Chapter 5: Effects of Climate Change on Outdoor Recreation in the Sierra Nevada

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Introduction

This chapter considers social vulnerability to climate change by assessing the effects of climate change on outdoor recreation in the Sierra Nevada bioregion (Fischer et al. 2013) (fig. 5.1), and providing the information needed to manage for risk and to minimize loss (Aplet et al. 2010). By considering current and projected effects, we hope to better equip land managers and stakeholders with information that can aid management and planning for socioecological resilience.

The report expands the emphasis on recreation provided in a recent science synthesis for the Sierra Nevada (Long et al. 2014). Although the final aim is to assist the development of adaptation strategies and tactics, with emphasis on reducing vulnerability, exposure, and uncertainty (e.g., Aplet et al. 2010), the complexity and uncertainty involved require an adaptive management approach to effectively address climate change effects (Arvai et al. 2006, Clark 2002, Joyce et al. 2009). More recent examinations of recreation-related impacts, including this chapter with its greater level of detail and focus, are essential to informing adaptation that improves resilience around outdoor recreation management and use.

Nationwide, outdoor recreation provides substantial economic benefits. In 2016, the Outdoor Recreation Jobs and Economic Impact Act required an assessment of the outdoor recreation economy and its effects on the overall economy of the United States. According to the Bureau of Economic Analysis (USDC BEA 2018), outdoor recreation accounted for 2.2 percent of the nation's gross domestic product in 2016, and between 2015 and 2016, the outdoor recreation economy grew faster (a 1.7 percent increase) than the overall economy in the same period (1.6 percent overall increase). Conventional outdoor recreation accounted for 32.7 percent of the gross output for recreation, and boating and fishing alone, as the largest core activity in 2016, produced $36.9 billion of that output.

California's economic contribution from outdoor recreation is likewise significant. Among the top 30 employment sectors in California, the contribution is even greater in northern California and the Sierra Nevada where total outdoor recreation-related employment ratios to total population are triple the statewide average (BBC Research & Consulting 2010). California State Parks reported 2,269,082 visits in the

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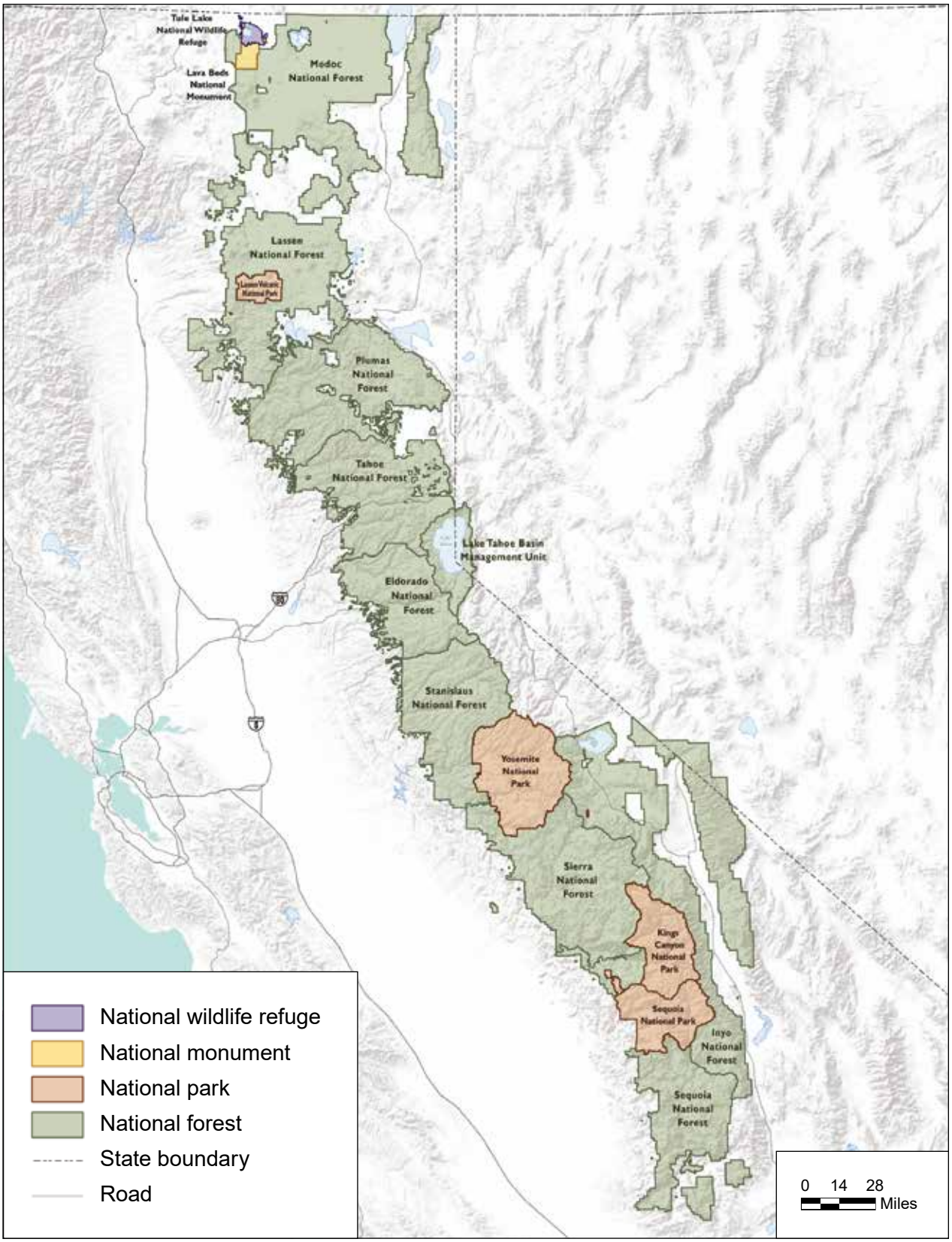

Figure 5.1—The Sierra Nevada assessment area.

2015–2016 reporting period for the Sierra District alone, bringing in revenue of $5,180,272 (California State Parks 2016). Outdoor recreation on federal lands accounted for about 23 million visitation days on average annually (table 5.1). This translates into a further contribution to the state economy. Statewide direct expenditures for outdoor recreation on federal lands are highest in the Sierra region, accounting for about one-third of the contribution from federal lands. In 2008, the economic benefit to the state from outdoor recreation in the Sierra Nevada alone was $333 million (BBC Research & Consulting 2010).

Economic benefits from outdoor recreation and tourism are important to the communities adjacent to, and surrounded by, national forests in the Sierra Nevada. Many rural economies in the region depend on recreation and tourism (Chan and Wichman 2018, Hatchett and Eisen 2018), and related projects can be conducted in

Table 5.1—Total annual visitation to federally managed parks, forests, monuments, and refuges by geographic zone

Zone	Unit	Total annual visits	Confidence interval
			Percent
North	Modoc National Forest (NF)	146,203[a]	38.4 ±
	Tule Lake National Wildlife Refuge	60,000[b]	
	Lava Beds National Monument (NM)	135,286[c]	
	Lassen NF	269,108[d]	23.5 ±
	Lassen Volcanic National Park (NP)	507,256[c]	
	Plumas NF	357,253[d]	22.3 ±
Central	Tahoe NF	1,660,202[a]	17.8 ±
	Lake Tahoe Basin Management Unit	7,721,000[a]	23.2 ±
	Eldorado NF	1,202,000[e]	8.9 ±
	Stanislaus NF	1,085,000[e]	12.0 ±
	Yosemite NP	4,336,890[c]	
South	Inyo NF	2,309,000[a]	8.5 ±
	Sierra NF	610,878[e]	15.0 ±
	Devils Postpile NM	109,571[c]	
	Kings Canyon NP	692,932[c]	
	Sequoia NP	1,291,256[c]	
	Sequoia NF	777,000[a]	24.2 ±

[a] 2016 reporting estimate, NVUM NRM website.
[b] Sexton et al. (2012).
[c] SSRSR reports online, National Park Service, 2017 data accessed in 2018.
[d] 2015 reporting estimate, National Visitor Use Monitoring Natural Resource Management (NVUM NRM) website.
[e] 2017 reporting estimate, NVUM NRM website.

ways that further enhance opportunities for forest community residents (Charnley 2014). These economic contributions influence community well-being (Charnley 2014, Winter et al. 2014a). Furthermore, communities whose economies depend on natural resources and are adjacent to national forests are likely to experience the effects of climate change earlier than other communities in the state (Wear et al. 2012).

Considering benefits beyond direct and indirect economic values, outdoor recreation provides myriad individual, community, and societal benefits (Winter et al. 2014b). These include the opportunity to connect with forests, nature, wildlife, and other humans, which has been shown to produce several desirable outcomes including more environmentally sustainable behaviors (Winter et al. 2019, Zelenski et al. 2015), and, in some cases, support for conservation (Zaradic et al. 2009). Time in nature contributes to overall well-being and has been used as an intervention to encourage flourishing (Capaldi et al. 2015).

Accounts from hikers along the John Muir Trail cited multiple factors that contributed to their experience, including being with others, solitude, and overall spiritual benefits (Hitchner et al. 2019). Similar accounts were reported in a review of multiple wilderness studies (Winter 2013). A survey of whitewater rafters along the Kern River revealed visitor motivations included enjoying nature, escape, being with others who share a similar appreciation for nature, and learning new things (van Riper et al. 2018).

Public health also benefits from exposure to nature and outdoor recreation (Barton et al. 2009, Winter et al. 2014b). This is an important consideration when assessing the value of natural areas, representing an essential element of analyses of recreation vulnerability to climate change (Winter et al. 2019). Recreation opportunities in the Sierra Nevada assessment area help to counteract the health risks associated with a sedentary lifestyle (Kondo et al. 2015), as evidenced by an estimated $76.6 billion in reduced costs for medical care at the national level (Pratt et al. 2000). Although these value estimates vary based on the assumptions and populations involved, another analysis showed that if the number of physically active children (ages 8 to 11; three times a week for 25 minutes of high-calorie-burning activity) increased from the current 31.9 percent to 50 percent, $8.1 billion in direct medical costs would be saved over their lifetimes (Lee et al. 2017). Evidence suggests that parks and green spaces can help remedy some income-associated inequalities in health outcomes (Mitchell and Popham 2008, South et al. 2018).

National forest recreation represents significant public health benefits, owing to the level of recreation use and range of activities (Kline et al. 2011). An assessment of contributions to physical activity, calculated through Metabolic Expenditures

(an approach to estimate energy expended during a visit based on primary reported activities; Ainsworth et al. 2000, Cohen et al. 2007, Winter et al. 2019), revealed a significant contribution toward physical health. Overall patterns of estimated health benefits from physical activity disproportionally benefitted visitors of higher socioeconomic status. However, benefits favored lower income community members adjacent to forest lands (within a 60-mi road radius of the forest). This finding mirrors comparable work in urban settings pointing to the importance of urban parks within a walkable radius of communities, especially for those who are socioeconomically disadvantaged (Jennings et al. 2016).

Recreation opportunities offered on public lands in the Sierra Nevada are as diverse as the ecosystems of this mountain range. We describe that diversity and its influences on recreation in order to facilitate climate-informed planning and management.[2] Adopting this approach broadens the range of choices available to managers toward sustainable resource management (Vose et al. 2012).

Relationships Between Climate Change and Outdoor Recreation

Demand for outdoor recreation opportunities as well as the supply and quality of opportunities in the assessment area are sensitive to climate change effects. Effects may be direct or indirect and may vary in duration and magnitude. Climate change effects are already evident in the Sierra Nevada (chapter 2), and further change is anticipated. In this section, we review current and anticipated effects on outdoor recreation. Recent observed changes and additional projected changes affect recreationist decisions and the derived benefits in many ways. Climate change also affects the contributions of recreation to physical and mental health (Evans 2019).

Direct effects may be experienced through altered ambient temperature, both minimum and maximum. As described in chapter 2, changes in temperature have already occurred in the region. An overall increase in the minimum and maximum air temperatures in the Sierra Nevada has occurred over the past 20 years, and annual average temperatures have increased (see chapter 2). The rate of temperature increase varies by elevation (Jardine and Long 2014), so effects vary by recreation destination, season, and type of activity. Projected effects of higher temperatures on outdoor recreation are expected to be moderate to high in the assessment area. (Reynier et al. 2015).

[2] In this chapter's focus on recreation, we will not include the full array of ecosystem services represented in the assessment area, including the importance of the non-use values in the bioregion (Cordell et al. 2003, Williams and Watson 2007). An overview of ecosystem services and the assessment area can be found in Patterson (2014).

Recreationists are more likely to seek respite from heat in natural areas as average temperatures rise (Morris and Walls 2009), increasing overall participation, especially in warm seasons, and extending the warm-weather recreation season. However, thermal comfort will likely influence the types of locations visited and activities pursued on warm days (Chen and Ng 2012, Potchter et al. 2018), and unusually hot days may lead to a notable decline in visitation (Richardson and Loomis 2004, Rosselló-Nadal 2014). Anticipated increases in the number of annual high-heat days (chapter 2) or elevated temperature extremes across the region may have effects beyond that of an increase in average temperature. Moderate changes may result in extended recreation seasons; for example, reduced length of cold-weather seasonal closures may increase the number of days recreationists seek opportunities in forest areas (Rosselló-Nadal 2014). Increased recreation associated with temperature increase may have adverse impacts on sustainable recreation management (Ellison et al. 2018).

Increasing air temperatures will also increase surface water temperatures (Hunsaker et al. 2014). The change in water temperatures is of considerable concern in the assessment area, owing to its network of lakes, rivers, and streams. In addition to serving as habitat for endemic species of fish, many streams support prized fishing opportunities that may be adversely affected by continuing effects of a warmer climate (Hunsaker et al. 2014, Reynier et al. 2015).

Altered precipitation may affect some aspects of recreation in the assessment area (Reynier et al. 2015). There will be more rain than snow with increasing temperature, with the most significant changes occurring in the northern Sierra Nevada at lower elevations (Jardine and Long 2014) (chapter 3). Snow-dependent recreation across Sierra Nevada national forests will be especially sensitive to this shift (Reynier et al. 2015), reducing the length of the winter recreation season and participation in snow-dependent activities (Wobus et al. 2017). Although projected changes in the Sierra Nevada in cross-country skiing, snowmobiling, and downhill skiing are smaller than projected for other Resources Planning Act assessment regions (USDA FS 2016), the benefits to recreationists and economies from snow-based activities in the Sierra Nevada require consideration.

Although overall precipitation may not shift substantially across the assessment area, extended drought (fig. 5.2) and extreme weather through atmospheric-river events (chapter 2) will have immediate and extended impacts on recreation use. Reduced waterflow caused by extended drought, or reduced water levels in lakes and reservoirs, may negatively affect recreation opportunities and access (Hand and Lawson 2018a). Drought tends to affect summer recreation differently, where water-dependent activities may decrease, while dryland activities may increase

(Prestemon et al. 2016). Altered temperature, snowmelt timing, and precipitation have impacts on whitewater boating, although the impacts vary across the Sierra Nevada, depending on whether the river is managed through hydropower projects (Ligare et al. 2012).

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Figure 5.2—Oaks killed by extended drought (photo taken in Madera County, California).

Conversely, an abundance of water through atmospheric-river events may lead to large increases in waterflow, extended high water levels that require shifts in management approaches, and longer term impacts in which water-based recreation and adjacent habitat are altered or damaged from extreme events (Huang et al. 2018). For example, extreme events have been shown to contribute to elevated pollutant loads in rivers, which may compound ecosystem impacts and human health concerns about use for some areas (Clow et al. 2011, 2013). Human behaviors also shift after extreme events, especially when recreationists actively seek to modify an area to restore preferred-use opportunities (e.g., Milburn and Winter[3]).

[3] Milburn, L-A.S.; Winter, P.L. 2015. Final report: Cattle Canyon participant observations. California State Polytechnic, Pomona. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 4955 Canyon Crest Drive, Riverside, CA 92507.

Observations conducted on the Angeles National Forest revealed that recreationists used preexisting deeper pools created naturally or by other recreationists, thus "dam building" was infrequently seen. An uptick of new dam building occurred immediately after a large rain event, where artificially built structures and natural pools had been washed away or eroded (see footnote 3).

Other ecological shifts exacerbated by climate change may result in adverse effects on ecosystems, wildlife, fish, and the health of recreationists. For example, algal blooms are associated with many factors, including effects from climate change. Although risks from inhalation appear to vary, direct exposure from water contact can be toxic to both people and animals (Backer et al. 2009, Derlet et al. 2009).

Additional indirect effects may be associated with changes in ecological features and ecosystem inputs, including vegetation, wildlife, and water. For example, demands for access and use may increase if high rainfall leads to a shift in flowering species (box 5.1, fig. 5.3). Postfire recovery may include an array of blooms not seen elsewhere (fig. 5.4). Higher than average snowfall or an extended snow season may lead to increased recreational use of an area, which must be managed effectively to preclude severely diminished visitor experiences owing to perceived crowding, or inability to access desired opportunities. Perceptions of degraded quality of an area or resource may result in altered visitor behaviors, including decisions to not visit an area (Ferguson et al. 2018, Morris and Walls 2009).

Additional indirect effects may influence the recreational setting and its features through wildland fire. In Sierra Nevada forests, fire may result in an area closure and preclude access, discourage access because of smoke, diminish viewsheds, and reduce economic benefits from recreation through limited access or diminished resource quality (Wigtil et al. 2016) (figs. 5.5 and 5.6, box 5.2). Annual area burned has increased in recent decades in the Sierra Nevada, with temperature and drought influencing this increase (Gonzalez 2012). Use of prescribed fire to reduce fuels and avoid large, high-intensity fires and their effects on ecosystems and public health necessitates some tolerance for emissions and other fire-related, short-term impacts (Schweizer and Cisneros 2014). Survey results for visitors to Yosemite Valley suggest that a majority of visitors were aware of the park's prescribed fire program and "were likely to tolerate short periods of occasional smoke or reduced visibility caused by prescribed burns" (Blotkamp et al. 2010).

Wildfires near urban areas represent much larger health-related concerns (Sierra Nevada Conservancy 2017), including the impacts of degraded air quality on local communities, recreationists, and tourists in the Sierra Nevada (see Burley et al. 2016, Bytnerowicz et al. 2013, Cisneros et al. 2010, Preisler et al. 2010). Some

Box 5.1

Unusual Rainfall Created Super Bloom, Leading to "Poppy Apocalypse"

An unusually robust rainy season in 2019 affected one southern California town to the extent it was challenged to rapidly shift its management of a natural resource area. In March 2019, Lake Elsinore experienced what was labelled a "poppy apocalypse" when, in a single day, over 100,000 visitors converged on the town of 60,000 residents to view the California poppy (*Eschscholzia californica* Cham.) "super bloom" in Walker Canyon. Visitation far exceeded the projected numbers for the location, resulting in overflowing parking areas, insufficient bathroom facilities, vehicles stopped on adjacent roads causing safety concerns and traffic jams, and trampling of flowers as visitors left the paths and trails to see and photograph the flowers.

Steve Manos, the mayor of Lake Elsinore, declared a short-term emergency, employing additional personnel to manage visitation, placing limits on parking in the immediate area, and requiring shuttle access for a fee. Appeals were issued on news and social media sites to communicate a message about responsible visitation. By mid-April, the flowers began to drop their petals, requiring a mile or more hike into the canyon to see the remaining blooms. Manos was quoted as saying "The super bloom has been unlike any event we have experienced before."

Summarized from the following sources: www.cbsnews.com/news/california-poppy-super-bloom-crowds-overwhelm-lake-elsinore; www.desertsun.com/story/news/environment/2019/03/21/want-see-poppy-super-bloom-lake-elsinore-youll-have-pay/3234318002 (May 2019).

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Figure 5.3—Closeup of California poppies in bloom (photo taken in Madera County, California).

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Figure 5.4—Flowers in bloom after wildfire (photo taken in Madera County, California).

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Figure 5.5—Postfire landscape in Nelder Grove, Sierra National Forest.

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Figure 5.6—Postfire mosaic along highway north of Wawona entrance inside Yosemite National Park, Ferguson Fire, 2018.

of these impacts may continue to increase in severity under climate change owing to increased temperatures, a longer period of elevated temperatures, and altered precipitation (Winter et al. 2019). In recent years, air quality impacts from wildfires have become significant health events and are now, in fact, the greatest source of air pollution exposure faced by the American public. In addition, as wildfires increase in duration, communities often face multiple weeks of exposure. In 2018, fine particulate levels exceeded the 24-hour standard in the Western United States over 3,700 times. (https://www.fs.fed.us/blogs/pardon-our-smoke; accessed 5/10/2019).

Longer term effects may be compounded where ability to restore an area is limited by available resources or capacity. One limit is available funding sources for recreation sites and amenities. Emergency restoration funds under Forest Service Manual 2523.01 allow the agency to conduct emergency stabilization through Burned Area Emergency Response (BAER), which provides for the use of Wildland Fire Management funds for emergency rehabilitation of burned-over National Forest System lands and water. Recreation per se is not included under BAER funding because the loss of recreation-related facilities and amenities is not

Box 5.2

Wildfires Result in Smoke and Health Advisories, Leading to Closure of Recreation Areas

In 2018, the Lions Fire, Ferguson Fire, and other wildfires had significant impacts on communities and outdoor activities in portions of the Sierra Nevada. On July 24, the National Park Service closed Yosemite Valley, Wawona, and the Mariposa Grove of giant sequoias, owing to diminished air quality and visibility from the Ferguson Fire on nearby Sierra National Forest.

Health effects from the diminished air quality were of concern. For example, on July 30, a stage 2 health advisory was issued for Mono County, recommending that people refrain from strenuous outdoor activities, including in the popular Mammoth Lakes area. Smoke from the Lions Fire was visible near Reds Meadow Road (Minaret Vista and Devils Postpile National Monument), Mammoth Mountain, and the town of Mammoth Lakes. Numerous fires throughout the state affected air quality in the eastern Sierra Nevada.

On July 29–30, an air quality alert was also issued for San Joaquin, Mariposa, Stanislaus, Merced, Madera, Fresno, Kings, Tulare, Tuolumne, and Kern Counties. The forecasted impact was based on elevated particulate matter in the size range of 2.5 microns ($PM_{2.5}$). Yosemite Village recorded unhealthy air quality on July 29, with very unhealthy air quality in the afternoon.

Trails and recreation areas in national forests were closed as a result of unhealthy air quality from multiple fires. For example, an emergency closure was issued for the Fern Lake and Beck Lake Trails on Inyo National Forest. An emergency trail closure and a Forest Order were issued to close a large portion of Sierra National Forest (west of the North Fork of the San Joaquin River, north of the Middle Fork of the San Joaquin River and South of Iron Creek).

Yosemite Valley and the Mariposa Grove were reopened in mid-August, although selected areas remained closed. The Fern Lake and Beck Lake Trails on the Inyo National Forest were reopened on August 30, while trails on the Sierra National Forest remained closed.

Summarized from the following sources: www.sierrawave.net/community-meeting-in-mammoth-for-lions-fire; www.fs.usda.gov/detail/inyo/news-events/?cid=FSEPRD590115; www.sierrarecmagazine.com/the-inyo-national-forest-to-re-open-fern-beck-trails; www.travelyosemite.com/alerts/2018/ferguson-fire.

generally considered an emergency, and recreation managers cannot access funds used by national forests to respond to fire events (Chavez and McCollum 2004).

Lack of funds and capacity to restore damaged areas can extend the effects of wildland fire events and postfire damage for many years (box 5.3). Where extensive damage occurs to recreation infrastructure, the ability to recover or restore an area for visitor use may represent extended losses to the recreating public by way of reduced benefits and limited substitution opportunities. Surrounding communities may be affected by loss of recreation and tourism revenue (Winter et al. 2014a).

Box 5.3

Gabrielino Trail Restored After Almost a Decade

The 2009 Station Fire, and subsequent damage caused by postfire rain, erosion, and fallen trees left large portions of the Gabrielino Trail, a 26-mi trail on Angeles National Forest, closed to public use for almost a decade. In 2016, a plan was developed to restore the trail. The Gabrielino was the country's first National Recreational Trail designated under the National Trails System Act in 1968. In September 2018, U.S. Department of Agriculture, Forest Service (USFS) employees joined volunteer groups, community members, and sponsors in celebrating completion of the extensive restoration effort. The reopening occurred on the 50th anniversary of the trail designation, the culmination of a successful partnership involving grants to hire contractors for technical aspects of trail restoration, U.S. Forest Service funding and personnel, and over 1,900 contributed volunteer hours.

Sources: Cardine (2018), MWBA (2018).

Indirect effects of climate change on recreation will be affected by social change (USDA FS 2016). Interest in overall participation, and types of activities engaged in, are influenced by interests in technology, increasing urbanization, economic conditions, changing age-related demographics, and cultural shifts embedded in ethnicity, race, and community. Furthermore, increasing population may result in increased conflicts over residential developments abutting natural resource areas, as well as increased demand and popularity of some spaces. This increased demand and popularity, though desirable in the sense of greater participation and engagement in recreation and experiences in the outdoors, may necessitate limits or controls on access. The overall experience may be diminished owing to a sense of crowding associated with even modest increases in the total number of participants and days of participation (USDA FS 2016).

These larger trends are considered to have a moderate impact on forest systems (Reynier et al. 2015) but a low potential for increasing sensitivity under climate change. Interaction of these trends with other impacts may be of greater concern. The intersection of recreation settings and opportunities sought by communities of color and the areas projected to be altered by climate change will determine the degree to which vulnerable populations may be affected. For example, if locations popular among Latino visitors require more extensive closures either short term (to mitigate risk) or longer term (for recovery from damage), an environmental justice perspective suggests a need to identify substitute areas for use, and enhanced efforts to expedite restoration (ideally including an assessment of how the area might be

improved to serve diverse visitors). Latino recreationists have been found to prefer recreation settings with more developed amenities, likely in support of extended families in the recreating group (Roberts et al. 2009). Loss of these enhanced built amenities, which require resources and time to restore, are of concern when the loss affects underserved groups.

Communities dependent on the outdoor recreation and tourism economy may see some increases in use from extended recreation seasons but may also see increased impacts to the community's way of life and ecosystem services (Lal et al. 2011). Furthermore, recreationists on many forests tend to stay within the local area. Impacts in the form of access and the range of opportunities available within a close travel distance may increase or decrease. The ability of economically disadvantaged community members to travel farther to alternate destinations may be constrained when local areas are adversely affected by climate change.

Recreation Participation and Economic Value

An update to the 2010 Resources Planning Act (USDA FS 2016) assessed current and projected recreation use in the Pacific Coast Region (U.S. Forest Service [USFS] Pacific Northwest and Pacific Southwest Regions, which include the Sierra Nevada assessment area) by groups of activities (table 5.2). "Region" in this analysis is based on point of origin of the visitors, rather than on their destination (a distinction worth keeping in mind throughout this section). It is not specific to recreation use in the assessment area. Askew and Bowker (2018) identified the Pacific Coast region as having the greatest stability in recreation activity participation and consumption overall, with smaller climate-associated effects than other regions assessed, or with wider ranges of variation that are unclear.

Increases of 50 percent or more were outlined for some categories of activities (table 5.2). Developed site use, including visiting developed and interpretive sites, is expected to increase in the Pacific Coast region. Developed sites as used here include developed camping and picnic sites; interpretive sites include nature centers and historical sites (Askew and Bowker 2018). Nature observation, including birding and nature viewing, is projected to increase more than 50 percent. Backcountry activities in wilderness and primitive camping are projected to increase as well. Motorized water activities show the highest projected increases in motorized use. Increases at or above 50 percent with and without climate change also include fishing, developed skiing, and floating.

Some activity types show small to marginal effects associated with climate change, including visiting developed sites, nature observation, backcountry activities, motorized activities (off-roading and motorized water use), fishing,

and nonmotorized water activities. Activities affected by climate change in the 5-percent-or-more range include developed and undeveloped skiing and motorized snow activities (decreased by climate change). Whitewater recreation activities are affected in various ways, depending on elevation and the type of run (Ligare et al. 2012).

Table 5.2—Modeled projections of the effects of climate change on recreation in the Sierra Nevada assessment area[a] for 2060[b]

Recreation activity	Number of participants in 2008	Projected change without climate change[c]	Projected change with climate change	Net effects of climate change[d]
	Millions	- - - - - - - - - - - - *Percent* - - - - - - - - - - - -		
Developed site usage:				
Visiting developed sites	31	68	67	-1
Visiting interpretative sites	26	72	71	-1
Observing nature:				
Birding	13	69	71	2
Nature viewing	31	66	65	-1
Backcountry activities:				
Challenge activities	5	54	57	3
Horseback riding on trails	3	78	75	-3
Day hiking	17	67	63	-4
Primitive area use	18	53	55	2
Motorized activities:				
Motorized off-roading	9	47	49	2
Motorized water activities	10	80	78	-2
Motorized snow activities	1	52	44	-8
Consumptive activities:				
Hunting	3	9	19	10
Fishing	10	52	54	2
Nonmotorized winter activities:				
Developed skiing	5	91	96	5
Undeveloped skiing	1	22	32	10
Nonmotorized water activities:				
Swimming	25	75	74	-1
Floating	6	55	53	-2

[a] Data are from the "RPA Pacific Coast Region" (USDA FS 2016), which includes the Sierra Nevada assessment area.
[b] Model output is based on an average of results under the A2, A1B, and B2 emission scenarios.
[c] Percentage changes for total number of participants are compared to 2008.
[d] Net effects of climate change equal "with climate change" minus "without climate change."

Areas for which an increase in climate change effects are projected can be a focus in sustainable recreation plans. A helpful tool for assessing delivery of sustainable recreation activities, and a requirement of the 2012 USFS Planning Rule, is the Recreational Opportunity Spectrum. Although not covered in detail here, the Recreational Opportunity Spectrum provides for a variety of outdoor experience under six management class categories including primitive, semiprimitive nonmotorized, semiprimitive motorized, roaded natural, rural, and modern developed. Physical, social, and managerial characteristics are included (Hand et al. 2018).

More broadly, the USFS framework for sustainable recreation (USDA FS 2010) outlines the importance of restoring and adapting recreation settings; implementing "green" operations; enhancing communities; investing in special places; forging strategic partnerships; promoting citizen stewardship; knowing visitors, community stakeholders, and other recreation providers; providing the right information; building a solid financial foundation; and developing the workforce. An emphasis on knowing the visitors along with their values and preferences relies on monitoring systems and data, including the National Visitor Use Monitoring (NVUM) Survey.

The USFS NVUM program is the nationwide, systematic assessment of recreation visitation, conducted in 5-year rotations for each national forest. A total of 27 activities (and one other category) are examined. Overall use for each forest/unit, as reported in table 5.1, paired with national park and national monument data, speak to the importance of recreation use in the assessment area.

The NVUM surveys (round 4), reported between 2015 and 2017, covered the 10 national forests/units in the assessment area, and indicated that the majority of visitation (74.9 percent) involved warm-weather and winter activities (table 5.3, fig. 5.7) (note that more than one main activity could be reported by respondents; percentage of the total represents weighted estimates for visits involving single or multiple main activities). The categories of activities under "other" are probably less susceptible to climate change than the other categories listed, although variations may occur.

The activities reported in table 5.3 and categories in fig. 5.7 indicate that warm-weather activities account for 41.9 percent of recreation visits, with hiking/walking and viewing natural features being most popular. Hiking and walking accounted for over 2.5 million visits per year, and viewing natural features another 2.4 million visits. Additional warm-weather activities contributing to this activity category included other nonmotorized use, bicycling, developed camping, picnicking, backpacking, horseback riding, and primitive camping.

Snow-based winter activities were the second most frequently reported category of main activities, with downhill skiing accounting for 31 percent of overall

Table 5.3—Twenty-eight main activities for national forests in the assessment area (2015–2017)

Main activity	Frequency	Percentage of total
Warm-weather activities:		
Hiking/walking	2,583,474	15.0
Viewing natural features	2,445,312	14.2
Other non-motorized	643,251	3.7
Bicycling	559,879	3.2
Developed camping	484,178	2.8
Picnicking	232,997	1.4
Backpacking	187,954	1.1
Horseback riding	60,678	0.4
Primitive camping	31,099	0.2
Total	7,228,822	41.9
Winter activities:		
Downhill skiing	5,348,025	31.0
Cross-country skiing	309,583	1.8
Snowmobiling	31,267	0.2
Total	5,688,875	33.0
Wildlife activities:		
Fishing	629,632	3.6
Hunting	182,427	1.1
Viewing wildlife	184,925	1.1
Total	996,984	5.8
Gathering forest products:		
Gathering forest products	99,784	0.6
Water-based activities, not including fishing:		
Motorized water activities	175,772	1.0
Nonmotorized water	155,601	0.9
Total	331,373	1.9
Other activities:		
Relaxing	1,512,490	8.8
Driving for pleasure	448,112	2.6
Some other activity	438,796	2.5
Off-highway vehicle use	113,150	0.7
Nature center activities	111,442	0.6
Motorized trail activity	85,205	0.5
Nature study	68,362	0.4
Resort use	46,312	0.3
Visiting historic sites	57,516	0.3
Other motorized activity	28,404	0.2
Total	2,909,789	16.9
Total for all activities	17,255,625	100

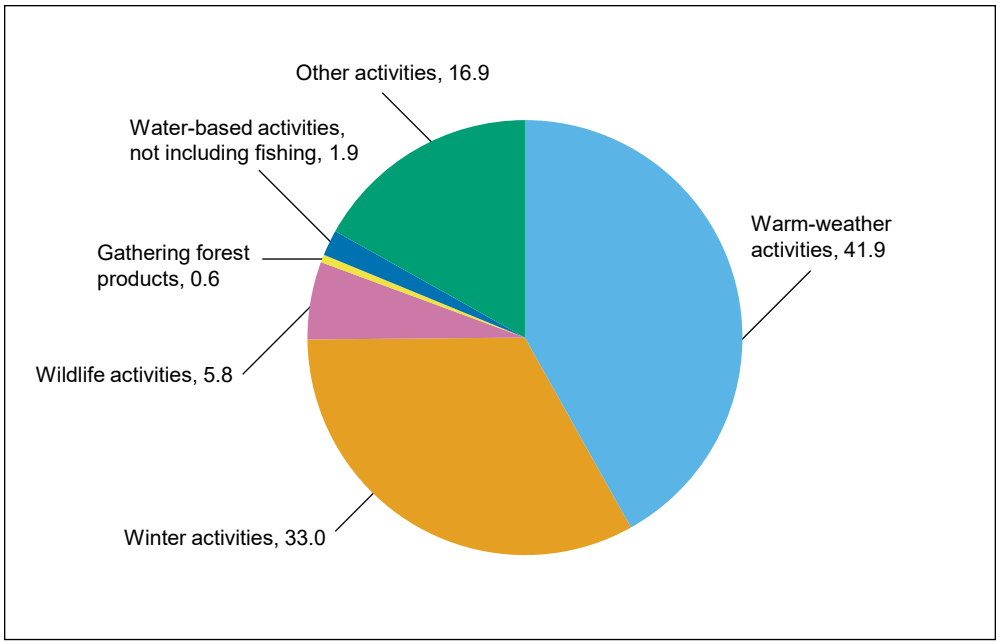

Figure 5.7—Percentage of total national forest visits by category of primary activity.

Table 5.4—Total annual expenditures within 50 mi of the survey site by nonlocal and local visitors to the assessment area, by spending category

Spending category	Nonlocal spending ($2017)[a b]		Local spending	
	Total annual expenditures	Spending for each category	Total annual expenditures	Spending for each category
	Thousands of dollars[c]	*Percent*	*Thousands of dollars*[c]	*Percent*
Lodging	406,069	26.9	4,190	3.1
Camping fees	26,737	1.8	5,353	4.0
Restaurant	308,794	20.5	19,151	14.2
Groceries	176,481	11.7	25,733	19.1
Gas and oil	197,544	13.1	41,396	30.7
Local transportation	8,049	0.5	489	0.4
Entry fees	122,299	8.1	16,879	12.5
Recreation and entertainment	156,573	10.4	10,151	7.5
Sporting goods	49,307	3.3	9,016	6.7
Souvenirs and other expenses	57,314	3.8	2,381	1.8
Total	1,509,167	100	134,741	100

Note: Spending totals were calculated using the procedures outlined in White (2017) and parameters and spending averages used by the U.S. Forest Service office of Ecosystem Management Coordination.

[a] Nonlocal refers to trips that required traveling more than 50 mi to the survey site.

[b] Data source is the fourth round of the National Visitor Use Monitoring (NVUM) surveys.

[c] NVUM data, 2015–2017.

annual visitation at over 5.3 million visits. Cross-country skiing and snowmobiling represented 1.8 and 0.2 percent of total visitation.

Wildlife-related activities, including fishing (3.6 percent), hunting (1.1 percent), and viewing wildlife (1.1 percent), accounted for 5.8 percent of overall visitation, representing just under 1 million visits. Water-based activities including motorized and nonmotorized, other than fishing, accounted for 1.9 percent of visits, and gathering forest products was less than 1 percent of visitation.

Total annual expenditures within 50 mi of the survey site (viewed as local community area adjacent to the survey forest/unit location) was considerably higher among those travelling from outside a 50-mi radius, than for locally originating visitation (table 5.4). Lodging expenditures accounted for 26.9 percent of expenditures among nonlocal visitation, followed by restaurants at 20.5 percent. Gas and oil was the primary spending category for local visitation.

The **economic value** of recreation is the benefits that recreationists received from engaging in a recreation activity. This differs from the **economic impact** of recreation, which measures how spending by recreationists affects economies in a geographical area. Rosenberger et al. (2017) estimated recreation economic values using the benefit transfer method based on the updated Recreation Use Visitor Database (Loomis 2005, Rosenberger and Loomis 2001) and annual visitation estimates from the NVUM survey. The same procedure was used to estimate the annual economic benefits to individuals recreating in the national forests in the Sierra Nevada. Equation (1) uses the NVUM dataset on the total annual recreation visits per national forest and the percentage of primary activity to obtain the estimated number of visits per activity.

$$\textit{Visits per activity} = \textit{Annual NF recreation visits} \times \textit{Percentage of main activity} \quad (1)$$

The conversion coefficient derived by Rosenberger et al. (2017) is multiplied with visits per activity to translate visits into primary activity days. The conversion coefficients are the average number of days a recreation activity lasts for a national forest visit. For example, backpacking has a 2.8 conversion coefficient, meaning a national forest visit for backpacking lasts on average 2.8 days.

$$\textit{Primary activity days} = \textit{Conversion coefficient} \times \textit{Visits per activity} \quad (2)$$

Next, primary activity days are multiplied by the average economic value for each recreation activity that was updated by Rosenberger et al. (2017) to estimate the aggregate recreation benefit value:

$$\textit{Aggregate recreation benefit value} = \textit{Average economic value} \times \textit{Primary activity days} \quad (3)$$

For example, using the NVUM dataset for the Lake Tahoe Basin Management Unit (LTBMU), we multiplied the percentage of main activity with the annual number of national forest visits (over 7.7 million in 2015) to obtain the number of visits per activity. To estimate the primary activity days, we multiplied the conversion coefficient with the number of visits (Equation 2). Finally, we multiplied this value with the average economic value (Equation 3). The same procedure was undertaken for all other national forests in the assessment area. Annual aggregate economic values ranged from $11.1 million (Modoc National Forest) to $604.2 million (LTBMU).

The annual economic benefit for each zone was estimated by aggregating the economic value of each national forest within a zone (table 5.5). The North Zone had the lowest aggregate economic benefit at $60.3 million, followed by the South Zone at $293.1 million, and the highest was the Central Zone with an annual value of $923 million. Downhill skiing had the highest annual economic benefit for both Central and South Zones, whereas fishing was the highest for the North Zone.

It is important to understand whether there are differences in visitation patterns or activities that are sensitive to climate change effects. Overall projected visitation under climate change was explored by Smith et al. (2016). Visitors who felt their personal identity was tied to an area, who believed the area provided unique opportunities not available elsewhere, and who had family ties to the area were less likely to foresee changes in how they would recreate under climate change than those whose identities were not similarly tied to an area (Smith et al. 2016). In addition, expenditures offer a way to understand social vulnerability, where economic benefits to local communities may shift under climate change (Fischer et al. 2013).

In the following sections, we consider the Northern, Central, and Southern Sierra Zones of the assessment area individually to further explore recreation activities supported in the region, economic contributions, niche recreation opportunities and special places, and current or expected climate change effects specific to these opportunities and places. NVUM reports provide insight into how recreation visitors might respond to climate change effects, wildfires, and other factors that make a national forest inaccessible. Visitors were asked to select one of several substitute choices, if for some reason they were unable to visit the national forest where they were contacted. On most forests, the majority of visitors indicate that their substitution behavior choice is activity driven (going elsewhere for the same activity). This overall response pattern is independent of questions surrounding place attachment, place dependence, and recreation specialization, which all intersect with likely substitution behaviors (Kainzinger et al. 2018, Orr and Schneider 2018).

We consider these patterns of reported likely substitution, as well as the average distance respondents were willing to travel to arrive at a different location. This is

Table 5.5—Estimate of annual aggregate economic benefits for the assessment area, all zones combined

Activity participation[a]	All zones economic benefit
	2016 dollars
Warm-weather activities:	
Hiking/walking	206,908,496
Viewing natural features	152,145,214
Bicycling	44,363,206
Developed camping	36,427,954
Other nonmotorized	41,918,724
Backpacking	12,394,747
Picnicking	10,791,680
Horseback riding	4,070,833
Primitive camping	1,793,947
Total	510,814,801
Winter activities:	
Downhill skiing	422,518,140
Cross-country skiing	14,717,980
Snowmobiling	1,461,653
Total	438,697,773
Wildlife activities:	
Fishing	48,133,575
Hunting	17,544,811
Viewing wildlife	10,610,993
Total	76,289,379
Gathering forest products:	
Gathering forest products	6,301,155
Water-based activities, not including fishing:	
Nonmotorized water	20,417,077
Motorized water activities	11,822,182
Total	32,239,259
Other activities:	
Relaxing	123,915,062
Some other activity	24,910,419
Driving for pleasure	27,005,615
Resort use	7,961,398
Off-highway vehicle use	5,410,316
Motorized trail activity	4,511,528
No activity reported	2,780,544
Visiting historic sites	2,971,991
Other motorized activity	1,191,581
Nature center activities	6,987,297
Nature study	4,409,061
Total	212,054,812
Total for all activities	$1,276,397,182

[a] Considers only main recreation activity.

paired with a consideration of distances typically traveled by visitors to each forest/unit in the assessment area, where patterns of willingness to travel for each forest align with distances traveled by a majority. These patterns intersect, and many people can adapt by moving to different areas for similar activities, although effects on the recreation experience, benefits derived, and relationships to perceptions of place are not well understood.

Climate Change Vulnerability Assessment

Northern Sierra Zone

The Northern Sierra Zone of the assessment area includes Modoc (fig. 5.8), Lassen (fig. 5.9), and Plumas National Forests (fig. 5.10). Primary recreation visits in this zone (table 5.6) involve many warm-weather activities (40.3 percent); developed camping (13.5 percent) and viewing natural features (13.5 percent) represent the majority of visits. Wildlife-related activities account for the next highest recreation visits (21.0 percent), especially fishing (15.8 percent). Gathering forest products is the third highest category of main activity during forest visits at 10.0 percent of the total.

Modoc National Forest provides a broad range of recreational opportunities, including niche experiences for this forest and the Northern Zone. Devil's Garden Ranger District is home to a number of marshy reservoirs and the highest diversity of breeding waterfowl in the state (Audubon, n.d.). The area is remote and sees light recreation use. If climate change reduces bird viewing in other areas of the state, this area may see an increase in use in the future. However, climate shifts could reduce the value of marshy reservoirs as bird habitat.

Modoc National Forest is also home to the South Warner Wilderness, which provides opportunities for backpacking, horseback riding, hunting, wildlife viewing, and fishing. Ash Creek and a number of lakes on this forest are stocked by the California Department of Fish and Wildlife. Higher water temperatures may degrade habitat, and access to preferred water sources may decrease. Therefore, it will be important to monitor trends in quality fishing opportunities, and administrative decisions to shift stocking practices may be needed in some cases.

Gathering forest products is a larger proportion of recreation use in this zone than in the Central and Southern Zones. On Modoc National Forest, forest products requiring permits for gathering include obsidian, Christmas trees, and mushrooms. The effect of climate change on gathering forest products is uncertain (Hand and Lawson 2018b).

The Northern Zone is host to the Hat Creek Rim section of the Pacific Crest Trail (PCT) on Lassen National Forest. Owing to a 26-mi stretch of trail without water, the section has been named "a legendary stretch on a trail of legends"

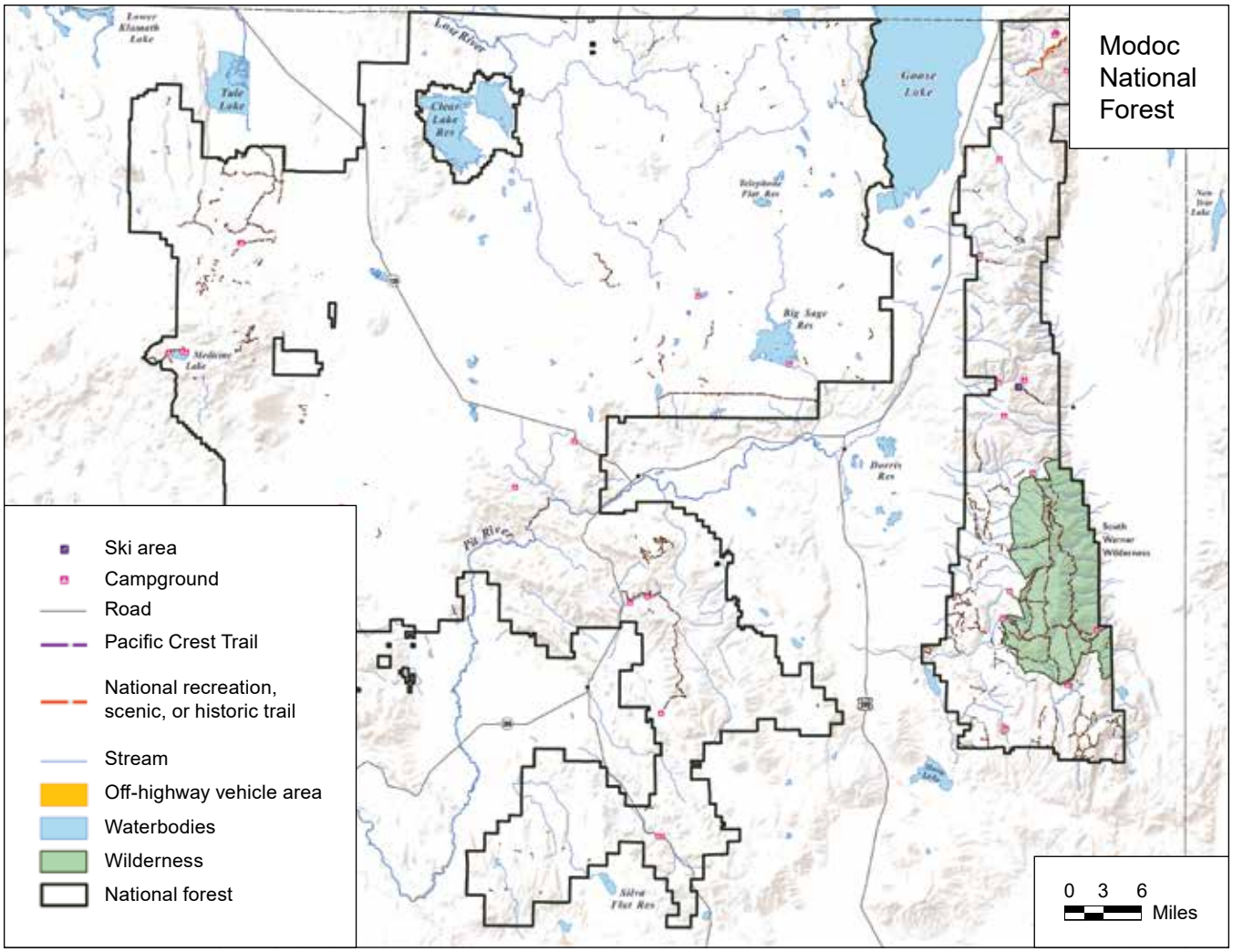

Figure 5.8—Recreation niche map of the Northern Sierra Zone, Modoc National Forest.

by Cheryl Strayed, the author of "Wild" (https://wild.pcta.org/hike-from-wild/hat-creek-rim-california). In 2017, a large water tank was installed, replacing a community-sourced water cache for hikers. Although this section of trail dictates that prudent hikers remember to bring water and that they hike in the cooler months, other sections can be impassable owing to deep snow or flooding.

Extended warm-weather seasons, increased temperatures, or more high-heat days are likely to affect the experience along this section of the PCT and increase the importance of the partnership between the USFS and recreation partners in maintaining access to water and providing clear messaging to enhance visitor safety. Collaborating with the PCT Association and other groups may increase visitor awareness of risks in advance of a trip, and increase preparedness, visitor safety, and enjoyment.

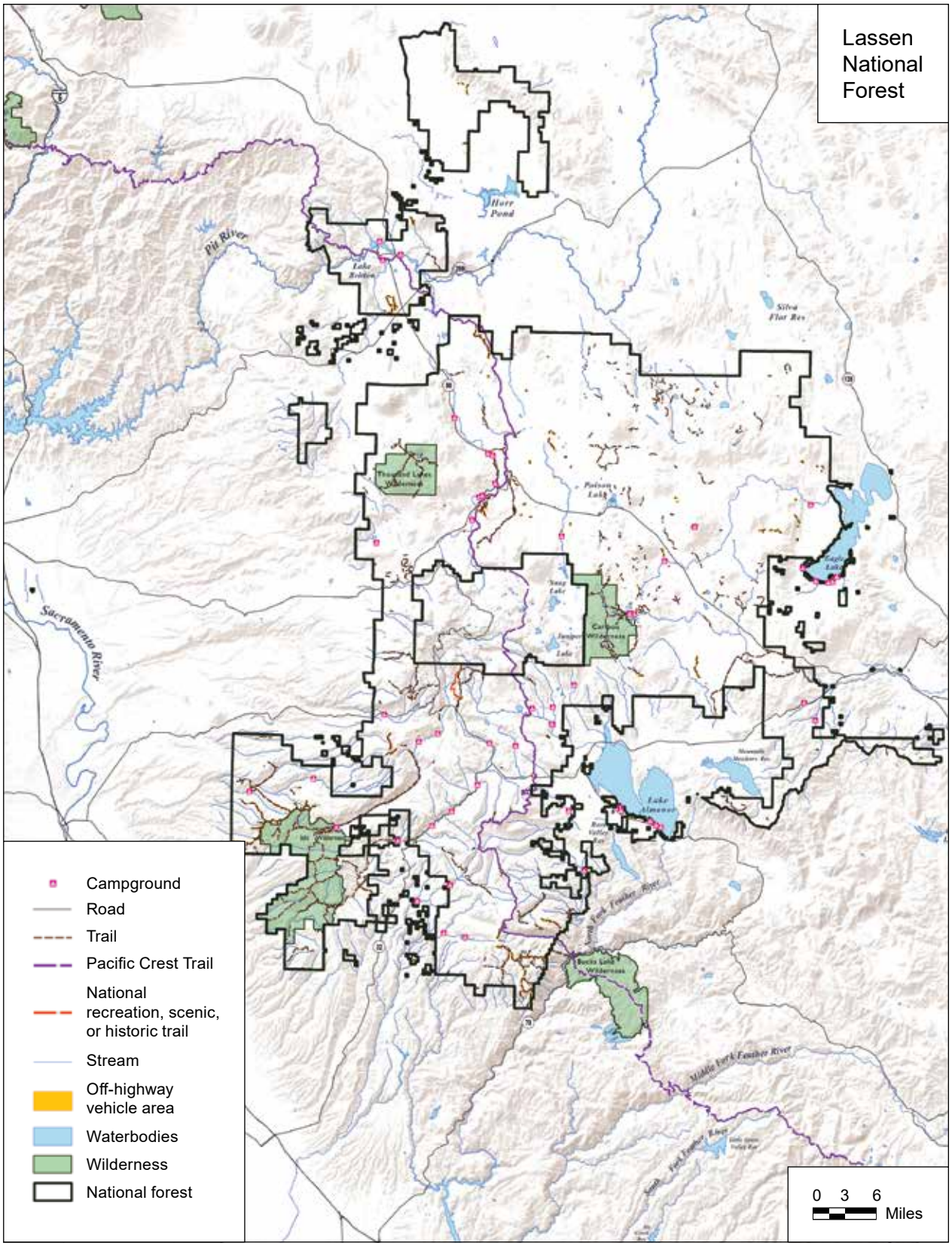

Figure 5.9—Recreation niche map of the Northern Sierra Zone, Lassen National Forest.

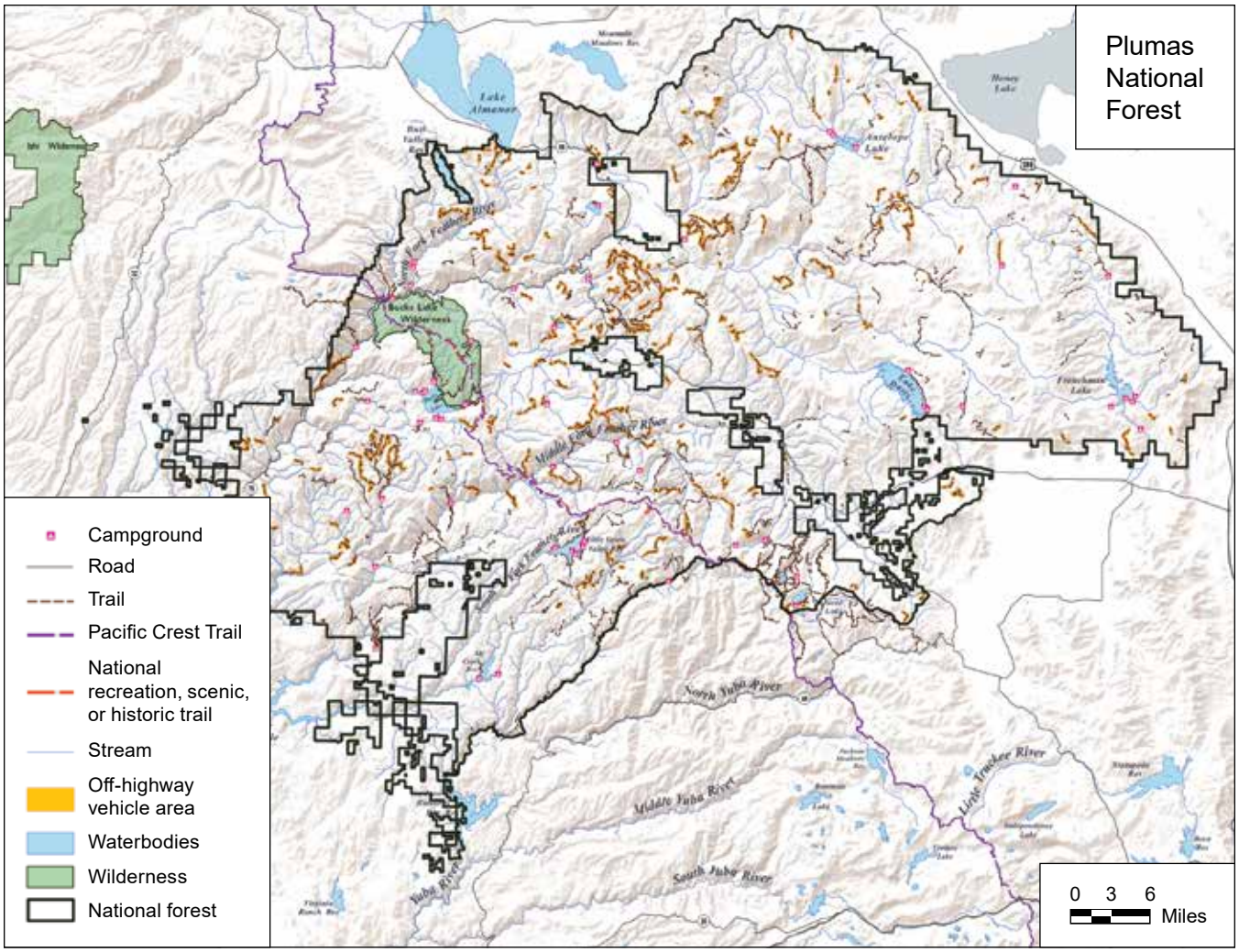

Figure 5.10—Recreation niche map of the Northern Sierra Zone, Plumas National Forest.

In Lassen National Forest, a self-guided interpretive trail guides visitors along a route where they can see spatter cones, craters, and the Hat Creek Valley, all centered around the Hat Creek Lava Flow. As of the writing of this report, the Spattercone Day Use area where this trail is accessed was closed because of recent damage from a severe storm. This example highlights the potential of extended effects from storm damage, which reduces access and opportunities for recreation use.

The PCT extends about 75 mi across Plumas National Forest, crossing the Middle and North Fork canyons of the Feather River. Under climate change, the Feather River is projected to have a decrease in mean annual flow of 2.2 to 8.8 percent, depending on the modeled increase in temperature (Hunsaker et al. 2014). In addition, the Feather Falls National Recreation Trail takes hikers to the 640-ft falls, identified as a special place. Decreased waterflow may alter these recreational opportunities in the future.

Table 5.6—Main recreation activities for the Northern Sierra Zone (2015–2017)

Main activity	Frequency	Percentage of total
Warm-weather activities:		
Developed camping	98,382	13.5
Viewing natural features	98,291	13.5
Hiking/walking	49,298	6.8
Picnicking	15,848	2.2
Other nonmotorized	11,031	1.5
Bicycling	10,337	1.4
Backpacking	4,606	0.6
Horseback riding	3,923	0.5
Primitive camping	983	0.1
Total	292,698	40.3
Winter activities:		
Downhill skiing	13,763	1.9
Snowmobiling	6,075	0.8
Cross-country skiing	315	0.0
Total	20,153	2.8
Wildlife activities:		
Fishing	114,825	15.8
Viewing wildlife	22,037	3.0
Hunting	15,570	2.1
Total	152,432	21.0
Gathering forest products:		
Gathering forest products	72,357	10.0
Water-based activities, not including fishing:		
Motorized water activities	22,713	3.1
Nonmotorized water	11,913	1.6
Total	34,627	4.8
Other activities:		
Relaxing	64,363	8.9
Driving for pleasure	54,900	7.6
Some other activity	23,176	3.2
Resort use	3,983	0.5
Motorized trail activity	2,799	0.4
Off-highway vehicle use	2,477	0.3
Nature center activities	1,606	0.2
Nature study	1,376	0.2
Visiting historic sites	113	0.0
Other motorized activity	0.0	0.0
Total	154,792	21.3
Total for all activities	727,058	100

Spending associated with local visitation in the Northern Zone forests is about 44 percent of that expended for nonlocal visitation. Among local visitation, gas/oil and groceries account for the largest portion of expenditures (table 5.7).

Table 5.7—Total annual expenditures within 50 mi of the survey site by nonlocal and local visitors to the Northern Sierra Zone, by spending category

	Nonlocal spending[a b]		Local spending	
Spending category	**Total annual expenditures**	**Spending for each category**	**Total annual expenditures**	**Spending for each category**
	Thousands of dollars ($2017)[c]	*Percent*	*Thousands of dollars ($2017)[c]*	*Percent*
Lodging	6,802	22.1	510	3.8
Camping fees	1,846	6.0	1,084	8.0
Restaurant	4,670	15.1	1,313	9.7
Groceries	5,393	17.5	3,823	28.3
Gas and oil	7,110	23.0	4,487	33.2
Local transportation	175	0.6	32	0.2
Entry fees	1,093	3.5	637	4.7
Recreation and entertainment	1,392	4.5	273	2.0
Sporting goods	1,325	4.3	1,168	8.6
Souvenirs and other expenses	1,039	3.4	197	1.5
Total	30,845	100	13,524	100

Note: Spending totals were calculated using the procedures outlined in White (2017) and parameters and spending averages used by the U.S. Forest Service office of Ecosystem Management Coordination.
[a] Nonlocal refers to trips that required traveling more than 50 mi to the survey site.
[b] Data source is the fourth round of the National Visitor Use Monitoring (NVUM) surveys.
[c] NVUM data, 2015–2017.

The estimated annual economic benefit for recreation participation associated with the Northern Zone is about $60.3 million (table 5.8), or 4.7 percent of the overall estimated value for the three zones ($1.3 billion). Plumas National Forest has the highest annual economic benefit (47.7 percent of total Northern Zone value), followed by Lassen National Forest (33.8 percent), and Modoc National Forest (18.5 percent). Highest economic benefits for the entire Northern Zone are associated with fishing, developed camping, relaxing, and viewing natural features. Hiking/walking and gathering forest products also provide substantial economic benefits. It should be noted that gathering forest products is considered in the recreation context as captured by NVUM data but may also represent maintenance of traditional tribal and cultural values (Lake and Long 2014). Gathering forest products represents a higher percentage of overall recreation use in the Northern Zone than in the Central and Southern Zones.

Table 5.8—Estimate of annual aggregate economic benefit for the Northern Sierra Zone

Activity participation[a]	Economic benefit
	2016 dollars
Warm-weather activities:	
Hiking/walking	4,693,572
Viewing natural features	6,737,356
Bicycling	1,050,758
Developed camping	8,670,423
Other nonmotorized	902,349
Backpacking	395,144
Picnicking	897,528
Horseback riding	270,080
Primitive camping	70,829
Total	23,688,039
Winter activities:	
Downhill skiing	1,090,578
Cross-country skiing	17,707
Snowmobiling	308,095
Total	1,416,380
Wildlife activities:	
Fishing	10,299,748
Hunting	1,766,215
Viewing wildlife	1,389,336
Total	13,455,299
Gathering forest products:	
Gathering forest products	4,760,588
Water-based activities, not including fishing:	
Nonmotorized water	1,918,378
Motorized water activities	1,780,401
Total	3,698,779
Other activities:	
Relaxing	6,088,460
Some other activity	1,577,315
Driving for pleasure	3,555,733
Resort use	824,446
Off-highway vehicle use	153,597
Motorized trail activity	188,071
No activity reported	659,108
Visiting historic sites	6,795
Other motorized activity	0.0
Nature center activities	121,498
Nature study	101,921
Total	13,276,944
Total for all activities	60,296,029

[a] Main recreation activity.

When asked what the forest visit would be substituted with if the current forest visited was not available, the most common response from visitors to Modoc, Lassen, and Plumas National Forests was they would have gone elsewhere for the same activity (46.5, 35.9, and 69.5 percent, respectively) (fig. 5.11). However, more than one-fourth of Lassen National Forest visitors indicated they would have stayed at home, and another fifth would have come back another time. Modoc National Forest visitors split their remaining options between coming back another time, staying at home, or going elsewhere for a different activity. Plumas National Forest visitors indicated they would be more likely to stay at home or come back another time.

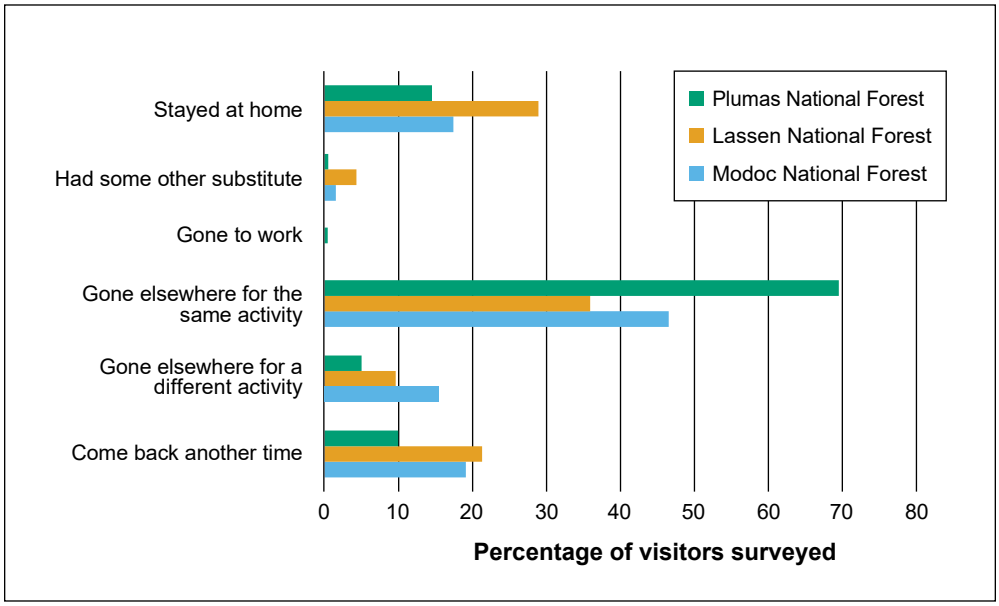

Figure 5.11—Alternative location or option that Northern Sierra Zone forest visitors would choose if unable to visit the national forest where they were surveyed.

When traveling to another location to recreate as a substitute for Modoc and Plumas National Forests, just over half would travel between 26 and 50 mi (52.5 and 51.2 percent, respectively) (USDA FS 2018e, 2018f), whereas nearly half (49.6 percent) of Lassen National Forest visitors would travel between 0 and 50 mi (USDA FS 2018d) (fig. 5.12). In each case, visitors to the Northern Sierra Zone indicated they were most likely to stay local (within a 50-mi radius). This finding seems reasonable, given that NVUM reports show a near majority or majority of recreation visitors originate from within a 50-mi radius of their recreation destination.

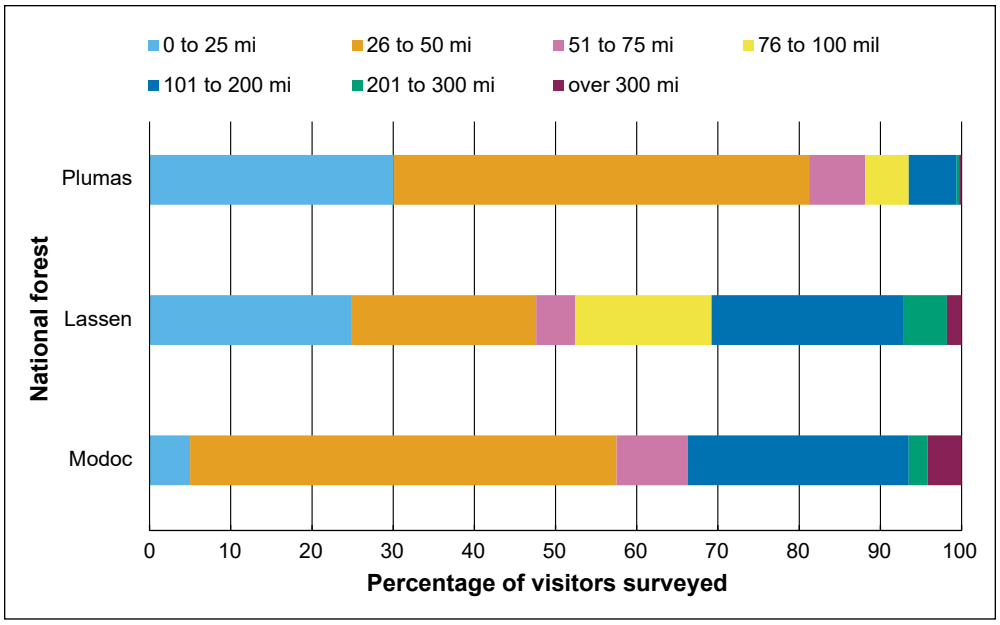

Figure 5.12—Distance that Northern Sierra Zone forest visitors would travel if they could not visit the national forest where they were surveyed.

Central Sierra Zone

The Central Sierra Zone encompasses four national forests/units, including Tahoe National Forest (fig. 5.13), LTBMU (fig. 5.14), Eldorado National Forest (fig. 5.15), and Stanislaus National Forest (fig. 5.16). Warm-weather activities represent the largest portion of activities in this zone, with viewing natural features (16 percent) and hiking/walking (15.1 percent) the largest share of activities in this category (table 5.9). Winter activities accounted for 37.1 percent of recreational activities in the Central Zone, with downhill skiing the predominant recreation use (35.8 percent). Winter activities were almost equal in economic benefit to warm-weather activities in the Central Zone.

Tahoe National Forest is a popular forest, situated within a 1- to 2-hour drive of San Francisco, Sacramento, and Reno. Special places are numerous on this forest, including the Donner Camp Picnic Site and Interpretive Trail of historical interest. The North Fork American River, also on Tahoe National Forest, was designated as a wild and scenic river in 1978. It provides recreation opportunities in the late fall and spring when other sections of the forest are still covered in snow. Extended warm-weather seasons may affect these patterns of use in ways that will require future monitoring and assessment for sustainable recreation delivery.

LTBMU and Eldorado National Forest jointly manage the Desolation Wilderness, covering 63,960 ac of lakes, subalpine forests, and alpine habitat. The Desolation Wilderness is among the most popular in the National Wilderness

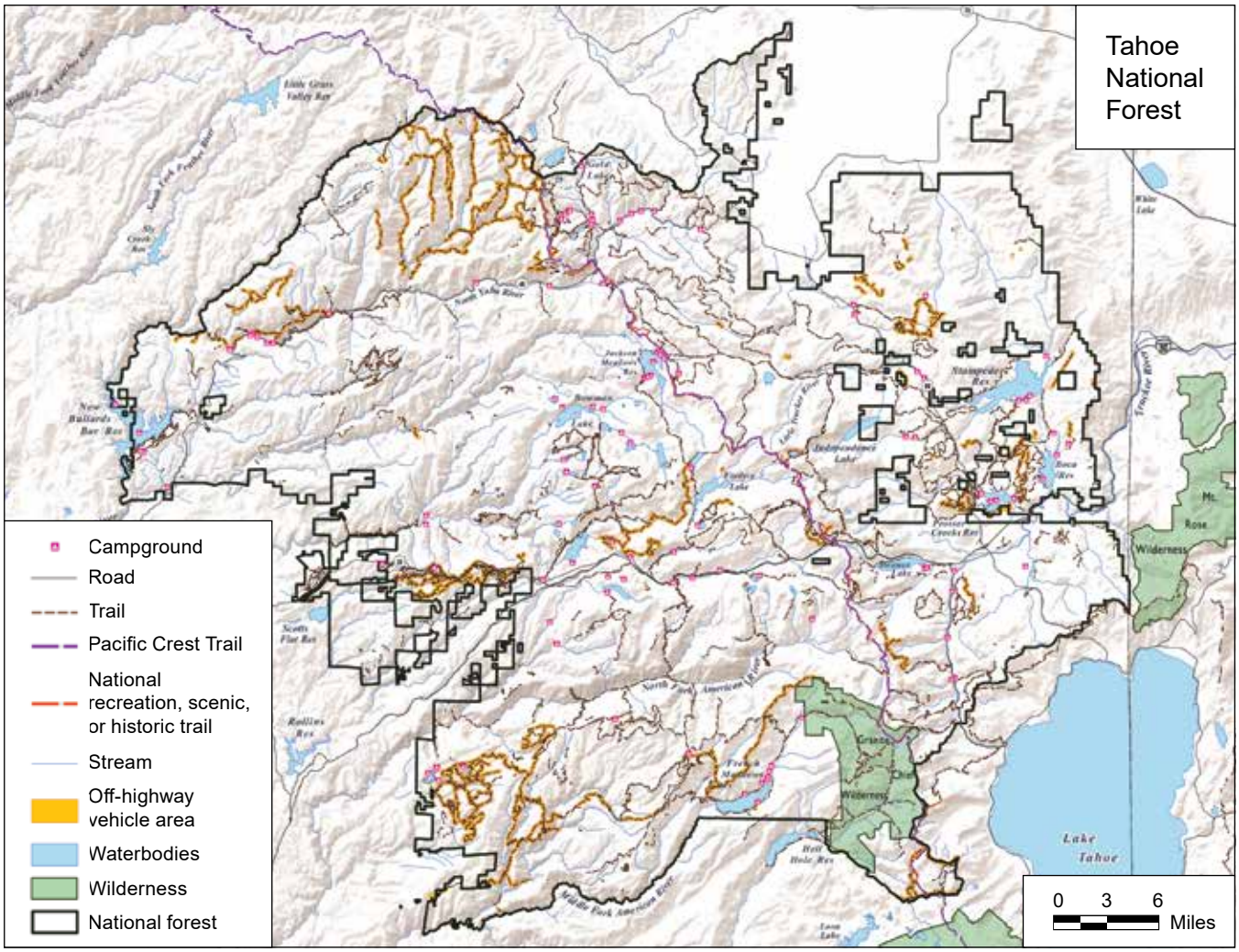

Figure 5.13—Recreation niche map of the Central Sierra Zone, Tahoe National Forest.

Preservation System, and visitors must obtain a permit for day or overnight use year-round. As a Class I Wilderness Area, air quality and visibility are monitored with specific targets for improvement. Viewsheds contribute to the wilderness visitor experience. Good air quality is important to the recreationist experience related to these viewsheds as well as the overall benefits to physical health gained during outdoor recreation. If climate change increases the frequency and extent of wildfire, air quality may be diminished significantly by smoke.

The basin is also home to the Tallac Historic Site, hosting three estates that are maintained for historical interest. These locations are open from late spring through early fall for hiking and sightseeing, with summer-season heritage tours. An extended warm-weather season may increase interest in this location, which is already heavily used during the summer peak season.

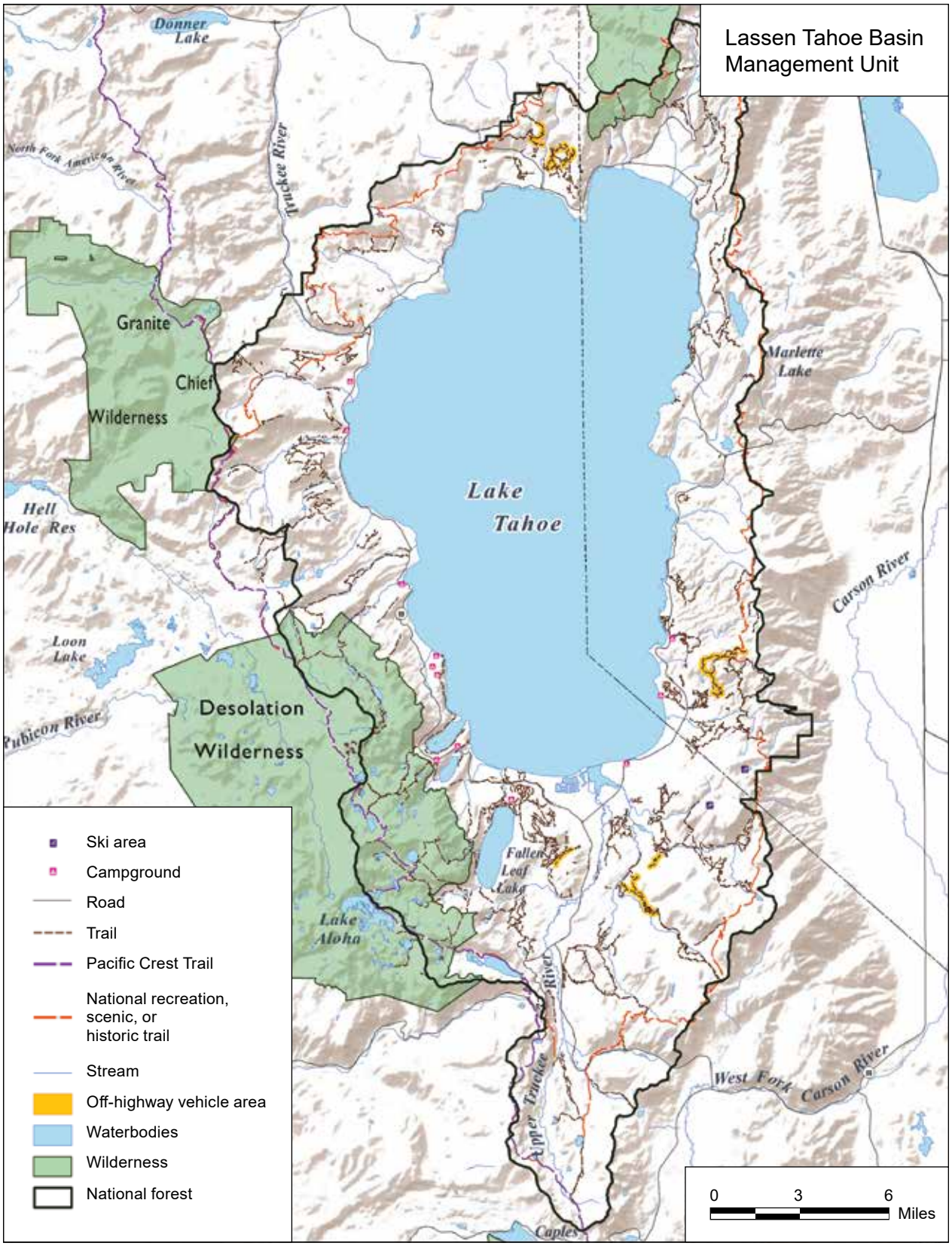

Figure 5.14—Recreation niche map of the Central Sierra Zone, Lake Tahoe Basin Management Unit.

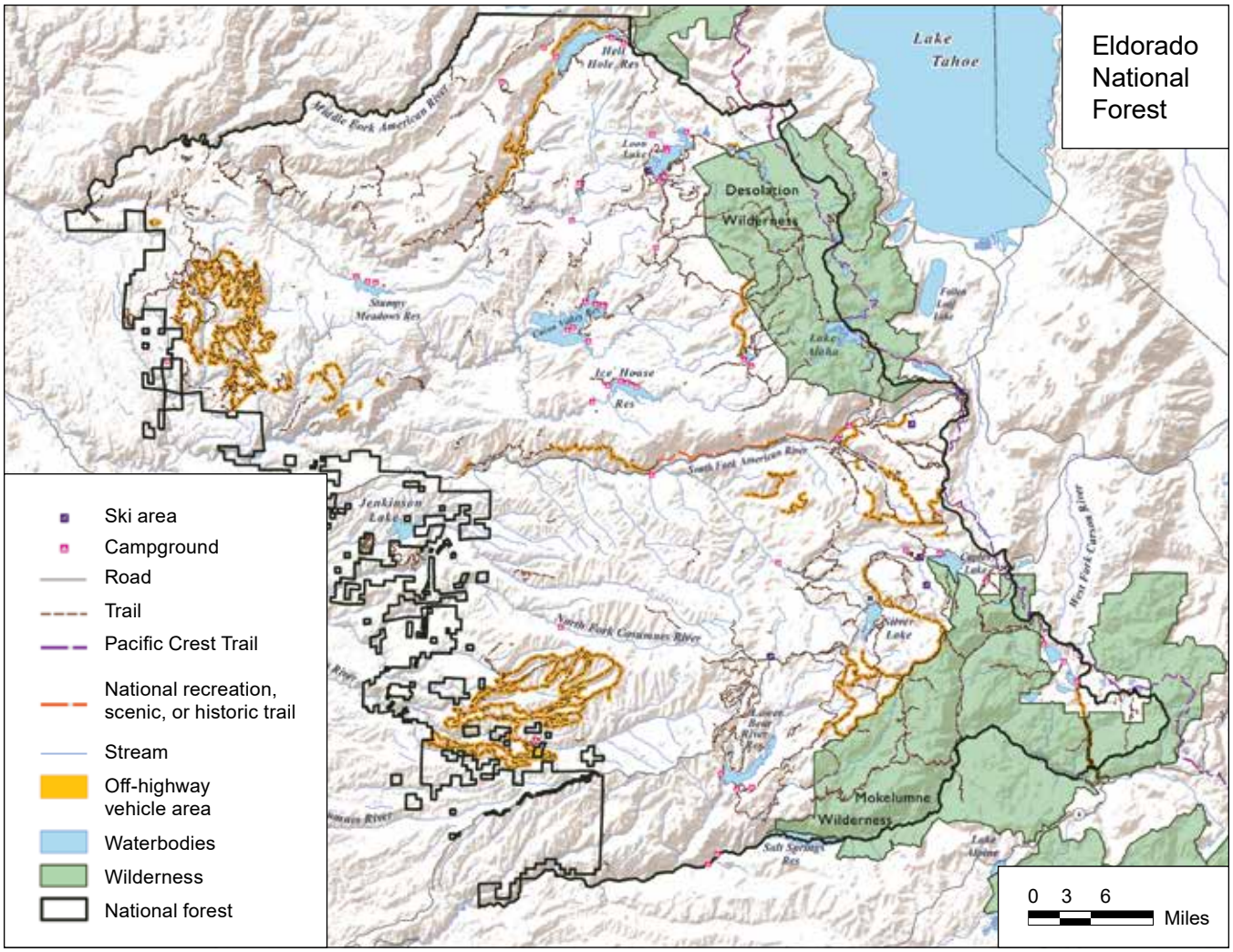

Figure 5.15—Recreation niche map of the Central Sierra Zone, Eldorado National Forest.

Eldorado National Forest is considered an urban forest, owing to its proximity to multiple large metropolitan centers. The forest ranges from 1,000 to 10,000 ft elevation. The Pony Express National Historic Trail is 19 mi long. The renowned Rubicon Trail supports off-highway vehicles (OHVs) and four-wheel drive vehicles. In most cases, the trail is kept open, although observing fire restrictions is strongly encouraged year-round. According to the Rubicon Trail Foundation, (1) wet trails should be avoided to reduce erosion damage, (2) winter travel is inadvisable because of snow cover and constrained options for rescue, (3) summer brings increased fire danger and crowding, and (4) fall brings fast-moving storms (https://www.rubicontrailfoundation.org/trailinfomation/conditions). Although this foundation is part of a robust volunteer and partnership network that works to maintain and restore trail access, climate change may bring more extreme storm events that would require strengthening of these supporting networks.

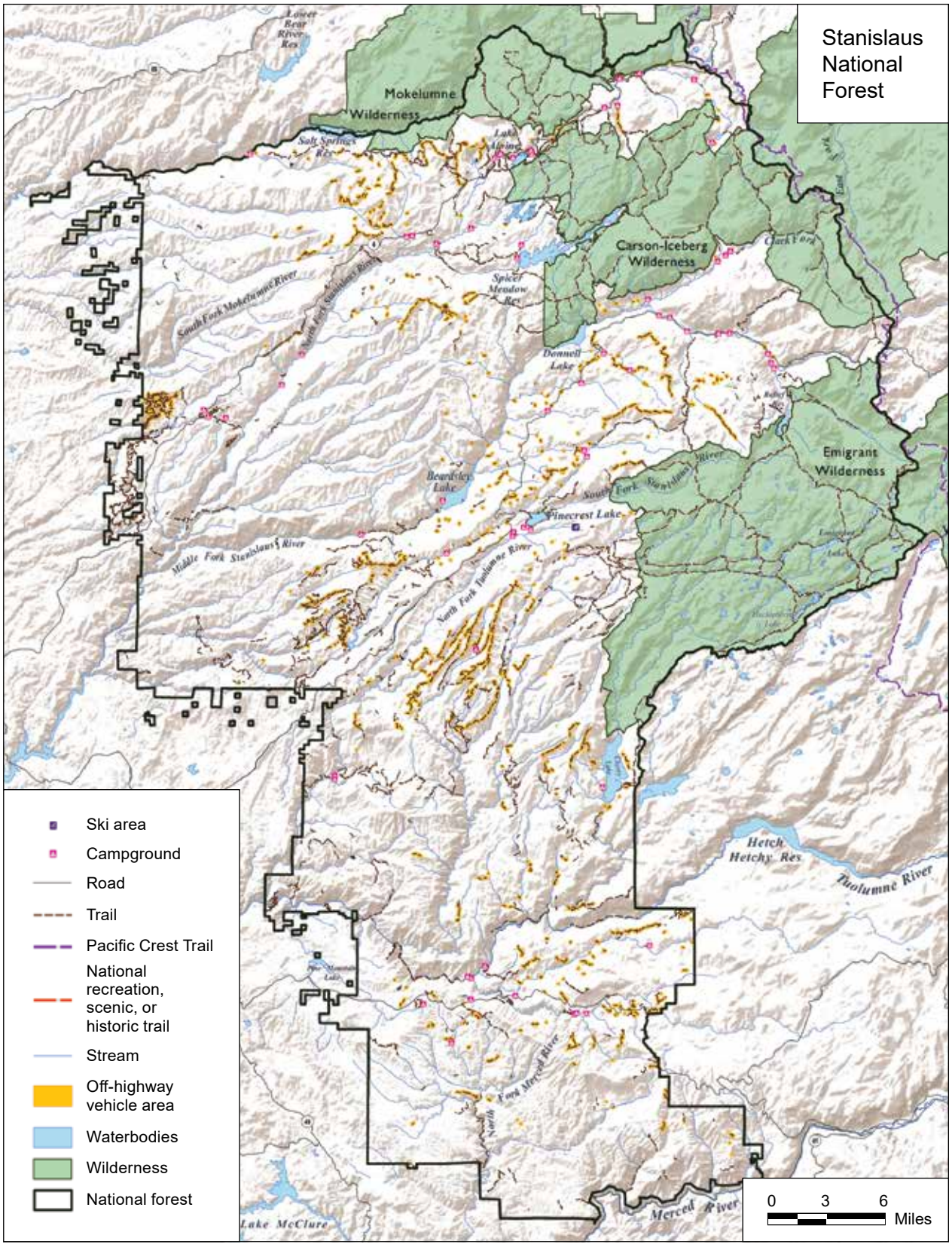

Figure 5.16—Recreation niche map of the Central Sierra Zone, Stanislaus National Forest.

Table 5.9—Main recreation activities for the Central Sierra Zone (2015–2017)

Main activity	Frequency	Percentage of total
Warm-weather activities:		
Viewing natural features	1,907,080	16.0
Hiking/walking	1,791,801	15.1
Other nonmotorized	454,480	3.8
Bicycling	268,538	2.3
Developed camping	213,408	1.8
Picnicking	136,859	1.1
Backpacking	101,462	0.9
Horseback riding	44,926	0.4
Primitive camping	21,377	0.2
Total	4,939,930	41.5
Winter activities:		
Downhill skiing	4,257,643	35.8
Cross-country skiing	136,189	1.1
Snowmobiling	21,417	0.2
Total	4,415,250	37.1
Wildlife activities:		
Fishing	275,531	2.3
Viewing wildlife	135,573	1.1
Hunting	63,318	0.5
Total	474,422	4.0
Gathering forest products:		
Gathering forest products	8,990	0.1
Water-based activities, not including fishing:		
Motorized water activities	133,174	1.1
Nonmotorized water	104,298	0.9
Total	237,472	2.0
Other activities:		
Relaxing	1,078,350	9.1
Driving for pleasure	256,649	2.2
Some other activity	172,636	1.5
Nature center activities	89,582	0.8
Off-highway vehicle use	68,306	0.6
Nature study	59,224	0.5
Motorized trail activity	49,259	0.4
Visiting historic sites	28,937	0.2
Resort use	19,754	0.2
Other motorized activity	2,372	0.0
Total	1,825,068	15.3
Total for all activities	11,901,133	100

Stanislaus National Forest provides a variety of recreation opportunities and settings. The Tuolumne Wild and Scenic River and the North Fork of the Stanislaus offer whitewater boating, and fishing opportunities are abundant in lakes, streams, and rivers (Three Forests Interpretive Association 2017). Although increased temperatures may draw more visitors to these water activities, reduced flows may adversely affect experiences offered, and increased water temperatures may adversely affect suitable conditions for fish.

Changes in winter activities associated with climate change effects are of concern in the Central Sierra Zone. In the Lake Tahoe region, the onset of adequate snow depth to provide for over-snow recreation has been shifted by about 2 weeks since 1985 (Hatchett and Eisen 2018). This shift is significant, given the economic contributions from over-snow use, expected increase in other types of winter recreation, and need for more accurate quantification of adequate snow depth to protect long-term ecosystem sustainability. Additional loss of Sierra snowpack is anticipated (Huang et al. 2018) (chapter 2).

As was the case for the Northern Zone, nonlocal visitors have much higher total annual expenditures within a 50-mi radius of the survey site (table 5.10). Overall annual expenditures among nonlocals bring approximately $1.1 billion to local

Table 5.10—Total annual expenditures within 50 mi of the survey site by nonlocal and local visitors to the Central Sierra Zone, by spending category

Spending category	Nonlocal spending[a] [b]		Local spending	
	Total annual expenditures	Spending for each category	Total annual expenditures	Spending for each category
	Thousands of dollars ($2017)[c]	*Percent*	*Thousands of dollars ($2017)*[c]	*Percent*
Lodging	294,085	26.9	3,065	3.2
Camping fees	14,736	1.3	3,285	3.4
Restaurant	227,749	20.8	14,151	14.9
Groceries	123,787	11.3	16,539	17.4
Gas and oil	135,978	12.4	28,093	29.5
Local transportation	5,654	0.5	359	0.4
Entry fees	95,918	8.8	13,758	14.4
Recreation and entertainment	120,340	11.0	8,409	8.8
Sporting goods	35,582	3.3	5,861	6.2
Souvenirs and other expenses	40,821	3.7	1,711	1.8
Total	1,094,650	100	95,231	100

Note: Spending totals were calculated using procedures outlined in White (2017) and parameters and spending averages used by the U.S. Forest Service office of Ecosystem Management Coordination.

a Nonlocal refers to trips that required traveling more than 50 mi to the survey site.

[b] Data source is the fourth round of the National Visitor Use Monitoring (NVUM) surveys.

[c] NVUM data, 2015–2017.

economies. Nonlocal visitors have the largest proportion of expenditures in the lodging and restaurants categories.

The estimated annual economic benefit for recreation participation associated with the Central Zone is about $923 million (table 5.11), 72.3 percent of the overall estimated value for the three zones ($1.2 billion). The LTBMU has the highest annual economic benefit (65.5 percent of total Central Zone value), followed by Tahoe (14.2 percent), Eldorado (10.8 percent), and Stanislaus (9.6 percent). In the Central Zone, warm-weather activities and winter activities are more similar in economic benefit than in any other zone (table 5.11). The largest estimated economic benefit is from downhill skiing, representing about 38 percent of the overall economic benefit from forest recreation activities.

Comparison of several NVUM surveys over time shows how recreation benefits have changed for downhill skiing on the LTBMU. California experienced drought conditions from 2007 to 2009 (California Department of Water Resources 2010) and more recently from 2011 to 2017 (National Integrated Drought Information System 2019). Some recreation activities that depend on water and winter conditions, including downhill skiing, were significantly affected.

In the LTBMU, downhill skiing is by far the most popular outdoor recreation activity. Prior to the 2007–2009 California drought, 2005 NVUM data showed there were more than 3.8 million annual visits for downhill skiing. Data from the subsequent NVUM surveys (2010 and 2015) showed a decrease of annual visits by 19 percent and 21 percent, respectively, despite an overall population increase in California and Nevada for the same time period. Applying the economic benefits methodology, the predrought (2005) estimated economic benefit for downhill skiing was $321.6 million (based on 2016 dollars). The drought conditions were associated with fewer snow-use days, resulting in fewer visits and an associated decline in economic benefit to $269.4 million in 2010 and $265.9 million in 2015 (based on 2016 dollars). The actual economic losses may be larger than these reported values, because the estimates do not include other revenue streams (e.g., special use fees). Similar results can be found for Inyo and Tahoe National Forests, both also highly dependent on water conditions and supply, and the activities they support.

When asked what the forest visit would be substituted with if the current forest visited was not available, the most common response from visitors to Tahoe, Eldorado, and Stanislaus National Forests, and LTBMU was they would have gone elsewhere for the same activity (59.8, 54.9, 41.2, and 37.8 percent, respectively; USDA FS 2018j, 2018a, 2018i, and 2018c, respectively) (fig. 5.17). Almost a fifth of LTBMU visitors indicated they would have gone elsewhere for a different activity (18.1 percent) or come back another time (17.1 percent).

Table 5.11—Estimate of annual aggregate economic benefit for the Central Sierra Zone

Activity participation[a]	Economic benefit
	2016 dollars
Warm-weather activities:	
Hiking/walking	150,986,676
Viewing natural features	122,384,578
Bicycling	23,711,367
Developed camping	16,637,376
Other nonmotorized	31,308,533
Backpacking	7,167,298
Picnicking	6,726,514
Horseback riding	3,112,378
Primitive camping	1,285,243
Total	363,319,963
Winter activities:	
Downhill skiing	351,748,822
Cross-country skiing	7,285,442
Snowmobiling	1,005,763
Total	360,040,027
Wildlife activities:	
Fishing	21,679,079
Hunting	6,207,997
Viewing wildlife	7,931,485
Total	35,818,561
Gathering forest products:	
Gathering forest products	511,664
Water-based activities, not including fishing:	
Nonmotorized water	14,042,193
Motorized water activities	8,965,903
Total	23,008,096
Other activities:	
Relaxing	91,700,178
Some other activity	10,670,568
Driving for pleasure	16,271,581
Resort use	3,424,770
Off-highway vehicle use	3,379,153
Motorized trail activity	2,689,409
No activity reported	621,402
Visiting historic sites	1,671,347
Other motorized activity	110,016
Nature center activities	5,847,377
Nature study	3,905,714
Total	140,291,515
Total for all activities	922,989,827

[a] Main recreation activity.

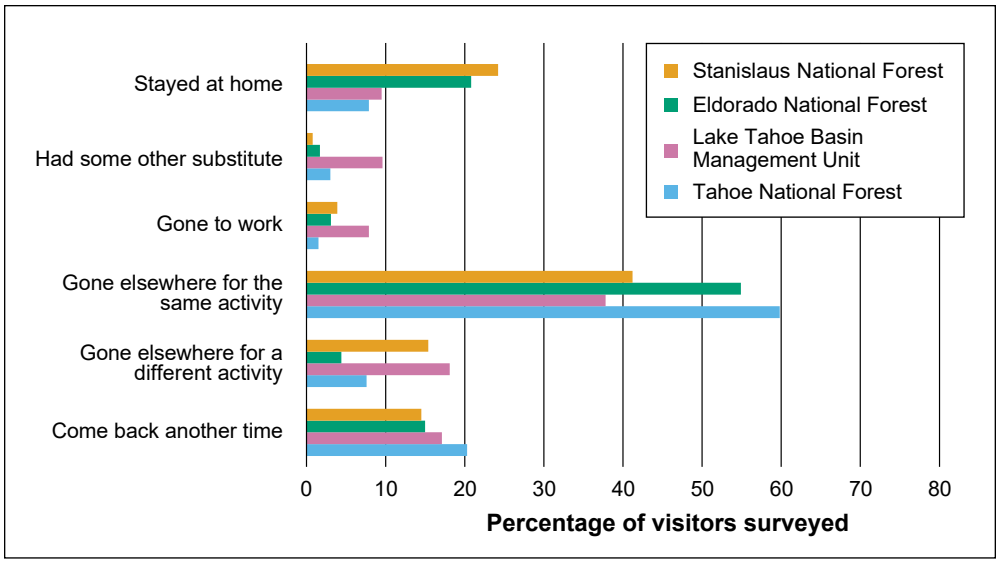

Figure 5.17—Alternative location or option that Central Sierra Zone forest/unit visitors would choose if unable to visit the forest/unit where they were surveyed.

The distance that respondents would have traveled to an alternate location varied by forest/unit. The largest proportion of visitors to Tahoe National Forest would have traveled between 0 and 25 mi (thus staying local), whereas on Eldorado and Stanislaus National Forests, more than one-fourth would have traveled between 101 and 200 mi (fig. 5.18). Visitors to the LTBMU were unique in that more than one-third indicated they would travel over 300 mi to an alternate location.

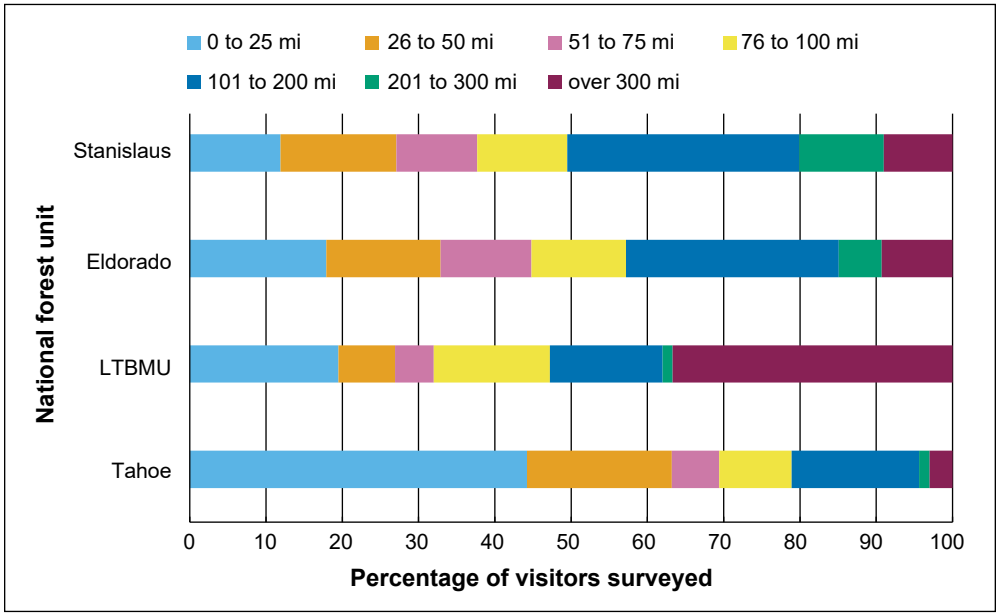

Figure 5.18—Distance that Central Sierra Zone forest/unit visitors would travel if they could not visit the national forest/unit where they were surveyed. LTBMU = Lake Tahoe Basin Management Unit.

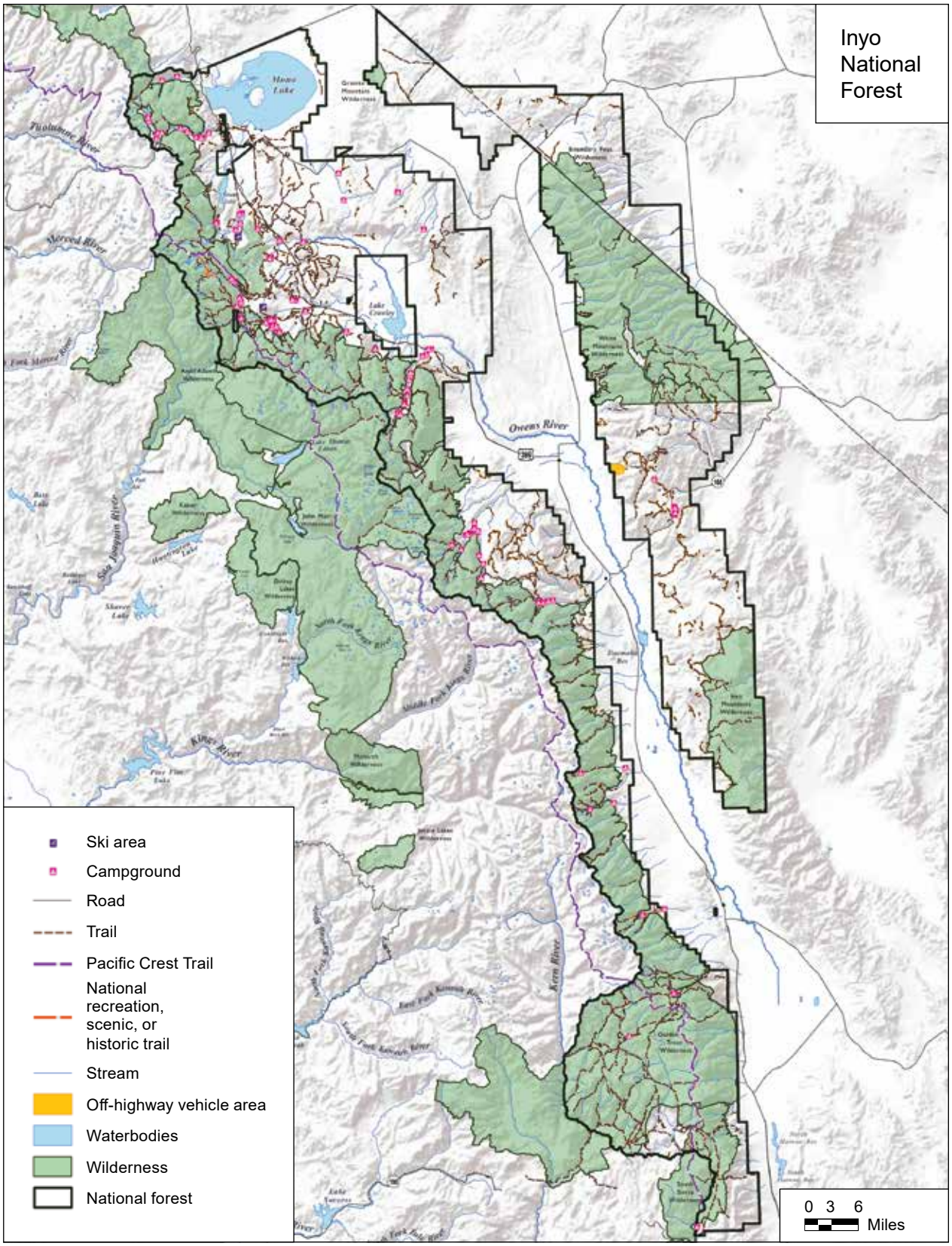

Figure 5.19—Recreation niche map of the Southern Sierra Zone, Inyo National Forest.

NVUM data provide useful insight into these responses. A majority of visitors to Stanislaus National Forest reportedly traveled more than 100 mi to arrive at their recreation destination, similar to LTBMU visitors for whom more than half traveled more than 200 mi.

Southern Sierra Zone

The Southern Sierra Zone of the assessment area contains Inyo (fig. 5.19), Sierra (fig. 5.20), and Sequoia (fig. 5.21) National Forests. Warm-weather activities represent the largest share of recreation use in the Southern Zone, followed by winter activities, with downhill skiing the largest single type of use reported (table 5.12). Inyo National Forest is home to two ski areas, 100 mi of snowmobile trails, and 25 mi of Nordic ski trails. The town of Mammoth Lakes is central to the Mammoth

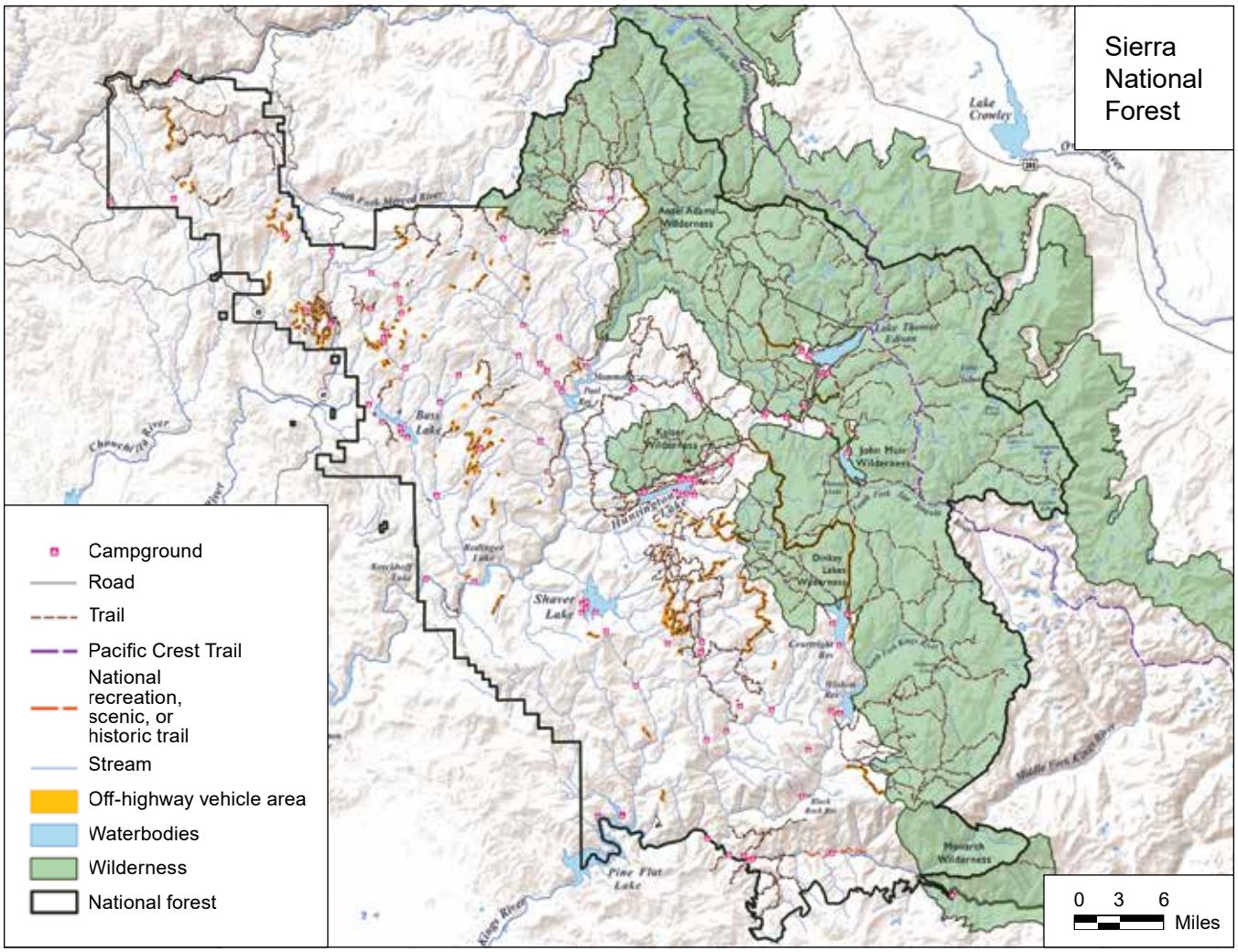

Figure 5.20—Recreation niche map of the Southern Sierra Zone, Sierra National Forest.

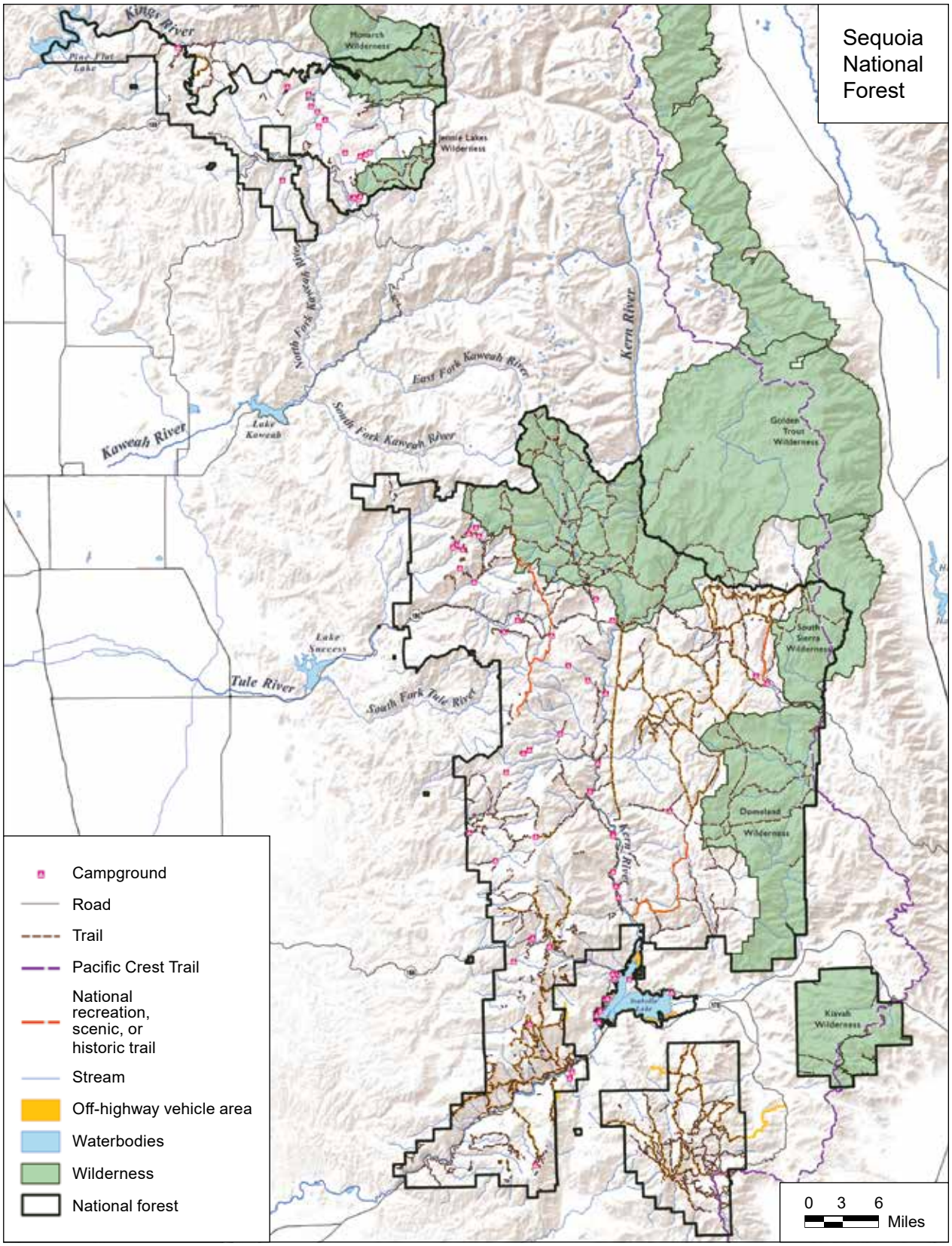

Figure 5.21—Recreation niche map of the Southern Sierra Zone, Sequoia National Forest.

Table 5.12—Main recreation activities for the Southern Sierra Zone (2015–2017)

Main activity	Frequency	Percentage of total
Warm-weather activities:		
Hiking/walking	742,375	16.0
Viewing natural features	439,942	9.5
Bicycling	281,004	6.1
Other nonmotorized	177,741	3.8
Developed camping	172,388	3.7
Backpacking	81,886	1.8
Picnicking	80,291	1.7
Horseback riding	11,829	0.3
Primitive camping	8,740	0.2
Total	1,996,193	43.1
Winter activities:		
Downhill skiing	1,076,619	23.3
Cross-country skiing	173,079	3.7
Snowmobiling	3,775	0.1
Total	1,253,472	27.1
Wildlife activities:		
Fishing	239,276	5.2
Hunting	103,538	2.2
Viewing wildlife	27,315	0.6
Total	370,129	8.0
Gathering forest products:		
Gathering forest products	18,437	0.4
Water-based activities, not including fishing:		
Nonmotorized water	39,389	0.9
Motorized water activities	19,885	0.4
Total	59,274	1.3
Other activities:		
Relaxing	369,777	8.0
Some other activity	242,984	5.3
Driving for pleasure	136,564	3.0
Off-highway vehicle use	42,367	0.9
Motorized trail activity	33,147	0.7
Visiting historic sites	28,466	0.6
Other motorized activity	26,032	0.6
Resort use	22,575	0.5
Nature center activities	20,255	0.4
Nature study	7,762	0.2
Total	929,929	20.1
Total for all activities	4,627,435	100

Lakes Ranger District, a home to winter sports and popular in the summer for mountain biking and fishing. Although snowmaking capabilities can likely sustain some winter sports, uses outside of developed runs may be affected by reduced snow.

Nine federally designated wilderness areas are on Inyo National Forest covering approximately 1 million ac. Hiking to the top of Mount Whitney is popular and requires a permit. This forest is home to long-lived Great Basin bristlecone pines (*Pinus longaeva* D.K. Bailey) at high elevation. The scenic byway offers opportunities to view these trees, and a visit to the Schulman Grove visitor's center offers an opportunity to learn more about them. The center is closed during the winter season, although travel along the route may increase if warm-weather use increases. An increased visitor season could increase impacts and require expansion of parking lots and overlooks.

Sierra National Forest is home to groves of giant sequoia (*Sequoiadendron giganteum* [Lindl.] J. Buchh.) (e.g., the McKinley Grove) and five wilderness areas (including the John Muir and Ansel Adams Wildernesses), providing year-round recreation use. A standing forest order was issued for the Kaiser Wilderness to increase camping setbacks to 200 ft from lakes within the wilderness to allow for recovery of vegetation and mitigation of impacts from camping. Further restrictions include limits on stock use within 100 ft of the lakes, and a decreased length of stay. These measures were attributed in part to the continued high level of recreation use, a reminder that increases in the number of visitors or length of seasons may result in ecological effects that require changes in management. Wildfires have likewise had considerable impacts on this forest (e.g., the Kaiser and Thomas Fires). Nelder Grove was severely affected by the Railroad Fire (fig. 5.5).

Positioned between two wilderness areas is the Dusy Ershim OHV trail, a 30-mi point to point trail known for its considerable challenges to the OHV rider, camping, fishing, and a lake (https://www.alltrails.com/trail/us/california/dusy-ershim-4x4-trail).

Sequoia National Forest is home to whitewater rafting and other uses on the Kern and Kings Rivers, and Lake Isabella offers the only motorized boating opportunity. The Kern River can become hazardous when the flow of water is increased, a likely event in some years as mentioned previously in this report, and may result in injury or loss of life (see Lin 2017).

Giant Sequoia National Monument on Sequoia National Forest contains 33 giant sequoia groves or grove complexes (USDA FS 2012). Recent research suggests the giant sequoias are being affected by extended drought as well as increased

temperature (Su et al. 2017). Impacts on this iconic species are of concern for current and future generations of visitors and the managers addressing social and ecological change in the region.

The South Zone includes two federally designated iconic places: Mono Basin National Forest Scenic Area on Inyo National Forest and Giant Sequoia National Monument on Sequoia National Forest. Site managers of 41 U.S. Forest Service iconic places were surveyed during 2016–2017 (Ellison et al. 2018). Managers of these places (including the two in the South Zone) identified scenic value as a primary reason for designation as an iconic place. Additional values were biophysical features and unique recreation opportunities. Ratings of current conditions and resource condition trends were not always reassuring, with some areas in impaired or deteriorated condition.

Although current levels of recreation use were believed to be sustainable by a majority of respondents, future trends in use were not believed sustainable by a majority. The largest perceived challenges for sustainable management among survey respondents were internal funding, staffing shortages, and competing demands on staff time. Recreation use demands were noted as challenges by more than half of the respondents, and climate change was cited by less than a third of respondents (Ellison et al. 2018). Noteworthy is the likely impact on scenic value and recreation opportunities from climate change, as well as increased pressures in the form of deteriorated conditions, increased demands in selected areas, and funding issues. Although climate change was less often cited as a concern, the main issues of concern to respondents are likely to intersect with climate change effects. Monitoring of current and expected effects on recreation sustainability as viewed by managers would be an interesting focus for ongoing information gathering to inform development and modification of adaptation strategies.

Southern Sierra forests are home to endemic native trout, with other native species confined to smaller areas of forests, owing to stocking practices and their effects on habitat (Hunsaker et al. 2014). Limited habitat and projected climate change effects leave native trout species vulnerable (Hunsaker et al. 2014).

Increased average annual and winter temperatures along with decreased snowpack are of concern in the Southern Zone forests (Gonzalez 2012). Projections show a continuing increase in extreme temperatures as well as extreme precipitation events where a 1-in-20-year storm is projected to occur every 8 to 10 years (Gonzalez 2012). Of further concern in the Southern Zone forests is the well-documented relationship among wildfire, intense rainstorms, and debris flows that threaten recreation sites and access as well as surrounding communities (Hunsaker et al. 2014) (fig. 5.22).

James D. Absher

Figure 5.22—Postfire erosion, Sierra National Forest.

The majority of dollars expended in the Southern Zone are for lodging costs for nonlocal visitation. Nonlocal visitation expenditures are the vast majority of recreation expenditures in the zone (table 5.13). The estimated annual economic benefit for recreation participation associated with the Southern Zone is about $293 million (table 5.14), about 22.9 percent of the overall estimated value for the three zones ($1.3 billion). Inyo National Forest has the highest annual economic benefit (62.3 percent of total Southern Zone value), followed by Sequoia National Forest (21.6 percent), and Sierra National Forest (16.1 percent). The largest estimated economic benefit for recreation in the Southern Zone is from downhill skiing, although as a group, warm-weather activities provide the larger share of estimated benefits by category of activity (table 5.14).

When asked what the forest visit would be substituted with if the current forest visited was not available, the most common response from visitors to Inyo, Sierra, and Sequoia National Forests was that they would have gone elsewhere for the same activity (45.6, 34.7, and 44.3 percent respectively; USDA FS 2018b, 2018h, and 2018g, respectively) (fig. 5.23). Almost a third of Sierra National Forest visitors would have come back another time.

Distance respondents would have traveled to an alternate location varied by forest (fig. 5.24). More than a third of visitors (43.4 percent) to Inyo National Forest

Table 5.13—Total annual expenditures within 50 mi of the survey site by nonlocal and local visitors to the Southern Sierra Zone, by spending category

Spending category	Nonlocal spending[a b]		Local spending	
	Total annual expenditures	Spending for each category	Total annual expenditures	Spending for each category
	Thousands of dollars ($2017)[c]	*Percent*	*Thousands of dollars ($2017)[c]*	*Percent*
Lodging	105,182	27.4	615	2.4
Camping fees	10,156	2.6	984	3.8
Restaurant	76,375	19.9	3,688	14.2
Groceries	47,301	12.3	5,371	20.7
Gas and oil	54,456	14.2	8,815	33.9
Local transportation	2,220	0.6	98	0.4
Entry fees	25,287	6.6	2,483	9.6
Recreation and entertainment	34,841	9.1	1,469	5.7
Sporting goods	12,399	3.2	1,988	7.6
Souvenirs and other expenses	15,453	4.0	474	1.8
Total	383,672	100	25,985	100

Note: Spending totals were calculated using the procedures outlined in White (2017) and parameters and spending averages used by the U.S. Forest Service office of Ecosystem Management Coordination.

[a] Nonlocal refers to trips that required traveling more than 50 mi to the survey site.

[b] Data source is the fourth round of the National Visitor Use Monitoring (NVUM) surveys.

[c] NVUM data, 2015–2017.

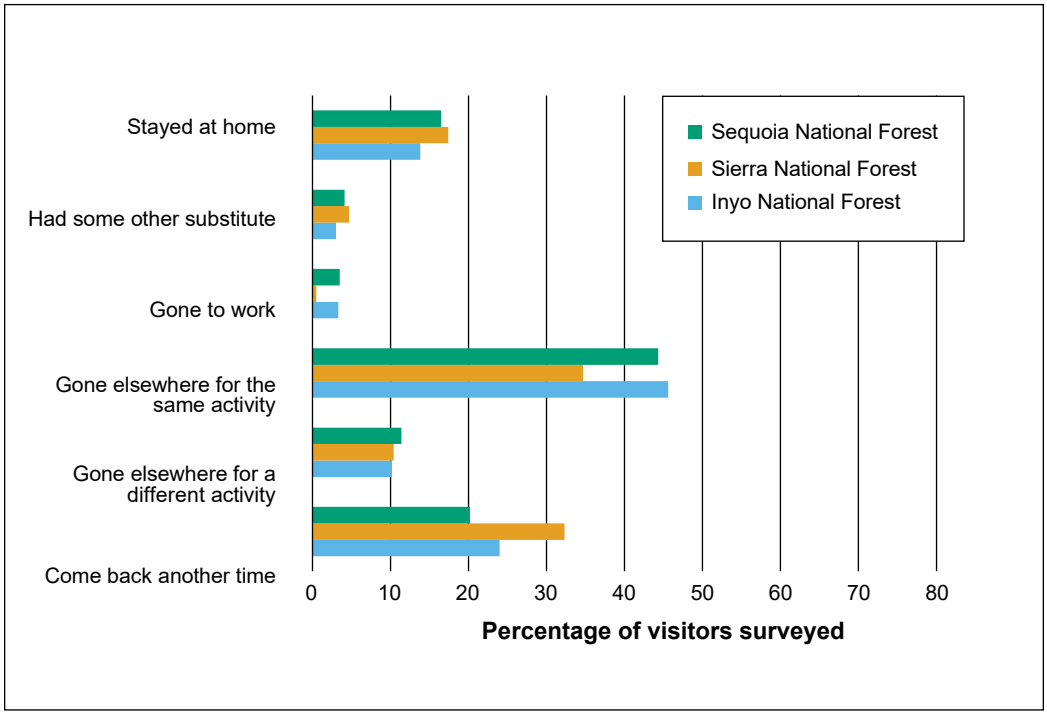

Figure 5.23—Alternative location or option that Southern Sierra Zone forest visitors would choose if unable to visit the national forest where they were surveyed.

Table 5.14—Estimate of annual aggregate economic benefit for the Southern Sierra Zone

Activity participation[a]	Economic benefit
	2016 dollars
Warm-weather activities:	
Hiking/walking	51,228,248
Viewing natural features	23,023,280
Bicycling	19,601,081
Developed camping	11,120,155
Other nonmotorized	9,707,842
Backpacking	4,832,305
Picnicking	3,167,638
Horseback riding	688,375
Primitive camping	437,875
Total	123,806,799
Winter activities:	
Downhill skiing	69,678,740
Cross-country skiing	7,414,831
Snowmobiling	147,795
Total	77,241,366
Wildlife activities:	
Fishing	16,154,748
Hunting	9,570,599
Viewing wildlife	1,290,172
Total	27,015,519
Gathering forest products:	
Gathering forest products	1,028,903
Water-based activities, not including fishing:	
Nonmotorized water	4,456,506
Motorized water activities	1,075,878
Total	5,532,384
Other activities:	
Relaxing	26,126,424
Some other activity	12,662,536
Driving for pleasure	7,178,301
Resort use	3,712,182
Off-highway vehicle use	1,877,566
Motorized trail activity	1,634,048
No activity reported	1,500,034
Visiting historic sites	1,293,849
Other motorized activity	1,081,565
Nature center activities	1,018,422
Nature study	401,426
Total	58,486,353
Total for all activities	293,111,326

[a] Main recreation activity.

indicated they would travel over 300 mi to an alternate location. Following similar patterns for prior sections in this report, Inyo visitors traveled a considerable distance to recreate at their final destination according to the latest NVUM survey results, with almost three-fourths reporting distances of more than 200 mi.

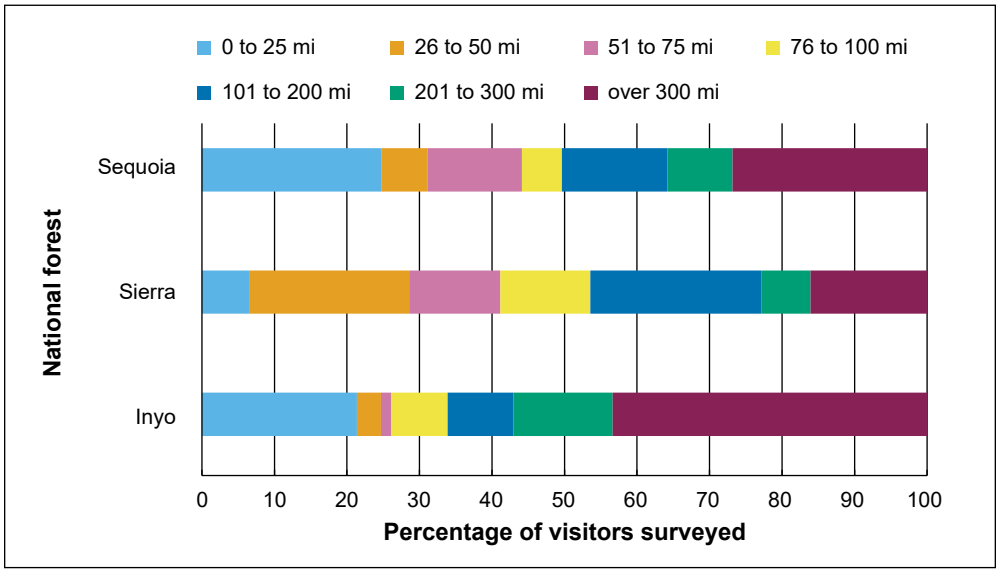

Figure 5.24—Distance that Southern Sierra Zone forest visitors would travel if they could not visit the national forest where they were surveyed.

Adapting Recreation to the Effects of Climate Change

Although many effects from climate change are anticipated, and some have already occurred to varying degrees, many strategies will likely be effective in adapting to climate change effects. We consider a few of these in this chapter and give a place-based view of their consideration in the chapter exploring adaptation strategies and tactics (chapter 6). To promote climate change resilience, Jardine and Long (2014) outlined several approaches, including a focus on longer time horizons for planning, setting of adaptable objectives, and ability to revisit and modify as needed; and use of valuation tools, monitoring, and research.

The Interagency Visitor Use Management Council's resources, particularly the "Indicators, Thresholds, and Monitoring Guidebook" (IVUMC 2019a) and the "Visitor Use Capacity Guidebook" (IVUMC 2019b) may be helpful toward planning for and monitoring of recreation use levels and selection of indicators. Additional resources that address concerns such as recreation use impacts under different social and ecological conditions and approaches to monitoring include Marion's work (see Marion et al. 2016), and a handbook for managers developed by Burn and Winter (Burn and Winter 2007, 2008; Winter and Burn 2010).

An additional strategy is to ensure a solid disciplinary mix in the consideration of socioecological linkages in assessment of impacts and development of tactics, monitoring, and adaptive responses. In other words, a robust systems approach and the willingness to incorporate complex and diverse sources of information are needed to develop appropriate climate change responses. Additional research focused on the intersection of climate change and recreation is needed, as the understanding of short and longer term direct and indirect effects is not sufficiently understood (Brice et al. 2017). Beyond the impacts, an improved understanding of the effectiveness of various adaptation strategies and tactics requires study over time. For example, impacts of substitution behaviors and their degree of effectiveness in maintaining the myriad benefits of recreation require additional study.

Adaptation to climate change effects is already evident in the assessment area. For example, messaging of air quality impacts from wildfires and smoke was widely shared across media during the summer of 2018 when multiple fires affected conditions on several forests and communities in the area. National forest websites list area and site closures, frequently along with a description of causes for the closures. These are also shared with relevant media. In April 2017, the Stanislaus National Forest announced closure of four roads and the recreation areas along the roads in response to damage from extreme snow levels and winter storms. The closure was expected to run through the end of 2018 (Peterson 2017).

Consideration of available technologies that may augment communication of associated risks as well as public actions is warranted (e.g., Ballew et al. 2015). For example, the U.S. Forest Service has a novel smartphone and iPhone® application that helps address:

- Agency strategic goal 2 (USDA FS 2015): Deliver benefits to the public.
    - Strategic objective F: Connect people to the outdoors—Utilize new and emerging technologies and techniques to reach nontraditional and diverse audiences in order to share recreational opportunities throughout the region.
- Agency strategic goal 3 (USDA FS 2015): Apply knowledge globally.
    - Strategic objective H: Transfer technology and applications—Further expand our use of technology to accomplish our work, manage our information, and share evolving knowledge (https://usdagcc.sharepoint.com/sites/fs-rhvr-mit/SitePages/Let%27s%20Get%20Started.aspx, drawn from the Salmon-Challis presentation posted to this site).

Because the app allows national forest staff to update messaging and information, areas that are affected by closures or reduced access could be noted for

potential visitors, and the app could be used to identify locations nearby that would still be open for similar recreation opportunities.

Messaging itself benefits from use of the best available science. For example, a recent study reported that visitors to the Lower Klamath and Tule Lake National Wildlife Refuges would find messaging around climate change most relevant when framed as a quality of life issue (e.g., preserving recreation opportunities) or as an economic issue (e.g., maintaining revenues from recreation and tourism) (Sexton et al. 2012). The authors suggested placing science-based issues in a context that various audiences can relate to. The relevance of messaging for diverse audiences can be improved by addressing environmental issues from the context of importance to communities (Marcus et al. 2011).

Adaptation by Recreation Participants

Recreationists may benefit from searching information resources to plan forest visits (potential elevation of know-before-you-go messaging) and may need to develop alternative plans in case unexpected events render an area or opportunity unavailable. Substitution of alternative locations and activities is complex and may be less inviting to recreationists with a personal and or family connection to a location or activity, an identity associated with that place or activity, or a view that the activity and location are unique in a way that cannot be replaced elsewhere (Winter et al. 2014a). Although recreation visitors are most likely to adapt to short-term patterns where the primary forest location is not available for a planned recreation activity and visit, longer term impacts on recreation experience quality, recreation benefits, and place attachments are not well understood. Consideration may be given to implementing restoration and conservation engagement for visiting recreationists in the form of stewardship tourism given the considerable draw of some activities in the Sierra Nevada (Schild 2019, USDA FS 2010).

Adaptation by Public Land Managers

The U.S. Forest Service will likely need an expanded portfolio of approaches to address uncertainty surrounding climate change effects (Aplet et al. 2010). Projections overall show a continuing pattern of increased recreation use across the assessment area, suggesting the need to ensure adequate staffing and resources to continue to manage for a diversity of high-quality recreation opportunities. Increased staffing will be needed to aid delivery of recreation opportunities and to maintain visitor safety, as well as to aid protection and restoration of affected settings. Climate change will likely extend the season for warm weather activities, increase the variability of conditions for snow-dependent outdoor recreation activities, and consolidate outdoor recreation in remaining settings when outdoor

Projections overall show a continuing pattern of increased recreation use across the assessment area, suggesting the need to ensure adequate staffing and resources to continue to manage for a diversity of high-quality recreation opportunities.

recreation infrastructure and transportation systems are negatively affected by the extreme weather events and wildfire severity that climate change exacerbates.

Limits on visitation through determination of carrying and social capacity may be increasingly necessary, as will approaches that incorporate messaging around alternative areas and activities, and warnings about potential crowding and capacity issues. Strategies can be targeted to aid visitors in decision processes surrounding destinations and activities. Similarly, when environmental hazards may be higher (e.g., when air quality or water quality are degraded), messaging can inform visitors, particularly those with sensitivities, to avoid locations or activities until hazards are diminished or resolved.

Current platforms used to communicate availability of recreation opportunities, such as national forest websites, will increase in importance as messaging tools to maintain visitor awareness of specific seasons, closures, or limits to types of use. Social media platforms may be useful for a subset of interested parties seeking forest updates, although social media used and relied upon is diverse, changes rapidly, and requires investment and frequent updating to remain relevant (Ballew et al. 2015). Smartphone applications are a more recent innovation for the U.S. Forest Service and can be an essential tool in the agency's communication portfolio if updated in a timely way.

Partnerships and volunteer programs will continue to aid the U.S. Forest Service in providing and managing for its diverse recreation opportunities and settings. Partnerships and volunteers have been instrumental in providing recreation opportunities and in restoring areas, as was described earlier in this paper regarding the reopening of the Gabrielino Trail. These opportunities provide benefits to participating volunteers and partners, although considerable variation exists among national forests (Winter 2014b). Partnerships among agencies and institutions, resource management agencies, and others focused on resource sustainability are needed to support information needs and inform adaptive responses (CIRMOUNT Committee 2006). The examples of niche opportunities presented in this chapter included selected stories of how partners and volunteers contribute to sustainable recreation opportunities in the Sierra Nevada.

Monitoring of impacts from climate change that may disproportionally affect underrepresented groups will increase in importance as climate change effects continue to emerge.

As stated earlier in the chapter, monitoring of impacts from climate change that may disproportionally affect underrepresented groups will increase in importance as climate change effects continue to emerge. Where recreation access is of elevated benefit to populations otherwise at risk, preserving high-quality opportunities and access is a cornerstone of sustainable recreation delivery (Winter et al. 2019).

Literature Cited

Ainsworth, B.E.; Haskell, W.L.; Whitt, M.C. [et al.]. 2000. Compendium of physical activities: an update of activity codes and MET intensities. Medicine & Science in Sports & Exercise. 32: S498–S516.

Aplet, G.H.; Anderson, H.M.; Wilmer, B. 2010. Managing the risk of climate change to wildlands of the Sierra Nevada. Washington, DC: The Wilderness Society. 51 p.

Arvai, J.; Bridge, G.; Dolsak, N. [et al.]. 2006. Adaptive management of the global climate problem: bridging the gap between climate research and climate policy. Climatic Change. 78: 217–225.

Askew, A.E.; Bowker, J.M. 2018. Impacts of climate change on outdoor recreation participation: outlook to 2060. Journal of Park and Recreation Administration. 36: 97–120.

Audubon [N.d.]. Modoc Plateau. https://www.audubon.org/important-bird-areas/modoc-plateau. (22 June 2019).

Backer, L.C.; McNeel, S.V.; Barber, T. [et al.]. 2009. Recreational exposure to microcystins during algal blooms in two California lakes. Toxicon. 55: 909–921.

Ballew, M.T.; Omoto, A.M.; Winter, P.L. 2015. Using Web 2.0 and social media technologies to foster proenvironmental action. Sustainability. 7: 10620–10648.

Barton, J.; Hine, R.; Pretty, J. 2009. The health benefits of walking in greenspaces of high natural and heritage value. Journal of Integrative Environmental Sciences. 6: 261–278.

BBC Research & Consulting. 2010. California outdoor recreation economic study: statewide contributions and benefits. Denver, CO. https://www.parks.ca.gov/pages/795/files/ca%20outdoor%20rec%20econ%20study-statewide%2011-10-11%20for%20posting.pdf. (1 August 2019).

Blotkamp, A.; Meldrum, B.; Morse, W.; Hollenhorst, S.J. 2010. Yosemite National Park visitor study: summer 2009. Visitor Serv. Rep. 215. Moscow, ID: University of Idaho, Park Studies Unit.

Brice, B.; Fullerton, C.; Hawkes, K.L. [et al.]. 2017. The impacts of climate change on natural areas recreation: a multi-region snapshot and agency comparison. Natural Areas Journal. 37: 86–97.

Burley, J.D.; Bytnerowicz, A.; Buhler, M. [et al.]. 2016. Air quality at Devils Postpile National Monument, Sierra Nevada Mountains, California, USA. Aerosol and Air Quality Research. 16: 2315–2332.

Burn, S.M.; Winter, P.L. 2007. Environmental intervention handbook for resource managers: a tool for proenvironmental behavior change. 2nd ed. https://digitalcommons.calpoly.edu/psycd_fac/29/. (4 February 2020).

Burn, S.M.; Winter, P.L. 2008. A behavioral intervention tool for recreation managers. Park Science. 25: 66–68.

Bytnerowicz, A.; Burley, J.D.; Cisneros, R. [et al.]. 2013. Surface ozone at the Devils Postpile National Monument receptor site during low and high wildland fire years. Atmospheric Environment. 65: 129–141.

California Department of Water Resources. 2010. California's drought of 2007–2009. Sacramento, CA. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Resources/California-Drought-of-200709.pdf. (21 June 2019).

California State Parks. 2016. Statistical report 2015/2016 fiscal year. Sacramento, CA: Strategic Planning and Recreation Division, Marketing and Business Development Office. https://www.parks.ca.gov/pages/795/files/15-16%20Statistical%20Report%20FINAL%20ONLINE.pdf. (1 August 2019).

Capaldi, C.A.; Passmore, H.-A.; Nisbet, E.K.; Zelenski, J.M.; Dopko, R.L. 2015. Flourishing in nature: a review of the benefits of connecting with nature and its application as a wellbeing intervention. International Journal of Wellbeing. 5: 1–16.

Cardine, S. 2018. Gabrielino Trail fully reopened after 2009 Station Fire, thanks to massive volunteer cleanup. La Cañada Valley Sun, September 5, 2018. http://www.latimes.com/socal/la-canada-valley-sun/news/tn-vsl-me-gabrielino-restoration-20180905-story.html. (10 April 2019).

Chan, N.W.; Wichman, C.J. 2018. The effects of climate on leisure demand: evidence from North America. Washington, DC: Resources for the Future. http://caseyjwichman.com/wp-content/uploads/2018/04/leisure_demand_v042418.pdf. (4 February 2020).

Charnley, S. 2014. Strategies for job creation through National Forest management. In: Long, J.W.; Quinn-Davidson, L.; Skinner, C.N., eds. Science synthesis to support socioecological resilience in the Sierra Nevada and southern Cascade Range. Gen. Tech. Rep. PSW-GTR-247. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 599–627.

Chavez, D.J.; McCollum, D. 2004. Using BAER reports to investigate recreation impacts of fire events. In: Proceedings of the fourth social aspects and recreation research symposium. San Francisco, CA: San Francisco State University: 120–125.

Chen, L.; Ng, E. 2012. Outdoor thermal comfort and outdoor activities: a review of research in the past decade. Cities. 29: 118–123.

CIRMOUNT Committee. 2006. Mapping new terrain: climate change and America's West. Report of the Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT). Misc. Publ. PSW-MISC-77. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 29 p.

Cisneros, R.; Bytnerowicz, A.; Schweizer, D.; Zhong, S.; Traina, S.; Bennett, D.H. 2010. Ozone, nitric acid, and ammonia air pollution is unhealthy for people and ecosystems in southern Sierra Nevada, California. Environmental Pollution. 158: 3261–3271.

Clark, M.J. 2002. Dealing with uncertainty: adaptive approaches to sustainable river management. Aquatic Conservation: Marine and Freshwater Ecosystems. 12: 347–363.

Clow, D.W.; Forrester, H.; Miller, B. [et al.]. 2013. Effects of stock use and backpackers in wilderness in Sequoia and Kings Canyon National Parks, USA. Environmental Management. 52: 1400–1414.

Clow, D.W.; Peavler, R.S.; Roche, J. [et al.]. 2011. Assessing possible visitor-use impacts on water quality in Yosemite National Park, California. Environmental Monitoring and Assessment. 183: 197–215.

Cohen, D.A.; McKenzie, T.L.; Sehgal, A. [et al.]. 2007. Contribution of public parks to physical activity. American Journal of Public Health. 97: 509–514.

Cordell, H.K.; Tarrant, M.A.; Green, G.T. 2003. Is the public viewpoint of wilderness shifting? International Journal of Wilderness. 9: 27–32.

Derlet, R.W.; Ger, L.A.; Richards, J.R. 2009. Algae in Sierra Nevada mountain wilderness areas: potential health hazards. Journal of Mountain Medicine and Ecology. 1: 2–10.

Ellison, A.; White, E.M.; Arnn, M. 2018. Iconic places of the USDA Forest Service: values, conditions, challenges, and opportunities. Work. Pap. 85. Eugene, OR: University of Oregon, Ecosystem Workforce Program.

Evans, G.W. 2019. Projected behavioral impacts of global climate change. Annual Review of Psychology. 70: 449–474.

Ferguson, M.D.; Meuller, J.T.; Graefe, A.R.; Mowen, A.J. 2018. Coping with climate change: a study of Great Lakes water-based recreationists. Journal of Park and Recreation Administration. 36: 52–74.

Fischer, A.P.; Paveglio, T.; Carroll, M.; Murphy, D.; Brenkert-Smith, H. 2013. Assessing social vulnerability to climate change in human communities near public forests and grasslands: a framework for resource managers and planners. Journal of Forestry. 111: 357–365.

Gonzalez, P. 2012. Climate change trends and vulnerability to biome shifts in the southern Sierra Nevada. Washington, DC: National Park Service, Climate Change Response Program. https://mltpa.org/images/downloads/704_01_Gonzalez_climate_change_southern_Sierra.pdf. (4 February 2020).

Hand, M.S.; Lawson, M. 2018a. Effects of climate change on recreation in the Northern Rockies. In: Halofsky, J.E.; Peterson, D.L., eds. Climate change and Rocky Mountain ecosystems. Cham, Switzerland: Springer International Publishing. Vol. 63. https://doi.org/10.1007/978-3-319-56928-4_9.

Hand, M.S.; Lawson, M. 2018b. Effects of climate change on recreation in the Northern Rockies region. In: Halofsky, J.E.; Peterson, D.L.; Dante-Wood, S.K. [et al.]., eds. Climate change vulnerability and adaptation in the Northern Rocky Mountains. Gen. Tech. Rep. RMRS-GTR-374. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 398–433.

Hand, M.S.; Smith, J.W.; Peterson, D.L. [et al.]. 2018. Effects of climate change on outdoor recreation. In: Halofsky, J.E.; Peterson, D.L.; Ho, J.J., eds. Climate change vulnerability and adaptation in the Intermountain Region. Gen. Tech. Rep. RMRS-GTR-375. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 316–338.

Hatchett, B.J.; Eisen, H.G. 2018. Early season snowpack loss and implications for over-snow vehicle recreation travel planning. The Cryosphere. 13: 21–28.

Hitchner, S.; Schelhas, J.; Brosius, J.P.; Nibbelink, N. 2019. Thru-hiking the John Muir Trail as a modern pilgrimage: implications for natural resource management. Journal of Ecotourism. 18: 82–99.

Huang, X.; Hall, A.D.; Berg, N. 2018. Anthropogenic warming impacts on today's Sierra Nevada snowpack and flood risk. Geophysical Research Letters. 45: 6215–6222.

Hunsaker, C.T.; Long, J.W.; Herbst, D.B. 2014. Watershed and stream ecosystems. In: Long, J.W.; Quinn-Davidson, L.; Skinner, C.N., eds. Science synthesis to support socioecological resilience in the Sierra Nevada and southern Cascade Range. Gen. Tech. Rep. PSW-GTR-247. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 265–322.

Interagency Visitor Use Management Council [IVUMC]. 2019a. Monitoring guidebook: evaluating effectiveness of visitor use management. Denver, CO. https://visitorusemanagement.nps.gov/VUM/Framework. (4 February 2020).

Interagency Visitor Use Management Council [IVUMC]. 2019b. Visitor capacity guidebook: managing the amounts and types of visitor use to achieve desired conditions. Lakewood, CO. https://visitorusemanagement.nps.gov/VUM/Framework. (4 February 2020).

Jardine, A.; Long, J.W. 2014. Synopsis of climate change. In: Long, J.W.; Quinn-Davidson, L.; Skinner, C.N., eds. Science synthesis to support socioecological resilience in the Sierra Nevada and southern Cascade Range. Gen. Tech. Rep. PSW-GTR-247. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 71–81.

Jennings, V.; Larson, L.; Yun, J. 2016. Advancing sustainability through urban green space: cultural ecosystem services, equity, and social determinants of health. International Journal of Environmental Research and Public Health. 13(2): 196.

Joyce, L.A.; Blate, G.M.; McNulty, S.G. [et al.]. 2009. Managing for multiple resources under climate change: national forests. Environmental Management. 44: 1022–1032.

Kainzinger, S.; Arnberger, A.; Burns, R.C. 2018. An examination of whitewater boater's place attachment and specialization in four different river settings. Environmental Management. 62: 832–844.

Kline, J.D.; Rosenberger, R.S.; White, E.M. 2011. A national assessment of physical activity in U.S. national forests. Journal of Forestry. 109: 343–351.

Kondo, M.C.; South, E.C.; Branas, C.C. 2015. Nature-based strategies for improving urban health and safety. Journal of Urban Health. 92: 800–814.

Lake, F.K.; Long, J.W. 2014. Fire and tribal cultural resources. In: Long, J.W.; Quinn-Davidson, L.; Skinner, C.N., eds. Science synthesis to support socioecological resilience in the Sierra Nevada and southern Cascade Range. Gen. Tech. Rep. PSW-GTR-247. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 173–186.

Lal, P.; Alavalapati, J.; Mercer, D.E. 2011. Socioeconomic impacts of climate change on rural communities in the United States. In: Alig, R.J., tech. coord. Effects of climate change on natural resources and communities: a compendium of briefing papers. Gen. Tech. Rep. PNW-GTR-837. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 73–118.

Lee, B.Y.; Adam, A.; Zenkov, E. [et al.]. 2017. Modeling the economic and health impact of increasing children's physical activity in the United States. Health Affairs. 5: 902–908.

Ligare, S.T.; Viers, J.H.; Null, S.E. [et al.]. 2012. Non-uniform changes to whitewater recreation in California's Sierra Nevada from regional climate warming. River Research and Applications. 28: 1299–1311.

Lin, R-G. 2017. Deadly holiday weekend on roaring Kern River: 3 dead, 24 rescued. Los Angeles Times. May 29. https://www.latimes.com/local/california/la-me-ln-kern-river-dead-20170529-htmlstory.html. (4 February 2020).

Long, J.W.; Quinn-Davidson, L.; Skinner, C.N., eds. 2014. Science synthesis to support socioecological resilience in the Sierra Nevada and southern Cascade Range. Gen. Tech. Rep. PSW-GTR-247. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 712 p.

Loomis, J. 2005. Updated outdoor recreation use values on national forests and other public lands. Gen. Tech. Rep. PNW-GTR-658. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 26 p.

Marcus, B.J.; Omoto, A.M.; Winter, P.L. 2011. Environmentalism and community: connections and implications for social action. Ecopsychology. 3: 11–24.

Marion, J.L.; Leung, Y-F.; Eagleston, H.; Burroughs, K. 2016. A review and synthesis of recreation ecology research findings on visitor impacts to wilderness and protected natural areas. Journal of Forestry. 114: 352–362.

Mitchell, R.; Popham, F. 2008. Effect of exposure to natural environment on health inequalities: an observational population study. The Lancet. 372: 1655–1660.

Morris, D.; Walls, M. 2009. Climate change and outdoor recreation resources: backgrounder. Washington, DC: Resources for the Future. 26 p.

Mt. Wilson Bicycling Association [MWBA]. 2018. Gabrielino Trail restoration press release. https://mwba.org/news/gabrielino-trail-restoration-press-release. (10 April 2019).

National Integrated Drought Information System. 2019. California is no stranger to dry conditions, but the drought from 2011–2017 was exceptional. California Drought 2011–2017. https://www.drought.gov/drought/california-no-stranger-dry-conditions-drought-2011-2017-was-exceptional. (17 April 2019).

Orr, M.; Schneider, I. 2018. Substitution interests among active-sport tourists: the case of a cross-country ski event. Journal of Sport & Tourism. 22: 315–332.

Patterson, T. 2014. Ecosystem services. In: Long, J.W.; Quinn-Davidson, L.; Skinner, C.N., eds. Science synthesis to support socioecological resilience in the Sierra Nevada and southern Cascade Range. Gen. Tech. Rep. PSW-GTR-247. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 543–568.

Peterson, T. 2017. Storm damage shuts down roads and recreation in Stanislaus National Forest. https://www.mymotherlode.com/news/local/296347/storm-damage-shuts-down-roads-and-recreation-in-stanislaus-national-forest.html. (21 June 2019).

Potchter, O.; Cohen, P.; Lin, T-P.; Matzarakis, A. 2018. Outdoor human thermal perception in various climates: a comprehensive review of approaches, methods and quantification. Science of the Total Environment. 631–632: 390–406.

Pratt, M.; Macera, C.A.; Wang, G. 2000. Higher direct medical costs associated with physical inactivity. The Physician and Sports Medicine. 28: 63–70.

Preisler, H.K.; Zhong, S.; Esperanza, A. [et al.]. 2010. Estimating contribution of wildland fires to ambient ozone levels in National Parks in the Sierra Nevada, California. Environmental Pollution. 158: 778–787.

Prestemon, J.P.; Kruger, L.; Abt, K.L. [et al.]. 2016. Economics and societal considerations of drought. In: Vose, J.; Clark, J.; Luce, C.; Patel-Weynand, T., eds. Effects of drought on forests and rangelands in the United States: a comprehensive science synthesis. Gen. Tech. Rep. WO-93b. Washington, DC: U.S. Department of Agriculture, Forest Service: 253–281.

Reynier, W.A.; Hauptfeld, R.S.; Kershner, J.M. 2015. Ecosystem service vulnerability assessment: recreation. In: Kershner, J.M., ed. A climate change vulnerability assessment for focal resources of the Sierra Nevada. Bainbridge Island, WA: EcoAdapt.

Richardson, R.B.; Loomis, J.B. 2004. Adaptive recreation planning and climate change: a contingent visitation approach. Ecological Economics. 50: 83–99.

Roberts, N.S.; Chavez, D.J.; Lara, B.M.; Sheffield, E.A. 2009. Serving culturally diverse visitors to forests in California: a resource guide. Gen. Tech. Rep. PSW-GTR-222. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 76 p.

Rosenberger, R.S.; Loomis, J.B. 2001. Benefit transfer of outdoor recreation use values: a technical document supporting the Forest Service Strategic Plan (2000 revision). Gen. Tech. Rep. RMRS-GTR-72. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 59 p.

Rosenberger, R.S.; White, E.M.; Kline, J.D.; Cvitanovich, C. 2017. Recreation economic values for estimating outdoor recreation economic benefits from the National Forest System. Gen. Tech. Rep. PNW-GTR-957. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 33 p.

Rosselló-Nadal, J. 2014. How to evaluate the effects of climate change on tourism. Tourism Management. 42: 334–340.

Schild, R. 2019. Civic recreation: outdoor recreationists as advocates, stewards, and managers of natural resources. Environmental Management. 63: 629–646.

Schweizer, D.; Cisneros, R. 2014. Wildland fire management and air quality in the southern Sierra Nevada: using the Lion Fire as a case study with a multi-year perspective on $PM_{2.5}$ impacts and fire policy. Journal of Environmental Management. 144: 265–278.

Sexton, N.R.; Dietsch, A.M.; Don Carlos, A.W. [et al.]. 2012. National wildlife refuge visitor survey 2010/2011—individual refuge results. Data Ser. 643. Reston, VA: U.S. Department of the Interior, Geological Survey.

Sierra Nevada Conservancy. 2017. The state of the Sierra Nevada's forests: from bad to worse. Auburn, CA: Sierra Nevada Conservancy. 18 p.

Smith, J.W.; Seekamp, E.; McCreary, A. [et al.]. 2016. Shifting demand for winter outdoor recreation along the North Shore of Lake Superior under variable rates of climate change: a finite-mixture modeling approach. Ecological Economics. 123: 1–13.

South, E.C.; Hohl, B.C.; Kondo, M.C. [et al.]. 2018. Effect of greening vacant land on mental health of community-dwelling adults: a cluster randomized trial. JAMA Network Open. 1(3): e180298.

Su, Y.; Bales, R.C.; Ma, Q. [et al.]. 2017. Emerging stress and relative resiliency of giant sequoia groves experiencing multiyear dry periods in a warming climate. Journal of Geophysical Research: Biogeosciences. 122: 3063–3075.

Three Forests Interpretive Association. 2017. Stanislaus traveler: a visitor's guide to the Stanislaus National Forest. Tollhouse, CA.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2010. Connecting people with America's great outdoors: a framework for sustainable recreation. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5346549.pdf. (4 February 2020).

U.S. Department of Agriculture, Forest Service [USDA FS]. 2012. Giant Sequoia National Monument management plan including errata. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3797629.pdf. (4 February 2020).

U.S. Department of Agriculture, Forest Service [USDA FS] 2015. USDA Forest Service Strategic Plan: 2015–2020. FS 1045, June 2015. https://www.fs.usda.gov/sites/default/files/strategic-plan[2]-6_17_15_revised.pdf. (28 June, 2021).

U.S. Department of Agriculture, Forest Service [USDA FS]. 2016. Future of America's forests and rangelands: update to the 2010 Resources Planning Act Assessment. Gen. Tech. Rep. WO-GTR-94. Washington, DC. 250 p.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2018a. Visitor use report: Eldorado National Forest. National Visitor Use Monitoring data collected fiscal year 2017. Last updated 29 November 2018. https://apps.fs.usda.gov/nvum/results/ReportCache/2017_A05003_Master_Report.pdf. (10 April 2019).

U.S. Department of Agriculture, Forest Service [USDA FS]. 2018b. Visitor use report: Inyo National Forest. National Visitor Use Monitoring data collected fiscal year 2016. Last updated 21 January 2018. https://apps.fs.usda.gov/nvum/results/ReportCache/2016_A05004_Master_Report.pdf. (10 April 2019).

U.S. Department of Agriculture, Forest Service [USDA FS]. 2018c. Visitor use report: Lake Tahoe Basin Management Unit. National Visitor Use Monitoring data collected fiscal year 2015. Last updated 27 January 2018. https://apps.fs.usda.gov/nvum/results/ReportCache/2015_A05019_Master_Report.pdf. (10 April 2019).

U.S. Department of Agriculture, Forest Service [USDA FS]. 2018d. Visitor use report: Lassen National Forest. National Visitor Use Monitoring data collected fiscal year 2015. Last updated 27 January 2018. https://apps.fs.usda.gov/nvum/results/ReportCache/2015_A05006_Master_Report.pdf. (10 April 2019).

U.S. Department of Agriculture, Forest Service [USDA FS]. 2018e. Visitor use report: Modoc National Forest. National Visitor Use Monitoring data collected fiscal year 2016. Last updated 21 January 2018. https://apps.fs.usda.gov/nvum/results/ReportCache/2016_A05009_Master_Report.pdf. (10 April 2019).

U.S. Department of Agriculture, Forest Service [USDA FS]. 2018f. Visitor use report: Plumas National Forest. National Visitor Use Monitoring data collected fiscal year 2015. Last updated 27 January 2018. https://apps.fs.usda.gov/nvum/results/ReportCache/2015_A05011_Master_Report.pdf. (10 April 2019).

U.S. Department of Agriculture, Forest Service [USDA FS]. 2018g. Visitor use report: Sequoia National Forest. National Visitor Use Monitoring data collected fiscal year 2016. Last updated 21 January 2018. https://apps.fs.usda.gov/nvum/results/ReportCache/2016_A05013_Master_Report.pdf. (10 April 2019).

U.S. Department of Agriculture, Forest Service [USDA FS]. 2018h. Visitor use report: Sierra National Forest. National Visitor Use Monitoring data collected fiscal year 2017. Last updated 29 November 2018. https://apps.fs.usda.gov/nvum/results/ReportCache/2017_A05015_Master_Report.pdf. (10 April 2019).

U.S. Department of Agriculture, Forest Service [USDA FS]. 2018i. Visitor use report: Stanislaus National Forest. National Visitor Use Monitoring data collected fiscal year 2017. Last updated 29 November 2018. https://apps.fs.usda.gov/nvum/results/ReportCache/2017_A05016_Master_Report.pdf. (10 April 2019).

U.S. Department of Agriculture, Forest Service [USDA FS]. 2018j. Visitor use report: Tahoe National Forest. National Visitor Use Monitoring data collected fiscal year 2015. Last updated 27 January 2018. https://apps.fs.usda.gov/nvum/results/ReportCache/2015_A05017_Master_Report.pdf. (10 April 2019).

U.S. Department of Commerce, Bureau of Economic Analysis [USDC BEA]. 2018. Outdoor Recreation Satellite Account: updated statistics for 2012–2016. BEA 18–48. http://www.bea.gov. (21 June 2019).

van Riper, C.J.; Lum, C.; Kyle, G.T. [et al.]. 2018. Values, motivations, and intentions to engage in proenvironmental behavior. Environment and Behavior. doi: 10.1177/00/3916518807963.

Vose, J.M.; Peterson, D.L.; Patel-Weynand, T., eds., 2012. Effects of climatic variability and change on forest ecosystems: a comprehensive science synthesis for the U.S. forest sector. Gen. Tech. Rep. PNW-GTR-870. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 265 p.

Wear, D.N.; Joyce, L.A.; Butler, B.J. [et al.]. 2012. Climate change, human communities, and forests in rural, urban, and wildland-urban interface environments. In: Vose, J.M.; Peterson, D.L.; Patel-Weynand, T., eds. Effects of climatic variability and change on forest ecosystems: a comprehensive science synthesis for the U.S. forest sector. Gen. Tech. Rep. PNW-GTR-870. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 97–123.

White, E. 2017. Spending patterns of outdoor recreation visitors to national forests. Gen. Tech. Rep. PNW-GTR-961. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 70 p.

Wigtil, G.; Hammer, R.B.; Kline, J.D. [et al.]. 2016. Places where wildfire and social vulnerability coincide in the conterminous United States. International Journal of Wildland Fire. 25: 896–908.

Williams, D.R.; Watson, A.E. 2007. Wilderness values: perspectives from non-economic social science. In: Watson, A.; Sproull, J.; Dean, L., comps. Science and stewardship to protect and sustain wilderness values: eighth world wilderness congress symposium. RMRS-P-49. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 123–133.

Winter, P.L. 2013. Values of the urban wilderness. In: Cordell, H.K.; Betz, C.J.; Zarnoch, S.J. Recreation and protected land resources in the United States: a technical document supporting the Forest Service 2010 RPA assessment. Gen. Tech. Rep. SRS-GTR-169. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 67–70.

Winter, P.L.; Burn, S.M. 2010. Fostering sustainable operations in a natural resource management agency: insights from the field. Journal of Forestry. 108: 86–92.

Winter, P.L.; Long, J.W.; Lake, F.K. 2014a. Sociocultural perspectives on threats, risks, and health. In: Long, J.W.; Quinn-Davidson, L.; Skinner, C.N. eds. Science synthesis to support socioecological resilience in the Sierra Nevada and southern Cascade Range. Gen. Tech. Rep. PSW-GTR-247. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 569–598.

Winter, P.L.; Long, J.W.; Lake, F.K.; Charnley, S. 2014b. Broader context for social, economic, and cultural components. In: Long, J.W.; Quinn-Davidson, L.; Skinner, C.N. eds. Science synthesis to support socioecological resilience in the Sierra Nevada and southern Cascade Range. Gen. Tech. Rep. PSW-GTR-247. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 501–541.

Winter, P.L.; Padgett, P.E.; Milburn, L-A. S.; Li, W. 2019. Neighborhood parks and recreationists' exposure to ozone: a comparison of disadvantaged and affluent communities in Los Angeles, California. Environmental Management. 63: 379–395.

Wobus, C.; Small, E.E.; Hosterman, H.J. [et al.]. 2017. Projected climate change impacts on skiing and snowmobiling: a case study of the United States. Global Environmental Change. 45: 1–14.

Zaradic, P.A.; Pergams, O.R.W.; Kareiva, P. 2009. The impact of nature experience on willingness to support conservation. PLOS One. 4(10): e7367.

Zelenski, J.M.; Dopko, R.L.; Capaldi, C.A. 2015. Cooperation is in our nature: nature exposure may promote cooperative and environmentally sustainable behavior. Journal of Environmental Psychology. 42: 24–31.