Climate
31) svc.mt.gov/deq/todaysair/smokereport/mostrecentupdate.aspx
32) http://www.msucommunitydevelopment.org/ClimateSmartMontana.html
33) climatescineceandpolicy@sympa.montana.edu
34) https://www.bozeman.net/home/showdocument?id=9681
35) http://toolkit.climate.gov/tool/tribal-climate-change-adaptation-planning-toolkit
36) https://www.bia.gov/bia/ots/tribal-resilience-program
37) https://toolkit.climate.gov/topics/tribal-nations
38) https://biamaps.doi.gov/tribalresilience/resourceguide/training/index.html
39) https://www.nihb.org/public_health/climate_ready_tribes.php; https://www.nihb.org/public_health/climate_resources.php
40) https://blackfeetclimatechange.com; https://bcapwebsite.files.wordpress.com/2018/04/bcap_final_4-11.pdf
41) https://largelandscapes.org/wp-content/uploads/2019/03/Climate_Landscapes__Health_Guidebook_10.9.18.pdf
42) faithandclimateactionmontana.weebly.com
43) fscaconference.org
44) http://blessedtrinitymissoula.org/outreach/social-concerns-parish-team/interfaith-power-and-light/
45) https://blessedtomorrow.org/
46) https://www.climate.gov/teaching

LITERATURE CITED

American Lung Association. 2016. Lung health policy brief: clean energy and health. 2 p. Available as download at online https://www.lung.org/getmedia/e310efd8-b189-4411-b3a3-7db31dc54baa/clean-energy-policy-brief_.pdf. Accessed 22 Apr 2020.

Anderson H, Brown C, Cameron LL, Christenson M, Conlon KC, Dorevitch S, plus 23 more. 2017. Climate and health intervention assessment: evidence on public health interventions to prevent the negative health effects of climate change. Climate and health technical report series. Atlanta GA: Centers for Disease Control and Prevention, Climate and Health Program. 96 p. Available online https://www.cdc.gov/climateandhealth/docs/ClimateAndHealthInterventionAssessment_508.pdf. Accessed 14 May 2020.

Bloomfield LSP, McIntosh TL, Lambin EF. 2020. Habitat fragmentation, livelihood behaviors, and contact between people and nonhuman primates in Africa. Landscape Ecology 35(4):985–1000. doi:10.1007/s10980-020-00995-w.

Bower P, Gilbody S. 2005. Stepped care in psychological therapies: access, effectiveness, and efficiency—narrative literature review. British Journal of Psychiatry 186:11-7.

Burke SEL, Sanson AV, Van Hoorn J. 2018. The psychological effects of climate change on children. Current Psychiatry Reports 20(5). doi:10.1007/s11920-018-0896-9

Byron L. 2019. Significant concern about climate among Montana public health and environmental health professionals [masters' thesis]. Baltimore MD: Johns Hopkins University. 48 p. Available online https://jscholarship.library.jhu.edu/handle/1774.2/62338. Accessed 31 Mar 2020.

[CDC] Centers for Disease Control and Prevention. 2017. Hot weather tips [website]. Available online https://www.cdc.gov/disasters/extremeheat/heattips.html. Accessed 4 Apr 2020.

[CDC] Centers for Disease Control and Prevention. 2019. Climate and Health: CDC's Building Resilience Against Climate Effects (BRACE) Framework. [website] Available online https://www.cdc.gov/climateandhealth/BRACE.htm. Accessed 4 Mar 2020.

Clayton S, Manning C, Krygsman K, Speiser M. 2017. Mental health and our changing climate: impacts, implications, and guidance [report]. Washington DC: American Psychological Association and ecoAmerica. 70 p. Available online https://www.apa.org/images/mental-health-climate_tcm7-215704.pdf. Accessed 29 Feb 2020.

Climate Smart Missoula. [undated]. Local food and agriculture [website]. Available online https://www.missoulaclimate.org/local-food-and-agriculture.html. Accessed 1 Mar 2020.

Cui Y, Zhang Z-F, Froines J, Zhao J, Wang H, YuS-Z, Detels R. 2003. Air pollution and case fatality of SARS in the People's Republic of China: an ecologic study. Environmental Health 2(1):15. doi:10.1186/1476-069x-2-15.

DeFries R, Edenhofer O, Halliday A, Heal G, Lenton T, Puma M, Rising J, Rockström J, Ruane AC, Schellnhuber HJ, Stainforth D, Stern N, Tedesco M, Ward B. 2019 (Sep). The missing economic risks in assessments of climate change impacts [report]. New York NY: Columbia University Earth Institute, Grantham Research Institute on Climate Change and the Environment, Potsdam Institute for Climate Impact Research. 15 p. Available online http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2019/09/The-missing-economic-risks-in-assessments-of-climate-change-impacts-1.pdf. Accessed 14 May 2020.

Eckelman MJ, Sherman J. 2016. Environmental impacts of the US healthcare system and effects on public health. Public Library of Science 11(6). doi:https://doi.org/10.1371/journal.pone.0157014.

Faust CL, McCallum HI, Bloomfield LSP, Gottdenker NL, Gillespie TR, Torney CJ, Dobson AP, Plowright RK. 2018. Pathogen spillover during land conversion. Ecology Letters 21(4):471–83. doi:10.1111/ele.12904.

[FEMAa] Federal Emergency Management Administration. [undated]. The national flood insurance program [website]. Available online https://www.fema.gov/national-flood-insurance-program. Accessed 1 Mar 2020.

[FEMAb] Federal Emergency Management Administration. [undated]. Avoiding wildfire damage: a checklist for homeowners [report]. 2 p. Available online https://www.fema.gov/pdf/hazard/wildfire/wdfrdam.pdf. Accessed 2 Mar 2020.

[FEMAc] Federal Emergency Management Administration. [undated]. Fire adapted communities: how the fire service, local officials, and the public can work together [report]. 14 p. Available online https://www.usfa.fema.gov/downloads/pdf/publications/fire_adapted_communities.pdf. Accessed 2 Mar 2020.

Fitch Ratings. 2018 (May 29). Environmental risks in US state and local government ratings [report]. 9 p. Accessible online (requires login) https://www.fitchratings.com/site/re/10031874. Accessed 18 May 2018.

Guardian. 2019 (Aug 26). After the wildfire: treating the mental health crisis triggered by climate change [article]. Available online https://www.theguardian.com/world/2019/aug/26/climate-change-mental-health-wildfires-santa-rosa. Accessed 15 Apr 2020.

Hayes K, Blashki G, Wiseman J, Burke S, Reifels L. 2018. Climate change and mental health: risks, impacts and priority actions. International Journal of Mental Health Systems 12(1):28. doi:10.1186/s13033-018-0210-6.

Hayes K, Poland B. 2018. Addressing mental health in a changing climate: incorporating mental health indicators into climate change and health vulnerability and adaptation assessments. International Journal of Environmental Research and Public Health 15:1806.

Islam N, Winkel J. 2017. Climate change and social inequality [report]. UN Department of Economic and Social Affairs working paper #152. New York NY: United Nations. https://doi.org/10.18356/2c62335d-en.

Janney Investment Strategy Group. 2019 (Oct 22). Muni report: climate change and potential impact on state and local government credit analysis [report]. Available online https://www.janney.com/docs/default-source/latest-articles-insights/isg/municipal-market-monthly/climate-change-and-munis-(oct-22).pdf. Accessed 3 Mar 2020.

Koger SM, Leslie JE, Hayes ED. 2011. Climate change: psychological solutions and strategies for change. Ecopsychology 3(4):227-35.

Khumalo L, Stonecipher G. 2018. Healthy landscapes, healthy people: a guidebook for Montana communities preparing for a changing climate [report]. 38 p. Bozeman MT: Center for Large Landscape Conservation. Available online https://static1.squarespace.com/static/59775f896b8f5b54f7106ff8/t/5c12b89f70a6ad8392faa29b/1544730786109/CLLC+project.pdf. Accessed 11 May 2020.

Lemon SM, Sparling PF, Hamburg MA, Relman DA, Choffnes ER, Mack A. 2008. Vector-borne diseases: understanding the environmental, human health, and ecological connections [workshop summary]. Washington DC: National Academies Press, Institute of Medicine. 350 p. Available online http://www.nap.edu/catalog/11950.html. Accessed 6 Apr 2020.

[MCO] Montana Climate Office. 2020. Montana Mesonet dashboard [website]. Available online https://mco.cfc.umt.edu/mesonet_data/. Accessed 3 May 2020.

[MHAM] Mental Health America of Montana. 2009. A parent’s guide to children’s mental health services in Montana [report]. Bozeman MT: Mental Health America of Montana. 34 p. Available online http://montanamentalhealth.org/wordpress/wp-content/uploads/2014/07/ParentsGuide2009.pdf. Accessed 11 May 2020.

Moody’s Investor Services. 2017. Moody's: climate change is forecast to heighten US exposure to economic loss placing short- and long-term credit pressure on US states and local governments. Available online https://www.adaptationclearinghouse.org/resources/moody-s-environmental-risks-evaluating-the-impact-of-climate-change-on-u-s-state-and-local-issuers.html. Accessed 14 May 2020.

[MSU Extension] Montana State University Extension. 2017. How Montana agriculture can respond to changing weather and climate patterns [report]. 4 p. Available online https://store.msuextension.org/publications/AgandNaturalResources/MT201704AG.pdf. Accessed 1 Mar 2020.

[MTDPHHS] Montana Department of Public Health and Human Services. [undated]. Public health and safety: harmful algal blooms [website]. Available online https://dphhs.mt.gov/publichealth/Epidemiology/hab. Accessed 1 Mar 2020.

[MTDPHHS] Montana Department of Public Health and Human Services. 2019. Harmful algal bloom guidance document [report]. 25 p. Helena MT: MTDPHHS, MT Department of Environmental Quality, and MT Fish, Wildlife, and Parks. Available online https://dphhs.mt.gov/publichealth/Epidemiology/hab. Accessed 1 Mar 2020.

[MTGIC] Montana Geographic Information Clearinghouse. [undated]. Water information system: groundwater [website of Montana State Library]. Available online http://geoinfo.msl.mt.gov/geography/water_information_system/groundwater.aspx. Accessed 2 Mar 2020.

National Geographic. 2019 (Apr 22). Inequality is decreasing between countries—but climate change is slowing progress. Available online https://www.nationalgeographic.com/environment/2019/04/climate-change-economic-inequality-growing/. Accessed 2 Mar 2020.

NBC News. 2018 (Dec 24). Climate grief: the growing emotional toll of climate change [article]. Available online https://www.nbcnews.com/health/mental-health/climate-grief-growing-emotional-toll-climate-change-n946751. Accessed 4 May 2020.

New York Times. 2019 (Jul 24). Moody’s buys climate data firm, signaling new scrutiny of climate risks [article]. Available online https://www.nytimes.com/2019/07/24/climate/moodys-ratings-climate-change-data.html. Accessed 2 Mar 2020.

[NIOHS] National Institute for Occupational Health and Safety. [undated]. Prevent heart-related illness [poster]. DHHS (NIOSH) publication #2016-151. Available online https://www.cdc.gov/niosh/docs/2016-151/pdfs/fy16_heat-related-illness-poster_2016-151.pdf. Accessed 4 Apr 2020.

[NLCI] National League of Cities. [undated]. Local actions to mitigate and build resilience to climate change [report]. Available online https://pathtopositive.org/wp-content/uploads/2019/09/P2P-checklist-Sep13-Final.pdf. Accessed 2 Mar 2020.

[NOAA-NCEIa] National Oceanic and Atmospheric Administration—National Centers for Environmental Information. [undated]. Data tools: local climatological data [website]. Available online https://www.ncdc.noaa.gov/cdo-web/datatools/lcd. Accessed 3 May 3 2020.

[NOAA-NCEIb] National Oceanic and Atmospheric Administration—National Centers for Environmental Information. [undated]. Global historical climatology network [website]. Available online https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/global-historical-climatology-network-ghcn. Accessed 3 May 2020.

[NSC] National Safety Council. 2020. Learn how to avoid heat-related illnesses and death [website]. Available online https://www.nsc.org/home-safety/tools-resources/seasonal-safety/summer/heat?utm_term=&utm_source=adwords&utm_campaign=Home+Safety+DSA&utm_medium=ppc&hsa_net=adwords&hsa_acc=3965156914&hsa_cam=1746410392&hsa_ad=340458811893&hsa_kw=&hsa_ver=3&hsa_tgt=dsa-722474504807&hsa_mt=b&hsa_grp=71101885840&hsa_src=g&gclid=EAIaIQobChMIm5jF4qjP6AIV2x-tBh32ug5bEAAYASAAEgJqFvD_BwE. Accessed 4 Apr 2020.

[NWSa] National Weather Service. [undated]. Heat cramps, exhaustion, stroke [website]. Available online https://www.weather.gov/safety/heat-illness. Accessed 1 Mar 2020.

[NWSb] National Weather Service [undated]. Cooperative observer program [website]. Available online https://www.weather.gov/coop/. Accessed 4 May 2020.

Ozy. 2019 (Aug 16). The Alcoholics Anonymous approach meets climate change [article]. Available online https://www.ozy.com/rising-stars/the-alcoholics-anonymous-approach-meets-climate-change/95736. Accessed 5 May 2020.

Pew. 2019. Climate change could make borrowing costlier for states and cities [article]. Available online https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2019/10/01/climate-change-could-make-borrowing-costlier-for-states-and-cities. Accessed 14 May 2020.

Plowright RK, Eby P, Hudson PJ, Smith IL, Westcott D, Bryden WL, Middleton D, Reid PA, McFarlane RA, Martin G, Tabor GM, Skerratt LF, Anderson DL, Crameri G, Quammen D, Jordan D, Freeman P, Wang LF, Epstein JH, Marsh GA, Kung NY, McCallum H. 2015. Ecological dynamics of emerging bat virus spillover. Proceedings of the Royal Society B: Biological Sciences 282(1798):20142124. doi:10.1098/rspb.2014.2124.

Rao K. 2006. Psychosocial support in disaster-affected communities. International Review of Psychiatry 18(6):501-6.

Reser JP, Bradley GL, Ellul MC. 2012. Coping with climate change: bringing psychological adaptation in from the cold. In: Molinelli B, Grimaldo V (eds). Handbook of the psychology of coping: psychology of emotions, motivations, and actions. New York NY: Nova Scotia Publishers. p 1-34.

Smith KF, Goldberg M, Rosenthal S, Carlson L, Chen J, Chen C, Ramachandran S. 2014. Global rise in human infectious disease outbreaks. Journal of the Royal Society Interface 11(101):20140950. doi:10.1098/rsif.2014.0950.

Twomey C, Byrne M. 2012. A stepped-care approach to mental health. Forum 29(11):31-2. Available online https://www.lenus.ie/handle/10147/250780. Accessed 5 Apr 2020.

[UNDDR] United Nations Office for Disaster Risk Reduction. 2020. Public health system resilience scorecard [website]. Available online https://www.unisdr.org/campaign/resilientcities/toolkit/article/public-health-system-resilience-scorecard. Accessed 17 Apr 7 2020.

[UNDRR and WHO] United Nations Office for Disaster Risk Reduction and the World Health Organization. 2020. Resilience of local governments: a multi-sectoral approach to integrate public health and disaster risk management [webinar]. Available online https://www.undrr.org/event/undrr-geti-and-who-webinar-resilience-local-governments-multi-sectoral-approach-integrate. Accessed 7 Apr 7 2020.

[USAID] US Agency for International Development. [undated (last update 2 Jun 2019)]. Emerging pandemic threats [website]. Available online https://www.usaid.gov/global-health/health-areas/emerging-pandemic-threats. Accessed 16 Apr 16 2020.

[USEPAa] US Environmental Protection Agency. [undated]. Wildfire smoke factsheet: indoor air filtration [report]. Report #EPA-452/F-18-005. Washington DC: USEPA. 2 p. Available online https://www3.epa.gov/airnow/smoke_fires/indoor-air-filtration-factsheet-508.pdf. Accessed 1 Mar 2020.

[USEPAb] US Environmental Protection Agency. [undated]. EPA Region 8 drinking water unit tech tips: simple fixes for wellheads [report]. 2 p. Available online https://www.epa.gov/sites/production/files/documents/Tech_Tip_Wellheads.pdf. Accessed 1 Mar 2020.

[USEPAc] US Environmental Protection Agency. [undated]. Groundwater and drinking water: emergency disinfection of drinking water [website]. Available online https://www.epa.gov/ground-water-and-drinking-water/emergency-disinfection-drinking-water. Accessed 1 Mar 2020.

[USEPAd] US Environmental Protection Agency. [undated]. Reduce urban heat island effect [website]. Available online https://www.epa.gov/green-infrastructure/reduce-urban-heat-island-effect. Accessed 1 Mar 2020.

[USEPAe] US Environmental Protection Agency. [undated]. Using trees and vegetation to reduce heat islands [website]. Available online https://www.epa.gov/heat-islands/using-trees-and-vegetation-reduce-heat-islands. Accessed 1 Mar 2020.

[USEPA] US Environmental Protection Agency. 2012. A brief guide to mold, moisture, and your home [report]. Report #EPA 402-K-02-003. Washington DC: USEPA. 20 p. Available online https://www.epa.gov/sites/production/files/2016-10/documents/moldguide12.pdf. Accessed 1 Mar 2020.

[USEPA] US Environmental Protection Agency; Indoor Environments Division. 2018a (Jul). Guide to air cleaners in the home, 2nd ed [report]. Report #EPA-402-F-08-004. Washington DC: USEPA. 7 p. Available online https://www.epa.gov/sites/production/files/2018-07/documents/guide_to_air_cleaners_in_the_home_2nd_edition.pdf. Accessed 23 Mar 2020.

[USEPA] US Environmental Protection Agency. Indoor Environments Division. 2018b (Jul). Residential air cleaners: a technical summary, 3rd ed [report]. Report #EPA 402-F-09-002. Washington DC: USEPA. 74 p. Available online https://www.epa.gov/sites/production/files/2018-07/documents/residential_air_cleaners_-_a_technical_summary_3rd_edition.pdf. Accessed 23 Mar 2020.

[USEPA] US Environmental Protection Agency. 2019. Indoor air quality: air cleaners and air filters in the home [website]. Available online https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home-0. Accessed 23 Mar 2020.

[USGCRP] 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.

Wellbery C, Sarfaty M. 2017. The health hazards of air pollution—implications for your patients. American Family Physician 95(3):146-8.

Wettstein ZS, Hoshiko S, Fahimi J, Harrison RJ, Cascio WE, Rappold AG. 2018. Cardiovascular and cerebrovascular emergency department visits associated with wildfire smoke exposure in California in 2015. Journal of the American Heart Association 7(8). doi:10.1161/jaha.117.007492.

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.

[WHO] World Health Organization. [undated]. Health and sustainable development: climate impacts [website]. Available at https://www.who.int/sustainable-development/health-sector/health-risks/climate-impacts/en/. Accessed 1 May 2020.

Wu X, Nethery RC, Sabath BM, Braun D, Dominici F. 2020. Exposure to air pollution and COVID-19 mortality in the United States [unreviewed online preprint]. MedRxiv. Available online https://www.medrxiv.org/content/10.1101/2020.04.05.20054502v2. Accessed 14 May 2020.

Ziska L, Knowlton K, Rogers C, Dalan D, Tierney N, Elder MA, Filley W, Shropshire J, Ford LB, Hedberg C, Fleetwood P, Hovanky KT, Kavanaugh T, Fulford G, Vrtis RF, Patz JA, Portnoy J, Coates F, Bielory L, Frenz D. 2011. Recent warming by latitude associated with increased length of ragweed pollen season in central North America. Proceedings of the National Academy of Sciences 108(10):4248-51. https://doi.org/10.1073/pnas.1014107108

Section 6. Moving Forward

— Alexandra Adams

This report, with its focus on human health impacts from climate change, represents the first document of this nature to be produced specifically for Montanans. As an addendum to 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-change-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 these findings.

The report presents the best available science and resources at the time of publication. We recognize the interconnectedness of various topics within, and also appreciate that these topics are likely to evolve in years to come. As our access to better data becomes available, and other influences impact the health of Montanans, we understand that new knowledge will inevitably expand the foundation this report offers. Thus, while this effort fills a key gap, the work will be sustained, updated, and expanded on a regular basis as part of the overall MCA program. The authors welcome continuing focus and collaborations on these issues[77] to assure Montanans are not only informed about the impacts of climate change on their health, but are also prepared to respond to those impacts in the coming decades.

[77] Contact the MCA program through montanaclimate.org/contact.

We believe we have provided 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.

Appendix A. Vulnerability to heat based on historic and future temperature as well as socioeconomic factors analysis

— Nicholas Silverman, Bruce Maxwell, Rob 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[78] were estimated using the Moderate Resolution Imaging Spectroradiometer (MODIS) Land Surface Temperature 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.

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

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[79] 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).

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).

Socioeconomic 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[a]	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,	Carbon, Jefferson, Granite, Yellowstone, Lewis	Dawson, Flathead, Carter, Fergus, Liberty, Ravalli,	Golden Valley, Rosebud, Big Horn, Pondera, Lake, Hill,

[79] 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).

Socioeconomic 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)
	Stillwater, Garfield, Teton, Powder River, McCone, Gallatin, Wibaux, Beaverhead	and Clark, Sweet Grass, Sheridan, Prairie, Madison, Cascade, Petroleum, Park, Missoula, Judith Basin	Toole, Powell, Treasure, Musselshell, Meagher, Lincoln, Phillips, Deer Lodge, Silver Bow	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[b]	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 historic 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 historic 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 agriculture 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.

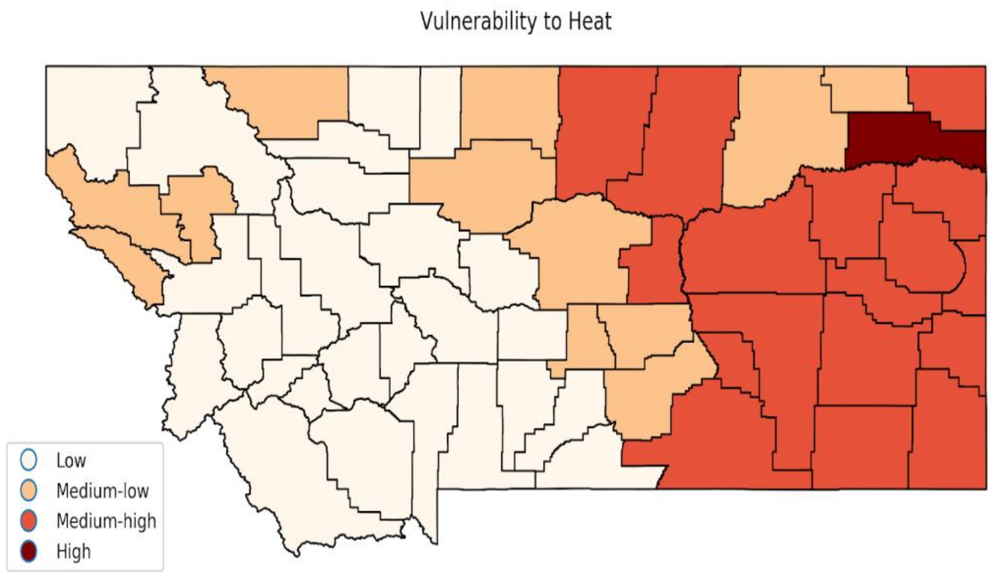

Figure A-1. Montana heat vulnerability ratings from the multi-criteria decision analysis.

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.

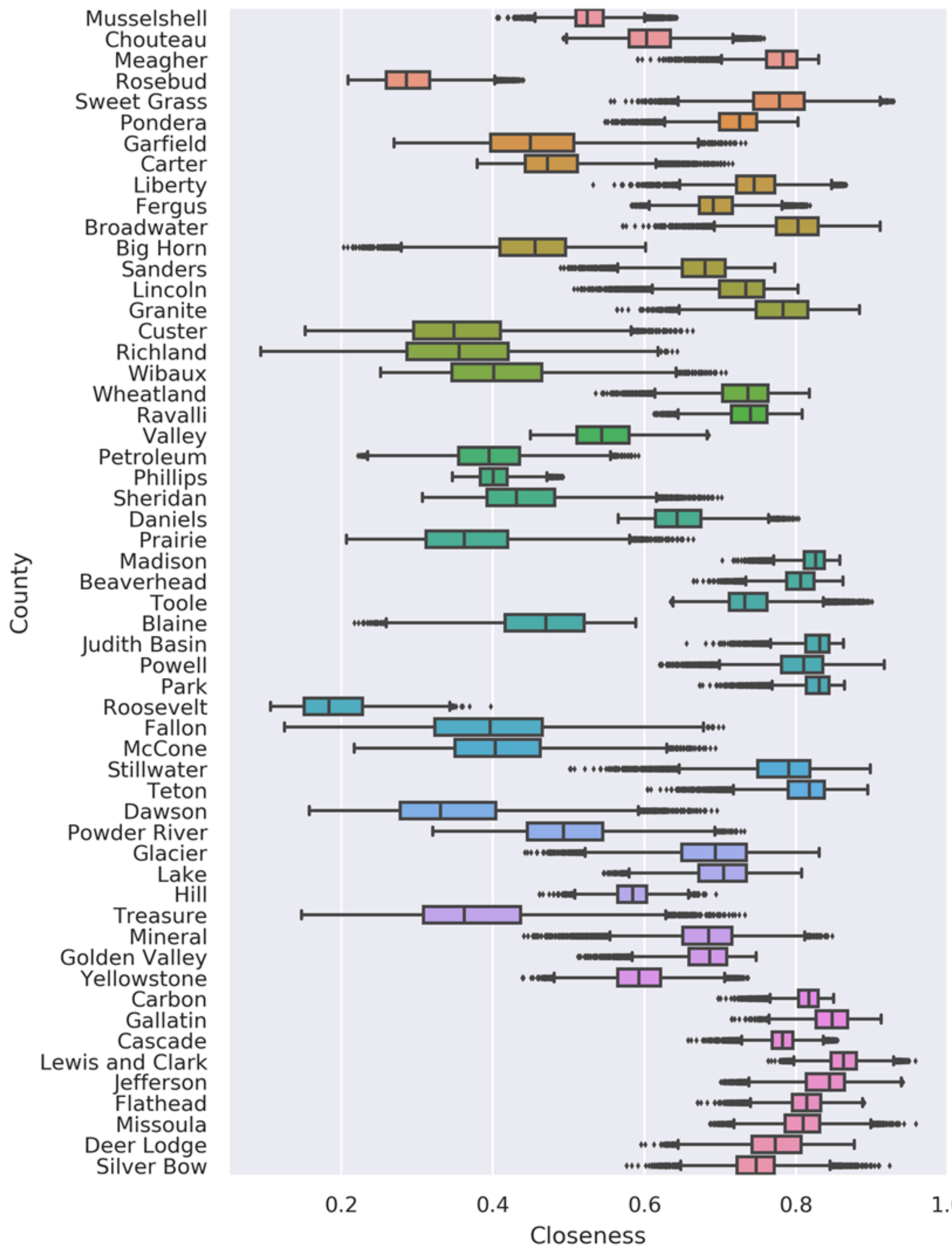

Figure A-2. Monte-Carlo analysis of socioeconomic weights to predict closeness to ideal (not vulnerable) is used as the metric of human health vulnerability.

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LITERATURE CITED

Chi G. 2010. Land developability: developing an index of land use and development for population research. Journal of Maps 2010(1):609-17.

Ho HC, Mylroie J, Infante L, Rodgers III J. 2014. Fuzzy-based spatial modeling approach to predict island karst distribution. Environmental Earth Sciences 71:1369–77

Ho HC, Knudby A, Huang W. 2015. A spatial framework to map heat health risks at multiple scales. International Journal of Environmental Research and Public Health 12:16110–23. doi:10.3390/ijerph121215046.

Hwang CL, Yoon K. 1981. Methods for multiple attribute decision-making [chapter]. In: Multiple attribute decision-making. Berlin GDR: Springer. p 58-191.

Morabito M, Crisci A, Gioli B, Gualtieri G, Toscano P, di Stefano V, Orlandini S, Gensini GF. 2015. Urban-hazard risk analysis: mapping of heat-related risks in the elderly in major Italian cities. PLOS ONE 10(5):e0127277. https://doi.org/10.1371/journal.pone.0127277.

Reid CE, O'Neill MS, Gronlund CJ, Brines SJ, Brown DG, Diez-Roux AV, Schwartz J. 2009. Mapping community determinants of heat vulnerability. Environmental Health Perspectives 117:1730-6.

Sevachandran G, Quek SG, Smarandache F, Broumi S. 2018. An extended technique for order preference by similarity to an ideal solution (TOPSIS) with maximizing deviation method based on integrates weight measure for single-valued neutrosophic sets. Symmetry 10:236. doi:10.3390/sym10070236.

Thompkins J. 2018. Just open a window: understanding the vulnerability to summer heat of a mountain community in the western United States, Missoula, MT [master's thesis]. Missoula MT: University of Montana. 53 p. Available online https://pdfs.semanticscholar.org/889e/1883fe683f37bac12602f944314bd0a31708.pdf?_ga=2.100382622.1055626674.1589500024-1171419070.1589500024. Accessed 14 May 2020.

[UCS] Union of Concerned Scientists. 2019. Killer heat in the United States; climate choices and the future of dangerously hot days [report]. Dahl K, Spanger-Siegfried E, Licker R, Caldas A, Abatzoglou J, Mailloux N, Cleetus R, Udvardy S, Declet-Barreto J, Worth P, authors. Available online https://www.ucsusa.org/sites/default/files/attach/2019/07/killer-heat-analysis-full-report.pdf. Accessed 15 Sep 2019.

Wan Z, Hook S, Hulley G. 2015. MYD11A1 MODIS/Terra Land Surface Temperature/Emissivity Daily L3 Global 1km SIN Grid V006 [data set]. NASA EOSDIS Land Processes DAAC. Accessed 26 Jun 2019 from https://doi.org/10.5067/MODIS/MOD11A1.006.

Wild rose (*Rosa acicularis*). Photograph 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 climat 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 (CO_2) — 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 climat 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 — Describes an individual or community's ability to reliably access a sufficient quantity of affordable, nutritious food.

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 how hot it feels 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.)

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/m^2, 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 climat 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 >90th percentile.

warm nights — Percentage of time when daily minimum temperature >90th 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.

Snow geese near Fairfield, Montana. Photograph courtesy of Scott Bischke.

List of Contributors

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Scott Bischke of MountainWorks Inc. served as Science Writer for this report, as well as for the *2017 Montana Climate Assessment*. Scott is a BS (Montana State University), MS (University of Colorado) chemical engineer who has worked as an engineering researcher at three national laboratories: the National Bureau of Standards (now National Institute of Science and Technology), Sandia, and Los Alamos. He worked for roughly 11 yr as lead environmental engineer for a Hewlett-Packard business unit. Scott has authored, co-authored, or edited two environmental impact statements, book chapters, technical papers, five popular press books, and successful proposals totaling tens of millions of dollars.

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 2 yr 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 MT, 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 yr 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 yr, 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.

Margaret (Mari) Eggers is a research assistant professor in environmental health at Montana State University Bozeman (MSU). She previously lived in Crow and taught science at the Tribal 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 M.A. (Stanford), an MS in Ecology and a PhD in environmental health (MSU).

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. .

Bruce Maxwell is Professor of Agroecology and Applied Plant Ecology in the Department of Land Resources and Environmental Science (LRES) at Montana State University. Maxwell was instrumental in the formation of the Department of LRES and has received national awards for outstanding teaching, best peer reviewed papers and outstanding graduate student from the Weed Science Society of America. He has published over 100 scientific journal articles and book chapters, chaired and been a member of numerous agricultural and ecological research grant review panels and been a member of two National Academy of Sciences National Research Council Committees on Agriculture. He was a Fulbright Fellow in Argentina in 2007. His research has historically straddled the disciplines of invasion biology and agroecology.

Cathy Whitlock 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*.

Sunset in the Beartooth Mountains of southeast Montana.
Photograph courtesy of Scott Bischke.