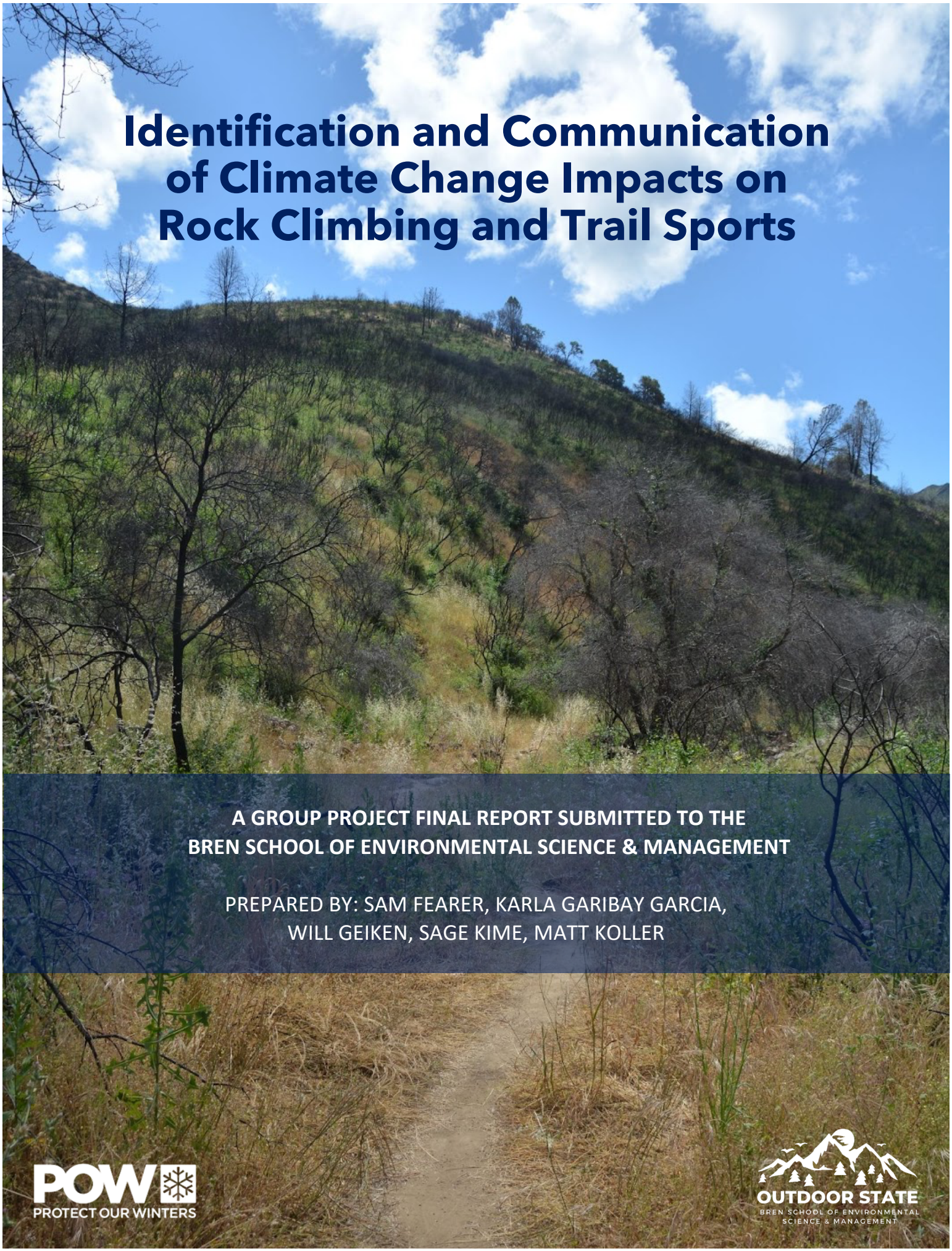


Identification and Communication of Climate Change Impacts on Rock Climbing and Trail Sports

A GROUP PROJECT FINAL REPORT SUBMITTED TO THE BREN SCHOOL OF ENVIRONMENTAL SCIENCE & MANAGEMENT

PREPARED BY: SAM FEARER, KARLA GARIBAY GARCIA, WILL GEIKEN, SAGE KIME, MATT KOLLER

POW
PROTECT OUR WINTERS

OUTDOOR STATE
BREN SCHOOL OF ENVIRONMENTAL SCIENCE & MANAGEMENT

Activate the Outdoor State:
Identification and Communication of Climate Change Impacts on Rock Climbing and Trail Sports

---

UNIVERSITY OF CALIFORNIA
Santa Barbara

A Final Report submitted in partial satisfaction of the requirements for the degree of
Master of Environmental Science and Management
for the
Bren School of Environmental Science & Management

by

SAM FEARER
KARLA GARIBAY GARCIA
WILL GEIKEN
SAGE KIME
MATT KOLLER

Faculty advisor:
DR. JAMES FREW

External advisors:
DR. LISA LEOMBRUNI
DR. SAMANTHA STEVENSON

3/18/2022

SIGNATURE PAGE

As authors of this Group Project report, we archive this report on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.

Team members:

_____	_____
Matt Koller	Karla Garibay Garcia
_____	_____
Sage Kime	Will Geiken
_____	
Sam Fearer	

The Bren School of Environmental Science & Management produces professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principle of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project is a year-long activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Group Project Final Report is authored by MESM students and has been reviewed and approved by:

_____	_____
Dr. James Frew	Date

ACKNOWLEDGEMENTS

Our team would like to extend our deepest gratitude to everyone who contributed to and guided us through this project, with special thanks to:

Faculty Advisor:
Dr. James Frew

External Advisors:
Dr. Lisa Leombruni
Dr. Samantha Stevenson

Protect Our Winters Staff:
Lindsay Bourgoine
Jake Black
Sam Killgore
Brian Aucoin
Donny O'Neill

Financial Support:
DiPaola Foundation

Photography Credit:
Matt Koller

Protect Our Winters Alliance Members:
Graham Zimmerman
Stephanie Howe
Dr. Elizabeth Burkowski
Dr. Jude Bayham
Nina Aragon
Dr. Ian Bolliger
Canyon Woodward
Dr. Jen Kay
Clare Gallagher
Dillon Osleger
Kurt Refsnider
Kait Boyle

Additional Support:
Joseph Gray
Dr. Erik Murdock
Dr. Allison Horst

UC SANTA BARBARA
Bren School of Environmental Science & Management

POW PROTECT OUR WINTERS

DIPAOLA foundation

TABLE OF CONTENTS

LIST OF TABLES & FIGURES

---

1. PROJECT DESCRIPTION

Protect Our Winters (POW) is a non-profit organization that mobilizes American outdoor enthusiasts, which POW calls the “Outdoor State,” to advocate for non-partisan climate solutions to protect the places they love to recreate. Founded in 2007, POW has highlighted the threat climate change poses to winter sports participants, such as a shortened winter season and decreased snowpack, to engage this community in outreach campaigns that advance non-partisan climate solutions.

This project developed messaging to help POW recruit additional sport communities to take climate action. In particular, our project detailed the impacts of climate change on the rock climbing and trail sports (hiking, trail running, and mountain biking) communities at a national and state level.

We also produced targeted strategic communication materials for POW’s Alliance members (see “Alliance” on p. 9) to use when recounting their personal experiences with climate impacts and encouraging POW’s audience to take action to protect the lifestyles that they love. This project created tools to help POW motivate thousands of additional outdoor enthusiasts to support elected officials and policies that advance systemic climate solutions.

2. BACKGROUND

Climate Science and U.S. Policy

In 2018, the U.S. Global Change Research Program released the Fourth National Climate Assessment (NCA), which outlines 16 national and 10 regional impacts of climate change[1]. This report clearly and definitively demonstrates that climate change is already negatively impacting many aspects of life for U.S. citizens and that we can expect additional negative impacts. Climate change presents an immediate threat, including exacerbated vulnerabilities in specific communities, economic losses to infrastructure and property, and threats to health and well-being.

In 2015, nearly 200 countries committed to the Paris Agreement under the United Nations Framework Convention on Climate Change, which aims to slow the effects of climate change by dramatically reducing greenhouse gas emissions[2]. Under the Paris Agreement, the U.S. must reduce its emissions by 26 to 28 percent of 2005 baseline values (6635 million tonnes CO2e) by 2025, and by 2030 the U.S. must achieve a 50 to 52 percent reduction from that baseline[3].

At the 2021 COP26 Climate Summit in Glasgow, the U.S. signed the Global Methane Pledge, contributed to the Adaptation Fund for the first time, pledged to end new international finance for unabated fossil fuel energy by 2022, and entered potentially impactful climate collaborations with China, South Africa, and the United Arab Emirates[4].

Systemic changes are required at all levels of U.S. society to achieve emissions reduction targets and comply with its re-commitment to the Paris Agreement and its COP26 pledges. Achieving these goals will require aggressive domestic climate action, which requires strong climate leaders and significant political pressure at all levels of government.

Background on POW

POW is a non-profit organization that mobilizes American outdoor enthusiasts, which POW calls the “Outdoor State,” to advance non-partisan climate solutions that protect the places they love to recreate. POW’s Theory of Change is predicated on three approaches to help solve the climate crisis:

- Cultural Shift
- Technological and Financial Solutions
- Political Will

POW highlights climate impacts in specific sport categories to generate a cultural shift, where members of the Outdoor State advocate for technological and financial solutions and generate the political will necessary to impact elections and policy decisions at the thin margins needed to generate change.

To date, POW has focused on mobilizing winter sports participants into a cohesive, engaged stakeholder group by highlighting the threat that climate change poses to winter sports. POW has built large audiences on Instagram (250,000+ followers), Facebook (100,000+ followers), and Twitter (25,000+ followers)[5], and uses these social media channels to amplify their message and motivate these audiences to advocate for climate solutions. In addition to its direct social media audiences, POW has cultivated Alliance partnerships that share POW's values and can collectively reach approximately 25 million followers. POW's Alliances include the following:

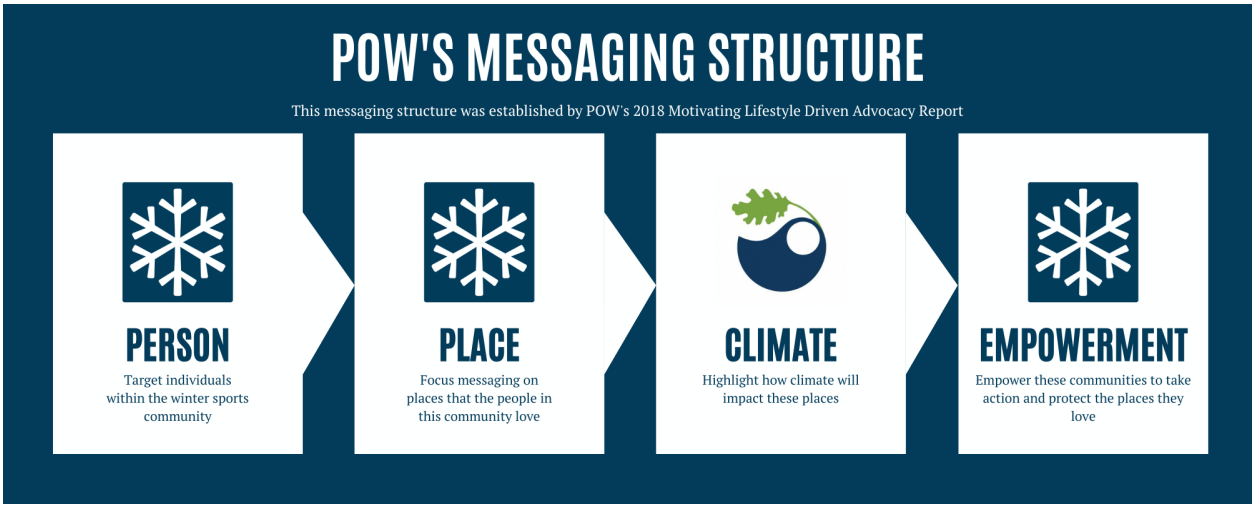
- **Athlete Alliance**, which is made up of professional skiers, snowboarders, rock climbers, trail runners, and mountain bikers.
- **Science Alliance**, which is made up of professional climate scientists studying the impacts of climate change on Earth.
- **Creative Alliance**, which is made up of professional photographers, writers, filmmakers, and communicators in the outdoor industry.
- **Brand Alliance**, which is made up of prominent outdoor brands, such as Burton, Aspen Snowmass, and The North Face, who are engaged in climate advocacy.

POW's messaging has significant reach through its direct audience engagement and Alliance members' audience engagement. For example, in 2019, POW's digital communications reached 5,049,306 voters through 134,440,300 media impressions and recruited 20,500 advocates through outdoor-focused educational campaigns, bringing significant visibility to climate issues[5].

POW uses outreach campaigns to mobilize the Outdoor State to influence climate policies. In 2019, POW recruited 17,000 new advocates to take actions such as submitting public comments against drilling in the Arctic National Wildlife Refuge, mobilized 34,000 members to send emails to elected officials demanding climate action, and organized over 100 professional athletes, scientists, and outdoor industry brand leaders to attend congressional events and meetings advocating for climate legislation[6]. POW also mobilized its network to help pass Colorado's 2019 Climate Action Plan to Reduce Pollution. Additionally, POW directly influences the U.S. political system through voter engagement. The 2020 'Make a Plan to Vote' campaign secured commitments from approximately 40,000 people to prioritize climate policies with their vote[5] and partnered with Strava to recruit 25,598 people to run or bike to polling places.

3. SIGNIFICANCE

According to their 2021-2024 Strategic Plan, POW seeks to create the most influential climate group in the U.S. through the Outdoor State. POW has used the following messaging structure successfully to engage winter sports participants in climate advocacy by highlighting the threat that climate change poses to their ability to recreate:



This messaging structure was first outlined in the "Motivating Lifestyle Driven Advocacy" report produced by POW and the Artemis Strategy Group & Neimand Collaborative, a marketing consulting firm[7]. POW refers to this report as the "Neimand Report" and the messaging structure as "Neimand messaging," terminology that we used in this report. POW seeks to use Neimand messaging to expand its influence by mobilizing two additional stakeholder groups as climate advocates: rock climbers and trail sports participants (hikers, trail runners, and mountain bikers).

In this context, POW has already identified the people they want to target (rock climbers and trail sports participants), all of whom have places they want to protect (i.e., where they recreate). This project will assist POW by outlining how climate will impact these places and sports participants. POW will use our research and project deliverables to better inform, engage, and empower the rock climbing and trail sports communities to take climate action.

The educational work and messaging behind POW's advocacy is firmly rooted in the scientific research performed by POW's Science Alliance, which consists of 10 leading scientists in climate-related fields, including Dr. James White, Director of the Institute for Arctic and Alpine Research (INSTAAR) and the founding Director of Environmental Studies Department at CU Boulder, and Dr. Kevin E. Trenberth, a senior scientist at the National Center for Atmospheric Research. The Science Alliance brings facts to the forefront of POW's messaging and climate advocacy, which helps its

Alliance members understand and communicate scientific information to their peers. In addition to their science-based advocacy, POW's outreach and messaging campaigns are guided by a scientific understanding of what motivates outdoor enthusiasts[7].

It has long been established that warmer winter temperatures will result in more precipitation falling as rain instead of snow. This climate impact directly affects the resource that winter sports participants rely upon for recreational pursuits (i.e., there is less snow in a warmer world; because you need snow to ski, you ski less).

With some exceptions, snow sports are primarily performed at discrete locations that constantly monitor climate and weather conditions. This makes it fairly straightforward to identify how climate change will impact winter sports and the communities connected to them. However, identifying the current and projected impacts of climate on the rock climbing and trail sports participants is less straightforward. This is true for several reasons:

- **Nature of resource required to recreate**: Winter sports participants require a specific resource to recreate: snow. Rock climbers require a rock surface to climb, however, the nature of the rock is highly variable across different climbing areas and regions. Trail sports participants require trails; however, the composition of trails is highly variable across regions. Given that these resources are not uniformly affected by climate change, it is difficult to say that these sports communities are uniformly impacted by climate change. Furthermore, the non-uniform impacts of climate change across the U.S. create regional differences in the relevant impacts to these communities.

- **Oversight/management**: Except for day passes for limited access areas and permits pulled for multi-day activities in national wilderness areas, rock climbing and trail sports participants are not required to "check in" or report on activities. To this extent, climbing and trail activities are not regulated or overseen by a network of governing bodies in the same way snow sports are.

- **Disparate locations**: Rock climbing resources are scattered throughout the country, while hikers, mountain bikers, and trail runners are typically independent participants that recreate using trail networks not actively monitored. While some recreational pursuits require overnight and backcountry permitting administered by local, state, and federal governments, the recreational locations are less clearly defined than for winter sports. For example, ski resorts and government entities like NOAA are well-known for tracking their daily, weekly, and annual snow totals, making it easier to identify changes in this resource in a specific recreational area with a large concentration of winter sports participants.

The disparate nature of the rock climbing and trail sports communities makes it difficult to identify how climate change impacts the ability of our target sports participants to pursue their sports, particularly when these participants are spread out across a wide range of geographies that will experience variable climate impacts.

Therefore, this report provides a first pass at outlining the current and projected impacts of climate change on rock climbing and trail sports participants and will provide POW with a scientific framework for developing messaging campaigns targeted at engaging the rock climbing and trail sports communities in climate action.

4. PROJECT OBJECTIVES

POW will target rock climbing and trail sports participants by highlighting how climate change will impact them. However, POW currently lacks a resource that outlines how climate change will impact rock climbing and trail sports participants, which is needed to create messaging that will inspire these groups to take climate action.

This project aimed to answer the following questions:

1. How will climate change affect the rock climbing and trail sports communities?
2. Are there opportunities for audience expansion within those communities?

Objective 1

The primary objective of this project was to detail the current and projected impacts of climate change on rock climbing and trail sports communities at a national level and within five target states: Arizona, Colorado, Nevada, Montana, and Utah. To answer this question, we critically assessed the latest climate science, reviewed relevant national recreation reports, and distilled this information into concise and accessible deliverables for POW's messaging campaigns. We then identified the main climate impacts within POW's target states, including localized impacts on the rock climbing and trail sports communities, where applicable. Finally, we used a comprehensive literature review and discussions with climate scientists, professional rock climbing and trail sports athletes, and economists to answer this research question.

While assessing the distributional impacts of climate change on different demographics was not a specific goal of this project, we recognize that marginalized communities disproportionately bear climate impacts and that these populations have historically been underrepresented in the outdoor recreation industry despite being an active and growing audience segment. Therefore, our report highlights the inequitable climate impacts relevant to participation in outdoor recreation, the historical barriers to access these communities have experienced, and the importance of marginalized communities as a growing proportion of outdoor enthusiasts.

Objective 2

As POW begins to focus its state-specific work, it will require a better understanding of its current potential audiences within these states (i.e., how many mountain bikers, hikers, trail runners, and rock climbers are in each state). Therefore, the secondary objective of our project was to evaluate the opportunities for audience expansion within the rock climbing and trail sport communities. This project analyzed POW's existing member data and compared this information with publicly available data on sport participation rates in each target state. This allowed us to provide

preliminary recommendations as to where POW should concentrate future outreach efforts within states and across sport groups (e.g., POW should seek to increase membership in Arizona, as the proportion of members to residents is lower there; or POW should conduct outreach to the mountain biking community in Utah, as they have the highest participation).

Deliverables

Along with the deliverables required by the Bren School, this project produced three additional deliverables to guide POW's advocacy efforts:

1. **State Fact Sheets**, which provide bite-sized information about how climate will impact POW's five target states. These will help inform POW's advocacy efforts.
2. **Alliance Toolkits**, which break down climate impacts by sport category. POW will use these to educate its Alliance members, the individuals responsible for amplifying POW's climate messaging to their audiences, and the greater Outdoor State.
3. **Media Publication**, which will be a visually compelling and easily digestible version of our Bren School report that POW can release publicly and use as a resource to highlight the impacts of climate change on the rock climbing and trail sports communities.

The State Fact Sheets and Alliance Toolkits are included in Appendix 1 and Appendix 2, respectively. The Media Publication will be a standalone deliverable, produced as a Strategic Environmental Communications Capstone following the completion of this report.

A robust understanding of how climate change will affect the rock climbing and trail sports communities will enable POW to expand its audience and outreach efforts to include a greater proportion of the Outdoor State.

5. METHODS

Our project sought to (i) outline how climate change will affect the rock climbing and trail sports communities and (ii) identify opportunities for audience expansion within those communities. We accomplished this through the following stages:

1. Project Scoping
2. Identifying Climate Change Impacts
3. Producing Strategic Communications Materials
4. Audience Expansion Analysis
5. Evaluating Strategic Communication Materials Efficacy

Project Scoping

Our initial research question was: "What strategic communications messaging can most effectively recruit members of the rock climbing and trail sports communities as climate activists?" However, after re-scoping the project with the client based on feasibility, usefulness, and the fact that all communications materials produced by this project must follow the Neimand messaging structure, we produced two research questions—one qualitative and one quantitative—that better reflect the final scope of our project:

1. How will climate change affect the rock climbing and trail sports communities?
2. Are there opportunities for audience expansion within those communities?

Regional Scope of Impacts in Target States

POW had not yet identified their target states at the beginning of the project. Therefore, we began by assessing national-level impacts and regional-level case studies. In summer 2021, POW identified Arizona (AZ), Colorado (CO), Nevada (NV), Montana (MT), and Utah (UT) as their five target states. We then began researching and writing State Fact Sheets for each target state (one of our client deliverables). These documents outline the high-level climate impacts in each state and include any relevant sport-specific impacts we could find.

Given the lack of primary literature on this subject, it was not feasible to analyze how climate change will impact the rock climbing and trail sports communities within POW's five target states using only state-specific findings. Therefore, we used national-level and regional-level information to ensure that each State Fact Sheet had comprehensive information.

Audience Characterization

This project aimed to identify how climate change impacts the rock climbing and trail sports (hiking, trail running, and mountain biking) communities. Many participants in these communities view their preferred activity as more than just a sport: they see recreation as a way of life. To participate in these activities, they need access to certain recreational locations—such as hiking trails and rock crags—and certain recreational conditions—such as safe temperatures.

Identifying Climate Change Impacts

Literature Review

We performed an extensive literature review to assess how climate change will impact the rock climbing and trail sports communities. This included searching peer-reviewed publications, UCSB's library resources, Google Scholar, government publications, and reports from non-profit and government organizations for various combinations of the following search terms:

- "Climate change"/"Climate change impact(s)"
- "Economic(s)"/"Economic impact(s)"
- "Rock climbing"
- "Trail sport(s)"
- "Hike"/"Hiker"/"Hiking"
- "Trail run"/"Trail running"/"Trail runner"
- "Mountain bike"/"Mountain biking"/"Mountain biker"
- "Arizona"/"Colorado"/"Nevada"/"Montana"/"Utah"

We reviewed all publications identified by these searches and identified additional resources by finding which studies they cited or were cited by. In total, we reviewed more than 300 studies, journal articles, and reports. This included studies and reports highlighting the economic benefits of these sport categories.

The literature review process addressed several thematic topics:

- **Assessment of sport-specific climate impacts.** As we performed our literature review, we categorized our findings by sport. Given that almost all rock climbing locations require trail usage in some form, virtually all climate impacts experienced by the trail sports community are also experienced by the rock climbing community. However, given that rock climbing-specific impacts were identified, our findings were ultimately divided by sport category. This will allow POW to identify and communicate sport-specific information to relevant audiences more easily.

- **Assessment of sport-specific economic value.** A key aspect of the literature review was identifying the economic impacts of the rock climbing and trail sports communities. Additionally, POW Alliance Members were asked if they were aware of the economic value of a sport category. Because the economic data we found largely focuses on past and projected productivity, it was used as a proxy to indicate potential economic losses due to climate impacts. Examples include total mountain bike sales in North America and case studies assessing the economic impact of rock climbing in particular regions. The connection to economic losses was extrapolated based on anecdotal examples such as canceled races and closed recreation areas due to wildfires, wildfire smoke, and erosion.

- **Exploration of participation demographics and environmental justice (EJ) issues.** We initially planned to assess participation demographics and EJ issues to frame our strategic communications messaging in a way that would resonate with multiple audiences, including marginalized communities. However, after summer 2021, we learned that all of POW's messaging follows the Neimand messaging of "People, Place, Climate, Empowerment." While we recognize that this messaging structure might not apply equally to all demographic groups, it informs POW's communications strategy. However, it remains important to understand the differential climate impacts on various groups. Throughout the project, we attempted to account for the low participation rates of historically underrepresented communities in POW's target sports and the disproportionate climate impacts borne by these very same communities. We approached this point by answering the following question: "How can we connect with those who have not traditionally been represented in climate discussions in the outdoor community while recognizing that these very same people often pay a disproportionate price for climate impacts?"

Discussions with Experts

We conducted informational discussions with athletes, scientists, economists, and policy experts to identify lines of research as we performed our literature review. These discussions were structured as informal conversations, where one group member led the conversation and others could raise additional considerations. We provided a brief overview of our project goals before asking the individual to share what they knew or were learning about the impacts of climate change on the rock climbing and trail sports communities. Individuals were asked to share specific examples of observed or otherwise relevant climate change impacts if they knew of any. We used these conversations to inform our research directions and identify new case studies.

At no point in this project were an individual's responses generalized to suggest that their responses were representative of a larger group.

Producing Strategic Communications Materials

This project had a strong communications component with the following deliverables:

1. **Literature review (Bren deliverable/POW deliverable).** We performed and wrote a literature review as part of our final Bren report and as a deliverable for POW. This literature review informed and supported additional deliverables for POW, including the Alliance Toolkits, State Fact Sheets, and Media Publication.

2. **State Fact Sheets (POW deliverable).** POW identified five target states for upcoming campaign and advocacy efforts: Arizona, Colorado, Montana, Nevada, and Utah. We produced one fact sheet per state that combines key findings from our literature review with state-specific recreation figures, economic contribution statistics, and relevant climate impacts. These findings are organized by the overarching impact categories described in the literature review with slight modifications for accessibility. POW will use these fact sheets to empower and educate their team of 300+ Alliance members as they perform outreach and communicate change impacts within the target states.

3. **Alliance Toolkits (POW deliverable).** We produced an Alliance Toolkit for each sport category (Trail, Climb) that highlights the climate impacts outlined in our literature review. POW Trail and Climb Alliance captains will use these toolkits when training new POW Alliance members on sport-specific impacts. The goal of this deliverable is to educate and instill confidence in POW athlete representatives to deliver accurate and personalized messaging to their respective audiences.

4. **Strategic communications analysis (POW deliverable).** While this project initially sought to identify specific outreach messaging channels, calls-to-actions, and A/B testing to gauge the efficacy of messaging, we found that these aspects of the project did not align with POW's established Neimand messaging structure. Additionally, POW clarified that this project should not identify state-specific climate actions (e.g., supporting/opposing upcoming State legislation), nor should we develop any deliverables with specific actions in mind. Therefore, we did not test various messaging styles, and all deliverables were produced such that POW can modify them for future campaigns.

In addition to the above materials, group members pursuing Bren's Strategic Environmental Communication and Media developed an additional deliverable as a Communications Capstone project during Spring Quarter 2022:

5. **Media Publication (POW deliverable).** The Media Publication will draw from the research and findings of this report and will revise them into a graphically rich, broadly accessible

manuscript that POW can use as a public resource to highlight the impacts of climate change on these sport categories. This deliverable will use additional material from discussions with Alliance Members (as illustrative, anecdotal evidence), State Fact Sheet material (for regional spotlights), and visual design and layout elements from POW's 2018 Economic Report.

Audience Expansion Analysis

This project sought to identify audience expansion opportunities for POW within the rock climbing and trail sport communities in the five target states (Arizona, Colorado, Montana, Nevada, Utah). This required (i) accurately characterizing POW's existing membership and their participation rates in the target states and (ii) identifying overall participation rates in the target states. This would allow us to identify states in which POW had membership levels for a particular sport below the state participation rate.

Analyzing POW's Existing Membership Data

To identify potential audience expansion opportunities, we first analyzed and characterized POW's existing membership data to identify states with low POW membership and high participation rates in rock climbing and trail sports.

We obtained data from POW, which consisted of data from both Salesforce and Phone2Action member accounts. POW uses Salesforce as a customer relationship management tool and Phone2Action as an advocacy tool to engage and mobilize POW members to take climate action. Throughout this project, Phone2Action changed its name to Capitol Canary, but remains an advocacy tool for organizations like POW. We filtered the large datasets into a subset of only the five target states and their associated member data. There were two separate fields for members to provide their state information in the Phone2Action dataset, leading to inconsistencies between which field recorded the member's state. We merged into one definitive column with a single state listed for each member account to address this issue.

The client's existing data contained numerous missing data placeholders, which may compromise the accuracy of our audience characterization. Although we were provided with two unique data sources (Salesforce and Phone2Action), there was no unambiguous linking of accounts between the two sources. This meant there were likely entries in both datasets for the same individual, leading to an inaccurate characterization of POW's existing audience. To avoid potential double counts of POW members within target states, we analyzed the two datasets separately. We chose the Salesforce dataset as our primary source because it contained more POW members (~267,000 in Salesforce and ~70,000 in Phone2Action).

After cleaning the datasets, we determined the number of POW members within each target state. We also grouped the sport categories members identified as their interests according to their home state. The intent was to reveal any differences in sport participation within target states, but there was not a sufficient amount of data to draw conclusions about sport participation rates. Therefore, we began searching for alternate sources of participation data.

Identifying External Data Sources

We tried to obtain data on the levels of participation in our target sport categories (rock climbing, trail running, hiking, and mountain biking) in our target states (Arizona, Colorado, Montana, Nevada, Utah). The Outdoor Industry Association (OIA) produces the most comprehensive outdoor recreation participation data in the U.S. However, this data is gathered nationally and is not disaggregated by state. We contacted OIA to request state-level data, but POW informed us that the data comes from a survey that cannot be projected to the state level.

We next assessed internet-based services that track metrics related to our target sports. These included Strava (a platform for runners and cyclists to track their activity), onX (a GPS mapping tool for outdoor enthusiasts), and Gaia GPS (a tool that outdoor enthusiasts can use to find trails and plot their own trails). However, we were unable to obtain datasets that contained estimates of state-level sport participation.

We next assessed the feasibility of using other data as a proxy to estimate sport participation rates in our target states, using publicly available data from the following additional sources:

- **AllTrails**, a platform designed for outdoor enthusiasts to explore over 200,000 trails with extensive information such as location, reviews, photos, and more.
- **Hiking Project**, a platform focused specifically on trail use for hiking, shares thousands of trails from crowd-sourced data users contribute.
- **Mountain Project**, a climbing-focused platform that allows users to submit crags and climbing routes to share with the broader community. This is a free, crowd-sourced, online climbing guide and resource for climbers across the globe. Climbers use the site to view climbing routes, gather detailed information, and leave reviews for past climbs.
- **Mountain Bike Project**, a platform focused specifically on trail use for mountain biking that shares thousands of trails from crowd-sourced data contributed by users.
- **Trailforks**, a platform and trail management system for outdoor enthusiasts, aims to showcase and collect information on trail networks and destinations. This is a crowd-sourced database where trail enthusiasts can submit new trails, update existing trails, and log their

activities. Though this source now focuses on all trail sports, historically it focused on mountain biking.

We collected the following data from the sources' websites, which were used as proxies to estimate sport participation rates in the five target states:

1. National Participation Data (source: OIA)
2. Number of Trail Reviews (source: AllTrails)
3. Number of Trails (source: AllTrails)
4. Miles of Hiking Trails (source: Hiking Project)
5. Number of Climbing Routes (source: Mountain Project)
6. Miles of Mountain Biking Trails (source: Mountain Bike Project)
7. Number of Annual State Page Views (source: Mountain Project)
8. Number of Ride Logs (source: Trailforks)

Approximating Sport Participation Rates

Although we were unable to obtain consistent data related to sport participation at the state level, we were able to compile national outdoor recreation participation data from the OIA. This data estimates the total number of participants in the U.S. for several sport categories, including hiking, trail running, mountain biking, and several types of climbing.

We used this national participation data from OIA to estimate potential state participation in POW's five target states: AZ, CO, MT, NV, and UT. We assumed that state participation trends follow national per-capita participation rates. While we recognize that this assumption is not accurate, it served as a starting point to determine a baseline approximation of participation. To extrapolate state participation estimates from total national participation, we did the following:

1. Compile the national estimates of sport participation (number of participants) and calculate the national per capita participation rate for each sport by age group (under 18 and 18+),
2. Gather data from the U.S. Census to determine the proportion of children (under 18) to adults (18+) for each of the target states, and
3. Extrapolate state participation estimates for each sport from the national per capita participation rates for children and adults.

Example:
*Total AZ Hiking Participants(adult) = National Participation Rate(hiking) * AZ Population(adult)*

The tables located in "Chapter 7: Results & Discussion" show the results of this state-level approximation of sport participation. Ultimately, we were not confident about the estimates for total sport participation in each target state because we know that participation in a particular state

depends on more than just the state population. We also discovered that this data is based on a national panel survey conducted by the Outdoor Industry Association and was not designed to be projected at the state level. Due to this uncertainty, we decided not to move forward with these estimates. Rather, the methods described above can serve as a template for POW to pursue if they perform further research or obtain representative data.

Using Alternative Proxies for Participation Estimates

We categorized the remaining proxy data into two subsections based on the type of analysis we would pursue: absolute measures and relative measures. Absolute proxy data are informative on their own and do not necessarily depend on state population (e.g., the total number of climbing routes in a target state). Relative proxy data may be related to population, such as the number of web page views in a target state.

While the number of climbing routes or hiking trails is an absolute that can be compared independent of state population or sport participation, the number of page views or trail reviews on a website is likely correlated with the total number of sport participants recreating within the state. We extrapolated relative measure data to a rate per 10,000 individuals for each target state. However, it is important to note that certain factors can skew this data; for example, the data may be biased by relatively few enthusiasts leaving several reviews or navigating to a state's page repeatedly.

Absolute Proxy Data

The data that we determined would be most valuable on an absolute basis was visualized to examine potential trends across target states. These proxy data included the following:

- Number of trails in each target state
- Miles of trails in each target state
- Number of climbing routes in each target state

We assessed absolute measures to approximate the relative audience size based on the presumption that higher numbers of trails and climbing routes provide greater potential for participation by the trail sports and rock climbing communities in those regions. However, these measures cannot be used to compare across target states because they are not directly correlated to participation rates.

Relative Proxy Data

Mountain Project. The Mountain Project site has a webpage for each state in the U.S., and these pages report the annual and the monthly number of views they receive. This absolute number tells us how many times a state's webpage has been viewed to get information about rock climbing,

which we used as a proxy for overall participation. However, this absolute number may be impacted by a state's population. For example, a state with a higher population may expect to receive more page views from residents than one with a lower population. To account for this discrepancy, we calculated the per capita view rate for each target state. This allowed us to compare site activity without influence from population size.

Example:
Per capita view rate$_{state}$ = annual webpage visits$_{state}$ / population$_{state}$

Table 1. Per capita Mountain Project webpage visits for each target state

State	Population	Annual Webpage Visits	Per Capita View Rate
AZ	7,276,316	17,683,967	2.4
CO	5,812,069	55,724,103	9.6
MT	1,104,271	4,267,213	3.9
NV	3,123,991	13,065,752	4.2
UT	3,337,975	32,178,328	9.6

AllTrails. Similar to Mountain Project, the AllTrails site has a webpage for each state in the U.S. These pages report the total number of trail reviews for the entire state, which may act as a proxy for overall participation. The number of total reviews is likely influenced by the total state population, so we used the same method outlined above to calculate the number of reviews per 10,000 individuals in each state.

Table 2. AllTrails reviews per 10,000 individuals for each target state

State	Population	Total Trail Reviews	Reviews per 10,000 Individuals
AZ	7,276,316	612,938	842
CO	5,812,069	889,210	1,530
MT	1,104,271	93,355	845
NV	3,123,991	128,823	410
UT	3,337,975	491,785	1,473

Trailforks. The Trailforks website has records of trail sport "ride logs" for each state in the U.S. These ride logs are essentially personal records of sport participation based on location. Given that these data points are clearly influenced by the number of participants in a state, we followed the same method above by calculating the number of ride logs per 10,000 individuals for each target state.

Table 3. Trailforks mountain bike ride logs per 10,000 individuals

State	Population	Total Trail Reviews	Reviews per 10,000 Individuals
AZ	7,276,316	809,094	1,112
CO	5,812,069	750,597	1,291
MT	1,104,271	160,110	1,450
NV	3,123,991	185,641	590
UT	3,337,975	872,530	2,614

Evaluating Strategic Communication Materials Efficacy

We initially planned to analyze the efficacy of all strategic communication materials, however, subsequent re-scoping by the client determined these efforts to be unnecessary. While this project does not assess the efficacy of the project deliverables, the Recommendations section of this report outlines several methods for POW's consideration.

6. LITERATURE REVIEW

The primary effect of anthropogenic climate change is increased temperatures. The Fourth National Climate Assessment (NCA) reports that global average temperatures have increased by approximately 1.8°F from 1901 to 2016 and that human activities are an unequivocal cause[8].

Increased temperatures affect Earth's systems in several ways:

1. **Increased aridification**. As higher temperatures increase evaporation rates, surface soil moisture decreases. This dries out the land surface[8].
2. **More frequent and severe drought**. Increased aridification means that droughts across most of the U.S., particularly west of the Rockies, are projected to become longer and more intense. This is especially true in the Southwestern U.S (defined as California, Nevada, Arizona, Utah, New Mexico, and Colorado), where precipitation levels are projected to decrease[8].
3. **Decreased precipitation**. In the Southwestern U.S., climate change is projected to decrease springtime precipitation by 20% or more in 2070-2099 compared to 1986-2015[8].
4. **More frequent and severe wildfires**. On average, spring temperatures are rising, and summers are becoming longer and drier, resulting in drier soils and vegetation. These factors have lengthened the wildfire season and resulted in more frequent large wildfires[8].
5. **Decreased air quality.** Climate change is increasing levels of surface ozone pollution, the incidence of dust storms, particulate air pollution (which comes from wildfires and dust storms), and aeroallergens (which can induce allergic reactions)[8].

The direct and combined effects of these changes impact the trail sport and rock climbing communities.

Trail Impacts

Decreased Access - Wildfires

Although wildfire is a natural part of ecosystem dynamics in many places, fire weather conditions (when hot, dry, and windy events occur at once) have become more prevalent in the Western U.S.[1]. Average temperatures are increasing across all seasons, creating hotter and drier summer conditions. As a result, vegetation is drying out sooner, which increases the fuel stock and leads to larger and more frequent wildfires and a longer fire season (i.e., from the day the first wildfire starts to the day the last wildfire is contained)[1,9,10].

In the Western U.S., the area of forest burned is estimated to have doubled from 1984-2015 due to climate change[1]. The shifting climate has also caused fire seasons to start earlier and finish later[11]. In the Western U.S., the average length of the wildfire season increased by 78 days from 1970-1986 to 1987-2003[10]. This has largely resulted from climate factors rather than non-climate factors, such as fire suppression and management activities, and these trends are expected to continue[1].

In western states, the greatest increase in wildfire frequency has been in the Northern Rockies, followed by the Sierra Nevada, southern Cascades, and Coast Ranges of northern California and southern Oregon[10]. Arizona had a record-setting fire season in 2020, with 978,000 acres burned[12], including over 100 miles of the Arizona Trail[13]. Additionally, Utah (329,000 acres), Montana (369,000 acres), and Nevada (259,000 acres) all had significant fire seasons[12].

In 2020, 665,000 acres[14] burned in Colorado and national forest land was closed in five counties[15]; 4 million acres burned in California[12] and all 18 of California's national forests and 34 state parks were closed for multiple days[16]; and over 1.1 million acres burned in Oregon, including 900 acres of state park land[17]. Moreover, recreational closures from wildfires are only projected to increase as the effects of climate change intensify[18].

Increases in wildfire frequency and intensity will also spread fire-fighting efforts increasingly thin, diminishing the ability to effectively contain fires[19]. For trail sport enthusiasts and rock climbers, this means that many of their favorite areas to recreate are more likely to close. One study found that wildfires negatively impacted visitation to four of Utah's national parks: Arches, Bryce Canyon, and Capitol Reef National Parks all experienced decreases in visitation during and after wildfires, while Zion National Park experienced reduced visitation when wildfires were active[20].

In addition to direct decreased access due to wildfires, wildfire smoke will indirectly decrease access to recreational opportunities. According to the NCA, the increases in wildfire smoke events caused by climate change are projected to reduce both the time and quality of time spent participating in outdoor recreation[1], largely because the wildfire smoke events are projected to impair outdoor recreation and visibility[1]. Air quality impacts are explored further in Threats to Health.

Decreased Access – Erosion

Climate change is expected to increase occurrences of both heavy precipitation and drought conditions, which increases rainfall erosivity (the potential for soil erosion)[1]. There is a well-established positive relationship between precipitation intensity and rates of trail degradation[21]. As erosion increases, trail sports enthusiasts experience higher rates of trail closures. One example is the seven-year-long closure of the Young Gulch Trail in Poudre Canyon, Colorado, which was demolished by post-fire flooding[22]. Another was the largest local erosion event in 1,000 years in Valles Caldera National Preserve in New Mexico due to the 2011 Las Conchas Fire[23].

In combination with changing participation, wildfires in the Western U.S. destabilize trails by burning away vegetation that anchors the soil, which can cause trees to topple and block trail access[24]. The remaining soil becomes hydrophobic, which, combined with post-fire rain events, can trigger debris flow, mudslides, and landslides—all of which can impact trail accessibility or even trap trail users in the outdoors[25,26]. Both the intensity and risk of debris flow are expected to grow as fire frequencies and the length of fire season increase in the Western U.S.[27]. Debris can also accumulate downstream, altering water flow and leading to creek bed erosion. These temporary blockages can burst, sending water and debris downstream in surge events that may prove dangerous to individuals recreating at or near the water line[28].

Projected increases in trail usage will also contribute to trail degradation. For example, the USDA predicts that the total number of adults in the U.S. who participate in hiking will increase from 78.3 million in 2008 to 102.2 million by 2030[29]. Along with decreased overall access due to the impacts described above, this increase in hikers will significantly increase usage rates on trails that remain open.

These projected participation increases will lead to acute impacts on mountain biking trails, which experience loosened track surfaces, soil displacement, linear rut development, and the creation of secondary, user-created trails[30]. This will result in rapid degradation that is already well-documented on some trails[31]. Additionally, crowding and trail closures can also lead to the creation of non-designated “social trails” on non-mountain biking trails, which compacts soil in areas that would otherwise remain untouched.

Soil compaction outside of designated trail systems is problematic since it limits the absorption of water by the soil and can lead to sheet runoff during precipitation events, further increasing erosion[32]. Therefore, even trails that are not directly affected by weather-induced erosion or fire-related closures are still likely to experience higher rates of erosion due to increases in usage.

Decreased Access – Temporal Shifts

Average annual temperatures in the U.S. have increased by 1.2°F (0.7°C) in recent decades, and by 1.8°F (1°C) since 1900[8]. Temperatures are expected to increase by 2.5°C (1.4°C) over the next several decades, and increases of 3-12°F (1.6-6.6°C) are expected by 2100, depending on the emissions scenario[8]. These effects will be particularly acute in the Southwestern U.S. (California, Nevada, Utah, Colorado, New Mexico, and Arizona), where already-warm average temperatures are projected to rise by 5.5 to 9.5 degrees Fahrenheit by 2100[33]. Parts of this region could experience 45 more days every year with high temperatures exceeding 90°F[1]. Summer heatwaves are also projected to become hotter and longer[33], limiting outdoor enthusiasts' access to safe weather conditions.

These high temperatures create temporal access issues for many sports. For example, cyclists often opt for early morning or evening rides during periods of warm weather, which is an indicator of recreational preferences for cooler times of day[34]. Additionally, temperatures have even resulted in trail closures in some regions. In 2021, Phoenix approved a pilot program designed to restrict the use of certain trails during extreme heat, which could limit outdoor recreation opportunities for rock climbers and trails sports enthusiasts[35].

In other regions, increased temperatures will do more than limit recreational opportunities. Currently, 12% of the global land area experiences deadly climate conditions, meaning that at certain times people cannot remain outdoors for long periods and survive[36]. By the end of the 21st century, that area is expected to increase to 45-70% of all land[36]. This means that 44-75% of the global human population will be chronically stressed by heat[36].

Decreased Access – Sea Level Rise

As Earth's temperature increases, glaciers and ice sheets will melt, increasing the volume of the ocean. Additionally, the ocean will absorb significant amounts of heat as the atmosphere warms, resulting in the thermal expansion of seawater. These two factors will result in higher sea levels, meaning that coastal communities stand to lose access to lowland trails. Case studies have primarily focused on urban areas such as Philadelphia, which could lose 57% of its off-street trail mileage by 2100 due to sea level rise[37]. Similar effects are also likely to occur in rural areas. Nationally, the east coast of Florida, coastal North Carolina, and coastal Texas can all expect to lose local trails due to sea level rise[38].

Decreased Access – Forest Demise

In addition to wildfires, two other climate impacts will affect U.S. forests and therefore impact the recreational activities within them. The first is severe drought (which can kill vegetation) and the second is insect outbreaks (due to expanded habitat ranges due to shifts in climate). These factors

resulted in the deaths of 300 million trees in Texas in 2011 and 129 million trees in California from 2010-2017[1].

Bark beetles, which are associated with drought conditions and higher temperatures, are a particular problem[39]. In the Western U.S., bark beetles have killed more trees than wildfire over the past 30 years[40]. From 1979 to 2012, warmer winters and drought conditions allowed bark beetle infestations to proliferate, killing 7% of forested areas in the Western U.S.[1]. These downed trees present a danger if they fall near individuals recreating in a forest and can block trails frequented by recreational users.

Threats to Health – Temperature

The primary impact of climate change is higher atmospheric temperatures, which are expected to occur globally and vary by region. Average annual temperatures in the U.S. have increased by 1.8°F (1°C) since 1900 and are expected to increase by 2.5°F (1.4°C) over the next several decades. By 2100, increases of 3-12°F (1.6-6.6°C) are projected to occur, depending on global emissions scenarios[8]. These temperature increases are expected to be more dramatic during the summer months[8]. Therefore, summer sports participants will be recreating in higher and higher temperatures.

Higher temperatures increase the occurrence of both heat-related morbidity and mortality events[41]. Extreme temperatures compromise the body's ability to regulate internal temperature, which increases both the frequency and severity of negative health effects[42]. Therefore, climate change is expected to cause a rise in heat-related illnesses.

Extreme heatwaves have already caused dramatic increases in heat-related deaths. For example, in one two-week span in 2003, approximately 22,000 to 45,000 people died during a heatwave in Europe[43], while extreme heatwaves and hotter average temperatures have resulted in heat-related illness and death in both Arizona and California[1]. The most at-risk populations for these heat effects include children, elderly individuals, those with chronic diseases, and those who are not properly hydrated[1].

Unsurprisingly, heat-related illnesses directly impair athletic performance. In a comprehensive assessment, the International Olympic Committee determined that physical performance across a diverse and wide range of sports can be severely impaired by higher temperatures[44]. Exercising in hot environments presents severe challenges to cardiovascular, thermoregulatory, metabolic, neural, and cognitive function[44].

In endurance sports and high-intensity sports, warm temperatures can result in heat exhaustion and life-threatening heatstroke[44]. A recent example was the 2016 U.S. Olympic Marathon Trials, which featured only elite distance runners. In that race, unseasonably warm temperatures caused 25% of

female and 36% of male competitors to drop out[45]. Additionally, the 2020 Tokyo Olympics saw record-high temperatures, making it difficult for Olympic athletes to perform at an elite level[46].

Threats to Health – Air Quality

According to the NCA, in the American Southwest, "the environmental conditions of greatest concern for human health [after extreme heat] are ground-level ozone air pollution, dust storms, particulate air pollution (including that from wildfires and dust storms) [and] aeroallergens (airborne substances that trigger allergic reactions)[1]."

Wildfire smoke can contain carbon monoxide (CO), nitrogen dioxide, ozone, particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs) that can then be inhaled by humans[47]. According to the NCA, "more frequent and severe wildfires due to climate change would further diminish air quality, increase incidences of respiratory illness from exposure to wildfire smoke, impair visibility, and disrupt outdoor recreational activities[1]." This effect is likely to be experienced by outdoor enthusiasts in the Western U.S. where wildfires are more common.

From 2016 to 2020, people in the Western U.S. experienced roughly six to ten weeks of wildfire smoke exposure[48]. Smoke from Western wildfires has been experienced as far east as New Hampshire, making it a national issue. Breathing wildfire smoke and its associated particulates is correlated with increased mortality and respiratory issues such as asthma, chronic obstructive pulmonary disease (COPD), chronic bronchitis, and pneumonia[49,50]. Particulate matter (PM 2.5) from wildfires may even be more toxic than inhaling equivalent PM from other sources, such as ambient pollution, due to differences in the chemical composition of the particulates[51]. The short-term effects of prolonged exposure to particulate matter from wildfire include shortness of breath, variability of heart rate, lung function decline, sore throat, cough, itchy and watery eyes, and congestion[52].

Climate-related health impacts are not limited to smoke alone. Wildfires contribute to the formation of ozone[1]. Additionally, drier and warmer fall conditions increase ground levels of ozone in many states, which can worsen respiratory issues and compromise lung function[53]. According to the NCA, ground-level ozone is produced by the combustion of certain chemicals, and its production increases with increased energy input via UV radiation[1]. Exposure to ozone can result in hospital visits, shortness of breath, and aggravated asthma and respiratory allergies. Unless there is a decrease in ozone precursor emissions, ozone levels are expected to increase over most of the U.S.[1].

Dust also represents an increasing threat to air quality in the U.S. As a result of climate change, soils are drying out faster in the Western plains and desert regions of the U.S., increasing dust levels[54]. As a result of increased dust inhalation, hospitalizations due to cardiovascular and respiratory illness

and premature mortality are all expected to increase[55]. This trend is already being observed, and research suggests that total non-accidental mortality attributed to dust exposure increased by 7.4% between 1993 and 2005[56]. These dust storms can result in respiratory and cardiovascular diseases, particularly in the American Southwest[1].

Additionally, increased temperatures due to climate change and increased CO_2 concentrations due to fossil fuel extraction and combustion induce respiratory reactions by lengthening the pollen season and increasing the amount of pollen plants produce. This increases the intensity and frequency of allergic reactions to pollen[1]. These conditions can produce new cases of asthma as well as exacerbate existing conditions[1].

Regardless of geographic location, outdoor recreation is threatened by increasingly poor air quality, and health professionals and IPCC scientists agree that risks related to air quality increase as levels of physical exertion increase[57]. Exercising outdoors is discouraged once the air quality index (AQI) exceeds 150, even for those without underlying conditions[52].

Threats to Health – Mental Health

Outdoor enthusiasts are fond of the benefits that outdoor recreation has on mental health, and academic studies have documented this phenomenon. For example, exercise typically decreases anxiety[58], while time spent in forests and natural settings is positively correlated with stress reduction, improved mood, and enhanced cognitive function[59]. Outdoor enthusiasts actively seek these benefits. For example, hikers often opt to recreate on trails with more primary vegetation[60].

Decreases in recreational access due to poor air quality, wildfire risk, or increased temperatures can reduce these mental health benefits. One study found increased rates of depression in those who did not exercise during the COVID-19 lockdown compared to those who did[58]. And as contact with nature decreases, so too does a sense of connectedness with nature and its associated benefits to well-being[61]. Thus, access to outdoor experiences and recreation are closely tied to improved mental health.

Threats to Health – Vector-Borne Diseases

Climate change will increase the rates of vector-borne disease transmission through insects and pests[1]. Warmer temperatures have allowed many tick species to increase their habitat range and relative abundance within those ranges[62,63]. As a result, tick-borne diseases are expected to rise in humans, livestock, and companion animals. For climbers and trail sports enthusiasts, who are often moving through grasses and brush, this will result in increased rates of exposure to ticks and tick-borne diseases such as Lyme disease.

Unlike ticks, it remains unclear how climate change will affect, although this is largely due to the uncertainty of current climate models[64]. However, numerous authors agree that the habitat range of mosquitos will change, which could introduce new diseases to vulnerable populations with limited prior exposure and resistance[64]. This can increase rates of vector-borne diseases and compromise otherwise enjoyable outdoor experiences.

Diminished Experience – Aesthetic Value

Since the Endangered Species Act was signed into law in 1973, the "aesthetic" and "recreational" value of vulnerable species and places have been recognized by American law[65]. From classics like Thoreau's *Walden* to modern works like Richard Power's *The Overstory*, these themes are widely echoed in American literature, with countless examples of inspiration drawn from experiences within thriving natural settings; be they "wild," tightly managed, or undisturbed. Healthy ecosystems and the landscapes that they shape can have a profoundly positive impact on the perceived experience of those who visit them[59].

Climate change threatens species and landscapes in several ways that affect the visitor experience. For example, wildfires damage the aesthetic quality of recreational sites and vistas[66], and post-fire soil erosion can negatively affect recreational opportunities for decades[22]. Significantly, the NCA recognizes that air quality affects "aesthetic considerations (such as visibility) that affect appreciation of the natural beauty of national parks and other outdoor spaces[1]."

Studies assessing recreation demand have found that demand decreases in areas that have been burned by wildfire, as prescribed burns in New Mexico resulted in decreased recreational demand by both hikers and bikers[67]. Another study found that fire and smoke affected 400,000 and 1 million visitor-days per year, respectively[68].

Climate change will also increase drought stress, which is projected to decrease forest biomass for all but the most drought-resistant trees[69]. This trend, along with an earlier spring, means that the plants of many regions will experience population declines due to climate change[70]. Coupled with the previously discussed increases in wildfires and forest losses due to bark beetles, the overall experience sought by outdoor enthusiasts is likely partially, if not completely compromised in many locations[66].

However, this trend is not a surprise to conservation planners: a 2020 U.S. Forest Service report predicted that nearly all recreation in California's Sierra Nevada range will be negatively impacted by climate change due to projected increases in extreme weather[71].

While experience is closely tied to mental and physical health, it can extend beyond those impact categories. For many groups, emotional bonds form with particular landscapes or places, and their

use becomes associated with the user's sense of identity[72]. When that landscape or place changes, it renders a blow to their sense of self. Additionally, the aesthetic value of a place may also be tied to individuals' spiritual well-being[73]. Therefore, it is unsurprising that outdoor enthusiasts exhibit preferences for pristine landscapes, and as wildfires and droughts degrade those landscapes, outdoor enthusiasts' experiences decrease.

Diminished Experience – Crowding

Along with the negative aesthetic effects, projected increases in outdoor visitation due to increasing population and increasing demand[71,73] are likely to decrease the enjoyment that outdoor enthusiasts experience. Recreation demand modeling suggests that anticipated crowding decreases a user's valuation of a site: in other words, individuals have a lower desire to visit sites that they anticipate will be crowded with other people[74]. Other stated preference studies found similar results, as respondents indicated their marginal welfare—a value akin to personal enjoyment—decreased as congestion increased[75].

Further highlighting the crowding problem is the backlog of federal trail repairs in the U.S. The U.S. Forest Service manages approximately 159,000 miles of trails, but roughly 120,000 of those miles require maintenance or repair[76]. The backlog on forest roads and bridges alone is estimated to cost $3.4 billion, and it has been increasing over time. Without interventions, outdoor enthusiasts will have increasingly limited access to trails, which is likely to further increase crowding issues on trails that remain accessible[76].

Economic Impacts – National Level

Loomis has highlighted the difference between the "Old West" economy, which encompasses natural resource extraction and ranching, and the "New West" economy, which encompasses recreation, retail, tourism, and environmental protections[77]. The "New West" economy is driven by the recreation demands of the group that POW calls the Outdoor State: those who use the landscapes of the West for outdoor recreation, including hiking, trail running, and mountain biking. These communities often feel an intense "sense of place" and psychological connection to the natural resources used for recreation[77]. As a result of this connection, strong financial ties can form between these communities and outdoor recreation.

The U.S. Bureau of Economic Analysis (BEA) provides comprehensive annual reports on various industries, including the outdoor recreation economy. The BEA produces an outdoor recreation report that measures the production of outdoor goods and services and their contribution to U.S. gross domestic product (GDP)[78]. According to the most recently published report (2019), the outdoor recreation economy accounted for 2.1% ($459.8 billion) of U.S. GDP[78]. The outdoor recreation industry also has an economic impact beyond GDP: over five million outdoor recreation-dependent jobs were reported in 2019[78].

The BEA's report divides outdoor recreation into three categories: conventional activities, including bicycling, boating, hiking, climbing, and hunting; other core activities, such as gardening and outdoor concerts; and supporting activities, such as construction, travel and tourism, local trips, and government expenditures. The analysis found that conventional activities account for 30% of all value added from outdoor recreation while supporting activities account for 51% of the total value added from outdoor recreation[78].

Different value estimates emerge for differing sport categories. Some estimates only account for direct value added, while others include value estimates for supporting activities. BEA estimates of the real outdoor recreation value added fall into the former category and include only the direct value added. In 2020, the real value added by bicycling was $2.11 billion and the real value added by climbing/hiking/tent camping is $3.69 billion[79]. This indicates that outdoor recreation and its associated costs, including gear sales, travel to and from the recreation destination, and incidental expenses, such as food and gas, contribute a considerable amount to the U.S. economy.

The U.S. Forest Service has also assessed the value of outdoor recreation, and a 2020 report found that visitors spent approximately $10 billion in the areas near national forests and grasslands in FY2019. This ultimately contributed $12 billion to the national GDP and supported approximately 154,000 jobs[80].

Given these statistics, the value of outdoor recreation is clear. However, the continued productivity is less certain. A 2019 report by the International Labour Organization suggests that heat stress will be responsible for a total financial loss of approximately $2,400 billion by 2030[81]. Heat stress primarily affects those who work outside, including those employed in the tourism and sports industries. The report found that by 2030, 2.2% of the total global hours worked could be lost due to high temperatures, which could produce a loss in productivity equivalent to 80 million full-time jobs[81]. While the exact proportion of the total loss made up by outdoor recreation is unclear, the industry is undeniably at risk in many regions.

Economic Impacts – State Level

According to the BEA, in 2019, the states with the highest total outdoor recreation value added were: California ($57.4 billion), Florida ($49.1 billion), New York ($29.2 billion), Texas ($35.1 billion), and Illinois ($15.6 billion)[78]. The top states with the highest outdoor recreation value added as a percent of state GDP were Hawaii (5.8%), Vermont (5.2%), Montana (4.7%), Florida (4.4%), and Wyoming and Maine (4.2% each)[78]. Although these states enjoyed the largest economic benefits from outdoor recreation, every state in the U.S. profits from conventional and supporting activities related to the outdoor recreation industry.

Economic Impacts – Gear Sales

Equipment and gear sales make up a significant portion of economic activity in the outdoor recreation industry. Bicycle sales in the U.S. totaled $1.4 billion in 2017; the top-selling category—outperforming even road bikes—was mountain bikes, which accounted for $577.5 million of total sales[82]. Hiking gear sales, including clothes, footwear, backpacks, and other equipment, totaled approximately $2.8 billion in North America in 2019[83]. The global market for trail running shoes was valued at $5.97 billion in 2018 and is expected to continue growing at an annual rate of 5.9% from 2019 to 2025[84]. Additionally, almost ⅔ of consumers prefer to purchase trail running shoes in retail stores to better understand the performance of the shoe they are buying, suggesting that the economic benefits of sales are dispersed across the nation[84].

Economic Impacts – Case Studies

Lost Economic Value in Utah due to Wildfire

One study found that Utah's five National Parks experienced a significant decline in annual visitation due to wildfires, with a loss of approximately 11,125 to 30,851 annual visitors. Direct losses in visitor spending were estimated to be between $780,000 and $2.34 million annually, and the regional economic impact of wildfires was estimated to be between $1.22 million and $3.65 million[20].

Regional Case Studies for Mountain Biking

In 2018, Outdoor Alliance, a trade association that "unites the voices of outdoor enthusiasts to conserve public lands and ensure those lands are managed in a way that embraces the human-powered experience," commissioned studies assessing the economic impacts of mountain biking in several regions across the United States[85]. In Grand Mesa, Uncompahgre, and Gunnison National Forests (Colorado), it is estimated that mountain bikers visiting the region spend $24 million annually[86]; in the Custer Gallatin National Forest (Montana), $9.1 million annually[87]; and in the Nantahala and Pisgah National Forests (North Carolina), $30.2 million annually[88].

These studies also point out that undercounting outdoor recreation is easy to do given that outdoor recreation users are often less visible or in remote areas[87]. Another study found that mountain bikers spend an average of $2.3 million to $4.9 million in Oakridge, Oregon annually[89]. Meanwhile, total expenditures associated with mountain biking in the state of Oregon, as a whole, in 2012 totaled $27.9 million[89].

Regional Case Studies for Hiking and Trail Running

Another 2018 Outdoor Alliance study found that non-local day hikers, backpackers, trail runners, and "peak baggers" in Grand Mesa, Uncompahgre, and Gunnison National Forests (Colorado) also generated approximately $24 million annually within the national forests and surrounding communities[90]. A separate report assessing Mesa County's (Colorado) Bureau of Land Management trails, specifically the Kokopelli, 18 Road, and Lunch Loops trail system, found that their usage

contributed approximately $14.5 million to Gross Regional Product, a regional valuation calculated in the same manner as Gross Domestic Product[91].

Climb Impacts

The sport of rock climbing has grown at an increasing rate in recent years, adding an estimated 1.2 million new participants in the United States between 2007 and 2016. While exact numbers vary, different reports have estimated that between 7.7 million and 21 million individuals rock climb in the U.S. each year[92,93]. According to the American Alpine Club's 2019 "State of Climbing" report, over 400,000 new individuals began climbing between 2014-2019 alone, and the majority (65%) of rock climbers are millennials or slightly younger (ages 18–35)[94]. Despite recent increases in indoor gym climbing popularity, many participants still prefer climbing outside and are therefore constrained by outdoor conditions and access limitations[92].

Nearly every outdoor climbing venue requires trail use, meaning that all climate impacts outlined for the trail sports community (decreased access, threats to health and well-being, and lessened experience) will also impact the rock climbing community. However, some impacts are unique to rock climbers.

Decreased Access – Temperature

Rock climbing is made possible by contact security, which measures a climber's ability to safely and efficiently move from one series of holds to the next and is contingent upon a climber's ability to establish secure contact where the hands and feet meet the rock[95]. It is difficult to establish contact security when friction is reduced or rock integrity is damaged.

As temperatures rise, the coefficient of friction, also known as slip resistance, declines on holds through increased perspiration of the hands and rubber deformation on shoe soles[96,97]. In a sport where performance is often reliant on thin margins, a reduced coefficient of friction is likely to be more than just an inconvenience and can result in a loss of access for certain routes[95]. Beyond personal preference, climate-induced heat events are likely to prevent climbing altogether when temperatures rise above participants' physical tolerance thresholds.

In areas where daytime temperatures already prohibit climbing activities, climbers typically adopt one of two adaptive approaches: they will either (i) shift their activity timeline away from peak temperatures, or (ii) shift their activities to a more temperate location. Intentionally climbing outside of daylight hours is a long-practiced approach to avoid peak sun exposure and is observed by amateurs and elite professionals alike (e.g. Tommy Caldwell and Kevin Jorgeson's successful ascent of the Dawn Wall). However, neither approach is desirable, and most climbers would prefer to climb in moderate temperatures.

Rock climbing in the U.S. is a largely itinerant activity, with seasons dictating access to different locations at different points in the year. As summertime temperatures rise, climbers tend to

abandon hotter venues in favor of cooler ones. The cooling effect of elevation upon air temperature results in summertime migrations to venues at higher altitudes. High-altitude regions such as California's High Sierra, Nevada's Spring Mountains, Wyoming's Wind River Range, and Colorado's Rocky Mountain National Park all experience summertime influxes of climbers searching for pristine settings and cooler temperatures.

As rock climbing becomes more popular and temperatures rise, climbers will increasingly converge upon these select and often fragile natural climbing locations. This convergence represents a growing challenge for land managers, as additional use and access restrictions can be expected in regions with increased visitation rates. Temporal shifts—driven by increasing lowland temperatures—could result in an expansion or realignment of summer destinations, which are often limited by available permits.

Decreased Access – Wildfire

Rock climbing locations across the country are at risk from wildfires, with much of America's rock-climbing activity taking place in the semi-arid, forested mountain regions of the Western U.S.[98] These regions are prone to wildfire activity and have experienced record wildfires in recent years, leading to higher incidences of land closures[19]. Wildfires can also permanently degrade the integrity of the rock and thus its suitability for climbing.

Forest fire is by far the most significant element in rock weathering[99]. When intense fires burn close to rock formations, the outer portion of the rock expands quickly, overcoming the tensile strength of the matrix within and leaving a fractured, "scaly" outer layer that is prone to exfoliation[98,99]. In this state, the rock integrity is severely compromised and offers little to no value to climbers. Additionally, the load-bearing capacity of fixed hardware (i.e., bolts) may become compromised if located in fire-impacted rock, rendering such hardware potentially hazardous for future use. All rock types exposed to extreme wildfire conditions have exhibited extensive and permanent damage[99]. While land closures are a temporary inconvenience to climbers, an increase in the frequency and intensity of wildfires could permanently damage the very rock needed for climbing.

Decreased Experience – Aesthetic Value

In addition to the aesthetic value of the rock face and the vistas revealed upon summiting, rock climbers also enjoy the often-unique flora and fauna present within mountain and cliff area ecosystems. Like much of the alpine environment, these ecosystems tend to be fragile, and can be negatively impacted by increased climbing activity[100,101]. For example, increases in climbing in certain locations have been observed to influence bird behavior and interfere with breeding, predator detection, foraging, and nesting[94]. Along with the impacts of concentrated recreation, climate change is expected to shift the territory and migration patterns of certain species, resulting in altered user group experiences and the potential for additional closures to protect various

species[1]. As area closures and increased participation concentrate climbers within specific regions, they may cause unintentional harm to cherished flora and fauna, diminishing the experience of future rock climbers.

Economic Impacts – Gear Sales

Equipment and gear sales make up a significant portion of the economic value that climbing adds to the outdoor recreation industry. Climbers spent approximately $169 million on gear in 2018[94]. Climbing shoes make up the largest portion of gear sales (25%), with 396,554 units reported sold in 2018[94]. While this spending increase was driven by unit price increases rather than the number of units sold, it still indicates economic growth in the climbing industry through increased willingness to pay. Additionally, climbers spend over $1,200 more than the average outdoor participant on gear and apparel, making this group a significant driver in outdoor recreation's economic impact[94].

Economic Impacts – Indoor Rock Climbing

While this report focuses on outdoor rock climbing, many climbers also spend a portion of their time training at indoor climbing facilities. Expenses associated with indoor climbing significantly contribute to rock climbing's total economic impact. According to the American Alpine Club's 2019 "State of Climbing" report, an estimated 43.4 million check-ins occurred at indoor climbing gym facilities in 2017. Total revenue for the U.S. climbing gym industry in 2017 was estimated at $618 million and was expected to increase to $1 billion by 2021[94]. Despite economic downturns associated with the 2020-2021 fiscal year, gym climbing represents a significant element of rock climbing's total economic contribution.

Economic Impacts – Case Studies

Rock Climbing on Public Lands

Nearly 60% of rock climbing areas are located on public lands, and the regulation of rock climbing activities has become a land management issue. For example, certain kinds of rock climbing require the climber to place fixed anchors into the rock. In 1998, the U.S. Forest Service, the Bureau of Land Management, and the National Park Service considered banning anchors in wilderness areas, but ultimately abandoned the policy after a 2002 study found that losses in economic value could total up to $100 million annually[93].

Regional Case Studies for Rock Climbing

In 2019, Access Fund, a rock climbing advocacy group, worked with scholars from Eastern Kentucky University to publish an economic impact analysis of rock climbing in the New River Gorge region of West Virginia. The report found that non-local climbers visiting the region spent approximately $12.1 million in the local economy[102]. These climbers also supported an estimated 168 local jobs and $6.3 million in wages in the region[102].

Another study assessing North Carolina's Nantahala and Pisgah National Forests found that rock climbing tourism brought an estimated 200,000 climber visits each year (60% of which were residents of western North Carolina) to the region, contributing 170 full-time jobs and $4 million in income[103]. A third study, which analyzed rock climbing tourism in developed countries, found that this industry "has gradually become an important economic driving force to promote the development of rural and mountainous areas[104]." These studies highlight that the rapidly growing sport of rock climbing is a highly valuable source of economic activity in regional economies within the U.S.

Environmental Equity Impacts

The NCA states that "climate change creates new risks and exacerbates existing vulnerabilities in communities across the United States, presenting growing challenges to human health and safety, quality of life, and the rate of economic growth[1]." While this should be a consideration regardless of its relevance to the rock climbing and trail sports communities, it is helpful to keep in mind that rural communities, which often serve as the gateway to remote outdoor recreation destinations, are particularly vulnerable to the effects of climate change[1].

Disadvantaged communities suffer disproportionately from climate change impacts[105]. For example, heat-related deaths due to climate change are projected to increase disproportionately among economically disadvantaged people and communities of color[106]. Whether it is increased heat-stress in lower socioeconomic and racially diverse communities[107] or more devastating impacts from severe storms[108], these disadvantages are often the result of societal inequalities, including differences in residence, race/ethnicity, income, and political power. These inequalities are exacerbated in an inequality cycle for three reasons: first, inequality increases disadvantaged individuals' exposure to climate change impacts; second, greater exposure increases disadvantaged individuals' susceptibility to these impacts; and third, inequality lowers disadvantaged individuals' ability to deal with and recover from the consequences of climate change[105].

The outdoor recreation implications of this inequality cycle revolve around the growing-yet-underrepresented group of vulnerable and socially marginalized individuals that participate in outdoor recreation. Their disproportionate exposure to economic inequities, extreme heat, and air quality hazards, along with their compromised ability to deal with and recover from these impacts, will create additional barriers for their participation in outdoor recreation that non-marginalized groups do not experience in the same way.

Several studies project climate-induced reductions in air quality and highlight the relationship between low socioeconomic status and low education levels, and a positive correlation with increased prevalence and incidence of asthma, chronic bronchitis, and chronic obstructive pulmonary disease (COPD)[109,110]. For communities already bearing the brunt of domestic air pollution impacts, climate change will only exacerbate these conditions and increase existing barriers to participation.

However, access to outdoor recreation, including trails and green spaces, has been shown to improve the health and quality of life for groups who have historically been marginalized[111]. Therefore, access to outdoor recreation can confer outsized benefits on marginalized communities.

Participation in Trail Sports and Rock Climbing

Participation Demographics

In 2019, trail sports and rock climbing participants made up approximately 26% (80,020,000) and 1.5% (4,583,000) of the total 2019 U.S. population (302,756,603)[92]. The following is the estimated sport-specific breakdown from 2019[92]:

- Climbing
  - Sport/Boulder Climbers: 0.7% (2,183,000)
  - Traditional/Ice/Mountaineering Climbers: 0.8% (2,400,000)*

- Trail
  - Backpackers: 3.5% (10,660,000)
  - Mountain Bikers: 2.8% (8,666,000)
  - Trail Runners: 3.6% (19,997,000)
  - Hikers: 16.4% (49,697,000)

*Although the 2019 data combined these three subgroups, our project will only target traditional climbers, which represent a portion of this estimate.

Outdoor recreation participants are slightly skewed toward males in their mid-30s with some college education and above-average household income[92]. This trend was further illustrated by a survey of national forest and wilderness land that found only 38% and 42% of visitation was by females even though 50.8% of the U.S. population is female (this survey was gender-binary and only allowed respondents to identify as male or female)[80].

However, outdoor recreation activities, such as rock climbing and trail sports, have the potential to appeal to and welcome Americans of all demographics—regardless of socioeconomic background, geography, or physical ability. In fact, bicycling, hiking, and camping (three trail sports of interest for this project) were among the outdoor activities of greatest interest to non-participants of all income and age levels in 2019[92]. Moreover, trail running, hiking, backpacking, and mountain biking have some of the highest participation rates of outdoor activities across the United States[92].

Engaging Underrepresented Communities

The U.S. public lands system, where a significant portion of climb and trail sports activities take place, has historically been a source of racial discrimination[112–114]. In addition, socioeconomic barriers have often precluded disadvantaged communities from participating in outdoor recreation[115,116]. However, BIPOC (Black, Indigenous, and people of color) communities have still

found ways to enjoy and contribute to outdoor recreation[117,118]. Unfortunately, Black Americans and Hispanic Americans are consistently underrepresented in terms of traditional outdoor recreation participation.

While Black Americans currently represent approximately 12.4% of the U.S. population, they only account for 9.4% of outdoor participants, making for a 24% participation deficit[92]. Hispanic Americans represent approximately 17.9% of the population but only 11.6% of outdoor participants, a 35% participation deficit[92]. Nevertheless, outdoor recreation participation rates in these underrepresented groups are growing despite disproportionate socioeconomic barriers to participation.

Hispanic American participation increased by 7.8% from 2018 to 2019, raising the average annual growth rate to 6.7% for the past three years. Black Americans are experiencing a similar trend, with an average annual growth rate of 6.2% over the past three years[92]. In comparison, participation decreased by 3.1% in White participants from 2018 to 2019. While White participants currently make up a disproportionately high proportion of total outdoor participants in the U.S. (72%), that number is down from 80% of all participants a decade ago[92].

The U.S. is becoming more ethnically and racially diverse and is expected to become a "majority-minority" nation by 2045, meaning non-Hispanic White will no longer be the majority demographic[119]. Moreover, underrepresented racial and ethnic groups are believed to be equally inclined, if not more so, to engage in pro-environmental behavior and are more concerned with environmental issues and actions than White Americans, especially after positive outdoor recreation experiences[120–122]. The increase in diverse participation in outdoor recreation suggests that BIPOC communities are a discrete audience segment within the Outdoor State[80] for which there is high potential for engagement on climate issues. This presents an opportunity for advocacy organizations to engage a broader audience of outdoor enthusiasts in climate advocacy—one that is more representative of U.S. demographics.

7. RESULTS & DISCUSSION

Literature Review

Climate Impact Assumptions

One of the challenges of this report was identifying impacts that are directly related to climate change and our sport categories. This required us to critically assess the difference between natural variability[8] with demonstrated climate impacts.

In our initial research efforts, we found few primary studies directly assessing the impacts of climate change on the trail sports and rock climbing communities. Therefore, the project shifted to evaluating the current and projected impacts of climate change on factors relevant to those communities, including access to the resources needed to recreate and conditions under which recreation occurs (e.g., temperature, AQI). We then sought to determine how these factors impact the rock climbing and trail sport communities.

Most of the climate impacts we identified have a logical pathway through which they can negatively impact rock climbing and trail sports: loss of access to recreational areas, the health risks posed by reduced air quality, the spread of vector-borne diseases, and reduced mental wellness are all likely to negatively impact recreational communities and experiences. However, some of these climate impacts are more nuanced and require certain assumptions to classify the impact as negative.

Assumption 1: Changing conditions will create negative impacts

We assumed that a change in the relevant recreational factors will negatively impact sports participants, however, the degree of these impacts varies by region. For example, a 1.5°C temperature increase in Arizona (a state where heat already limits activity through documented area closures) is likely to have a stronger negative impact on participants than a 1.5°C temperature increase in Montana (a state currently less prone to excessive heat days).

Despite this regional variability, the net impact of temperature increases is assumed to negatively impact athletes across the U.S. due to the well-documented relationship between increased temperatures and heat-related illness. General experience impacts are similarly complex due to the role of individual preferences and tolerance levels but are considered to negatively impact recreational opportunities at the national level.

Assumption 2: Current economic value is at risk

A second assumption was used to identify the economic impacts of climate change on the rock climbing and trail sports communities. Due to a lack of primary studies assessing future economic impacts of climate change, the vast majority of the information we found consisted of current and historical evaluations of the economic productivity of these sport communities. While we were unable to project the economic losses that could occur due to climate change, the information provided emphasizes the potential magnitude of the economic losses that could occur should these sport communities be negatively impacted by climate change.

Assumption 3: Climate impacts will be novel for new participants

A third assumption was used to identify the impacts of climate change on environmental equity. The literature we reviewed identified several existing inequities relating to climate impacts and focused on larger consequences experienced by marginalized communities that are directly relevant to outdoor recreation. For example, AQI deterioration will impact marginalized communities, who already experience higher rates of multiple chronic and severe respiratory illnesses, including asthma, chronic bronchitis, and chronic obstructive pulmonary disease (COPD).

Additionally, these marginalized communities are expected to participate in rock climbing and trail sports at higher rates. Therefore, we assume that members of marginalized communities will experience two-fold negative climate impacts: as members of marginalized communities and as members of the rock climbing and trail sports communities.

Categorical Structure

We categorized the results of our literature into five overarching impact categories for the trail sports and rock climbing communities. They are:

1. Decreased access to recreation opportunities
2. Threatened health and well-being while recreating
3. Diminished recreation experience
4. Economic losses
5. Exacerbated environmental inequities

These impacts were detailed in two separate sections: one for trail sports and one for rock climbing. Given that most rock climbers must use a trail system to access their climbing resources, all climate impacts on access, health, and experience for the trail sports community were also considered relevant impacts on the rock climbing community. Additionally, information on exacerbated inequities was generalized to broader outdoor recreation and a specific sport and was thus included in a separate section.

Trail Impacts – Decreased Access

Five primary climate impacts are likely to decrease the ability of the trail sports community to access recreational locations. These climate impacts primarily affect the resources these communities rely upon to recreate.

Wildfires. As annual temperatures increase and precipitation levels decrease, wildfires will become more frequent and severe. Rock climbers and trail sports participants frequently recreate in forested locations susceptible to wildfires. More frequent wildfires will decrease their ability to access these recreational locations, both because it is dangerous and irresponsible to recreate when active wildfires are nearby and because wildfires destroy the resources these participants rely upon, such as crags and trails.

Erosion. Damage from wildfires and increased storm frequency and intensity can greatly increase erosion rates, resulting in trail closures. In addition, wildfires destabilize trails by burning away the vegetation that anchors soil, and severe storms can lead to runoff that further degrades these trails. These impacts compromise trail quality, but worst-case scenarios include large debris flow events that can lead to extended trail closures.

Temporal shifts. Physical impediments are not the only access issues for outdoor enthusiasts. One of the most obvious climate impacts is increased temperatures. Many participants typically refrain from recreating in the midday heat, and increased temperature extremes will lengthen the daily window in which it is too hot to recreate. This change will force participants to choose between shifting the temporal window of their recreation or simply recreating in hotter temperatures (see Threats to Health below).

Sea level rise. Sea level rise will significantly impact coastal recreation. The ocean encroaching on land will cause many coastal communities to lose access to lowland trails.

Forest demise. Warmer temperatures lead to worsened drought conditions and the spread of certain insect species, such as bark beetles. As a result of these two factors, many forests are experiencing rapid die-offs, leading to tree limbs or trunks falling across trails. While potentially only a mild irritation, fallen trees can also completely block trails or create unsafe conditions that prevent access.

Trail Impacts – Threats to Health

Four primary climate impacts pose significant threats to the health and well-being of the trail sports community. These climate impacts primarily affect the conditions under which trail enthusiasts recreate.

Temperature. Climate change will increase external temperatures, compromising the body's ability to regulate internal temperature. This will increase the frequency and severity of heat-related illnesses since increased heat taxes cardiovascular, thermoregulatory, metabolic, neural, and cognitive functions. Participants recreating in hotter temperatures are subject to increased risk of heat exhaustion and heatstroke.

Air quality. Climate change will negatively affect air quality due to increased levels of wildfire smoke (climate change will increase the frequency and severity of wildfires), increased dust (droughts result in dry conditions where dust particulates are swept into the air), and higher surface-level ozone concentrations.

Wildfire smoke can contain carbon monoxide, nitrogen dioxide, ozone, particulate matter, polycyclic aromatic hydrocarbons, and volatile organic compounds. The short-term effects of wildfire smoke exposure include shortness of breath, heart rate variability, lung function decline, sore through, cough, itchy and watery eyes, and congestion, while the long-term effects of wildfire smoke exposure are increased mortality and increased prevalence and incidence of respiratory issues such as asthma, chronic obstructive pulmonary disease (COPD), bronchitis, and pneumonia. Therefore, in a warming world, participants must either forgo recreational opportunities or forge ahead outdoors and risk compromising their health.

Mental health. Members of the rock climbing and trail sports communities rely upon outdoor recreation for their physical and mental health. Exercise is known to decrease anxiety and stress and can improve mood. Climate change will decrease access to the activities that provide these positive mental health benefits, threatening the health and well-being of these communities.

Vector-borne disease. Climate change will have significant ecological impacts, shifting the habitat range of many species—some of which carry illnesses, such as ticks with Lyme disease. The increased range of vector-borne disease carriers threatens recreationists spending time in areas where no threat previously existed.

Trail Impacts – Diminished Experience

Two primary climate impacts will affect how the trail sports community recreates by diminishing overall experience. These climate impacts affect both the conditions and resources under which trail enthusiasts recreate.

Aesthetic Value. Members of the rock climbing and trail sports communities value the athletic pursuits that outdoor recreation provides and the overall experience. This includes forming a special attachment with a place and its overall aesthetic value, which can become associated with a participant's sense of identity. Healthy ecosystems and scenic landscapes positively impact the

perceived experience of those who visit them. Wildfires and other events can destroy these landscapes for years and even decades, robbing rock climbing and trail sport communities of the opportunity to experience these areas.

Crowding. In recent years, participation rates for trail sports (and rock climbing) have steadily increased, while the impacts of wildfires and erosion have decreased available recreation sites. As a result, crowding is expected to increase, which is undesirable for most outdoor enthusiasts and diminishes their perceived enjoyment while recreating.

Trail Impacts – Economic Impacts

We assessed the potential magnitude of the economic impacts of climate change on trail sports at three different levels (national, state, and regional). While the current literature does not robustly project sport-specific economic losses that could occur due to climate change, the total value of trail sports at the three levels gives perspective on the potential scale of such losses.

National level. Outdoor recreation represents a significant portion of U.S. GDP, with trail sports accounting for an undetermined but significant amount. While research on the projected losses in GDP from the impacts of climate change on trail sports has not been conducted, decreases in demand from the sport community will likely negatively impact national GDP.

State level. Outdoor recreation economies vary by state. At the high end, they can account for up to $57.4 billion in value added (California) and as much as 5.8% of state GDP (Hawaii). The projected losses in GDP due to climate change impacts on trail sports specifically have yet to be investigated.

Regional level. The regional level is where the impacts of climate change on trail sports are likely to be most significant. Outdoor recreation gear sales and the expenditures associated with trail sports can generate millions of dollars in regional GDP, the loss of which could severely impact local economies.

Climb Impacts – Decreased Access

In addition to trail users' projected decreases in access, rock climbers face additional reductions in access due to temperature increases and wildfires.

Temperature. Rock climbing is highly dependent on the amount of friction between a rock climber and the rock face. Warmer rock surfaces promote reduced friction at all contact points, reducing contact security and compromising participants' abilities to climb successfully. This impact is so significant that it can result in temporal activity shifts, within a single day (avoidance of peak heat hours) and across seasons, influencing when and where rock climbers choose to recreate.

Wildfire. While wildfires can temporarily prevent access to recreation areas due to the dangerous conditions they create, they can also have a secondary impact on rock climbers: damage and even permanent destruction of rock faces and equipment. Extreme heat caused by wildfires can exfoliate certain rock types and may cause damage to permanently affixed hardware such as bolts, rendering them unsafe for future climbers.

Climb Impacts – Diminished Experience

Aesthetic value. One of the draws of rock climbing is the opportunity to behold the unique but often fragile ecosystems that can overlap with climbing routes in mountain and cliff areas. However, increases in rock climbing activity have been observed to degrade such ecosystems. Combined with recent increases in the sport's popularity, increased area closures are expected to exacerbate crowding issues and will further concentrate these negative ecological impacts, diminishing aesthetic value for participants.

Climb Impacts – Economic Impacts

We also assessed the economic value of rock climbing at the national and regional levels to offer a scale of the potential impact of climate change.

National level. While the total number of rock climbers in the U.S. is lower than that of trail sports, rock climbers spend over $1,200 more than the average outdoor participant, indicating that rock climbers have a higher individual impact on GDP. Furthermore, the impact of rock climbing on national GDP is at least multiple hundreds of millions of dollars and continues to rise, making it an increasing contributor to GDP.

Regional level. Rock climbing can play a significant role in local economies, particularly rural mountain communities. The loss of access to rock climbing in these locations would equate to millions of dollars in lost GDP, negatively impacting the entire community.

Environmental Equity Impacts

Marginalized communities experience negative climate change impacts at disproportionately high rates. Existing inequalities increase disadvantaged individuals' exposure to climate change impacts, and that exposure increases disadvantaged individuals' susceptibility to these impacts. Additionally, inequality lowers disadvantaged individuals' ability to deal with and recover from the consequences of climate change, thus perpetuating the inequality cycle. Research has already found that marginalized communities experience higher rates of heat-related illness and respiratory disease due to poor air quality.

Participation in Trail Sports and Rock Climbing

Trail sports and rock climbing participants made up approximately 26% and 1.5% of the total 2019 U.S. population, making them a large proportion of U.S. society. Although participation in outdoor recreation is biased towards wealthier White males, outdoor recreation appeals to a much wider audience. There is a participation deficit for many communities of color in outdoor recreation. Both Black Americans and Hispanic Americans have lower participation rates than their proportion of the population. However, participation is increasing in both communities. As climate change creates negative impacts for the rock climbing and trail sport communities, participants from marginalized communities will incur additional climate-related burdens through participation—further exacerbating the inequities they face.

Discussions with Experts

We had 14 conversations with eight athletes, three scientists, two economists, and one policy expert. A complete list of these individuals and the date that the discussion took place is displayed in Table 4. We used these discussions to identify additional climate impacts that we then researched and incorporated into the literature review.

Individuals pointed to specific experiences and impacts that are not reflected in available research or readily accessible data at multiple points. While these impacts may extend to other individuals or the greater outdoor community, this project was not designed to analyze the experiences of these individuals. Therefore, these individual experiences and impacts are not incorporated in the literature review or formal conclusions, though they are worth noting as potential areas for future research.

Competition Cancellations

Multiple athletes commented on experiencing an increased number of competition cancellations; the root cause listed for nearly all of these cancellations was wildfire. For example, Dillon Osleger was supposed to participate in the 2021 Trans Cascadia Mountain Bike race, a blind-format race in the backcountry and small towns of the Pacific Northwest. However, the Twentyfive Mile Fire burned half of the course by Lake Chelan, threatening the safety of the participants and their ability to secure an FKT (fastest known time) or even compete.

Loss of Income

Athlete incomes depend on multiple factors that vary by contract(s). Two important factors in most contracts are competition performance and individual achievements (such as FKTs). Therefore, competition cancellations can lead to a direct loss of income. Similarly, lost training time due to unsafe conditions, such as wildfire smoke, can decrease fitness and performance. Additionally, unsafe or diminished conditions, such as an eroded trail, can impact an athlete's abilities to accomplish unique achievements that also factor into their sponsorships. For example, athletes like

Clare Gallagher may only race two to three times a year. If one to two of those races are canceled, as has happened in recent years, she cannot fulfill her sponsor contracts. And for many runners, this also compromises their ability to win bonuses associated with podium finishes.

Diminished Water Access

Professional mountain bikers Kurt Refsnider and Kait Boyle noted a lack of access to water on the Arizona Trail at sites that could be historically relied upon to have water. Water is necessary for those racing or recreating on the Arizona trail, and many other trails in the U.S. As droughts become more pronounced in some regions, decreases in water access can compromise safety for outdoor recreationists.

Ongoing Trail Loss

Along with recent increases in trail usage, climate change impacts present an additional burden to trail restoration and management efforts. Professional mountain biker Dillon Osleger performs extensive work in trail restoration and has studied the increasing deficit in trail maintenance and repair relative to trail degradation rates. He noted that federal expenditures on maintenance and repair are shrinking in some areas, as traditional work crews, such as offseason “hotshots,” are having their budgets cut. With a lack of maintenance, many trails have already been lost, which will only be exacerbated by climate change.

Responses to Temporal Shifts

Rock climbing performance depends on weather conditions, with ideal conditions including dry and cool ambient air. Professional climber and alpinist Graham Zimmerman noted that hotter summers are likely to cause a shift in the timing of ideal rock climbing seasons. Temperature increases caused by climate change will interfere with climbing activities and can threaten the health of participants. Depending on the degree of such a shift, months previously defined by lower climbing activity may experience significant increases in activity. Changes in recreation patterns are likely to result in new management regulations, further hindering rock climbers’ ability to recreate.

Exacerbating Differential Access

When assessing the impacts of climate change upon recreational access, several individuals noted that low-income and marginalized communities are already less likely to have access to open spaces. Instead, they may be bordered by areas not conducive to outdoor recreation, such as Superfund sites. Low-income communities are also less likely to have access to indoor training facilities, which is an alternative that allows for safer training during hazardous conditions such as wildfire smoke.

Representation in Outdoor Recreation

One individual noted that young athletes of color describe feeling unwelcome in the trail sport communities, which are predominantly White, partially due to lack of representation in outdoor recreation and sports media. This individual also noted that young athletes of color have described outdoor recreation as being "for White people," and they may be cut off from the institutional knowledge of how to advance within the field.

Table 4. Discussions with experts

Date	Name	Expertise
5/24/2021	Graham Zimmerman	Athlete (Rock Climbing)
5/27/2021	Stephanie Howe	Athlete (Trail Running)
6/2/2021	Dr. Elizabeth Burkowski	Economist (UNH)
6/2/2021	Dr. Jude Bayham	Economist (CSU)
6/24/2021	Nina Aragon	Scientist (OSU)
7/29/2021	Dr. Ian Bolliger	Scientist (BlackRock, Inc.)
8/4/2021	Canyon Woodward	Athlete (Trail Running)
8/13/2021	Dr. Jen Kay	Scientist (CU Boulder)
9/15/2021	Clare Gallagher	Athlete (Trail Running)
9/23/2021	Dr. Erik Murdock	Policy Expert (AccessFund)
10/14/2021	Dillon Osleger	Athlete (Mountain Biking)
11/5/2021	Joseph Gray	Athlete (Trail Running)
11/10/2021	Kurt Refsnider	Athlete (Mountain Biking) / Scientist
12/2/2021	Kait Boyle	Athlete (Mountain Biking)

Strategic Communications Materials

We created State Fact Sheets and Alliance Toolkits as supplementary deliverables supported by findings from our literature review and conversations.

State Fact Sheets

We reviewed over 100 state-specific resources to assess the individualized impacts of climate change on POW's five target states: Arizona (AZ), Colorado (CO), Montana (MT), Nevada (NV), and Utah (UT). We then synthesized the resulting information into five state-specific fact sheets that are included in Appendix 1.

While the overarching impact categories identified in the literature review were similar for each state (notable exceptions being sea level rise and vector-borne disease, because not every state experiences these impacts), the relevance of each impact category differed. Therefore, the State Fact Sheets include the most relevant climate impacts in each state that are best supported by the existing data. The final categories included in each state fact sheet were:

1. Heat
2. Wildfire
3. Air Quality
4. Drought
5. Meltwater Runoff and Flooding
6. Economic Losses

The fact sheets also include summary information on trail sport and rock climbing recreation within each state. That information, along with the climate impacts, can be used to generate targeted messaging in POW's future outreach campaigns.

Alliance Toolkits

We produced Alliance Toolkits for both sport communities using the information gathered in the literature review and additional research from the State Fact Sheets. These Toolkits communicate the observed and projected impacts on each of the two target sports. Unlike the literature review, which is written for an academic audience, the Alliance Toolkits present information using the messaging structure outlined in POW's Neimand Report (people, place, climate, empowerment). This structure allows POW Alliance Members of all backgrounds to readily access the information and provides a summary of consequential impacts, couched as "What is at stake?" for Alliance Members to use in their outreach efforts. The Alliance Toolkits are included in Appendix 2.

Audience Expansion Analysis

The first objective of this project was to identify how climate change impacts the rock climbing and trail sports communities. The second objective was to identify audience expansion opportunities for POW within the rock climbing and trail sports communities in five target states (AZ, CO, MT, NV, UT).

Analysis of POW's Existing Membership Data

We calculated the number of members POW currently has in each target state using internal POW Salesforce and Phone2Action data. However, this analysis very likely underestimated the true membership total in each state because 43% of the Salesforce membership data did not include any state information (Table 5). Although the Phone2Action dataset contained fewer total entries, only 3% were missing state information, indicating that it may be a more robust dataset to compare membership trends across states. Moreover, only 16% of the Salesforce and 32% of the Phone2Action entries were for members associated with the five target states (AZ, CO, NV, MT, UT).

To further characterize POW's existing membership, we assessed how members' preferred sports varied across target states. The Salesforce dataset had two relevant variables for sport ("sport category" and "sport interest"), while the Phone2Action dataset had three relevant variables ("what is your favorite sport," "what is your sport," and "favorite summer sport"). However, most of these variables had "NA" values, meaning that neither dataset had sufficient sport-specific membership data within the target states.

Additionally, neither dataset included unique identifying values, making it impossible to determine whether members or their preferred sports were double-counted within and across datasets. Therefore, we did not combine the Salesforce or Phone2Action datasets for any analysis.

As a result, our data visualizations, such as Figure 5 below, are not accurate representations of actual POW member sport interest by state. This clear underestimation of POW's actual membership and sport participation hindered our ability to draw definitive conclusions about the following:

- Total membership in target states;
- Membership distribution among target states;
- Membership expansion potential in each target state;
- Sport interest of members in target states;
- Sport interest distribution among target states.

This section highlights the general trends from the available data and associated visualizations. Each figure below shows target states in descending population order. Figures in blue are visualizations of absolute data values, while figures in orange are per capita, or relative, visualizations.

Table 5. Salesforce and Phone2Action dataset details

Variable	**Salesforce Entries**	**Phone2Action Entries**
Total # of entries in dataset	268,179	69,920
Entries with NA for state	116,498 (43%)	1,783 (3%)
Entries from target states	43,112 (16%)	22,595 (32%)
Entries with NA for sport in target states	42,415 (98%)	22,378 (99%)

Data Visualizations of POW Membership

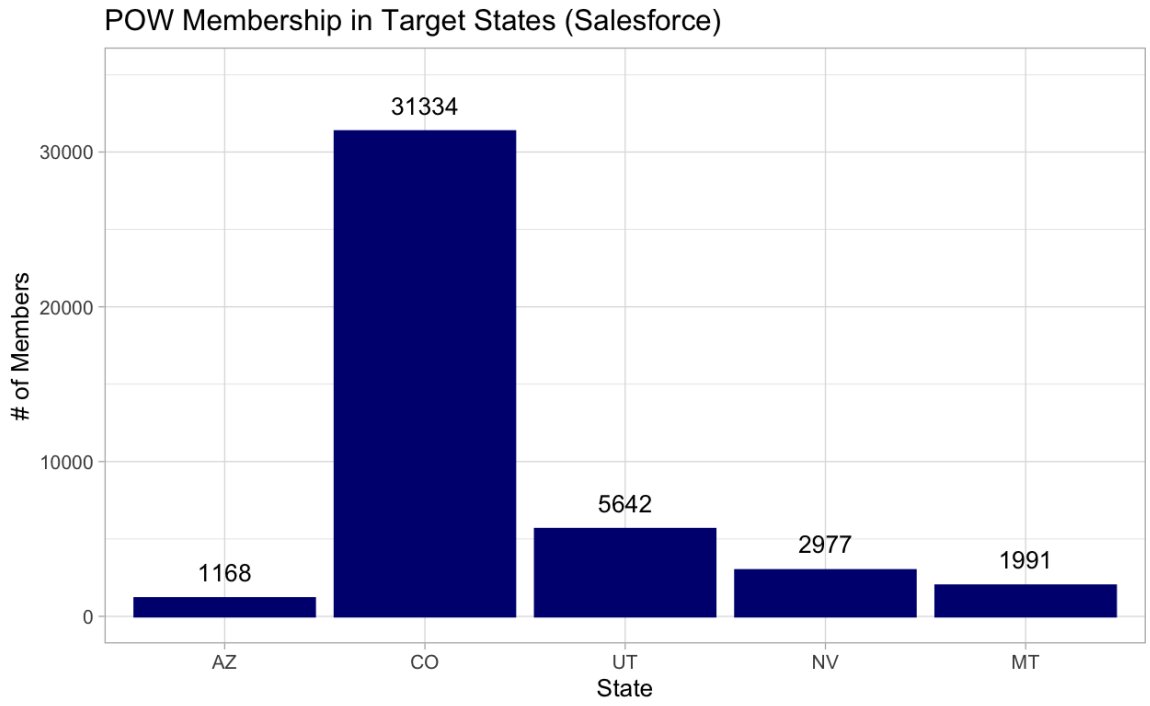


Figure 1. Total number of POW members in each target state. Data: POW Salesforce (2021)

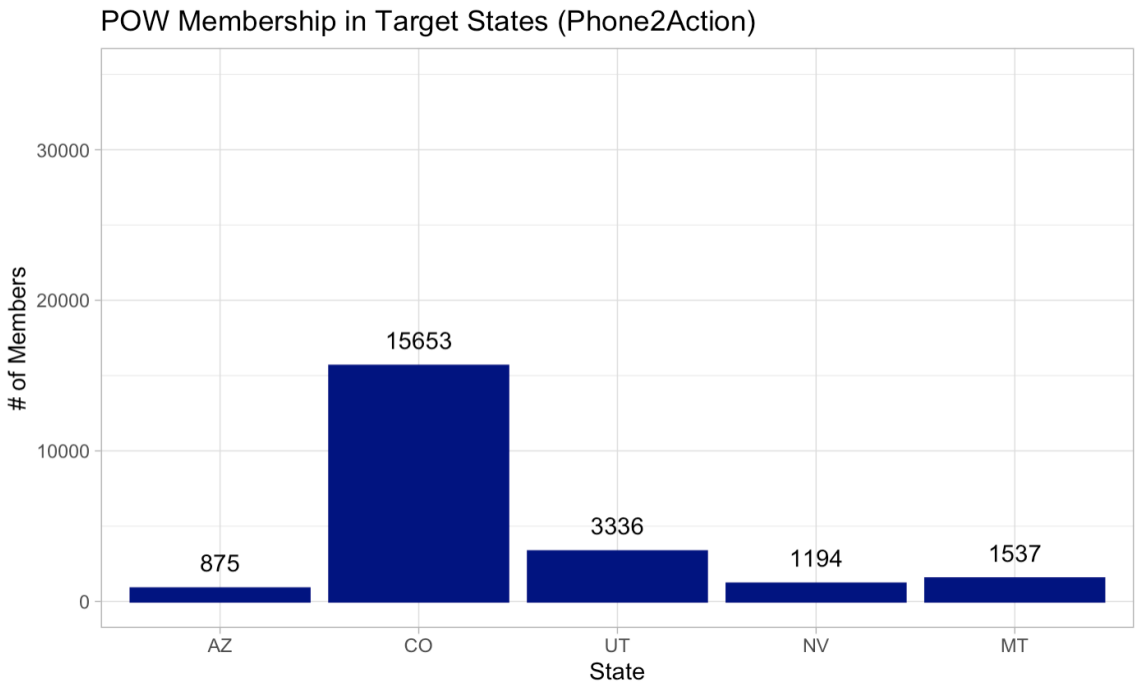


Figure 2. Total number of POW members in each target state. Data: POW Phone2Action (2021)

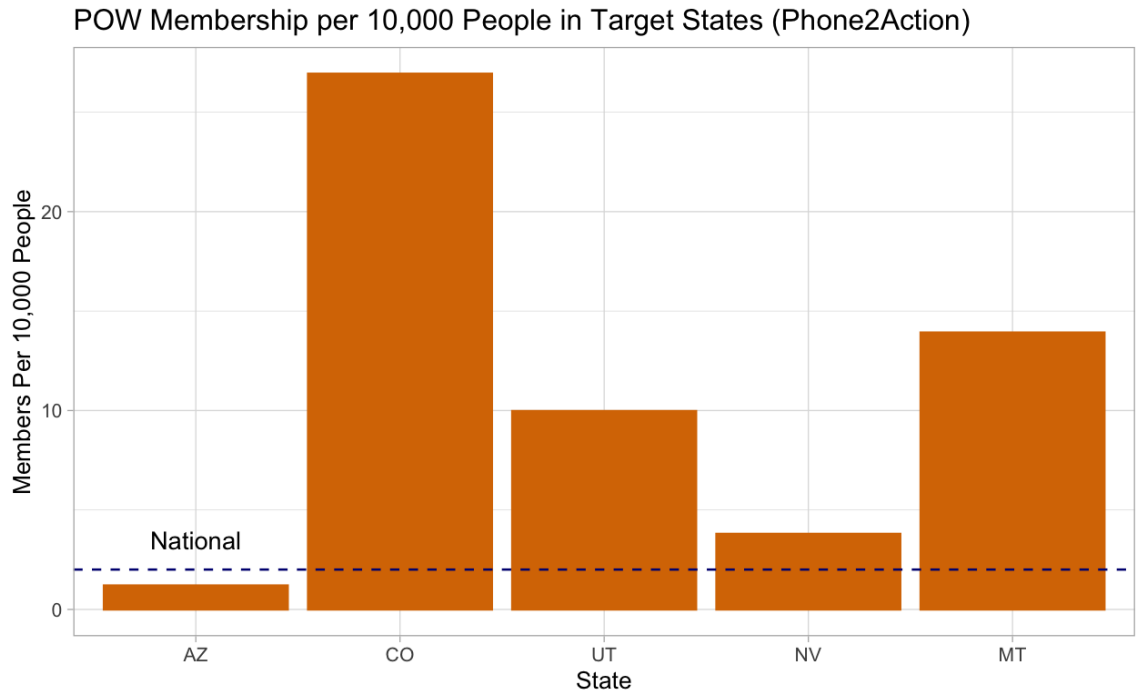


Figure 3. Total number of POW members per 10,000 people in each target state. Data: U.S. Census and POW Phone2Action (2021)

Figures 1–2 show that most of POW's existing membership is in CO. Figure 3 shows that membership per 10,000 people is highest in CO, followed by MT, UT, NV, and AZ. We calculated the

membership proportion per 10,000 people rather than per capita because per capita calculations gave us fractional member totals, which is unrealistic for counting humans.

It is beyond the scope of this project to determine whether the significantly higher membership count in CO because POW is a CO-based organization, or due to other factors, including how, where, when, and why POW collected membership data, or whether individuals had the option to include or exclude geographic information when POW collected their personal information.

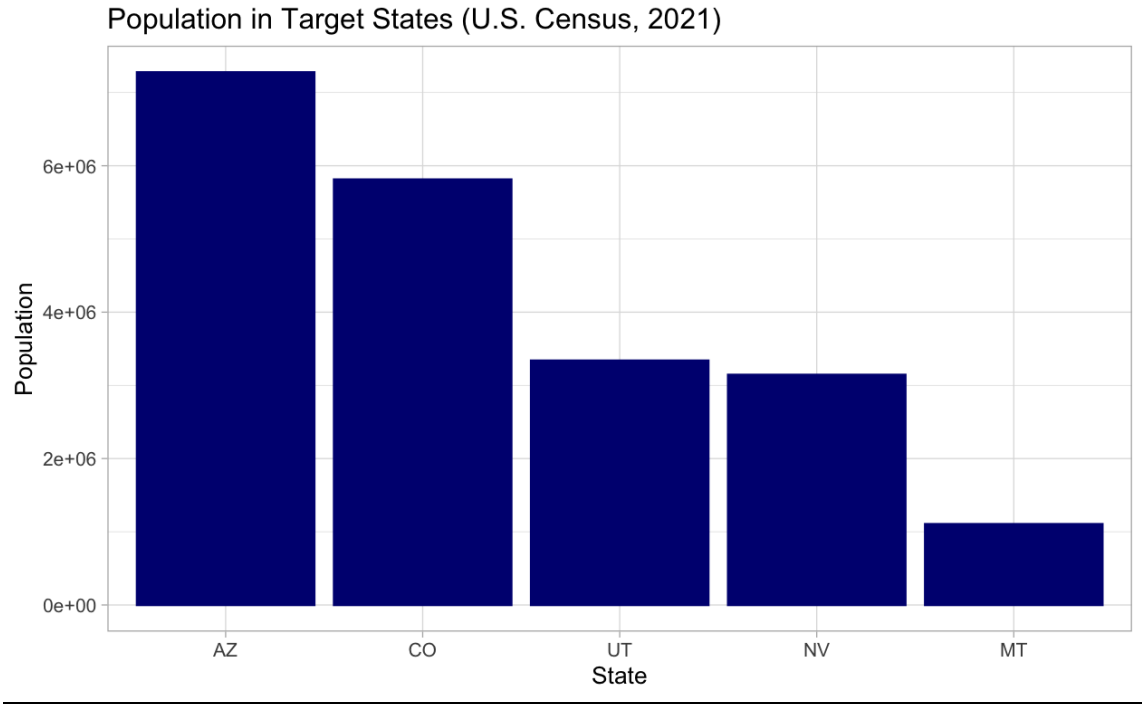


Figure 4. U.S. Census population estimate for each target state. Data: U.S. Census (2021)

Although we recognize that membership is not a direct function of state population, we observed a few notable trends when analyzing the membership and population figures. Figures 1, 2, and 4 show that while Arizona had the highest population out of the target states, POW's estimated absolute membership is lowest in Arizona in both datasets.

Additionally, while Utah and Nevada have relatively comparable state populations, POW membership in Utah is two to three times higher than in Nevada. While Nevada's population is almost three times that of Montana, POW membership per 10,000 people is higher in Montana than in Nevada, according to Phone2Action data.

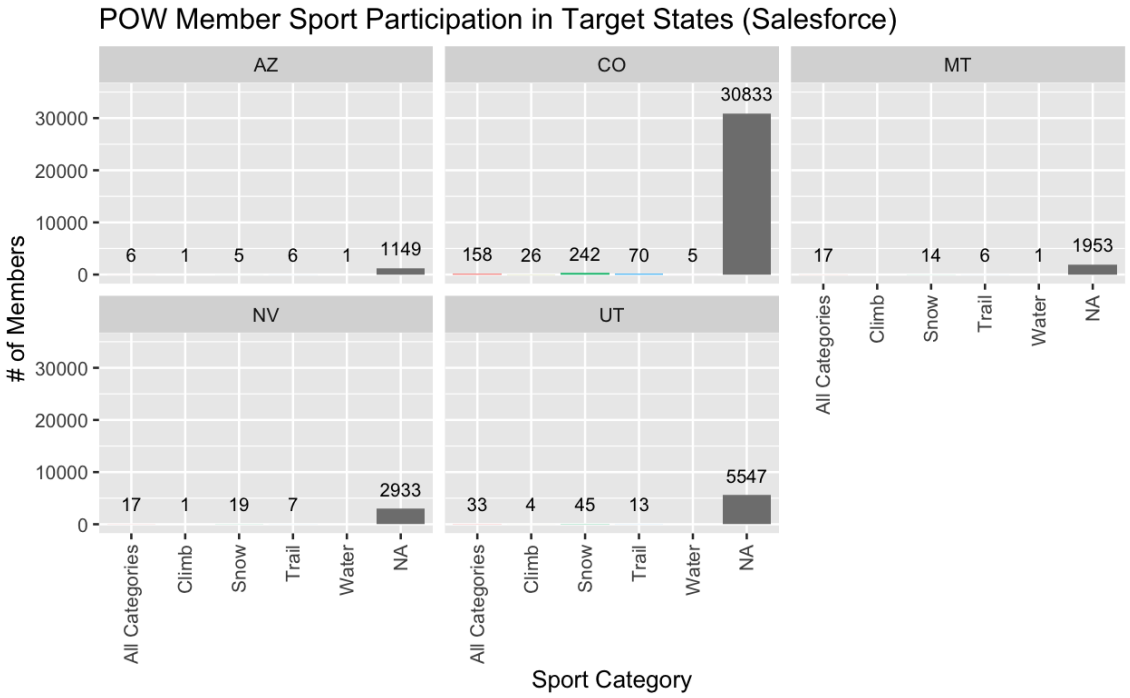


Figure 5. Total count of POW member sport participation within all target states. Data: Salesforce (2021)

The Salesforce and Phone2Action datasets were used to visualize member sport participation across and within each target state. Both datasets produced figures similar to Figure 5, which shows how few dataset entries contained member information related to climbing and trail sports. From the limited information that we analyzed, more members indicated participation/interest in the trail category than the climb category. Due to the high rate of NA's in the datasets, we were unable to draw definitive conclusions about participation.

Analysis of Sport Participation Proxies

We attempted to procure comprehensive state-specific sport participation data for trail sports and rock climbing from sources like Strava, Gaia, and onX. However, we could only obtain this type of data for hiking, trail running, and mountain biking from Trailforks.

Note: the following recommendations are made based upon the analysis of proxy data for sport participation in a given state, which includes both state residents and non-residents.

Trailforks. Trailforks is a crowd-sourced resource that allows users to query and add information based on trail activity. However, after further exploration of the site, we found that Trailforks users can easily add trail information to the site without any apparent oversight that would prevent double-counting. We also found that although the site now accommodates multiple trail activities, it was originally designed as a resource for mountain biking. Therefore, mountain biking trails and

activity logs far outnumber those of other trail sports, which led us to question the efficacy of using the site as a proxy for all trail sports.

Given that trend, we decided to explore publicly accessible information from other reputable outdoor recreation websites to estimate participation rates for all sports and identify audience expansion opportunities within the target states.

Hiking+. Determining the best proxy for each sport was challenging, given the varying types of trail recreation and the likelihood of significant overlap between sources. For example, AllTrails technically contains trail information for several trail activities (including all target sports for this project and beyond). While they are technically separate websites, Hiking Project and Trail Running Project both report the same information. For simplicity, our project excluded Trail Running Project data under the assumption that Hiking Project contained the best participation proxies for hiking, trail running, backpacking, and other similar trail activities. Therefore, the term "hiking+" in our narrative encompasses all non–mountain biking trail activities.

AllTrails. AllTrails could potentially serve as a single proxy for all target sports, given that the site allows users to query trail information based on desired activity. However, the sport-specific trail estimates on AllTrails were significantly lower than those reported by other sport-specific proxies. We did not observe any other meaningful trends between numbers reported on AllTrails and other proxies. This prevented us from relying solely on AllTrails to capture the same proportions of sport participation information as other proxies. For example, AllTrails reported 722 mountain biking trails in Arizona, compared to 1,025 reported on Mountain Bike Project—a 30% difference. Similarly, AllTrails reported 1,130 hiking trails in Montana, while Hiking Project reported 2,378—a 52% difference.

Moreover, each source had different publicly available information. For example, only the total number of trails and trail reviews per state were available on AllTrails, while Mountain Project reported the total number of climb routes, as well as monthly and annual page views per state, and Hiking Project includes miles of trails and the total number of trails per state. Table 6 outlines the potential participation proxies that we identified; it should be noted that relative data proxies more reliably approximate participation than absolute data proxies.

Table 6. Publicly accessible participation proxies for trail and climb sports

Participation Proxy	Applicable Sports	Data Source
Number of Trail Reviews	Hiking+, Mountain Biking, Rock Climbing, and more.	AllTrails
Number of Trails	Hiking+, Mountain Biking, Rock Climbing, and more.	AllTrails
Miles of Hiking Trails	Hiking+	Hiking Project
Miles of Mountain Biking Trails	Mountain Biking	Mountain Bike Project
Number of Climbing Routes	Rock Climbing	Mountain Project
Number of Annual Page Views	Rock Climbing	Mountain Project
Number of Hiking Logs	Hiking+	Trailforks
Number of Trail Running Logs	Trail Running	Trailforks
Number of Mountain Biking Logs	Mountain Biking	Trailforks

AllTrails Data Proxies

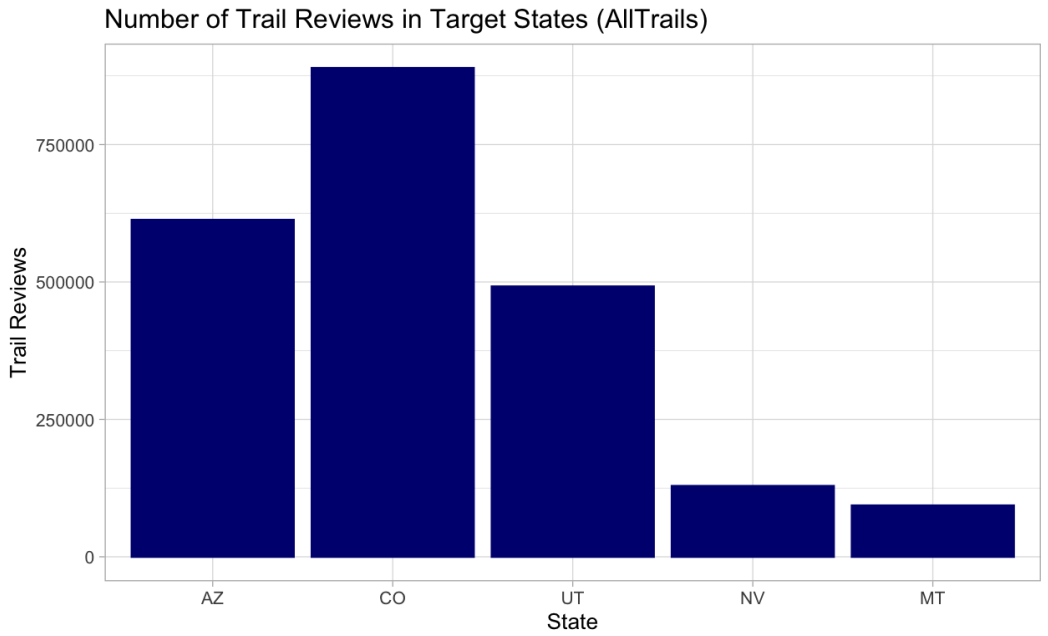


Figure 6. Total number of trail reviews in each target state. Data: AllTrails (2022)

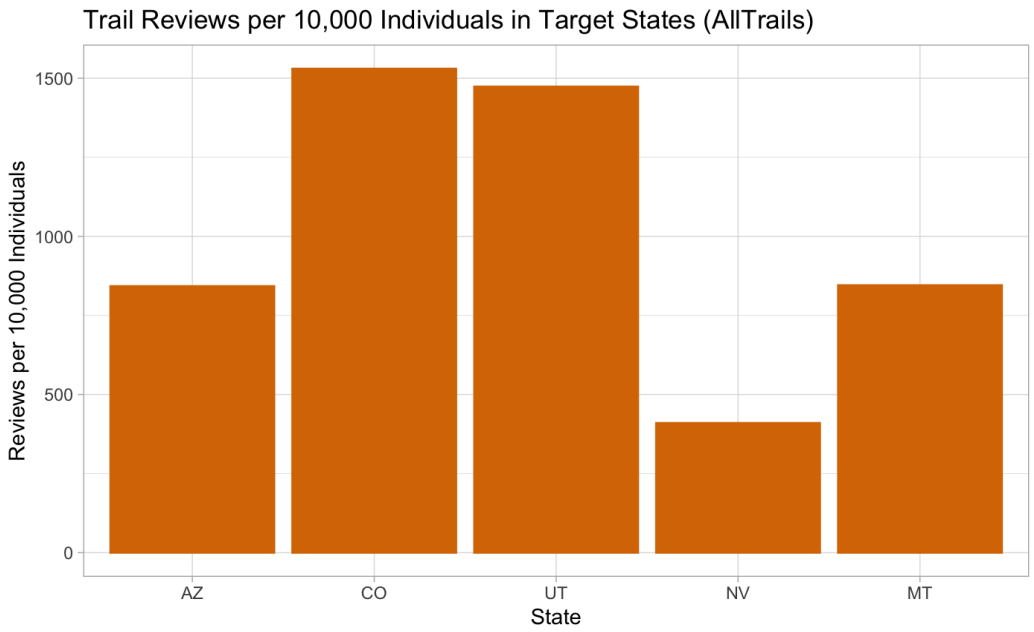


Figure 7. Trail reviews per 10,000 people in each target state. Data: U.S. Census and AllTrails (2022)

Figure 6 shows that target states with lower populations also had fewer trail reviews, except for CO, which had the highest number of trail reviews. Figure 7 shows that per 10,000 people, UT and CO had a similar number of trail reviews, while MT had nearly the same number of reviews per 10,000 people as AZ, despite having roughly one-seventh of AZ's population.

While we did not find any studies assessing the relationship between the distance of a trail from an individual's home and the likelihood of individuals to leave a review on trails, we did find that 63% of people who recreate outdoors tend to recreate within 10 miles of their home[123]. However, many factors—related to participation rates and otherwise—can influence an individual's decision to leave a review, including familiarity with the website and mobile app, tendency to leave internet reviews, and their experience while visiting the site. Furthermore, studying internet reviews and outdoor recreation is not within the scope of this report.

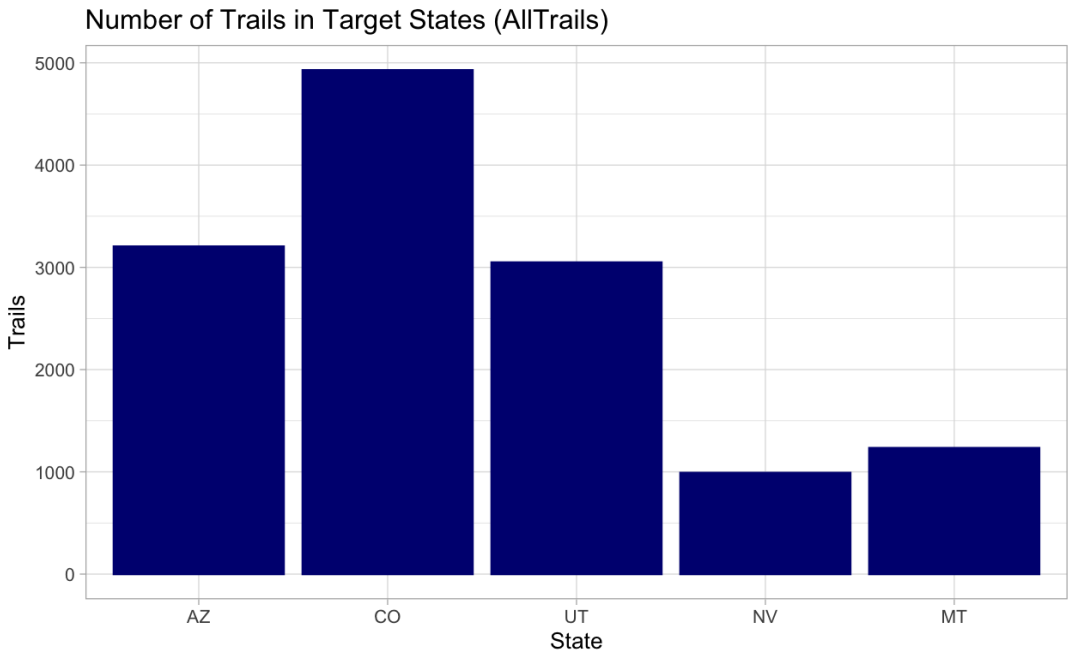


Figure 8. Total number of trails in each target state. Data: AllTrails (2022)

Figure 8 demonstrates that target states with lower population estimates do not necessarily have fewer total trails.

Given that AllTrails allows users to add new trails to the site, it was difficult to identify how users define a discrete trail (e.g., based on trail distance, topography, accessibility, visitation, maintenance, popularity). Trails often connect and have multiple entries and exit points, which further complicates how participation or use of a single trail is defined and counted.

Hiking Project Data Proxies

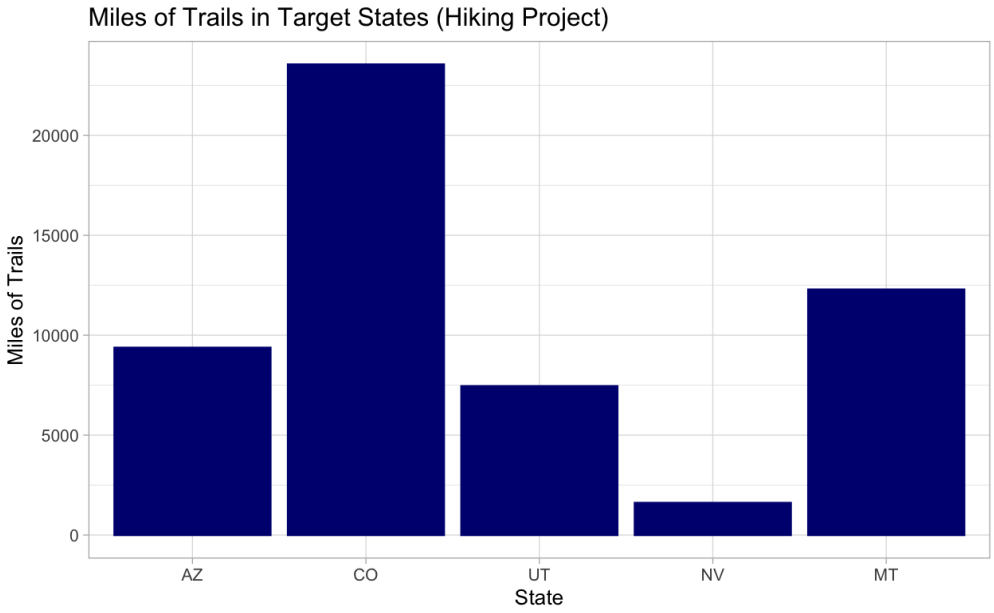


Figure 9. Total miles of hiking trails in each target state. Data: Hiking Project (2022)

Figure 9 demonstrates that CO has the most reported miles of hiking trails out of the target states, according to Hiking Project. MT has roughly half the number of trails that CO has, despite being 40% larger in size (147,040 mi^2 vs. 104,185 mi^2, respectively) and having a population size almost four and a half times lower than CO.

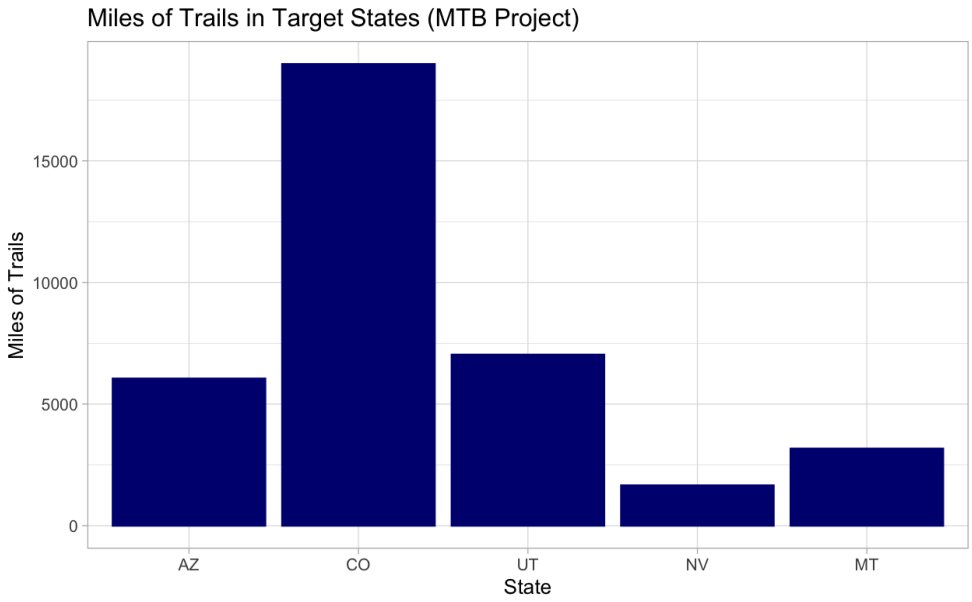


Figure 10. Total miles of mountain biking trails in each target state. Data: Mountain Bike Project (2022)

Figures 8–10 demonstrate that NV has the lowest total miles of hiking and mountain biking trails out of all target states. In addition, Figure 10 shows that CO has the most reported total miles of mountain biking trails out of the target states.

Our State Fact Sheet research shows that most of NV's population and outdoor recreation is concentrated in the Las Vegas and Reno areas. The NV trail maps on Hiking Project and Mountain Bike Project also show that most trails are concentrated near Las Vegas and Reno. These geographic limits potentially explain why the state has significantly fewer miles of trails than the others but do not explain sport participation rates. UT is similar to NV in population size and in that UT's population is also geographically concentrated in two locations. Despite these similarities, UT has roughly three times the miles and number of trails that NV does. Because of these inconsistencies among proxies, it is difficult to estimate whether the same number of people participate in trail sports in NV's smaller trail system than in UT's widespread trails.

Mountain Project Data Proxies

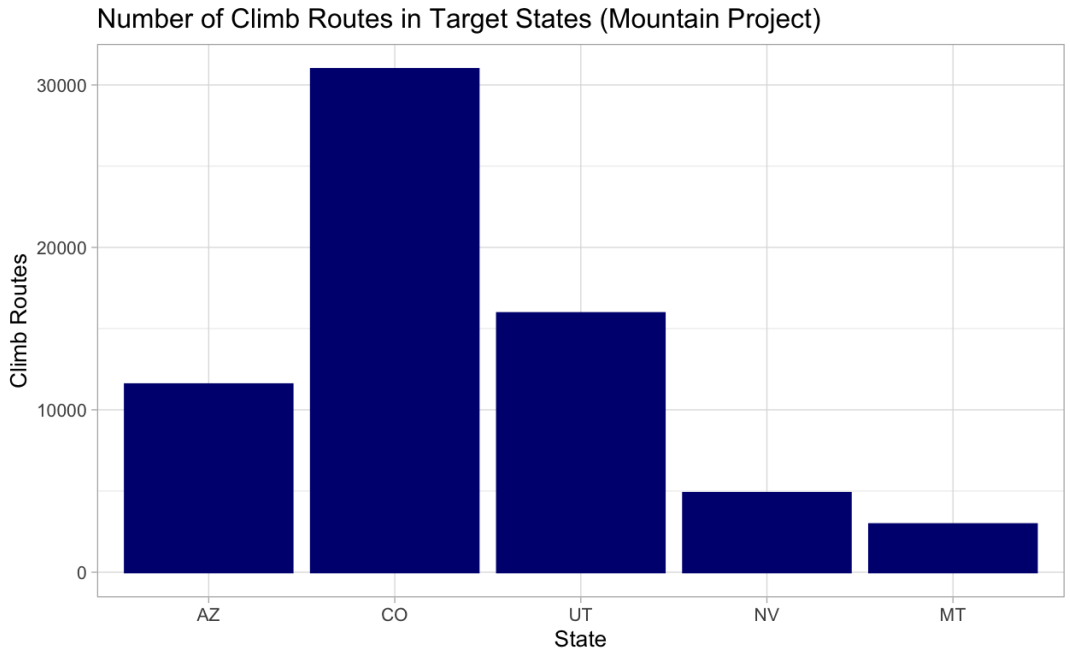


Figure 11. Total number of rock climbing routes in each target state. Data: Mountain Project (2022)

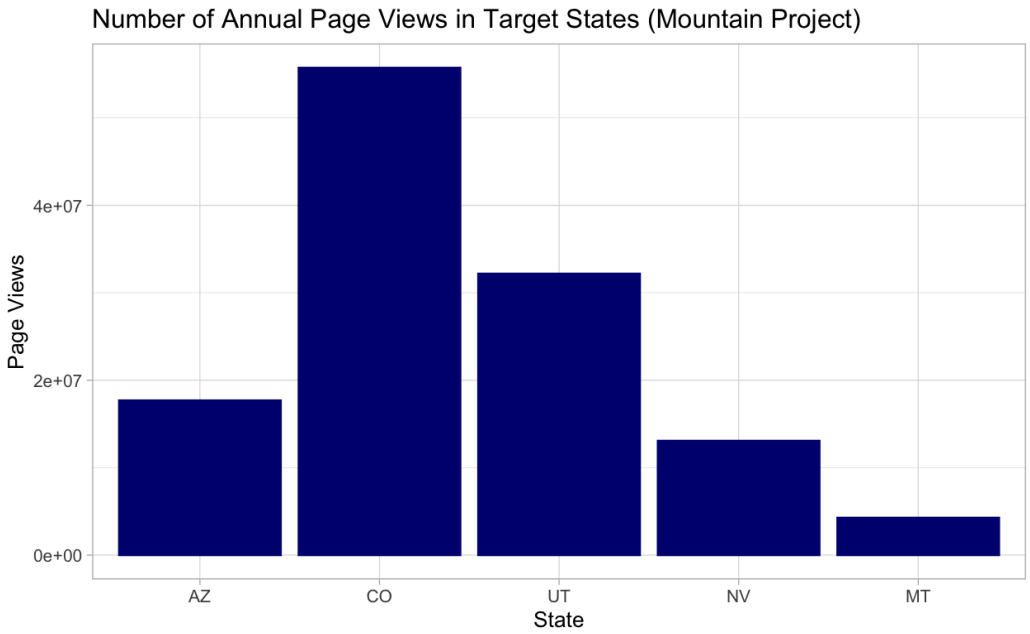


Figure 12. Total number of annual page views for each target state. Data: Mountain Project (2022)

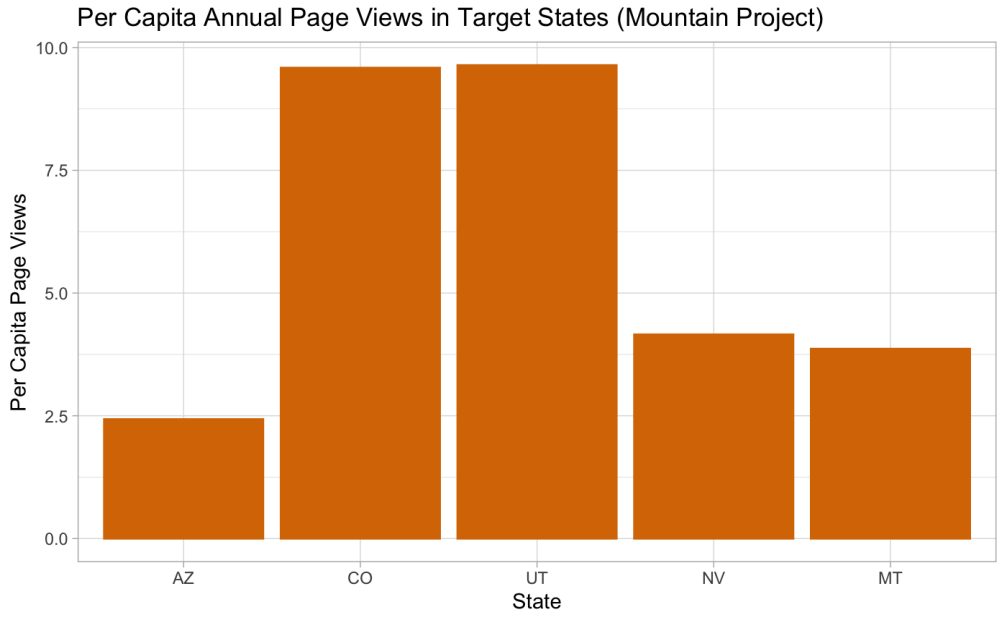


Figure 13. Per capita annual page views for each target state. Data: Mountain Project (2022)

Figures 11–13 are visualizations of rock climbing proxies from Mountain Project. Figures 11 and 12 show that states with lower population sizes also had fewer climb routes within the state and fewer annual state page views on the Mountain Project website—with AZ being an exception. Figure 13 shows that CO and UT have similar page views relative to population, as do NV and MT. We elected to show Figure 13 as a per capita graph, rather than per 10,000 people because the per capita results for all target states were whole numbers.

Trailforks Data Proxies

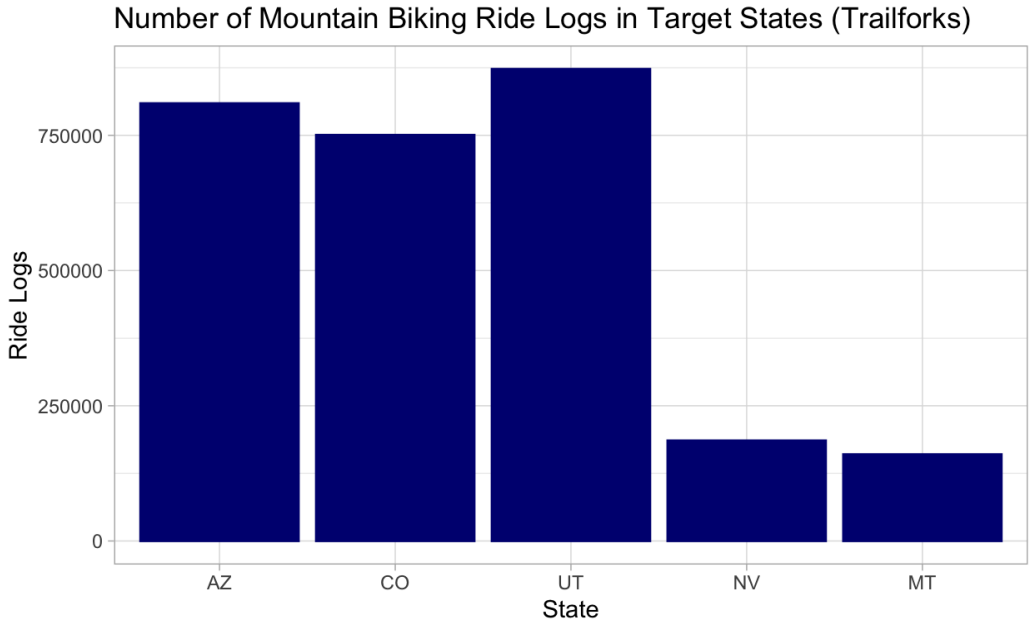


Figure 14. Total number of mountain biking ride logs in each target state. Data: Trailforks (2022)

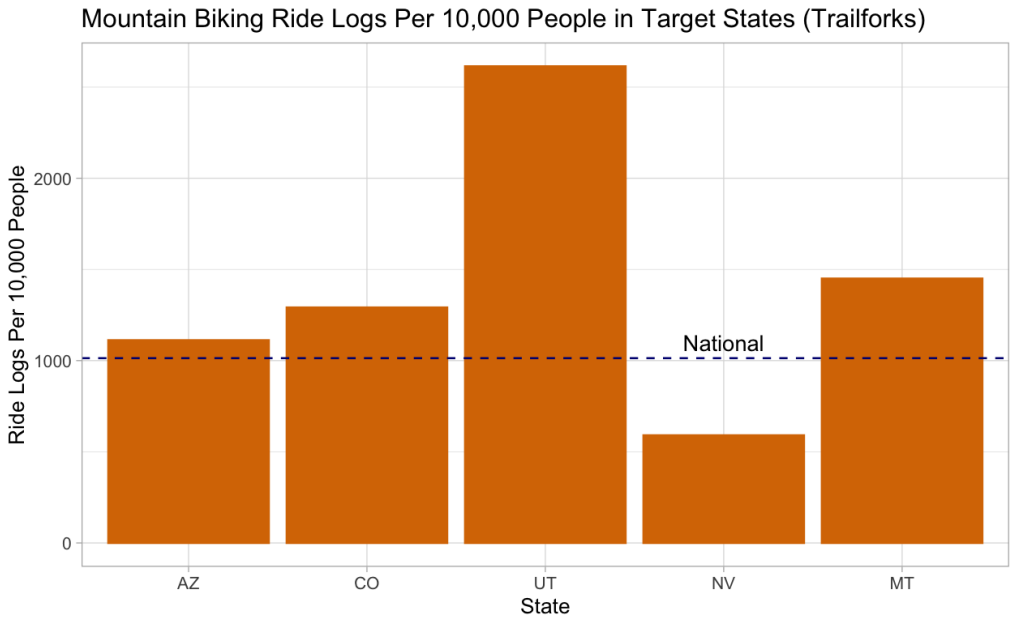


Figure 15. Mountain biking ride logs per 10,000 people in each target state. Data: Trailforks (2022)

Figures 14–19 are visualizations of hiking, trail running, and mountain biking participation proxies from Trailforks. Trailforks was initially designed as a resource for mountain biking alone, suggesting that Trailforks data for "hiking+" are less robust on this multi-activity platform than on other sport-specific platforms. Figure 14 shows that mountain biking ride logs are highest in UT, AZ, and CO. Figure 15 shows that mountain biking ride logs per 10,000 people are highest in UT and that MT has

the second highest despite having the lowest total absolute ride logs. Ride logs per 10,000 people are above the national rate for all states except NV.

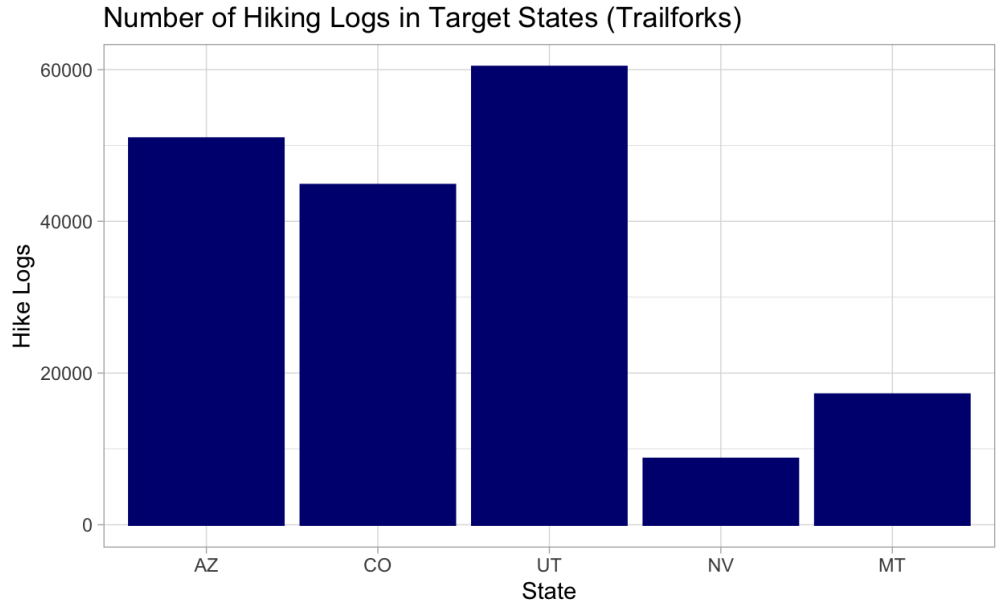


Figure 16. Total number of hiking logs in each target state. Data: Trailforks (2022)

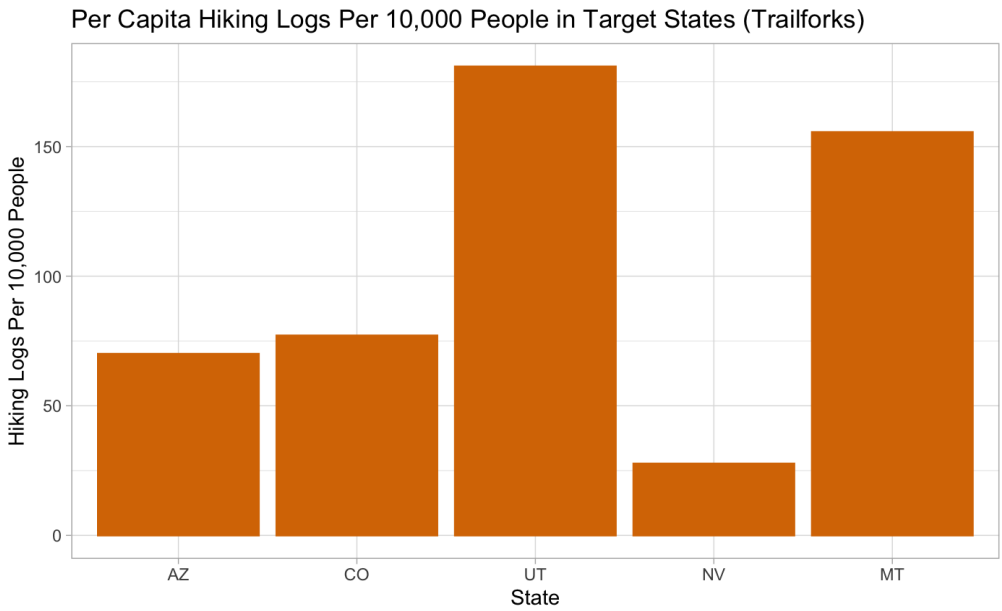


Figure 17. Per capita hiking ride logs in each target state. Data: Trailforks (2022)

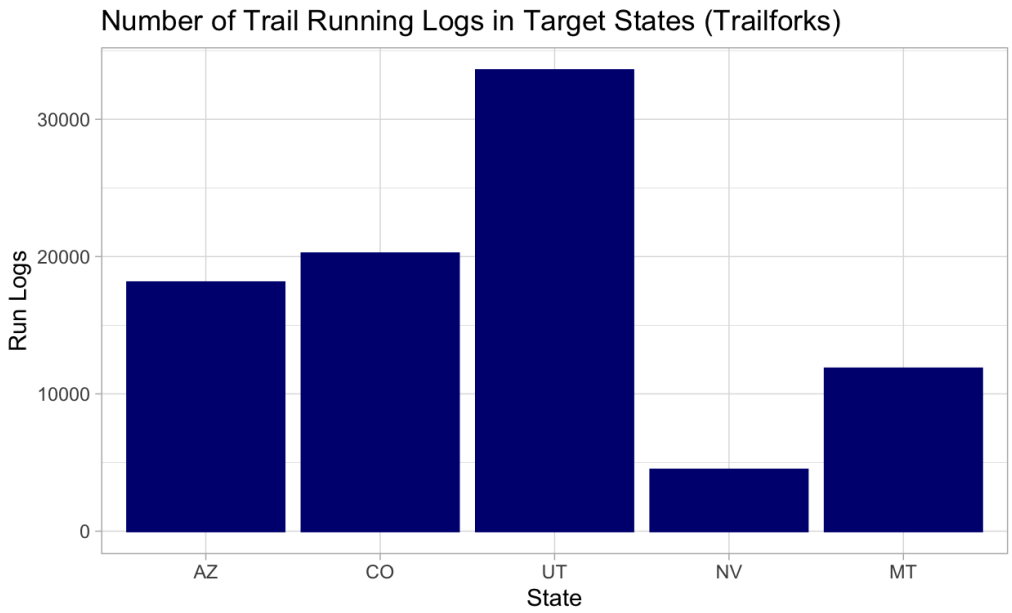


Figure 18. Total number of trail running logs in each target state. Data: Trailforks (2022)

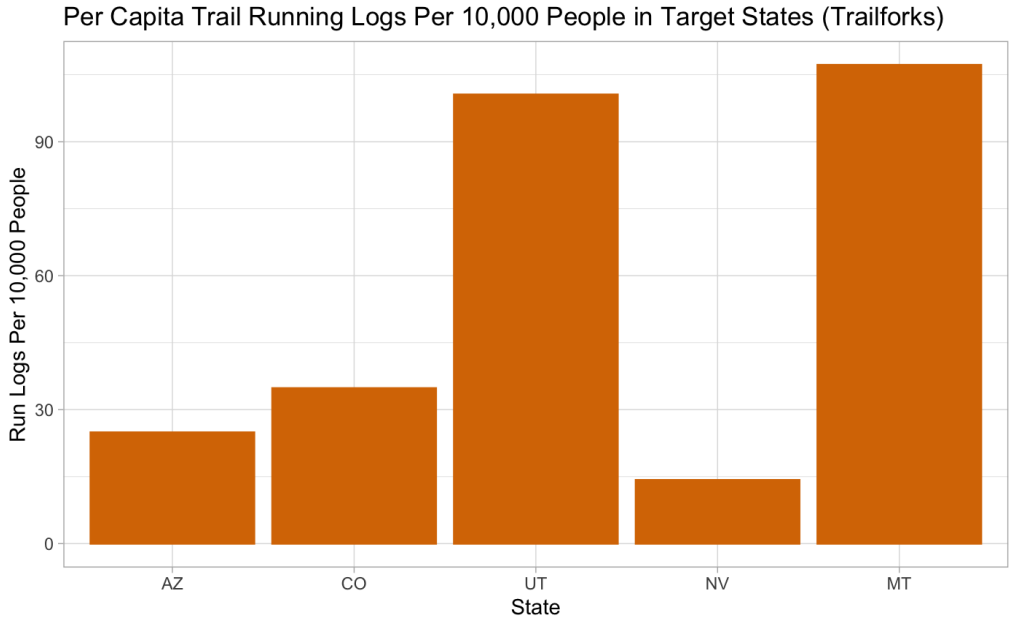


Figure 19. Per capita trail running ride logs in each target state. Data: Trailforks (2022)

Figures 16–19 show that UT had the highest absolute number and per capita hiking and trail running logs out of the target states. However, given that Trailforks is a resource primarily used by mountain bikers, the information in Figures 16–19 is likely not an accurate representation of actual hiking and trail running participation in target states. We believe that because mountain bikers have historically used the platform, we are seeing false inflation of hiking and trail running logs in Utah and Montana due to their high concentration of mountain bikers that use Trailforks.

Therefore, we are confident that these data visualizations are not accurate representations of the distribution of hikers and trail runners in each of the target states. As a result, we cannot use the observed trends to make definitive recommendations or conclusions related to sport participation.

8. CONCLUSIONS

Climate Impacts On Rock Climbing And Trail Sports

Climate change impacts on winter sports are easy to understand: in a warmer world, less precipitation will fall as snow. Snow is needed to ski and snowboard. Therefore, current and future impacts of climate change reduce the number of days suitable for skiing and snowboarding.

Given the disparate nature of the regions, seasons, and resources needed to engage in rock climbing and trail sports (hiking, mountain biking, trail running), it is far more difficult to clearly identify simple, significant, and uniform climate impacts on these sport categories. However, the primary climate impacts identified in this report—decreased access, threats to health and well-being, and diminished experience—all have one common theme: they increase barriers to outdoor recreation.

Increased Barriers to Access

These barriers to access can be categorized into two groups: direct barriers and indirect barriers.

1. **Direct barriers to access** impact the **resources** that participants need to recreate and are frequently associated with area closures. Examples include:
    a. **Wildfires** – Increased frequency and severity of wildfires can directly damage the rocks, trails, forests, and parks that members of the rock climbing and trail sports communities rely upon for recreation.
    b. **Erosion** – Increased rates of erosion as droughts and heavy precipitation events become more frequent and lead to recreation area closures that prevent the rock climbing and trail sports communities from recreating.

Fortunately, most of these direct barriers represent reversible impacts: a forest that has burnt down will eventually regrow, a trail that has been washed away by erosion can be rebuilt, and a park that has been closed due to wildfire damage will eventually reopen. Loss of access associated with such direct barriers is typically limited in duration as well, as area closures eventually lift.

2. **Indirect barriers** to access impact recreational **conditions**. Examples include:
    a. **Heat** – Hotter temperatures increase the risk of heatstroke and make daytime recreation uncomfortable and even unsafe.
    b. **Poor air quality** – Particulate matter negatively impacts respiratory and cardiovascular health, threatening the health of rock climbers and trail sport athletes.

Unfortunately, most of these **indirect barriers** represent long-term, potentially irreversible impacts for two reasons:

1. **Indirect barriers represent impacts that accumulate over time.** While poor air quality will not necessarily prohibit outdoor recreation, the health implications of continuous exposure to poor air quality can negatively accumulate over time.
2. **Indirect barriers are often incremental and irreversible.** Many negative impacts of climate change on outdoor recreation occur incrementally and—while preventable—are difficult to reverse. For example, the average global temperature is increasing slowly and will not decrease in the short-term.

Observed vs. Projected Impacts

Throughout our research, we noted an important distinction between climate impacts: observed impacts (impacts currently being experienced) vs. projected impacts (impacts expected to occur based on modeling or inference). Observed impacts tend to be visible, easy to communicate, and clearly connected to increased barriers to recreation. For example, acres of national forest burned by wildfires is an observed impact that can be easily quantified and messaged. On the other hand, projected changes are changes that have yet to be observed. Therefore it is more difficult to directly connect these impacts to the lives and interests of target audiences.

Most reports and articles written for non-academic audiences focused primarily on observed climate impacts. Significantly less attention was given to projected impacts. This trend highlights the value of observed climate impacts for strategic communications efforts while providing an opportunity to communicate projected climate impacts. If effectively communicated, messaging both observed and projected impacts is likely to generate the strongest response.

Spatial Variability

This project identified significant variability in each impact category across regions and communities. Therefore, understanding and accurately communicating the impacts at a community level will be important for generating advocacy through outreach efforts.

This highlights the importance of POW's messaging structure of "People, Place, Climate, Empowerment." Although it is difficult to clearly outline uniform climate impacts on our two sport categories, there are many personal experiences, in many geographies, that can be reasonably tied to climate impacts and messaged in a way that compels members of the Outdoor State to engage in climate advocacy.

Disproportionate Impacts for Disadvantaged Communities

Increased barriers to recreational access will affect all communities of people engaging in rock climbing and trail sports. However, not all communities currently have the same access to these resources—disadvantaged communities, particularly BIPOC, have faced historical and contemporary exclusion from many outdoor spaces.

Historically marginalized communities already face countless environmental, social, and economic inequities. With increased participation rates in outdoor recreation, many will experience increased barriers to access due to the impacts of climate change—adding to existing inequities. These increased barriers to recreational access can significantly exacerbate existing inequity and representation in the outdoor industry, representing a significant environmental justice concern for all outdoor recreationists.

Audience Expansion

POW's Existing Membership Data

The main conclusion from our analysis is that the Salesforce and Phone2Action data were not robust enough to make reliable conclusions about POW's existing membership or their participation in climb or trail sports in the five target states. However, we observed the following high-level trends:

- POW's absolute and relative membership was highly underrepresented in Arizona and overrepresented in Colorado compared to the other target states and POW's national membership rate (according to Salesforce and Phone2Action data).
- POW's relative membership in Colorado, Montana, Utah, and Nevada is higher than the national rate per 10,000 people (according to Phone2Action data).
- POW's absolute membership in Colorado is roughly 10 times greater than absolute membership in Montana, roughly 5 times greater than in Utah, and roughly 13 times greater than in Nevada (according to Phone2Action data).
- However, relative membership per 10,000 people is roughly 2 times greater in Colorado than in Montana, roughly 1.5 times greater than in Utah, and 4.5 times greater than in Nevada (according to Phone2Action data).

Given the member and sport participation data limitations, we could not make any responsible conclusions about the proportion of POW's membership in each target state that belongs to the trail or climb communities nor describe any high-level trends observed across either dataset.

Sport Participation Proxies

We found several websites with data that could serve as participation proxies for climb and trail sports, including Strava, AllTrails, Trailforks, Hiking Project, Mountain Project, and Mountain Bike Project. Each proxy had benefits and limitations, which made it difficult to determine absolute target sport participation in each target state. Additionally, these data are proxies for sport participation alone within a given state; they do not distinguish between state residents and non-residents.

Considering these limitations, we made the following high-level observations:

- Relative measures (e.g., number of trail reviews per capita, number of mountain biking ride logs per 10,000 people, etc.) are a more robust proxy for sport participation than absolute measures (e.g., total number of climbing routes, total miles of trails, etc.) because relative measures are more closely related to population, and they have been estimated by taking state population into account.
- While proxies give insight into participation within geographic areas, they do not indicate whether the participant resides in the same area or is visiting the area.
- We could not identify an activity or participation tracker for climbers in which they can report attempting or completing climb routes across the target states in the same way that trail participants can track their activity on platforms like Strava.
- If relative AllTrails trail reviews accurately measure relative trail sports participation, then:
  - Relative participation in trail sports is highest and comparable in Colorado and Utah, despite an absolute greater number of trails in Colorado than in Utah.
  - Relative participation in trail sports is lowest in Nevada, which also has the lowest number of trails of all target states.
- Assuming that relative Mountain Project annual state page views are an accurate measure of relative rock climbing participation:
  - Relative rock climbing participation is highest in Colorado and Utah, despite Colorado having approximately twice as many absolute climb routes as Utah.
  - Relative rock climbing participation is lowest in Arizona, despite having the third-highest absolute number of climb routes across target states.
- Assuming that relative mountain biking ride logs are an accurate measure of relative mountain biking participation:
  - Relative mountain biking participation is highest in Utah; in particular, roughly twice that of Colorado despite Colorado having twice Utah's absolute number of climb routes, according to Mountain Project.
  - Of all target states, relative mountain biking participation is lowest in Nevada, which is also the only target state below the relative national mountain biking participation rate.

9. RECOMMENDATIONS

Recommendations for Existing Data Collection

Membership Data

As a result of our analysis, we believe POW would greatly benefit from maintaining comprehensive and tidy internal data across all software and information acquisition formats (e.g., Salesforce, Phone2Action, member surveys, social media metrics).

Certain information is vital to accurately characterizing POW's membership base, which is the first step to understanding where audience/membership expansion efforts should be concentrated. The most important data points that were not consistently included in POW's 2021 membership data are "state of residence" and "sports of interest." These two data points alone have the potential to show POW exactly how their membership is distributed across the U.S. and where sport interests are concentrated. For example, if all POW members included these data points, POW could analyze their membership to see where a certain sport is most popular and determine where to focus related communication efforts.

Specific recommendations to address this issue include the following:

- Make critical fields on the membership signup form mandatory (i.e., state and sports).
- Consider making other demographic fields mandatory (e.g., gender, race/ethnicity, political affiliation, zip code) with a decline-to-state option for members who prefer not to answer.
- Do not allow "free response" type answers for critical data points—these should be multiple-choice format instead (e.g., do not allow members to type in their sport of interest because free-response leads to different data points for "snowboarding" vs. "snowboard" vs. "Snowboarding" vs. "snow boarding").
- Avoid repetitive fields in member surveys or platforms (e.g., "What is your favorite sport?" and later "Which sports are you interested in?").

Participation Data

POW should leverage its existing partnerships with Strava, Gaia GPS, and other organizations to request nationwide participation data that could inform strategic decisions. POW could also consider pursuing new partnerships with organizations such as Mountain Project or AllTrails to

create a mutually beneficial relationship that would help POW better understand the distribution of rock climbing and trail sports participants in their target states.

POW may also consider investing in a national representative survey to collect data on state-specific sport participation trends. According to our research, this data does not currently exist. The closest data is the national participation report from OIA, but OIA informed us that this data could not be accurately projected at the state level. A survey of state-level sport participation would provide POW with robust data that would justify targeting communication and advocacy efforts in specific geographic areas with high concentrations of outdoor recreation participants.

Alliance Distribution

As POW's advocacy efforts shift to the target states, we recommend that POW analyze the distribution of existing Athlete, Science, Brand, and Creative Alliances within and across target states. Additionally, if POW has access to Alliance member social media metrics and reach, we believe that POW could use these metrics to identify the number of people that each member reaches in each target state.

Recommendations for Audience Expansion

Based on our analysis of POW's member data sourced from both Salesforce and Phone2Action, the following are our recommendations on areas for POW to concentrate its audience expansion efforts.

General Audience

POW's 2021 membership data shows that POW's membership is highly underrepresented in Arizona compared to the other target states as well as POW's national membership rate. Arizona has the lowest absolute number of POW members, even though it has the highest population of the five target states. It also has the lowest membership rate (number of POW members per capita). Therefore, we recommend that POW focus general audience expansion efforts on the state of Arizona.

Given that Phone2Action is an advocacy tool, if POW has not already done so, we recommend that POW query the data on the Phone2Action platform to determine which members have taken the most state and federal actions across target states. Comparing where active members reside and whether their location matches up with campaign needs would allow POW to focus on recruiting members in strategic locations.

We believe there is an opportunity for POW to expand its membership and its audience (i.e., social media reach from POW's account or any of the Alliance member accounts, general POW communications, etc.) to climb and trail sport communities within the target states. However, we

were not able to estimate the proportion of climb and trail sports participants that are POW members or that are within POW's audience.

Note: the following recommendations are made based upon the analysis of proxy data for sport participation in a given state, which includes both state residents and non-residents.

Mountain Biking Audience

According to data from Trailforks, a crowd-sourced trail platform predominantly used by mountain bikers, Utah has the highest rate of mountain biking ride logs (number of recorded ride logs per capita) followed by Montana, Colorado, Arizona, and finally, Nevada. All of the target states (except Nevada) have a higher rate of mountain biking ride logs than the national average. Assuming that this proxy accurately represents mountain biking participation, we recommend that POW focus messaging related to climate change impacts on mountain biking in its target states in the following order: Utah, Montana, Colorado, Arizona, and then Nevada.

Rock Climbing Audience

According to data from Mountain Project, a crowd-sourced online climbing guide and resource for climbers across the globe, Utah has the highest proportion of state page views (number of state page views per capita), followed closely by Colorado. The remaining states in order of descending number of page views per capita are Nevada, Montana, and finally, Arizona. Assuming that this proxy is an accurate representation of rock climbing participation, we recommend that POW focus messaging related to climate change impacts on rock climbing in its target states in the following order: Utah, Colorado, Nevada, Montana, and then Arizona.

General Trail Sport Audience

According to data from AllTrails, an online platform for trail enthusiasts around the world, Colorado has the highest rate of state trail reviews (number of state trail reviews per 10,000 people), followed closely by Utah. The remaining states in order of descending number of trail reviews per capita are Montana, Arizona, and finally, Nevada. Assuming that this proxy is an accurate representation of general trail sport participation, we recommend that POW focus messaging related to climate change impacts on trail sports in its target states in the following order: Colorado, Utah, Montana, Arizona, and then Nevada.

Diversifying POW's Audience

Although outdoor equity is not POW's specific mission, we know that climate change is a justice issue as much as it is an environmental issue and that climate action cannot be achieved without racial and social justice. This means that all environmental organizations must do their part to ensure their advocacy efforts account for America's diverse perspectives and demographics. Outdoor recreation organizations like POW must recognize that Black, Indigenous, people of color

(BIPOC), and other historically marginalized and excluded communities from the outdoors are a growing segment of the Outdoor State. With this in mind, we recommend that POW strategically consider that these participants may not yet see themselves represented in POW's Alliances. This growing segment may also not yet feel motivated to take climate action by POW's messaging because it may not resonate or align with the lived experiences of themselves or their community. To appeal to these growing segments of the Outdoor State, we recommend that POW continue prioritizing the diversification of its Athlete, Science, Brand, and Creative Alliances to include BIPOC people, people living with disabilities, low-income people, or people that have otherwise been underrepresented in climbing and trail sports.

The way POW carries out these efforts will be critical to recruit and retain diverse Alliance members. We recommend that POW place the utmost importance on ensuring that this outreach is ethical and responsible so that these relationships are not extractive and ultimately benefit POW and the communities that the diverse Alliance members represent. One way to do this could be to hire an experienced Diversity, Equity, Inclusion, and Justice (DEIJ) professional to work on staff at POW or contract with an experienced DEIJ and outdoor equity consulting company to evaluate processes and messaging. We firmly believe that a professional with experience in the intersection of DEIJ and the outdoor industry can help POW create meaningful and lasting relationships with diverse communities in the outdoor industry.

Lastly, we want to acknowledge and celebrate the work that DEIJ and outdoor equity professionals and organizations have done to date. Without their leadership and courage to challenge the status quo and reclaim space for historically underrepresented communities in the outdoors, the field would not be as inclusive and welcoming as it is today. As POW advances along its DEIJ journey, we urge POW to intentionally consider whether any unintended consequences of the organization's diversity efforts arise, such as unintentionally erasing or ignoring the efforts of the leaders already doing this work.

Recommendations For Strategic Communication Materials

Assessing the Impact of Strategic Communication Materials

Given the necessary time and resources, we believe that POW would benefit from assessing the impact of the Strategic Communication Materials produced by this project. To assess the impact of the Alliance Toolkits, POW could use a simple metric such as tallies of the number of athletes trained using the materials and their total reach on social media. State Fact Sheets would be more difficult to assess, as they will be an internal reference document for POW. However, POW could tally the number of actions and total reach of the campaigns that these documents educate to measure their impact.

Conducting these assessments will allow POW to generate useful data on the relative importance of these materials and, more importantly, quantify the breadth and depth of their reach, which can be used as promotional materials for POW's development team.

Potential Messaging Frameworks

The primary climate impact experienced by rock climbing and trail sports participants is increased barriers to accessing recreational opportunities. This provides several opportunities for high-level messaging campaigns that can be expanded upon to detail the experiences of specific participants, sport categories, and geographies. Potential messaging frameworks include the following:

- "Summer is no longer the season for summer sports."
- "Summer is not what it used to be."
- "We know that winter isn't winter anymore…but summer isn't summer anymore either."
- "Our athletes had a feeling that something was different. This report shows that they are onto something."

Recommendations for Additional Research

Answering the question "How will climate change impact the rock climbing and trail sports communities?" requires connecting climate impacts to outdoor recreation: we found that hotter temperatures, bigger and more frequent wildfires, and poor air quality will negatively affect the ability of participants to recreate.

However, constructing an empirical framework to answer this question is a significant undertaking that requires time and resources far beyond those available to this group. We identified the following lines of research that could be of interest to researchers seeking to more robustly quantify climate impacts on the rock climbing and trail sport communities.

Climate Impact Perception

While it was not feasible under the scoping of our project to administer a large-scale survey that seeks to understand the climate impacts that the Outdoor State is most concerned about, a large survey that accounts for national participation rates in all sport categories and asks respondents what climate impacts they are most concerned about could provide valuable quantitative data to inform POW's messaging efforts.

This project outlined current and projected climate impacts; however, it is extremely difficult to quantify how these will impact sports participants. When it comes to climate activism, perception is reality, and obtaining a clear and quantifiable dataset of the climate impacts that the Outdoor State is most concerned with will allow POW and other advocacy organizations to tailor their messaging to account for these perceptions.

Baseline or Optimal Conditions

Quantifying how climate change will impact the rock climbing and trail sports communities would greatly benefit from a quantitative assessment of the baseline or optimal conditions needed for participants to meaningfully engage in each activity. Due to the disparate nature of these sports, establishing a nationally representative baseline or optimal conditions may require administering a survey to representative populations of each community in all target regions. The information gathered in such a survey would allow POW to create better-targeted messaging to highlight the specific threats that climate change poses to individual subgroups of the Outdoor State, potentially increasing engagement.

Dropout Rates

Hot temperatures affect recreational conditions, but there is currently no primary research that empirically links hotter temperatures with reduced participation. One way to do this would be to identify a series of competitive races in the trail running and mountain biking communities, identify the "dropout rate" in each year, and identify years in which the race was held under "high heat conditions." If this study was conducted properly, it could allow one to conclude that high heat days increase dropout rates during races, providing quantitative evidence that hotter temperatures reduce participation.

Valuation of Trails

It is difficult to identify the economic value of the rock climbing and trail sports communities. However, relevant metrics include gear sales, camping fees collected, and a few economic studies that estimate the value that these sports participants provide to communities located near recreational sites. However, these figures estimate the current economic value of these recreational activities and do not quantify how climate change will affect the sport.

One way to quantify the impacts of climate change on rock climbing and trail sports is to analyze the dollar value of a mile of trail. This could be performed by administering a contingent valuation survey, which would ask respondents to assign a discrete dollar value for one mile of trail in a particular region. Another way to do this would be to analyze the cost of maintaining and rebuilding these trails using USFS data and federal maintenance allocation estimates.

Services like onX, Strava, and Gaia likely have the total number of miles of trail per state. This data would allow one to provide a dollar value estimate of the recreational value that is jeopardized when trails are burnt by wildfire, closed due to wildfires or heat, or washed away due to erosion.

Spatial Impact Assessment

Various government agencies such as NASA and NOAA have detailed spatial datasets of regions that have been and are projected to be affected by increased temperatures, droughts, precipitation

events, wildfires, and poor air quality. Obtaining datasets such as these and overlaying them with spatial datasets displaying the location of rock climbing hotspots, mountain biking trails, and hiking trails would allow POW to more precisely identify regions that are projected to experience climate impacts over a 50–100 year period. It could also provide accessible visuals that may increase the impact of messaging. Coupled with the economic value of a mile of trail, or similar contingent valuation surveys, one could identify specific regions vulnerable to climate impacts and quantify the dollar value of recreation that is at stake.

Timing and Location

As POW seeks to increase messaging efficacy to target audiences within the climb and trail sports communities, temporal analyses of visitation on relevant platforms (e.g., Mountain Project, AllTrails, Trailforks) and geographical visitation data (e.g., via Strava) could be leveraged to better understand patterns of geographical interest throughout the calendar year.

A temporal analysis of state or subarea interest and visitation trends could be used by POW to inform marketing efforts throughout the year and to inform the timing and location of targeted campaign messaging. For example, if Mountain Project's Moab page were found to receive much higher visitation during fall than it does during spring, POW may conclude that advocacy efforts in this geographical area would be better suited to launch in the fall instead of spring. Despite data and scope limitations for this current project, an analysis of this type may prove valuable to POW marketing and advocacy efforts in the future.

10. Meet the Team

Matt Koller is a writer, photographer, and environmental educator who aims to use his personal experiences and training in environmental science to inspire conservation of the natural world and advocate for policies that promote the sustainable use of resources. While at Bren, Matt specialized in Coastal Marine and Resources Management and Strategic Environmental Communications and Media. He loves spending his free time surfing, skiing, biking, hiking, and dancing.

Karla Garibay Garcia is a marine and environmental justice policy professional whose work is rooted in science, social justice, and intersectionality. While at Bren, Karla specialized in Coastal Marine Resources Management with a focus in Strategic Environmental Communication and Media. Karla loves to spend her free time outdoors, preferably without cell reception, and with good friends.

Sage Kime is an energy and environmental justice professional with experience in the renewable energy industry and environmental/social justice research. While at Bren, Sage specialized in Energy & Climate and researched the equity implications of low carbon energy transitions. Sage loves collecting vintage clothing, organizing community markets, and spending time outdoors with her two dogs.

Will Geiken is a former outdoor educator who hopes to help create policies that mitigate both climate change and societal inequities. While at Bren, Will specialized in Economics and Politics of the Environment with a focus in Strategic Environmental Communication and Media. When he is not working, Will is typically running, surfing, or pursuing some other means of remaining outside for as long as possible.

Sam Fearer is a passionate outdoorsperson who hopes to leverage a "connection to place" in order to support meaningful environmental action. In his free time, Sam loves surfing, backcountry climbing, and making the most of daylight hours. While at Bren, Sam specialized in Corporate Environmental Management, Coast & Marine Resource Management, and Strategic Environmental Communications.

11. APPENDICES

Appendix 1. State Fact Sheets

Along with the deliverables required by the Bren School, this project produced several additional deliverables for Protect Our Winters to help guide their advocacy efforts. The State Fact Sheets outline climate change-related observations, trends, and projections in each of POW's five target states (Arizona, Colorado, Montana, Nevada, Utah), relating to the unique natural and economic resources valued by residents and recreationists within each state.

By employing a "What is at stake?" framing, these materials will inform POW's Alliance members on climate risk in each target state and help inform subsequent advocacy efforts. The fact sheets included below represent nearly-finalized drafts, although additional editing may be performed by Protect Our Winters before their internal publication. Additionally, all data sources were referenced in Winter 2022 and are subject to change over time.

Arizona Fact Sheet

STATE OVERVIEW

Hot summers, mild winters, and a rugged landscape of deserts, mountains, and river-hewn canyons make Arizona one of the most picturesque but underrated recreation destinations in the American West. This is the Grand Canyon state.

According to the U.S. Census, Arizona currently has the fourth-fastest growing population in the country. Residence in the state is concentrated primarily within Maricopa County (64%), which is home to the Phoenix metropolitan area and has the fastest growing population of any county in the U.S. Arizona's land is largely divided between federal management (42%), and tribal management (27%), with the remainder overseen by state and private parties. The environmental stability of these lands supports Arizona's outdoor industry—an estimated $9.6 billion (2.6%) contribution to state GDP annually. This value continues to grow in Arizona and does so at a rate 1.1% faster than national averages.

But the impacts of climate change threaten outdoor recreation—both now, and in the future.

From 2011 to 2020, Arizona was impacted by 12 separate billion-dollar climate disaster events—one more than that of the preceding decade. Of these events, 5 were due to wildfire, and 7 were due to drought. In addition to these highly-visible impacts, there are also many dispersed, but equally persistent, impacts of climate change on outdoor recreation in the state. As climate change continues, Arizonans are likely to face diminished access to the sports that define their lifestyles as well as lessened economic productivity in their communities.

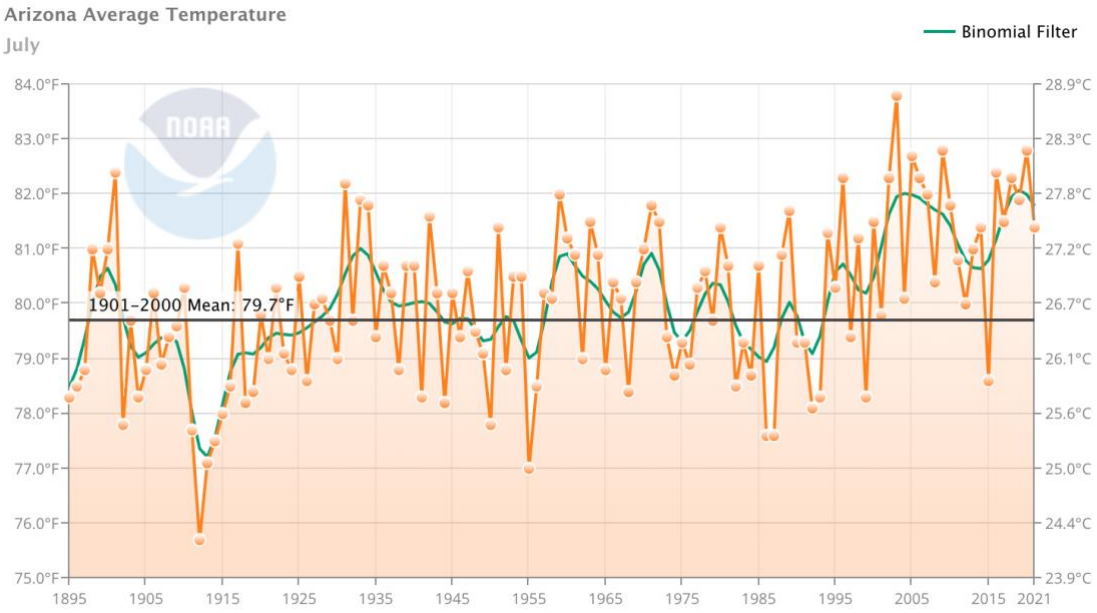
CLIMATE IMPACTS ON ROCK CLIMBING AND TRAIL SPORTS

The impacts of climate change create multiple barriers to access for the rock climbing and trail sports communities. Heat, reduced air quality, and increased droughts all threaten the health and well-being of outdoor enthusiasts, while more frequent wildfires and trail degradation from increased water runoff physically prevent enthusiasts from participating in the sports that they love.

Heat

⇨ Hotter temperatures resulting from climate change threaten the health of rock climbers and trail users by compromising the body's ability to regulate internal temperatures, which increases both the frequency and severity of heat-related illnesses.

- Temperatures in Arizona increased by about 2.5ºF over the 20th century.
- Arizona had the fastest rate of temperature increase out of any state from 1912 to 2012.
- Extreme heat days lead to public trail closures in Arizona to protect recreationalists.
- In 2021, Phoenix approved a pilot program designed to restrict use of certain trails during extreme heat.
- Arizona currently averages over 50 "dangerous heat days" per year (heat index of 105F or higher) and is projected to increase to almost 80 per year.



Annual variation in average July Temperatures. Published December 2021, retrieved on January 4, 2022 from NOAA.

Wildfire

⇨ Climate change is contributing to larger and more frequent wildfires in the Western U.S., thereby decreasing access for both rock climbers and trail users due to recreation area closures.

- There were 4 times as many large fires (1000+ acres) on USFS land in Arizona from 2005-2015 than from 1970-1980.
- Arizona had the third highest number of wildfires and number of acres burned by wildfires in the U.S. in 2020.
- 2.9M Arizonans live within the Wildland Urban Interface zone, meaning wildfires directly threaten 45% of the state's population.
- In June 2021, Arizona closed the Coconino and Kaibab national forests due to wildfire danger.
- Arizona's average number of days with high wildfire potential is projected to increase from 80 days per year to 115 days per year by 2050.

Air Quality

⇨ As a result of climate change, wildfire smoke, dust, and surface-level ozone concentrations are increasing. Exposure to these compounds is correlated with increased mortality and respiratory issues such as asthma, chronic obstructive pulmonary disease, bronchitis, and pneumonia, thus decreasing safe access for both rock climbers and trail users.

- The number of smoke days in Phoenix, Tucson, and Mesa more than doubled comparing the period of 2016-2020 with 2009-2013.
- People living in Arizona are disproportionately impacted by asthma when compared to the national average.
- For the ALA's State of the Air Report, most counties in Arizona are assigned a grade between "C" and "F" due to the number of high ozone days.

Drought

⇨ Drought does not generally represent a direct threat to rock climbers and trail users, but it's role in increasing wildfire risk, dust generation, and higher rates of erosion threaten both access to recreation areas and the health of those recreating.

- In February 2022, 56.7% of Arizona was experiencing at least moderate drought, 25.9% of Arizona was experiencing severe drought, and 5.1% was experiencing extreme drought.
- In 2021, the state hit a record high in terms of drought severity, which was estimated to be one of the worst in the region in the last 1200 years.
- The longest drought on record in Arizona lasted nearly 10 years, beginning on August 18, 2009, and ending on June 4, 2019.
- On December 1, 2020, 76.81% of Arizona was experiencing exceptional drought (the highest drought level), making it the most intense period of drought in state history.
- Average precipitation in Arizona has been decreasing steadily, especially during the spring/summer months.

Meltwater Runoff and Flooding

⇨ The increasing severity of storms resulting from climate change leads to severe runoff and flooding events that erode trail systems and prevent rock climbers and trail users from accessing recreation areas.

- To be updated as additional Arizona-specific information is produced.

OUTDOOR RECREATION ECONOMY

Arizona's outdoor recreation economy contributes significantly to state GDP and employment. As such, climate change's potential impacts on recreation demand pose a threat to Arizona's economy as a whole.

In 2019 alone, Arizona's outdoor industry:

- Created $9.6 billion in added value, accounting for 2.6% of state GDP.
    - Climbing, hiking, and camping alone contributed $65.6M.
- Created 110,172 jobs, accounting for 2.8% of state employment.

Compared to the outdoor industry of other American states:

- Value added is growing faster in Arizona– 1.1% faster than the national average.
- Employment generated is growing faster in Arizona– 0.2% faster than the national average.
- Compensation for related jobs is increasing faster in Arizona– 1.2% faster than the national average.

RECREATION SUMMARY

Arizona has a diverse landscape, with resident populations concentrated in the expansive Salt River Valley (Phoenix metropolitan area) and recreation opportunities dispersed throughout the arid deserts of the south and mountainous Colorado Plateau region of the north. The state as a whole contains 3 national parks, 8 national monument and conservation areas, 31 state parks, and 6 national forests.

Arizona residents are more likely to participate in hiking than the average American, with approximately 59% of the state's residents participating in outdoor recreation each year.

ROCK CLIMBING

Where

Cochise, Sedona, Mt. Lemmon, Paradise Forks, the VRG. Arizona is a state with options for every climber, offering challenge and adventure in numerous areas nested throughout the state.

- Mountain Project lists a total of 11,687 routes in Arizona
    - Of those routes 35% are in central Arizona, 34% are in southern Arizona, and 31% are in northern Arizona.

Spotlight: Mt. Lemmon

Three hours south of Phoenix and just north of Tucson, Mt. Lemmon sits nested within the arid Santa Catalina Mountains. With over 1500 routes and crags ranging in elevation from 2500ft to 9000ft, Mt. Lemmon offers reliable climbing during colder months, and a respite from Arizona's searing heat during hotter months. Predominantly a sport climbing venue, this area offers intro climbing for newcomers and powerful but intricate climbing for seasoned pros. With views of the

Sonoran desert below and sub-alpine throughout its higher elevations, Mt. Lemmon is a special area for resident and visiting climbers alike.

When

Climbing season in Arizona is location dependent.

- Summer climbing is popular in the Northern Arizona region near Flagstaff, allowing climbers to escape the often extreme heat in other regions of the state.
- Climbing throughout the rest of the state is accessible during other seasons.

TRAIL SPORTS (MOUNTAIN BIKE/HIKE/RUN)

Where

Although there is a greater concentration of trails in the mountainous regions of Arizona, there are plenty of opportunities throughout the state. According to a year-long economic study conducted at the University of Arizona, an estimated 59.2% of Arizona's adult population used trails in the state for non-motorized recreation approximately 83,110,000 times—an average of 27 trail visits each.

Estimations of trail use and length vary between sources:

- According to Mountain Bike Project, Arizona has 6,048 miles of mountain biking trails.
- According to Hiking Project, Arizona has 9,434 miles of hiking trail.
- According to Alltrails, Arizona has 3,227 hiking trails (total mileage not listed).

Spotlight: Flagstaff

Home to elite endurance athletes from all disciplines, Flagstaff is one of the premiere trail sport destinations in the U.S. The city is effectively surrounded by open-spaces where trail sport participants can climb mountains, descend through canyons, and everything in between. The added perks of high altitude training make the beautiful scenery all the more appealing.

When

Arizona's warm climate allows for year-round trail sports throughout much of the state.

ADDITIONAL RESOURCES

- Current AQI: Click here
- Current Smoke Exposure: Click here
- Current Drought Conditions: Click here
- Data on the Economic Value of National Parks in AZ: Click here
- Study on the Economic Value of State Parks in AZ: Click here
- Study on the Economic Value of Trails in AZ: Click here
- Fourth National Climate Assessment, Southwest Region: Click here

Colorado Fact Sheet

STATE OVERVIEW

The state of Colorado and outdoor recreation are practically synonymous. Named for the "ruddy" color of the red sandstone that permeates the Colorado front range, the state's opportunities for outdoor recreation extend across the entire state in all seasons. From the high plains to the snow-capped Rocky Mountains, Colorado has seemingly endless opportunities to enjoy the outdoors.

This abundance has led Colorado to becoming one of *the* outdoor recreation hubs of the U.S. and has contributed to an extensive outdoor industry. Despite having the 21st highest population by state, in 2019 Colorado had the 9th highest value of outdoor recreation among states. In total, outdoor recreation contributed an estimated $12.2 billion (3.1%) to state GDP that year.

But the impacts of climate change threaten outdoor recreation—both now, and in the future.

From 2011 to 2020, Colorado was impacted by 29 separate billion-dollar climate disaster events—more than doubling that of the preceding decade. Of these events, 5 were due to wildfire, 6 were due to drought, 16 were due to severe storms, and 2 were due to flooding events. In addition to these highly-visible impacts, there are also many dispersed, but equally persistent, impacts of climate change on outdoor recreation in the state. As climate change continues, Coloradans are likely to face diminished access to the sports that define their lifestyles as well as lessened economic productivity in their communities.

CLIMATE IMPACTS ON ROCK CLIMBING AND TRAIL SPORTS

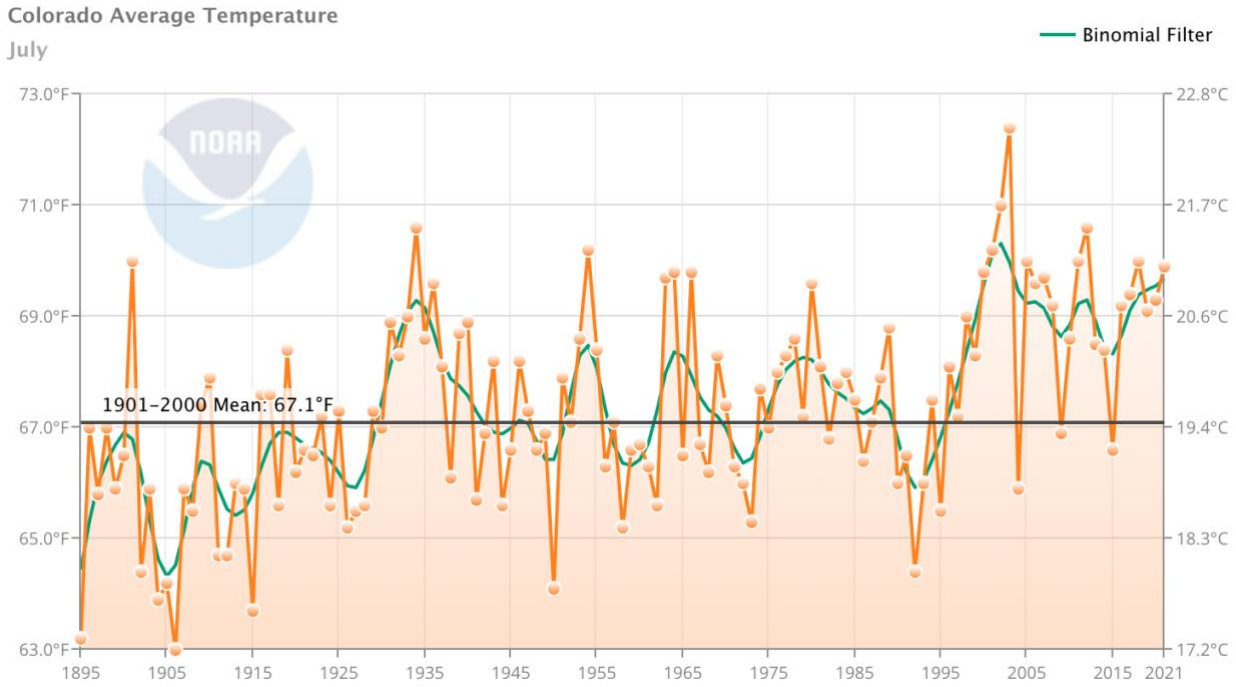
The impacts of climate change create multiple barriers to access for the rock climbing and trail sports communities. Heat, reduced air quality, and increased droughts all threaten the health and well-being of outdoor enthusiasts, while more frequent wildfires and trail degradation from increased water runoff physically prevent enthusiasts from participating in the sports that they love.

Heat

⇨ Hotter temperatures resulting from climate change threaten the health of rock climbers and trail users by compromising the body's ability to regulate internal temperatures, which increases both the frequency and severity of heat-related illnesses.

- Temperatures in Colorado increased by 2.5ºF over the 20th century.

- Colorado had the 10th fastest rate of temperature increase out of any state from 1912 to 2012.
- Climate models project Colorado will warm by 2.5ºF by 2025 and 4ºF by 2050, relative to the 1950–99 baseline.



Annual variation in average July Temperatures. Published December 2021, retrieved on January 4, 2022 from NOAA.

Wildfire

⇨ Climate change is contributing to larger and more frequent wildfires in the western U.S., thereby decreasing access for both rock climbers and trail users due to recreation area closures.

- 4 of the 5 largest fires in Colorado history have occurred since the start of 2018
- The 20 largest fires in Colorado history have occurred since the start of 2001.
- In 2020, 665,000 acres burned in Colorado and national forest land was closed in five counties.
- Approximately 30,000 acres in Rocky Mountain National Park (10% of the Park) were impacted by the East Troublesome and Cameron Peak Fires of 2020.
- The Cameron Peak Fire (2020) burned hundreds of miles of trails in Larimer County.
- The Calwood fire (2020) closed the Heil Valley Ranch and Bobcat Ridge trails indefinitely.
- The Grizzly Peak fire (2020) burned parts of No Name Canyon, home to several popular climbing routes.

- The Waldo Canyon fire (2012) closed down all of Rampart Range Road for two years, preventing access to climbing spots like Parachute Rock, Devil's Head, Scorpio Crack, Jackson Creek, Split Rock, The Taj Mahal and Cabin Ridge Rock.
- The National Research Council (2011) projects that if temperatures increase by 1.8°F (1°C) ... there will be a 470% increase in the area burned on the Colorado Plateau and a 656% increase in the southern Rocky Mountains.

Air Quality

⇨ As a result of climate change, wildfire smoke, dust, and surface-level ozone concentrations are increasing. Exposure to these compounds is correlated with increased mortality and respiratory issues such as asthma, chronic obstructive pulmonary disease, bronchitis, and pneumonia, thus decreasing safe access for both rock climbers and trail users.

- From 2016 to 2020 residents of Jackson County, Colorado experienced an additional month of smoky skies each year, the largest increase of any Colorado county.
- From 2016 to 2020 Denver and Colorado Springs residents experienced more than two weeks of additional smoky days each year.
- From 2016 to 2020 the Front Range, western Slope and northern regions of the state saw their number of smoke days nearly double, effectively tying the eastern Plains for the smokiest skies with an average of about 50 smoke days each year.
- In 2021 the Front Range experienced a record-breaking year for the total number of days with hazardous surface-level ozone concentrations.

Drought

⇨ Drought does not generally represent a direct threat to rock climbers and trail users, but it's role in increasing wildfire risk, dust generation, and higher rates of erosion threaten both access to recreation areas and the health of those recreating.

- In January 2022, 95.5% of Colorado was experiencing at least moderate drought, 67.1% of Colorado was experiencing severe drought, and 22.3% was experiencing extreme drought.
- Aspen diebacks are predicted to increase due to increased drought.
- Visitors to State Forest Park in Colorado experienced more enjoyment when viewing healthy forests, suggesting Coloradans enjoyment will decrease as forests die-off.
- By 2050 Colorado is projected to experience some of the most severe summer droughts in the country.

Meltwater Runoff and Flooding

⇨ The increasing severity of storms resulting from climate change leads to severe runoff and flooding events that erode trail systems and prevent rock climbers and trail users from accessing recreation areas.

- The Young Gulch Trail in Poudre Canyon, Colorado was closed for seven years after being demolished in post-fire flooding.
- Flooding in the Colorado front range is expected to increase in the summer due to faster snowmelt.

OUTDOOR RECREATION ECONOMY

Colorado's outdoor recreation economy contributes significantly to state GDP and employment. As such, climate change's potential impacts on recreation demand pose a threat to Colorado's economy as a whole.

In 2019 alone, Colorado's outdoor industry:

- Created $12.2 billion in added value, accounting for 3.1% of state GDP.
    - Climbing, hiking, and camping alone contributed $118.5M.
- Created 149,140 jobs, accounting for 3.8% of state employment.

Compared to the outdoor industry of other American states:

- Value added is growing faster in Colorado– nearly 1.1% faster than the national average.
- Employment generated is growing faster in Colorado– 0.1% faster than the national average.
- Compensation for related jobs is increasing faster in Colorado– 1.0% faster than the national average.

RECREATION SUMMARY

Colorado has a plethora of opportunities for recreation, and while the majority are concentrated in the Rockies in the western half of the state, there are plenty of opportunities along the eastern plains as well. The state as a whole contains 4 national parks, 5 national monuments, 1 national recreation area, 42 state parks, 11 national forests, and 2 national grasslands.

World-class climbing and trail networks across the state make Colorado one of the world's premiere destinations for both rock climbing and trail users. Because of this bounty, 71% of Coloradans participate in outdoor recreation each year.

ROCK CLIMBING

Where

While climbing opportunities exist across the state, venues in and along the Rocky Mountains are amongst the most visited in the world. Sweeping vistas, easy access, and seemingly countless options allow climbers of all ability levels to explore and to test themselves in a variety of locations.

- Mountain Project lists a total of 29,819 routes within Colorado, representing the highest concentration of climbing opportunities (*routes per square mile*) in any state.
- The vast majority of Colorado climbing takes place in western Colorado, in and below the Rocky Mountains.

Spotlight: Boulder Climbing

Boulder Canyon. Eldorado Canyon. The Flatirons. Need we say more? The city of Boulder is aptly named and represents one of the most iconic climbing hubs in the country.

- Boulder Canyon.
    - Granite climbing located throughout a scenic canyon just west of town.
    - Year-round, easy access, high visitation. Sport and trad. All difficulties.
- Eldorado Canyon ("Eldo").
    - Compact sandstone climbing located throughout a scenic canyon just south of town.
    - Year-round, easy access, high visitation. Sport and trad. All difficulties.
    - Located within a state park, managed access.
- The Flatirons.
    - Classic, easy scrambling along iconic front range formations, with a few challenging test pieces thrown in for good measure.

When

Prime climbing season in Colorado is location dependent but generally extends from May to October for the majority of locations.

- Warmer summer months allow rock climbers to venture to higher elevations within the Rockies.
- Colder spring temperatures and autumnal snows blanket higher elevations, shifting climbing activity to routes in the front range as well as locations in eastern Colorado.

TRAIL SPORTS (MOUNTAIN BIKE/HIKE/RUN)

Where

While trail users are concentrated in the Colorado front range and the Rocky Mountains, trail activities and opportunities spread across the state.

Estimations of trail use and length vary between sources:

- According to Mountain Bike Project, Colorado has 18,978 miles of mountain biking trails.
- According to Hike Project, Colorado has 23,552 miles of hiking trail.
- According to Alltrails, Colorado has 4,928 trails (total mileage not listed)

Spotlight: Colorado Springs

Seated below Pikes Peak, Colorado Springs is a destination for athletes of all disciplines. The ample outdoor spaces and 6,000 ft elevation make it an ideal spot for the U.S. Olympic Training Center. But the natural beauty and demanding conditions aren't for elite athletes alone. Whether at Garden of the Gods, Bear Creek Regional Park, Palmer Park, or even up Pikes' itself, trail sports enthusiasts have plentiful reasons to stay in love with what Colorado Springs has to offer.

When

As a result of Colorado's winters, trail sports can be only pursued year-round throughout much of the eastern state. In the Rockies, trail sports are limited during winter months due to snow and ice, although that presents an opportunity for the cross-country skiers, snowshoers, and other snow sport enthusiasts.

ADDITIONAL RESOURCES

- Current AQI: Click here
- Current Smoke Exposure: Click here
- Current Drought Conditions: Click here
- Colorado Climate Plan: Click here
- 2019 Statewide Comprehensive Outdoor Recreation Plan: Click here
- Economic Value of Grand Mesa, Uncompahgre, and Gunnison National Forests
    - Rock Climbing: Click here
    - Mountain Bikers: Click here
    - Hikers, Backpackers, Trail Runners, and Peak Baggers : Click here
- Economic Value of Mesa County Bureau of Land Management Trails: Click here
- Fourth National Climate Assessment, Southwest Region: Click here

Montana Fact Sheet

STATE OVERVIEW

From the rolling plains of the east to the grand and countless mountains of the west, Montana's vast and varied landscapes offer an open canvas for trail sports and rock climbing adventure. Named after the mountains that give the western half its rugged beauty, Montana is one of the premiere outdoor destinations in the U.S. This allure has contributed to a healthy outdoor industry in the state. In total, the outdoor industry generates an estimated $2.5 billion (4.7%) contribution to state GDP.

But the impacts of climate change threaten outdoor recreation—both now, and in the future.

From 2011 to 2020, Montana was impacted by 12 separate billion dollar climate disaster events—1.5 times that of the preceding decade. Of these events, 6 were due to wildfire, 3 were due to drought, 2 were due to severe storms, and 1 was due to a flooding event. In addition to these highly-visible impacts, there are also many dispersed, but equally persistent, impacts of climate change on outdoor recreation in the state. As climate change continues, Montanans are likely to face diminished access to the sports that define their lifestyles as well as lessened economic productivity in their communities.

CLIMATE IMPACTS ON ROCK CLIMBING AND TRAIL SPORTS

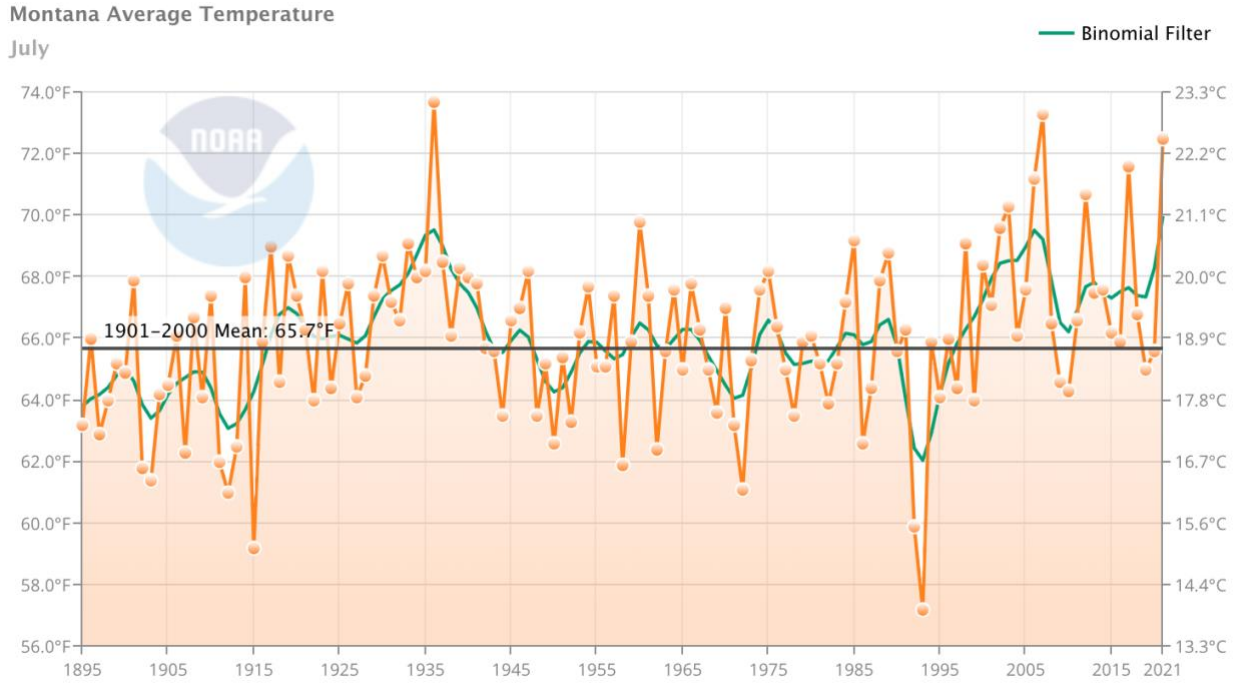
The impacts of climate change create multiple barriers to access for the rock climbing and trail sports communities. Heat, reduced air quality, and increased droughts all threaten the health and well-being of outdoor enthusiasts, while more frequent wildfires and trail degradation from increased water runoff physically prevent enthusiasts from participating in the sports that they love.

Heat

⇨ Hotter temperatures resulting from climate change threaten the health of rock climbers and trail users by compromising the body's ability to regulate internal temperatures, which increases both the frequency and severity of heat-related illnesses.

- Temperatures in Montana increased by almost 2.5ºF over the 20th century.
- "The 21st century has been the warmest period on record for Montana."
- Since 1985, Montana's temperature warming rate has been greater than the rest of the U.S.
- Montana is projected to experience 5-54 additional extreme heat days by 2050, with greatest increases in the northeast and south regions.

- Up to 2.5 weeks of 105ºF days are expected in the northeast and southeast regions of Montana by 2050.



Annual variation in average July Temperatures. Published December 2021, retrieved on January 4, 2022 from NOAA.

Wildfire

⇨ Climate change is contributing to larger and more frequent wildfires in the Western U.S., thereby decreasing access for both rock climbers and trail users due to recreation area closures.

- Wildfire frequency and severity is projected to increase in Montana.
- From 1970 to 2015 the average number of large wildfires (1,000+ acres) burning each year increased by 10.
- From 1970 to 2015 the average number of acres burned in wildfires each year increased by 134,000 acres.
- 62% of Montanans live in an area that is at elevated risk of wildfire.
- Fires reduce the value of and demand for recreation in Montana over time.

Air Quality

⇨ As a result of climate change, wildfire smoke, dust, and surface-level ozone concentrations are increasing. Exposure to these compounds is correlated with increased mortality and respiratory issues such as asthma, chronic obstructive pulmonary disease, bronchitis, and pneumonia, thus decreasing safe access for both rock climbers and trail users.

- Comparing 2009-2013 with 2016-2020, nearly every county in Montana experienced an increase in the number of smoke days per year.
- The American Lung Association ranked Missoula the 10th worst city in terms of the number of days with high PM 2.5.
- Smoke from nearby Western states and Canada negatively impacts Montana's air quality.
- Areas in Montana with more intense wildfire smoke and particulate matter exposure in the summer experience worse flu seasons the following winter.
- The risk of smoke days is projected to increase in every county in Montana from 2005 to 2050.

Drought

⇨ Drought does not generally represent a direct threat to rock climbers and trail users, but it's role in increasing wildfire risk, dust generation, and higher rates of erosion threaten both access to recreation areas and the health of those recreating.

- In February 2022, 89.8% of Montana was experiencing at least moderate drought, 85.9% of Montana was experiencing severe drought, and 48.9% was experiencing extreme drought.
- Longer summer droughts in Montana increase disease spread by mosquitoes that breed in stagnant water.
- Drought negatively impacts trail-using communities that rely on wild foods for sustenance.
- In 2016, 75% of Montana's mountainous weather stations (at 5,000 to 8,000 ft) reported a decrease in the percentage of precipitation falling as snow, which meant less water was stored in snowpack.
- The intensity of future droughts in Montana is expected to increase as temperatures rise.
- Montana's varying topography results in regional precipitation variations but winter, spring, and fall are projected to get wetter and summer to get drier.

Meltwater Runoff and Flooding

⇨ The increasing severity of storms resulting from climate change leads to severe runoff and flooding events that erode trail systems and prevent rock climbers and trail users from accessing recreation areas.

- The largest floods on record for Montana occurred in 2011, affecting most of the state at some point during winter, spring, and summer.
- Montana is projected to experience more frequent heavy rains during the spring thaw that cause severe flooding and erode trail systems.

OUTDOOR RECREATION ECONOMY

Montana's outdoor recreation economy contributes significantly to state GDP and employment. As such, climate change's potential impacts on recreation pose a threat to Montana's economy.

In 2019 alone, Montana's outdoor industry:

- Created $2.5 billion in added value, accounting for 4.7% of state GDP.
    - Climbing, hiking, and camping alone contributed $32M.
- Created 31,598 jobs, accounting for 4.5% of state employment.

Compared to the outdoor industry of other American states:

- Value added is growing slower in Montana– but only 0.2% slower than the national average.
- Employment generated is growing faster in Montana– 0.2% faster than the national average.
- Compensation for related jobs is increasing in Nevada– 1% faster than the national average.

RECREATION SUMMARY

Outdoor enthusiasts in Montana can experience everything from jaw-dropping glacial mountains to serene pastoral plains. Extensive access to outdoor recreation can be found at the 2 national parks, 1 national monument, 1 national recreation area, 9 national forests, or 56 state parks in the state. With expansive opportunities to get outside, Montana has one of the highest outdoor recreation participation rates in the country at 81%.

ROCK CLIMBING

Where

With the Northern Rocky Mountains and dozens of adjacent ranges defining the western half of the state, rock climbing is centered in Montana's western half.

- Mountain Project lists a total of 2,710 routes in Montana.
    - Of those routes, 65% are in southwestern Montana, 26% are in northwestern Montana, and 9% are in south central Montana.

Spotlight: Big Sky Climbing

Located in Montana's Southwest region, the Big Sky area offers something for everyone. From multipitch outings in the Beehive Basin's alpine playground to bouldering in the secluded gneiss wonderland of the Hidden Lakes region, Big Sky is a worthwhile stop for visiting climbers. With expansive views of glacial valleys and rushing rivers, the surroundings alone provide more than enough incentive to pack bags and head out.

When

Due to snow and ice, the prime rock climbing season in Montana runs from June to September.

TRAIL SPORTS (MOUNTAIN BIKE/HIKE/RUN)

Where

With more mountainous terrain in the western half of the state, the bulk of Montana's trail activity is located in that region. However, opportunities to pursue trail sports exist across the entire state.

Estimations of trail use and length vary between sources:

- According to Mountain Bike Project, Montana has 3,167 miles of mountain biking trails.
    - Of the 534 trails listed, 46.5% are in southwestern Montana, 45% are in northwestern Montana, and 8.5% are in eastern Montana
- According to Hiking Project, Montana has 12,288 miles of trails/
- According to Alltrails, Montana has 1,233 trails.

Spotlight: Bozeman

As it seems to become more popular by the day, the trails and other natural features surrounding Bozeman leave little doubt as to why. With an extensive trail system in the hills and mountains surrounding the town as well as easy access to the Gallatin National Forest just north of town, the opportunities for trail enthusiasts are among the best in the U.S.

When

Due to cold winter temperatures and the presence of snow and ice, trail recreation in Montana generally begins in the spring and carries through into the fall. That being said, there are plenty of snow sports that enthusiasts pursue in the months when trails aren't accessible.

ADDITIONAL RESOURCES

- Current AQI: Click here
- Current Smoke Exposure: Click here
- Current Drought Conditions: Click here
- Current Fire conditions: Click here
- Montana Climate Assessment: Click here
- Montana Statewide Comprehensive Outdoor Recreation Plan: Click here
- Recent Flooding in Montana: Click here
- University of Montana Study on Recreation Increase During COVID-19: Click here
- Fourth National Climate Assessment, Northern Great Plains Region: Click here

Nevada Fact Sheet

STATE OVERVIEW

Trees, mountains, deserts, and canyons—Nevada has it all. Named in reference to the "snow-capped" mountains of its higher elevations, in the eyes of the outdoor enthusiast the state's unique landscape is more synonymous with the blue skies, desert cliffs, and endless singletracks it has to offer.

Residence in the state is concentrated between Las Vegas' Clark County in the south (74%) and Reno's Washoe County in the west (15%). Over 80% of Nevada's land is managed by federal agencies, making it the state with the highest proportion of public land. The environmental stability of these lands supports Nevada's thriving outdoor industry—an estimated $5.5 billion (3.1%) contribution to state GDP annually. This value continues to grow in Nevada and does so at a rate 2.4% faster than national averages.

But the impacts of climate change threaten outdoor recreation—both now, and in the future.

From 2011-2020, Nevada was impacted by 12 separate billion-dollar climate disaster events—nearly doubling that of the preceding decade. Of these events, 5 were due to wildfire and 7 were due to drought. In addition to these highly-visible impacts, there are also many dispersed, but equally persistent, impacts of climate change on outdoor recreation in the state. As climate change continues, Nevadans are likely to face diminished access to the sports that define their lifestyles as well as lessened economic productivity in their communities.

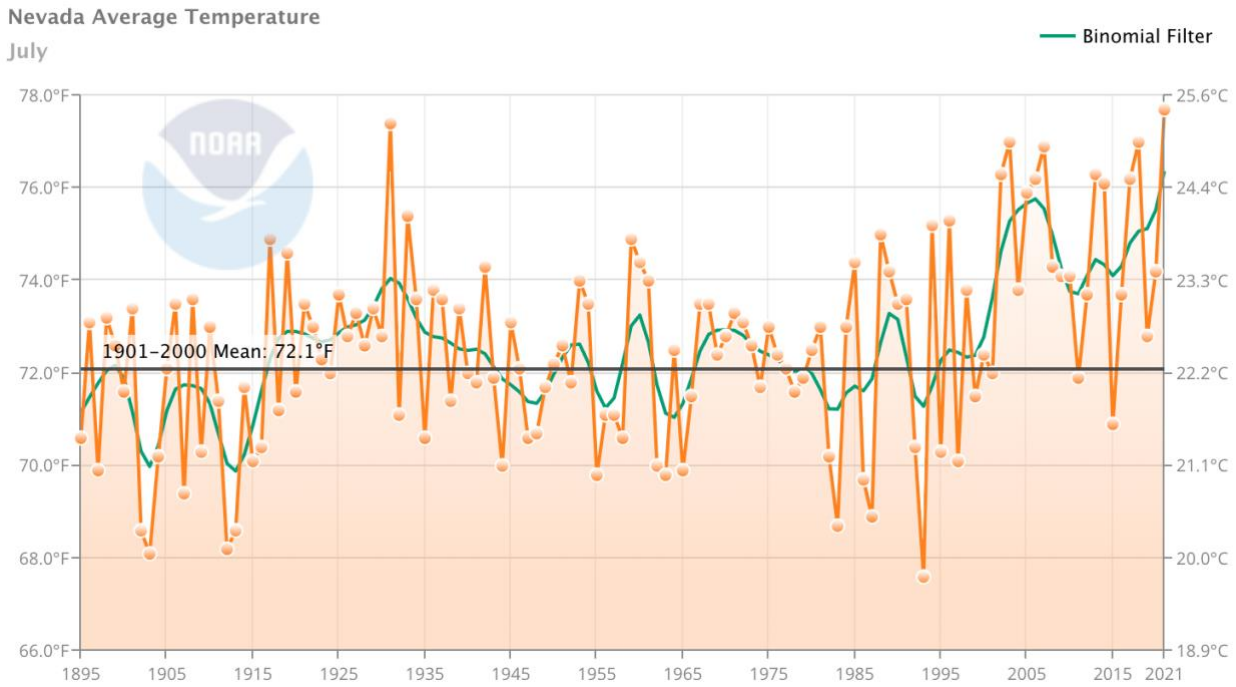
CLIMATE IMPACTS ON ROCK CLIMBING AND TRAIL SPORTS

The impacts of climate change create multiple barriers to access for the rock climbing and trail sports communities. Heat, reduced air quality, and increased droughts all threaten the health and well-being of outdoor enthusiasts, while more frequent wildfires and trail degradation from increased water runoff physically prevent enthusiasts from participating in the sports that they love.

Heat

⇨ *Hotter temperatures resulting from climate change threaten the health of rock climbers and trail users by compromising the body's ability to regulate internal temperatures, which increases both the frequency and severity of heat-related illnesses.*

- With a state-wide average temperature increase of 2ºF within just the past century, Nevada keeps getting hotter.
- Nevada had the 15th fastest rate of temperature increase out of any state from 1912 to 2012 according to a report by Climate Central using data from the United States Historical Climatological Network.
- According to Nevada's Department of Conservation & Natural Resources: *"By end of century, six extra weeks of hot days [>90ºF] are projected in most of the State under the reduced GHG emissions scenario ...and a scorching 10 to 12 more weeks of hot days under the high GHG emissions scenario."*



Annual variation in average July Temperatures. Published December 2021, retrieved on January 4, 2022 from NOAA

Wildfire

⇨ *Climate change is contributing to larger and more frequent wildfires in the Western U.S., thereby decreasing access for both rock climbers and trail users due to recreation area closures.*

- Wildfire burn acreage in Nevada has more than doubled over the past decade, representing an eight-fold increase since the 1970s.
- All 5 years of highest burn acreage in Nevada have occurred since 2005.
- Between 2017 and 2018 alone, over 2 million acres in Nevada were burned in wildfires.
- The 2018 Martin Fire was the largest in state history, burning over 400k acres and costing taxpayers $10.3M.
- 1.2M Nevadans live within the Wildland Urban Interface zone. Wildfire potential now directly threatens 46% of the state's population.

Air Quality

⇨ As a result of climate change, wildfire smoke, dust, and surface-level ozone concentrations are increasing. Exposure to these compounds is correlated with increased mortality and respiratory issues such as asthma, chronic obstructive pulmonary disease, bronchitis, and pneumonia, thus decreasing safe access for both rock climbers and trail users.

- Comparing 2016–2020 to 2009–2013:
  - Reno averaged 42 smoke days per year, a 123% increase.
  - Las Vegas averaged 24 smoke days per year, a 200% increase.
- Smoke from wildfires—both inside and outside state borders—increasingly impacts air quality during much of the summer months. In 2021, Clark County (Las Vegas) had already experienced 26 ozone exceedances by September, largely due to CA wildfires (especially the Caldor Fire).

Drought

⇨ Drought does not generally represent a direct threat to rock climbers and trail users, but it's role in increasing wildfire risk, dust generation, and higher rates of erosion threaten both access to recreation areas and the health of those recreating.

- As the driest state in the country, in January 2022, the entirety of Nevada was in a state of Moderate to Severe Drought. Extreme and Exceptional Drought have been declared in areas of highest population.
- While there is no designation more extreme than Exceptional, an additional 5-10% decrease in annual precipitation is expected in the southern portion of the state by 2050.

Meltwater Runoff and Flooding

⇨ The increasing severity of storms resulting from climate change leads to severe runoff and flooding events that erode trail systems and prevent rock climbers and trail users from accessing recreation areas.

- With a warming atmosphere, precipitation that would have previously fallen as snow is expected to fall as rain instead, failing to penetrate the desiccated surface of drought barren land.
- A 10-25% snow-to-rain conversion is expected throughout the entirety of the state by 2100.
- Peak-runoff rates throughout Nevada are projected to increase by 25-50% over historical levels by 2030-2059.

OUTDOOR RECREATION ECONOMY

Nevada's outdoor recreation economy contributes significantly to state GDP and employment. As such, climate change's potential impacts on recreation demand pose a threat to Nevada's economy as a whole.

In 2019 alone, Nevada's outdoor industry:

- Created $5.5 billion in added value, accounting for 3.1% of state GDP.
    - Climbing, hiking, and camping alone contributed $32.9M.
- Created 59,499 jobs, accounting for 3.1% of state employment.

Compared to the outdoor industry of other American states:

- Value added is growing faster in Nevada– 2.4% faster than the national average.
- Employment generated is growing faster in Nevada– 2.1% faster than the national average.
- Compensation for related jobs is increasing faster in Nevada– 2.1% faster than the national average.

RECREATION SUMMARY

Nevada has a diverse landscape, with resident populations and recreation opportunities concentrated in the open desert of the south (Las Vegas) and semi-arid foothills of the west (Reno). The state as a whole contains 2 national parks, 5 national monument and conservation areas, 24 state parks, and 42 wilderness areas.

World class climbing in the South and robust trail networks in the South and West make Nevada popular for rock climbers and trail users alike. In addition, the largest group of outdoor enthusiasts in Nevada—the state's own residents—are more likely to participate in various trail activities than the average American, and 57% of Nevada residents participate in outdoor recreation each year.

ROCK CLIMBING

Where

While climbing opportunities and potential are located throughout much of the state, the ease of access and world-class offerings of Clark County make Las Vegas a climber's paradise. Despite little attention prior to the 1980's, the year-round climbing options and route-types suited to every style have since transformed Las Vegas into a world-renowned climbing destination and the chosen home of several top athletes.

- Mountain Project lists a total of 4,832 routes in Nevada
    - Of those routes 86% are located in southern Nevada (Las Vegas-adjacent) and 13% are located in western Nevada (Reno-adjacent).

Spotlight: Las Vegas Climbing

- Red Rocks
    - Low elevation, deep history, high visitation, shoulder season sport and trad climbing destination (domestic/international).
    - Current visitation through managed access points exceeds 2M entries per year.
- Mt. Charleston
    - Higher elevation, summer sport climbing destination (domestic).
- Clark Mtn (CA)
    - Location of the long-standing hardest route in America, just outside of Las Vegas.

When

Climbing season in Nevada is location dependent.

- Summer month daytime climbing in the South is intolerable to most, forcing evening forays and trips to higher elevation (i.e. Mt. Charleston).
- Winter in the northern portion of the state can be snowy, forcing trips to the South and warmer climes.

TRAIL SPORTS (BIKE/HIKE/RUN)

Where

As in all other states, trail activities and opportunities in Nevada exist in a larger portion of the state than is relevant for rock climbing access alone. Despite this, the majority of Nevada's trail resources are concentrated in Clark County (Las Vegas) and Washoe County (Reno).

Estimations of trail use and length vary between sources:

- According to Mountain Bike Project, Nevada has 1,648 miles of mountain biking trails.
- According to Hiking Project, Nevada has 1,610 miles of hiking trail.
- According to Alltrails, Nevada has 975 hiking trails (total mileage not listed).

Across all sources, distribution of trail systems closely resembles distribution of state population and popular climbing regions.

Spotlight: Nighttime Trail Use in Las Vegas

Unique to the southern portion of the state is the vibrant nighttime trail scene that exists each summer in Las Vegas. Recently completed Late Night Trailhead parking and other staging areas serve as jump-off points for a robust community of hikers, trail runners, and mountain bikers who take advantage of after-hours trail access to escape the heat.

When

Due to Nevada's warm climate, trail sports can be pursued year-round throughout much of the state.

ADDITIONAL RESOURCES

- Current AQI: Click here
- Current Smoke Exposure: Click here
- Current Drought Conditions: Click here
- Nevada's State Climate Strategy: Click here
- Fourth National Climate Assessment, Southwest Region: Click here

Utah Fact Sheet

STATE OVERVIEW

The state of Utah was named in reference to the Ute Native Americans, which translates to *people of the mountains*. In addition to its breathtaking peaks and ranges, Utah is also home to stunning deserts, mesas, and incomparable canyonlands—all of which provide ample opportunities for rock climbers and trail sports enthusiasts. Residents of the state take full advantage of this landscape, with 72% of Utah residents participating in outdoor recreation each year.

The bounty of Utah's adventurous landscape is also a driving force in its flourishing outdoor recreation economy, as outdoor recreation contributed an estimated $6.4 (3.3%) billion to state GDP in 2019. The outdoor lifestyle and access to outdoor recreation opportunities are also among the most frequently cited factors for why businesses choose to headquarter in Utah.

But the impacts of climate change threaten outdoor recreation—both now, and in the future.

From 2011 to 2020, Utah was impacted by 10 separate billion-dollar climate disaster events—two more than the preceding decade. Of these events, 3 were due to wildfire, 6 were due to drought, and 1 was due to severe storms In addition to these highly-visible impacts, there are also many dispersed, but equally persistent, impacts of climate change on outdoor recreation in the state. As climate change continues, Utahans are likely to face diminished access to the sports that define their lifestyles as well as lessened economic productivity in their communities.

CLIMATE IMPACTS ON ROCK CLIMBING AND TRAIL SPORTS

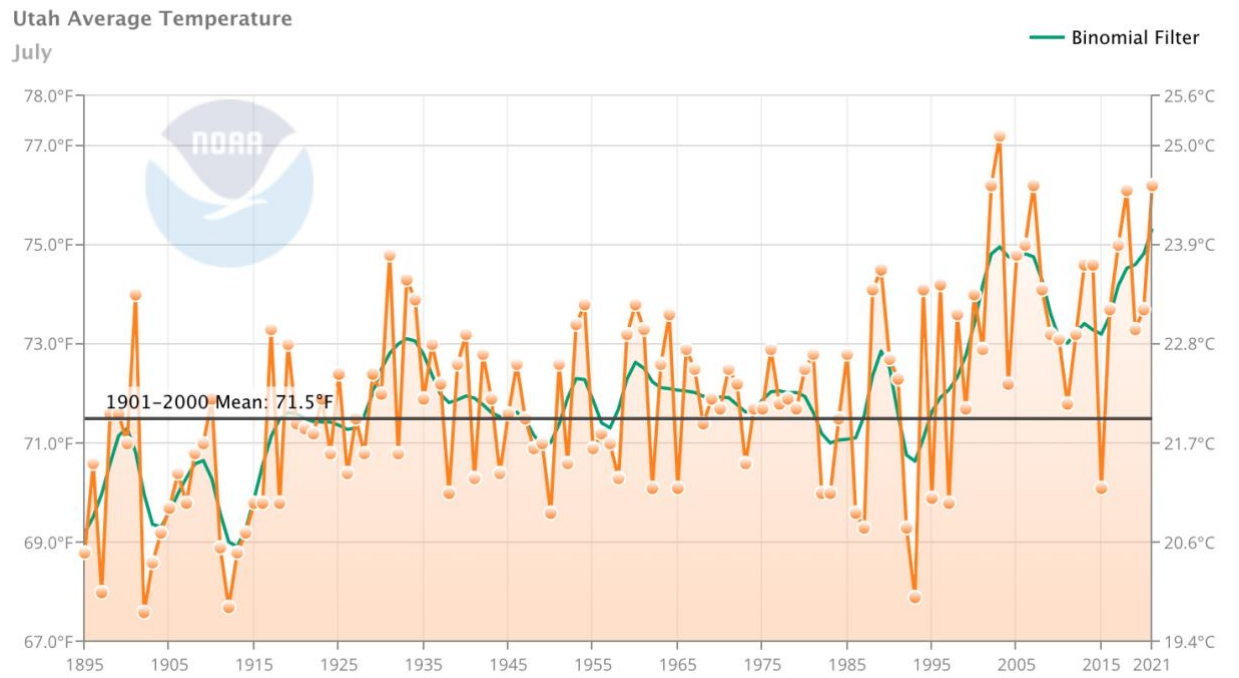
The impacts of climate change create multiple barriers to access for the rock climbing and trail sports communities. Heat, reduced air quality, and increased droughts all threaten the health and well-being of outdoor enthusiasts, while more frequent wildfires and trail degradation from increased water runoff physically prevent enthusiasts from participating in the sports that they love.

Heat

⇨ *Hotter temperatures resulting from climate change threaten the health of rock climbers and trail users by compromising the body's ability to regulate internal temperatures, which increases both the frequency and severity of heat-related illnesses.*

According to NOAA's National Centers for Environmental Information…

- Temperatures in Utah increased by more than 2.5°F over the 20th century.
- Utah had the 8th fastest rate of temperature increase out of any state from 1912 to 2012.
- The number of "extremely hot days" (temperatures exceeding 100°F) per year is increasing.
- Temperatures in Utah are projected to increase by 3-6°F by 2060 and 4-10°F by 2100.



Annual variation in average July Temperatures. Published December 2021, retrieved on January 4, 2022 from NOAA.

Wildfire

⇨ Climate change is contributing to larger and more frequent wildfires in the Western U.S., thereby decreasing access for both rock climbers and trail users due to recreation area closures.

- There were 6 times as many large fires (1000+ acres) on USFS land in Utah from 2005-2015 than from 1970-1980.
- Average land area burned in Utah from 2005-2015 is 29 times higher than from 1970-1980.
- Currently Utah has approximately 40 days with high wildfire potential, which will increase to 65 days by 2050.
- 1.2M Utahans live within the Wildland Urban Interface zone, meaning wildfires directly threaten 45% of the state's population.

Air Quality

⇨ As a result of climate change, wildfire smoke, dust, and surface-level ozone concentrations are increasing. Exposure to these compounds is correlated with increased mortality and respiratory issues such as asthma, chronic obstructive pulmonary disease, bronchitis, and pneumonia, thus decreasing safe access for both rock climbers and trail users.

- From 2016-2020, Utah was exposed to wildfire smoke for approximately 4 to 8 weeks every year.
- From 2016-2020, Salt Lake City experienced an average of 30 smoke days per year, a doubling compared to 2009-2013.
- Air Quality Index (AQI) in Utah can reach dangerously elevated levels due to smoke produced by out-of-state wildfires hundreds of miles away.

Drought

⇨ Drought does not generally represent a direct threat to rock climbers and trail users, but it's role in increasing wildfire risk, dust generation, and higher rates of erosion threaten both access to recreation areas and the health of those recreating.

- In February 2022, 100% of Utah was experiencing at least moderate drought, 96.9% of Utah was experiencing severe drought, and 33.6% was experiencing extreme drought.
- Utah regularly experiences water-scarcity and climate change is projected to increase the severity of droughts.
- More precipitation is expected to fall as rain instead of snow, threatening snowpack and water supplies.

Meltwater Runoff and Flooding

⇨ The increasing severity of storms resulting from climate change leads to severe runoff and flooding events that erode trail systems and prevent rock climbers and trail users from accessing recreation areas.

- Extreme participation events are expected to increase in Utah, which could increase the frequency and severity of floods.

OUTDOOR RECREATION ECONOMY

Utah's outdoor recreation economy contributes significantly to state GDP and employment. As such, climate change's potential impacts on recreation demand pose a threat to Utah's economy as a whole.

In 2019 alone, Utah's outdoor industry:

- Created $6.4 billion in added value, accounting for 3.3% of state GDP.

    - Climbing, hiking, and camping alone contributed $65.7M.
- Created 83,365 jobs, accounting for 3.9% of state employment.

Compared to the outdoor industry of other American states:

- Value added is growing faster in Utah– 2% faster than the national average.
- Employment generated is growing faster in Utah– 1.7% faster than the national average.
- Compensation for related jobs is increasing faster in Utah– 1.2% faster than the national average.

RECREATION SUMMARY

Utah has a diverse landscape, with resident populations and recreational opportunities concentrated in southwestern (St. George area) and northern Utah (the Salt Lake City metropolitan area). It is known for its world-class snow, and often boasts that it has the "Greatest Snow on Earth."

The state as a whole contains 5 national parks, 8 national monuments, 44 state parks, and 35 wilderness areas.

ROCK CLIMBING

Where

Climbing areas are found throughout the state, with notable destinations in the Salt Lake City vicinity, the Moab region, and within Zion National Park.

- Mountain Project lists a total of 15,819 routes in Utah.
    - Of those routes, 37% are in the Wasatch Range, 21% are in southeastern Utah, 16% are in southwestern Utah, 11% are in central Utah, 8% are in south central Utah, 4% are in the west desert, and 3% are in northeastern Utah.

Spotlight: Moab Area Climbing

Moab is a truly special place. World-renowned for its laser-cut cracks through perfect Wingate sandstone, the mesas, towers, and endless walls that define this uniquely western landscape are a treasure to the domestic and global climbing community. Despite hot summers, cold winters, and increasingly heavy crowds during the shoulder seasons, climbing in Moab is possible as a year-round activity and empty lines are easy enough to find. The Moab area serves as a jump off point for Indian Creek, the ever-popular Castleton Valley, and the beautiful walls along River Road.

When

Due to the variety of locations with climbing opportunities, the prime season extends all the way from March until November.

TRAIL SPORTS (BIKE/HIKE/RUN)

Overview

As in all other states, trail recreation opportunities in Utah occur in higher quantity and broader distribution than is relevant for rock climbing access alone. Trails are primarily concentrated in the Salt Lake City region and in southeastern Utah (Moab area).

Estimations of trail use and length vary between sources:

- According to Mountain Bike Project, Utah has 7,026 miles of mountain biking trails.
    - Of the 1,271 trails listed, 11% are in northern Utah, 39% are near Salt Lake City and the Wasatch Front, 24% are in southeastern Utah, 20% are in southwestern Utah, 5% are in Uintas and eastern Utah, and less than 1% are in west central Utah.
- According to Hiking Project, Utah has 7,484 miles of trails
- According to Alltrails, Montana has 3,015 trails.

Spotlight: Park City

Although famous for world-class snow sport opportunities, Park City also boasts some of Utah's greatest opportunities for trail sport enthusiasts. Beautiful alpine lakes pair with an idyllic and robust trail network, creating opportunities for enthusiasts of all disciplines and ability levels. The high altitude also makes it a destination for elite athletes who come from all over the world to train.

When

Although trails in the mountain regions may lose due to snow and ice during the winter, many lower-elevation trails remain accessible year-round.

ADDITIONAL RESOURCES

- Current AQI: Click here
- Current Smoke Exposure: Click here
- Current Drought Conditions: Click here
- Active Wildfires: Click here
- Utah’s State Hazard Mitigation Plan: Click here
- Governor’s Office for Economic Opportunity: Click here
- An Economic Study of the Impact of Wildfires on National Park Visitation: Click here
- An Economic Study of the Individual Value of an MTB Trip to Moab: Click here
- Fourth National Climate Assessment, Southwest Region: Click here

Appendix 2. Alliance Toolkits

Along with the deliverables required by the Bren School, this project produced several additional deliverables for Protect Our Winters to help guide their advocacy efforts. The Alliance Toolkits break down climate impacts by sport category, offering educational material for POW's Alliance members, and, in turn, enables these members to effectively amplify POW's messaging through the education of a broader audience. The Alliance Toolkits included below represent drafts that are subject to editing by Protect Our Winters prior to their internal publication.

Please click here for a link to the Trail Alliance Toolkit
This Toolkit will be available May 2022

Please click here for a link to the Climb Alliance Toolkit
This Toolkit will be available May 2022

Appendix 3. Additional Resources

As the POW team constructs further outreach and communications materials, we recommend consulting the following list for potential sources of scientific content and information for engagement with POW's audience:

- John Abatzoglou is a professor at the University of California, Merced, and has produced some of the most valuable research connecting climate change to wildfire in the Western U.S. This paper, published in the Proceedings of the National Academy of Sciences in 2016, is one of the most valuable resources we found.
- Killian Jornet's Podcast, The Athlete Climate Academy, was frequently referenced as a resource connecting climate to outdoor recreation.
- Headwaters Economics is "an independent, nonprofit research group that works to improve community development and land management decisions," and produced several impactful studies about the economics of outdoor recreation, such as
  - Inspiring the Future Outdoor Recreation Economy and
  - Innovative New Ways to Count Outdoor Recreation: Using data from cell phones, fitness trackers, social media, and other novel data sources.
- The USFS National Visitor Use Monitoring Program has a robust dataset highlighting annual usage rates of outdoor recreation.
- The Bureau of Economic Analysis has robust data assessing national participation in outdoor recreation.
- The Wilderness Society produced a 2020 report, "The Climate Report 2020: Greenhouse Gas Emissions from Public Land," which assesses the role that public lands play in contributing to climate change.
- The National Center for Natural Resources Economic Research (NCNRER) produced a 2014 paper on "Federal Outdoor Recreation Trends: Effects on Economic Opportunities."
- The American Hiking Society produced a 2015 report on Hiking Trails in America.

11. REFERENCES

1. USGCRP. Fourth National Climate Assessment. 1–470 https://nca2018.globalchange.gov (2018).
2. February 19 & Denchak, 2021 Melissa. Paris Climate Agreement: Everything You Need to Know. NRDC https://www.nrdc.org/stories/paris-climate-agreement-everything-you-need-know.
3. United States of America, Nationally Determined Contribution. Paris Agreement. UNFCCC. https://www4.unfccc.int/sites/NDCStaging/pages/Party.aspx?party=USA (2021).
4. FACT SHEET: Renewed U.S. Leadership in Glasgow Raises Ambition to Tackle Climate Crisis. The White House https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/13/fact-sheet-renewed-u-s-leadership-in-glasgow-raises-ambition-to-tackle-climate-crisis/ (2021).
5. Protect Our Winters 2020 Strategic Plan. 16 https://protectourwinters.org/wp-content/uploads/2019/12/POW-2020-strategic_plan.pdf (2020).
6. Protect Our Winters. Protect Our Winters 2019 Annual Report. 31 https://protectourwinters.org/wp-content/uploads/2020/08/2019-POW-Annual-Report_Final.pdf (2019).
7. Protect Our Winters. Motivating Lifestyle Driven Advocacy. 22 https://protectourwinters.org/motivating-lifestyle-advocacy/ (2019).
8. Hayhoe, K. et al. Chapter 2 : Our Changing Climate. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II. https://nca2018.globalchange.gov/chapter/2/ (2018) doi:10.7930/NCA4.2018.CH2.
9. Abatzoglou, J. T. & Williams, A. P. Impact of anthropogenic climate change on wildfire across western US forests. Proc. Natl. Acad. Sci. 113, 11770–11775 (2016).
10. Westerling, A. L., Hidalgo, H. G., Cayan, D. R. & Swetnam, T. W. Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity. Science 313, 940–943 (2006).
11. Bowman, D. M. J. S. et al. Human exposure and sensitivity to globally extreme wildfire events. Nat. Ecol. Evol. 1, 1–6 (2017).
12. Geographic Area Coordination Center (GACC) Website Template. https://www.predictiveservices.nifc.gov/intelligence/2020_statssumm/2020Stats&Summ.html.
13. Climate Change Action for Cyclists: Part I – Climate Change, the Cycling Experience, and Why We Care. The Radavist https://theradavist.com/climate-change-action-for-cyclists-part-i-climate-change-the-cycling-experience-and-why-we-care/.
14. Five charts that show where 2020 ranks in Colorado wildfire history. The Colorado Sun https://coloradosun.com/2020/10/20/colorado-largest-wildfire-history/ (2020).
15. Sakas, M. E. Most National Forest Land Is Now Closed In These 5 Counties To Prevent New Wildfires. Colorado Public Radio https://www.cpr.org/2020/10/20/colorado-wildfires-national-forest-land-closed-in-boulder-clear-creek-jefferson-gilpin-larimer-county/.

16. How will state parks survive 2020? Travel https://www.nationalgeographic.com/travel/article/state-parks-face-budget-cuts-wildfires-coronavirus (2020).
17. Navarrete, D. From the Ashes: Parks Plan for Recovery After Wildfire. My Oregon News https://www.myoregon.gov/2020/11/04/from-the-ashes-parks-plan-for-recovery-after-wildfire/ (2020).
18. Gergel, D. R., Nijssen, B., Abatzoglou, J. T., Lettenmaier, D. P. & Stumbaugh, M. R. Effects of climate change on snowpack and fire potential in the western USA. Clim. Change 141, 287–299 (2017).
19. Abatzoglou, J. T., Juang, C. S., Williams, A. P., Kolden, C. A. & Westerling, A. L. Increasing Synchronous Fire Danger in Forests of the Western United States. Geophys. Res. Lett. 48, e2020GL091377 (2021).
20. Kim, M.-K. & Jakus, P. M. Wildfire, national park visitation, and changes in regional economic activity. J. Outdoor Recreat. Tour. 26, 34–42 (2019).
21. Leung, Y.-F. & Marion, J. L. Trail degradation as influenced by environmental factors: A state of-the-knowledge review. J. Soil Water Conserv. 51, 130 (1996).
22. Miller, M. Closures, Floods, Erosion: The Wildfire Effect on Trails and Why it Probably Won't get Better Soon. Singletracks Mountain Bike News https://www.singletracks.com/environment/closures-floods-erosion-the-wildfire-effect-on-trails-and-why-it-wont-get-better-soon/ (2021).
23. Orem, C. A. & Pelletier, J. D. The predominance of post-wildfire erosion in the long-term denudation of the Valles Caldera, New Mexico. J. Geophys. Res. Earth Surf. 121, 843–864 (2016).
24. Gottfried, D. G. et al. Post- Wildfire Erosion in the Southwest: Causes and Control.
25. Highland, L. M. Landslides in Colorado, USA: Impacts and Loss Estimation for the Year 2010. 54.
26. Gartner, J. E., Cannon, S. H., Santi, P. M. & Dewolfe, V. G. Empirical models to predict the volumes of debris flows generated by recently burned basins in the western U.S. Geomorphology 96, 339–354 (2008).
27. Nikolopoulos, E. I., Destro, E., Bhuiyan, M. A. E., Borga, M. & Anagnostou, E. N. Evaluation of predictive models for post-fire debris flow occurrence in the western United States. Nat. Hazards Earth Syst. Sci. 18, 2331–2343 (2018).
28. Riley, K. L., Bendick, R., Hyde, K. D. & Gabet, E. J. Frequency–magnitude distribution of debris flows compiled from global data, and comparison with post-fire debris flows in the western U.S. Geomorphology 191, 118–128 (2013).
29. White, E. et al. Federal outdoor recreation trends: effects on economic opportunities. PNW-GTR-945 https://www.fs.usda.gov/treesearch/pubs/53247 (2016) doi:10.2737/PNW-GTR-945.
30. Marion, J. & Wimpey, J. Environmental Impacts of Mountain Biking: Science Review and Best Practices. 19.
31. Rangel, L., Jorge, M. do C., Guerra, A. & Fullen, M. Soil Erosion and Land Degradation on Trail Systems in Mountainous Areas: Two Case Studies from South-East Brazil. Soil Syst. 3, 56 (2019).

32. McHugh, K. Y. WILDERNESS ROCK CLIMBING INDICATORS AND CLIMBING MANAGEMENT IMPLICATIONS IN THE NATIONAL PARK SERVICE. 193.
33. Cayan, D. et al. Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment. 153–196 (Island Press, 2013).
34. Chan, N. W. & Wichman, C. J. Climate Change and Recreation: Evidence from North American Cycling. Environ. Resour. Econ. 76, 119–151 (2020).
35. Pilot Program Approved to Restrict Use of Select Phoenix Trails During Extreme Heat. https://www.phoenix.gov:443/newsroom/parks-and-recreation/1987.
36. The upper temperature thresholds of life - The Lancet Planetary Health. https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(21)00079-6/fulltext.
37. Oswald Beiler, M. R. & Miller, G. Sea-Level Rise Vulnerability Assessment of Bicycle and Trail Networks. J. Transp. Eng. Part Syst. 145, 05018003 (2019).
38. Buis, A. Can't 'See' Sea Level Rise? You're Looking in the Wrong Place. Climate Change: Vital Signs of the Planet https://climate.nasa.gov/blog/2974/cant-see-sea-level-rise-youre-looking-in-the-wrong-place/.
39. Bark Beetles - US Forest Service Research & Development. https://www.fs.fed.us/research/invasive-species/insects/bark-beetle.php.
40. Hicke, J. A., Meddens, A. J. H. & Kolden, C. A. Recent Tree Mortality in the Western United States from Bark Beetles and Forest Fires. For. Sci. 62, 141–153 (2016).
41. Kingsley Samantha L., Eliot Melissa N., Gold Julia, Vanderslice Robert R., & Wellenius Gregory A. Current and Projected Heat-Related Morbidity and Mortality in Rhode Island. Environ. Health Perspect. 124, 460–467 (2016).
42. Lay, C. R. et al. City-level vulnerability to temperature-related mortality in the USA and future projections: a geographically clustered meta-regression. Lancet Planet. Health 5, e338–e346 (2021).
43. Patz, J. A., Campbell-Lendrum, D., Holloway, T. & Foley, J. A. Impact of regional climate change on human health. Nature 438, 310–317 (2005).
44. Bergeron, M. et al. International Olympic Committee consensus statement on thermoregulatory and altitude challenges for high-level athletes. Br. J. Sports Med. 46, 770–779 (2012).
45. Butler, S. L. After Olympic Marathon Trials, Athletes Question How Officials Handled Heat and Hospitality. Runner's World https://www.runnersworld.com/news/a20861507/after-olympic-marathon-trials-athletes-question-how-officials-handled-heat-and-hospitality/ (2016).
46. Hot Tokyo days and nights: Sweltering Olympics brutal for athletes. Los Angeles Times https://www.latimes.com/sports/olympics/story/2021-08-01/tokyo-olympics-heat-hot-weather-athletes-competition (2021).
47. Naeher, L. P. et al. Woodsmoke Health Effects: A Review. Inhal. Toxicol. 19, 67–106 (2007).
48. As California burns, America breathes toxic smoke | KCRW Features. KCRW https://www.kcrw.com/news/shows/kcrw-features/smoke-story (2021).
49. Cascio, W. E. Wildland fire smoke and human health. Sci. Total Environ. 624, 586–595 (2018).

50. Reid, C. E. et al. Critical Review of Health Impacts of Wildfire Smoke Exposure. Environ. Health Perspect. 124, 1334–1343 (2016).
51. Liu, J. C. et al. Wildfire-specific Fine Particulate Matter and Risk of Hospital Admissions in Urban and Rural Counties. Epidemiol. Camb. Mass 28, 77–85 (2017).
52. Is wildfire smoke bad for your health? CU Boulder Today https://www.colorado.edu/today/2021/07/12/wildfire-smoke-bad-your-health (2021).
53. Zhang, Y. & Wang, Y. Climate-driven ground-level ozone extreme in the fall over the Southeast United States. Proc. Natl. Acad. Sci. 113, 10025–10030 (2016).
54. Projection of American dustiness in the late 21st century due to climate change | Scientific Reports. https://www.nature.com/articles/s41598-017-05431-9.
55. Drought-sensitivity of fine dust in the US Southwest: Implications for air quality and public health under future climate change - IOPscience. https://iopscience.iop.org/article/10.1088/1748-9326/aabf20.
56. Crooks, J. L. et al. The Association between Dust Storms and Daily Non-Accidental Mortality in the United States, 1993-2005. Environ. Health Perspect. 124, 1735–1743 (2016).
57. Dokken, D. 11 — Human Health: Impacts, Adaptation, and Co-Benefits. Hum. Health 46.
58. Filgueiras, A. & Stults-Kolehmainen, M. Factors linked to changes in mental health outcomes among Brazilians in quarantine due to COVID-19. 2020.05.12.20099374 https://www.medrxiv.org/content/10.1101/2020.05.12.20099374v2 (2020) doi:10.1101/2020.05.12.20099374.
59. Winter, P. L., Selin, S., Cerveny, L. & Bricker, K. Outdoor Recreation, Nature-Based Tourism, and Sustainability. Sustainability 12, 81 (2020).
60. Aiba, M., Shibata, R., Oguro, M. & Nakashizuka, T. The seasonal and scale-dependent associations between vegetation quality and hiking activities as a recreation service. Sustain. Sci. 14, 119–129 (2019).
61. Capaldi, C. A., Passmore, H.-A., Nisbet, E. K., Zelenski, J. M. & Dopko, R. L. Flourishing in nature: A review of the benefits of connecting with nature and its application as a wellbeing intervention. Int. J. Wellbeing 5, (2015).
62. Sonenshine, D. E. Range Expansion of Tick Disease Vectors in North America: Implications for Spread of Tick-Borne Disease. Int. J. Environ. Res. Public. Health 15, 478 (2018).
63. Brownstein, J. S., Holford, T. R. & Fish, D. Effect of Climate Change on Lyme Disease Risk in North America. EcoHealth 2, 38–46 (2005).
64. Franklinos, L. H. V., Jones, K. E., Redding, D. W. & Abubakar, I. The effect of global change on mosquito-borne disease. Lancet Infect. Dis. 19, e302–e312 (2019).
65. [USC02] 16 USC 1531: Congressional findings and declaration of purposes and policy. https://uscode.house.gov/view.xhtml?req=(title:16%20section:1531%20edition:prelim).
66. Zajchowski, C. A. B., Link to external site, this link will open in a new window, Tysor, D. A., Brownlee, M. T. J. & Rose, J. Air Quality and Visitor Behavior in U.S. Protected Areas. Hum. Ecol. 47, 1–12 (2019).

67. Hesseln, H., Loomis, J. B., González-Cabán, A. & Alexander, S. Wildfire effects on hiking and biking demand in New Mexico: a travel cost study. J. Environ. Manage. 69, 359–368 (2003).
68. Wildfire, Smoke, and Outdoor Recreation in the Western United States. Resources for the Future https://www.rff.org/publications/working-papers/wildfire-smoke-and-outdoor-recreation-in-the-western-united-states/.
69. Gustafson, E. J. & Sturtevant, B. R. Modeling Forest Mortality Caused by Drought Stress: Implications for Climate Change. Ecosystems 16, 60–74 (2013).
70. Schwartz, M. D., Ahas, R. & Aasa, A. Onset of spring starting earlier across the Northern Hemisphere. Glob. Change Biol. 12, 343–351 (2006).
71. Halofsky, J. E., Peterson, D. L., Buluç, L. & Ko, J. Climate change vulnerability and adaptation for infrastructure and recreation in the Sierra Nevada. 296.
72. Williams, D. R. & Vaske, J. J. The Measurement of Place Attachment: Validity and Generalizability of a Psychometric Approach. 11.
73. Holmes, T., Prestemon, J. & Abt, K. The Economics of Forest Disturbances: Wildfires, Storms, and Invasive Species. vol. 79 (2008).
74. O'Hara, M. Congestion Effects in a Seasonal Model of Recreation Demand. SSRN Electron. J. (2012) doi:10.2139/ssrn.2027137.
75. Boxall, P., Rollins, K. & Englin, J. Heterogeneous preferences for congestion during a wilderness experience. Resour. Energy Econ. 25, 177–195 (2003).
76. USDA Forest Service announces challenge to increase focus on problems facing nation's largest public trail system. US Forest Service http://www.fs.usda.gov/news/releases/usda-forest-service-announces-challenge-increase-focus-problems-facing-nations (2020).
77. Keske, C. M. H. & Mayer, A. Visitor Willingness to Pay U.S. Forest Service Recreation Fees in New West Rural Mountain Economies. Econ. Dev. Q. 28, 87–100 (2014).
78. van Duym, D. & Washington, P. Outdoor Recreation Satellite Account, U.S. and States, 2019. 57 https://www.bea.gov/sites/default/files/2020-11/orsa1120-fax.pdf (2020).
79. Aversa, J. Outdoor Recreation Satellite Account, U.S. and States, 2020. 24.
80. Warren, L. National Visitor Use Monitoring Results. 36 (2020).
81. Working on a warmer planet: The impact of heat stress on labour productivity and decent work. 98.
82. Statista. Bike sales value by type of bicycle in the US 2017 | Statista. Statista.com https://www.statista.com/statistics/236150/us-retail-sales-of-bicycles-and-supplies/ (2021).
83. Hiking Gear & Equipment Market Size | Industry Report 2020-2027. https://www.grandviewresearch.com/industry-analysis/hiking-gear-equipment-market (2020).
84. Global Trail Running Shoes Market Share Report, 2019-2025. https://www.grandviewresearch.com/industry-analysis/trail-running-shoes-market (2020).
85. Outdoor Alliance - About Us. Outdoor Alliance https://www.outdooralliance.org/about-us (2019).

86. Maples, J. N. & Adley, M. J. B. Economic Impact of Mountain Biking in the Grand Mesa, Uncompahgre & Gunnison National Forests. 17 https://www.imba.com/sites/default/files/content/resources/2018-11/OA_GMUGNF_MtnBikingStudy2018.pdf (2018).
87. Maples, J. N. & Adley, M. J. B. Economic Impact of Mountain Biking in the Custer Gallatin National Forest. 17 https://www.imba.com/sites/default/files/content/resources/2018-11/OA_CusterGallatinNF_MtnBikingStudy2018.pdf.
88. Maples, J. N. & Adley, M. J. B. Economic Impact of Mountain Biking in the Nantahala and Pisgah National Forests. 14 https://www.imba.com/sites/default/files/content/resources/2018-06/OA_NPNF_MtnBikingStudy.pdf (2017).
89. Meltzer, N. Adapting to the New Economy: The Impacts of Mountain Bike Tourism in Oakridge, Oregon. 53 https://www.imba.com/sites/default/files/content/resources/2018-11/Copy%20of%202014%20Oakridge%20OR%20June%202014The_Impacts_of_Mountain_Bike_Tourism_in_Oakrige_Oregon%20%281%29.pdf (2014).
90. Maples, J. N. & Adley, M. J. B. Economic Impact of Hiking in the Grand Mesa, Uncompahgre & Gunnison National Forests. 16.
91. Socioeconomic Studies | Colorado Mesa University. https://www.coloradomesa.edu/natural-resource-center/nrc-reports/socioeconomic-studies.html.
92. Outdoor Foundation. 2020 Outdoor Participation Report. https://outdoorindustry.org/resource/2020-outdoor-participation-report/ (2020).
93. Grijalva, T. C., Berrens, R. P., Bohara, A. K., Jakus, P. M. & Shaw, W. D. Valuing the Loss of Rock Climbing Access in Wilderness Areas: A National-Level, Random-Utility Model. Land Econ. 78, 103 (2002).
94. American Alpine Club. State of Climbing Report, 2019. https://aac-publications.s3.amazonaws.com/articles/State_of_Climbing_Report_2019_Web.pdf (2019).
95. Fuss, F. K., Weizman, Y., Niegl, G. & Tan, A. M. Climbers' Perception of Hold Surface Properties: Roughness Versus Slip Resistance. Front. Psychol. 11, (2020).
96. Amca, A. M., Vigouroux, L., Aritan, S. & Berton, E. The effect of chalk on the finger–hold friction coefficient in rock climbing. Sports Biomech. 11, 473–479 (2012).
97. The Science of Climbing Shoe Sticky Rubber. Climbing https://www.climbing.com/gear/the-science-of-climbing-shoe-sticky-rubber/ (2017).
98. Blackwelder, E. Fire as an Agent in Rock Weathering. J. Geol. 35, 134–140 (1927).
99. Gisborne, H. T. Forest Fire as a Rock Disintegrating Agent. Sci. Mon. 35, 191–192 (1932).
100. Holzschuh, A. Does rock climbing threaten cliff biodiversity? - A critical review. Biol. Conserv. 204, 153–162 (2016).
101. Lorite, J. et al. Rock climbing alters plant species composition, cover, and richness in Mediterranean limestone cliffs. PLOS ONE 12, e0182414 (2017).

102. Maples, J., Bradley, M., Giles, S., Leebrick, R. & Clark, B. Climbing Out of Coal Country: The Economic Impact of Rock Climbing in West Virginia's New River Gorge. J. Appalach. Stud. 25, 184–201 (2019).
103. Maples, J. N. & Adley, M. J. B. Economic Impact of Rock Climbing in the Nantahala and Pisgah National Forests. 10.
104. Qianru, C. & Yuan, L. Economic driving force: An Analysis of Rock Climbing Tourism in developed countries. 251, 03033 (2021).
105. Islam, S. N. & Winkel, J. Climate Change and Social Inequality. 32.
106. Sarofim, M. C. et al. Ch. 2: Temperature-Related Death and Illness. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. https://health2016.globalchange.gov/downloads#temperature-related-death-and-illness (2016) doi:10.7930/J0MG7MDX.
107. Harlan, S. L., Brazel, A. J., Prashad, L., Stefanov, W. L. & Larsen, L. Neighborhood microclimates and vulnerability to heat stress. Soc. Sci. Med. 63, 2847–2863 (2006).
108. Baird, R. The Impact of Climate Change on Minorities and Indigenous Peoples. Minor. Rights Group Int. (2008).
109. Schyllert, C. et al. Low socioeconomic status relates to asthma and wheeze, especially in women. ERJ Open Res. 6, (2020).
110. Ellison-Loschmann, L. et al. Socioeconomic status, asthma and chronic bronchitis in a large community-based study. Eur. Respir. J. 29, 897–905 (2007).
111. The Future of the Outdoor Recreation Economy. Headwaters Economics https://headwaterseconomics.org/outdoor-recreation/soban/ (2021).
112. Rigolon, A. & Németh, J. What Shapes Uneven Access to Urban Amenities? Thick Injustice and the Legacy of Racial Discrimination in Denver's Parks. J. Plan. Educ. Res. 41, 312–325 (2021).
113. Bengston, D. N., Schermann, M., Moua, M. & Lee, T. T. Listening to Neglected Voices: Hmong and Public Lands in Minnesota and Wisconsin. Soc. Nat. Resour. 21, 876–890 (2008).
114. Thomas, A., Sánchez, J. & Flores, D. A review of trends and knowledge gaps in Latinx outdoor recreation on federal and state public lands. J. Park Recreat. Adm. 401 24-43 40, 24–43 (2022).
115. Searle, M. S. & Jackson, E. L. Socioeconomic variations in perceived barriers to recreation participation among would-be participants. Leis. Sci. 7, 227–249 (1985).
116. Shores, K. A., Scott, D. & Floyd, M. F. Constraints to Outdoor Recreation: A Multiple Hierarchy Stratification Perspective. Leis. Sci. 29, 227–246 (2007).
117. Flores, D. & Sánchez, J. J. The Changing Dynamic of Latinx Outdoor Recreation on National and State Public Lands. J. Park Recreat. Adm. 38, 58–74 (2020).
118. Mag, F. 50 Black, Indigenous & POC Outdoor Collectives to Support. Field Mag https://www.fieldmag.com/articles/black-indigenous-poc-outdoor-collectives-nonprofits-instagram (2020).
119. Vespa, J., Medina, L. & Armstrong, D. M. Demographic Turning Points for the United States: Population Projections for 2020 and 2060. 15 (2020).

120. Larson, L. R., Whiting, J. W. & Green, G. T. Exploring the influence of outdoor recreation participation on pro-environmental behaviour in a demographically diverse population. Local Environ. 16, 67–86 (2011).
121. Mohai, P. & Bryant, B. Is there a 'race' effect on concern for environmental quality? Public Opin. Q. 62, 475 (1998).
122. Whittaker, M., Segura, G. M. & Bowler, S. Racial/Ethnic Group Attitudes toward Environmental Protection in California: Is 'Environmentalism' Still a White Phenomenon? Polit. Res. Q. 58, 435–447 (2005).
123. 2019 OUTDOOR PARTICIPATION REPORT. Outdoor Industry Association https://outdoorindustry.org/resource/2019-outdoor-participation-report/.