

United States Senate Committee on Environment and Public Works

**May 24 2007 Hearing on
“The Issue of the Potential Impacts of Global Warming on Recreation
and the Recreation Industry”**

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Biography of Witness:

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Acknowledgements:

Parts of this testimony draw on publications co-authored by the witness and the contributions of the following collaborators are gratefully acknowledged:

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Introduction

In its Fourth Assessment Report, the United Nations Inter-governmental Panel on Climate Change (2007) indicated that some degree of climate change was inevitable in the 21st century regardless of the success of international efforts to reduce greenhouse gas emissions. As a consequence, societies around the world will need to adapt to some magnitude of climate change in the decades ahead, adjusting human systems in order to moderate potential damages or realize new opportunities. Climate change was recognized by the United States National Research Council (on behalf of the National Science Foundation) as one of eight “grand challenges” in the environmental sciences (Committee on Grand Challenges in Environmental Sciences, 2001). Of particular importance, the Council noted, is the need for improved assessment capabilities with regards to the impacts of climate change on human and natural systems.

One economic sector in which climate change is anticipated to have considerable consequences is that of outdoor recreation, because it is highly influenced by climate. Climate defines the length and quality of multi-billion dollar outdoor recreation seasons, such as skiing, snowmobiling, golf, boating, and beach use, which subsequently influence sales of related sporting equipment and also tourism related spending. Climate also affects a wide range of environmental resources that are critical to the recreation sector, such as snow conditions, wildlife productivity, and water levels, and affects various facets of recreation operations (e.g., snowmaking or irrigation needs, open fire or swimming bans). Despite the importance of weather and climate to outdoor recreation, the sensitivity of individual recreation industries to climate variability the complexities of the interactions between climate change and recreation sector have not been adequately assessed to date.

It is beyond the scope of this testimony to provide a comprehensive assessment of the implications of climate change for the recreation sector of the United States, instead illustrative examples of the implications of projected changes in climate are provided for a variety of participation land, water and snow-based outdoor recreation activities, including hunting, fishing, park visitation, golf, boating, beach use, skiing, and snowmobiling.

Outdoor Recreation in the United States

Demand for outdoor activities in the United States substantial and varied geographically. According to the most recent National Survey on Recreation and the Environment (NSRE, U.S. Forest Service, 2000), 97.5% of Americans aged 16 and over participate in some form of outdoor recreation at least once per annum. When Americans participate in outdoor recreation, they spend money and create jobs while at the same time improving their physical and mental health. A recent assessment of the ‘Active Outdoor Recreation Economy’ estimated that this sector has an annual economic contribution of \$730 billion and supports over 6.5 million jobs (Southwick Associates 2006). This suggests that if substantive climate change impacts (positive or negative) occur in this sector, the economic implications are not likely to be trivial.

Implications of Climate Change for Outdoor Recreation in the United States: A Review of Empirical Evidence

As in the National Survey on Recreation and the Environment (U.S. Forest Service, 2000), this discussion is organized into three sections, covering land-based, water-based, and snow and ice-based, recreation activities. Where possible, existing empirical analyses of the potential impacts of climate

change on specific recreation activities are summarized; where no such investigations are available, broad-level implications are conjectured. As indicated, climate change would have both direct and indirect impacts on recreation activities – direct, through changes in climatic conditions such as temperature and precipitation, and indirect via the impacts of these climatic changes on the natural resources base. Both types of impacts are considered in the discussion below.

Land Based Activities

Land based activities constitute the largest category of outdoor recreation participation (U.S. Forest Service, 2000), and, in many cases, the positive experience of such activities is contingent upon one or more elements of the landscape (flora, fauna, and/or natural scenery) in which they occur. Despite the large numbers of Americans engaging in such activities, the relatively narrow range of atmospheric conditions in which they ideally occur, and the potential impacts of projected climate change on both atmospheric and environmental conditions, there appears to have been limited research into the likely impacts of climate change on patterns of participation. Studies addressing the potential implications of climate change for camping, hunting, viewing wildlife and natural scenery, and golf, are summarized below.

Camping

According to the National Sporting Goods Association (2005), over 55.3 million Americans aged seven or older went camping once or more in 2004, making this the second most popular of the sporting activities this agency monitors. While styles of camping may vary considerably, from large recreational vehicles with all modern conveniences, to back-country and wilderness locations with no facilities provided, most camping trips are impacted by weather conditions to a lesser or greater extent. Loomis and Crespi (1999) and Mendelsohn and Markowski (1999) concurred that at the national-level increases in temperature (from 1.5°C to 5°C) and precipitation (from 0% to 15%) would have a negative impact on the numbers of people participating in, and the welfare value generated by, camping. Key limitations of both of these studies are that they fail to take into consideration regional variations in seasonal activity patterns or climate change scenarios and thus provide no information on regions that may see reduced or increased camping activity. Illustrative of the regionally specific impacts on camping seasons are studies in southern Canada that are latitudinal (and climatological) equivalents to northern states in New England or the Midwest, which project an extension of the camping season in the spring and fall shoulder seasons and increases in camping related revenues (23% to 36% by the 2050s - Wall et al. 1986).

Hunting

According to the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (U.S. Fish and Wildlife Service, 2002), over 13 million Americans aged 16 or older spent over 228 million days and nearly \$22 billion on hunting-related activities in 2001. The Wildlife Society (2004) has examined the potential impacts of climate change for wildlife in North America and concluded that wildlife managers, including those who manage wildlife populations for recreational hunting, cannot ignore the important implications.

According to Mendelsohn and Markowski (1999), climate change (increases in temperature from 1.5°C to 5°C and in precipitation from 0% to 15%) is unlikely to have any significant impact on the welfare value generated by hunting activity in the US over the next 50 years. While the total value of hunting

within in the US may indeed remain relatively unchanged under warmer, wetter conditions, considerable geographic shifts in hunting activity should be anticipated as a result of changes in the geographic distribution and relative abundance of species. Vegetation modeling studies on the impacts of climate change on terrestrial vegetation have consistently projected major shifts in vegetation types over much of the continent (Neilson, 1998; Cramer et al., 2001), with interconnected impacts on wildlife habitat. Thomas et al. (2004, p.147) stated that, “Despite the uncertainties... the overall conclusions ... establish that anthropogenic climate warming at least ranks alongside other recognized threats to global biodiversity [and] contrary to previous projections, it is likely to be the greatest threat in many if not most regions.” Indeed, a series of meta-analyses (Parmesan and Yohe, 2003; Root et al., 2003) have compiled evidence that physical and biological systems are already responding to the changing climate of the twentieth century.

Loomis and Crespi’s (1999) analysis of the potential impact on waterfowl hunting suggested there would be virtually no change in hunter days in the US, however this analysis only considered the implications of climate change for the future availability of wetlands on the east coast of the US, while implications for the single most important waterfowl habitat region in North America, the prairie pothole region, were overlooked. The prairie pothole region is one of the most productive waterfowl regions in the world and although it only represents an estimated 10% of waterfowl breeding habitat in North America, the region produces 50-80% of the continents ducks annually (Batt, Anderson, Anderson, & Caswell, 1989). Some anticipated ecological impacts of climate change in this region include: fewer wetlands on average; shorter flooding duration for wetlands; greater annual variability in surface water; changes in agriculture and waterfowl food supply; and changes to water depth, salinity, temperature, plants, and aquatic food webs. A study by LeBlanc et al. (1991) estimated that the impacts of climate change would bring about a decline of 22% in duck productivity in North Dakota and concluded that this result could be approximated to the entire prairie pothole and parkland region of the US and Canada. Had Loomis and Crespi (1999) used this region as the basis for their study, the outcome would have been significantly different.

Viewing wildlife and natural scenery.

The viewing of wildlife and natural scenery is a broad category that encompasses a variety of activities in a variety of settings. In 2001, over 66 million Americans aged 16 or older spent over \$38 billion on wildlife watching activities (U.S. Fish and Wildlife Service, 2002). Eagles et al. (2000) estimated that over 2.6 billion visitor days were spent in national-state parks and protected areas in the US and Canada in 1996.

An ongoing study of the potential implications of climate change for national park visits illustrates that there are likely to be very different regional impacts (Hyslop and Scott 2007). Recreation activities in many of the parks in the northern US are constrained by winter conditions, and with a lengthened and improved warm-weather recreation season, visitation to national-state parks in these regions are expected to increase. For example, Acadia national park was projected to have increased visitation of between 4-6% in the 2020s and 7-18% in the 2080s and Cuyahoga Valley increases of 3-8% in the 2020s and 6-22% in the 2080s. Other national parks projected to experience potentially large increases in visitation were Rocky Mountain, Yosemite, and Olympic. Conversely, some national parks in southern and desert states were projected to have reduced visitation, including Everglades, Mesa Verde, and Saguaro. Notable, the negative impact on visitation levels in these parks was not as great as the increase in other more northerly parks. Increased visitation would have benefits for park revenues and the economies of nearby communities, but could exacerbate visitor-related ecological

pressures in some parks. The implications of a changed climate for park visitation in more southern regions of the US remain uncertain however.

Although the direct impacts of a changed climate alone may increase visitation to some parks, the environmental changes resulting from alterations in climate may reduce the attractiveness of the landscape to the extent that visitation may be adversely impacted. Two studies have assessed the potential impacts of climate-induced environmental change in the Rocky Mountain region. Richardson and Loomis (2005) asked visitors to Rocky Mountain National Park how their visitation patterns (number and length of stays) might change under a series of hypothetical environmental change scenarios for the 2020s. Scott et al. (2007) used a similar approach in Glacier-Waterton Lakes International Peace Park, where they asked tourists to consider three hypothetical environmental change scenarios (for the 2020s, 2050s and 2080s) and indicate whether they would still visit the park and, if so, more or less frequently.

Richardson and Loomis (2005) found that the majority of respondents indicated that they would not change their visitation patterns to Rocky Mountain National Park under the three scenarios provided. The changes in visitation behavior resulted in a 10% to 14% increase in annual visitation under the first two scenarios, while the 'extreme heat' scenario caused a 9% decline in visitation. The findings of Scott et al. (2007) in Glacier-Waterton International Peace Park for the 2020s were largely consistent with those of Richardson and Loomis (2005). Under the 2080s scenario, however, 19% of respondents reported that they would no longer visit the park and, of the 81% who would still visit, 37% stated they would do so less often. The loss of glaciers in the park was the most important reason cited for not intending to visit the park in the future.

Landscape change in parks is likely to be personally meaningful to many Americans and therefore presents an educational opportunity via interpretive programs. For example, while the loss of Glacier National Park's namesake would be a significant heritage loss, it could serve an important educational role to inform visitors about climate change.

Bird watching has undergone tremendous growth over the past 30 years in the US. Participation in birding among Americans grew 232% between 1983 and 2001 (Cordell and Herbert 2002) and today there are over 70 million bird watchers in the United States. Of the 51 recreational activities currently tracked through the US National Survey on Recreation and the Environment, birding represents the 15th most popular activity (US Department of the Interior, Fish and Wildlife Service 2001). Avitourism is a significant and growing tourism market. In 1996, over US\$6 billion was spent on trips associated with birding in the United States (American Birding Association 2002). The number of communities organizing birding festivals has increased from 12 in 1993 to over 200 in 2002 (Cordell and Herbert 2002) and birding travel routes are being established to attract avitourism.

Bird species can be affected by climatic changes in a number of ways, including changes in their habitat range, availability of food sources at certain times of the year, the timing and path of migrations, and nesting behaviour. Research suggests that climatic changes during the 20th century have already had a discernable impact on bird populations in North America (Price and Glick 2002) and Europe (Lemoine and Bohning-Gaese 2002). Climate change in the 21st century is projected to further impact the distribution and diversity of bird populations in North America. Price and Root (2001) argue that the number of neotropical migrant species present in the US would decline under projected climate change, with the largest species losses in the Eastern Midwest (-30%), Great Lakes (-29%), Mid-Atlantic (-23%), and Southeast (-22%) regions. With an estimated one in every three of

North American songbirds born in Canada's boreal forest (Blancher 2002), the projected decline and retreat of the southern boreal forest due to climate change (Hogg and Hurdle 1995, Scott et al. 2002) has important implications for songbird populations. The degradation or loss of critical habitats (particularly key wetlands) could have a significant impact on birding destinations. The increased rarity of some species could however generate increased tourism, as birders travel further in search of these species.

Climate change impacts on the vegetation and hydrology of the New England and Midwest states could also impact recreation associated with fall foliage (leaf colour touring) that currently a highly popular and economically valuable activity in these regions. Fall colour sightseeing draws visitors from across the US (Andrews 1999) and would be negatively affected by the projected decline in maple trees (which provide the bright red colour essential to spectacular fall landscapes) and a greater abundance of less colourful tree species. Vegetation modelling has projected the maple- beech-birch forest type that currently dominates the region would be replaced by the oak-hickory forest type under climate change conditions (Iverson and Prasad 1998). How people respond to changes in forest landscapes remains an important uncertainty in determining the vulnerability of fall tourism in this region (U.S. National Assessment-NE regional report 2000).

Golf

The golf industry is one of the largest recreation sectors in US and one that is highly influenced by weather and climate. There are approximately 20,000 golf courses (World Golf Foundation, 2001) and according to the U.S. Census Bureau (2004), 27.6 million golfers (persons aged twelve or older who played one round or more) played 552 million rounds of golf in 2001. In 2000, golf accounted for \$62 billion worth of goods and services in the US and supported over 295,000 paid employees, of which \$20.5 billion in revenues were generated directly at golf facilities, mainly through green fees (World Golf Foundation, 2002). By comparison, the golf sector is estimated to approximate the economic size of the motion picture industry in the United States (\$57.8 billion) (U.S. Census Bureau, 2001).

Golf industry reports and professional journal articles, the golf industries in the United States are very aware of the importance of weather and climate to their business. According to the *2001 Golf 20/20 Industry Report*, the single most important factor impacting rounds played [both positively and negatively each year] continues to be weather (World Golf Foundation, 2001). In a survey of 2,426 golf courses in the United States, 52% identified climate variability as the leading reason for lower than expected rounds played in 2000 and 2001, while 35% cited climatic variability as the primary reason for higher than expected rounds played (World Golf Foundation, 2004). By comparison, less than 10% of golf courses participating in the same survey identified the economy or course renovations in positively or negatively influencing rounds played. Another analysis of golf participation (1,849 golf courses) in the United States also identified variations in weather as the primary reason for positively (35%) and negatively (62%) affecting annual rounds played in 2003 over 2002 (National Golf Foundation, 2004).

It is clear that the North American golf industry attributes a considerable share of its economic success to weather and climate, yet surprisingly very few studies have attempted to assess the empirical relationship between weather and climate and the golf sector. The lack of research examining the impact of weather and climate on the golf industry was acknowledged by the World Golf Foundation (2001) in its *2001 20/20 Golf Industry Report*. The report recommended that more analysis of rounds

played and weather [and climate] was needed. The need for research into the potential impacts of climate change on the golf sector has also been acknowledged by the European golf industry. Drawing on the input of over 250 stakeholders, including course managers, union leaders and professional organizations, the Golf Course Advisory Panel at the Royal and Ancient Golf Course of St. Andrews (Scotland) identified climate change as one of six strategic issues facing the golf industry over the next twenty years (Royal and Ancient Golf Club of St. Andrews, 2000).

Loomis and Crespi (1999) attempted to project golf participation in the United States under climate change scenario. Although they do not describe how rounds played were converted into golf days, they projected that under the arbitrary climate change scenario they used (+2.5°C/4.5°F; +7% precipitation), the US golf industry would benefit from a 14% increase in golf days in the 2050s. The methodology used in this study was limited in that a single climate change scenario was applied to the entire country and as such it did not take into account climate change uncertainty by examining a range of future climates and ignored the regional differences of projected climate change in the US. More importantly, the study did not distinguish local and state-level golf from out-of-state tourism-based participation (e.g., golf tourism to states like Florida and Arizona from regions where golf courses are closed in winter). The model therefore projected increased participation in northern states as temperature increased, but did not subtract the diminished flow of golf tourists to states that are currently golf destinations in the winter months.

Illustrative of the regionally specific impacts on golfing are studies in southern Canada that are latitudinal (and climatological) equivalent to northern New England or Midwest states. Scott and Jones (2005) examined the influence of weather conditions and climate change on the season length and the number of rounds played in southern Ontario (Canada). The model projected that as early as the 2020s the average golf season could be one to seven weeks longer and with much improved shoulder seasons annual rounds played could increase 6% to 14%. The model results for the 2050s projected an increase in rounds played of 8% to 24%. The increase in rounds played occurs largely because of more conducive weather conditions that extend the golf season up to 16 weeks in the 2080s. Similar magnitude of impacts would be anticipated in Michigan and upstate New York and other nearby states.

To assess the full potential impact of climate change on the golf industry the implications for a full range of golf course operations in regions across the US is needed. A warmer climate would lead to greater demand for turf grass irrigation in all regions. With increased competition for water in the future, climate change is anticipated to exacerbate the challenge of water supply for the industry. This is particularly the case in some of the top golf destinations in the US that are projected to have acute water supply challenges in the coming decades even if climate change does not occur. Another important issue for golf operations is the potential impact of climate change on grass maintenance issues, such as turf grass selection, turf diseases and insect pests. Pests that currently have only one life cycle in northern states could adapt to new climate regimes and have two life cycles. Perhaps more importantly, there is the potential for turf grass diseases and pests currently limited to more southerly latitudes to expand into northern states and require new management interventions in the future. Future analysis of these operational issues is essential to provide insight into the potential ability of golf courses to take advantage of the opportunities projected climate change would bring.

Water Based Activities

Boating

According to the U.S. Census Bureau (2004), in 2001 Americans owned over 17 million recreational boats and made over \$28.5 billion of retail expenditures on this activity. In the same year, over 4,000 US marinas supported close to 25,000 employees and reported revenues in excess of \$3 billion. Nearly one-third of all registered boaters in the US reside in one of the eight Great Lakes states and over 1,800 marinas exist in Minnesota, Wisconsin and Michigan alone (Lindeberg and Albercook, 2000; Sousounis and Albercook, 2000). The potential implications of climate change for boating in the Great Lakes region are, therefore, of special importance from both an economic and a social perspective.

Nevertheless, despite the size of the boating industry and the number of participants involved, the impacts of climate change on boating appear not to have been addressed empirically other than in one study conducted on a national-level dataset from 1990 (Mendelsohn & Markowski, 1999). According to the analyses conducted by these authors, climate change is likely to have a positive impact on boating activity, with increases in value ranging from \$1.1 billion (for a 1.5°C increase in temperature, and increases in precipitation from 0 to 15%) to \$13.1 billion (for a 5°C increase in temperature, and increases in precipitation from 0 to 15%). However, these figures do not include consideration of the likely negative impacts of declining water levels on the Great Lakes and reservoir lakes in the western US and thus, may overestimate this positive impact at the regional and local level. For example, as a result of recent drought in western states, the Colorado River Outfitters Association experienced a 40% decline in business, with an estimated impact of \$50 million (Associated Press 2002) and water levels in the Lake Mead, the largest western U.S. reservoir with ten million visitors annually, dropped nearly 30-meters since 1999. Each six-metre reduction in water level costs \$6 million for adapting infrastructure (Allen et al. 2003).

Fishing

According to the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (U.S. Fish and Wildlife Service, 2002), over 34 million Americans aged 16 or older spent over 557 million days and \$36 billion on fishing-related activities in 2001. The majority of anglers (83%) fished in freshwater (including the Great Lakes), compared to 27% in saltwater. The American Sportfishing Association (2001) estimates the value of freshwater sport fishing and the associated tourism market to exceed US\$11 billion in North America.

A limited number of studies that have investigated the potential impacts of climate change on recreational fishing in North America. Wall (1998) provided an overview of the implications of global climate change for tourism and recreation in wetland areas, including those for fishing. For marine wetlands, he listed inundation, erosion and saltwater intrusion as three key negative impacts of rising sea levels, whereas for inland wetlands, declining water levels and loss of wetland species were noted. Such changes have important implications for water supply and equality, as well as the distributions of vegetation, wildlife (and, hence, wildlife viewing and hunting), and fish (and fishing). Wall identified the most threatened coastal and inland wetland areas as the coastal wetlands of Louisiana, and the Great Lakes, respectively.

A number of cold-water fish species are particularly sought by anglers. Studies of the potential impact of changes in water temperatures for selected cold-water species have projected negative impacts throughout the United States, including the lower Great Lakes. The US Environmental Protection Agency (1995) quantified the potential economic impact of the projected losses of 50% to -100% loss in cold-water fish habitat in the Great Lakes and New England states. Their analyses suggested annual

economic damages to the US sportfishing industry of \$320 million by the 2050s. This study also found that when alternative modelling assumptions were used, the estimated damages increased substantially, suggesting the need for further research to narrow the range of uncertainty.

A study of the impact of climate change on the recreational trout fishery in the southern Appalachian Mountains of North Carolina found that the decrease in thermal habitat for trout (82% of streams would no longer support brook trout) would result in an annual economic loss of \$61-584 million (1995 dollars) (Ahn et al. 2000). Similar research on the thermal habitat for salmonid species in the Rocky Mountain region of the United States found that the projected 4⁰C summer warming in the region would reduce habitat area by an estimated 62% (Keleher and Rahel 1996). In contrast, smallmouth bass, a popular warm-water sport fish species, was projected by Casselman (2002) to increase substantially in the eastern Lake Ontario area (a 1⁰C warming = 2.5 times increase in abundance, 2⁰C warming = 6 times increase).

The cumulative impact and regional vulnerability of the North American sportfishing industry to climate change has not been completed, nor has there been a rigorous analysis of the potential adaptation strategies (e.g., lake stocking strategies, angler choice of species).

Beach Recreation

Coastal zones are among the most highly valued recreational areas and are primary resources for the economy of communities that exploit the sea, sun and sand for recreation. Climate change has important implications for coastal areas both through the redistribution of climate resources for beach use and the possible inundation of recreation beaches by sea level rise. An early study of beach nourishment as an adaptation strategy to preserve major recreational beaches throughout the United States estimated the cost at \$14.5 billion for a 50cm sea level rise and \$26.7 billion for a 1 metre sea level rise (Smith and Tirpak 1990). A regional study in Florida by the US EPA (1999) reported that a 60cm sea level rise would erode beaches in parts of south Florida 30 to 60 metres unless beach nourishment efforts were expanded. The cumulative cost of sand replenishment to protect Florida's coast from a 50cm rise in sea level by 2100 is estimated at \$1.7 to \$8.8 billion (EPA 2003).

Diving

The reefs of the Florida Keys support a large diving and fishing industry. These activities generated an estimated \$4.4 billion in revenues in a four-county area of south Florida (Johns et al. 2001). Like reef systems around the world, the reefs across this region have been under considerable human-induced stress (overfishing, pollution). Coral reefs in parts of the Caribbean and Gulf of Mexico have suffered an 80% decline in cover over the past 30 years (Gardner et al. 2003). Recent coral bleaching events caused by high water temperatures and scenarios for future water temperatures in the region project an imperiled future for coral reefs and related recreational diving in the region.

Snow and Ice Based Activities

Skiing

Snow-based recreation in the United States, encompassing downhill (alpine) skiing and snowboarding, cross-country (nordic) skiing, and snowshoeing, was recently estimated to contribute an estimated \$66 billion to the US economy and support approximately 556,000 jobs (Southwick Associates 2006). Just

over 8% of the US population (15.5 million people) participate in these forms of snow-based recreation.

The ski industry has been repeatedly identified as being particularly vulnerable to climate change and studies on the ski industry in the US (Lipski and McBoyle 1991; Hayhoe et al. 2004; Casola et al. 2005, Reuer 2006) have each projected negative impacts, though to varying degrees and over different time horizons. While not all ski industry executives share his view, Patrick O'Donnell, the Chief Executive Officer of Aspen Skiing Company, recently referred to climate change as "the most pressing issue facing the ski industry today" (Erickson 2005).

Considering only changes in natural snow conditions, the ski season in the Sierra Nevada of California was projected to 3-6 weeks (2050s) and 7-15 weeks (2080s) (Hayhoe et al. 2004). Reuer (2006) modelled potential changes in snow pack in Rocky Mountain States in the latter decades of this century, specifically the depth of snow on April 1, and projected reductions ranging from 26% in Teton County (Wyoming) to over 80% in Salt Lake County (Utah), San Miguel County (Colorado) and Taos County (New Mexico). It is not clear how such changes in the spring snow pack would translate into changes in the ski season length, so statements related to this study that the 'ski industry in the Rockies could be shut down by 2050' must be considered speculation at this time. Furthermore, these US studies have a very critical limitation, in that the widespread climate adaptation of snowmaking has not been accounted for. Consequently, these studies of the impact of climate change on ski operations have likely overestimated future damages.

Studies by Scott et al. (2003, 2006, 2007a, 2007b) were the first to couple a snowmaking module using climatic thresholds and operational decision rules derived from interviews with ski area managers into a physical snow model.. Their studies found that the incorporation of snowmaking substantially lowered the vulnerability of ski areas in eastern North America through the middle of the 21st century. In a recently completed study of 14 clusters of ski areas in the US Northeast (Scott et al. 2007), even with the assumption of advanced snowmaking systems in place, the climate change scenarios consistently projected a trend toward shorter ski seasons.

Under the lower emission scenario for 2010-2039, only three study areas were projected to lose less than 10% of the ski season, while 10 study areas lost 10-17% and only the Connecticut location lost more than 20%. In 2040-2069, ski season losses were not substantially higher, with only the Connecticut location projected to lose greater than 25% of its ski season. The level of climate change impact increased in the 2080s where half of the study areas were projected to lose 25% or more of their ski season. The higher emission scenario had a much greater impact on the length of ski seasons in the region, especially in 2040-2069 and beyond. In 2040-2069, eight of the study areas were projected to lose 25% or more of their ski season. By 2070-2099 all 14 of the study areas had lost at least 25% of the ski season and half of the study areas lost 45% or more.

In order to limit ski season losses to the levels described above, snowmaking requirements were projected to increase throughout the Northeast. Under the lower emission scenario for 2010-2039, snowmaking requirements would increase by at least 25% at half of the study areas. In 2070-2099, climate change had distinctly different impacts on snowmaking requirements. Five of the study areas were projected to require at least 50% more snowmaking and increases of 25 to 49% were projected for an additional four locations. The remaining five study areas were projected to make the same amount or less machine-made snow in 2070-2099 than 2040-2069 due to the inability to make snow in unsuitably warm temperatures during the early and latter part of the current ski season.

The higher emission scenario again had a much greater impact on snowmaking requirements. In 2010-2039, nine of the study areas were projected to require at least 25% more machine-made snow. In 2070-2099, three study areas were projected to require over a 100% increase in machine-made snow and four other locations require at 50 to 99% more machine-made snow. Snowmaking was projected to decline relative to 2040-69 in five locations (West Pennsylvania, East Pennsylvania, Southeast New York, West New York, and Connecticut) where warm temperature made it unfeasible during parts of the winter months.

The large increases in snowmaking requirements under climate change also raised important questions about the sustainability of this critical adaptation strategy in certain locations. Communities and environmental organizations have expressed concern about the environmental impact of water withdrawals associated with snowmaking. Under the higher emission scenario, where a 50-100% increase in snowmaking was modelled at several locations, water conflicts may be heightened and access to water may be a critical constraint for future snowmaking. The economic costs of increased snowmaking (energy and water costs) were not factored into this assessment because the detailed economic information required is not publicly available, and this remains a critical uncertainty for the future profitability of ski areas in the region.

Based on this analysis, it would appear that it is not the Northeast ski industry that is at risk to climate change but rather individual ski businesses and communities that rely on ski tourism. The probable consequence of climate change will be a continuation of the historic contraction and consolidation of the ski industry in the region. It will be the relative advantages of local climatic resources and the adaptive capacity of individual ski areas that will 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 Northeast, it could advantage some of the ski operations that remain. Assuming that skier demand declines only to the level observed in the climate change analogue winter of 2001-02 (approximately 10% fewer skier visits), then ski businesses in Vermont, Northeast New Hampshire, Northeast New York, and West Maine would be in a position to gain market share (through diminished competition) and potentially offset revenue losses due to reduced ski seasons and higher snowmaking costs.

Large corporate ski conglomerates like Intrawest, the American Skiing Company, Boyne USA Resorts and Booth Creek Resorts may be less vulnerable to the impacts of climate change than single ski operations because they generally have more diversified business operations (real estate, warm-weather tourism resorts and four-season activities), are better capitalized (so that they can make substantial investments in snowmaking systems) and, perhaps most importantly, are regionally diversified (which reduces their business risk to poor snow conditions in one location).

Snowmobiling

According to the International Snowmobile Manufacturers Association (ISMA, 2004), there are approximately 1.77 million registered snowmobiles in the United States. ISMA estimates the economic impact of snowmobiling is equal US\$20 billion per annum in the US; over 85,000 full time jobs are generated by the snowmobile industry in North America, including those in manufacturing, dealerships and tourism related businesses (ISMA, 2004).

Due to the long, linear nature of snowmobile trails, snowmaking is rarely a viable adaptation option and the snowmobile industry relies almost exclusively on natural snowfall. As such, several studies have found that snowmobiling is more vulnerable to the negative impacts of climate change than is downhill skiing. A recent study of snowmobiling seasons in 15 study areas in the Northeast (Scott et al. 2007) found that the climate change scenarios consistently projected a trend toward shorter snowmobile seasons throughout the Northeast and a northward shift in the southern margin of snowmobiling activity. As early as 2010-2039, four of the 15 study areas are projected to lose more than 50% of their snowmobiling season under the lower emission scenario and six locations under the higher emission scenario. The majority of the 15 locations examined in this study were projected to have marginal or non-existent snowmobile seasons in 2040-2069 under both lower and higher emission scenarios. Consequently, the loss of snowmobiling activity and related tourism would appear unavoidable in the following locations if the climate change scenarios projected for 2040-2069 were realized: Western New York, North-central Pennsylvania, Southeast New York, South-central Pennsylvania, East Pennsylvania, West Massachusetts, South New Hampshire, and Northeast New York.

The implication of a substantial decline in nearby opportunities for snowmobile participation remains an important uncertainty. If participation remains unchanged or declines only slightly, the few locations that are projected to continue to have sufficient natural snow for snowmobiling later into the 21st century (North-central New York, North Vermont, South Vermont, North New Hampshire, Northeast Maine, and Northwest Maine) may be in a position to market their area to winter recreation enthusiasts and potentially benefit from a change in the competitive relationships between winter recreation destinations. Further research is needed to understand the influence of distance costs and destination loyalty on changes in snowmobile patterns as well as the environmental implications of a greater concentration of snowmobile activity on the remaining trails with reliable snow conditions.

Given the projected reductions to an already short snowmobile season in much of Northeast, it is possible that snowmobilers may choose to discontinue the use of their snowmobile and adopt another type of recreational vehicle that is not limited by snow conditions (i.e., all-terrain vehicles [ATVs]) or perhaps a completely different form of recreation. Growing ATV and declining snowmobile sales in the US over the last five years may provide evidence to suggest that the transition is already underway in some regions (Suthey Holler Associates 2003). If a large number of snowmobilers in the region adopt this climate adaptation strategy there would be important implications for land managers and communities, including recreational planning and infrastructure development, to minimize the environmental impacts of trail use by ATVs. Under such a scenario, communities that developed recreational trail networks for ATVs might gain a competitive advantage over communities that continue to cater to snowmobiles.

Conclusions

Although the aforementioned examples of potential climate change impacts discussed are no means exhaustive, it is clear that climate change has far-reaching consequences for US recreation and the recreation businesses and industries. Importantly, it must be emphasized that climate change will have both negative and positive impacts on recreation sector in the US creating both threats and opportunities for both participants and recreation providers. There will be ‘winners and losers’ at the business and community level, and each will need to adapt to climate change but in different ways (e.g., adapting to employment and economic losses versus congestion and development pressures). As the tourism and recreation section of the IPCC (2001) North American chapter (section 15.2.6)

concluded, until systematic regional and industry level assessments are conducted a definitive statement of the net economic or social impacts for this sector will not be possible. At the community level, the magnitude of the impact of climate change will depend upon the importance of the recreation industries in the regional economy, the characteristics of climate change and its affect on the natural environment, the adaptive response of recreationists, the capacity of recreation businesses adapt to climate change, and how the impacts of climate change interact with other long-term influencing variables in the recreation sector (globalization and economic fluctuations, fuel prices, aging populations in industrialized countries, increasing travel safety and health concerns, increased environmental and cultural awareness, advances in information and transportation technology, environmental limitations – water supply and pollution - and so on).

Finally, because climate change is already entering into decision-making in the recreation sector it is in the best interest of the recreation industry and applicable government agencies (federal, state and local levels) to engage in collaborative research to determine the potential implications of climate change issue, in order to best prepare recreation businesses and communities to minimize the risks and capitalize upon the opportunities likely to be brought about by climate change in an economically and environmentally sustainable manner.

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