WESTERN WATER ASSESSMENT
WHITE PAPER

Socioeconomic Impacts and Adaptation Strategies: Assessing Research on Drought, Climate Change and Recreation

by Roberta A. Klein and William R. Travis

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associated database located at
http://www.socioeconimpacts.org

Western Water Assessment
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Introduction

Attention is needed in the Western Water Assessment (WWA) region[1] to both climate impacts and adaptation, and to the types of socioeconomic data and tools that can aid adaptation strategies. The State of Colorado's Colorado Climate Preparedness Project (CCPP) started the process of identifying information that would be useful to state agencies and other entities as they plan for climate variability and change. After interviewing representatives of five climate sensitive sectors in Colorado[2] about climate change adaptation planning and information needs the CCPP found that "additional research on the impacts of climate change on physical, ecological, economic, and legal systems was a need common to all sectors" (Averyt et al., 2011, p. 94). Climate variability and change, including drought, affects multiple sectors, from agriculture to transportation, but the CCPP study especially found a gap in, and demand for, more information about climate impacts in the outdoor recreation sector. For example, the Colorado State Parks interviewees indicated they would like information about the impact of climate on state parks visitation as they prepare strategic plans and consider closing some parks. The US Forest Service interviewee called the lack of information about the impact of climate on recreation a big gap in their planning process (Averyt et al., 2011).

This is a significant need since the outdoor recreation and tourism industries are major components of the economies of the Western U.S. The Western Governors' Association estimated that, in 2011, outdoor recreation produced $255.6 billion in spending, 2.3 million jobs, and $110.3 billion in salaries, wages and profits in the Western states (Western Governors' Association, 2012). Economic benefits from outdoor recreation in Colorado alone have been estimated as anywhere from $8.5 billion to $15 billion, depending on which activities are included and the methodologies used (Averyt et al., 2011). A recent report about climate impacts on the U.S. winter tourism economy found that Colorado benefitted more than any other state from winter sports tourism during the 2009/10 season, with 37,800 industry-related employees and $2.2 billion in total added economic value. During that season Utah employed close to 13,000 in the winter sports tourism industry with $744 million in value added, while Wyoming employed 2,773 and had $161 million in value added (Burakowski and Magnusson, 2012). These estimates of the economic contribution of outdoor recreation all point to the conclusion that this is a significant sector in the WWA region.

The WWA funded this project, "A Socioeconomic Impacts and Adaptation Strategies Clearinghouse," primarily to create a clearinghouse of literature on the socioeconomic impacts of and adaptations to climate variability and change, relevant to the WWA three-state region and beyond. This clearinghouse--a publicly accessible, searchable database of literature--is located at http://www.socioeconimpacts.org. Entries can be sorted by sector (agriculture, water, and outdoor recreation), phenomenon (climate variability, climate change, drought, floods, etc.), geographical location, and year. One may also select ongoing or future studies, studies about economic impacts, and studies with a RISA author.[3] The entries include both peer-reviewed

1 WWA is one of several Regional Integrated Sciences and Assessment (RISA) programs funded through NOAA. The WWA region includes Colorado, Utah and Wyoming.

2 The five sectors were water, wildlife/ecosystems/forests, electricity, agriculture, and outdoor recreation.

3 One objective of the project was to gather socioeconomic impacts research from the RISA programs across the country. The Climate Assessment for the Southwest (CLIMAS) provided over 20 articles focusing on drought and climate change impacts on water resources, agriculture, and tourism; adaptation; socioeconomic scenarios; and nonmarket damages. Several items with WWA authors are included, most of which focus on drought or climate change in Colorado but a handful discuss Utah and Wyoming impacts. A handful of items from the Southeast Climate Consortium (SECC) and Alaska Center for Climate Assessment and Policy (ACCAP) are also included.

journal articles as well as other types of reports, studies, presentations, and websites pertaining to the socioeconomic impacts of climate variability and change, with a focus on the WWA region. This material is largely drawn from the following sources:

- Theoretical, modeling, and empirical studies at various scales (global to local) transferable to the WWA context;
- The relevant literature on the economics of natural hazards, some of which are climatic and applicable to the WWA context (including specific events in UT, WY and CO);
- Studies specific to the WWA context.

Another objective of the project is to identify gaps in knowledge about the socioeconomic effects and adaptations associated with climate variability and change of interest to WWA stakeholders. To identify stakeholder interests in socioeconomic impacts information we reviewed a database of 55 reports and studies from the WWA region, as well as the CCPP report, and also compiled a limited number of comments from WWA stakeholders.[4] We identified the following stakeholder questions concerning climate socioeconomic impacts to the tourism/ outdoor recreation sector:

- How will "geography" of tourism be affected?
- Who will be the winners and losers in the ski industry?
- How have skiers responded to analog events?
- How will adaptation options alter projected impacts to skiing?
- What is the impact of earlier runoff on fishing and boating?
- What are the impacts of forest die-off on recreation (especially hunting and fishing)?
- How will changes in species, including migration, affect recreation?
- What will be the impact of reduced precipitation on park visitation?
- Which parks are most vulnerable to climate change?

This white paper discusses literature in the database at the end of 2012 that is relevant to these stakeholder interests. A companion white paper discusses literature in the database regarding drought impacts and loss assessment methods.

Stakeholder interests in the impacts of climate variability and change on tourism and outdoor recreation

How will "geography" of tourism be affected?

Climate variability and change impact tourism and outdoor recreation primarily at the

4 The database was compiled by Lisa Dilling and John Berggren for another WWA project, "Toward a Framework for Assessing Stakeholder Needs for Climate Information."

local level, but stakeholders are interested in how these impacts potentially could affect the geographic distribution of tourism through the U.S. and beyond. Scott and McBoyle (2001) and Scott et al. (2004) use a 'tourism climate index' (TCI) that incorporates 7 tourism-relevant climate variables[5] to evaluate how tourism in Canada could be impacted by climate change. The authors estimate that western Canadian locations would improve as tourist destinations in spring and summer. Shorter and less severe Canadian winters will decrease the incentive of Canadians to travel to warm U.S. locations such as Arizona, Florida, Hawaii, and Texas. The authors acknowledge, however, that "the critical uncertainties regarding climate change impacts on the full range of tourism resources in Canada preclude a definitive statement regarding the net impact of climate change on this economic sector" (Scott and McBoyle, 2001, p. 86).

Such efforts to link climate with specific economic activities help us establish better knowledge about specific gains and losses, but researchers also need to account for non-climatic factors. For example, Gossling and Hall (2006) caution against using only a few selected climate-related parameters to predict travel flows since this approach fails to account for the influence of non-climate factors in travel decisions. A key element in all such studies is some effort to account for non-climatic variables, as illustrated in some of the studies on climate impacts on the ski industry described next.

Impacts to ski industry

Several assessments have identified the ski industry, a significant component of the WWA regional economy, as particularly vulnerable to climate change (see, e.g., Scott et al., 2006; Scott et al., 2008). A recent study examined the economic impacts of low snowfall years, similar to what might be expected under climate change, on the U.S. winter tourism economy. Based on observed declines in skier visits from high to low snowfall years ranging from 7.7% in Colorado to 14% in Utah, the study estimated losses in ski resort revenues ranging from $11 million in Wyoming to $154 million in Colorado, with corresponding losses of jobs and declines in added economic value.[6]

(Burakowsi and Magnusson, 2012). Other studies have concluded that, within each state, some ski areas will be "winners" and some will be "losers" under climate change (see, e.g. Scott et al., 2006), an issue that was not addressed in this report and that is of interest to stakeholders.

"Winners and Losers"

The following articles compare potential impacts of climate change to several ski resorts, primarily by modeling or by examining the response of resorts to historic climate variability.

Scott et al. (2006) recognize that climate change as well as business factors such as access to capital and energy prices will produce winners and losers within the ski industry. To help identify these winners and losers the study models the impact of climate change in 2020 and

5 The original TCI variables were monthly means for maximum daily temperature, mean daily temperature, minimum daily relative humidity, mean daily relative humidity, total precipitation, total hours of sunshine, and average wind speed. The original TCI was modified to use 'Apparent Temperature' or 'Heat Index' to measure thermal comfort.

6 The study obtained state ski day-trip statistics from the National Ski Areas Association, then estimated average expenditures for a ski trip. Changes in ski resort revenue were calculated based on the difference in skier visits between high and low snowfall years, then used as an input to the IMPLAN economic model. IMPLAN calculated the difference in direct, indirect and induced economic impacts using fixed multiplier ratios of 1.7 for employment and 2.48 for added economic value (Burakowsi and Magnusson, 2012).

2050 on six ski areas in Ontario, Quebec, Michigan and Vermont (Mt. Brighton, Horseshoe, Mont Sainte-Anne, Killington, Mt. Tremblant and Loch Lomond), taking into account snowmaking as an adaptation. The study looks at impacts to ski season length, probability of operating between Christmas and New Year and during spring break, and snowmaking cost and the water requirements for additional snowmaking. It finds that, even under a high impact climate scenario, by 2020 only the southern Michigan ski areas would be at risk. Under the high impact 2050 scenario, "the sustainability of some ski operations could be jeopardized" if reductions in the ski season are combined with increased snowmaking costs (Scott et al., 2006, p. 394). Of the six study areas the two Québec locations would be the least vulnerable under the high impact climate change scenario.

Dawson and Scott (2007) look at the potential impact of climate change on all 18 of Vermont's existing ski areas to identify winners and losers[7]. They model impacts of climate change under six scenarios in the early, middle and late 21st century. Using two key economic indicators – number of ski season days and likelihood that the ski area would be open the entire Christmas -New Year holiday period – the study finds that none of the 18 areas would meet these risk criteria in the early 21st century or under the low emissions scenario for the middle 21st century. Cochran, a low elevation area, would meet the risk criteria under the high emission scenario in the middle 21st century. Suicide Six, another low elevation area, would meet the risk criteria under the high emissions scenario in the later 21st century. These findings assume the availability of advanced snowmaking and water supply, a key uncertainty. As the study concludes, "it is not the entire Vermont ski industry that is at risk to climate change, but rather a relatively small number of individual low-lying ski areas" (Dawson and Scott, 2007, p. 566).

Scott et al. (2008) model potential climate change impacts to 14 northeastern U.S. ski areas. Using an average ski season length below 100 days and a less than 75% probability a ski area would not operate for the Christmas-New Year's period as the risk criteria, the study finds that through the mid-21st century, 7 of the study areas (Connecticut, western New York, southeastern New York, western Pennsylvania, southeastern Maine, eastern Pennsylvania and eastern Massachusetts) would be economically at risk. Under the higher emissions scenario, by the later 21st century only four areas (southern Vermont, northeastern New Hampshire, northeastern New York, and western Maine) would not be at risk, although that assumed large increases in snowmaking and the occasional shorter season. The authors note that "it is not the Northeast's ski industry that is at risk to climate change but rather individual ski businesses and communities that rely on ski tourism… It will be the relative advantages of local climatic resources and the adaptive capacity by individual ski areas that determine the 'survivors' in an era of climate change. Although projected climate change would contribute to the demise of ski businesses in some parts of the Northeast, it could advantage some of the ski operations that remain" (Scott et al., 2008, p. 593). Areas in southern Vermont, northeastern New Hampshire, northeastern New York, and western Maine that take advantage of the demise of other northeastern ski areas would clearly "win" from climate change.

Hamilton et al. (2003) examine trends in the northeastern ski industry referred to above by looking at the history of New Hampshire's ski industry. They note that many of New Hampshire's 123+ ski areas have closed since the 1970s partially due to a warming trend in New Hampshire in the 20th century. However, other non-climatic factors including construction of an interstate highway that improved access to the northern ski resorts played a role in many closures. The

7 A total of 110 ski areas have opened and closed in Vermont over the years.

authors observe that most of the 17 surviving ski areas are in the northern mountains, have heavily invested in snowmaking and grooming, and have diversified economically through real-estate developments and year-round businesses (Hamilton et al., 2003).

Less is known about winners and losers in the western U.S. ski industry and, in particular, in the WWA region. Two U.S. national assessment reports discuss the vulnerability of ski areas in the western U.S. Wagner and Stohlgren (2003) note that smaller, lower-elevation ski resorts such as Beaver Mountain, Utah, were most at risk: a rise in temperature of 2 degrees could cause a 20% reduction in its profits. In contrast, higher elevation resorts were not at risk and might even benefit. Karl et al. (2009) concur that the more vulnerable ski areas will be at lower elevations and in more southern parts of the region.

Bark et al. (2010) looked at the future of skiing at Arizona's two largest ski resorts (Snowbowl and Sunrise) and concluded that, with snowmaking, both could survive through 2030. However, both may experience a shortened season by 2050. By 2080 snowmaking will become increasingly difficult and operations may need to move to higher elevations.

Nolin and Daly (2006) look at the impact of converting from a snow-dominated to a rain-dominated winter precipitation regime in the Pacific Northwest. While most ski areas in the region are not within the area where projected warming will convert precipitation from predominantly snowfall to predominantly rainfall, 20 ski areas will experience significantly warmer winters under a climate warming scenario which could impact snow quality or longevity. However, the study did not assess how warmer winters would impact number of skier days or the length and quality of the ski season.

The question of winners and losers has been addressed in the context of real estate development in western resort areas. Butsic et al. (2009) find that warming is likely to reduce home prices around major ski resorts in the western U.S. They conclude that high elevation areas such as found in Colorado, Wyoming and Montana are unlikely to see an impact while already warm ski areas such as those in New Mexico could suffer substantial drops in housing values.

Potential climate change impacts to snow conditions at two major ski resorts in the WWA region have been examined in separate studies. Climate Change and Aspen projects base area snow accumulation starting around 1 week later by 2030 and 1.5 to 4.5 weeks later by 2100. Melting at the base will begin 4 to 5 days earlier by 2030 and 2.5 to 5 weeks earlier by 2100. The snow season length will decrease 1.5 weeks by 2030 and 4 to 10 weeks s by 2100. The study projects that it is unlikely there will be any winter snowpack at the base area by 2100, except under the lower emissions scenario (Aspen Global Change Institute et al., 2006).

Based on the statistical relationship between snowfall and skier visits in the past the Aspen study projects anywhere from a drop of 243,000+ visits to an increase of 243,000+ visits, and a corresponding drop/increase of total personal income of $56 million, with the wide variation due to the unknown direction of future precipitation. The Aspen study also assesses impacts on retail sales, employment, and real estate, and addresses the question of just how much of the base economy of Aspen depends on skiing. Though the study offers no quantitative answer, it does conclude that while skiing acted as the anchor of the economy, ski-driven impacts will be minor over the next few decades, and that other aspects of Aspen's climate and mountain setting could continue to fuel the economy even in a changing climate.

The Aspen study includes a brief discussion of factors that make Aspen more resilient to climate change than other ski areas: Aspen's four separate mountains, mid-continental location, higher elevation, colder winters, northerly latitude, gondolas and significant financial resources. The study does not analyze potential climate impacts at other western ski areas.

A similar study, *Climate Change in Park City*, models potential future snowpack at the Park City, Utah ski area using 3 emissions scenarios and finds that snow accumulation would start later, maximum snow depth would be smaller, and onset of spring melt would occur earlier. The study uses the statistical relationship between snowpack and skier days to predict that, by 2030, decreased snowpack would result in 152,453 lost skier days, and in 2050, anywhere from 203,800 to 498,353 lost skier days, depending on emissions scenario, and ~$20 - $67 million in lost earnings (Stratus Consulting, 2009).

How skiers have reponded to analog events

Stakeholders also were interested in how skiers responded in the past to conditions similar to what could be expected with climate change. The "analog approach" looks at how skiers responded to past events and what adaptation strategies were made during those events, to evaluate potential climate change impacts in the ski industry. This approach has been under-utilized despite its "potential to offer new insights into future impacts and effectiveness of adaptations" (Dawson et al., 2009, p.2). A handful of studies use this approach.

Scott (2005) reports a 7-11% decline in skier visits in the northeast U.S., Ontario and Quebec during the 2001-2002 season when temperatures were analogous to expected temperatures under a mid-range 2050 climate scenario. This was a smaller decline than had been projected from studies that relied on surveys of skiers.

Dawson et al. (2009) compare ski season length, ski area visitation, profits and snowmaking costs for the northeastern U.S. during two average years with two very warm years, one of which was similar to conditions under a mid-range climate scenario and was the third of three poor years while the other was similar to a high impact scenario conditions. The authors find an 11 - 12% decline in skier visits in the warm years. Profits in the high impact year were 32% lower than normal, though were unchanged in the mid-impact year. The study also finds a smaller reduction of the season length during the analog years than in the modeled studies, leading the authors to conclude that more adaptations take place in the real world than the models account for.

In two related studies, researchers use records of actual skier visits or ticket sales to identify specific factors during the ski season that impact visitation. Hamilton et al. (2007) construct time series models of skier visits to two New Hampshire ski resorts using records of skier attendance, daily snowfall, snow depth and temperature data for the vicinity of the ski resorts as well as Boston, the major urban center where most skiers live. The study finds that yesterday's mountain and city snow depth and yesterday's snowfall in the city, net of mountain conditions, influenced skier visits. The study notes that snowmaking can help cushion the impacts of low snow years, but will not be a complete substitute for a lack of natural snow because it needs cold temperatures.

Shih et al. (2009) look at the impact of daily weather on daily ski lift ticket sales at two Michigan resorts. They find that temperature, snow depth, and wind chill had a statistically significant impact on ticket sales.

Burakowski and Magnusson (2012), referred to above, find that that skier visits in the WWA region declinein low snowfall years compared to high snowfall years by anywhere from 7.7% in Colorado to 14% in Utah.

How adaptation options will alter projected impacts to skiing

Stakeholders were interested in how ski area adaptations might reduce some potential climate change impacts. Early assessments of impacts to the ski industry largely failed to consider the adaptive capacity of the industry, but more recent studies have included adaptation in their analyses.

Scott et al. (2003) was an early study that included snowmaking as a climate change adaptation. Under a roughly doubled-atmospheric CO2 scenario in the 2050s, the study estimates that with existing snowmaking technology the ski season length will be reduced 7% to 32% in Ontario. With more advanced snowmaking technology the reduction would be between 1% and 21%. In comparison, earlier studies that failed to include the impact of snowmaking estimate between a 40% and 100% loss of the ski season.

After Scott et al. (2006) included snowmaking in their modeling of future climate change impacts, the losses in eastern North America estimated for the 2050s were 30% - 100% lower than earlier studies that did not account for snowmaking.

Snowmaking has significant limitations, however. Its high cost must be weighed against the amount of revenue it is expected to produce. Snowmaking costs at one Arizona resort range from $2.1 million in a wet year to $4.3 million in a dry year. Even with such high costs Bark et al. (2010) find the estimated increased revenues from snowmaking are likely to exceed the costs, except possibly in La Nina years, making it a worthwhile investment. However, Colby and Frisvold (2011) note that use of snowmaking as an adaptation strategy will be limited if overnight temperatures become too warm to make snow, and if more precipitation falls as rain than as snow. Warmer temperatures will also push up the cost of snowmaking because greater energy inputs will be required (Dawson and Scott, 2007).

Aspen Global Change Institute et al. (2006) note that existing snowmaking practices will be an important climate change adaptation for Aspen but it might also be necessary to add snowmaking at the top of the mountain and lengthen the season. The biggest costs and constraints of this approach are the need for more water and more water storage, as well as the possibility of dewatering streams during low-flow periods, and increasing spring runoff.

Scott and McBoyle (2007) describe other important adaptations for ski areas in addition to snowmaking that include slope development and operational practices, ski resort conglomerates, revenue diversification, and marketing incentives. The paper notes that "Individual ski areas that are better climate adapted and with greater adaptive capacity … than their competitors will be the survivors in an era of climate change" and cites the following factors that help create adaptive capacity:

- Potential to expand into higher elevation terrain where exposure to climate change is lower and snowmaking capabilities enhanced;

- Capital to develop efficient and extensive snowmaking systems;
- Capacity to expand water supply for increased snowmaking;
- Capacity to further diversify resort operations (multiple winter activities and four-season operation);
- Are part of a larger company or regionally diversified ski conglomerate that could provide financial or human-resource support during poor business conditions; and
- Are located in jurisdictions with less land use restrictions (e.g., outside of national parks or in states/provinces where skiing makes a large contribution to the economy) and have positive relationships with host communities, both of which may reduce constraints to adaptation (p. 1427).

Earlier runoff impact on fishing and boating

One already observable consequence of both drought and climate change is earlier spring runoff. Stakeholders were interested in the impact of earlier runoff on fishing and boating. Some of the consequences of early runoff include a reduction in cold water fisheries habitat, which would negatively impact fishing; and a lowering of reservoir levels which would negatively impact boating (Morris and Walls, 2009).

Aspen Global Change Institute et al. (2006) note that rafting companies in the vicinity of Aspen, Colorado could be significantly impacted by a shift toward earlier runoff. Peak runoff currently occurs in June, during vacations and the tourism season. A shift to May would conflict with school schedules. Earlier runoff could also change the timing of fishing in the main stem of the Roaring Fork. Low flows in June and July could keep tourists away such as observed during the 2002 drought.

Two studies estimate the potential socioeconomic impact from reduced flows in Colorado. Loomis (2008) estimates that reducing river flows to half of their current levels would result in the loss of 1,000 jobs and almost half the income of Colorado's rafting and related industries. A substantial reduction in flows could cause losses of 2,000 fishing-related jobs and $35 million in annual income. Shrestha and Schoengold (2008) find that, after controlling for weather, lower river flows during the 2002 drought partially explained the decline in customers but other factors such as media coverage, the economy, price of gas, etc., likely explained the remainder of the decline.

Impacts of forest die-off on recreation (especially hunting and fishing)

Another area of stakeholder concern is the impacts of forest die-off and wildfire on recreation, especially hunting and fishing. The Southern Rocky Mountains and other parts of the West have experienced a significant and widespread forest die-off from drought and the Mountain Pine Beetle (MPB) infestation over the last decade. It is widely believed that forest decline can and will affect tourism, outdoor recreation, real estate values, and other economic bases of mountain communities, though we found little analysis of the socioeconomic effects of these changes. A draft study, Travis et al. (no date), compares the trends in lodging and restaurant revenue in Colorado resort towns that have experienced different levels of beetle kill. The study finds that revenue at resorts with greater amounts of beetle kill, such as Vail, Winter Park and Estes Park, was just as high, if not higher, than the areas without significant kill such as Telluride and Aspen. With one exception, this study also fails to find an impact on real estate prices in affected areas. One area in which socioeconomic impacts from MPB have been observed is campground closures and concern about the safety of roads, trails, picnic and other areas (Morris and Walls, 2009). The threat of falling trees killed by the MPB has forced some campgrounds to close, causing state parks agencies to lose revenue and creating a "much different experience" for campers after trees were removed. The epidemic has also resulted in the closures of Colorado State Parks trails. The cost of tree removal and the revenue losses have had a substantial impact on the State Parks budget (Averyt et al., 2011, p. 74).

Further, it is widely believed that beetle-killed forests increase the risk of large forest fires, as does drought and potential climate drying. Catastrophic fires will result in the closure of popular areas or, at a minimum, decrease their attractiveness (Morris and Walls, 2009). Starbuck et al. (2006) find that catastrophic burns decrease trips while low-intensity burns slightly increase visits to the burned area. The study simulated a 60-day closure of New Mexico's national forests and found the potential loss to the regional economy of $479 million in output (0.817% of gross state output), $191 million in earnings (0.416% of total income), and 11,606 jobs (1.37% of total employment).

How changes in species, including migration, will affect recreation

Climate change is expected to cause shifts in species populations, distribution, and phenology primarily at higher elevations and latitudes (Rice et al., 2012). Big game species such as deer, elk and moose are expected to migrate in response to changes in ecosystems from climate change, and moose will also migrate in response to warmer winters (Morris and Wall, 2009). Big game species are also expected to decline as warming reduces suitable habitat and nutritional forage, with the southwest and western U.S. being the most vulnerable (Wildlife Management Institute, ed., 2008).[8] The total economic impact of hunting and fishing in Colorado in 2007 was estimated at just over $1.8 billion (BBC Research & Consulting, 2008), so any reduction in hunting could have a substantial economic impact. Mendelsohn and Markowski (1999) estimate that climate change will have no impact on hunting demand in 2060, though under one model it would have a net positive effect if applied to the economy of 1990 and under a second model it would have a net negative effect.

Losses to freshwater fisheries have received more study. "Water temperature is believed to be one of the most important physical factors pertaining to the survival of trout. Global warming is expected to increase water temperature of trout streams and the solubility of oxygen in the stream decreases with rising water temperature" (Ahn et al., 2000, p. 495). Declines in trout populations of 50% or more in some parts of the country have been predicted (Wildlife Management Institute, 2008).

Ahn et al. (2000) estimate a potential welfare loss of between $5.63 and $53.18 per angler per single occasion in the Southern Appalachians from global warming. Pendelton and Mendelsohn (1998) estimate the potential economic impact on sportfishing from climate change at anywhere from a $4.6 million loss to a $20.5 million benefit, depending on climate scenario. They find that the economic impact of climate change on anglers depends on geographic location, with anglers

8 However, Colorado's Drought Plan reported that the 2002 drought in Colorado appeared to have had little impact on big game populations (CWCB, 2010, p.51)

in New Hampshire and Maine likely to benefit, while those in New York and Vermont likely to suffer. Mendelsohn and Markowski (1999) estimate that climate change will increase demand for fishing in the U.S., with the extent of the increase depending on the extent of warming.

Impact of reduced precipitation on parks visitation

Stakeholders expressed interest in the impact of reduced precipitation on parks visitation. Reduced precipitation can affect park visitation by lowering reservoir levels which can make boat ramps unavailable, and can result in crowding. Three studies in the database attempt to quantify these impacts in the U.S. Southwest. Frisvold et al.(2011) find that a 29% decline from 1998 to 2003 in the surface area of Lake Powell and a 24% decline of Lake Mead resulted in a decrease of almost 900,000 visits and resulting losses of $29 million in sales, $10 million in personal income, and over 700 jobs. They estimate elasticities of visits with respect to lake surface areas at 0.11 for Lake Powell/Glen Canyon NRA, and 0.45 for Lake Mead NRA (previous estimates of elasticities include 0.39 for California reservoirs and 0.47 in a study of 115 reservoirs). The following table summarizes their projections of economic impacts from declining reservoir levels:

Lake Mead lake levels (1,145 baseline level)	Lake Powell lake levels (3,608 baseline level)	Economic Impacts
1,075’	3,560’	-897,047 visits -$27.6 mil sales -703 jobs -$8.6 mil income
1,050’	3,490’	-1,247,107 visits -$32.9 mil sales -855 jobs -$11.6 mil income
1,000’	3,370’	-1,982,805 visits -$69.6 mil sales -1,715 jobs -$24.7 income

From Frisvold et al. (2011) pp. 136-37, tables 6.7 and 6.8.

Morehouse et al. (2007) find that a year of extreme drought (Standardized Precipitation Index < -2) reduced national parks visits by 7%. A 2.1% drop in Lake Mead and a 5.4% drop in Lake Powell led to a loss of over 500,000 visits to Glen Canyon NRA in 2003, 758 jobs, $ 32.1 million in visitor spending and $ 13.4 million in personal income. For Lake Mead NRA, lower lake levels contributed to losses of 900,000 visits, 680 jobs, $ 28.1 million in visitor spending and $ 9.6 million in personal income. Saunders and Easley (2006) report that a drought-related reduction in Lake Powell levels from full in 1999 to 1/3rd full in 2005 resulted in a 30% decline in visitors at Lake Powell and a 13% decline at Lake Mead.

Loomis and Crespi (1999) look at the combined impact of temperature, precipitation and reservoir surface area, as well as additional crowding, on reservoir visitation and estimate there would be a 9.2% increase in visitor days under a climate change scenario of 2.5 degree C warming and 7% precipitation increase.

Which parks are most vulnerable to climate change

A related stakeholder concern is which parks are most vulnerable to climate change. Hyslop (2007) uses two climate change scenarios to compare climate change impacts to 14 national parks and the likely changes in visitation in the 2020s, 2050s, and 2080s. The study projects increases in visitation to northern U.S. parks (Olympic, Grand Teton, Cuyahoga Valley, and Acadia) of 4%-6% in the 2020s, 5%-16% in the 2050s, and 7%-23% in the 2080s. Mid-latitude parks (Yosemite, Rocky Mountain, Hot Springs, and Great Smoky Mountains) would see slightly smaller increases (2-7% for the 2020s, 3-15% for the 2050s, and 5-19% for the 2080s). Southern parks (Channel Islands, Mesa Verde, Saguaro, and Everglades) would see decreases from 2-3% in the 2020s, 2-7% in the 2050s, and 3-9% in the 2080s.

Frisvold et al. (2011) examine the impact of long-term average temperature increases of 1 degree F in January and July for 42 national park system sites in the southwestern U.S. They find warming will increase visitation at 27 higher elevation and higher latitude parks such as Bryce Canyon, but will decrease visitation at 15 low desert parks such as Joshua Tree.

Saunders and Easley (2006) summarize the impacts of climate change to 12 western national parks including loss of glaciers and snowfields, changes in vegetation, loss of wildlife, parks closed due to fire, intolerable heat, and loss of boating, fishing and winter recreation. Grand Teton, Rocky Mountain and Yellowstone are projected to experience the greatest number of these impacts. Scott et al. (2007) use both a statistical model of monthly visitation and climate at Canadian Rocky Mountain national parks, as well as a visitor survey, to analyze how both higher temperatures and changes in environmental factors such as those listed by Saunders and Easley would affect visitation. Similar to other studies, they find that visitation would increase as the climate warmed (+6%-10% by the 2020s, +10%-36% by the 2050s, +11% - 60% by the 2080s). At the same time, responses to a visitor survey that asked visitors to consider the frequency of future visits under possible scenarios of potential environmental change in 2020, 2050 and 2080[9] indicated there would be little change in visitation due to more modest environmental changes in the 2020s and 2050s, but by the 2080s when environmental changes were more drastic, a majority of visitors either would not visit or would visit less often. The authors conclude that "long-term environmental changes may diminish the attractiveness of [the park's] landscape to some visitors and offset some of the potential gains in visitation made possible by an extended and climatically improved warm-weather tourism season" (Scott et al., 2007, p. 577). They caution against reading too much into the survey results, however, since most people visiting parks in the 2080s will not have been born until the 2040s and by then may have come to accept environmental changes such as loss of glaciers as the norm.

Conclusions

Ski Industry

A substantial body of research exists addressing the potential impacts of climate change on the ski industry, either through modeling or by analyzing the impact of past (analog) events. Most of the academic research addressing winners and losers within the ski industry has focused

9 These changes included a decline in wildlife and rare plants; reduced number of glaciers; change in vegetation composition; increase in forest fires; chance of a campfire ban; decreased fishing catch rate; and warmer lake water temperature.

on the Northeast, Midwest and Canadian ski industry. The studies have found that both climate and non-climate factors such as resort size, investment in snowmaking and grooming, real-estate developments and year-round business diversification as well as easy access by interstate highway, affect vulnerability. Less vulnerable resorts are likely to benefit as climate change causes the industry to consolidate. The studies indicate that, because of the industry's ability to adapt through measures such as snowmaking, the impact of climate change on ski areas may be less severe than has been estimated by studies relying on surveys or modeling. However, the economic and environmental costs of snowmaking must be weighed against its benefits to determine its viability as an adaptation option.

The studies from the WWA region have largely focused on modeling potential impacts to specific ski resorts rather than across the industry. The methodologies used elsewhere in the country, and in particular the analog events approach, could be applied usefully within the WWA region to start to identify probable winners and losers in the region's ski industry.

Literature in database about climate impacts to ski industry

Article	Geographic Scope	Stakeholder Interest
Aspen Global Change Institute et al. (2006)	Aspen, CO	Winners and losers Adaptation
Bark et al. (2010)	AZ	Winners and losers Adaptation
Burakowski and Magnusson (2012)	U.S.	Winners and losers
Butsic et al. (2009)	AZ, CA, CO, ID, MT, NV, NM, OR, UT, WY, British Columbia	Winners and losers
Colby and Frisvold (2011)	AZ	Adaptation
Dawson and Scott (2007)	VT	Winners and losers
Dawson et al. (2009)	CT, ME, MA,NH, NY, RI, VT	Analog events
Hamilton et al. (2003)	NH	Winners and losers
Hamilton et al. (2007)	NH	Analog events
Nolin and Daly (2006)	OR, WA	Winners and losers
Scott et al. (2003)	Ontario	Adaptation
Scott (2005)	Northeast U.S., Ontario, Quebec	Analog events
Scott et al. (2006)	Ontario, Quebec, MI, VT	Adaptation
Scott et al. (2008)	CT, MA, NH, NY, ME, PA, VT	Winners and losers
Scott and McBoyle (2007)	International	Adaptation
Shih et al. (2009)	MI	Analog events
Stratus Consulting (2009)	Park City, UT	Winners and losers

Climate impacts to other recreation/outdoor recreation industries

Socioeconomic impacts to outdoor recreation from early runoff, forest die-off, change in species, or reduced precipitation have not received the same level of attention as impacts to the ski industry, particularly within the WWA region. Preliminary findings indicate that the MPB epidemic generally has not affected tourism or real estate values in Colorado resort towns suffering the more serious effects of the epidemic. However, trees weakened or killed by the MPB epidemic have impacted access to campgrounds and trails, and removal of those trees has affected park budgets. The literature includes somewhat conflicting estimates of the potential economic impacts of climate change on hunting, and estimates of the impact on fishing appear to depend on species and geographic location. Studies project that warming temperatures will increase visitation at more northerly, higher elevation national parks (up to a point), but climate change-induced declines in precipitation at water-based parks, as well as other negative impacts to parks from climate change, may reduce demand as those impacts become more severe. It is unclear what the net impact on park visitation will be. Future research should attempt to better quantify the combined impact on parks visitation in the WWA region from projected temperature increases, reductions in lake and reservoir levels, and declines in other environmental factors.

Literature in database about climate impacts to other tourism and outdoor recreation activities

Article	Activity	Stakeholder Interest
Ahn et al. (2000)	Hunting, fishing	Changes in species
Aspen Global Change Institute et al. (2006)	Rafting	Early runoff
Averyt et al. (2011)	Camping, hiking	Forest die-off
Frisvold et al. (2011)	Parks	Most vulnerable parks; reduced precipitation
Hyslop (2007)	Parks	Most vulnerable parks
Loomis (2008)	Rafting	Early runoff
Loomis and Crespi (1999)	Parks	Reduced precipitation
Morehouse et al. (2007)	Parks	Reduced precipitation
Mendelsohn and Markowski (1999)	Hunting	Changes in species
Morris and Walls (2009)	Several	Early runoff Forest die-off Changes in species
Pendelton and Mendelsohn (1998)	Fishing	Changes in species
Saunders and Easley (2006)	Parks	Reduced precipitation Most vulnerable parks
Scott et al. (2007)	Parks	Most vulnerable parks
Shrestha and Schoengold (2008)	Rafting	Early runoff
Starbuck et al. (2006)	Parks	Forest die-off
Travis et al. (no date)	Resorts	Forest die-off
Wildlife Management Institute, ed. (2008)	Hunting, fishing	Changes in species

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