Chapter 14: Adapting to the Effects of Climate Change

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Introduction

Adapting to climate change, or adjusting to current or future climate and its effects (Noble et al. 2014), is critical to minimizing the risks associated with climate change impacts. Adaptation actions can vary from passive (e.g., a "wait and see" approach), to relatively simple (e.g., increasing harvest rotation age), to complex (e.g., managing forest structure and processes across large landscapes for a future range of conditions) (Spittlehouse and Stewart 2003). Many adaptation actions are complementary to other land management goals and actions, and most land managers already have the tools and knowledge to start addressing climate change. However, managers may need to make some adjustments, considering new issues, scale and location of implementation, timing, and prioritization of actions (Swanston et al. 2016). For example, it will be increasingly important to prioritize which management actions to take, and where to take those actions, based on the vulnerability of resources to climate change and the likelihood that actions in those places will be effective.

Federal land and water management agencies are required to consider climate change in planning and project analysis, and to begin preparing for the effects of climate change (Federal Register 2009, 2013; USDA FS 2012). The processes and tools for developing adaptation strategies and tactics have differed within and among Federal agencies (Halofsky et al. 2015). However, as outlined in Peterson et al. (2011b), key steps in the process include: (1) education on basic climate change science, integrated with knowledge of local resource conditions and issues (review); (2) evaluation of the sensitivity of specific natural resources to climate change (rank); (3) development and implementation of adaptation strategies and tactics (resolve); and (4) monitoring of the effectiveness of adaptation options (observe), with adjustments as needed.

The development of climate change adaptation strategies and tactics is conducted in the third ("resolve") step. Adaptation **strategies** describe how adaptation options could be employed, but they are still broad and general in their application across ecosystems. **Tactics** are more specific adaptation responses and can provide prescriptive directions for actions to be applied on the ground. At the broadest level, climate change adaptation strategies can be differentiated into four types: (1) resistance, (2) resilience, (3) response, and (4) realignment strategies (Millar et al. 2007). The resistance strategy includes tactics that forestall impacts to protect highly valued resources. Resistance strategies are only a short-term solution but often describe the intensive and localized management of rare and isolated species (Heller and Zavaleta 2009). The resilience strategy includes tactics that improve the capacity of systems to return to desired conditions after disturbance. The response strategy employs tactics to facilitate transition of systems from current to new desired conditions. Finally, the realignment strategy uses restoration practices to ensure persistence of ecosystem processes and functions in a changing climate.

The Intermountain Adaptation Partnership (IAP) project incorporated all steps in the adaptation process. An initial kickoff meeting with leadership and managers from the U.S. Department of Agriculture Forest Service (USFS) Intermountain Region involved review of basic climate change information set in a local context. The initial meeting was followed by a vulnerability assessment process that evaluated potential effects of climate change on water and soils (Chapter 4), fish and aquatic habitat (Chapter 5), forest vegetation (Chapter 6), nonforest vegetation (Chapter 7), ecological disturbance (Chapter 8), terrestrial species (Chapter 9), outdoor recreation (Chapter 10), infrastructure (Chapter 11), cultural resources (Chapter 12), and ecosystem services (Chapter 13). Vulnerability assessments set the stage for hands-on development of adaptation options (the "resolve" step) by resource managers in a series of five workshops across the IAP region. Managers engaged in facilitated discussions and completed worksheets, adapted from Swanston and Janowiak (2012), identifying key climate change vulnerabilities and related adaptation strategies (overarching approaches for resource planning and management) and tactics (on-the-ground management actions). Participating land managers were encouraged to use the Climate Change Adaptation Library (http://adaptationpartners.org/library.php) for ideas on adaptation strategies and tactics, and to identify several types of strategies, including resilience, response, and realignment strategies. They also identified where tactics could be applied and opportunities for implementation of tactics, where applicable. This chapter describes adaptation strategies and tactics developed in the workshops for each of the 10 resource areas covered in the vulnerability assessment. This chapter covers only adaptation strategies and tactics considered high priority by resource managers and discussed in the workshops. It is thus not intended to be an exhaustive list of possible actions.

Adapting Water Resources Management to the Effects of Climate Change

Across the IAP region, lower snowpack and increased drought with changing climate are likely to lead to lower base flows, reduced soil moisture, wetland loss, riparian area reduction or loss, and more frequent and possibly severe wildfire (Luce and Holden 2009) (table 14.1). In response to these changes, managers identified four main adaptation strategies: (1) conserve water; (2) store water; (3) manage for highly functioning riparian areas, wetlands, and groundwater-dependent ecosystems; and (4) develop policies for water rights (table 14.1). Although these adaptation options may do little to alleviate some of the direct consequences of shifting precipitation, snowpack timing, and temperature changes for ecosystems during drought conditions (e.g.,Vose et al. 2016), they can affect downstream water availability and consequences of hydrological drought.

Lower soil moisture and low flows in late summer, combined with increasing demand for water with population growth, are expected to reduce water availability for aquatic resources, recreation, and municipal uses (Chapter 4). A key adaptation strategy is to improve water conservation (Water Resources and Climate Change Workgroup 2016). For example, identify feasible and effective water-saving tactics. Drought-tolerant plants can be used for landscaping (table 14.1). Livestock water improvements can be managed efficiently (e.g., cattle troughs and float valves). The benefit of water conservation can be communicated to public land user groups, and over the long term, increasing water conservation and reducing user expectations of water availability will help to ensure adequate water supply.

In principle, replacing snowpack storage with storage in constructed reservoirs to carry water over from winter into summer could benefit municipal water supplies and irrigators in locations with irrigated agriculture. However, the degree of potential benefit varies substantially with existing water right regulations, reservoir operating rules, snowpack sensitivity to temperature and precipitation, expectations for future precipitation, and the role and future of summer precipitation. The benefits of replacing snowpack storage with reservoir storage are based on the rationale that only timing is changing and total runoff volumes remain unchanged. If precipitation increases, temperature-induced changes could be compensated for in relatively cold regions (Luce et al. 2014). On the other hand, if precipitation decreases, total flow volume will be reduced, and it will be harder to fill reservoir storage because of other rights for water farther downstream that might not be fulfilled. Given the sizable financial and ecological costs of constructing dams and high-elevation reservoirs, coupled with the uncertainties around precipitation, a cost-benefit analysis is advised before considering dam construction.

Shifting dam operation is another possibility for increasing water storage. It would cost significantly less than constructing reservoirs but would require some investment in monitoring upstream snowpack, soil, and weather. Streamflow forecasting informs management decisions on the balance between water storage for irrigation and maintenance of storage capacity to buffer potential flooding (e.g., Wood and Lettenmaier 2006). The current state of snowpack is more beneficial than climate or weather forecasts for predicting runoff in basins with substantial snowmelt contributions (Wood et al. 2015). In addition to informing reservoir operation, improved runoff forecasting can be used to improve decisions for how to best use available water (Broad et al. 2007).

Reduced overall base flows (especially in summer) are expected to reduce riparian and wetland habitat and water storage. Managing for riparian, wetland, and groundwater-dependent ecosystem function can increase water storage and slow the release of water from the landscape (Peterson and Halofsky 2017). Specifically, ecosystem function can be improved through active or passive restoration and by designing infrastructure to accommodate changes in flows (table 14.1). Some adaptation strategies that could help to maintain and improve groundwater-dependent ecosystems (GDEs) include: decommissioning and improving road systems to increase interception of precipitation and local retention of water, improving grazing management practices, and maintaining more water at developed spring sites through improved engineering practices (e.g., float valves, diversion valves, pumps) (Peterson and Halofsky 2017). Promoting and establishing (where currently extirpated) American beaver populations, water storage in beaver dam complexes and ponds, and beaver-related overbank flow processes could also help increase water storage (Pollock et al. 2014, 2015). Common and scientific names for species mentioned in this chapter are given in Chapters 5, 6, and 8, and Appendix 3.

Vegetation management, such as mechanical treatments and prescribed fire, can be used to achieve vegetation density and composition that are optimum for water balance and healthy watersheds (table 14.1). Harvesting trees to increase water yield has been a practice of interest for some time (e.g., Bates and Henry 1928). In general, removing trees increases water yields, since trees are major consumers of water on the landscape (Brown et al. 2005; Jones and Post 2004; Troendle and King 1987; Troendle et al. 2010) but comes with certain caveats. For example, increases in water yield are generally greater in moister environments or years, with lower increases in drier locations or years (e.g., Brown et al. 2005). In some circumstances in drier climates, canopy removal will reduce water yields because of increased growth of understory plants and increasing solar radiation reaching the soil surface (Adams et al. 2011; Guardiola-Claramonte et al. 2011). Overall, areas where increases in water yield are desired are the same areas in which forest harvest is least effective (Troendle et al. 2010; Vose et al. 2012). Thinning treatments have proven ineffective for

Table 14.1—Water resources adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Increased drought will lead to lower base flows, higher tree mortality, lower rangeland productivity, loss of habitat, lower soil moisture, wetland loss, riparian area reduction or loss, and more frequent and possibly more severe wildfire			
Adaptation strategy/approach: Conserve water			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Promote xeriscape facilities	Provide conservation education	Better manage livestock water improvements
Where can tactics be applied?	Administrative facilities; campgrounds	In public outreach; communities; Forest websites; kiosks; local environmental programs; Smokey Bear messages	Cattle troughs; float valves; in groundwater-dependent ecosystems (developed and undeveloped)
Adaptation strategy/approach: Store water			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Manage special-use dams on high-elevation mountain lakes; manage proposals for reservoir construction and additions	Conduct vegetation management (e.g., mechanical treatments, prescribed fire, and wildland fire use) to develop appropriate vegetation density and composition for optimal water balance and healthy watersheds (e.g., aspen/conifer and water yield)	Conduct meadow restoration and promote healthy, active beaver colonies
Where can tactics be applied?	Existing facilities; water storage structures	Prioritize watersheds where fire suppression or management has altered vegetation density and composition (e.g., where conifers have replaced aspen); identify areas where wildland fire use could be an appropriate tactic	Existing meadow locations; impacted riparian areas; where there is sufficient habitat for beaver and they will not interfere with infrastructure
Adaptation strategy/approach: Develop policies for water rights			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Develop policies regarding ski-area water rights	Develop policies regarding livestock management water use and water rights	Develop policies regarding ecosystem values and services (e.g., instream use)
Where can tactics be applied?	Ski areas	Grazing allotments	National Forest lands and adjacent lands
Sensitivity to climatic variability and change: Changes in type and amount of precipitation, leading to changes in timing of water availability			
Adaptation strategy/approach: Manage for highly functioning riparian areas that can absorb and slowly release the flow of water off the landscape			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Preserve riparian area functionality through terms and conditions of permitted activities (e.g., grazing), and utilize best management practices for Federal actions	Implement active stream channel and riparian area restoration (e.g., natural channel design, log structures, reconnecting floodplains), or passive restoration (e.g., appropriate management of beaver populations, reduction or removal of activities that are detrimental to riparian function)	Design new infrastructure and rebuild existing infrastructure to accommodate flooding (e.g., place or relocate infrastructure outside of riparian areas; design stream crossings to minimize restriction of flow above bankfull depth; and minimize impervious surfaces)
Where can tactics be applied?	In permits	In degraded riparian ecosystems	Everywhere

increasing water yields in the long term (Lesch and Scott 1997; Wilm and Dunford 1948), but thinning treatments can be useful in augmenting snow accumulation depths, for wildlife or recreational benefit (Sankey et al. 2015; Wilm 1944).

Canopy removal for streamflow augmentation is not always beneficial. Canopy reduction treatments may lead to advanced timing of runoff (Luce et al. 2012). An example of large-scale canopy loss in an area with vegetation and climate similar to the IAP region is the Boise River Basin, where about 45 percent of one basin burned while the other was left relatively unchanged after 46 years of calibration. This allowed for detection of a 5 percent increase in water yield from the 494,211-acre burned basin, providing an average of an additional 50,000 acre-feet of water storage each year. However, the average timing of release advanced by 2 weeks because the exposed snowpack melted faster, and most of the additional runoff was available prior to April, when it would be of little use in bolstering low flows. Large-scale canopy treatments can also affect water quality, for example by warming stream temperatures (Isaak et al. 2010) or increasing sediment from additional road construction and use (Black et al. 2012; Luce and Black 1999).

A comprehensive summary of strategies and tactics for adapting water resource management to the effects of climate change can be found in Appendix 4.

Adapting Soils Management to the Effects of Climate Change

Though there has been a focus on forest soils management to increase carbon storage to mitigate climate change (e.g., Malmsheimer et al. 2008), little information is available on adapting management to maintain soil resistance and resilience to climate change. Changes in soils will take time, but unfortunately, they cannot be restored easily or quickly. Proactive, preventive methods are needed to increase the resistance and resilience of soils to climate change effects. Maintaining and protecting soil cover (both canopy and ground cover) and cryptobiotic crusts are critical to mitigating heating of the soil surface and reducing evaporation and runoff (table 14.2). Utilizing grazing management systems that promote healthy root systems in plants can help them to survive short-term weather events, such as periods of drought and temperature increases, and can protect soils. Other tactics that help to increase soil resilience include promoting native plant species and plant diversity, limiting establishment and expansion of invasive plants that disturb soil processes, and restoring degraded systems. Managers may also want to consider soil climate vulnerability mapping at various scales to categorize soils for their resilience to climate change (table 14.2).

Adapting Fisheries and Aquatic Habitat Management to the Effects of Climate Change

Many options are available to facilitate climate change adaptation and improve the resilience of fish populations. Adaptation for fish conservation has been the subject of several comprehensive reviews (Beechie et al. 2013; Isaak et al. 2012; ISAB 2007; Luce et al. 2013; Mantua and Raymond 2014; Rieman and Isaak 2010; Williams et al. 2015). Resource managers used information from these reviews and a vulnerability assessment for aquatic organisms (Chapter 5) to develop adaptation strategies and tactics for aquatic organisms in the IAP region (table 14.3). Strategies focused on increasing resilience of native fish species by restoring structure and function of streams, riparian areas, and wetlands; monitoring for invasive species and eliminating or controlling invasive populations; understanding and managing for community-level patterns and processes; and conducting biodiversity surveys to describe current baseline conditions and manage changes in fish distribution.

To increase resilience of native fish species and habitats, specific tactics include reconnecting floodplains and side channels to improve hyporheic and base flow conditions, ensuring that passage for aquatic organisms is effective, and maintaining large wood in forested riparian areas for shade and recruitment to streams (Peterson and Halofsky 2017). Accelerating restoration in riparian areas and meadows may be an effective and lasting way to improve hydrological function and water retention. Prioritizing watershed restoration is critical because funds, labor, and time for management of native fish populations are limited (Peterson et al. 2013). Maintaining or restoring American beaver populations provides a "natural" engineering alternative for water retention (Pollock et al. 2014, 2015). Managers may consider augmenting snowpack with snow fences, such as on the Wasatch Plateau, to increase late summer flows.

In stream systems adjacent to grasslands and shrublands, livestock grazing can damage aquatic habitat, causing stress that may be exacerbated by warmer stream temperatures (Peterson and Halofsky 2017). An important adaptation approach is to manage livestock grazing to restore ecological function of riparian vegetation and maintain streambank conditions. Specifically, managers can work to ensure that standards and guidelines for water quality are adhered to and monitored; alter the duration, timing, and intensity of grazing to improve streambank vegetative conditions; and make improvements that benefit water quality (e.g., offsite watering, fencing).

Interactions with nonnative fish species and other aquatic organisms are a significant stress for native cold-water fish species, and brook trout are a particular concern in the IAP region (Chapter 5). Removal of nonnative fish species, although challenging in some locations, may be the best option for maintaining or restoring native fish populations.

Table 14.2—Soils adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Climate change will result in changes in soil temperature and soil moisture, thus affecting soil processes				
Adaptation strategy/approach: Increase soil resistance and resilience to climate change				
	Specific tactic – A	**Specific Tactic – B**	**Specific tactic – C**	**Specific tactic – D**
Tactic	Maintain or increase soil cover to mitigate heating of the soil and reduce carbon loss, evaporation, and runoff	Categorize soils for their resilience to climate change through completion of soil climate vulnerability mapping at various scales	Utilize grazing management systems that can respond quickly to short term periods of drought and temperature increases	Promote native plant species and plant diversity that is adapted to the projected soil properties
Where can tactics be applied?		National Forest plan revisions and individual project implementation assessments		
	Specific tactic – E	**Specific tactic – F**	**Specific tactic – G**	**Specific tactic – H**
Tactic	Maintain and protect soil cover (canopy and ground cover); manage to maintain or restore biological soil crusts where they are ecologically appropriate	Promote the maintenance and the addition of soil organic matter	Promote native vegetation and minimize the expansion of invasive species	Focus restoration efforts on areas that can support management objectives
Where can tactics be applied?	National, Regional and Forest level planning and guidance; project design; national best management practices	National, Regional and Forest level planning and guidance; project design; national best management practices	National, Regional and Forest level planning and guidance; project design; national best management practices	

Table 14.3—Aquatic organisms adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Warmer stream temperatures may favor nonnative species			
Adaptation strategy/approach: Increase resilience of native fish species			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Manage livestock grazing to restore ecological function of riparian vegetation and maintain vegetated streambank conditions	Maintain large wood in forested riparian areas for shade and wood recruitment to streams; reconnect floodplains and side channels to improve hyporheic and baseflow conditions; conduct meadow restoration; augment snowpack with snow fences on the Wasatch Plateau to increase late summer flows	Reduce habitat fragmentation of native trout habitat through barrier removal (e.g., culverts and water diversions); restore native trout to high elevation, cold water refugia
Where can tactics be applied?	All perennial and intermittent streams and wetlands	All perennial and intermittent streams and wetlands	Prioritize areas based on site-specific conditions
Adaptation strategy/approach: Monitor for invasive species and suppress/eliminate/control populations			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Conduct environmental DNA (eDNA) monitoring for early detection of invasions	Reduce or suppress brook trout populations	Maintain or construct barriers to prevent spread of non-native species in headwaters
Where can tactics be applied?	High-value populations that are thought to be at significant risk of invasion	Headwater lakes that act as source populations; small, isolated streams where complete eradication is possible.	Southern portions of IAP region where stream habitats are smaller and more fragmented

Table 14.3 (continued)—Aquatic organisms adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Climate change will lead to shifts in native species distributions and community reorganization			
Adaptation strategy/approach: Conduct biodiversity surveys to describe current baseline conditions and manage distribution shifts			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Formalize, expand and standardize biological monitoring programs (e.g., management indicator species)	Use modern, low-cost technologies like eDNA, DNA barcoding, and digital photo points	Use assisted migration to establish populations in suitable but currently unoccupied habitats
Where can tactics be applied?	Streams, rivers, and lakes throughout the IAP region	Streams, rivers, and lakes throughout the IAP region	Consider habitats outside of historical range (e.g., northern extent of species distributions) in addition to historical range
	Specific tactic – D	**Specific tactic – E**	**Specific tactic – F**
Tactic	Use digital technology in data collection and database uploads	Streamline and integrate field crew data collection protocols	Fully utilize existing corporate databases and legacy datasets
Where can tactics be applied?	Everywhere	Everywhere	Everywhere
Sensitivity to climatic variability and change: Climate change may lead to loss of biodiversity and exceeding ecological type thresholds (because of changes in connectivity, temperature, and water quantity)			
Adaptation strategy/approach: Understand and manage for community level patterns and processes			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Utilize the best available technology to monitor, record, and distribute information regarding the distribution of a broad array of aquatic species (e.g., use eDNA, national databases)	Develop and improve understanding, adaptive actions, and models related to non-game aquatic species (e.g., mussels, dace, sculpin, spring snails, and amphibians)	Continue to refine and improve understanding, adaptive actions, and models related to cold water salmonids
Where can tactics be applied?			

Environmental DNA (eDNA) monitoring can be useful for early detection of invasive species (table 14.3). To increase resilience of native species, maintaining or increasing habitat connectivity will be important to maintain access to summer cold-water refugia (Isaak et al. 2012). In some situations, however, improving habitat connectivity may present a dilemma, because newly accessible waters can be invaded by nonnative fish species that can extirpate native species (Fausch et al. 2009). In some cases, barriers can be installed to prevent nonnative species invasions. Native populations above barriers may be secure but could be susceptible to loss from extreme disturbance events in limited habitats, requiring human intervention to reestablish or supplement populations.

In a warmer climate, it is almost certain that increased wildfire occurrence will contribute to erosion and sediment delivery to streams, thus reducing water quality for fisheries (Luce et al. 2012). Increasing resilience of vegetation to wildfire may reduce the frequency and severity of fires when they occur. Hazardous fuels treatments that reduce forest stand densities and surface fuels are an adaptation tactic that is already widely used in dry forest ecosystems (Halofsky and Peterson 2016). Disconnecting roads from stream networks is especially important because roads are a major source of sediment delivery to streams (Luce et al. 2012). Finally, erosion control measures can reduce postfire sediment delivery and are often a component of Burned Area Emergency Response (commonly known as "BAER") on Federal lands.

Management actions in a changing climate will be more effective when informed by baseline surveys and long-term monitoring (Isaak et al. 2016). More data are needed for streamflow (more sites), stream temperature (annual data from sensors maintained over many years), and distributions of aquatic organisms. These data can be used for improved status-and-trend descriptions and to develop robust (more accurate and precise) models for species to understand the interactions of climate change, natural variation, and land management on aquatic species. The NorWeST stream temperature database (described in Chapter 5) could provide information for monitoring network design. The feasibility of monitoring at small to broad scales is increasing with the advent of rapid, reliable eDNA inventories of aquatic organisms (Thomsen et al. 2012) and the availability of inexpensive, reliable temperature and flow sensors (USEPA 2014).

A comprehensive summary of strategies and tactics for adapting fisheries and aquatic habitat management to the effects of climate change can be found in Appendix 5.

Adapting Forest Vegetation Management to the Effects of Climate Change

In the IAP region, wildfire exclusion, combined with extensive even-aged timber management and other land uses, has resulted in dry forests at risk to wildfire, insects, and disease (Schoennagel et al. 2004). As in other adaptation efforts (Halofsky and Peterson 2016; Peterson and Halofsky 2017), many tactics developed by IAP managers were focused on increasing resilience of forests to disturbance, mainly fire (table 14.4). Thinning and prescribed fire can both be used to reduce forest density and promote drought- and disturbance-resilient species, such as western larch. Promoting landscape diversity, in terms of species, age classes, and structure, is also likely to increase forest resilience to wildfire, insects, and disease (Janowiak et al. 2014). Promoting legacy trees of disturbance-resilient species may help to increase postfire regeneration. Managers may also want to increase seed collection and ensure that adequate nursery stock is available for postdisturbance planting (e.g., serotinous lodgepole pine) (Halofsky and Peterson 2016). Better understanding of potential disturbance regimes of the future and potential thresholds will help managers to better assist in ecosystem transition (Janowiak et al. 2014). With larger fires in the future, it will also be increasingly important for agencies to coordinate and work across boundaries to manage and suppress fire (Spies et al. 2010).

The area of alpine and subalpine vegetation will probably decrease in the IAP region, and frequency of drought and fire is likely to increase in subalpine forests (Chapter 6). Development of a consistent monitoring framework that can capture ecosystem changes with shifting climate is a key adaptation approach (Halofsky and Peterson 2016). For example, tracking tree species regeneration and distribution will help managers to determine how species are responding to climatic changes and how to adjust management accordingly (e.g., guidelines for planting). For species that are currently stressed, such as spruce and fir species in the subalpine zone, seed collection, regeneration treatments, and planting may be necessary to ensure their persistence on the landscape.

Climate change will probably accelerate whitebark pine mortality through increased mountain pine beetle activity, fire, and white pine blister rust (Chapter 8). There is also likely to be a loss of site conditions that support whitebark pine (Chapter 6). To promote resilient whitebark pine communities, managers may want to focus restoration efforts on sites less likely to be affected by climate change (i.e., refugia). A variety of management strategies can be implemented to promote whitebark pine, including fire management with fuelbreaks, removing competing species (e.g., subalpine fir), and increasing structural and age-class diversity of whitebark pine communities (Keane et al. 2017). Genetically selected seedlings can be planted to promote

Table 14.4—Forested vegetation adaptation options for the Intermountain Adaptation Partnership Region.

Sensitivity to climatic variability and change: Increased disturbance with climate change will affect patterns, structure, and species composition at large spatial scales			
Adaptation strategy/approach: Create landscape patterns that are resilient to past and expected disturbance regimes			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Continue research on expected future disturbance regimes; evaluate potential transitions and thresholds	Improve communication across boundaries	Manage for diversity of structure and patch size with fire and mechanical treatments
Where can tactics be applied?	Local, Regional, and National scales	Internally and externally (with partners)	Watershed(s)
Sensitivity to climatic variability and change: Lack of disturbance has caused shifts in species composition and structure in dry mixed-conifer forests, putting them at risk of high-severity fire with climate change			
Adaptation strategy/approach: Maintain and restore species and age-class diversity			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Identify and map highest risk areas at large spatial sales to provide context for prioritization	Reduce stand density and shift composition toward species that are more fire adaptive and drought tolerant	Restore age class diversity while protecting legacy trees
Where can tactics be applied?	All lands	Prioritize highest risk stands in terms of fire, insects, and disease	Prioritize highest risk stands in terms of fire, insects, and disease that currently contain a component of legacy trees
Sensitivity to climatic variability and change: Western larch habitat and regeneration may be reduced with climate change			
Adaptation strategy/approach: Increase the competitive ability of western larch and its resilience to changing fire regimes			
	Specific tactic – A	**Specific tactic – B**	
Tactic	Create gaps in forests to reduce competition and increase larch vigor	Regenerate larch with appropriate site preparation (e.g., prescribed burning, followed by planting); create appropriate fire regimes and fuel loads	
Where can tactics be applied?	Stands with larch	Habitats that can support larch	
Sensitivity to climatic variability and change: Climate change may lead to an incursion of upper treeline into alpine communities			
Adaptation strategy/approach: Acquire information to develop a better understanding of high-elevation system sensitivity to climate change			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Establish monitoring sites	Develop seed transfer guidelines.	Develop seed collection and storage guidelines
Where can tactics be applied?	Research natural areas	Research natural areas	

Sensitivity to climatic variability and change: Climate change may lead to a reduced spruce-fir component in subalpine spruce-fir forests, which will be exacerbated by ongoing spruce beetle outbreaks that have reduced available seed sources			
Adaptation strategy/approach: Maintain species and age class diversity in subalpine spruce-fir forests			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Conduct regeneration treatments (e.g., harvest, prescribed fire) that focus on maintaining species diversity; plant a variety of species, including Engelmann spruce, Douglas-fir and lodgepole pine	Collect seed that will cover a wide range of seed zones and species	Plant a genetically diverse mix based on adaptive traits
Where can tactics be applied?	Forest and adjacent lands	Forest and adjacent lands	Forest and adjacent lands
Sensitivity to climatic variability and change: Large-scale disturbance with climate change will affect landscape structural diversity of persistent lodgepole pine and available seeds sources			
Adaptation strategy/approach: Maintain landscape heterogeneity to mitigate adverse impacts on lodgepole pine from fire and mountain pine beetles			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Promote structural diversity at multiple scales	Focus attention on collection of viable serotinous lodgepole pine seed sources	Use available mapping products to identify areas of potential serotinous lodgepole pine seed sources
Where can tactics be applied?	Homogeneous landscapes	From serotinous lodgepole pine cones that cover a wide range of elevation bands on forest and adjacent lands	Forest and adjacent landowners
Sensitivity to climatic variability and change: Large-scale disturbances with climate change (e.g., beetles, fire, white pine blister rust) will negatively affect whitebark pine			
Adaptation strategy/approach: Increase the competitive ability and resilience of whitebark pine to changing disturbance regimes			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Control beetles (use Verbenone after snowmelt)	Daylight (thin) to reduce competition (usually involves removing subalpine fir)	Regenerate rust-resistant strains; increase seed sources; maintain cache sites
Where can tactics be applied?	Protect trees in high-value areas; important in central Idaho and the Greater Yellowstone Area	Implement in accessible areas and high value areas (best rust resistant areas and areas of high habitat and recreation value)	Areas of disturbance, or areas with low resistance; maintain density for Clark's nutcracker
	Specific tactic – D	**Specific tactic – E**	**Specific tactic – F**
Tactic	Create fuel breaks in locations adjacent to subalpine fir or other lethal fire regime areas	Improve structural and age class diversity of whitebark communities at multiple scales	Restore sites where the species is currently absent
Where can tactics be applied?	In accessible and high value areas	Whitebark pine communities dominated by late successional conifer species	Sites that have present and future potential to support whitebark pine

Table 14.4(continued)—Forested vegetation adaptation options for the Intermountain Adaptation Partnership Region.

Sensitivity to climatic variability and change: Direct and indirect effects of climate change will reduce the capacity for aspen stand regeneration			
Adaptation strategy/approach: Increase the capacity for aspen stand regeneration			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Increase the proportion of the landscape that is in early successional stages	Maximize flexibility in managing herbivory	Maximize genetic diversity
Where can tactics be applied?	Landscapes with high proportion of later-seral aspen in mixed-conifer forest	Focus on sites with good aspen site potential	On landscapes following severe fire
Sensitivity to climatic variability and change: Climate change may lead to reduced water availability on the fringe of persistent aspen communities.			
Adaptation strategy/approach: Focus treatments on areas where persistent aspen communities are expected to expand and maintain communities where future climatic conditions will allow			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Remove competing vegetation (e.g., juniper) and control ungulate browsing to allow for recruitment	Reduce density of conifer species	Use available mapping products to identify areas of potential expansion
Where can tactics be applied?	On existing fringe persistent aspen communities	Outside of existing stands where persistent aspen is expected to expand	Areas adjacent to existing persistent aspen
Sensitivity to climatic variability and change: Climate change will lead to shifts in hydrologic regime, altering the timing and magnitude of flows. Anticipated changes include lower summer flows, higher winter flows, and a potential decrease in riparian vegetation abundance			
Adaptation strategy/approach: Maintain and promote riparian area and wetland processes and functions.			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Manage upland vegetation that influences riparian and wetland function and process (e.g., with thinning and prescribed fire)	Restore riparian obligate species	Promote stream channel function
Where can tactics be applied?	Adjacent to riparian vegetation, where conditions do not optimize or promote riparian function and process; where conifers are encroaching in meadows and grasslands	Where upland, invasive or undesirable species are outcompeting natives; locations that have been inappropriately managed in the past	Where stream function is impaired; prioritize treatments where they are most likely to be effective

blister rust resistance. Managers may want to control beetle outbreaks in whitebark pine with Verbenone, particularly in high-value areas.

Recent decline has made quaking aspen a species of concern in the IAP region (Chapter 7), particularly because of its value as wildlife habitat (see the *Adapting Terrestrial Animal Management to the Effects of Climate Change* section below). Direct and indirect effects of future climate change may further stress this species. In older aspen stands, increasing the early-seral component may help to increase resilience. On sites with good aspen potential, managing herbivory by wildlife and livestock will help to ensure aspen regeneration and stand development (Rogers and Mittanck 2014). Removing competing vegetation, such as juniper and other conifers, is likely to help to increase aspen vigor and regeneration. Following fire, maximizing genetic diversity will help to ensure future persistence of aspen (DeRose et al. 2014).

Key climate change vulnerabilities for riparian areas and GDEs include shifts in the hydrological regime (changes in timing and magnitude of flows, lower summer flows) and changing biotic productivity and diversity in springs and wetlands. Maintaining or restoring stream channel form helps to increase hydrological function and store water, thereby benefiting riparian and wetland vegetation, water quality, and aquatic habitat (Peterson and Halofsky 2017). Restoring and protecting riparian vegetation by managing livestock, wild horse and burro, and recreational use similarly helps to protect aquatic habitat and water quality by increasing water storage and providing shade to streams (Peterson and Halofsky 2017). In areas where upland, invasive, or undesirable species are outcompeting native species, restoring riparian and wetland obligate species may help to restore ecological function. Riparian zones will probably burn more frequently with warming climate, and thus managers may want to manage upland vegetation to reduce impacts in riparian areas (Luce et al. 2012). In some riparian areas, managers may want to reintroduce fire to help facilitate the transition to future conditions.

A comprehensive summary of strategies and tactics for adapting forest vegetation management to the effects of climate change can be found in Appendix 6.

Adapting Nonforest Vegetation Management to the Effects of Climate Change

Nonforest vegetation in the IAP region will almost certainly be affected by altered fire regimes, increased drought, and increased establishment of invasive species in a changing climate (Chapter 7). Effects of climate change will also compound existing stressors in nonforest ecosystems caused by human activities (Chapter 7). Thus, adaptation options for nonforest vegetation focus on increasing the resilience of rangeland ecosystems, including sagebrush and persistent pinyon-juniper ecosystems (table 14.5).

To control invasive species in rangelands, managers suggested minimizing spread and using biological controls, herbicides, and mechanical treatments (table 14.5). It may be particularly important to protect refugia, or areas that have not been invaded, and make sure that invasive species do not become established. Proactive management tactics such as early detection and rapid response can be used for new invasions (Reeves et al. 2017). Conducting outreach to educate employees and the public about invasive species and increasing collaboration among landowners and managers will also be necessary to effectively control invasive species (Hellmann et al. 2008).

In addition to invasive species control and prevention, grazing management will be important in maintaining and increasing resilience of nonforest vegetation to climate change. Climatic changes will lead to altered availability of forage and water, requiring some reconsideration of grazing strategies; flexible and perhaps novel grazing management plans may be necessary (Reeves et al. 2017). For example, altering the timing of use from year to year may help encourage recovery of all species by avoiding stress at the same period of growth (or dormancy) every year. Adapting grazing management may be particularly effective in allotments where soils and hydrology will support future sagebrush ecosystems in a warming climate (table 14.5).

To maintain native perennial species in sagebrush ecosystems, native seed sources adapted to future climatic conditions can be used for planting and restoration, fuelbreaks and fencing can be used for protection, and modified grazing strategies can be used to allow for flexibility in season of use (Reeves et al. 2017). Developing modified seed zones and promoting propagation of native seed sources for sagebrush ecosystems will help to ensure the success of restoration efforts. In sagebrush ecosystems where pinyon pine and juniper have encroached, active management (removal) is likely to help increase sagebrush resilience (Creutzburg et al. 2014). Given limited budgets, managers will need to prioritize areas for treatments where they will get the most return on investment (table 14.5).

A comprehensive summary of strategies and tactics for adapting nonforest vegetation management to the effects of climate change can be found in Appendix 7.

Adapting to the Effects of Ecological Disturbances in a Changing Climate

The frequency and extent of wildfire are likely to increase with warming in many dry forest and shrubland ecosystems of the IAP region (Littell et al. 2009). Increased fire activity was identified during the workshops as a primary concern for resource managers in the IAP because of the potential negative effects on species, ecosystems, and

Table 14.5—Non-forested vegetation adaptation options for the Intermountain Adaptation Partnership Region.

Sensitivity to climatic variability and change: Climate change may lead to further loss of sagebrush ecosystems (Wyoming, mountain, basin big sagebrush species)			
Adaptation strategy/approach: Improve resilience and resistance of sagebrush ecosystems			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Control invasive species affecting ecology of sagebrush ecosystems by minimizing spread and using biological controls, herbicides, and mechanical treatments	Maintain native perennials by: utilizing native seed sources for restoration (planting) that will be adapted to future climate conditions; using fuel breaks and fencing for protection; modifying grazing strategies to allow for flexibility in season of use	Map resilience and resistance to climate change to aid in prioritizing areas for treatments
Where can tactics be applied?	Prioritize and implement in areas with high probability of treatment success and in areas of high value	Prioritize and implement in areas with high probability of treatment success and in areas of high value	Across all areas using soil, vegetation and existing information; utilize sagebrush resilience and resistance rating criteria
	Specific tactic – D	**Specific tactic – E**	**Specific tactic – F**
Tactic	Develop seed zones and promote propagation of native seed sources for sagebrush ecosystems	Adapt grazing management to changing climates and ecological potential	Protect refugia; if annuals grasses are not present, keep them out through: repeat monitoring (of experiments with controls); education; seed collection; and genetic analysis
Where can tactics be applied?	Region-wide seed zone mapping	Allotments where soils and hydrology support future sagebrush ecosystems in a warming climate	
	Specific tactic – G	**Specific tactic – H**	**Specific tactic – I**
Tactic	Actively manage pinyon-juniper encroachment to maintain sagebrush ecosystems	Adapt grazing management practices and policies to improve ecological resilience and resistance	Protect existing sagebrush communities from fire
Where can tactics be applied?	Phase 1 and 2 pinyon-juniper communities	All grazing allotments	Areas where dry sagebrush plant communities exist and have long fire return intervals
Sensitivity to climatic variability and change: Climate change may lead to a loss of climatically suitable habitat for persistent pinyon-juniper ecosystems			
Adaptation strategy/approach: Maintain and restore ecological integrity of persistent pinyon-juniper communities			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Identify and map persistent pinyon-juniper communities and assess current conditions	Reduce invasive species; maintain or restore native understory composition	Maintain or restore structural diversity to promote natural disturbance regimes
Where can tactics be applied?	All lands	At-risk persistent communities	At-risk persistent communities

ecosystem services. Managers recommended that fuels treatments be conducted in strategic locations with the goal of protecting the wildland-urban interface and other high-value resources (table 14.6). Effective fire management requires better communication that helps clarify what actions need to occur and in what locations. For example, fire managers need to know when it is acceptable for a fire to cross administrative boundaries (e.g., move from USFS to Bureau of Land Management lands). As noted previously, with larger fires in the future, it will be increasingly important for agencies to coordinate and work across boundaries to both manage (e.g., fire for resource benefit) and suppress fire (Spies et al. 2010).

After fires occur, managers will need to identify, prioritize, and protect values at risk from postfire events such as flooding, erosion, and drought (e.g., soil, water, infrastructure, and vegetation) (table 14.6) (Luce et al. 2012). Programs could be initiated to assess values and determine the best protective actions to prevent negative impacts on species and ecosystems. Proactive, strategic plans for postfire response and restoration would make postfire management more efficient and effective over the long term. Postfire management would also benefit from increased collaboration among agencies.

Native insect species have long played a role in ecosystem dynamics in the IAP (Chapter 8), and it will be important to recognize the role of insects and accept that there will be insect-caused tree mortality under changing climate. However, there are some management actions that may increase ecosystem resilience to native insect outbreaks, such as mountain pine beetle outbreaks. For example, restoring historical fire regimes in dry forests, and increasing diversity of forest structure and age and size classes may help to minimize the impacts of insect outbreaks (Churchill et al. 2013). Increasing tree species diversity may also help to improve resilience to insect outbreaks (Dymond et al. 2014), particularly in low-diversity stands. In high-value areas, tactics such as beetle traps, spraying, and pheromones can be used to control beetles (table 14.6).

To manage invasive insect outbreaks, a first step is to identify nonnative invasive insects currently in the region (e.g., balsam woolly adelgid), monitor them, and consider potential future distribution. Monitoring could also be done for other invasive insects that are not currently present in the region, but that may be a future risk (e.g., spruce aphid, spruce-fir looper). Development of an integrated pest management strategy would help guide strategic monitoring and response to invasive insect outbreaks.

Human activities can also be considered a type of ecosystem disturbance, and climate change may exacerbate stresses to ecosystems and infrastructure caused by more people residing in the forest environment (table 14.6). To mitigate human impacts on ecosystems, managers can work to minimize increases in area of human disturbance and minimize adverse effects of infrastructure (roads, driveways, power lines, water delivery) on National Forest lands. Increasing ecological connectivity and habitat continuity and viability will also help plants and animals adjust to human disturbance and climate change effects (Mawdsley et al. 2009).

A comprehensive summary of strategies and tactics for adapting to the effects of increased disturbance with climate change can be found in Appendix 8.

Adapting Terrestrial Animal Management to the Effects of Climate Change

Effects of climate change on terrestrial animals (wildlife) may already be recognized as threats (e.g., loss of wetlands or old-growth forest) or may point toward novel impacts (e.g., effects of earlier snowmelt). Exacerbation of current threats may require intensified conservation efforts, while threats unique to climate change will require innovative strategies (Bagne et al. 2014). The key to finding effective management actions is to identify the factors responsible for how a species may be vulnerable or resilient. In addition to enhancing single species management, a list of species and their vulnerabilities can make efforts more efficient by identifying common issues among species.

Increased water stress is likely to be a common issue among many animal species in the IAP region in a changing climate (table 14.7) (Chapter 9). Increasing temperatures and changing hydrology will affect riparian areas and, in particular, wetlands. Riparian and wetland habitats are important for many wildlife species across the IAP region (Chapter 9). The primary strategy for improving riparian habitat resilience is to restore or preserve floodplain connectivity appropriate to the landscape setting to promote retention of flood flows and improved storage of groundwater; maintaining healthy American beaver populations is one of several ways that this can be accomplished (Pollock et al. 2014, 2015). Beaver complexes can buffer riparian systems against both low and high streamflows, and provide habitat structure and foraging opportunities for multiple species. As described previously, increasing hydrological function and minimizing stressors (e.g., unmanaged or mismanaged livestock grazing and recreational use) to riparian and wetland systems will help to increase their resilience, and the resilience of species that depend on them, to climate change (Peterson and Halofsky 2017). Promoting connectivity of riparian habitat conditions along stream networks can also help to provide for animal movement and range shifts (Mawdsley et al. 2009).

Removal or control of invasive plants or animals is another strategy that is likely to increase resilience of plant communities and wildlife that depend on them. Climate change may present more opportunities for establishment of invasive species. However, control of invasive species may be more successful when they are stressed by climate extremes (Higgins and Wilde 2005; Rahel and Olden 2008).

Table 14.6—Ecological disturbance adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Wildfires will increase with warmer and drier conditions under changing climate			
Adaptation strategy/approach: Reduce the adverse effects of fire in the wildland-urban interface (WUI) and other non-negotiable values while allowing fire to play a natural role on the landscape			
	Specific tactic – A	**Specific tactic – B**	
Tactic	Strategically place fuel treatments to manage for wildfire in an ecologically appropriate way depending on vegetation types; some treatments may be out of natural range of variation to protect values	Develop communications strategy to determine what needs to happen and where before fires occur (e.g., need to know when it is acceptable to let fires cross boundaries and when it is not); all partners need to be involved	
Where can tactics be applied?	In the WUI and other strategic locations; consider management boundaries (wilderness), topography, dominant winds	Needs to be an "all lands" approach: counties, states, residents, Bureau of Land Management, National Park Service, etc.; for the Forest Service, both Forests and Districts need to be involved	
Adaptation strategy/approach: Conduct post-fire restoration and manage post-disturbance response			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Identify, prioritize and protect values at risk; initiate programs to assess values and determine best protective actions	Conduct pre-fire planning to improve response time and efficiency, prioritizing key areas at risk to geologic hazard	Conduct post-fire vegetation management and prevent invasives with weed control and monitoring
Where can tactics be applied?	Needs to be done at Forest level, as it will be dictated by local needs; focus on areas threatening public health and safety	Needs to be an "all lands" approach; for Forest Service, both Forests and Districts need to be involved	In key areas identified in pre-planning and Burned Area Emergency Response; monitor invasives in transition zones between ecotypes, south-facing slopes, along road corridors, and campgrounds
Adaptation strategy/approach: To protect values on the landscape, allow for more managed fire to reduce available fuel loadings			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Develop understanding or products that help managers and line officers make decisions on managing long duration fires; incorporate information learned into the Wildland Fire Decision Support System	Utilize a risk benefit model to identify key locations where fuels modifications would benefit the potential use of managed fire	Find opportunities to work with partners to expand use of natural fire ignitions (support network of collaborators); increase education to public on the role of fire on the landscape
Where can tactics be applied?	Anywhere on the landscape	All fire-prone landscapes	Lands adjacent to local communities

Table 14.6 (continued)—Ecological disturbance adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Climate change will likely result in increased mortality caused by native insects and diseases (bark beetles, defoliators, and dwarf mistletoes)			
Adaptation strategy/approach: Increase resistance and resilience to insects and disease in stands and landscapes			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Manage for age, size class, and species diversity	Protect high value areas with trap tree felling, beetle traps, spraying, reduced basal area, beetle risk rating, and pheromones	Protect and manage areas of special classification
Where can tactics be applied?	High value landscapes with low diversity; limited to where there is access	Areas of high value	Roadless areas, wilderness, and areas restricted to non-mechanical treatments
Sensitivity to climatic variability and change: Invasive insects may increase with changing climate			
Adaptation strategy/approach: Increase resilience and resistance of trees to invasive insects			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Develop an integrated pest management strategy, including identifying insect-resistant seed (balsam woolly adelgid)	Identify current and projected distribution of balsam woolly adelgid and other species	Identify and monitor other non-native, invasive insects (e.g., spruce aphid, spruce-fir looper) not currently present in the region but that may be a future risk
Where can tactics be applied?	In true fir communities and subalpine areas	In true fir communities; Region-wide; areas where loss of subalpine fir would be ecologically significant	Region-wide
Sensitivity to climatic variability and change: More people residing in the forest environment will increase stresses to ecosystems, infrastructure, and biological and physical resources; shifting of utilization of ecosystem services closer to the source			
Adaptation strategy/approach: Manage for the human disturbance footprint caused by higher populations of people living in forests and the forest interface			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Manage the effects of infrastructure (roads, driveways, powerlines, water delivery) on national forest lands	Minimize increases in areas of disturbance	Manage ecological connectivity and energy flow; maintain habitat continuity and viability
Where can tactics be applied?	Apply on roads and driveways and with collaborators responsible for the whole system (e.g., the power company, county transportation department, canal company)	In and around residential and other development	Maintain natural corridors (streams, riparian) where they exist; maintain large habitat blocks; maintain habitat diversity in appropriate proximities

Table 14.7—Terrestrial animal adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Vegetation and animals will be stressed because of reduced soil moisture with changes in timing and amount of precipitation, drought, and earlier snowmelt under changing climate			
Adaptation strategy/approach: Restore and enhance water resource function and distribution at the appropriate watershed level; prioritize watersheds based on condition and a variety of resource values, including terrestrial animals			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Improve management of existing seep and spring water developments, and design proposed developments for ecological appropriateness	Manage for maintenance of vegetative cover sufficient to retain snowpack within watersheds	Provide enhanced water distribution with appropriate wildlife use designs and balance water use with wildlife needs; protect headwaters, spring heads, riparian areas, etc.
Where can tactics be applied?	Any wasteful or redundant developments, or on sites causing unintended ecological consequences	Particularly within subalpine ecosystems, but also other areas targeted for vegetation management activities	Areas where there is concern about amphibian populations and other wildlife species dependent on water sources
	Specific tactic – D	**Specific tactic – E**	**Specific tactic – F**
Tactic	Reduce biomass to reduce evapotranspiration and mortality resulting from water stress for groundwater-fed systems (with thinning and other vegetation treatments) and maintain shade for non-groundwater fed systems	Increase water storage by managing for beaver populations using a comprehensive beaver strategy, and by reducing cattle impacts on small water sources	Actively restore and maintain functioning wetlands; manage grazing to promote riparian and wetland function
Where can tactics be applied?	Suggested scale of HUC 8 to 12 based on assessment for watershed prioritization	Riparian areas where conditions are appropriate (presence of aspen and willow) that will not result in conflict (culvert damage, flooding roads)	

Table 14.7 (continued)—Terrestrial animal adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Changing intensity and frequency of fire with climate change will decrease area and connectivity of some habitats, notably late-successional and mature forest and big sagebrush			
Adaptation strategy/approach: Maintain current habitat, restore historical habitat, promote potential future habitat, and increase resilience of these habitats			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Strategically place fuel breaks to minimize risk to important habitat areas	Restore disturbance regimes by reducing accumulated fuel loads; remove pinyon and juniper in sagebrush ecosystems; where there are fire deficits, allow wildfires to burn for resource benefit	Identify areas that will support late-successional and mature forests and big sagebrush in the future, and mange to promote their development and resilience
Where can tactics be applied?	On the windward side of important habitat areas; place in a configuration to minimize risk of fire spread across the landscape	Within the habitats where uncharacteristic fuel loads have developed; balance with other objectives for species dependent on a complex understory	Identify where disturbance regimes associated with your target habitat will shift, and focus restoration on those areas and connectivity to those areas
Sensitivity to climatic variability and change: Climate change may increase uncharacteristic fires in ponderosa pine that result in loss of late-seral forest and snags (affecting Lewis' woodpecker, Allen's big-eared bat, Abert's squirrel, northern goshawk, and Utah prairie dog)			
Adaptation strategy/approach: Maintain current habitat, restore historical structure, and increase mosaic structure (including snags).			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Conduct thinning and prescribed fire treatments; use thinning from below; maintain natural structure (diversity and density); control ladder fuels	Manage grazing to discourage overgrazing of native plants and to maintain fine fuels to carry fire	Plant adapted (locally-sourced) ponderosa pine
Where can tactics be applied?	Existing stands on public and private lands (although thinning is limited in roadless areas and wilderness)	Everywhere ponderosa pine occurs	In areas where stand-replacing fires have occurred, keeping in mind the capacity of the area to support ponderosa pine (soils and water considerations)

Table 14.7 (continued)—Terrestrial animal adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Climate change will likely lead to increased fire frequency, which may lead to loss of mixed-age aspen stands and loss of mature aspen and snags (affecting ruffed grouse, flammulated owl, goshawk, and many other species)			
Adaptation strategy/approach: Maintain/sustain/retain aspen and encourage recruitment to the overstory			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Remove conifers with prescribed fire and logging	Protect/encourage regeneration using fencing, ungulate management (reduce numbers and change season of use [graze early]), and development plans like that implemented by Wolf Creek Ranch (works closely with Wild Utah Project)	Conduct public outreach to help manage for aspen snags; restrict firewood cutting; target ranchette owners with information; include aspen in public education; use "this is a wildlife home" signs and similar tools
Where can tactics be applied?	Forest, state, and private lands that are with conifer encroachment	Anywhere	Schools, anywhere
Sensitivity to climatic variability and change: Climate change will lead to changes in alpine species composition (of both plants and animals, e.g., spruce-fir encroachment, rodents, humans) because of shrinking snowpack, changes in timing of snowmelt, and increasing temperatures that allow species to move up into alpine ecosystems (affecting pika, endemic plants, pollinators, and black rosy finch)			
Adaptation strategy/approach: Reduce additional stressors in alpine habitats			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Manage human access (e.g., build trails, harden sites, use permit systems or outfitter guides)	Maintain mountain goats at population levels that eliminate adverse impacts (remove goats if needed and discourage continued introduction of goats)	Monitor movement of plants (including both conifers and exotic weeds) and monitor movement of treeline
Where can tactics be applied?	Alpine trailheads; areas of high use (e.g., La Sals)	La Sals, Tushars, Mt. Dunton, Ashley	Everywhere habitat is present

Preventive and early intervention programs to control invasive species can be applied where range expansion is predicted (Davies and Johnson 2011). Targeting the vulnerabilities of undesirable species fits well with "no regrets" and "win-win" strategies of climate change adaptation (Bagne and Finch 2013; Peterson et al. 2011b).

Changing fire regimes are another climate stressor common to many species in the IAP region (Chapter 8). Changing intensity and frequency of fire with climate change are likely to decrease area and connectivity of some habitats, notably late-successional and mature forest and big sagebrush (Chmura et al. 2011). Fuels reduction and strategic placement of fuelbreaks could help to lower fire severity and protect valued habitats (Peterson et al. 2011a). In ponderosa pine forests, where there are currently high levels of fuel loading relative to historical conditions (Chapter 6), creating more open conditions with fewer trees may be desirable for long-term sustainability in areas where increased seasonal drought stress is anticipated. Diverse understory food plants and shrub patches are important components of this habitat, and minimizing grazing impacts and controlling invasive plants can help to maintain characteristic fuel patterns and understory diversity (table 14.7). In areas where stand-replacing fires have occurred, planting adapted (locally sourced) ponderosa pine is likely to enhance survival. A significant challenge will be promoting the development of large tree and open understory conditions in capable areas where large trees of fire-resilient species are not currently present (Stine et al. 2014).

Quaking aspen was identified as important because of its high productivity, role in structural diversity, and habitat for cavity-nesting birds. Ruffed grouse were also identified as strongly tied to aspen habitats. Reduction in the distribution and abundance of aspen is projected for some locations (especially lower elevation) in a warmer climate (Chapter 6). Tactics for promoting aspen resilience are use of prescribed fire and logging to remove conifers from aspen stands, protection from grazing, and public outreach on the importance of aspen for wildlife habitat (table 14.7).

In high-elevation alpine habitats, climate change will probably alter species composition of both plants and animals because of shrinking snowpack, changes in timing of snowmelt, and increasing temperatures that allow species to move into alpine ecosystems (Chapter 6). Minimizing new stressors on alpine ecosystems may help to increase their resilience. For example, mountain goat populations can be maintained at levels that eliminate adverse impacts. As snow-based recreation is concentrated in smaller areas, efforts to minimize human impacts may be needed. Identifying and protecting climate and disturbance refugia can help to maintain high-elevation habitats for wildlife (Morelli et al. 2016). Population monitoring can also be a useful tool when climate effects or management options are uncertain.

A comprehensive summary of strategies and tactics for adapting terrestrial animal and habitat management to the effects of climate change can be found in Appendix 9.

Adapting Outdoor Recreation Management to the Effects of Climate Change

Outdoor recreationists are highly adaptable to changing conditions (Hand and Lawson 2017). For example, water-based recreationists may adapt to climate change by choosing different sites that are less susceptible to changes in water levels (e.g., by seeking higher-elevation natural lakes) and changing the type of water-based recreation activity they engage in (e.g., from motorized boating on reservoirs to nonmotorized boating on natural lakes). Hunters may adapt by altering the timing and location of hunts or by targeting different species. Similarly, wildlife viewers may change the timing and location of viewing experiences and target different species. However, adaptation options for wildlife recreation may be limited if the abundance or distribution of highly valued species decreases the chance of viewing, and if substitute species are not available (Scott et al. 2007).

Management of recreation by Federal agencies may present considerable challenges under climate change (Hand and Lawson 2017). Managers may need to reconsider how infrastructure investments and the provisioning and maintenance of facilities align with changing ecological conditions and demands for recreation settings. The Recreation Opportunity Spectrum (Clark and Stankey 1979) can be used to match changing conditions and preferences to the allocation of available recreation opportunities. Adaptation by managers may take the form of responding to changing recreation patterns, but also helping to shape the settings and experiences that are available to recreation users on public lands in the future (Hand and Lawson 2017).

For winter recreation, a general adaptation strategy is to transition recreation management to address shorter winter recreation seasons and changing recreational use patterns. Specifically, opportunities may exist to expand facilities where concentrated use increases, and options for snow-based recreation can be diversified to include more snowmaking, additional ski lifts, and higher-elevation runs (Scott and McBoyle 2007). In some cases, however, adaptation actions related to the availability and quality of winter recreation opportunities could result in tradeoffs with other activities (e.g., warm-weather access to higher-elevation sites or effects of snowmaking on streamflow) (Hand and Lawson 2017).

With higher temperatures and earlier snowmelt, warm-weather activity seasons are likely to lengthen (Mendelsohn and Markowski 2004). Recreation managers have options for responding to changing patterns in warm season recreation demand in order to provide sustainable recreation opportunities. A first step will be to conduct assessments to understand the changing patterns of use (Hand and Lawson 2017) (table 14.8). Then, adjustments can be made to increase the capacity of recreation sites that are showing

Table 14.8—Recreation adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Climate change will lead to changes in recreation use patterns (year-round seasons for non-snow activities, shift in snow-dependent activities, changes in use types and demand)			
Adaptation strategy/approach: Increase flexibility and capacity for managing recreation resources to meet shifting demands			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Develop creative budget strategies to support longer/overlapping use seasons; pursue additional grant funding and partnerships and opportunities for new fees (e.g., something similar to Adventure Pass, parking fees, use for peak use times); leverage outfitting and guiding funds	Increase flexibility for year-round use of facilities; redevelop/harden/mitigate existing or new sites (e.g., integrate summer uses into ski area operations); pave access roads for winter and wet uses; install gates or other access control where snow no longer closes areas; change types of infrastructure (e.g., marinas used to be static but now need to be flexible); increase capacity at existing sites to accommodate longer use seasons	Leverage local partnerships to assist with management of recreation facilities (e.g., develop partnerships with local government, other agencies, tribes, and user groups, non-governmental organizations; promote trail adoption; facilitate local economic development opportunities)
Where can tactics be applied?	Forest- and region-wide; all recreation sites	Places with vulnerability to flooding, changing water levels, and expanding summer activities in previously winter-only areas; consider design for year round use (vault versus flush toilets)	Forest- and region-wide; especially important in areas that are far from National Forest facilities
	Specific tactic – D	**Specific tactic – E**	**Specific tactic – F**
Tactic	Implement seasonal use and/or permitting for activities that are usually seasonally constrained but that may have longer seasons with warming climate (e.g., all-terrain vehicles, mountain biking)	Develop capacity for flexibility in seasons (opening dates for campgrounds, access to trails, road closures)	Evaluate impacts to resources and potential conflicts between user groups with changes in seasonal use
Where can tactics be applied?	Especially at higher elevations	Analysis of need done at Regional level, each unit left to carry out in practice	District and Forest level decisions
Sensitivity to climatic variability and change: Season of use, types of recreation, and location of activities may change as the climate changes			
Adaptation strategy/approach: Identify and prioritize recreational sites that are prone to change			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Use predictive modeling that incorporates changing climate conditions (precipitation, temperature, etc.)	Survey the public directly or indirectly to determine use patterns and sensitivity to changing climate patterns	Educate the public about likely impacts of climate change and changing recreational opportunities
Where can tactics be applied?	During long-term planning processes, identify potential user conflicts (e.g., non-motorized versus motorized winter use)	In National Visitor Use Monitoring; trail counters; web-based tools	Focus on National Forest locations/sites in which changes are occurring (e.g., in locations with pine beetle infestations)

Table 14.8 (continued)—Recreation adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Increased flooding and fire will result in fewer recreational sites, more use of alternative campgrounds, reduced services, and increased use of fewer facilities			
Adaptation strategy/approach: Research and document existing uses			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Inventory–use and update the infrastructure database to assure correct information is available	Manage people–as conditions change, move people to more desirable sites	Communicate–have clear and constant discussions with Forests and Districts
Where can tactics be applied?	All Forests and sites	As weather changes and floods and/or fire increase, may need to utilize underused or new sites	At all levels as need arises
Sensitivity to climatic variability and change: Change in timing of water availability and absolute amount of water available will affect water-based recreation. High temperatures may drive up demand for water recreation			
Adaptation strategy/approach: Plan to account for these changes in demand			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Identify places that are likely to be affected by climate change (either loss of water-based recreation, or where more recreation will be concentrated)	Rethink campground locations to make them more pleasant for hot climates (e.g., spots in the shade) and near existing water resources; use intentional locations to control impacts of dispersed camping	Future reservoirs may be needed to meet municipal water demand that will also be used for recreation, but may also flood existing recreation sites (campgrounds, etc.)
Where can tactics be applied?	On all Forests	Forests especially attractive to recreational vehicles	Near existing water resources, and likely new sites for reservoirs

increased use (e.g., campgrounds can be enlarged, and more fences, signs, and gates can be installed where necessary). However, there may be some limitations to increasing the capacity of some recreation sites. Managers will have to consider how use in the shoulder seasons is managed, adjusting timing of actions such as road and trail openings and closures and special use permits (Strauch et al. 2015). Managers may want to establish defined season of use for activities that were historically most popular in the summer but that may become more common in the spring and fall shoulder seasons, such as all-terrain vehicles and mountain bikes. As an alternative to date-specific closures, recreation managers could continuously monitor conditions and use weather- or condition-specific closures.

As temperatures increase, there may be increased demand for water-based recreation in particular (Mendelsohn and Markowski 2004). With shifts in timing of flow and lower summer streamflows, however, water-based recreation may become unavailable in some locations at certain times (Hand and Lawson 2017). Identifying places that are likely to be affected by climate change (either loss of water-based recreation, or where more recreation will be concentrated) will help managers plan for these changing patterns. Managing lake and river access capacity, and managing public expectations on site availability may also be necessary. Monitoring will be critical to assessing changes in use patterns and identifying demand shifts.

A comprehensive summary of strategies and tactics for adapting outdoor recreation management to the effects of climate change can be found in Appendix 10.

Adapting Infrastructure Management to the Effects of Climate Change

As snowpacks decline and rain-to-snow ratios increase with warming temperatures, flooding may increase in some parts of the IAP region (Chapter 4). Thus, reducing the vulnerability of roads and infrastructure to flooding is a primary concern to managers. National Forests contain thousands of miles of roads, mostly unpaved. Damage to those roads and associated drainage systems reduces access by users and is extremely expensive to repair (Strauch et al. 2015). Road damage often has direct and deleterious effects on aquatic habitats as well, particularly when roads are adjacent to streams (Luce and Black 1999). Resilience to higher peakflows and frequency of flooding can be increased by (1) adapting the design standards where future rain-on-snow events are expected (Halofsky et al. 2011), (2) conducting a risk assessment of vulnerable roads and infrastructure (Strauch et al. 2015), and (3) performing road blading and grading activities during periods when natural moisture conditions are optimum (using water trucks as needed to supplement) (table 14.9).

In addition to flooding, fire and changing recreation demands may affect access to infrastructure for forest use (Strauch et al. 2015). As a first step, it will be important to determine how traffic patterns are changing seasonally. At-risk roads, specifically those that are prone to flooding, have insufficient culverts, or are located on unstable surfaces, can then be identified in high-use locations and be either upgraded or decommissioned (Halofsky et al. 2011). Damaged roads should not necessarily be rebuilt in kind, but rather rebuilt using specifications that account for climate-related changes (e.g., different levels and seasons of precipitation and use) or decommissioned (Halofsky et al. 2011; Strauch et al. 2015) (table 14.9).

Increases in extreme storm events and flooding with climate change may also affect bridges, dams, and levees. It will be important for specialists to consider increases in future extreme storm events when evaluating existing inventory for capacity and structural integrity, in structure design, and when determining location of new infrastructure (Strauch et al. 2015). Infrastructure management in a changing climate will benefit from increased coordination with partners (table 14.9).

Buildings, including recreation residences, may face increased risk from catastrophic events, including fire, snow, flooding, avalanche, and ecological disturbance (Chapters 4, 8). The high cost of relocating buildings from floodplains and other high-risk locations will require that adaptation options focus on prevention of damage. For example, areas surrounding buildings can be examined for hazard trees, and the hazard trees removed. Managers and recreation residence holders can follow recommended practices for keeping buildings safe from fires (e.g., by removing flammable vegetation in areas near buildings) (table 14.9). In some cases, however, risk thresholds may be exceeded, and recreation residences and other buildings may need to be relocated or removed.

A comprehensive summary of strategies and tactics for adapting infrastructure management to the effects of climate change can be found in Appendix 11.

Adapting Cultural Resource Management to the Effects of Climate Change

Climate change poses several threats to cultural resources in the IAP region (Morgan et al. 2016; Rockman 2015). Increased fire will result in increased erosion and loss of vegetation, which may exacerbate damage and other impacts to cultural resources (Davis 2017). Fuels reduction around significant cultural resources already takes place in some locations, but these efforts could be increased to further reduce likelihood of high-severity fire and damage to cultural resources (table 14.10). Fuels treatments are particularly important around flammable wooden structures (Davis 2017). In some cases, wooden shingles on historic buildings can

Table 14.9—Infrastructure adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Increased temperatures will have broad implications for road design and maintenance			
Adaptation strategy/approach: Increase resilience where roads/streams interact			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Adapt the design standards where future rain on snow events are expected	Develop risk assessment for road infrastructure	Perform road blading/grading activities during periods when natural moisture conditions are optimum, and use water trucks as needed to supplement
Where can tactics be applied?	Agency and partner road systems	Agency and partner road systems	Agency and partner road systems
Sensitivity to climatic variability and change: Climate change may alter access to infrastructure for forest use			
Adaptation strategy/approach: Increase the resilience of transportation infrastructure to climate-related stressors, such as changing recreation demands, fire, and water impacts			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Identify changing traffic patterns and uses in relation to precipitation levels and seasonal distribution	Identify roads prone to flooding based on their location (e.g., in riparian areas) as well as roads with insufficient culverts or which are located on unstable surfaces	Do not rebuild damaged roads in kind; rather, use specifications that account for climate-related changes
Where can tactics be applied?	Public surveys, county meetings, during monitoring, and in locations at which the activities are occurring	Stream crossings and on unstable soil locations	During regularly scheduled maintenance; after catastrophic events
Sensitivity to climatic variability and change: Increased temperatures will have broad implications for building design and maintenance			
Adaptation strategy/approach: Protect existing and future infrastructure by examining present and future hazards on building infrastructure			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Examine surroundings for hazard trees, and remove those that present hazards to facilities	Follow recommended practices for keeping buildings safe from fires	Anticipate where ice dam problems may occur in the future
Where can tactics be applied?	Any building	Any building	Buildings at higher elevations where winter temperature may fluctuate near freezing

Table 14.9—Infrastructure adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Recreation residences may see increased risk from extreme climatic events (e.g., fire, snow, flooding, avalanche, and ecological disturbance)			
Adaptation strategy/approach: Develop risk assessment tools, and address risk with holders and county Emergency Medical Services			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Communicate with existing recreation resident holders	Develop clear procedures for removing a recreation residence that exceeds a risk threshold	Consider developing in-lieu lots or other recreation tracts
Where can tactics be applied?	All recreation residences	Site-specific and in each District	Agency review of program
Sensitivity to climatic variability and change: Increased storm frequency and intensity will have broad implications for design and maintenance of bridges, dams, canals, and levees			
Adaptation strategy/approach: Protect existing and future infrastructure by examining present and future hazards on bridge and dam infrastructure			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Evaluate existing inventory for capacity and structural integrity using climate model projections for extreme storm events	Incorporate climate models projections for extreme storm events in structure design and bridge location	Facilitate partnerships between private, local, State, and Federal jurisdictions
Where can tactics be applied?	Any existing bridge, dam, canal, or levee	Any planned bridge, dam, canal, or levee	Any existing or planned bridge, dam, canal, or levee

Table 14.10—Cultural heritage adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Increased fire will result in increased erosion and loss of vegetation, which may increase damage and impacts to cultural resources				
Adaptation strategy/approach: Encourage pre- and post-disturbance strategies to protect cultural resources				
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	
Tactic	Increase the use of prescribed fire or other vegetation manipulation	Inventory, map, and rate fire risk for cultural resources	Develop a plan to address post-fire impacts to cultural resources that have been affected	
Where can tactics be applied?	In or around cultural resources that are susceptible to impact from severe wildfire	Across Forests	Across burned areas	
Sensitivity to climatic variability and change: Temperature changes bring changes in season, both for people and resources, and may put more pressure on cultural resources and sites (e.g., looting, collecting, inadvertent impacts from users to cultural heritage resources)				
Adaptation strategy/approach: Educate users and protect cultural resources				
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	**Specific tactic – D**
Tactic	Redirect public to less sensitive cultural areas	Provide education and interpretation to inform the public about why cultural resources are important; engage user groups	Directly protect cultural resources with physical barriers, fencing, vegetation screening, and access management	Inventory high-risk areas and monitor high priority resources
Where can tactics be applied?	Specific sites; need to identify high recreation use locations and where impacts are occurring or may occur in the future	Dispersed recreation sites, system trails	Specific sites	Set strategy at regional level; implement at unit level
Sensitivity to climatic variability and change: Traditional food sources may be lost with increased fire, invasive species establishment, and habitat changes under changing climate				
Adaptation strategy/approach: Integrate traditional ecological knowledge with fire management plans and cultural resource data base to holistically manage for traditional food sources (such as huckleberries, mushrooms, pine nuts, sage-grouse, etc.)				
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	
Tactic	Emphasize preservation of traditional food sources with tribal and local significance	Enhance resilience of specific habitats to fire and other threats; manage fire to maintain or protect sagebrush rangelands and other sensitive vegetation types	Identify and protect areas suitable for traditional food gathering under future climate conditions	
Where can tactics be applied?	Forest- and region-wide	Forest- and region-wide	Forest- and region-wide	

be replaced with fire-retardant treated wooden shingles, and where appropriate, susceptible structures can be wrapped with fire-retardant material when threatened by a wildfire. However, fire-retardant air drops on cultural resources should be avoided where possible, as they can stain cultural resources such as rock art, prehistoric stone structures, cliff faces and associated resources, historic buildings, and artifacts. Having archaeological resource advisors on fire teams can help ensure that practices which damage cultural resources are avoided whenever possible.

Traditional food sources may also be lost with increased fire, changing habitat conditions, and increased establishment of invasive species under changing climate (Chapter 12). Resilience of specific habitats to fire and other threats could be enhanced through silvicultural treatments and prescribed burning, although the effectiveness of treatments relative to the scope and scale of the cultural landscape is difficult to evaluate (Davis 2017). Careful monitoring and tracking of vegetation stability and change in cultural landscapes will become increasingly important in future decades (Davis 2017). Managers may also want to identify and protect areas that are likely to be suitable for traditional food gathering under future climatic conditions (table 14.10).

An effective defense against losing structures and other cultural resources to fire is for managers to know which resources are under their jurisdiction, and where those resources are located (Rockman 2015). Survey and evaluation in areas where cultural resources are concentrated or likely is ongoing, although intermittent, in the IAP region. It will be possible to locate and monitor cultural resources only if these efforts are significantly expanded. High-elevation melting ice patches are a particular priority, but surveys are also critical in other locations where cultural resources are likely to be affected by fire or flooding and debris flows in mountain canyon and foothills areas (Davis 2017). Correlating areas where cultural resources are common with areas where disturbances are expected will help to focus attention in landscapes at greatest risk. Having postfire management plans in place before events occur will help to ensure efficient and effective postfire actions (table 14.10).

Warming temperatures will extend the warm-weather recreation season, potentially putting more pressure on cultural resources and sites. These impacts can be minimized if land managers work closely with their heritage staff to identify sites that are being damaged due to visitation, implement on-the-ground site monitoring, and have a plan in place to address resources that are anticipated to have more frequent visitation in the future. Managers can also provide education and interpretation to inform the public about why cultural resources are important. Other options include redirecting users to less sensitive areas and protecting cultural resources with physical barriers, fencing, vegetation screening, and access management (table 14.10).

A comprehensive summary of strategies and tactics for adapting management of cultural resources to the effects of climate change can be found in Appendix 12.

Adapting Ecosystem Services to the Effects of Climate Change

The climate change vulnerabilities in ecosystem services that pose the highest concern include availability and quality of forage for livestock, the availability and quality of municipal water, and habitat for pollinators. Many of these vulnerabilities stem from likely climate change impacts on other resources covered in this chapter.

Increased atmospheric carbon dioxide concentrations may increase rangeland productivity by increasing water-use efficiency (Polley et al. 2013; Reeves et al. 2014). In moisture-limited systems, however, increased temperatures will increase evaporative demand and reduce soil moisture and productivity unless precipitation increases significantly (Polley et al. 2013). Increased wildfire area burned and establishment of nonnative species may also decrease rangeland productivity. Managers at the workshops proposed adaptation strategies for grazing that focused on increasing resilience of rangeland vegetation, primarily through nonnative species control and prevention (table 14.11). Demand for grazing on high-elevation National Forest land may increase with warming. Federal land managers identified increasing flexibility in timing, duration, and intensity of authorized grazing as a tactic to prevent ecosystem degradation under changing conditions. They also stressed the importance of developing a holistic approach to grazing management, taking the needs of ranchers into consideration, and developing a collaborative relationship with range permittees that focuses on problem solving rather than rule enforcement.

Climate change is expected to alter hydrological regimes, with impacts on quantity and quality of municipal water supply (Chapter 4). Therefore, strategies developed for water resource management on National Forest lands should consider the timing of water availability as well as the quality of water delivered beyond National Forest System lands. Conducting assessments of potential climate change effects on municipal water supply and identifying potential vulnerabilities will help facilitate adaptive actions that can minimize climate change impacts. Water quality can be addressed by: (1) reducing hazardous fuels in dry forests to reduce the risk of crown fires, (2) reducing other types of disturbances (e.g., off-road vehicles, unregulated livestock grazing), and (3) using road management practices that reduce erosion (Peterson and Halofsky 2017). These tactics should be implemented primarily in high-value locations (near communities and reservoirs) on public and private lands. Communication among agencies, landowners, stakeholders, and governments will be essential to ensure future municipal water supply (Peterson and Halofsky 2017) (table 14.11).

Increasing temperatures are likely to have an effect on the thermoregulation of pollinators and may lead to a mismatch in the timing of emergence of flowers and pollinators (Fagan et al. 2014). Another possible indirect effect of

Table 14.11—Ecosystem services adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Pollinators and their habitat may be sensitive to climate change			
Adaptation strategy/approach: Enhance pollinator habitat on Federal lands and Federal facilities			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Direct National Forests to improve pollinator habitat by increasing native vegetation and by applying pollinator-friendly forest-wide best management practices and seed mixes	Establish a reserve of native seed mixes, including pollinator-friendly plants that are adapted, available, affordable, and effective	Develop revegetation guidelines that incorporate menu-based seed mixes by habitat type (e.g., species that are good for pollinators, sage-grouse, umbrella species) and by empirical or provisional seed zones
Where can tactics be applied?	Priority areas include alpine, tall forbs, low-elevation wetlands, and dry and dwarf sagebrush communities	IAP geographic areas (e.g., Uintas and Wasatch Front).	Each National Forest
Adaptation strategy/approach: Increase agency and public awareness of the importance of native pollinators			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Establish a pollinator coordinator to communicate with District- and Forest-level teams, Regional Office, and public	Develop a checklist to consider pollinator services in planning, project analysis, and decision making	Establish pollinator gardens
Where can tactics be applied?	Each National Forest	In both the National Forest Management Act and National Environmental Policy Act processes	On Federal facilities or in partnership with other public entities (e.g., public spaces, parks, backyards)
Sensitivity to climatic variability and change: Amount and seasonal distribution of water may shift, thus affecting ability to meet water demand			
Adaptation strategy/approach: Assess and communicate Forest Service ability to help meet water demand			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Conduct integrated assessment of climate effects on water at a watershed scale	Encourage communication and full disclosure of information	Conduct water vulnerability assessments
Where can tactics be applied?		Watershed councils, municipal watersheds, interagency working groups (e.g., Mountain Accord), local communities	Assessments could be done by community, watershed, administrative boundary, etc.

Table 14.11 (continued)—Ecosystem services adaptation options for the Intermountain Adaptation Partnership region.

Sensitivity to climatic variability and change: Higher temperatures and increased fire activity will alter the composition and productivity of forage				
Adaptation strategy/approach: Increase resilience of habitats used by ungulates and that are vulnerable to climate change impacts				
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	**Specific tactic – D**
Tactic	Reduce conversion of native perennial vegetation to invasive species	Integrate grazing strategies and vegetation treatments (both wild and domestic ungulates)	Emphasize collaborative problem solving with permittees and other interested parties rather than enforcement	Modify flexibility in timing, duration, and intensity of authorized grazing
Where can tactics be applied?	Priority areas include tall forbs, low-elevation wetlands and riparian areas, and dry and dwarf sagebrush communities			Across the National Forest on all grazing allotments; prioritize allotments based vulnerability, soil type, etc.
Sensitivity to climatic variability and change: Climate variability and warming will impact grazing resources and policy				
Adaptation strategy/approach: Develop a holistic approach to grazing management; understand the ranching business approach, lands used, water management, and competing demands from other resources and multiple uses				
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	
Tactic	Partner with permittee and other managers of lands they use to create a holistic grazing program	Understand changes in water availability to prepare and adjust grazing management	Implement education programs about climate change impacts and sustainable grazing practices (highlight both positive and negative effects)	
Where can tactics be applied?	Public, private and all adjacent lands	Around water resources	Needs to be broadly implemented; partnership opportunities with Cattlemen's Association, Future Farmers of America, Natural Resources Conservation Service, schools, environmental organizations	

climate change on pollinators may be habitat loss and fragmentation with invasive species and vegetation type shifts, leading to a reduction in forage resources or an increase in pests and diseases. Tools to promote native pollinators include directing National Forests and other agency units to improve pollinator habitat by increasing native vegetation and by applying pollinator-friendly best management practices (table 14.11). Establishing a reserve of native seed mixes, including pollinator friendly plants that are adapted, available, affordable, and effective, will help to increase availability of pollinator friendly materials and encourage their use. Revegetation guidelines could be developed that incorporate menu-based seed mixes by habitat type (e.g., species that are good for pollinators, sage-grouse, umbrella species) and by empirical or provisional seed zones. To ensure that pollinators are considered in agency activities, a checklist could be developed that helps managers incorporate pollinator services in planning, project analysis, and decisionmaking.

A comprehensive summary of strategies and tactics for adapting management of ecosystem services to the effects of climate change can be found in Appendix 14.

Conclusions

The IAP vulnerability assessment and workshop process resulted in a comprehensive list of climate change adaptation strategies for natural resource management in the region. Although most of the suggested strategies and tactics focused on increasing resilience, there were some involving resistance (e.g., protection of whitebark pine) and response (e.g., transitioning recreation management to account for changing use patterns with climate change). Adaptation strategies and tactics that have benefits to more than one resource are likely to be most beneficial (Peterson et al. 2011b). Management activities intended to reduce fuels and restore hydrological function are standard practices, suggesting that many current resource management actions are already climate smart. However, the locations where actions are implemented may be different or strategically targeted in the context of climate change. For example, treatments for aspen may be targeted toward persistent aspen communities that are expected to expand and maintain communities where future climatic conditions will allow.

Implementation will be the next challenge for the IAP (Chapter 15). Although implementing all adaptation options described in this chapter may not be feasible, managers can choose from the menu of strategies and tactics presented here. These adaptation strategies and tactics can thus provide the basis for climate-smart management in the region.

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Appendix 5—Water Resource Adaptation Options Developed for the Intermountain Adaptation Partnership Region

The following tables describe climate change sensitivities and adaptation strategies and tactics for water resources, developed in a series of workshops as a part of the Intermountain Adaptation Partnership (IAP). Tables are organized by subregion within the IAP. See Chapter 14 for summary tables and discussion of adaptation options for water resources.

Table 5A.1—Water resource adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Increased drought will lead to lower base flows, greater tree mortality, reduced rangeland productivity, loss of habitat, reduced soil moisture, wetland loss, riparian area reduction or loss, and more frequent and possibly severe wildfire			
Adaptation strategy/approach: Manage adaptively			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Develop hydrological tools and products to predict or aid in range management with changing climate; explore various options to allow more flexibility in the management of rangelands	Develop hydrological tools and products to predict or aid in the prediction of recreation use (when will roads and other infrastructure be ready for use by the recreating public); explore various options to allow more flexibility in the management of public recreation (e.g., hiring of seasonal workforce)	Plan for possible changes in the calculation of Total Maximum Daily Loads (TMDLs) and the timing of permitted discharge; be able to adapt to those changes in stream flows and timing.
Where can tactics be applied?	Forest range management allotments; National Environmental Policy Act (NEPA) process; forest policy and directives; regional guidance; budget and grant timing	NEPA; forest policy and directives; regional guidance; seasonal hiring guidance and direction; budgeting	Interagency partnerships and coordination; planning
Opportunities for implementation	Best management practices; allotment management plans; annual operating instructions; forest plan direction	Recreation planning; budgeting and planning.	TMDL development or redevelopment; forest planning; water use planning; project design
Sensitivity to climatic variability and change: Soil productivity may decrease			
Adaptation strategy/approach: Identify vulnerabilities to soil processes including temperature, moisture, biological activity and carbon sequestration			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Maintain and protect soil cover (canopy and ground cover)	Promote the maintenance and the addition of soil organic matter	Promote native vegetation and minimize the expansion of invasive species
Where can tactics be applied?	National, regional, and forest-level planning and guidance; project design; national best management practices (BMPs)	National, regional, and forest-level planning and guidance; project design; national BMPs	National, regional, and forest-level planning and guidance; project design; national BMPs
Opportunities for implementation	BMPs; project design and development	BMPs; project design and development	BMPs; project design and development
Comments	May be specific to soil texture; strategize and prioritize based on soil texture; changes in soils will take time—they cannot be restored easily or quickly; need proactive preventive methods	May be specific to soil texture; strategize and prioritize based on soil texture	May be specific to soil texture; strategize and prioritize based on soil texture; may want to prioritize rare plants associated with specific soil types and conditions

Table 5A.1 (continued)—Water resource adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Increased drought will lead to lower base flows, greater tree mortality, reduced rangeland productivity, loss of habitat, reduced soil moisture, wetland loss, and riparian area reduction or loss			
Adaptation strategy/approach: Conserve water			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Xeriscape facilities	Provide conservation education	Better manage livestock water improvements
Where can tactics be applied?	Administrative facilities; campgrounds	In public outreach; communities; forest Web sites; kiosks; local environmental programs; Smokey Bear messages	Cattle troughs; float valves; in groundwater-dependent ecosystems (developed and undeveloped)
Opportunities for implementation	New construction or remodel and repair projects; sustainable operations programs; forest planning, revision	Partnerships; collaboratives; schools (education programs and outreach, camps); through public information officers	Annual operating instructions; project design; permit renewals; allotment management plans
Comments	Need funding and education	Public outreach and education is critical to explaining the "why"	Need inventory of existing conditions, and locations for developed and undeveloped seeps, springs, troughs, and groundwater-dependent ecosystems
Sensitivity to climatic variability and change: Increased drought will lead to lower base flows, greater tree mortality, reduced rangeland productivity, loss of habitat, reduced soil moisture, wetland loss, and riparian area reduction or loss			
Adaptation strategy/approach: Store water			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Manage special-use dams on high- elevation mountain lakes	Manage proposals for major reservoir construction and additions	Conduct meadow restoration and promote beaver dams
Where can tactics be applied?	Existing facilities; water storage structures	Where they are proposed	Existing meadow locations; impacted riparian areas
Opportunities for implementation	NEPA policies; forest planning and revision; special use permits	NEPA; policies; forest planning and revision; collaboration; coordination with other agencies and partners	Identify restoration opportunities and priorities
Comments	Increased storage may not always be the answer (because of evaporation loss, impacts to water quality, temperature, aquatic organism passage, etc.)	Increased storage may not always be the answer (because of evaporation loss, impacts to water quality, temperature, aquatic organism passage, etc.)	Increased storage may not always be the answer (because of evaporation loss, impacts to water quality, temperature, aquatic organism passage, etc.)

Table 5A.1 (continued)—Water resource adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Increased drought will lead to lower base flows, greater tree mortality, reduced rangeland productivity, loss of habitat, reduced soil moisture, wetland loss, and riparian area reduction or loss			
Adaptation strategy/approach: Develop policies for water rights			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Develop policies regarding ski area water rights	Develop policies regarding livestock management water use and water rights	Develop policies regarding ecosystem values and services (e.g., instream use)
Where can tactics be applied?	Ski areas	Grazing allotments	National forest lands and adjacent lands (e.g., private lands, BLM lands, and wildlife management areas)
Opportunities for implementation	National policy and directives; management plans	National policy and directives; management plans	National policy and directives; management plans
Comments	Higher level policy and direction needed	---	Need to consider groundwater and surface water interactions; consider the impacts of depleted recharge to groundwater systems; develop map products of groundwater systems and possibly inputs and outputs to streams and other groundwater-dependent systems
Sensitivity to climatic variability and change: Increased drought will lead to lower base flows, greater tree mortality, reduced rangeland productivity, loss of habitat, reduced soil moisture, wetland loss, riparian area reduction or loss, and more frequent and possibly severe wildfire			
Adaptation strategy/approach: Consider climate change in postdisturbance (fire, disease) restoration			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Develop map products for at-risk soils and vegetation communities	Develop forest or ecological region plans for postdisturbance rehabilitation, adjusted to warmer, drier climate scenarios	Develop forest-level strategies for altered hydrological regimes (related to infrastructure, roads, culverts, bridges, campgrounds, etc.)
Where can tactics be applied?	Forest-level planning; regional guidance	Forest-level planning; regional guidance	Forest-level planning; regional guidance
Opportunities for implementation	Burned Area Emergency Response (BAER); engineering designs; project design and implementation	BAER; engineering designs; project design and implementation	BAER; engineering designs; project design and implementation
Comments	---	---	---

Table 5A.2—Water resource adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: Flow regimes will be altered, with earlier snowmelt and lower summer base flows			
Adaption strategy/approach: Restore function of watersheds, riparian areas, wetlands, and groundwater-dependent ecosystems			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Promote and increase beaver populations where appropriate	Promote appropriate livestock grazing management	Improve water diversion and delivery systems for livestock and other uses
Where can tactics be applied?	Where there is sufficient habitat and beaver will not interfere with infrastructure	Grazing allotments, particularly in riparian areas, wetlands, and groundwater-dependent systems (e.g., springs)	Water developments and diversions; divert only what is needed from the natural system
Opportunities for implementation	Use Utah State University Beaver Restoration Assessment Tool (BRAT) to look for opportunities and priorities	Ensure compliance with proper use standards	Use shut-off valves and splitters; locate troughs away from water sources; improve spring developments (e.g., locate head box away from spring source)
Comments	Use living-with-beaver tactics; use education and outreach to promote the benefits of beaver, and address concerns (infrastructure)	---	---
Sensitivity to climatic variability and change: Higher peak flows and earlier runoff will occur with climate change			
Adaptation strategy/approach: Increase watershed resilience by restoring stream and floodplain structure and processes			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Manage for deep-rooted riparian vegetation (controlling invasive species) to increase channel stability	Reduce road and trail density near streams	Increase stream crossing capacity (e.g. culverts, bridges) to accommodate high flows and aquatic organism passage
Where can tactics be applied?	All streams	All streams	All streams
Opportunities for implementation	Manage for appropriate livestock use; manage recreation (e.g., all-terrain vehicles, trails, dispersed campsites)	Use travel analysis process to set priorities and eliminate unneeded roads and trails (both authorized and unauthorized)	Use travel analysis process to set priorities and eliminate unneeded roads and trails (both authorized and unauthorized); incorporate stream simulation tools in culvert and bridge design

Table 5A.2 (continued)—Water resources adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: Water temperatures will be higher during the summer low-flow period			
Adaptation strategy/approach: Increase habitat resilience by restoring structure and function of streams, riparian areas, and wetlands			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Manage livestock grazing to restore ecological function of riparian vegetation and maintain streambank conditions	Maintain large wood in forested riparian areas for shade and recruitment	Reconnect floodplains and side channels to improve hyporheic and base flow conditions
Where can tactics be applied?	All perennial and intermittent streams and wetlands	All perennial and intermittent streams and wetlands	All perennial and intermittent streams and wetlands
Opportunities for implementation	Ensure compliance with proper use standards in riparian areas	Ensure compliance with riparian buffer standards and best management practices	Relocate roads out of floodplains, reconnect old channels; reduce habitat fragmentation through barrier removal (e.g., culverts, water diversions); restore native trout to high-elevation, cold-water refugia

Table 5A.3—Water resource adaptation options developed at the Plateaus subregion workshop.

Sensitivity to climatic variability and change: Flow regimes will be altered, with earlier snowmelt and lower summer base flows			
Adaptation strategy/approach: Restore function of watersheds, floodplains, riparian areas, wetlands, and groundwater-dependent ecosystems; restore water quality, quantity, and timing			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Implement transportation system improvements (e.g., general BMPs, travel management implementation, culvert/bridge design with stream simulation, road relocation, permeable fill to encourage subsurface flow); promote and increase beaver populations where appropriate	Promote appropriate livestock grazing management and proper use standards; improve water diversions, delivery systems, and livestock distribution; divert only what is needed from the natural system and minimize impact to spring sources (e.g., use shut-off valves and splitters, locate troughs away from water sources, and locate head boxes away from spring sources)	Conduct vegetation management (e.g., mechanical treatments, prescribed fire, and wildland fire use) to develop appropriate vegetation density and composition for optimal water balance and healthy watersheds (e.g., aspen and conifers, and water yield)
Where can tactics be applied?	Prioritize areas for restoration, based on level of degradation and opportunities for improvement; analyze where funds will make the most difference	All grazing allotments and particularly around drinking water sources	Prioritize watersheds where fire suppression or management has altered vegetation density and composition (e.g., where conifers have replaced aspen); identify areas where wildland fire use could be an appropriate tactic

Table 5A.3—Water resource adaptation options developed at the Plateaus subregion workshop.

Sensitivity to climatic variability and change: Climate change may result in decreased monsoonal moisture in the summer, increased drought, wetland and riparian reduction or loss, and increased fire activity			
Adaptation strategy/approach: Improve natural water storage and retention through healthy watersheds, riparian and wetland areas, and groundwater- dependent ecosystems			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Conduct vegetation management (e.g., mechanical treatments, prescribed fire, wildland fire use) to develop appropriate vegetation density and composition for optimal water balance and healthy watersheds (e.g., aspen and conifers, and water yield)	Conduct stream and meadow restoration; promote and increase beaver populations where appropriate	Manage special-use authorizations for water storage (dams on high-elevation mountain lakes) and other water diversions; protect and manage water developments at groundwater-dependent ecosystems (springs, wetlands, fens, etc.)
Where can tactics be applied?	Prioritize watersheds where fire suppression or management has altered vegetation density and composition (e.g., where conifers have replaced aspen); identify areas where wildland fire use could be an appropriate tactic	Where there is sufficient habitat and beaver will not interfere with infrastructure	Existing and proposed facilities; water diversion and storage structures
Opportunities for implementation	---	Use Utah State University Beaver Restoration Assessment Tool (BRAT) to look for opportunities and priorities; use living-with-beaver tactics; conduct education and outreach to promote the benefits of beaver, and address concerns (infrastructure)	Analyze for water conservation and improved efficiency during National Environmental Policy Act process and reissuance of special use permits

Table 5A.4—Water resource adaptation options developed at the Great Basin and Semi Desert subregion workshop.

Sensitivity to climatic variability and change: Changes in type and amount of precipitation will lead to changes in timing of water availability			
Adaptation strategy/approach: Manage for highly functioning riparian areas that can absorb and slowly release the flow of water off the landscape			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Preserve riparian area functionality through terms and conditions of permitted activities, and utilize best management practices for Federal actions	Implement active stream channel and riparian area restoration (e.g., natural channel design, log structures, reconnecting floodplains), or passive restoration (e.g., appropriate management of beaver populations, reduction or removal of activities that are detrimental to riparian function)	Design new infrastructure and rebuild existing infrastructure to accommodate flooding (e.g., place or relocate infrastructure outside of riparian areas; design stream crossings to minimize restriction of flow above bankfull; and minimize impervious surfaces)

Appendix 6—Aquatic Organism Adaptation Options Developed for the Intermountain Adaptation Partnership Region

The following tables describe climate change sensitivities and adaptation strategies and tactics for aquatic organisms, developed in a series of workshops as a part of the Intermountain Adaptation Partnership (IAP). Tables are organized by subregion within the IAP. See Chapter 14 for summary tables and discussion of adaptation options for native fish and other aquatic organisms.

Table 6A.1—Aquatic organism adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Climate change will affect food web dynamics and nutrient flows in streams		
Adaptation strategy/approach: Maintain resilient flow, sedimentation, and thermal regimes		
	Specific tactic – A	**Specific tactic – B**
Tactics	Reduce fine sedimentation and substrate embeddedness	Restore anadromous fish runs (or carcass analogs, or both)
Where can tactics be applied?	Basins with high road density and where roads are directly adjacent to stream channels	Former anadromous fish habitats where migrations are blocked
Opportunities for implementation	---	Fish passage past dam that precludes migrations
Comments	Mitigate adverse effects of sedimentation on macroinvertebrate communities	---

Sensitivity to climatic variability and change: Warmer stream temperatures may favor nonnative species			
Adaptation strategy/approach: Monitor for invasive species and suppress, eliminate, and control populations			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Use environmental DNA (eDNA) monitoring for early detection of river or stream invasions	Reduce or suppress brook trout populations	Construct barriers that prevent access to and invasion of conservation populations in headwaters
Where can tactics be applied?	High-value populations that are thought to be at significant risk of invasion	Headwater lakes that act as source populations; small, isolated streams where complete eradication is possible	Southern portions of IAP region where stream habitats are smaller and more fragmented
Opportunities for implementation	---	Prioritize among hundreds (thousands?) of headwater streams and lakes across the IAP region	Small headwater streams where barrier construction is cost effective and possible
Comments	Costs of eDNA sampling are low enough to make this broadly applicable	Expensive and risky to implement; public support needed for success	Less useful tactic in areas with anadromous species or fluvial populations of bull trout and cutthroat trout

Table 6A.1 (continued)—Aquatic organism adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Native species distributions will shift, and communities will realign			
Adaptation strategy/approach: Conduct biodiversity surveys to describe current baseline conditions and manage distribution shifts			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Formalize, expand, and standardize biological monitoring programs (e.g., Management Indicator Species	Use modern, low-cost technologies such as eDNA/DNA barcoding and digital photopoints	Assisted migrations
Where can tactics be applied?	Streams/rivers/lakes throughout IAP area	Streams, rivers, lakes throughout IAP region	Suitable but currently unoccupied habitats; consider habitats outside of historical range (e.g., northern extent of species distributions) in addition to historical range
Opportunities for implementation	---	---	Climate Shield fish model can be used to identify high-probability habitats; use eDNA to confirm species presence or absence, and then move fish into high-probability areas based on current/future climate forecasts
Comments	Boise NF, Sawtooth NF, and Salmon-Challis NF have rotating panel monitoring designs that provide good templates because broad-scale status and local trend information are represented	New genomic techniques and technologies are inexpensive and make broad applications more feasible than previously	This is a controversial tactic and care is needed to do it properly; if threatened and endangered species are present, there are permitting procedures that must be followed; there are considerations about whether the system had fish historically or not (e.g., geologic barriers to suitable habitats); if it is a listed species, we may need to designate it as an "experimental population" to be politically feasible

Table 6A.2—Aquatic organism adaptation options developed at the Plateaus subregion workshop.

Sensitivity to climatic variability and change: Warmer stream temperatures may favor nonnative species			
Adaptation strategy/approach: Increase resilience of native fish species			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Manage livestock grazing to restore ecological function of riparian vegetation and maintain streambank conditions	Maintain large wood in forested riparian areas for shade and recruitment; reconnect floodplains and side channels to improve hyporheic and base flow conditions; conduct meadow restoration; augment snowpack with snow fences on the Wasatch plateau to increase late summer flows; maintain vegetation density and composition for optimal water balance and snow accumulation	Remove or control nonnative fish species; maintain or construct barriers to prevent spread of nonnative species; reduce habitat fragmentation of native trout habitat through barrier removal (e.g., culverts and water diversions); restore native trout to high-elevation, cold-water refugia
Where can tactics be applied?	All perennial and intermittent streams and wetlands	All perennial and intermittent streams and wetlands	Prioritize areas based on site specific conditions
Opportunities for implementation	Ensure compliance with proper use standards in riparian areas	---	Work with State fish and game agencies to facilitate nonnative species removal and native trout restoration

Table 6A.3—Aquatic organism adaptation options developed at the Great Basin and Semi Desert subregion workshop.

Sensitivity to climatic variability and change: Transition or loss of biodiversity may occur with crossing of ecological type thresholds (broadly accounting for changes in connectivity, temperature, and water quantity)			
Adaptation strategy/approach: Understand and manage for community-level patterns and processes			
	Specific tactic – A	**Specific tactic – B**	**Specific Ttactic – C**
Tactics	Utilize best available technology to monitor, record, and distribute information about the distribution of a broad array of aquatic species (e.g., environmental DNA, national databases)	Develop and improve understanding, adaptive actions, and models related to nongame aquatic species (e.g., mussels, dace, sculpin, springsnails, and amphibians)	Continue to refine and improve understanding, adaptive actions, and models related to cold-water salmonids

Appendix 7—Forest Vegetation Adaptation Options Developed for the Intermountain Adaptation Partnership Region

The following tables describe climate change sensitivities and adaptation strategies and tactics for forest vegetation, developed in a series of workshops as a part of the Intermountain Adaptation Partnership (IAP). Tables are organized by subregion within the IAP. See Chapter 14 for summary tables and discussion of adaptation options for forest vegetation.

Table 7A.1—Forest vegetation adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Disturbances will affect landscape-scale patterns, structure, and species composition			
Adaptation strategy/approach: Create landscape patterns that are resilient to past and expected disturbance regimes			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Continue research on expected future disturbance regimes; evaluate potential transitions and thresholds	Improve communication across boundaries	Manage for diversity of structure and patch size with fire and mechanical treatments
Where can tactics be applied?	Local, regional, national scales	Internally and externally (with partners)	Watershed(s)
Opportunities for implementation	Use Forest Inventory and Analysis (FIA) program data to improve or establish monitoring	Workshops; collaborative groups; get external partners to do "translational ecology" (telling a layperson story that the public will listen to and accept)	Landscape-scale projects (e.g., thinning, fire)

Sensitivity to climatic variability and change: Shifts in hydrological regime will occur and involve changes in timing and magnitude of flows; expected changes include lower summer flows, higher and more frequent winter flows, and potentially a decrease in riparian vegetation abundance		
Adaptation strategy/approach: Maintain and promote riparian processes and functions		
	Specific tactic – A	**Specific tactic – B**
Tactics	Manage upland vegetation that influences riparian function and process (e.g., with thinning and prescribed fire)	Restore "true" riparian obligate species
Where can tactics be applied?	Adjacent to riparian vegetation where conditions do not optimize or promote riparian function and process	Aquatic Conservation Strategy priorities (might have listed fish or wildlife); where upland, invasive, or undesirable species are outcompeting native species; locations that have been inappropriately managed in the past
Opportunities for implementation	Thinning and prescribed fire projects	Treatments of invasive species; planting and seeding; thinning and prescribed fire projects

Table 7A.1 (continued)—Forest vegetation adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: The western larch niche may be lost (loss of habitat); regeneration may be reduced by other conifers				
Adaptation strategy/approach: Increase competitive ability of western larch and its resilience to changing fire regimes				
	Specific tactic – A	**Specific tactic – B**		
Tactics	Create gaps in forests to reduce competition and increase larch vigor	Regenerate larch with appropriate site preparation (e.g., prescribed burning, followed by planting); create appropriate fire regime and fuel loads		
Where can tactics be applied?	Stands with larch	Habitats that can support larch		
Opportunities for implementation	Places with larger landscape management projects	Places with larger landscape management projects		
Sensitivity to climatic variability and change: Large-scale disturbances (beetles, fire, white pine blister rust) will impact whitebark pine				
Adaptation strategy/approach: Increase competitive ability and resilience of whitebark pine to changing disturbance regimes				
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	**Specific tactic – D**
Tactics	Control beetles	Daylight (thin) to reduce competition (usually involves removing subalpine fir)	Regenerate rust-resistant strains; increase seed sources; maintain cache sites	Create fuelbreaks
Where can tactics be applied?	Protect trees in high-value areas; important in Central Idaho and the Greater Yellowstone area	Implement in accessible areas and high-value areas (best rust-resistant areas and areas of high habitat and recreation value)	Areas of disturbance, or areas with low resistance; maintain density for Clark's nutcracker	In accessible and high-value areas
Opportunities for implementation	Use Verbenone to protect trees from beetles; use after snowmelt (consider seasonal constraints)	---	In accessible areas	In locations adjacent to subalpine fir or other lethal fire regime areas
Comments	---	Think about ladder fuels and fuel mitigation issues when daylighting	Only have small capacity so far. There is a whitebark pine seed orchard in Region 1.	Consider impacts to soils and long-term maintenance

Table 7A.2—Forest vegetation adaptation options developed at the Southern Greater Yellowstone subregion workshop.

Sensitivity to climatic variability and change: Capacity for aspen stand regeneration will be reduced due to direct and indirect impacts from climate change			
Adaptation strategy/approach: Increase capacity for aspen stand regeneration			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Increase the proportion of the landscape that is in early-successional stages	Maximize flexibility in managing herbivory	Maximize genetic diversity
Where can tactics be applied?	Landscapes with high proportion of later-seral aspen mixed conifer	Focus on sites with good aspen site potential	Landscapes following severe fire
Opportunities for implementation	Prescribed fire, wildfire management, cultural treatments	Continue to work with existing partnerships and develop new partnerships	Protecting seedlings
Comments	Reduced snowpack and increased frequency and severity of drought create increased aspen exposure to herbivory during postdisturbance regeneration	---	Currently establishing new aspen clones from seed
Sensitivity to climatic variability and change: Whitebark pine (WBP) communities will be susceptible to changes in disturbance regimes (i.e., fire, insects, and disease)			
Adaptation strategy/approach: Increase resilience of whitebark community types			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Improve structural diversity of WBP communities at multiple scales	Improve age-class diversity of WBP communities at multiple scales	Conduct restoration where WBP is currently absent
Where can tactics be applied?	WBP communities dominated by late-successional coniferous species	WBP communities dominated by late-successional coniferous species	Sites that have present and future potential to support WBP but where it is currently absent
Opportunities for implementation	Prescribed fire and silvicultural treatments	Prescribed fire and silvicultural treatments	Regeneration treatments using disease-resistant WBP
Comments	Although WBP has limited geographic extent, it is considered a keystone species	---	---

Table 7A.2 (continued)—Forest vegetation adaptation options developed at the Southern Greater Yellowstone subregion workshop.

Sensitivity to climatic variability and change: Climate change will result in changes in soil moisture in mesic meadows and riparian grassland and forb communities			
Adaptation strategy/approach: Implement management strategies that retain soil moisture			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Maintain and improve soil function and health	Improve stream channel function	Manage upland forest vegetation
Where can tactics be applied?	Areas contributing to detrimental soil moisture retention	Where stream function is impaired; prioritize where most effective	Conifer encroachment in meadows and grasslands
Opportunities for implementation	Diverting activities away from these areas; prioritize where most effective	Riparian restoration; restore and protect beaver populations; improve livestock management	Cultural treatments
Comments	Plan and implement infrastructure to minimize impacts on mesic and wet meadows		
Sensitivity to climatic variability and change: Upper treeline may move upward in elevation into alpine communities			
Adaptation strategy/approach: Acquire information to develop understanding of sensitivity to climate change			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Establish monitoring sites	Develop seed transfer guidelines	Develop seed collection and storage guidelines
Where can tactics be applied?	Research Natural Areas	Research Natural Areas	---

Table 7A.3—Forest vegetation adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: Large-scale disturbances will impact landscape structural diversity of persistent lodgepole pine (LP) and available seeds sources			
Adaptation strategy/approach: Maintain landscape heterogeneity to mitigate adverse impacts from fire and mountain pine beetles			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Promote structural diversity at multiple scales	Focus attention on collection of viable serotinous LP seed sources	Use available mapping products to identify areas of potential serotinous LP seed sources
Where can tactics be applied?	Homogeneous landscapes	From serotinous LP cones that cover a wide range of elevational bands on national forest and adjacent lands	Forest and adjacent landowners
Opportunities for implementation	Regeneration harvest and prescribed fire (including wildfire for ecological benefit) in areas where feasible	The Ashley National Forest has the highest potential for serotinous LP collections in the Uintas and Wasatch Front	Forest Inventory and Analysis
Comments	The north slope of the Ashley National Forest currently has an overabundance of younger age classes	The Uinta-Wasatch-Cache National Forest has limited LP cone serotiny; the Manti-La Sal National Forest does not have LP	---
Sensitivity to climatic variability and change: Reduced water availability will affect the fringe of persistent aspen community types			
Adaptation strategy/approach: Focus on areas where persistent aspen communities are expected to expand and maintain communities where future climatic conditions will allow			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Remove competing vegetation (e.g., common juniper) and control ungulate browsing to allow for recruitment	Reduce density of conifer species	Use available mapping products to identify areas of potential expansion
Where can tactics be applied?	On fringe of existing persistent aspen communities	Outside of existing stands where persistent aspen is expected to expand	Areas adjacent to existing persistent aspen
Opportunities for implementation	Passive management; limited use of cultural treatments, prescribed fire, and fencing	Focus on active management: cultural treatments and prescribed fire	Work with other disciplines to identify potential areas of expansion (e.g., soils, range)
Comments	Scale of treatments needs to be large enough to mitigate effects of ungulates	Where parent material will support persistent aspen (e.g., fine-textured calcareous soils)	Use existing data sources

Table 7A.3 (continued)—Forest vegetation adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: Climate change may lead to a reduction in the spruce-fir component in subalpine spruce-fir forests, which will be exacerbated by current spruce beetle outbreaks			
Adaptation strategy/approach: Maintain species and age-class diversity			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Regeneration treatments (e.g., harvest, prescribed fire) that focus on maintaining species diversity; plant a variety of species including Engelmann spruce, Douglas-fir, and LP	Collect seed that will cover a wide range of seed zones and species	Plant a genetically diverse mix based on adaptive traits
Where can tactics be applied?	Forest and adjacent landowners	Forest and adjacent landowners	Forest and adjacent landowners
Opportunities for implementation	Timber harvest and prescribed fire in areas where feasible	Areas that still have viable seed sources	Refine seed zone maps based on expected genetic adaptation

Table 7A.4—Forest vegetation adaptation options developed at the Plateaus subregion workshop.

Sensitivity to climatic variability and change: Lack of disturbance has caused shifts in species composition and structure in dry mixed conifer forests, putting them at risk of high-severity fire with climate change			
Adaptation strategy/approach: Maintain and restore species and age-class diversity			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Identify and map highest risk areas at the landscape level to provide context for prioritization	Reduce stand density and shift composition toward species that are more fire adaptive and drought tolerant	Restore age-class diversity while protecting legacy trees
Where can tactics be applied?	All lands	Prioritize highest risk stands in terms of fire, insects, and disease	Prioritize, in terms of fire, insects, and disease, the highest risk stands that currently contain a component of legacy trees
Opportunities for implementation	Integration with other resources (e.g., wildlife, aquatics, fire and fuels)	Cultural treatments and prescribed fire	Cultural treatments and prescribed fire
Comments	Will accept and recognize anticipated elevational shifts in species	Insect prevention and suppression treatments	Thin prior to prescribed fire to reduce risk of losing legacy trees

Appendix 8—Nonforest Vegetation Adaptation Options Developed for the Intermountain Adaptation Partnership Region

The following tables describe climate change sensitivities and adaptation strategies and tactics for nonforest vegetation, developed in a series of workshops as a part of the Intermountain Adaptation Partnership (IAP). Tables are organized by subregion within the IAP. See Chapter 14 for summary tables and discussion of adaptation options for nonforest vegetation.

Table 8A.1—Nonforest vegetation adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Climate change may result in a loss of sagebrush ecosystems (Wyoming, mountain big, basin sagebrush species)			
Adaptation strategy/approach: Improve resilience and resistance of sagebrush ecosystems			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Control invasive species affecting ecology of sagebrush ecosystems, by minimizing spread and using biological controls, herbicides, and mechanical treatments	Maintain native perennials by: utilizing for restoration (planting) native seed sources that will be adapted to future climate conditions; using fuelbreaks and grazing strategies; fencing for protection; and modifying grazing strategies to allow for flexibility on season of use	Map resilience and resistance to climate change to aid in prioritizing areas for treatments
Where can tactics be applied?	Prioritize and implement in areas with high probability of treatment success; also implement in high-value areas	Prioritize and implement in areas with high probability of treatment success; also implement in high-value areas	Across all areas using soil, vegetation, and existing information; utilize sagebrush resilience and resistance rating criteria
Opportunities for implementation	State and County weed management agreements; include in forest and allotment management plans	In postfire rehabilitation, oil and gas restoration sites, transportation and infrastructure, and allotments	In forest planning assessments, and allotment management plans
Comments	Need better monitoring and all-lands partnering	Need better monitoring and all-lands partnering	Need better monitoring and all-lands partnering
	Specific tactic – D	**Specific tactic – E**	
Tactics	Develop seed zones and promote propagation of native seed sources for sagebrush ecosystems	Adapt grazing management to changing climates and ecological potential	
Where can tactics be applied?	Regionwide seed zone mapping	Allotments where soils and hydrology support future sagebrush ecosystems in a warming climate (see resilience and resistance mapping tactic)	
Opportunities for implementation	Collaborate with State, other Federal agencies, nurseries, nongovernmental organizations, and private companies, prioritizing species for propagation	Prioritize sagebrush systems that have potential to maintain ecological components for listed or potentially listed species	

Table 8A.2—Nonforest vegetation adaptation options developed at the Plateaus subregion workshop.

Sensitivity to climatic variability and change: Climatically suitable habitat for persistent pinyon-juniper ecosystems may be lost			
Adaptation strategy/approach: Maintain and restore ecological integrity of persistent pinyon-juniper communities			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Identify and map persistent pinyon-juniper communities (versus encroached pinyon-juniper) and assess current conditions	Reduce invasive species; maintain or restore native understory composition	Maintain or restore structural diversity to promote natural disturbance regimes
Where can tactics be applied?	All lands	At-risk persistent communities	At-risk persistent communities

Table 8A.3—Nonforest vegetation adaptation options developed at the Great Basin and Semi Desert subregion workshop.

Sensitivity to climatic variability and change: Sagebrush (Wyoming, mountain big, basin sagebrush species) ecosystems may be lost to annual grasses			
Adaptation strategy/approach: Improve resilience and resistance of sagebrush ecosystems			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics:	Map resilience and resistance to climate change (specific to annuals) to aid in prioritizing areas for treatments. Where can we make a difference in the short term?	Protect refugia; if annual grasses are not present, keep them out through repeat monitoring (of experiments with controls), education, seed collection, and genetic analysis	Manage sagebrush to resist invasion of annuals; conduct: 1. Education 2. Targeted grazing (not changing permittee) 3. Invasive species control by minimizing spread and using biological controls, herbicides, and mechanical treatments 4. Maintenance of native perennials by: utilizing for restoration (planting) native seed sources that will be adapted to future climate conditions; using fuelbreaks and grazing strategies; fencing for protection; and modifying grazing strategies to allow for flexibility on season of use
Where can tactics be applied?	---	---	---
Opportunities for implementation	---	State and County weed management agreements; include in forest and allotment management plans	Postfire rehabilitation; oil and gas restoration sites; transportation and infrastructure; allotments
Comments	This is the first step; then other tactics can be implemented	Need better monitoring and all-lands partnering	Need better monitoring and all-lands partnering
Sensitivity to climatic variability and change: Sagebrush (Wyoming, mountain big, basin sagebrush species) ecosystems may be lost to annual grasses			
Adaptation strategy/approach: Improve resilience and resistance of sagebrush ecosystems			
	Specific tactic – D	**Specific tactic – E**	**Specific tactic – F**
Tactics	If annual grasses are present, adapt and make use of it; talk with other regions, such as Region 5, to share ideas; conduct research; consider nurse crops, especially after fire	Develop seed zones and promote propagation of native seed sources for sagebrush ecosystems	Adapt grazing management to changing climates and ecological potential
Where can tactics be applied?	Across all areas using soil, vegetation, and other existing information; utilize sagebrush resilience and resistance rating criteria	Regionwide seed zone mapping	Allotments where soils and hydrology support future sagebrush ecosystems in a warming climate (see resilience and resistance mapping tactic)
Opportunities for implementation	In forest planning assessments, and allotment management plans	Collaborate with State, other Federal agencies, nurseries, nongovernmental organizations, and private companies, prioritizing species for propagation	Prioritize sagebrush systems that have potential to maintain ecological components for listed or potentially listed species
Comments	Need better monitoring and all-lands partnering		

Appendix 9—Ecological Disturbance Adaptation Options Developed for the Intermountain Adaptation Partnership Region

The following tables describe climate change sensitivities and adaptation strategies and tactics for ecological disturbance, developed in a series of workshops as a part of the Intermountain Adaptation Partnership (IAP). Tables are organized by subregion within the IAP. See Chapter 14 for summary tables and discussion of adaptation options for ecological disturbances.

Table 9A.1—Ecological disturbance adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: More wildfires will occur with warmer, drier conditions			
Adaptation strategy/approach: Conduct postfire restoration and manage postdisturbance response			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Identify, prioritize, and protect values at risk; initiate programs to assess values and determine best protection actions; resources include soil, water, infrastructure, and vegetation for mass wasting prevention	Prefire planning to improve response time and efficiency; prioritizing key areas at risk to geologic hazard and other areas at risk (e.g., infrastructure, threatened and endangered species habitat, areas that may compromise public health and safety and water supply)	Conduct postfire vegetation management and prevent invasive species
Where can tactics be applied?	Needs to be done at forest level, as it will be dictated by local needs; focus on areas threatening public health and safety	Needs to be an all-lands approach; for Forest Service, both forests and districts need to be involved	In key areas identified in preplanning and BAER; needs to be an all-lands approach; for Forest Service, both forests and districts need to be involved
Opportunities for implementation	Postfire; initiate immediate response for physical resources (Burned Area Emergency Response [BAER]); identify values with non-Forest Service stakeholders	Conduct a GIS exercise to identify focal areas for soil stabilization; identify key cold-water refugia (use fish assessment information)	Postdisturbance; if planned ahead of time, fire (and the funding) can be used in a strategic way to improve ecological and other conditions, and public perception and understanding
Comments	---	Need a long-term plan for fire response and restoration; need to take a more strategic approach instead of waiting until after event occurs	Needs to be climate-smart and consider what is appropriate for a given niche

Table 9A.1 (continued)—Ecological disturbance adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Climate change may result in increased mortality due to native insects and diseases (bark beetles, defoliators, and dwarf mistletoes)			
Adaptation strategy/approach: Increase resistance and resilience to beetles in stands and landscapes			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Manage for age- and size-class diversity	Protect high-value areas with trap tree felling, beetle traps, spraying, reduced basal area, beetle risk rating, and pheromones	Manage for species diversity
Where can tactics be applied?	High-value landscapes with low size-class diversity; limited to where there is access	High-value areas	High-value landscapes with low species diversity (especially in monotypic areas); limited to where there is access
Opportunities for implementation	Merchantable timber areas, since there is a need for markets to pay for treatments; this may depend on species and quality (size, form); need to consider ecosystem services to get partner buy-in; biomass energy is a value-added product	Can be applied near campgrounds and other infrastructure and in the wildland-urban interface; can also be applied in seed orchards, progeny areas, and genetically resistant trees (whitebark pine)	In forest-type transition areas; needs to be an all-lands approach and include Counties, States, and residents
Comments	Need for the right timing, public education, and the right activities in the right places; mechanical treatments are limited; there are supply issues	Maintenance necessary; timing is important; need to monitor beetle populations to know when to do things; how do we do this with partners?	May provide opportunities for assisted migration; mechanical treatments are limited; how do we do this with partners?

Table 9A.1 (continued)—Ecological disturbance adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: More people residing in the forest environment will increase stresses to ecosystems, infrastructure, and biological and physical resources and will shift utilization of ecosystem services closer to the source			
Adaptation strategy/approach: Manage for the human disturbance footprint caused by higher populations of people living in forests and the forest interface			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Manage the effects of infrastructure (roads, driveways, power lines, water delivery) on Forest Service lands	Minimize increases in areas of disturbance	Manage ecological connectivity and energy flow; maintain habitat continuity and viability
Where can tactics be applied?	Apply on roads and driveways and with collaborators responsible for the whole system (e.g., the power company, County transportation department, canal company)	In and around residential and other development	Maintain natural corridors (streams, riparian) where they exist; maintain large habitat blocks; maintain habitat diversity in appropriate proximities
Opportunities for implementation	Predevelopment planning; take advantage during plan revision cycles; work with County planners—insert information (data, forest management objectives) into partner's planning process; planning for climate scenarios and avoidance of climate-associated disturbance events	Awareness; work with partners generally receptive to the message (minimize footprint)	Collaborate with wildlife protection groups (e.g., Rocky Mountain Elk Foundation, Wild Turkey, Trout Unlimited), recreation groups, and collaborative groups; identify important habitats and corridors
Comments	Also consider emergency services	There are secondary effects such as an increase in impervious surfaces, introduction of ornamental or invasive plants and livestock, pet conflicts with native wildlife, and groundwater drawdown; the extended human footprint is larger than ground disturbance	Consider pretreatment and posttreatment monitoring

Table 9A.2—Ecological disturbance adaptation options developed at the Southern Greater Yellowstone subregion workshop.

Sensitivity to climatic variability and change: Higher elevation fuels will be more available to burn, and more frequent fire will occur at higher elevations			
Adaptation strategy/approach: Increase resilience in vegetation types at high elevations			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Increase heterogeneity through prescribed fire	Conduct fire behavior and spatial modeling to identify high-priority areas to break up or maintain fuels	Manage vegetation through silvicultural means (prescribed fire, thinning, daylighting/radial thinning)
Where can tactics be applied?	Supportive wildland-urban interface (WUI) areas; wilderness areas, roadless areas; large continuous patches	All lands, across jurisdictional boundaries; high-value areas and highest risk comparison	High-value areas
Opportunities for implementation	Stanley Wildfire Collaborative; Farm Bill provisions	Same as above	---
Comments	Note differences and challenges by elevation, and by wilderness versus non-wilderness versus WUI	Calibration in models to accommodate observed and future fire behavior	Access, as well as funding, may be a key challenge; need to consider high-value habitat for species (lynx amendment) that require high-elevation forest
Sensitivity to climatic variability and change: More area will burn over a longer fire season			
Adaptation strategy/approach: Increase and maintain moderate fire danger conditions on the landscape			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Increase education to public on the role of fire on the landscape (fire today could save your home tomorrow)	Revise Forest Plan to incorporate managed fire for resource objectives	Limit potential for invasive establishment that may increase with increased fire through pretreatments and posttreatments, weed control, and monitoring
Where can tactics be applied?	Across the region	Fire-adapted landscapes (i.e., native plant communities, seed sources, multiple age classes to maintain diversity, homes with defensible space)	Transition zones between different ecotypes; south-facing slopes; along road corridors; high-elevation grazing; campgrounds
Opportunities for implementation	Use forest coalitions and collaboratives, fire protection districts and cooperators, Idaho Conservation League, The Nature Conservancy (TNC)	Use forest coalitions and collaboratives, fire protection districts and cooperators, Idaho Conservation League, TNC	Invasive species program managers, native plant and seed societies, researchers
Comments	Challenges: smoke, outreach delivery to the public	Need to avoid negative effects on other resources (i.e., water quality)	

Table 9A.2 (continued)—Ecological disturbance adaptation options developed at the Southern Greater Yellowstone subregion workshop.

Sensitivity to climatic variability and change: Invasive insects will likely continue to affect native trees in the future.			
Adaptation strategy/approach: Increase resilience and resistance of trees to invasive insects			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Develop an integrated pest management strategy, including identifying insect-resistant seed (balsam woolly adelgid)	Identify current and projected distribution of balsam woolly adelgid and other species	Identify and monitor other nonnative, invasive insects (i.e., spruce aphid, spruce fir looper) not currently present in the region but that may be a future risk
Where can tactics be applied?	True fir communities: subalpine	True fir communities; regionwide; areas where loss of subalpine fir would be ecologically significant	Regionwide
Opportunities for implementation	Biological and insecticide controls; phenotypic and genotypic seed identification and collection; tree gene conservation and diversity; possibly incorporate into project-level forest documents/guidelines; Farm Bill landscape-level analyses	Network of monitored plots to identify connections between insects and wildfire; research community, Forest Service Pacific Northwest Research Station, fire ecologists, entomologists	APHIS, detection and monitoring programs, invasive and disease action plans that prioritize targets for rapid response
Comments	Already present in the region and distribution is currently climate-limited but may expand range under warming conditions		Southwestern species that may expand range into region and may stress trees
Sensitivity to climatic variability and change: Disturbances may interact to affect postdisturbance processes			
Adaptation strategy/approach: Increase postdisturbance planning, management, and implementation			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Create a strategy and criteria to prioritize areas that are more likely to recover (i.e., critical habitats, population served by disturbed habitat, recovery likelihood)	Promote climate-adapted species (i.e., disturbance resistant or resilient) and genotypes; build seed banks for habitats that do not exist on the landscape yet	Identify sites more susceptible to compounding disturbances (i.e., dry fuel loads + beetle kills + invasives + geologic hazard); monitor occurrence and prioritize seed sources to preserve some sites; conduct spatial mapping of sites across landscape; implement proactive treatments of areas more resistant to disturbance
Where can tactics be applied?	Disturbed areas	May need to consider planting in wilderness	---
Opportunities for implementation	See Terrebonne Parish, Louisiana example of systematic prioritization of sites for restoration	Douglas-fir; included in Burned Area Emergency Response process	Forest Inventory and Analysis network of plots to look at compounding disturbances; Research
Comments	Impacts of "no action" option postdisturbance; adaptive and flexible strategies and criteria under future conditions	Challenges of seed translocation policies	---

Table 9A.3—Ecological disturbance adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: Increased mortality due to bark beetles will occur in a warming climate			
Adaptation strategy/approach: Increase resistance and resilience to beetles in stands and landscapes			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Manage for age- and size-class diversity	Protect high-value areas by trap tree felling, beetle traps, spraying, reduction of basal area, beetle risk rating, etc.	Manage for species diversity
Where can tactics be applied?	High-value landscapes with low size-class diversity	High-value areas	High-value landscapes with low species diversity (especially in monotypic areas)
Opportunities for implementation	Merchantable timber areas; need markets to pay for treatments; this may depend on species, quality (size, form)	Near campgrounds, other infrastructure, wildland-urban interface (WUI)	In forest-type transition areas
Comments	Timing, public education, right activities, right places	Maintenance necessary; timing is important; need to monitor beetle populations to know when to take action	May provide opportunities for assisted migration
Sensitivity to climatic variability and change: More wildfires will occur with warmer, drier conditions			
Adaptation strategy/approach: Reduce the adverse effects of fire in the WUI and other non-negotiable values while allowing fire to play a natural role on the landscape			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Identify, prioritize, and protect values at risk; programs assess values and determine best protection actions	Reduce fuels in systematic locations; some treatments may be out of natural range of variation to protect values; strategic placement of fuels treatments to manage for wildfire in an ecologically appropriate way depending on vegetation types	Develop communications strategy to determine what needs to happen where, and before fires occur (e.g., need to know when it is acceptable to let fires cross boundaries and when it is not); all partners need to be involved—it is not just a Forest Service or Federal problem
Where can tactics be applied?	Needs to be done at national forest level as it will be dictated by local needs; for example, a campground may require prevention education or "hardening strategies" (fireproof structures); isolated communities in high-risk locations may require well-developed communication strategies	WUI; strategic locations; look at management boundaries (wilderness), topography, dominant winds	Needs to be an all-lands approach: Counties, States, residents, Bureau of Land Management, National Park Service, etc.; for Forest Service, both forests and districts need to be involved
Opportunities for implementation	National forest level; Forest Plans; site-specific National Environmental Policy Act analysis; identify values with non-Forest Service stakeholders	Coordination between Fuels/Fire and all other resource managers; coordination with local agencies, private sector, etc.	Build off principles of National Cohesive Wildland Fire Management Strategy; this is underway already
Comments		Need long-term plan for fuels management and maintenance; what is best way to protect the resource/value?	If planned ahead of time, fire (and the funding) can be used in a strategic way to improve ecological and other conditions, and public perception and understanding

Table 9A.3 (continued)—Ecological disturbance adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: High-water events will occur with higher intensity and frequency and with different timing			
Adaptation strategy/approach: Identify and prioritize threatened values (infrastructure and ecological) and mitigation activities			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Move it; for example, move campground out of floodplain	Modify it; for example, replace low-flow culvert with larger culvert; floodproof campground structures; increase roughness to reduce velocity and improve safe sites for desired species during floods	Forget it; for example, permanent or seasonal closures of campground; no new structures in floodplains to allow for natural channel movement
Where can tactics be applied?	Stream and waterway corridors; where there are safety concerns or very economically important values	Stream and waterway corridors; where there are safety concerns or very economically important values	Stream and waterway corridors; where there are safety concerns; lower priority areas
Opportunities for implementation	Where there is overlap in values with partner agencies that have funding	Engineer to more extreme events (from 50-year flood specifications to 500-year flood)	Wherever Forest Service identifies a lower priority and where partnership opportunities are limited
Comments	---	---	Public communication and feedback will be issue; public may not see how these issues affect their values until flood occurs

Table 9A.4—Ecological disturbance adaptation options developed at the Southern Great Basin and Semi Desert subregion workshop.

Sensitivity to climatic variability and change: More fire will occur on the landscape			
Adaptation strategy/approach: To protect values on the landscape, allow for more managed fire to reduce available fuel loadings			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Develop understanding or products that help managers and line officers make decisions on managing long-duration fires; incorporate information learned into the Wildland Fire Decision Support System	Utilize a risk-benefit model to identify key locations where fuels modifications would benefit the potential use of managed fire (basically a fire behavior modeling exercise)	Find opportunities to work with partners to expand use of natural fire ignitions (develop greater support network of collaborators)
Where can tactics be applied?	Anywhere on the landscape	All of our fire-prone landscapes	Lands adjacent to local communities
Opportunities for implementation	Opportunities may at first be limited, but the hope is that the available landscape opens up through time	Align with other land management activities or other collaborative efforts; where it would help move toward desired condition	Develop opportunities where there is alignment in the landscapes and social acceptance or willingness to support the use of fire
Comments	Goal of this is to better articulate the benefits of managing a fire event now versus putting it off to the future and balancing the ecological and social benefits of fire	Goal is to prioritize and identify key strategic locations for fuels treatment that would enhance the ability to manage natural ignitions	Goal is to build local support for fire on the landscape and to develop and recognize the benefits and risks that can be realized; use this to help inform fire management decisionmaking
Sensitivity to climatic variability and change: Increased stress on rangeland resources will occur due to less forage production capability from managed and unmanaged ungulate use			
Adaptation strategy/approach: Look for options to improve range condition			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Look at options for changing turnout dates to capture the green-up phase of cheatgrass	Explore options for assisted migration of southern grasses, through either seed zone modifications or enhancement of genetic drift (hybridization)	In a collaborative setting, explore options to reach optimal feral horse numbers
Where can tactics be applied?	Locations that have abundant cheatgrass and that do not have other issues (e.g., threatened and endangered species)	Areas of critical habitat	Areas of critical habitat
Opportunities for implementation	May have limited options	Focus on favorable climate situations or suitable habitats for success	Remain opportunistic on locations where cooperators would be interested
Comments	Goal is to capture the ecosystem service; may be a tool to help with the conversion to native species	Goal is to improve the drought and grazing tolerance of range forage species	This is a controversial topic but an important consideration when thinking about long-term management of both the horses and native species

Appendix 10—Terrestrial Animal Adaptation Options Developed for the Intermountain Adaptation Partnership Region

The following tables describe climate change sensitivities and adaptation strategies and tactics for terrestrial animals, developed in a series of workshops as a part of the Intermountain Adaptation Partnership (IAP). Tables are organized by subregion within the IAP. See Chapter 14 for summary tables and discussion of adaptation options for terrestrial animals.

Table 10A.1—Terrestrial animal adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Food web and nutrient flows will be affected by changing climate			
Adaptation strategy/approach: Maintain resilient flow, sedimentation, and thermal regimes			
	Specific tactic – A	**Specific tactic – B**	
Tactics	Reduce fine sedimentation and substrate embeddedness	Restore anadromous fish runs (or carcass analogs)	
Where can tactics be applied?	Basins with high road density and where roads are directly adjacent to stream channels	Former anadromous fish habitats where migrations are blocked	
Opportunities for implementation	---	Fish passage past dam that precludes migrations	
Comments	Mitigate adverse effects of sedimentation on macroinvertebrate communities	---	
Sensitivity to climatic variability and change: Colonization and expansion of invasive species may occur with climate change			
Adaptation strategy/approach: Monitor for invasive species and suppress/eliminate/control populations			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Environmental DNA (eDNA) monitoring for early detection of river and stream invasions.	Reduce or suppress brook trout populations	barriers that prevent access to invasion or invasion of conservation populations in headwaters
Where can tactics be applied?	High-value populations that are thought to be at significant risk of invasion	Headwater lakes that act as source populations; small, isolated streams where complete eradication is possible	Southern portions of IAP region where stream habitats are smaller and more fragmented
Opportunities for implementation	---	Prioritize among hundreds (thousands?) of headwater streams and lakes across the IAP region	Small headwater streams where barrier construction is cost effective and possible
Comments	Costs of eDNA sampling are low enough to make this broadly applicable	Expensive and risky to implement; public support needed for success.	Less useful tactic in areas with anadromous species or fluvial populations of bull trout or cutthroat trout

Table 10A.1 (continued)—Terrestrial animal adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Colonization and expansion of invasive species may occur with climate change (continued)		
Adaptation strategy/approach: Monitor for invasive species and suppress/eliminate/control populations		
	Specific tactic – D	**Specific tactic – E**
Tactics	Implement monitoring and boat inspection programs to detect invasive mussel and aquatic plants species in lakes before populations are established	Conduct early-in-life education and educate during the initial stages of invasion (proactive crisis aversion)
Where can tactics be applied?	State borders and near-lake access points (e.g., Sawtooth NF) (e.g., 100th Parallel Initiative)	Schools (e.g., Trout Unlimited's Trout in the Classroom)
Opportunities for implementation	Near high-value resources where funding makes additional staffing possible	Early life experiences to create strong negative attitudes toward invasive species and teach value of native species

Sensitivity to climatic variability and change: Native species distributions will shift, and community realignments will occur with changing climate			
Adaptation strategy/approach: Conduct biodiversity surveys to describe current baseline conditions and manage distribution shifts			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Formalize, expand, and standardize biological monitoring programs (e.g., Management Indicator Species)	Use modern, low-cost technologies such as eDNA/DNA barcoding and digital photopoints	Implement assisted migrations
Where can tactics be applied?	Streams, rivers, lakes throughout IAP region	Streams, rivers, lakes throughout IAP region	Suitable but currently unoccupied habitats; consider habitats outside of historical range (e.g., northern extent of species distributions) in addition to historical range
Opportunities for implementation	---	---	Climate Shield fish model can be used to identify high-probability habitats; eDNA used to confirm species presence or absence; then move fish into high-probability areas based on current and future climate forecasts
Comments	Boise NF, Sawtooth NF, and Salmon-Challis NF have rotating panel monitoring designs that provide good templates because broad-scale status and local trend information is represented	New genomic techniques and technologies are inexpensive and make broad applications more feasible than previously	This is a controversial tactic and care is needed to do it properly; if threatened and endangered species are present, there are permitting procedures that must be followed; considerations about whether the system had fish historically or not (e.g., geologic barriers to suitable habitats); if it is a listed species, we may need to designate it as an "experimental population" to be politically feasible

Table 10A.1 (continued)—Terrestrial animal adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Native species distributions will shift, and community realignments will occur with changing climate (continued)			
Adaptation strategy/approach: Conduct biodiversity surveys to describe current baseline conditions and manage distribution shifts			
	Specific tactic – D	**Specific tactic – E**	**Specific tactic – F**
Tactics	Use digital technology in data collection and database uploads	Streamline and integrate field crew data collection protocols	Fully utilize existing corporate databases and legacy datasets
Where can tactics be applied?	Everywhere	Everywhere	Everywhere
Opportunities for implementation	Field computers for recording data digitally in standardized formats	One crew measures multiple parameters instead of five crews measuring one parameter	File cabinets need to be opened and technicians assigned to data entry task; huge value added by making existing datasets usable
Comments	Technical support staff members are key and need to be well integrated with resource experts	Could some terrestrial and aquatic parameters be measured by same crews?	

Table 10A.2—Terrestrial animal adaptation options developed at the Southern Greater Yellowstone subregion workshop.

Sensitivity to climatic variability and change: Climate change and fire regime shifts will affect persistence of mid- and late-successional sagebrush (affecting sage-grouse, sage thrasher, Brewer's sparrow, pygmy rabbit)			
Adaptation strategy/approach: Determine most appropriate management strategies to reduce conifer encroachment			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Determine whether future fire is moving toward or away from historical regime; where we suspect fire regimes are departed from historical, allow wildfires to burn for resource benefit	Use mechanical means to reduce pinyon-juniper; use fire to improve habitat for fire-positive species	Consider future climate envelopes of sagebrush when determining action (avoid investment in managing for sagebrush where it is unlikely to persist)
Where can tactics be applied?	Areas that do not have sage-grouse habitat and where there are few concerns about invasive species	Mechanical treatment where prescribed fire cannot be used	Engage restoration efforts and future investments for sagebrush where future climate is likely to support sagebrush communities; establish alternative plans for areas not likely to support persistent sagebrush
Opportunities for implementation	Areas where natural ignition occurs; condition (conifers encroaching?) and community type (e.g., mountain sagebrush) will determine whether fire will benefit	Already approved tactic for prescribed fire based on precipitation; fire for >12 inches diameter; only mechanical for <12 inches	Consider utility of landscape approach and seek cooperators
Comments	Tradeoff between fire and pinyon-juniper encroachment; increased fire is not always negative (e.g., mountain sagebrush); consider implications of increased fire for invasive species	---	Potentially engage Bureau of Land Management in burning and seeding activities

Table 10A.2 (continued)—Terrestrial animal adaptation options developed at the Southern Greater Yellowstone subregion workshop.

Sensitivity to climatic variability and change: Climate change will have negative effects on amphibians (yellow-legged frogs, Columbian spotted frogs, boreal toad)			
Adaptation strategy/approach: Maintain integrity and quality of remaining habitats or habitats that may become suitable as temperatures increase			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Manage for other related stressors: Maintain healthy forests, rangeland, riparian habitat near current or future core habitats; consider land use (e.g., road concentration)	Restore beavers and aspen; provide woody browse; consider restoring willow	Minimize diversion of flow through water range improvement
Where can tactics be applied?	Core areas identified through recent Bridger-Teton capable habitat modeling exercise and inventory work	1. Determined through modeling exercises of where beaver have occurred (e.g., sedimentation studies) 2. Determine where it would be socially acceptable to reintroduce beaver (e.g., prevent undesired consequences such as flooding of campground) and restore aspen 3. Determine where aspen restoration might be feasible 4. Prioritize on areas that may represent future habitat	As determined in tactics A (core areas) and B (feasible areas)
Opportunities for implementation	Determine opportunities through additional modeling exercises to determine future habitat (e.g., higher elevation)	Collaborate with ongoing beaver restoration project; collaborate with ongoing aspen restoration efforts (ongoing with many partners); consistent with Planning Rule that talks about natural range of variation; address this tactic in the Bridger-Teton Forest Plan revision process.	Start with any new range improvements or other water developments; areas where we are currently reconstructing range improvements
Comments	Stressors: disease, motorized routes, camping, reservoirs, water quality, sedimentation, introduced fish, fire, livestock grazing, timber harvest	Aspen restoration has implications for many ecosystem functions far beyond current tactic goals	---

Table 10A.3—Terrestrial animal adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: Higher temperatures will alter timing of life history events (e.g., breeding, dispersal, pelage change)			
Adaptation strategy/approach: Identify species where phenology mismatches are relevant, identify areas where phenology difference is currently minimal and is likely to be minimal into the future, prioritize those areas for protection, and manage for habitat resilience; scale: Protect and restore large enough areas to be relevant to the population			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Maximize habitat quality and availability so the population is more resilient, which may help minimize impact of phenology mismatch	In areas that remain matched, prioritize those areas for protection	Identify areas that will become matched in the future and maintain and promote connectivity so animals can migrate to the new habitats; also consider facilitated migration where appropriate
Where can tactics be applied?	Prioritize restoration resources where habitats are optimal or on the leading edge of range shift	Where it remains good habitat	Where it is becoming suitable habitat
Opportunities for implementation	Use a variety of methods to protect, maintain, or restore habitats where appropriate to increase resilience	During forest planning, conduct assessments to identify remaining high-quality habitats most likely to stay matched with phenology; protect these areas in forest plan land management prescriptions	Assess where habitat quality is likely to increase and become matched with phenology, manage to facilitate habitat improvements, and protect in forest plan
Comments	Monitor the most susceptible species to validate population response to these management actions	---	Assisted migration is a last resort; allowing natural migration by maintaining connectivity is preferred

Table 10A.3 (continued)—Terrestrial animal adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: Changing intensity and frequency of fire regimes will decrease area and connectivity of some habitats, notably late-successional and mature forest and big sagebrush			
Adaptation strategy/approach: Maintain current habitat, restore historical habitat, promote potential future habitat, and increase resilience of these habitats and surrounding habitats			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Strategically place fuel breaks to minimize risk to important habitat areas	Restore disturbance regimes by reducing accumulated fuel loads	Identify areas in the future that will have the disturbance regimes characteristic of late-successional and mature forests and big sagebrush, and manage to promote their development and resilience
Where can tactics be applied?	Strategically place on the windward side of important habitat areas; place in a configuration to minimize risk of fire spread across the landscape.	Within the habitats where uncharacteristic fuel loads have developed, and balanced with other objectives for species dependent on a complex understory	Identify where disturbance regimes associated with your target habitat will shift, and focus restoration on those areas and connectivity to those areas
Opportunities for implementation	Anywhere these habitats are identified and a break in fuel continuity is needed	Using prescribed fire and fire surrogates to create the conditions to replicate historical frequency and intensity	In areas that are prone to native type conversions resulting from changing ecological conditions
Comments	Species that use late-seral or mature stand characteristics	Recognize that these treatments will cause a short-term impact for long-term benefits	Policy change needed
Sensitivity to climatic variability and change: Increased duration and periodicity of drought and reduced soil moisture will stress vegetation and aquatic wildlife species			
Adaptation strategy/approach: Restore and enhance water resource function and distribution at the appropriate watershed scale; prioritize watersheds based on condition and a variety of resource values, including wildlife			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Reduce biomass to reduce evapotranspiration and mortality resulting from water stress for groundwater-fed systems (thinning and other vegetation treatments) and maintain shade for nongroundwater-fed systems.	Increase water storage by managing for beaver populations using a comprehensive beaver strategy (minimizing conflicts, such as by reducing cattle impacts on small water sources)	Provide enhanced water distribution with appropriate wildlife use designs and balance water use with wildlife needs; protect headwaters, spring heads, riparian areas, etc.
Where can tactics be applied?	Suggested scale of Hydrologic Unit Code 8 to 12 based on assessment for watershed prioritization	Riparian areas where conditions are appropriate (presence of aspen and willow) and conflict will not result (culvert damage, flooding roads)	Areas where there is concern about amphibian populations and other wildlife species dependent on water sources
Opportunities for implementation	Integrated approach with multiple resources (hydrology, fisheries, range, wildlife, etc.)	Partnerships with State, County, water districts, nongovernmental organizations; need public education to foster acceptance	Coordination with range staff; use volunteers to help create ponds and alternative water sources

Table 10A.3 (continued)—Terrestrial animal adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: Altered disturbance regimes and water availability and increasing temperatures will continue to facilitate the spread of invasive plant species			
Adaptation strategy/approach: Use an integrated approach to prevent the spread and establishment of invasive species			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Use rapid response to treat and restore newly invaded areas to prevent establishment	Enhance the resistance and resilience of native plant communities by maintaining vigorous growth of native shrub, perennial grass, and other perennial species through restoration activities, appropriate grazing techniques, and fire management treatments	Use integrated pest management to control established infestations, including biocontrol, herbicides, and ecological competition
Where can tactics be applied?	Identify susceptible areas through modeling and monitoring to allow for rapid response	Grazing allotments and known areas of healthy native plant communities	Areas known to be infested
Opportunities for implementation	Educate field employees and public to identify and report invasive occurrence	In areas departed from historical fire regime or identified through watershed assessment and range monitoring	Ongoing annual program of work and partnerships

Table 10A.4—Terrestrial animal adaptation options developed at the Plateaus subregion workshop

Sensitivity to climatic variability and change: Climate change will result in shifts in alpine species composition (of both plants and animals, e.g., spruce-fir encroachment, rodents, humans) due to shrinking snowpack, changes in timing of snowmelt, and increasing temperatures that allow species to move up into alpine ecosystems; species affected include pika, endemic plants, pollinators, and black rosy finch			
Adaptation strategy/approach: Reduce additional stressors in alpine habitats			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Manage human access (e.g., build trails, harden sites, use permit systems or outfitter guides)	Maintain mountain goats at populations that eliminate adverse impacts (remove goats if needed and discourage continued introduction of goats)	Monitor movement of plants (including both conifers and exotic weeds) and monitor movement of treeline
Where can tactics be applied?	Alpine trailheads; areas of high use (e.g., La Sals)	La Sals, Tushars, Mt. Dunton, Ashley NF	Everywhere habitat is present
Opportunities for implementation	Work with recreation staff; consider in development of new forest plans	Work with Utah Division of Wildlife Resources (DWR)	Ongoing treeline study
Sensitivity to climatic variability and change: Climate change will lead to changes in wetland habitat quantity and quality			
Adaptation strategy/approach: Maintain connectivity and habitat quality to promote resilience of wetland habitats			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Actively restore and protect functioning wetlands	Reintroduce beaver; expand or restore habitat where appropriate	Manage grazing to promote good riparian cover and properly functioning riparian habitats
Where can tactics be applied?	All perennial streams	Southeastern Utah; everywhere beavers were historically present	All grazed public lands with perennial streams
Opportunities for implementation	Work with State division of water rights, Utah DWR, conservation groups like Trout Unlimited, and the State watershed restoration initiative	DWR statewide beaver conservation and management plan; State and DWR wildlife action plan	Collaborative groups; grazing permit renewals; sage-grouse land use plan amendments
Comments	Identify, map, and assess important habitats; identify data gaps across all lands; this is relevant for all of the resource areas		

Table 10A.4 (continued)—Terrestrial animal adaptation options developed at the Plateaus subregion workshop.

Sensitivity to climatic variability and change: Uncharacteristic fires in ponderosa pine will result in loss of late-successional forest and snags (affects Lewis's woodpecker, Allen's big-eared bat, Abert's squirrel, northern goshawk, Utah prairie dog)			
Adaptation strategy/approach: Maintain current habitat, restore historical structure, and increase mosaic structure (including snags)			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Conduct thinning and prescribed fire treatments; use thinning from below; maintain natural structure with diversity, density; control ladder fuels	Manage grazing to discourage overgrazing of native plants and to maintain fine fuels to carry fire	Plant adapted (locally sourced) ponderosa pine
Where can tactics be applied?	Existing stands on public and private lands (though thinning is limited in roadless areas and wilderness)	Everywhere ponderosa pine occurs	In areas where stand-replacing fires have occurred, keeping in mind the capacity of the area to support ponderosa pine (soils and water considerations)
Opportunities for implementation	As funding is available; timber stand improvement; consider in public and private land management plans; supporting local businesses (e.g., small diameter processing mills and artisan furniture)	Collaborations (e.g., Four Forests, La Sal Sustainability Collaborative)	After wildfires
Comments	Must keep in mind the preservation of key habitat features of wildlife (e.g., snags)		
Sensitivity to climatic variability and change: Loss of mixed-age stands and loss of mature aspen and snags may occur with increased fire frequency (affects ruffed grouse, flammulated owl, goshawk, many others)			
Adaptation strategy/approach: Maintain and encourage recruitment of aspen to the overstory			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Remove conifers with prescribed fire and logging	Encourage aspen regeneration using fencing, ungulate management (reduce numbers and change season of use [graze early]), and development plans like that implemented by Wolf Creek Ranch (works closely with Wild Utah Project)	Conduct public outreach to help manage for aspen snags; restrict firewood cutting; target information toward ranchette owners; include aspen in public education; use "this is a wildlife home" signs and similar
Where can tactics be applied?	Forest, State, and private lands that are being encroached by conifers	Anywhere	Schools and anywhere
Opportunities for implementation	Monroe Mountain (collaboration on aspen, environmental assessment yet to be implemented)	La Sal Sustainability Collaborative (LSSC)	Southern Utah National Parks, ongoing social media communications, citizen science activities
Comments	---	Must consider both wildlife and livestock	---

Appendix 11—Outdoor Recreation Adaptation Options for the Intermountain Adaptation Partnership Region

The following tables describe climate change sensitivities and adaptation strategies and tactics for outdoor recreation, developed in a series of workshops as a part of the Intermountain Adaptation Partnership (IAP). Tables are organized by subregion within the IAP. See Chapter 14 for summary tables and discussion of adaptation options for recreation.

Table 11A.1— Outdoor recreation adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: There is a lack of information on the relationship between climate change and outdoor recreation			
Adaptation strategy/approach: Conduct research on visitors who are or will be coming, where they are from, what they are doing, and cultural differences and expectations			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Research all sources; research demographics related to hunting, fishing, nature viewing, hiking, roads, trails, facilities	Assimilate information into resource plans	Prepare information for specific populations that will be affected by climate change and in their respective language(s)
Where can tactics be applied?	All areas: campgrounds, trailheads, day use, wilderness	---	---
Opportunities for implementation	All resource areas		
Comments	Imperative; we do not have enough information available to ascertain specific tactics; which ethnic groups will be affected by climate change?	Lesser amounts of snow are expected	---
Sensitivity to climatic variability and change: People management: Increased flooding and fire will result in fewer recreational sites, more use of alternative campgrounds, reduced services, and increased use of fewer facilities; need flexibility in adapting to changing conditions and in moving people as needed			
Adaptation strategy/approach: Research and document existing uses			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Inventory: Use and update the Forest Service INFRA database to assure correct information is available	People management: As conditions change, move people to more desirable sites as needed; think creatively	Communication: Have clear and constant discussions with forests, and establish districts
Where can tactics be applied?	All forests and sites	Underused or new sites that may have to be utilized as weather changes and floods and fire increase; sites where season of use may change	At all levels as need arises
Opportunities for implementation	Annual and constant review of data to assure accuracy	As funding and conditions persist; changes to laws and direction may be affected; prepare for managing garbage and providing enhanced restroom amenities	Watch and monitor as climate changes
Comments	Proper training for data input	National Environmental Protection Act analysis and planning beforehand will be needed; Forest Plans will need to address these changes to be adequately prepared	Can include new technologies for quick exchange of information

Table 11A.1 (continued)—Recreation adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: Temperature changes bring changes in season, both for people and resources, and may put more pressure on cultural resources and sites (e.g., looting, collecting, inadvertent impacts from users to cultural resources)			
Adaptation strategy/approach: Educate users and protect cultural resources			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Redirect public to less sensitive cultural areas	Provide education and interpretation to inform the public about why these resources are important	Directly protect cultural resources
Where can tactics be applied?	All sites; collaborate with other agencies on strategies; National Park Service is very adept at people management	Developed and sustained sites	Specific sites
Opportunities for implementation	Divert public to more easily sustainable sites while highlighting sites that we want them to visit	Inform public of all ages about the importance of outdoor ethics and respecting outdoor resources	Physical barriers and monitoring
Comments	May need to use plantings, hardscape, etc. to divert visitors to where we want them to go; utilize engineering techniques	Explore all methods of delivery to the public	Law enforcement presence needed; engagement of tribes is vital

Table 11A.2—Outdoor recreation adaptation options developed at the Plateaus subregion workshop.

Sensitivity to climatic variability and change: Season of use, types of recreation, and location of activities may change as the climate changes			
Adaptation strategy/approach: Identify and prioritize recreation sites that are prone to change			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Use predictive modeling that incorporates changing climate conditions (e.g., precipitation, temperature)	Survey the public directly or indirectly to determine use patterns, sensitivity to changing climate patterns, trends	Educate the public about likely impacts of changing recreational opportunities
Where can tactics be applied?	During long-term planning processes to identify potential user versus user conflicts (e.g., nonmotorized versus motorized winter use)	National Visitor Use Monitoring, trail counters, Web-based tools	Focus on national forest locations or sites in which changes are occurring (e.g., pine beetle infestations)
Opportunities for implementation	In high-use locations; use information and data from other agencies (e.g., National Park Service)	Collect data from user groups, local interest groups; use social media	As we change road closure dates, for example, provide the "why"; use social media; set up kiosks at scenic overlooks to provide information, especially regarding pine beetle impacts
Comments	See how Recreation Opportunity Spectrum may change with regard to visitation, other variables	Encourage user groups to conduct the surveys	Encourage recreation activities to remove invasive species (e.g., Fish Lake perch tournament)

Table 11A.3—Outdoor recreation adaptation options developed at the Great Basin and Semi Desert subregion workshop.

Sensitivity to climatic variability and change: Changes in recreation use patterns will occur with warming (year-round seasons for non-snow activities, shift in snow-dependent activities, changes in use types and demand)			
Adaptation strategy/approach: Increase flexibility and capacity for managing recreation resources to meet shifting demands			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Develop creative budget strategies to support longer and overlapping use seasons; pursue additional grant funding and partnerships and opportunities for new fees (e.g., something similar to Adventure Pass, parking fees, use for peak use times); offer facilities through prospectus for businesses opportunities; leverage outfitting and guiding funds (FDDS42)	Increase flexibility for year-round use of facilities; redevelop or harden existing or new sites (e.g., integrate summer uses into ski area operations); pave access roads for winter and wet uses; install gates or other access control where snow no longer closes areas; change types of infrastructure (e.g., marinas used to be static but now need to be flexible); increase capacity at existing sites to accommodate longer use seasons	Leverage local partnerships to assist with management of recreation facilities (e.g., develop partnerships with local government, other agencies, tribes, and user groups, nongovernmental organizations [Great Basin Institute]; promote trail adoption; facilitate local economic development opportunities)
Where can tactics be applied?	Forestwide and regionwide; all recreation sites	Places with vulnerability to flooding, changing water levels, increased unfrozen saturation, and expanding summer activities in previously winter-only areas; consider design for year-round use (vault versus flush toilets)	Forestwide and regionwide; especially important in areas that are far from Forest Service facilities
Opportunities for implementation	Target most heavily used areas	Existing developed recreation facilities (restore vulnerable sites, change or close some sites) require sustainable facility investments under new prospectus bids; where money is available	Build on existing agreements; reach out for new partners; engage local stewardship groups; work with youth groups; work with tribes more
Comments	Educate public about fees to reduce pushback; support national policies for local fee retention	Flexible management of recreation sites is needed (e.g., change travel management plans to open areas based on condition, not date)	Reducing operational and travel costs is very important because of budget constraints and distances

Appendix 12—Infrastructure Adaptation Options for the Intermountain Adaptation Partnership Region

The following tables describe climate change sensitivities and adaptation strategies and tactics for infrastructure, developed in a series of workshops as a part of the Intermountain Adaptation Partnership (IAP). Tables are organized by subregion within the IAP. See Chapter 14 for summary tables and discussion of adaptation options for infrastructure.

Table 12A.1—Infrastructure adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Increased temperatures will have broad implications for building design and maintenance			
Adaptation strategy/approach: Protect existing and future infrastructure by examining present and future hazards on building infrastructure			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Examine surroundings for hazard trees, and remove those that present hazards to facilities	Follow recommended practices for keeping buildings safe from fires	Monitor movement of ranges of potential insects; educate those living in and maintaining buildings about the signs and risks of insects
Where can tactics be applied?	Any building	Any building	Any building
Opportunities for implementation	During general maintenance and landscaping, continually evaluate the site for hazards	Evaluate structures for compliance with best practices during building condition surveys	Regionwide education and research dissemination on insect issues
Sensitivity to climatic variability and change: Increased temperatures will have broad implications for building design and maintenance			
Adaptation strategy/approach: Add guidance to existing design standards and consider adjustment of maintenance activities to account for climate change			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Consider future of hotter temperatures during building HVAC design	Design for and install heat- and drought-resistant landscapes (xeriscape)	Anticipate where ice dam problems may occur in the future
Where can tactics be applied?	Any building	Any building	Buildings in higher elevations where winter temperature may fluctuate near freezing
Opportunities for implementation	During new construction and HVAC replacement	During new construction and when funding opportunities are present	During new construction and re-roofing projects, consider the potential for ice dam problems
Comments	Consider designing for increase in temperature of 10 °F by 2100	Concentrate on facilities with highest water use	

Table 12A.1 (continued)—Infrastructure adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Increased temperatures will have broad implications for road design and maintenance			
Adaptation strategy/approach: Increase resilience where roads and streams interact			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Adapt the design standards where future rain-on-snow events are expected	Develop risk assessment for road infrastructure	Perform road blading and grading activities during periods when natural moisture conditions are optimum, and use water trucks as needed to supplement
Where can tactics be applied?	Agency and partner road systems	Agency and partner road systems	Agency and partner road systems
Opportunities for implementation	Smaller project scale implementation and during regular maintenance and replacement	Develop partnership with Federal Highway Administration	Implement during regular maintenance activities
Comments	---	---	Maintenance may need to occur earlier and more often in the field season

Table 12A.2—Infrastructure adaptation options developed at the Southern Greater Yellowstone subregion workshop.

Sensitivity to climatic variability and change: Increased storm frequency and intensity conditions will have broad implications for design and maintenance of bridges, dams, canals, and levees			
Adaptation strategy/approach: Protect existing and future infrastructure by examining present and future hazards on dam infrastructure			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Evaluate existing inventory for capacity and structural integrity using projected climate models for extreme storm events	Incorporate projected climate models for extreme storm events in structure design and bridge location.	Facilitate partnering efforts between private, local, State, and Federal jurisdictions
Where can tactics be applied?	Any existing bridge, dam, canal, levee	Any planned bridge, dam, canal, levee	Any existing or planned bridge, dam, canal, levee
Opportunities for implementation	As part of scheduled inspections, maintenance activities, and as requested by partners	During scoping, planning, and engineering design	Ongoing
Sensitivity to climatic variability and change: Anticipated wildfire intensity conditions will have broad implications for infrastructure design and maintenance			
Adaptation strategy/approach: Protect existing and proposed infrastructure by examining present and future hazards due to increased wildfires and post-wildfire conditions			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Design bridges and culverts to minimize diversion potential	Increase defensible space around infrastructure and discourage development in the wildland-urban interface	Enhance existing public and private fire hazard education and mitigation as related to infrastructure design
Where can tactics be applied?	Any planned bridge or culvert	Existing and proposed structures within and adjacent to Federal lands	Public and private domain as well as local, State, and Federal fire-related agencies
Opportunities for implementation	During scoping, planning, engineering design	During inspection, scoping, planning, engineering design	Ongoing

Table 12A.3—Infrastructure adaptation options developed at the Great Basin and Semi Desert subregion workshop.

Sensitivity to climatic variability and change: Power line infrastructure may be increasingly impacted by ecological disturbances (e.g., wildland fire, insect and disease tree hazards, invasive plants [cheatgrass], and geologic hazards)			
Adaptation strategy/approach: Create plausible risk scenarios to utilize in current permit management			
	Specific tactic – A	**Specific tactic – B**	
Tactics	Communicate with existing power line permit holders and annually in wildland fire sand table exercises	Map all power lines in the IAP region	
Where can tactics be applied?	Emergency response plans for plausible scenarios	GIS project development	
Opportunities for implementation	In high fire risk areas, replace wood poles with steel poles	---	
Comments	Integrated vegetation management with power company	---	
Sensitivity to climatic variability and change: Use of power line infrastructure may change because of changes in power generation and demand (e.g., alternative energy sources such as solar and geothermal)			
Adaptation strategy/approach: Create plausible risk scenarios to utilize in approval process (National Environmental Policy Act process and design)			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Create response plans to risk scenarios	Incorporate risk scenarios in natural resource planning and forest plans	Garner broad support to consider risk assessments
Where can tactics be applied?	---	---	---
Opportunities for implementation	---	---	---
Sensitivity to climatic variability and change: Recreation residences may be subject to increased risk from extreme climatic events (e.g., fire, snow, flooding, avalanche, and ecological disturbance)			
Adaption strategy/approach: Develop risk assessment tools, and address risk with holders and County emergency medical services			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Communicate with existing recreation resident holders	Develop clear procedures for removing a recreation residence that exceeds a risk threshold	Consider developing in-lieu lots or other recreation tracts
Where can tactics be applied?	All recreation residences	Site-specific and in each district	Agency review of program
Opportunities for implementation	Communication during annual inspections and national homeowners association meetings	Annual inspections; national homeowners association meetings	National and regional-level meetings

Table 12A.3 (continued)—Infrastructure adaptation options developed at Great Basin and Semi Desert subregion workshop.

Sensitivity to climatic variability and change: Recreation events and trail infrastructure may face increased risk from extreme climatic events (e.g., fire, snow, flooding, avalanche, and ecological disturbance)			
Adaptation strategy/approach: Incorporate changes in extreme climatic events into recreation event planning			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Change timing and location of events	Conduct more indoor events, such as computerized bicycle "spin" events	Cancel events when human safety is at risk
Where can tactics be applied?	Road and mountain bike events	---	---
Opportunities for implementation	---	---	---

Appendix 13—Cultural Resource Adaptation Options for the Intermountain Adaptation Partnership Region

The following tables describe climate change sensitivities and adaptation strategies and tactics for cultural resources, developed in a series of workshops as a part of the Intermountain Adaptation Partnership (IAP). Tables are organized by subregion within the IAP. See Chapter 14 for summary tables and discussion of adaptation options for cultural resources.

Table 13A.1—Cultural resource adaptation options developed at the Southern Greater Yellowstone subregion workshop.

Sensitivity to climatic variability and change: Loss of traditional food sources may occur with severe wildfire			
Adaptation strategy/approach: Integrate traditional ecological knowledge with fire management plans and cultural resource database to holistically manage for traditional food sources (i.e., huckleberries, mushrooms, pine nuts, sage-grouse)			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Emphasize preservation of traditional food sources with tribal and local significance	Enhance resilience of specific habitats to fire and other threats; manage fire to maintain or protect sagebrush rangelands and other sensitive vegetation community types	Identify and protect areas suitable for traditional food gathering during fire suppression and rehab activities
Where can tactics be applied?	Across the national forest and region	Across the national forest and region	Across the national forest and region
Opportunities for implementation	Consult with tribes; eliminate commercial permits in areas with special tribal significance; work with local user groups to identify areas of concern	Consider all vegetation treatments including fire management planning as opportunities for enhancing resilience; consider traditional food sources during fire management planning	Continue to collect data and refine models to better understand location of traditional food-gathering areas
Comments	Need to integrate tribal and local knowledge with existing Forest Service information	Identify these areas as soon as possible	Need to coordinate with researchers, fire managers, tribes, and cultural resource staff
Sensitivity to climatic variability and change: Increased fire will result in increased erosion and loss of vegetation, which may increase damage and impacts to cultural resources			
Adaptation strategy/approach: Encourage predisturbance and postdisturbance strategies to protect cultural resources			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Increase the use of prescribed fire or other vegetation manipulation	Inventory, map, and rate fire risk for cultural resources	Develop a plan to address postfire impacts to cultural resources that have been affected
Where can tactics be applied?	In and around cultural resources that are susceptible to impact from severe wildfire	Across the national forest	Across the burned areas
Opportunities for implementation	At the project planning level; during the annual program of work discussion.	Integrate inventory with other survey needs focusing on high site potential areas across the forest; encourage forest personnel and the public to contribute information on at-risk site locations	Develop long-term stabilization and restoration plans; integrate into Burned Area Emergency Response (BAER) plans and during the forest planning effort.
Comments	Need to identify areas with high stand density	Be creative in finding ways to complete the surveys; utilize existing resource information (LiDAR) to identify cultural resources	Ensure communication between heritage and fire staff

Table 13A.1(continued)—Cultural resource adaptation options developed at the Southern Greater Yellowstone subregion workshop.

Sensitivity to climatic variability and change: Implementation of adaptation strategies by other resource areas may affect cultural resources			
Adaptation strategy/approach: Comply with National Historic Preservation Act (NHPA) before implementation of adaptation strategies			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Large-scale planning effort: Integrate NHPA considerations into the development of adaptation strategies; if considering modification of landscapes or habitats, consider opportunities to preserve or protect cultural resources within the areas considered for treatment	Early initiation of NHPA compliance during specific project planning	Develop a plan to address climate change impacts to cultural resources
Where can tactics be applied?	Must be applied project-wide	Across the national forest	Across the national forest and region
Opportunities for implementation	Ongoing, agency-wide	Project initiation, out year planning	Ensure communication between heritage and other resource areas
Comments	A requirement; tribal consultation also required	Be creative in finding ways to complete the surveys; utilize existing resource information (LiDAR) to identify cultural resources	Explore opportunities for other resource management to help us stabilize and preserve cultural resources
Sensitivity to climatic variability and change: Increased recreation may threaten cultural resources			
Adaptation strategy/approach: Educate users and protect cultural resources			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Redirect public to less sensitive cultural area	Education and interpretation to inform the public of why these resources are important; engage user groups	Direct protection with physical barriers, fencing, vegetation screening, access management
Where can tactics be applied?	Specific sites; need to identify high recreation use locations and where impacts are occurring or may occur in the future	Dispersed recreation sites, system trails	Specific sites
Opportunities for implementation	Divert public to more easily sustainable sites while highlighting sites that we want them to visit	Inform public about the importance of cultural resource ethics and respecting these resources	Physical barriers and monitoring
Comments	May need to use plantings, hardscape, etc. to divert visitors to where we want them to go; utilize engineering techniques	Need to work with recreation staff to determine public use patterns	More Forest Service presence, use ambassadors; tribal engagement is vital; NHPA compliance is required

Table 13A.2—Cultural resource adaptation options developed at the Plateaus subregion workshop.

Sensitivity to climatic variability and change: Increased fire will result in increased erosion and loss of vegetation, which may increase damage and impacts to archaeological sites			
Adaptation strategy/approach: Encourage predisturbance and postdisturbance strategies to protect high-value archaeological sites and resources			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Increase the use of prescribed fire or other vegetation manipulation	Inventory, map, and rate fire risk for archaeological resources	Develop a plan to address postfire impacts to archaeological sites that have been exposed
Where can tactics be applied?	In and around archaeological resources that are in fire-prone areas	In and around archaeological resources that are in fire-prone areas	Across the national forest
Opportunities for implementation	At the project planning level; during the annual program of work discussion	Focus on the high-risk areas as part of the required annual surveys; pursue partnerships with archaeology groups and organizations	In Burned Area Emergency Response (BAER) plans; during the forest planning effort; in prefire season planning
Comments	May need to prioritize archaeological sites, properties, resources	Be creative in finding ways to complete the surveys; use satellite imagery to identify changing fire risk	Communication with the heritage officer or staff; other major disturbances, such as flooding, can be addressed using these tactics

Table 13A.3—Cultural resource adaptation options developed at the Great Basin and Semi Desert subregion workshop.

Sensitivity to climatic variability and change: Pinyon pine forest may be lost as a cultural resource due to a severe wildfire			
Adaptation strategy/approach: Integrate traditional ecological knowledge with Western science to holistically manage for pine nuts and other values (e.g., sage-grouse)			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Emphasize preservation of stands with tribal significance	Enhance resilience of stands to fire and other threats; focus on phase 0/1 pinyon-juniper and isolated pinyon-juniper trees surrounded by good sage-grouse habitat; look for opportunities to create strategic fuelbreaks in contiguous woodland	Identify and protect areas suitable for pinyon under future climate conditions
Where can tactics be applied?	Across the national forest and regionwide	Across the national forest and regionwide	Across the national forest and regionwide
Opportunities for implementation	Attempt consultation with all affected tribes; eliminate commercial permits in areas with special tribal significance	Consider all vegetation treatments as opportunities for enhancing resilience	Continue to collect data and refine models to better understand future pinyon distribution; learn from past management projects
Comments	Work to use local knowledge in determining where pinyon should and should not be removed; need to compare tribal concerns with Western science and GIS information	Identify these areas as soon as possible	Collaborate with researchers, fire managers, and others

Appendix 14—Ecosystem Service Adaptation Options for the Intermountain Adaptation Partnership Region

The following tables describe climate change sensitivities and adaptation strategies and tactics for ecosystem services, developed in a series of workshops as a part of the Intermountain Adaptation Partnership (IAP). Tables are organized by subregion within the IAP. See Chapter 14 for summary tables and discussion of adaptation options for ecosystem services.

Table 14A.1—Ecosystem service adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Small rural communities are entirely dependent on a single watershed or source that may be exposed to fire, drought, and floods associated with climate change			
Adaptation strategy/approach: Develop preparedness plans for disaster and assess future needs for water			
	Specific tactic – A		
Tactics	Identify key watersheds that are sensitive		
Where can tactics be applied?	Forest and district level		
Opportunities for implementation	Future planning, working in watershed health with discussions on fire planning; include discussion with small communities on their vulnerabilities		
Sensitivity to climatic variability and change: Temperature changes bring changes in season for both people and resources (e.g., snowmobile use changes to ATV use, mountain biking occurs over longer seasons and at higher elevations, hunting and people put pressure on wildlife at sensitive times)			
Adaptation strategy/approach: Align human uses with new seasonalities, and implications for those changes on resources			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Implement seasonal use or other permitting for activities that were constrained by weather (e.g., ATV, mountain biking)	Develop capacity for flexibility in seasons (opening dates for campgrounds, access to trails, road closures)	Evaluate impacts and conflicts to resource and user groups (e.g., livestock) due to recommended changes in seasonal use
Where can tactics be applied?	Especially in higher elevations	Analysis of need done at regional level; each unit left to carry out in practice; problems observed at district level, but empowerment done at national forest level	District- and forest-level decisions
Opportunities for implementation	Permitting or seasonal closures (need to evaluate new need for these); longer operating periods (campgrounds, concessions); education and outreach (public, user groups, trailhead signage)	Planning and approving permitting for multiple sites that span a spectrum of weather outcomes	Public meetings, online surveys, research partners to conduct study of issue
Comments	---	Staffing and funding for extended seasons is problematic; uncertainty in contracts to concessionaires; may be a safety issue as people are in backcountry during shoulder seasons with rapidly changing weather	Noting conflicts between hunters being on the land at the same time cattle are being grazed; this is an issue for hunters that lose access with cows on the land, and ranchers whose livestock are shot; expanded ATV use can conflict with hunters and spread weeds

Table 14A.1 (continued)—Ecosystem service adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Air quality will be threatened by increased fire extent and frequency, and may adversely affect health, tourism, and opportunity to go outside			
Adaptation strategy/approach: Integrate fire planning and response with climate change considerations			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Model which places are susceptible to high smoke, and get that message out to developers, tourists, others	Inform people in advance of and during burn events—more effectively (both for prescription burns and wildfire); improve understanding for prescription burn necessity (habitat vs. logging?); improve messaging regarding natural fire cycles	Minimize impacts to tourism
Where can tactics be applied?	At unit level but have assistance from fire science centers/National Interagency Fire Council (NIFC), and Forest Service Research Centers	National, regional, and unit levels; consider the story-telling approach. Leverage existing messages about fire and the role of smoke in healthy ecosystems; the best place for getting the "webcam/current condition" data is the communities, tourism boards, etc.	Conversations with local public about what the tolerance level is—how to quantify? Communicate with tourists and tourism offices; give them information to pass along to others; add more information on recreation.gov so visitors can access information themselves; emphasize opportunities as well as closures
Opportunities for implementation	Incorporate into existing fire planning, transportation planning, recreation planning, wilderness planning; and communication strategy	Prioritize right before and during fire season (note: this is becoming year round)	---
Comments	---	There is an opportunity to get the message out about what is open as well as what is closed; could install webcams to show current conditions	---

Table 14A.1 (continued)—Ecosystem service adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Temperature changes bring changes in season, for both people and resources, and may put more pressure on cultural resources and sites (i.e., looting, collecting, inadvertent impacts from users to cultural heritage resources)			
Adaptation strategy/approach: (1) Improve state of our knowledge of remote cultural resources at risk from climate change impacts; (2) improve awareness to users before they get out there			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Communicate with users in a variety of ways before they hit the trail	Learn what we have; complete an inventory of high-risk areas	Develop a monitoring program for high-priority resources
Where can tactics be applied?	All levels, Web sites, trailhead signage, trifolds, social media, public service announcements; assess effectiveness! "Leave no trace," "Tread lightly," "Respect and protect" message; partner with interest and advocacy groups, tribes, outfitters	Set strategy at regional level; implement at unit level; funding has rarely been allotted to Section 110 of the National Historic Preservation Act; need to identify opportunities for this	Set strategy at regional level; implement at unit level; identify funding sources in climate change or other sources; again, this has been orphaned in the past
Opportunities for implementation	Consider Chamber of Commerce, other heritage tourism connections; leverage celebrations and centennials to get the message out	Celebrations and centennials may bring funding for awareness; systematic inventories; aerial photography	Collaborate with appropriate parties (tribes, vetted researchers, site steward program, interest groups) for citizen science; remote cameras for enforcement and monitoring of impacts to cultural sites
Comments	At higher geographic and societal scales to avoid revealing sensitive information or increasing risk; strategize using nonsensitive cultural resources in the messaging	Consider social vulnerability angles: at-risk resources and the larger picture of community health and identity	Need to be sensitive to tribes' reluctance to share information about important sites
Sensitivity to climatic variability and change: Fire, erosion, floods, and mass wasting will threaten trails and other recreational features of the landscape, resulting in safety issues			
Adaptation strategy/approach: Identify and describe threats; mitigate for threat			
	Specific tactic – A	**Specific tactic – B**	
Tactics	Use existing data and models to do overlays of highest vulnerability and threat levels (to ecosystem services, in general)	Understand demographic trends and demand for hunting, fishing, and wildlife viewing	
Where can tactics be applied?	At unit level with assistance from fire science centers, NIFC, Forest Service Research Stations; potentially U.S. Geological Survey	In partnerships with wildlife groups, State agencies	
Opportunities for implementation	Incorporate into existing fire planning, transportation planning, recreation planning, wilderness planning	In national reports such as the Resource Planning Act (RPA) Assessment, partnerships with groups such as Headwaters Economics	

Table 14A.1 (continued)—Ecosystem service adaptation options developed at the Middle Rockies subregion workshop.

Sensitivity to climatic variability and change: Change in timing of water availability and absolute amount of water available will affect water-based recreation; high temperatures may drive up demand for water recreation			
Adaptation strategy/approach: Plan to account for these changes in demand			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Identify places that are likely to be affected by climate change: either loss of water-based recreation, or where more recreation will be concentrated	Rethink campground locations to make them more pleasant for hot climates (e.g., spots in the shade) and near existing water resources; use intentional locations to control impacts of dispersed camping	Future reservoirs may be needed to meet municipal water demand that will also be used for recreation, but may also flood existing recreation sites (e.g., campgrounds)
Where can tactics be applied?	All forests	Forests especially attractive to RVs	Near existing water resources, and likely new sites for reservoirs
Opportunities for implementation	Partnering with GIS specialists, recreation specialists, and climate specialists	Will require awareness for future planning; a need for more enforcement to keep people where we want them and limit impacts where we do not; partnering with recreation user groups will be a key to success	Looking ahead to plan for such changes
Comments	A first requirement may be an assessment of current use, in order to forecast future demand	Need to educate people about the sensitivity of water resources to human impacts; it is very difficult to close sites	---

Table 14A.2—Ecosystem service adaptation options developed at the Southern Greater Yellowstone subregion workshop.

Sensitivity to climatic variability and change: Climate change is likely to lead to shift in grazing patterns between Bureau of Land Management (BLM) and Forest Service (FS) lands and may interfere with wildlife phenology (namely sage-grouse nesting)				
Adaptation strategy/approach: Develop a holistic approach to grazing management; understand rancher's business approach, lands used, water management, and competing demands from other resources and multiple uses				
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	**Specific tactic – D**
Tactics	Modify flexibility in timing, duration, and intensity of authorized grazing	Use grazing as a tool to achieve desired conditions: holistic grazing, target grazing on noxious weeds	Consider novel ways to manage grazing (e.g., contracting grazing opportunities on Forage Reserves on the Bridger-Teton NF and vacant allotments)	Minimize impacts; design livestock water developments (e.g., shutoff valves for tanks, and protection of spring sources) more efficiently
Where can tactics be applied?	Public, private, and all adjacent lands	Across the national forest on all grazing allotments	Across the national forest on all grazing allotments; especially needed in areas where there is a gap between availability of BLM land and FS land	On grazing areas, in sensitive spring-source ecosystems
Opportunities for implementation	Permit renewals and forest plan revision; collaboration with other governmental entities; regional directives	Partnerships with Natural Resources Conservation Service and with States, weed management groups, Counties	---	An engineering solution to water waste and impacts to riparian areas; partnerships
Comments	---	---	This gives a space for cattle during times when they have nowhere else to go	May need novel ways of funding

Table 14A.2 (continued)—Ecosystem service adaptation options developed at the Southern Greater Yellowstone subregion workshop.

Sensitivity to climatic variability and change: With higher variability in weather, timing of availability of recreation sites may become less predictable; warm temperatures at low elevations trigger desire for recreation, but colder and wet high elevations may not be capable of absorbing the human impact			
Adaptation strategy/approach: Change staffing and management in highly variable shoulder seasons to accommodate flexibility in seasons, dates, and travel management; consider tradeoffs between flexibility and predictability			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Add gates to closed areas that may be muddy; use multiple gate system to open lower trails but close off higher elevation trails; harden roads that are likely to be used in muddy season	Use social media and real-time information to communicate to the public the impacts of out-of-season or non-seasonally appropriate recreation	Flexible travel management plans, staffing; flexible dates for road openings
Where can tactics be applied?	Lower elevation access points	Virtually, local-level knowledge; strategic communications; forest-level contacts, Facebook®, Twitter®	Lower-elevation and mid-elevation roads
Opportunities for implementation	Travel plan revisions	In partnership with private and community organizations (e.g., Friends of Pathway); tech-savvy user groups	Travel plan revisions
Comments	---	Users often predict use based on past experiences, which are no longer good predictors of the present and future, so users may get caught off-guard by change in weather and trail conditions; need to educate people on changing hazards	---

Table 14A.3—Ecosystem service adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: Pollinators will be sensitive to climate change			
Adaptation strategy/approach: Increase agency and public awareness of the importance of native pollinators			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Establish a pollinator coordinator to communicate with district- and forest-level ID teams, as well as the Regional Office and the public	Develop a checklist to consider pollinator services in planning, project analysis, and decision making	Establish pollinator gardens
Where can tactics be applied?	Each national forest	In both the National Forest Management Act and National Environmental Policy Act processes	On Federal facilities or in partnership with other public entities (e.g., public spaces, parks, backyards)
Opportunities for implementation	---	During project initiation, ID team process, forest planning	Collaborative programs and partnerships, schools, State and private forests, nongovernmental organizations (e.g., Xerces Society), chambers of commerce
Comments	A coordinator can also be established for other ecosystem services that are not well-represented	A similar checklist may be useful at large spatial scales (establish need for change and desired future condition goals and objectives)	Seeds of local origin should be emphasized; encourage awareness of native, pollinator-friendly plants; use local nurseries, seed collectors, restoration ecologists, etc.

Table 14A.3 (continued)—Ecosystem service adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: Pollinators will be sensitive to climate change			
Adaption strategy/approach: Enhance pollinator habitat on Federal lands and Federal facilities			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Direct Forest Service units to improve pollinator habitat by increasing native vegetation (via integrated pest management and integrated vegetation management) by applying pollinator-friendly forest-wide best management practices and seed mixes	Establish a reserve of native seed mixes including pollinator-friendly plants that are adapted, available, affordable, and effective	Develop revegetation guidelines that incorporate menu-based seed mixes by habitat type (e.g., species that are good for pollinators, sage-grouse, umbrella species) and by empirical or provisional seed zones
Where can tactics be applied?	High-priority areas include alpine, tall forbs, low-elevation wetlands, and dry and dwarf sagebrush communities, all of which are vulnerable to climate change impacts	IAP geographic areas (e.g., Uintas and Wasatch Front)	Each national forest
Opportunities for implementation	Silvicultural and Burn Area Emergency Response (BAER) treatments, grazing and fuels management, postfire recovery, wildlife habitat improvement projects, or any reclamation or recovery projects; include premonitoring and postmonitoring	Develop empirical seed zones for your core list of native plant materials desired; in the absence of empirical seed zones, use provisional or interim seed zones and Level 3 ecoregions	Whenever revegetation is needed; for example, guidelines would help BAER teams, enterprise teams, forest planning teams
Comments	See tactic B	Reference FSM 2070 (Native plant materials policy) and the national seed strategy; see also Region 4 list of pollinator-friendly restoration species	This product will help us be consistent with FSM 2070 policy and accurately select adapted plant material when implementing revegetation and reclamation projects

Table 14A.3 (continued)—Ecosystem service adaptation options developed at the Uintas and Wasatch Front subregion workshop.

Sensitivity to climatic variability and change: Higher temperatures and increased fire activity will change the composition and alter the productivity of forage			
Adaptation strategy/approach: Increase resilience of habitats that are used by ungulates and that are vulnerable to climate change impacts			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Reduce conversion of native perennial vegetation to invasive species	Integrate grazing strategies and vegetation treatments (both wild and domestic ungulates)	Emphasize collaborative problem solving with permittees and other interested parties rather than enforcement
Where can tactics be applied?	High-priority areas include tall forbs, low-elevation wetlands and riparian areas, and dry and dwarf sagebrush communities, all of which are vulnerable to climate change impacts	---	---
Opportunities for implementation	Vegetation treatments, allotment management plans, meetings with county weed management areas, native plant projects, etc.	Wildlife advisory councils	County weed management areas, collaborative groups, allotment management plans, partnerships, annual operating instruction meetings with interested parties, native plant projects, field trials for innovative grazing
Comments	---	Research and identify new strategies; ensure that results are monitored	Consider payments for ecosystem services and incentives for participation in conservation programs
Sensitivity to climatic variability and change: Amount and seasonal distribution of water will change in relation to demand			
Adaptation strategy/approach: Assess and communicate Forest Service ability to help meet demand			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Conduct integrated assessment of water and local effects of climate change	Encourage communication and full disclosure of information	Conduct vulnerability assessments
Where can tactics be applied?	On a watershed basis; next, identify priorities to further assess timing and quantity at the stream level	Watershed councils, municipal watersheds, interagency working groups (e.g., Mountain Accord), local communities	Assessments could be done by community, watershed, administrative boundary, etc.
Comments	Assessment would focus on needs of a healthy watershed, not maximizing yield		

Table 14A.4—Ecosystem service adaptation options developed at the Great Basin and Semi Desert subregion workshop.

Sensitivity to climatic variability and change: Climatic variability and warming will affect grazing resources and policy			
Adaptation strategy/approach: Develop a holistic approach to grazing management; understand rancher's business approach, lands used, water management, and competing demands from other resources and multiple uses			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactics	Partner with permittee and other managers of lands they use to create a holistic grazing program	Understand changes in water availability to prepare and adjust grazing management	Implement education programs about climate change impacts and sustainable grazing practices (highlight both positive and negative effects)
Where can tactics be applied?	Public, private, and all adjacent lands	Around water resources	Needs to be broadly implemented; partnership opportunities with Cattlemen's Association, Future Farmers of America, Natural Resources Conservation Service, schools, environmental organizations
Opportunities for implementation	Whenever looking at Allotment Management Plan or annual operating plans	Improve maps and models of water availability and competing uses; work with partners on water infrastructure changes and funding	Bring message into forest plan revision discussions and when working with public
Comments	Work with extension services, research, others who understand ranching needs		Working ranches preserve large open landscapes and wildlife habitat