Research Reports

Potential effects of warming climate on visitor use in three Alaskan national parks

By Christine M. Albano, Courtney L. Angelo, Ronda L. Strauch, and Lindsey L. Thurman

Known for its vast system of glaciers, the Alaska Range is home to Mount McKinley—a key attraction for visitors to Denali National Park. Warming climate may affect the timing and duration of the visitor season at national parks in Alaska and also the natural wonders visitors come to see.

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Abstract

Alaska's national parks draw millions of people annually to enjoy wildlife, breathtaking scenery, and recreational adventure. Visitor use is highly seasonal and occurs primarily during the summer months when temperatures are warm and daylight is long. Climate is an important consideration when planning a trip to Alaska's national parks because of the great distances and associated costs of travel for many visitors. As a result of projected climate warming, peak visitor season of use in Alaska's national parks may expand. To examine the potential effects of warming climate on park visitor season of use, we used regression analyses to quantify the relationship between historical (1980–2009) visitor use and monthly temperatures for three Alaskan national parks and identified the monthly mean temperatures at which the peak visitor season of use occurred in each park. We compared these contemporary temperatures with projected future average monthly mean temperatures for 2040–2049 and 2090–2099 to provide context for how visitation might be affected by warming climate. Based on historical relationships among temperature, visitor use, and increased temperatures associated with climate change, our analysis suggests that peak season of visitor use could expand into May and September depending on the park, the climate scenario, and the time period. As a consequence of a warming climate, planning by the National Park Service and other stakeholders may need to consider this transition in temperatures and the potential for an extended peak season of visitor use, along with other climate-related changes (e.g., extreme weather), climate-induced environmental changes, and shifts in recreational opportunities that will likely accompany climate change.

Key words

Alaska, climate change, Denali, Gates of the Arctic, Katmai, national park, temperature, visitor use

ALASKA'S NATIONAL PARKS DRAW PEOPLE FROM ALL over the world for wildlife viewing, breathtaking scenery, and recreational opportunities, including hiking, backpacking, mountain climbing, boating, hunting, and fishing. In 2012 these parks received more than 2.4 million visitors (NPS 2013*a*) and in 2011 they generated $237 million in state economic benefit, a conservative estimate because of challenges in capturing the full spending attributed to visiting national parks in Alaska (Cui et al. 2013). National parks provide a large portion of nature-based tourism. Regional climate directly affects this tourism by influencing the activities of visitors and contributing to the quality of the visitor experience (Amelung et al. 2007). The climatic influence on visitation is most evident in the northern national parks found in Alaska, wherein the majority of visits occur during the warmer months of summer when weather and daylight are conducive to recreational activities. Shifts in the length and quality of the warm season caused by climate change will likely alter visitation to national parks in Alaska (Suffling and Scott 2002) and provide a key consideration for planning recreation and tourism activities and related services (Scott and Lemieux 2010).

Relatively rapid climate change in Alaska poses a significant challenge to ecological conservation and management and to land use planning (NPS 2012*a*). Alaska's climate has warmed over the last 50 years at an average rate of more than twice that of the rest of the United States (USGCRP 2009). During this time, annual mean air temperatures (hereafter referred to as "temperature") throughout the state increased by 3.4°F (1.9°C) (USGCRP 2009). The greatest increases in Alaska were seen in the winter, with temperatures rising by 6.3°F (3.5°C) (USGCRP 2009). Total precipitation also increased in all seasons except summer at the end of the 20th century throughout the state outside of the Arctic region (Stafford et al. 2000). By the middle of the 21st century, annual precipitation is expected to increase and annual mean temperatures are expected to be 3.6° to 7°F (1.9°–3.9°C) higher than at present with a longer summer growing season (USGCRP 2009). Thus, climate change will continue to affect ecological, hydrological, and human systems in a profound way throughout Alaska (USGCRP 2009). Impacts on glacial and permafrost extent, storm severity, sea-level rise, subsistence living, severity and extent of forest fires, insect outbreaks, and general disruption to ecosystem processes and functions will continue to challenge scientists and planners (USGCRP 2009). All of these factors play a role in the safety, frequency of visits, and enjoyment of Alaska's national parks.

The commitments associated with cost of travel, perceived isolation, and distance from the rest of the United States likely compel potential visitors to plan their vacations for times that maximize their chance of predictably good weather, which has been seen in other mountainous regions (Parks Canada 2004; Scott et al. 2007). National Park Service recreational visitor statistics for many U.S. national parks show that visitor use is related more often to regionally pleasant weather patterns than to institutional seasonality associated with school- and work-related vacation periods. For example, visitor use is highest during the spring and fall months in some parks located in the southwestern warm desert, where temperatures can be extreme in summer and winter. Alternatively, visitor use can be fairly consistent year-round in the Hawaiian Islands, where temperatures are generally pleasant throughout the year. Visitor use in the Rocky Mountains is often constrained to the summer months when temperatures typically exceed the likelihood of freezing conditions (NPS 2012*b*; figs. 1A, 1B, and 1C).

Scientists have established links between climate change and shifts in the timing of visitor use, with some parks already experiencing more visitor use earlier in the season than has been

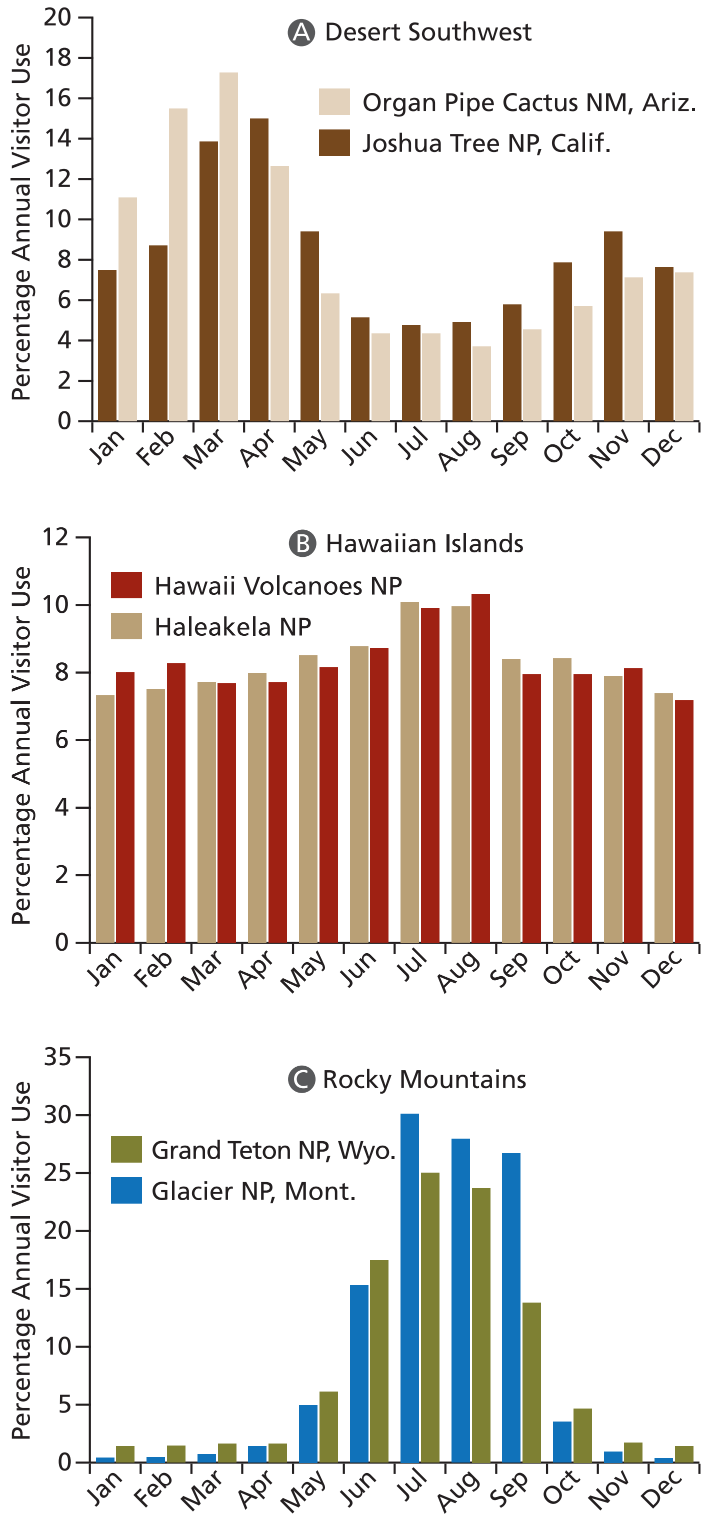

Figure 1. Seasonality of recreational visitor use in U.S. national parks (NP) and national monuments (NM) in regionally distinct areas: (A) southwestern deserts, (B) Hawaiian Islands, and (C) Rocky Mountains.

Figure 2. The study involved three Alaskan national parks—Gates of the Arctic (red), Denali (green), and Katmai (blue)—distributed over markedly different latitudes to gauge the influence of projected climate changes on visitor season of use.

observed historically (Buckley and Foushee 2012). Climate change is expected to expand periods of climate conditions conducive to visitor use at higher latitudes (Scott et al. 2004; Amelung et al. 2007), which may lead to more visitor use at times that are currently considered shoulder seasons (Scott et al. 2007). While many climate-related factors may directly or indirectly influence visitor use, temperature has been shown to be a stronger predictor of national park visits than other climate variables, such as precipitation (Richardson and Loomis 2004; Scott et al. 2007). Indeed, simple temperature-based models of snow accumulation and melt can simulate observations as well as, if not better than, more complex models that include other climate variables (Franz et al. 2008). Because of the strong seasonality of visitor use in Alaska's national parks and the expected changes in climate, we conducted a study to identify how historical visitor use relates to temperature to provide context for how future visitor season of use may change at each of three Alaskan national parks under three different climate change scenarios.

Methods

We selected three Alaskan national parks for study: Gates of the Arctic, Denali, and Katmai (fig. 2). We chose these parks because they are distributed across a latitudinal gradient within the state and may experience different magnitudes of climate change effects. To analyze the potential impacts of climate change on visitor season of use, we first examined the relationship between temperature and recreational visitor use (hereafter referred to as "visitor use," defined by the National Park Service as entries of persons onto lands or waters it administers; NPS 2013*b*). We used historical (1980–2009) monthly temperature data (decadal averages of monthly mean temperatures, averaged across the three historical decades) downscaled by SNAP (Scenarios Network for Alaska and Arctic Planning) (based on Climate Research Unit of the University of East Anglia time-series data, version 3.1; SNAP 2012) to a 2 km (1.2 mi) resolution. These data were then averaged across the entire park. To characterize historical visitor use, we used monthly recreational visitor use data from each of the parks (NPS 2012*b*) for the 1980–2009 period. Because average monthly park visitor use tended to increase over the study period, we calculated the percentage of annual visitor use that occurred in each month of a given year to standardize the monthly frequency of use across time.

Examination of plots of temperature and visitor use indicated a nonlinear relationship between these two variables. Following Scott et al. (2007), we used regression analysis to fit the data using a third-order polynomial equation to quantify the relationship between temperature and visitor use at each park. For our analysis we defined peak season as those months when >10% of annual visitor use occurred, as this was a natural break in the data for all three parks that appeared to distinguish peak season from shoulder seasons. We used the fitted regression equation to estimate the average monthly mean temperature at which 10% of annual visitor use occurred for each park and used this temperature as a point of reference to provide context for how the visitor peak season of use may change in the future given projected average monthly mean temperatures for 2040–2049 and 2090–2099, representing mid- and end-of-century conditions.

Future temperatures were derived from an average of five top-ranked global circulation models that perform best across Alaska and the Arctic (Walsh et al. 2008) under three emission scenarios adopted by the International Panel on Climate Change (IPCC; Nakićenović et al. 2000). The A2 scenario assumes a world with high population growth and slow technological and socioeconomic change, resulting in an increased rate of carbon dioxide emissions relative to today. The A1B scenario assumes rapid economic growth, new and efficient technologies, and finding a balance between fossil fuels and alternative sources of energy, resulting in a trajectory in carbon dioxide emissions similar to that of today. The B1 scenario represents the most optimistic case, in which carbon dioxide emissions level off at mid-century when population growth begins to decline, and governments emphasize global environmental sustainability through changes in economic and social structures (Nakićenović et al. 2000). As with the historical average monthly mean temperature data, we averaged

Table 1. Regression analyses between average percentage of annual visitor use and average monthly mean temperature for the 1980–2009 period in three Alaskan national parks

National Park	Equation	r^2	Temperature (°C) at 10% Annual Visitor Use
Gates of the Arctic	$Y = 0.002x^3 + 0.092x^2 + 1.2058x + 4.9768$	0.89	3.28 (37.9°F)
Denali	$Y = 0.0022x^3 + 0.084x^2 + 0.9714x + 3.2085$	0.96	4.77 (40.6°F)
Katmai	$Y = 0.0118x^3 + 0.0524x^2 - 0.0783x + 1.7909$	0.96	7.39 (45.3°F)

downscaled (based on Coupled Model Intercomparison Project model outputs for IPCC's Fourth Assessment Report; SNAP 2012) 2 km (1.2 mi) resolution data across each of the parks.

Results

From 2000 to 2009, Denali had the highest average number of annual visitors (386,805), Katmai had an intermediate number (56,237), and Gates of the Arctic had the lowest number (8,954). There is remarkable visitor seasonality in these national parks (fig. 3). Cool-season (October–April) visits represent a small percentage of annual visits: 1% for Gates of the Arctic, 6% for Denali, and 13% for Katmai. Visitor use at all three parks corresponded closely to high monthly mean temperatures (fig. 4). Peak season occurs in the warm summer months of June, July, and August when average monthly mean temperatures are typically greater than 50°F (10°C), while few people visit from October to May. September is a month of moderate visitation at Katmai. Regression analyses indicated strong relationships between temperature and visitor use at all three parks (table 1, fig. 4). Based on these regressions, the 1980–2009 average monthly mean temperatures associated with peak season were 38°F (3.3°C), 41°F (4.8°C), and 45°F (7.4°C) for Gates of the Arctic, Denali, and Katmai, respectively (table 1, fig. 4). These temperature values provided a point of reference for temperatures at which most visitation occurs in these parks and function as a baseline for comparing future projections of temperature change and its effects on peak visitor season of use.

Over the coming century, average monthly mean temperatures are projected to rise substantially in each of these parks, especially during the shoulder months in spring and fall, as well as in winter, regardless of emission scenario. By the 2040s, the projected average monthly mean temperature at Gates of the Arctic is expected to be similar to the historical average (1980–2009) in June and July, but temperatures will increase in August for each climate scenario (fig. 5A). Average monthly mean temperatures in May and September are projected to approach the 38°F (3.3°C) point of reference for Gates of the Arctic by the 2080s in the A1B and A2 scenarios. Fall and winter average monthly mean temperatures are also substantially warmer by the 2090s in all scenarios.

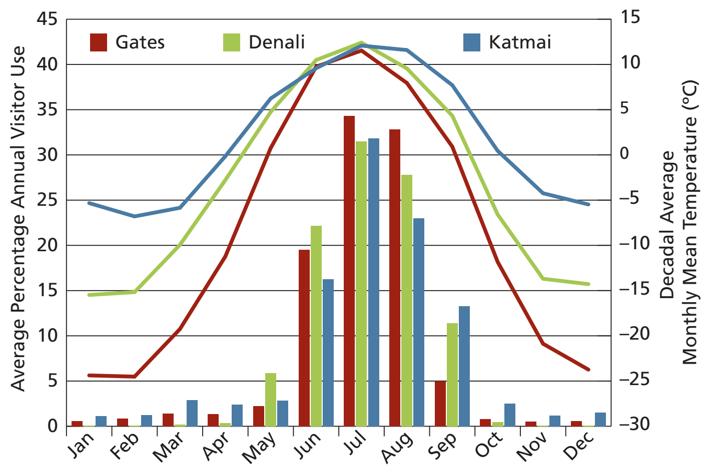

Figure 3. Average percent annual visitor use (bars) and average monthly mean temperatures (°C) (lines) by month at Gates of the Arctic (red), Denali (green), and Katmai (blue) National Parks. Values represent averages for 1980 to 2009.

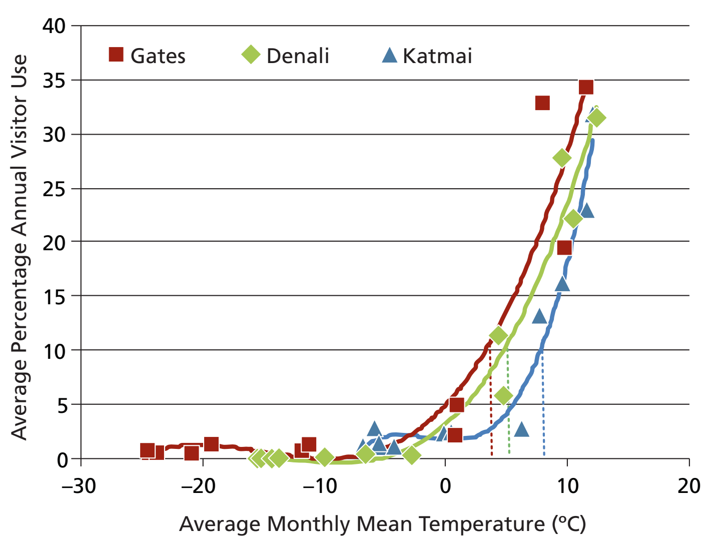

Figure 4. Relation of average percentage annual visitor use and average monthly mean temperatures (°C) (1980–2009) at Gates of the Arctic, Denali, and Katmai National Parks. The solid lines show the fitted regression line. The vertical dotted lines indicate points of reference for peak visitor season of use, defined as >10% annual visitor use. Points of reference correspond to 3.28°, 4.77°, and 7.39°C for Gates of the Arctic, Denali, and Katmai, respectively.

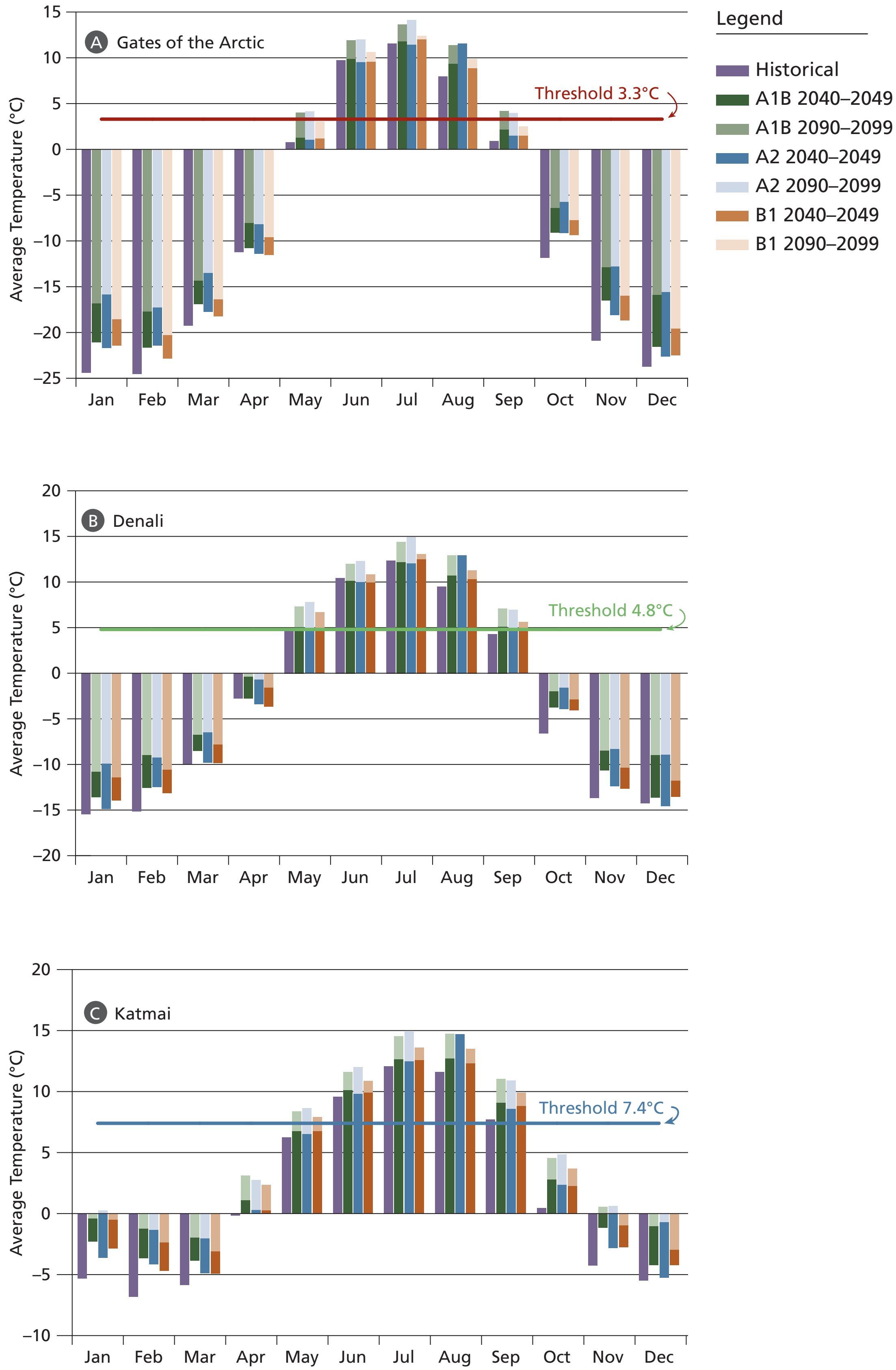

Figure 5. Historical (1980–2009) in purple and projected average monthly mean temperatures for the 2040s (darker color) and 2090s (lighter color) with three greenhouse gas emission scenarios (A1B, A2, and B1) for (A) Gates of the Arctic, (B) Denali, and (C) Katmai National Parks. Points of reference for peak visitor season of use (threshold) are shown as horizontal lines in each graph.

Similarly, by the 2040s Denali is projected to experience temperatures near the park's temperature point of reference of 41°F (4.8°C) under all emission scenarios from May through September and will be well above the point of reference by the 2090s (fig. 5B, previous page). During April and October historically, temperatures have been well below freezing, but are projected to be closer to 32°F (0°C) at Denali, and winters will also be substantially warmer by the 2090s, particularly under the A2 and A1B emission scenarios. Changes are less pronounced under the B1 emission scenario, which represents a leveling off of human-source emissions by mid-century.

By the 2040s, average monthly mean temperatures at Katmai are projected to be above the 45°F (7.4°C) point of reference for visitor use from June through September (fig. 5C, previous page). By the 2090s, May temperatures also rise above the Katmai point of reference, and even April and October averages are well above freezing temperatures, which has not been the case historically. Furthermore, average monthly mean temperatures during the rest of the year (November through March) are projected to be near or just below freezing by the 2090s, which represents substantial warming compared with historical conditions.

Discussion

Our analysis may help the parks to anticipate management needs under future climate change by providing context for understanding how temperature may relate to future visitor use. While short-term changes in climate have relevance for contemporary tourism planning, long-term climate change projections provide strategic relevance to park managers and the tourism industry (Scott et al. 2007). Based on historical relationships between temperature and visitor use and projected changes in temperature over the coming century, our research suggests that peak season of visitor use could expand by up to two months depending on the park, the climate scenario, and the time period analyzed. As temperatures in months currently considered shoulder seasons (e.g., May and September) become more similar to temperatures during the current peak season, we expect an increase in the percentage of annual visitation during these months, provided that other climatic, ecological, and social factors are conducive to this increase.

While climate is strongly linked to visitor use in Alaska's national parks, it acts in combination with other factors to determine seasonality and amount of visitor use and annual visitation trends. For example, human population growth and socioeconomic conditions may influence overall visitor use regardless of the environmental and climate conditions of these parks. Moreover, while some studies indicate that temperature more strongly affects visitor use than precipitation in mountainous regions (e.g., Richardson and Loomis 2004; Scott et al. 2007), changes in precipitation patterns associated with climate change may still affect conditions such that they are more uncertain or unpleasant during different times of year than has been the case with historical precipitation patterns. Twenty-first century changes in visitation may also be influenced by perceived diminishment of natural wonders (e.g., glaciers) as the climate warms; thus visitation may increase in the near future as people desire to see sights or events before they decline or disappear in the latter part of the century because of climate change. Although park managers may expect an increase in visitation over the next 20–30 years, visitors may view new conditions as having less value, which could result in a negative impact on visitation by the end of the century (Scott et al. 2007).

Our analysis may help the parks to anticipate management needs under future climate change by providing context for understanding how temperature may relate to future visitor use.

Numerous trade-offs are associated with the potential for increasing visitor use in Alaska's national parks. As a consequence of climate warming, planning by the National Park Service, park concessioners, and neighboring communities may need to consider potential changes in the timing, duration, and amount of visitor use. For example, park facilities (e.g., trails, lodging, roads, waste management, and water systems) may require additional maintenance and more frequent upgrades than in the past. Visitors may also expect park facilities to be operational earlier and later than historically prescribed, necessitating the hiring of seasonal staff earlier and for a longer duration. This will result in increased costs for operations and staffing that may be offset by increased economic benefits from user fees authorized under the Federal Lands Recreation Enhancement Act of 2004. Local businesses, particularly those in adjacent communities, could see increased revenue from park-related activities. For example, access to Katmai and Gates of the Arctic National Parks is largely restricted to airplane transport provided by local communities. An increase in visitor use in the shoulder seasons could generate more revenue for these local businesses, provided that they have the capacity and desire to expand these services.

Visitors hike among aspen trees on Taiga Trail in Denali National Park. Warming climate may extend the "shoulder" seasons for park visitation at Denali and other Alaskan national parks.

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Ecological changes and shifts in recreational opportunities that will likely accompany climate change may alter the seasonality in which peak recreation and wildlife viewing are possible. Phenological shifts associated with the timing of migratory or foraging patterns in fish, birds, and wildlife may disrupt the predictability of viewing opportunities (Taylor 2007; Post and Forchhammer 2008). For example, in Katmai, timing and locations of visitor use are closely tied to opportunities for viewing bears. Timing and locations of bears are related to summer salmon runs. It is unclear how climate will influence these complex ecological patterns and processes that will ultimately lead to shifts in visitor use trends. Thus, more research is needed to determine visitor responses to climate-induced ecological changes in Alaska's national parks.

Expected changes in the frequency, timing, and severity of extreme weather events causing fires, flooding, landslides, and avalanches may pose new hazards to visitor and staff safety, requiring heightened awareness of those working and playing in the national parks (Suffling and Scott 2002). Infrastructure damage caused by these events or from other climate-related changes, such as thawing permafrost, can result in increased maintenance and repair expenses. In addition, extreme events may dramatically alter the composition and structure of park ecosystems, such as vegetation in debris flows and inundated floodplains, with potentially long-lasting effects.

Conclusions

As indicated in this and other studies (see the introductory paragraphs to this article), climate change has the potential to alter visitor use patterns as well as the scenic, recreational, cultural, and ecological values for which the parks were designated. In this context, our research suggests that park managers may experience new challenges in balancing visitor support and conservation of natural and cultural resources in a warming world. Our temperature-based assessment provides a first approximation of potential changes in visitor use, but does not account for other factors that could influence visitation in the future, such as transportation costs, enhanced park facilities, indirect effects of climate change on park resources, and many other climate and non-climate factors.

The uncertainty associated with future visitor use patterns leads to several considerations for managers and the tourism industry. Should parks invest in building new infrastructure for access to wildlife and other viewing opportunities to accommodate ecological shifts associated with climate change? As thawing permafrost causes damage to structures of cultural significance or other types of infrastructure, should parks invest in stabilizing or moving these features? If climate change results in more seemingly pleasant conditions that attract a greater number of visitors or shifts in seasonal use patterns, should parks accommodate these visitors in places that typically experience low or short-duration human traffic? Future research aimed at planning for climate change impacts on the National Park System should incorporate climatic, environmental, and social data for a holistic evaluation of projected change and adaptive capacity. Conserving these areas will be a challenge for all stakeholders, but provides an opportunity to engage the public in understanding changing climate and the continued management and protection of our valuable national parks.

Acknowledgments

This project was made possible by funding from the U.S. Department of the Interior's Climate Science Centers located in Alaska, the Northwest, the Pacific islands, and the Southwest, along with funding from the International Arctic Research Center (IARC) at the University of Alaska–Fairbanks. Special thanks to John Walsh and Vladimir Alexeev of IARC for hosting the 2012 IARC summer school and to Stephanie McAfee from Scenarios Network for Alaska and Arctic Planning for help with the development of project ideas.

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