**Table 1.** Key climate change vulnerabilities of recreation linked to specific adaptation strategies and tactics. Implementation of adaptation strategies and tactics may help to directly reduce and/or address the impacts of identified climate and non-climate stressors and disturbance regimes. Adaptation tactics focused on cultural and heritage resources, as well as those focused on research, monitoring, planning, and collaboration are included at the end of the table. Adaptation strategies and tactics listed in this table were identified by workshop participants, in the scientific literature, and in other similar efforts.

**Key:**

● Evidence-based

○ Expert opinion

| Adaptation Strategies | Adaptation Tactics | ↑ Air temperature; ↑ Likelihood of extreme heat | Changes in precipitation (timing, amount, and type) | ↑ Drought | ↓ Low flows/water levels | ↓ Snowpack; Earlier timing of snowmelt/runoff | ↑ Water temperature | ↑ High peak flows/flooding | Altered wildfire regimes | Pollution & poisons | Tactic increases general resilience *(unrelated to climate change)* | Citations | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Climate Stressors** | | | | | | **Disturbances** | | **Non-climate Stressors** | **Other** | | |
| Manage recreation sites to mitigate risks to public safety and infrastructure and to continue to provide recreation opportunities | Modify existing infrastructure to better withstand future climate conditions | ● | ● | ○ | ○ | ○ | ● | ● | ○ | ● | | Bass & Baskaran 2003; Brattebo & Booth 2003; DeNardo et al. 2005; Stack et al. 2010 | > Green roofs reduced summer cooling load and roof temperature, increased winter roof temperature, and decreased rate, volume, and timing of runoff (Bass & Baskaran 2003; DeNardo et al. 2005).<br>> Vertical gardens reduced summer cooling load and surface temperature (Bass & Baskaran 2003).<br>> Permeable pavement reduced runoff, and decreased levels of copper, zinc, and motor oil in infiltrated water (Brattebo & Booth 2003).<br>> Upgraded culverts prevented damage from projected increases in precipitation, storm intensity, and high peak flows/flooding (Stack et al. 2010). |
| | Adjust infrastructure maintenance schedule as needed to accommodate changing climate conditions | ○ | ● | ○ | ○ | ○ | ○ | ● | ○ | | | Coe 2006; Stafford 2011 | > Road sediment can be limited by reducing road-grading activity (Coe 2006; Stafford 2011), especially at elevations under 1,400 m (Coe 2006) |
| | Relocate at-risk infrastructure (i.e., move from lower elevations) | | ○ | | | | | ○ | ○ | | | | |
| | Develop new recreation sites designed for flexibility in use, or create new recreation opportunities at existing sites | ● | ● | | | ● | | | | | | Balbi et al. 2007 | > Investing in quality accomodations and indoor activities around ski areas maintained existing tourism and economic return under future climate conditions; investing in alternative snow-based activities ranked second, and was more effective than traditional improvements to ski facilities (Balbi et al. 2007) |
| | Prioritize post-disturbance treatments (e.g., relocation, armoring) | | ○ | | | | | ○ | ○ | | | | |
| Increase management flexibility to respond to changing access demands and resource availability | Invest strategically in infrastructure that will accommodate new access needs and/or changes in existing access | ● | ● | ○ | ○ | ● | ○ | ○ | ○ | | | Balbi et al. 2007 | > Increasing free-ski/backcountry touring and investing in extended cross-country ski and other alternative snow-based activities maintains tourist volume and economic value better across the entire season than investment in traditional improvements to ski facilities (Balbi et al. 2007) |
| | Monitor recreation sites and set trigger points to determine when a site should be closed or access restricted | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | | | | |
| | Develop additional access restrictions, which may include changes to permitting processes, seasonal closures, or allowable uses | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | | | | |
| | Vary whitewater permit season to adapt to changes in peak flow and duration | | ○ | ○ | ○ | | | ○ | | | | | |
| | Educate the public about changing site conditions (e.g., snowpack, lake levels, streamflow) | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | | | | |
| Provide sustainable recreation opportunities in response to changing supply and demand | Adjust capacity of recreation sites (e.g., enlarge campgrounds, install fences or gates, collect additional fees) | ○ | ○ | ○ | ○ | ○ | ○ | ○ | | | ● | Beunen et al. 2008 | > Gateways at the entrance of a recreation site reduced traffic flow and associated impacts within the site (Beunen et al. 2008) |
| | Adjust the timing of actions (e.g. open/close dates, road or trail closures, food storage orders, special use permits) to accommodate changing climate conditions | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | | | | |
| | Focus on activities that will remain feasible given projected changes, and take action to preserve existing opportunities (e.g., invest in snow-making) | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | | | | |
| | Adopt new technology that may help disperse use, direct users, and provide information about the impacts of climate change | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | | | | |
| | Limit expansion and/or pioneering of new recreation sites in riparian areas as demand for water-based recreation areas increases (e.g., restrict access, revegetate impacted areas, increase signage) | | | | | | | | | | ○ | | |
| | Develop options for diversifying snow-based recreation (e.g., cat-skiing, helicopter skiing, higher-elevation runs) | ● | ● | | | ● | | | | | | Balbi et al. 2007; Scott et al. 2006, 2008 | > Increasing free-ski/backcountry touring and investing in extended cross-country ski and other alternative activities maintained ski area tourist volume and economic value under future climate conditions across the entire season better than traditional improvements (Balbi et al. 2007)<br>> Incorporating diversified winter recreation options improved the viability of ski areas under future climate conditions (Scott et al. 2006, 2008) |

**Key:**

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| Adaptation Strategies | Adaptation Tactics | ↑ Air temperature; ↑ Likelihood of extreme heat | Changes in precipitation (timing, amount, and type) | ↑ Drought | ↓ Low flows/water levels | ↓ Snowpack; Earlier timing of snowmelt/runoff | ↑ Water temperature | ↑ High peak flows/flooding | Altered wildfire regimes | Non-climate Stressors | Other | Citations | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Climate Stressors** | | | | | | **Disturbances** | | | | | |
| Make the necessary transitions to address shorter winter recreation seasons and changing use patterns | Increase safety education to make the public aware of the increased risk of avalanches and thin ice | ● | ● | | | ● | | | | | | Burkeljca 2013; Espiner 1999; McCammon & Hägeli 2007 | > Avalanche bulletins that balanced text with easy-to-understand graphics, included both numeric and descriptive elevation bands, and used graphics rather than the avalanche rose to communicate elevation and slope orientation were preferred and most understood by recreation users (Burkeljca 2013)<br>> Pictorial signs increase user awareness of hazards and behavior compliant with management restrictions (Espiner 1999)<br>> A checklist of obvious clues was the most effect decision aid under the widest variety of conditions (McCammon & Hägeli 2007) |
| | Maintain and/or improve current winter recreation infrastructure at sites that will remain viable under future climate conditions | ● | ● | | | ● | | | | | | Balbi et al. 2007 | > Modeling determined the best strategy for maintaining tourist demand and economic returns based on ski area supply and demand under future climate conditions (Balbi et al. 2007) |
| | Shift location of winter activities to maintain opportunities and/or to mitigate safety risks (e.g., move ski trails) | ○ | ○ | | | ○ | | | | | | | |
| Protect recreation users from exposure to contaminated water and/or sediments | Cap/harden contaminated water areas | | ○ | ○ | ○ | ○ | | ○ | | ● | | | *> This tactic could prevent user exposure to contaminants in areas where they have been heavily concentrated due to low water levels, and could also prevent movement of contaminants during flood events (expert opinion)* |
| | Provide alternative water-based recreation opportunities in areas with decreased risk of exposure | | ○ | ○ | ○ | ○ | | ○ | | ● | | | *> This tactic could prevent user exposure in areas where contaminants have been concentrated due to low water levels or disturbed during flood events (expert opinion)* |
| | Provide transportation to safer and more developed water-based recreation sites in economically depressed communities | | ○ | ○ | ○ | ○ | | ○ | | ● | | | *> This tactic could provide users access to safe recreation areas in situations where they otherwise would only have access to contaminated sites (expert opinion)* |
| **Adaptation strategies and tactics for cultural/heritage sites** | | | | | | | | | | | | | |
| Protect cultural and heritage sites and the use of cultural landscapes | Develop interpretation and education opportunities for the public in cultural and heritage sites that are most vulnerable to climate change | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | | | Brown et al. 2008 | > Recreation users responded positively to educational and informational strategies at a post-fire wilderness site (Brown et al. 2008) |
| | Develop a vegetation plan to help mitigate natural hazards and promote resilience in cultural landscapes (e.g., encourage age/size class heterogeneity, manage invasives, reestablish native vegetation) | | | ○ *(indirect)* | | | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | | | | |
| | Identify and prioritize cultural and heritage sites that are most vulnerable to climate change, and identify management approaches for these sites | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | | | Dupont and Van Eetvelde 2013 | > Vulnerability maps created in GIS based on impact and modeling studies identified the climate change impacts and areas that will be most affected for two heritage sites in Belgium (Dupont and Van Eetvelde 2013) |
| | Increase the use of surveys and monitoring at cultural and historic sites | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | | | | |
| **Adaptation strategies and tactics that are based on research, monitoring, and/or assessment** | | | | | | | | | | | | | |
| Use research, monitoring, and assessment to increase knowledge of current conditions and projected changes | Assess infrastructure vulnerability to climate change and natural hazards, and prioritize by seasonal use, viability, and required investment | ○ *(indirect)* | ● *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ● *(indirect)* | ○ *(indirect)* | | | Stack et al. 2010 | > Evaluate and prioritize culverts for replacement based on projected increases in precipitation, storm intensity, peak flows, and risk of damage to the natural and built environment (Stack et al. 2010) |
| | Assess changes in use patterns and identify expected shifts in supply and demand, demographics, and economic trends | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | | | Balbi et al. 2007; Peña et al. 2015; Richardson and Loomis 2004; Richardson et al. 2006 | > Modeling successfully identified future changes in ski area supply and demand, economic returns, and use patternsunder future climate conditions (Balbi et al. 2007)<br>> Assessing recreation preferences using photo-questionnaires is an effective proxy for measuring demand (Peña et al. 2015)<br>> A contingent visitor analysis can estimate changes in climate and resource variables on on recreation demand (Richardson and Loomis 2004)<br>> Visitor surveys provided information on visitor behavior, recreation benefits, and expected changes under future climate conditions (Richardson et al. 2006) |
| | Monitor climate variables critical to current and future site use | ● *(indirect)* | ● *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ● *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | | | Yu et al. 2009 | > The MCIT methodology is a tourism climate index designed to monitor tourism season quality by taking into account both use and weather conditions (Yu et al. 2009) |
| | Use monitoring results to determine whether to maintain current site use, develop alternative opportunities, or abandon the site | ● *(indirect)* | ● *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ● *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | | | Yu et al. 2009 | > The MCIT methodology is a tourism climate index designed to monitor tourism season quality by taking into account both use and weather conditions (Yu et al. 2009) |
| Use research, monitoring, and assessment to increase knowledge of current conditions and projected | Conduct a cost-benefit analysis of maintaining the current opportunities over time in order to determine whether prioritized opportunities should change | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | | | | |

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| Adaptation Strategies | Adaptation Tactics | ↑ Air temperature; ↑ Likelihood of extreme heat | Changes in precipitation (timing, amount, and type) | ↑ Drought | ↓ Low flows/water levels | ↓ Snowpack; Earlier timing of snowmelt/runoff | ↑ Water temperature | ↑ High peak flows/flooding | Altered wildfire regimes | Pollution & poisons | Tactic increases general resilience *(unrelated to climate change)* | Citations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Climate Stressors** | | | | | | **Disturbances** | | **Non-climate Stressors** | **Other** | |
| changes *(con't)* | Assess the viability of snow-based recreation sites (e.g., cross-country and downhill skiing) under future climate conditions | ○ *(indirect)* | ○ *(indirect)* | | | ○ *(indirect)* | | | | | | Balbi et al. 2007; Yu et al. 2009 |
| | Monitor snow dates, event dates, and snowpack depth using SNOTEL data and incorporate that data into decision-making processes | ● *(indirect)* | ● *(indirect)* | | | ● *(indirect)* | | | | | | Yu et al. 2009 |
| **Adaptation strategies and tactics that are based on planning and/or collaboration** | | | | | | | | | | | | |
| Increase collaborations and incorporate climate change into planning proceses | Evaluate and prioritize existing access by season to ensure consistency with changing Recreation Opportunity Spectrum settings | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | | | |
| | Develop management strategies to maintain or shift Recreation Opportunity Settings in areas likely to change under future climate conditions | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | | | Yu et al. 2009 |
| | Coordinate with partners and concessionaires to identify possible impacts on recreation resulting from changes in supply and demand | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | | | |
| | Collaborate with local Chambers of Commerce and other businesses/organizations that entice visitors to the area to address changes in supply and demand | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | ● *(indirect)* | | | McAvoy et al. 1991 |
| | Incorporate projected changes in concentrated winter use into forest management planning | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | | | |
| | Determine whether changes in winter recreation have already been addressed within the Master Development Plan, and incorporate these considerations if necessary (e.g., add permitted uses, extend the season) | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | ○ *(indirect)* | | | |

**Notes**

> Modeling helps to determine the best strategy for maintaining tourist demand and economic returns in and around traditional ski areas under future climate conditions (Balbi et al. 2007)

> The MCIT methodology quantifies changes in tourism season length and quality (Yu et al. 2009)

> The MCIT methodology is a tourism climate index designed to monitor tourism season quality by taking into account both use and weather conditions (Yu et al. 2009)

> The MCIT methodology quantifies the impact of climate change on specific tourism sectors and in specific locations (Yu et al. 2009)

> A modified transactive planning process that includes both public managers and private businesses promotes cooperation and improves communication among the parties, and can be effectively integrated into the implementation phase of a traditional allocative planning model (McAvoy et al. 1991)

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