

## 9 Synthesis and Conclusions

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|    |   |      |
|----|---|------|
| 1  | <b>Chapter Contents</b>   |      |
| 2  |   |      |
| 3  | 9.1 Introduction.....   | 9-3  |
| 4  | 9.2 Assessing Impacts to Support Adaptation .....                             | 9-3  |
| 5  | 9.2.1 Mental Models for Making Adaptation Decisions.....                      | 9-3  |
| 6  | 9.2.2 Elements of an Impact Assessment.....                                   | 9-4  |
| 7  | 9.2.3 Uncertainty and How to Incorporate it Into Assessments .....            | 9-10 |
| 8  | 9.3 Best Practices for Adaptation.....  | 9-12 |
| 9  | 9.3.1 Resilience.....   | 9-13 |
| 10 | 9.3.2 Adaptation Approaches.....  | 9-15 |
| 11 | 9.3.3 Confidence .....  | 9-17 |
| 12 | 9.3.4 Adaptive Management.....  | 9-18 |
| 13 | 9.4 Barriers and Opportunities for Adaptation .....                           | 9-19 |
| 14 | 9.4.1 Legislation and Regulation .....  | 9-21 |
| 15 | 9.4.2 Management Policies and Procedures .....                                | 9-22 |
| 16 | 9.4.3 Human and Financial Capital.....  | 9-24 |
| 17 | 9.4.4 Information and Science .....   | 9-26 |
| 18 | 9.5 Advancing the Nation’s Capability to Adapt.....                           | 9-28 |
| 19 | 9.5.1 Re-Evaluate Priorities and Consider Triage .....                        | 9-29 |
| 20 | 9.5.2 Manage at Appropriate Scales .....                                      | 9-30 |
| 21 | 9.5.3 Manage for Change.....  | 9-30 |
| 22 | 9.5.4 Expand Interagency Collaboration, Integration, and Lesson-Sharing.....  | 9-31 |
| 23 | 9.6 Conclusions.....  | 9-33 |
| 24 | 9.7 References.....   | 9-36 |
| 25 | 9.8 Appendix: Resources for Assessing Climate Vulnerability And Impacts ..... | 9-43 |
| 26 | 9.9 Boxes.....  | 9-45 |
| 27 | 9.10 Tables.....  | 9-51 |
| 28 | 9.11 Figures.....   | 9-60 |
| 29 |   |      |

## 1 **9.1 Introduction**

2 Today’s natural resource planning and management practices were developed under relatively  
 3 stable climatic conditions in the last century and under a theoretical notion that ecological  
 4 systems tend towards a natural equilibrium state for which one could manage. Most natural  
 5 resource planning, management and monitoring methodologies that are in place today are still  
 6 based on the assumption that climate, species distributions, and ecological processes will remain  
 7 stable save for the direct impacts of management actions and historical interannual variability.  
 8 Indeed, many government entities identify a “reference condition” based on historical ranges of  
 9 variability as a guide to future desired conditions (Chapter 3; Dixon, 2003).

10  
 11 Although mainstream management practices typically follow these traditional assumptions, in  
 12 recent years resource managers have recognized that climatic influences on ecosystems in the  
 13 future will be increasingly complex and often outside the range of historical variability and,  
 14 accordingly, more sophisticated management plans are needed to ensure that goals can continue  
 15 to be met. By transforming management and goal-setting approaches from a static, equilibrium  
 16 view of the natural world to a highly dynamic, uncertain, and variable framework, major  
 17 advances in managing for change can be made, and thus adaptation is possible.

18  
 19 As resource managers become aware of climate change and the challenges it poses, a major  
 20 limiting constraint is guidance on what steps to take, especially guidance that is commensurate  
 21 with agency cultures and the practical experiences that managers have accumulated from years  
 22 of dealing with other stresses such as droughts, fires, and pest and pathogen outbreaks. Thus, it is  
 23 the intent in this chapter to synthesize the lessons learned from across the previous chapters and  
 24 discuss how managers can: (1) assess the impacts of climate change on their systems and goals  
 25 (Section 9.2); (2) identify best practice approaches for adaptation (Section 9.3); and (3) evaluate  
 26 barriers and opportunities associated with implementation (Section 9.4). It may be the case that  
 27 certain management goals are unattainable in the future and no adaptation options exist. The  
 28 final sections of this report address these circumstances and conclude with observations about  
 29 how to advance our capability to adapt (Sections 9.5 and 9.6), along with approaches for making  
 30 fundamental shifts in how ecosystems are managed to anticipate potential future ecosystem  
 31 states. These discussions are based on the expert opinion of the authors of this report and  
 32 feedback from the stakeholder workshops.

## 33 **9.2 Assessing Impacts to Support Adaptation**

### 34 **9.2.1 Mental Models for Making Adaptation Decisions**

35 Within the context of natural resource management, an impact assessment is a means of  
 36 evaluating the sensitivity of a natural system to climate change. Sensitivity is defined by the  
 37 IPCC (Houghton *et al.*, 2001) as “the degree to which a system is affected, either adversely or  
 38 beneficially, by climate-related stimuli.” An impact assessment is part of a larger process to  
 39 understand the risks posed by climate change, including those social and economic factors that  
 40 may contribute to or ameliorate potential impacts, in order to decide where and when to adapt. In  
 41 the climate change community, this process is well established (see Figure 9.1a). It begins with  
 42 an assessment of impacts, followed by an evaluation of an entity’s capacity to respond (adaptive

capacity). The information on impacts is then combined with information on adaptive capacity to determine a system's overall vulnerability. This information becomes the basis for selecting adaptation options to implement. The resource managers' mental model for this larger decision making process (see Figure 9.1b), contains similar elements to the climate community's model, but addresses them in a different sequence of evaluation to planning. The managers' process begins with estimating potential impacts, reviewing all possible management options, evaluating the human capacity to respond, and finally deciding on specific management responses. The resource management community implicitly combines the information on potential impacts with knowledge of their capacity to respond during their planning processes. Since the primary audience for this report is the resource management community, the remainder of this discussion will follow their conceptual approach to decision making.

**Figure 9.1.** Two conceptual models for describing different processes used by (a) the resource management community and (b) the climate community to support adaptation decision making. Colors are used to represent similar elements of the different processes.

The following sub-sections lay out in greater detail some of the key issues and elements of an impact assessment, which must necessarily begin with a clear articulation of the goals and objectives of the assessment and the decisions that will be informed. This specification largely determines the technical approach to be taken in an assessment, including its scope and scale, the focal ecosystem components and processes to be studied, the types of tools most appropriate to use, and the baseline data and monitoring needed. The final subsection discusses ways in which uncertainty inherent in assessments of climate change impacts may be explicitly addressed.

## **9.2.2 Elements of an Impact Assessment**

Impact assessments combine (1) our understanding of the current state of the system and its processes and functions with (2) drivers of environmental change in order to project (3) potential responses to future changes in those drivers. Knowledge of the current state of the system, including its critical thresholds and coping ranges, provides the fundamental basis for understanding the implications of changes in future conditions. A coping range is the breadth of conditions under which a system continues to persist without significant, observable consequences, taking into account the system's natural resilience (Yohe and Tol, 2002). Several examples of approaches to conducting impact assessments are provided below along with a discussion of the types of tools needed and key issues related to conducting impact assessments.

### **9.2.2.1 A Guiding Framework for Impact Assessments**

The aim of a framework to assess impacts is to provide a logical and consistent approach for eliciting the information needs of a decision maker, for conducting an assessment as efficiently as possible, and for producing credible and useful results. While impact assessments are routinely done to examine the ecological effects of various environmental stressors, the need to incorporate changes in climate variables adds significantly to the spatial and temporal scales of the assessment, and hence its complexity. One example framework, developed by (Johnson and Weaver, In Press) for natural resource managers, is responsive to these and other concerns that

1 have been raised by those who work with climate data to conduct impact assessments. This  
2 framework is described in Box 9.1.

3  
4 A number of other frameworks have been developed as well. For example, within the  
5 international conservation arena, an extremely successful framework for managers is the one  
6 developed by (The Nature Conservancy, 2007). The steps include: (1) identifying the  
7 management goal and climate threat to that goal, (2) selecting measurable indicators; (3)  
8 determining the limits of acceptable variation in the indicators; (4) assessing the current status of  
9 the system with respect to meeting management goals, as well as with respect to the indicators;  
10 and (5) analyzing data on indicators to decide whether a change in management is required.  
11 These five steps were agreed upon by the Conservation Measures Partnership (2007), which  
12 includes the African Wildlife Foundation, Conservation International, The Nature Conservancy,  
13 the Wildlife Conservation Society, and the World Wide Fund for Nature/World Wildlife Fund.  
14 By melding these steps with an assessment of the costs of any management response (including  
15 “no response” as one option), it should be possible to offer practical guidance.

#### 16 **9.2.2.2 Tools to Assess Impacts**

17 The example frameworks described in the previous section reference two key types of tools:  
18 models that represent the climate system as a driver of ecological change and models that  
19 embody the physical world to trace the effect of climate drivers through relevant pathways to  
20 impacts on management endpoints of concern. There are numerous tools that begin to help  
21 managers anticipate and manage for climate change (see the Appendix, Section 9.8), although  
22 characterization of uncertainty could be improved, along with “user friendliness” and the ability  
23 to frame management endpoints in a manner that more closely meshes with the needs of federal  
24 agencies. Fortunately, tool development for impact analysis is one of the most active areas of  
25 climate research, and greatly improved tools can be expected within the next few years.

#### 26 **Climate Models**

27  
28 Across all types of federal lands, the most widely recognized need for information is the need for  
29 climate projections at useable scales—scales much finer than those associated with most general  
30 circulation model (GCM) projections (Chapter 6, Wild and Scenic Rivers). In particular, the  
31 resolution of current climate-change projections from GCMs is on the order of degrees of  
32 latitude and longitude (200-500 km<sup>2</sup>). Projections from regional climate models are finer in  
33 resolution (*e.g.*, 10 km<sup>2</sup>), but are not available for most regions. All climate projections can be  
34 downscaled using methods that take local topography and local climate patterns into account  
35 (Wilby *et al.*, 1998). Although relatively coarse climate projections may be useful for  
36 anticipating general trends, the effects of local topography, large water bodies, and specific  
37 ecological systems can make coarse predictions highly inaccurate. To be more useful to  
38 managers, projections will need to be downscaled using methods that account for local climate  
39 patterns. In addition, climate-change projections will need to be summarized in a way that takes  
40 their inherent uncertainty into account. That uncertainty arises from the basic model structure,  
41 the model parameters, and the path of global emissions into the future. Useful future projections  
42 will provide summaries that take this uncertainty into account and inform managers where the  
43 projections are more and less certain and, specifically, how confident we can be in a given level  
44 of change. Several different approaches exist for capturing the range of projected future climates  
45 (see comparison of approaches in Dettinger, 2005). It also will be important to work with climate

1 modelers to ensure that they provide the biologically relevant output variables from the model  
2 results.

3  
4 There are various methods of downscaling GCM data, including dynamical downscaling using  
5 regional climate models, statistical downscaling, and the change factor approach (a type of  
6 statistical downscaling). Dynamical downscaling uses physically based regional climate models  
7 that originate from numerical weather prediction and generate results at a scale of 50 km,  
8 although some generate results at 10km and finer scales (Georgi, Hewitson, and Christensen,  
9 2001; Christensen and Hewitson, 2007). As their name implies, they are typically run for a  
10 region of the globe, using GCM outputs as boundary conditions. Statistical downscaling uses  
11 various methods to estimate a relationship between large-scale climate variables (“predictors”)  
12 and finer-scale regional or local variables (“predictands”). This relationship is derived from an  
13 observed period of climate and then applied to the output from GCMs for future projections. This  
14 method is also used for temporal downscaling to project daily or hourly variables, typically for  
15 hydrologic analyses (Wilby *et al.*, 2004). Due to the complexity of determining a significant  
16 relationship between the “predictors” and “predictands,” most studies that use statistical  
17 downscaling only use the results from one GCM (*e.g.*, Shongwe, Landman, and Mason, 2006;  
18 Spak *et al.*, 2007; Benestad, Hanssen-Bauer, and Fairland, 2007). The change factor approach to  
19 downscaling involves subtracting the modeled future climate from the control run at the native  
20 coarse resolution of the GCM. These modeled climate “anomalies” are then interpolated to create  
21 a seamless surface of modeled change at a finer resolution. These interpolated data are then  
22 added to the current climate to provide an estimate of future climate. Researchers use the change  
23 factor approach when a rapid assessment of multiple GCMs and emissions scenarios is required  
24 (*e.g.*, Mitchell *et al.*, 2004; Wilby *et al.*, 2004; Scholze *et al.*, 2006; Malcolm *et al.*, 2006).

#### 25 26 **Impact Models to Assess Endpoints of Concern**

27 In addition to projections of changes in climate, managers will also require projections of  
28 changes in hydrology, sea level rise, vegetation, and species distributions that result from climate  
29 change (Chapter 4, National Parks; Chapter 5, National Wildlife Refuges). For example,  
30 managing forests in a changing climate will require data on projected potential changes to  
31 vegetation, as well as detailed data on the current condition of vegetation (Chapter 3, National  
32 Forests).

33  
34 A detailed sea level rise assessment was undertaken by the USGS for the lower 48 states and  
35 specifically for coastal national parks (U.S. Geological Survey, 2007a). More accurate  
36 projections of coastal inundation and saltwater intrusion, such as those based on LIDAR  
37 conducted for the Blackwater National Wildlife Refuge, will require more detailed elevation data  
38 and targeted hydrological modeling (Chapter 5, National Wildlife Refuges). One report that  
39 provides information on ongoing mapping efforts by federal and non-federal researchers related  
40 to the implications of sea level rise is Synthesis and Assessment Product 4.1 (U.S. Climate  
41 Change Science Program; in review), produced by the U.S. Climate Change Science Program.  
42 Various data layers are overlaid to develop new results, focusing on a contiguous portion of the  
43 U.S. coastal zone (New York to North Carolina).

44  
45 Projected shifts in individual species distributions are also generally based on relatively coarse-  
46 scale data (*e.g.*, Pearson *et al.*, 2002; Thuiller *et al.*, 2005). Regional projections of species range  
47 shifts will require more detailed species distribution data. Some of these data already exist (*e.g.*,

1 through the state Natural Heritage programs), but need to be organized, catalogued, and  
2 standardized. As with the climate projections, all projections of climate-change impacts will need  
3 to include estimates of the inherent uncertainty and variability associated with the particular  
4 model that is used (*e.g.*, Araújo and New, 2007). Recent analyses indicate that some models  
5 perform better than others. For example, with regard to range shifts, a model-averaging approach  
6 (*e.g.*, random forest models) was compared with five other modeling approaches and was found  
7 to have the greatest potential for accurately predicting range shifts in response to climate change  
8 (Lawler *et al.*, 2006).

9  
10 An important consideration for impact analyses is to provide information on endpoints that are  
11 relevant to managers (*e.g.*, loss of valued species such as salmon) rather than those that might  
12 come naturally to ecologists (*e.g.*, changes in species composition or species richness). An  
13 exemplary impact analysis in this regard was a study of climate change impacts in California  
14 funded by the Union of Concerned Scientists (UCS; Union of Concerned Scientists, 2007). The  
15 UCS study used a statistically downscaled version of two global circulation models to consider  
16 future emissions conditions for the state. It produced compelling climate-related outputs.  
17 Projections of impacts, in the absence of aggressive emissions regulations, included heat waves  
18 that could kill 165–330 additional people each year in Los Angeles, a shorter ski season, annual  
19 losses of \$266–836 million for the dairy industry, and bad-tasting wine from the Napa Valley.  
20 Because the impacts chosen were relevant to management concerns, the study was covered  
21 extensively by national and California newspapers, radio stations, and TV stations. California  
22 policy makers listened (Tallis and Kareiva, 2006).

23  
24 There are many new ecological models that would help managers address climate change, but  
25 the most important modeling tools will be those that integrate diverse information for decision  
26 making and prioritize areas for different management activities. Planners and managers need the  
27 capability to evaluate the vulnerability of each site to climate change and the social and  
28 economic costs of addressing those vulnerabilities. One could provide this help with a decision  
29 support model that allows the exploration of alternative future climate-change scenarios and  
30 different funding limitations that could be used for priority-setting and triage decisions.  
31 Comprehensive, dynamic, priority setting tools have been developed for other management  
32 activities such as watershed restoration (Lamy *et al.*, 2002). Developing a dynamic tool for  
33 priority setting will be critical for effectively allocating limited resources.

#### 34 **9.2.2.3 Establishing Baseline Information**

##### 35 **Collecting Information on Past and Current Condition**

36 To estimate current and potential future impacts, a literature review of expected climate impacts  
37 may be conducted to provide a screening process that identifies “what trends to worry about.”  
38 The next step beyond a literature review is a more focused elicitation of the ecological properties  
39 or components needed to reach management goals for lands and waters. For each of these  
40 properties or components, it will be important to determine the key to maintaining them (see  
41 Table 9.1 for examples). If the literature review reveals that any of the general climate trends  
42 may influence the ecological attributes or processes critical to meeting management goals, then  
43 the next steps are to identify baselines, establish monitoring programs, and consider specific  
44 management tools and models. For example, suppose the management goal is to maintain a

1 particular vegetation type, such as classical Mediterranean vegetation. Mediterranean vegetation  
2 is restricted to the following five conditions (Aschmann, 1973):  
3

- 4 • At least 65% of the annual precipitation occurs in the winter half of the year (November–  
5 April in the northern hemisphere and May–September in the southern hemisphere),
- 6 • Annual precipitation is greater than 275 mm,
- 7 • Annual precipitation is less than 900 mm,
- 8 • The coldest month of the year is below 15°C, and
- 9 • The annual hours below 0°C account for less than 3% of the total.

10  
11 If the general literature review indicates climate trends have a reasonable likelihood of  
12 influencing any of these defining features of Mediterranean plant communities, then there will be  
13 a need for deeper analysis. Sensitivity to current or past climate variability may be a good  
14 indicator of potential future sensitivity.  
15

16 Once the important ecological attributes or processes are identified, a manager needs to have a  
17 clear idea of the baseline set of conditions for the system. Ecologists, especially marine  
18 ecologists, have drawn attention to the fact that the world has changed so much that it can be  
19 hard to determine a baseline for any system (Pauly, 1995). The reason that an understanding of a  
20 system’s long history can be so valuable is that the historical record may include information  
21 about how systems respond to extreme stresses and perturbations. When dealing with sensitive,  
22 endangered, or stressed systems, experimental perturbation can be politically infeasible, socially  
23 unpalatable, and ecologically irresponsible. Where available, paleoecological records could be  
24 used to examine past ranges of natural environmental variability and past organismal responses  
25 to climate change (Willis and Birks, 2006). Although in an experimental sense “uncontrolled,”  
26 there is no lack of both historic and recent examples of perturbations (of various magnitudes) and  
27 recoveries through which to examine resilience.  
28

29 Historic baselines have the potential to offer insights into how to manage for climate change. For  
30 example, while the authority to acquire land interests and water rights exists under the Wild and  
31 Scenic Rivers Act, lack of baseline data on flow regimes makes it difficult to determine how,  
32 when, and where to use this authority (Chapter 6, Wild and Scenic Rivers). Other examples of  
33 baseline data important for making management decisions and understanding potential effects of  
34 climate change include species composition and distribution of trees in forests; rates of  
35 freshwater discharge into estuaries; river flooding regimes; forest fire regimes; magnitude and  
36 timing of anadromous fish runs; and home ranges, migration patterns, and reproductive dynamics  
37 of sensitive organisms.  
38

39 However, baselines also have the potential to be misleading. For example, in Chapter 3 (National  
40 Forests), it is noted that historic baselines are only useful if climate is incorporated into those  
41 past baselines and the relationship of vegetation to climate is explored. If a baseline is held up as  
42 a goal, and the baseline depends on historic climates that will never again be seen in a region,  
43 then the baselines could be misleading. On the other hand, if baselines are to be developed using  
44 changing reference points or conditions, this approach also requires caution. The goal would be  
45 to realistically consider how conditions may change without allowing our definition of baseline



1 conditions to rationalize acceptance of lower levels of “healthy” conditions, potentially risking  
2 ecosystem integrity for the future and losing valuable historical knowledge.

#### 3 **Monitoring to Inform Management Decisions**

4 Monitoring is needed to support a manager’s ability to detect changes in baseline conditions as  
5 well as to facilitate timely adaptation actions. Monitoring also provides a means to gauge  
6 whether management actions are effective. Although some monitoring may be designed to detect  
7 general ecological trends in poorly understood systems, the majority of the monitoring that is  
8 needed is hypothesis-based and specifically targeted to either determine vulnerabilities or to  
9 assess the effects of management as part of an adaptive management strategy. In many cases, the  
10 first step in developing a monitoring system will involve establishing baseline data, as described  
11 above. Some federal lands have detailed species inventories (*e.g.*, the national parks are  
12 developing extensive species inventories for the Natural Resource Challenge) or detailed stream  
13 flow measurements. However, other lands, such as the national wildlife refuges, lack even  
14 species inventories, much less records of population trends or disease prevalence (Chapter 5,  
15 National Wildlife Refuges).  
16

17  
18 Some systems will require site-specific monitoring programs whereas others will be able to take  
19 advantage of more general monitoring programs (see Table 9.2 for examples of potential  
20 monitoring targets). For example, the analysis of National Forests (Chapter 3, National Forests)  
21 highlights the need for monitoring both native plant species and non-native and invasive species.  
22 In addition, the severity and frequency of forest fires are clearly linked to climate (Bessie and  
23 Johnson, 1995; Fried, Torn, and Mills, 2004; Westerling *et al.*, 2006). Thus, managing for  
24 changing fire regimes will require assessing fire risk by detecting changes in fuel loads and  
25 weather patterns. Detecting climate-driven changes in insect outbreaks and disease prevalence  
26 will require monitoring the occurrence and prevalence of key insects, pathogens, and disease  
27 vectors (Logan, Regniere, and Powell, 2003). Detecting early changes in forests will also require  
28 monitoring changes in hydrology and phenology, and in tree establishment, growth, and  
29 mortality. Some key monitoring efforts are already in place. For example, the Forest Service  
30 conducts an extensive inventory through its Forest Inventory and Analysis program, and the  
31 collaborative National Phenology Network collects data on the timing of ecological events across  
32 the country to inform climate change research (University of Wisconsin-Milwaukee, 2007).  
33

34 In the National Wildlife Refuge System, monitoring might include targets associated with sea  
35 level rise, hydrology, and the dynamics of sensitive species populations. Monitoring of marine  
36 protected areas should address coral bleaching and disease as well as the composition of  
37 plankton, seagrass, and microbial communities. In the national estuaries, the most effective  
38 monitoring will be of salinity, sea level, stream flow, sediment loads, disease prevalence, and  
39 invasive species. Wild and scenic rivers should be monitored for changes in flow regimes and  
40 shifts in species composition. Finally, national parks, which encompass a diversity of ecosystem  
41 types, should be monitored for any number of the biotic and abiotic factors listed for the other  
42 federal lands.

43  
44 Although developing directed, intensive monitoring programs may seem daunting, there are  
45 several opportunities to build on existing and developing efforts. In addition to the Forest  
46 Service’s Forest Inventory and Analysis program and the National Phenology Network  
47 mentioned above, other opportunities include the National Science Foundation’s National

1 Ecological Observation Network and the Park Service’s Vital Signs program (*e.g.*, Mau-  
2 Crimmins *et al.*, 2005). Despite the importance of monitoring, it is critical to recognize that  
3 monitoring is only one step in the management process and that monitoring alone will not  
4 address the affects of climate change on federal lands.

### 5 **9.2.3 Uncertainty and How to Incorporate it Into Assessments**

6 The high degree of uncertainty inherent in assessments of climate change impacts can make it  
7 difficult for a manager to translate results from those assessments into practical management  
8 action. Importantly, uncertainty is not the same thing as ignorance or lack of information—it  
9 simply means that there is more than one outcome possible as a result of rising greenhouse gases.  
10 Fortunately, there are approaches for dealing with uncertainty that allow progress.

#### 11 **9.2.3.1 Examples of Sources of Uncertainty**

12 To project climate change in the future, climate modelers have applied seven “families” of  
13 greenhouse gas emissions scenarios that encompass a range of energy futures to a suite of 23  
14 GCMs (IPCC, 2007), all differing in their climatic projections. Global mean temperature  
15 projections range from 1.4–5.8°C (2.5-10.5°F) with considerable discrepancies in the distribution  
16 of the temperature and precipitation change. These direct outputs are typically not very useful to  
17 managers because they lack the resolution at local and regional scales where environmental  
18 impacts relevant for natural resource management can be evaluated. However, as mentioned  
19 above, GCM model outputs derived at the very coarse grid scales of 2.5° x 3.25° (roughly 200–  
20 500 km<sup>2</sup>, depending on latitude) can be downscaled (Melillo, Borchers, and Chaney, 1995; Pan  
21 *et al.*, 2001; Leung *et al.*, 2003; Salathé, Jr., 2003; Wood *et al.*, 2004; IPCC, 2007). But when  
22 GCM output data are downscaled, uncertainties are amplified. In Region 6 of the Forest Service,  
23 the regional office recommended that the National Forest not model climatic change as a part of  
24 a management plan revision process after science reviewers acknowledged the high degree of  
25 uncertainty associated with the application of climate change models at the forest level (Chapter  
26 3, National Forests). In the Northwest, management of rivers in the face of climate change is  
27 complicated by the fact that the uncertainty is so great that 67% of the modeled futures predict a  
28 decrease in runoff, while 33% predict an increase. Thus the uncertainty is not just about the  
29 magnitude of change—but the direction of change as well (Chapter 6, Wild and Scenic Rivers).

30  
31 Changes in temperature and precipitation will drive changes in species interactions, species  
32 distributions and ranges, community assemblages, ecological processes, and, therefore,  
33 ecosystem services. To understand the implications of the projected temperature and  
34 precipitation on species and/or vegetation distribution, models have been designed to assess the  
35 responses of biomes to climate change—but this of course introduces more uncertainty, and  
36 therefore management risk, into the final analysis. For terrestrial research, dynamic global  
37 vegetation models (DGVM) and Species Distributions Models (SDM) have been developed to  
38 help predict biological and species impacts. These models have weaknesses that make managers  
39 reluctant to use them. For example DGCM vegetation models, which should be useful to forest  
40 managers, are limited by the fact that they do not simulate actual vegetation (only potential  
41 natural vegetation); the full suite of species migration patterns and dispersal capabilities; or the  
42 integration of the impacts of other global changes such as land use change (fragmentation and  
43 human barriers to dispersal) or invasive species (Field, 1999). Where vegetation cover is more

1 natural and the impacts of other global changes are not prominent, the model simulations are  
2 likely to have a higher probability of providing useful information of future change. For regions  
3 where there is low percentage of natural cover, where fragmentation is great, and large areas are  
4 under some form of management, the models will provide limited insight into future vegetation  
5 distribution. It is unclear how climate change will interact with these other global and local  
6 changes, and the models do not address this.

### 7 **9.2.3.2 Using Scenarios as a Means of Managing Under Uncertainty**

8 It is not possible to *predict* the changes that will occur, but managers can get an indication of  
9 what *range* of changes is possible. By working with a range of possible changes rather than a  
10 single projection, managers can focus on developing the most appropriate responses based on  
11 that range rather than on a “most likely” outcome. To develop a set of scenarios—*e.g.*, internally  
12 consistent views of reasonably plausible futures in which decisions may be explored (adapted  
13 from Porter, 1985; Schwartz, 1996)—quantitative or qualitative visions of the future are  
14 developed or described. These scenarios explore current assumptions and serve to expand  
15 viewpoints of the future. In the climate change impacts area, approaches for developing  
16 scenarios may range from using a number of different realizations from climate models  
17 representing a range of emissions growths, to analog scenarios, to informal synthetic scenario  
18 exercises that, for example, perturbate temperature and precipitation changes by percentage  
19 increments (*e.g.*, -5% change from baseline conditions, 0, +5%, +10%).  
20

21 Model-based scenarios explore plausible future conditions through direct representations of  
22 complex patterns of change. These scenarios have the advantage of helping to further our  
23 understanding of potential system responses to a range of changes in drivers. When using  
24 spatially downscaled climate models and a large number of emissions scenarios and climate  
25 model combinations (as many as 30 or more), a subset of “highly likely” climate expectations  
26 may be identifiable for a subset of regions and ecosystems. More typically, results among models  
27 will disagree for many places, precluding any unambiguous conclusions. Where there is a high  
28 level of agreement, statements may be made such as, “for 80% of the different model runs, peak  
29 daily summer temperatures are expected to rise by at least x degrees.” When downscaled and  
30 multiple runs are available (see the Appendix, Section 9.8, for possible sources), managers can  
31 use them to explore the consequences of different management options. For instance, Battin *et*  
32 *al.* (2007) were able to identify specific places where habitat restoration was likely to be  
33 effective in the face of climate change if the goal was recovery of salmon populations, and in  
34 specific places where restoration efforts would be fruitless given anticipated climate change.  
35

36 Analog scenarios use historical data and previously observed sensitivity to weather and climate  
37 variability. When developing analog scenarios, if historical data are incomplete or non-existent  
38 for one location, observations from a different region may be used. Synthetic scenarios specify  
39 changes in particular variables and apply those changes to an observed time series. For example,  
40 an historic time series of annual mean precipitation for the northeastern United States would be  
41 increased by 2% to create a synthetic scenario, but no other characteristics of precipitation would  
42 change. Developing a synthetic scenario might start by simply stating that in the future, it is  
43 possible that summers will be hotter and drier. That scenario would be used to alter the sets of  
44 historic time series, and decision makers would explore how management might respond.  
45

1 Along with developing multiple scenarios using the methods described above, it may be helpful  
2 to do sensitivity analyses to discover a system’s response to a range of possible changes in  
3 drivers. In such analyses, the key attributes of the system are examined to see how they respond  
4 to systematic changes in the climate drivers. This approach allows managers to identify  
5 thresholds beyond which key management goals become unattainable.  
6

7 All of these scenario-building approaches and sensitivity analyses provide the foundation for  
8 “if/then” planning, or scenario planning. One of the most practical ways of dealing with  
9 uncertainty is scenario planning—that is, making plans for more than one potential future. If one  
10 were planning an outdoor event (picnic, wedding, family reunion), it is likely that an alternate  
11 plan would be prepared in case of rain. Scenario planning has become a scientific version of this  
12 common sense approach. It is appropriate and prudent when there are large uncertainties that  
13 cannot be reduced in the near future. This is exactly the case with climate change. The key to  
14 scenario planning is limiting the scenarios to a set of possibilities, typically anywhere from two  
15 to five. If sensitivity analyses are performed, those results can be used to select the most relevant  
16 scenarios that both address managers’ needs and represent the widest possible, but still plausible,  
17 futures. The strategy is to then design a variety of management strategies that are robust across  
18 the whole range of scenarios. Ideally scenarios represent clusters of future projections that fit  
19 together as one bundled storyline that is easy to communicate to managers (*e.g.*, warmer and  
20 wetter, warmer and drier, negligible change). When used deftly, scenario planning can alleviate  
21 decision-makers’ and managers’ frustration at facing so much uncertainty and allow them to  
22 proactively manage risks. For detailed guidance on using scenario data for climate impact  
23 assessments, see IPCC-TGICA (2007).

### 24 **9.3 Best Practices for Adaptation**

25 Another element essential to the process of adaptation decision making is to know the possible  
26 management options (*e.g.*, adaptation options) available to address the breadth of projected  
27 impacts, and how those options function to lessen the impacts. As defined in this report, the goal  
28 of adaptation strategies is to reduce the risk of adverse environmental outcomes through  
29 activities that *increase the resilience* of ecological systems to climate change (Scheffer *et al.*,  
30 2001; Turner, II *et al.*, 2003; Tompkins and Adger, 2004). Here, resilience refers to the amount  
31 of change or disturbance that a system can absorb *before it undergoes a fundamental shift* to a  
32 different set of processes and structures (Holling, 1973; Gunderson, 2000; Bennett, Cumming,  
33 and Peterson, 2005). Therefore, all of the adaptation approaches reviewed below involve  
34 strategies for supporting the ability of ecosystems to persist at local or regional scales.  
35

36 The suites of characteristics that distinguish different ecosystems and regions determine the  
37 potential for successful adaptation of management to support resilience. This section begins with  
38 a description of resilience theory, including examples of some types of biological and physical  
39 factors that may confer resilience to climate change. This is followed by a review of seven major  
40 adaptation approaches gleaned from across the chapters of this report, a discussion of the  
41 confidence levels associated with these approaches, and an examination of adaptive management  
42 as an effective means of implementing adaptation strategies.

### 1 **9.3.1 Resilience**

2 Resilience is a highly desired attribute in the face of change—whether it is climate change or any  
 3 other disturbance. Resilience is the ability of a system to return to its initial state and function in  
 4 spite of some major perturbation. For example, a highly resilient coral reef might bleach but  
 5 would be able to recover rapidly. Similarly, a resilient forest ecosystem would quickly re-  
 6 establish plant cover following a major forest fire, with negligible loss of soils or fertility. An  
 7 important contributing factor to overall resilience is *resistance*, which is the ability of an  
 8 organism or a system to remain un-impacted by major disturbance or stress. “Un-impacted,” in  
 9 this sense, means that the species or system can continue to provide the desired ecosystem  
 10 services. Resistance is derived from intrinsic biological characteristics at the level of species or  
 11 genetic varieties. Resistance contributes to resilience since ecosystems that contain resistant  
 12 individuals or communities will exhibit faster overall recovery (through recruitment and re-  
 13 growth) after a disturbance.

14  
 15 The science and theory of resilience may soon be sufficiently advanced to be able to confidently  
 16 predict what confers resilience upon a system; the scientific literature is rapidly developing in  
 17 this area and provides plausible hypotheses and likely resilience factors. Furthermore, and  
 18 perhaps more importantly, common sense indicates that healthier ecosystems will generally be  
 19 more resilient to disturbances. Activities that promote overall ecosystem health, whether they are  
 20 restorative (*e.g.*, planting trees, captive breeding, and re-introduction) or protective (*e.g.*,  
 21 restrictive of destructive uses) will tend to build resilience.

22  
 23 On the broadest level, working from the assumption that more intact and pristine ecosystems are  
 24 more resilient to disturbances such as climate change, there are several ways to manage for  
 25 resilience. The appropriate approach depends largely on the current state of the area being  
 26 protected and the available resources with which to execute that protection. Options include 1)  
 27 protecting intact systems (*e.g.*, Papahānaumokuākea Marine National Monument), 2) restoring  
 28 systems to more pristine states (*e.g.*, restoring marshes and wetlands), and 3) preventing further  
 29 degradation (*e.g.*, control of invasive species in national parks).

30  
 31 Beyond simply managing for pristine systems, which can be hard to identify, a quantifiable  
 32 objective is to manage for biodiversity and key structural components or features. An important  
 33 underlying challenge associated with resilience is what might be called a “timescale mismatch.”  
 34 Resilience can be destroyed quickly, but often is “derived from things that can be restored only  
 35 slowly, such as reservoirs of soil nutrients, heterogeneity of ecosystems on a landscape, or a  
 36 variety of genotypes and species” (Folke *et al.*, 2002). This implies that while taking the  
 37 necessary steps to prevent extinctions, management should worry most about species that have  
 38 long generation times and low reproductive potential.

39  
 40 Understanding of specific resilience factors for particular systems is sparse, making managing  
 41 for resilience currently more an art than a science. Fortunately, two approaches provide a simple  
 42 framework for thinking about and managing for resilience. One is to ensure that ecosystems have  
 43 all the components they need in order to recover from disturbances. This may be termed the  
 44 biodiversity approach. The other is to support the species composing the structural foundation of  
 45 the ecosystem, such as corals or large trees as habitat. This may be termed the structural

1 approach. Although resource managers may not explicitly use these terms, examples of both  
2 approaches may be found in their decision-making.

### 3 **Biodiversity Approach**

4 Much academic research on managing for resilience invokes the precautionary principle. In this  
5 context, the precautionary principle calls for ensuring that ecosystems have all the biotic building  
6 blocks (functional groups, species, genes) that they need for recovery. These building blocks can  
7 also be thought of as *ecological memory*: the “network of species, their dynamic interactions  
8 between each other and the environment, and the combination of structures that make  
9 reorganization after disturbance possible” (Bengtsson *et al.*, 2003).

10  
11 A recent meta-analysis of ocean ecosystem services provides support for the biodiversity  
12 approach with its conclusion that in general, rates of resource collapse increased—and recovery  
13 rates decreased—exponentially with declining diversity. In contrast, with restoration of  
14 biodiversity, productivity increased fourfold and variability decreased by 21% on average  
15 (Worm *et al.*, 2006). Several other studies have concluded that diversity at numerous levels—  
16 *i.e.*, of functional groups, of species in functional groups, and within species and populations—  
17 appear to be critical for resilience and for the provision of ecosystem services (Chapin *et al.*,  
18 1997; Luck, Daily, and Ehrlich, 2003; Folke *et al.*, 2004). National parks, national wildlife  
19 refuges, and marine protected areas all manage for maintaining as many native species as  
20 possible, and in so doing promote diversity as a resilience factor. The call for ecosystem-based  
21 management in the chapter on national estuaries represents a move toward a multi-species focus  
22 that could also enhance resilience. Although the detailed dynamics of the connection between  
23 biodiversity and resilience are not yet understood, it is both practical and sensible as a  
24 precautionary act to protect biodiversity as a means of promoting resilience.

25  
26 Biodiversity exists at multiple levels: genetic, species, function, and ecosystem. Table 9.3 briefly  
27 provides definitions and examples of management options for each of these four levels of  
28 biodiversity. It is worth noting that national parks, national wildlife refuges, and marine  
29 protected areas are all aimed at supporting diversity to the extent that any “reserve” or “protected  
30 area” is. Wild and scenic rivers, national estuaries, and national forests have not traditionally had  
31 diversity as a core management goal. It is noteworthy, however, that the 2004–2008 USDA  
32 Forest Service Strategic plan does describe the Forest Service mission in terms of sustaining  
33 “diversity” (Chapter 3, National Forests).

### 34 **Structural Approach**

35  
36 Organisms that provide ecosystem structure include trees in forests, corals on coral reefs, kelp in  
37 kelp forests, and grasses on prairies. These structure-providing groups represent the successional  
38 climax of their respective ecosystems—a climax that often takes a long time to reach. Logically,  
39 managers are concerned with loss of these species (whether due to disease, overharvesting,  
40 pollution, or natural disturbances) because of consequent cascading effects.

41  
42 One approach to managing for resilience is to evaluate options in terms of what they mean for  
43 the recovery rate of fundamental structural aspects of an ecosystem. For example, the fishing  
44 technique of bottom trawling and the forestry technique of clear-cutting destroy biological  
45 structure, thus hindering recovery because the ecosystem is so degraded that either succession  
46 has to start from a more barren state or the community may even shift into an entirely new stable

1 state. Thus, management plans should protect these structural species whose life histories dictate  
2 that if they are damaged, recovery time will increase.

3 It is important to note that while structural species are often representative of the ecosystem state  
4 most desirable to humans in terms of production of ecosystem services, they are still only  
5 representative of one of several states that are natural for that system. The expectation that these  
6 structural organisms will always dominate is unreasonable. In temperate forests, stand-replacing  
7 fires can be critical to resetting ecosystem dynamics; in kelp forests, kelp is periodically  
8 decimated by storms. Thus maintaining structural species does not mean management for  
9 permanence—it simply means managing for processes that will keep structural species in the  
10 system, albeit perhaps in a shifting mosaic of dominant trees in a forest, for example.

### 11 **9.3.2 Adaptation Approaches**

12 Managers' past experiences with unpredictable and extreme events such as hurricanes, floods,  
13 pest and disease outbreaks, invasions, and forest fires have already led to some existing  
14 approaches that can be used to adapt to climate change. Ecological studies combined with  
15 managers' expertise reveal several common themes for managing natural systems for resilience  
16 in the face of disturbance. A clear exposition of these themes is the starting point for developing  
17 best practices aimed at climate adaptation.

18  
19 The seven approaches that are discussed below involve techniques that manipulate or take  
20 advantage of ecosystem properties to enhance their resilience to climatic changes. These are:  
21 protection of key ecosystem features, reduction of anthropogenic stresses, representation,  
22 replication, restoration, refugia, and relocation. All of these adaptation approaches ultimately  
23 contribute to resilience as defined above, whether at the scale of individual protected area units,  
24 or at the scale of regional/national systems. While different chapters vary in their perspectives  
25 and terminologies regarding adaptation, the seven categories presented are inclusive of the range  
26 of adaptation approaches found throughout this report.

#### 27 **9.3.2.1 Protect Key Ecosystem Features**

28 Within ecosystems, there may be particular structural characteristics (*e.g.*, three dimensional  
29 complexity, growth patterns), organisms (*e.g.*, functional groups, native species), or areas (*e.g.*,  
30 buffer zones, migration corridors) that are particularly important for promoting the resilience of  
31 the overall system. Such key ecosystem features could be important focal points for special  
32 management protections or actions. For example, managers of national forests may proactively  
33 promote stand resilience to diseases and fires by using silviculture techniques such as widely  
34 spaced thinnings or shelterwood cuttings (Chapter 3, National Forests). Another example would  
35 be to aggressively prevent or reverse the establishment of invasive non-native species that  
36 threaten native species or impede current ecosystem function (Chapter 4, National Parks).  
37 Preserving the structural complexity of vegetation in tidal marshes, seagrass meadows, and  
38 mangroves may render estuaries more resilient (Chapter 7, National Estuaries). Finally,  
39 establishing and protecting corridors of connectivity that enable migrations can enhance  
40 resilience across landscapes in national wildlife refuges (Chapter 5, National Wildlife Refuges).  
41 Box 9.2 draws additional examples of this adaptation approach from across the chapters of this  
42 report.

**1 9.3.2.2 Reduce Anthropogenic Stresses**

2 Managing for resilience often implies minimizing anthropogenic stressors (*e.g.*, pollution,  
3 overfishing, development) that hinder the ability of species or ecosystems to withstand a stressful  
4 climatic event. For example, one way of enhancing resilience in wildlife refuges is to reduce  
5 other stresses on native vegetation such as erosion or altered hydrology caused by human  
6 activities (Chapter 5, National Wildlife Refuges). Marine protected area managers may focus on  
7 human stressors such as fishing and inputs of nutrients, sediments, and pollutants both inside the  
8 protected area and outside the protected area on adjacent land and waters (Chapter 8, Marine  
9 Protected Areas). The resilience of rivers could be enhanced by strategically shifting access  
10 points or moving existing trails for wildlife or river enthusiasts in order to protect important  
11 riparian zones (Chapter 6, Wild and Scenic Rivers). Box 9.3 draws additional examples of this  
12 adaptation approach from across the chapters of this report.

**13 9.3.2.3 Representation**

14 Representation is based on the idea that biological systems come in a variety of forms. Species  
15 include locally adapted populations as opposed to one monotypic taxon; and major habitat types  
16 or community types include variations on a theme with different species compositions, as  
17 opposed to one invariant community. The idea behind representation as a strategy for resilience  
18 is simply that a portfolio of several slightly different forms of a species or ecosystem increases  
19 the likelihood that among those variants, there will be one or more that are suited to the new  
20 climate. A management plan for a large ecosystem that includes representation of all possible  
21 combinations of physical environments and biological communities increases the chances that,  
22 regardless of the climatic change that occurs, somewhere in the system there will be areas that  
23 survive and provide a source for recovery. Employing this approach with wildlife refuges may be  
24 particularly important for migrating birds because they use a diverse array of habitats at different  
25 stages of their life cycles and along their migration routes, and all of these habitats will be  
26 affected by climate change (Chapter 5, National Wildlife Refuges). At the level of species, it  
27 may be possible to increase genetic diversity in river systems through plantings or via stocking  
28 fish (Chapter 6, Wild and Scenic Rivers), or maintain complexity of salt marsh landscapes by  
29 preserving marsh edge environments (Chapter 7, National Estuaries). Box 9.4 draws additional  
30 examples of this adaptation approach from across the chapters of this report.

**31 9.3.2.4 Replication**

32 Replication is simply managing for the continued survival of more than one example of each  
33 ecosystem or species within a reserve system, even if the replicated examples are identical.  
34 When one recognizes that climate change stress includes unpredictable extreme events and  
35 storms, then replication represents a strategy of having multiple bets in a game of chance. With  
36 marine protected areas, replication is explicitly used as a way to spread risk: if one area is  
37 negatively affected by a disturbance, then species, genotypes, and habitats in another area  
38 provide both insurance against extinction and a larval supply that may facilitate recovery of  
39 affected areas (Chapter 8, Marine Protected Areas). The analogy for forests would be spreading  
40 risks by increasing ecosystem redundancy and buffers in both natural environments and  
41 plantations (Chapter 3, National Forests). It is prudent to use replication in all systems. In  
42 practice, most replication strategies also serve as representation strategies (since no two  
43 populations or ecosystems can ever be truly identical), and conversely most representation



1 strategies provide some form of replication. Box 9.5 provides examples of this adaptation  
2 approach from chapters of this report.

### 3 **9.3.2.5 Restoration**

4 In many cases natural intact ecosystems confer resilience to extreme events such as floods and  
5 storms. One strategy for adapting to climate change thus entails restoring intact ecosystems. For  
6 example the restoration of wetlands and natural floodplains will often confer resilience to floods.  
7 Restoration of particular species complexes may also be key to managing for resilience—a good  
8 example of this would be fire-adapted vegetation in forests that are expected to see more fires as  
9 a result of hotter and drier summers (Chapter 3, National Forests). At Blackwater National  
10 Wildlife refuge, the USFWS is planning to restore wetlands that may otherwise be inundated by  
11 2100 (Chapter 5, National Wildlife Refuges). In the case of estuaries, restoring the vegetational  
12 layering and structure of tidal marshes, seagrass meadows, and mangroves can stabilize estuary  
13 function (Chapter 7, National Estuaries). Box 9.6 draws additional examples of this adaptation  
14 approach from across the chapters of this report.

### 15 **9.3.2.6 Refugia and Relocation**

16 The term *refugia* refers to physical environments that are less affected by climate change than  
17 other areas (*e.g.*, due to local currents, geographic location, etc.) and are thus a “refuge” from  
18 climate change for organisms. *Relocation* refers to human-facilitated transplantation of  
19 organisms from one location to another in order to bypass a barrier (*e.g.*, an urban area). Refugia  
20 and relocation, while major concepts, are actually subsets of one or more of the approaches listed  
21 above. For example, if refugia can be identified locally, they can be considered sites for long-  
22 term retention of species (*e.g.*, for representation and to maintain resilience) in forests (Chapter  
23 3, National Forests). Or, in national wildlife refuges, it may be possible to use restoration  
24 techniques to reforest riparian boundaries with native species to create shaded thermal refugia for  
25 fish species (Chapter 5, National Wildlife Refuges). In the case of relocation, an example would  
26 be transport of fish populations in the Southwest that become stranded as water levels drop to  
27 river reaches with appropriate flows (*e.g.*, to preserve system-wide resilience and species  
28 representation) (Chapter 6, Wild and Scenic Rivers). Transplantation of organisms among  
29 national parks could preserve system-wide representation of species that would not otherwise be  
30 able to overcome barriers to dispersal (Chapter 4, National Parks). Boxes 9.7 and 9.8 draw  
31 additional examples of these adaptation approaches from across the chapters of this report.

### 32 **9.3.3 Confidence**

33 Due to uncertainties associated with climate change projections and uncertainties surrounding  
34 species and ecosystem responses, there is also uncertainty as to how effective the different  
35 adaptation approaches listed above will be at supporting resilience. It is therefore essential to  
36 assess the level of confidence associated with each adaptation approach. Based on the expert  
37 opinion of the author teams, who considered the literature and the application of each approach  
38 within their specific management systems, confidence estimates are presented in Table 9.4. Such  
39 confidence estimates should be a key consideration when deciding which adaptation approaches  
40 to implement for a given system.

41

1 Confidence levels are presented for each of the seven adaptation approaches, within each  
 2 management system type. The goal of all of these adaptation approaches is to support the  
 3 resilience of ecosystems to persist *in their current form* (*i.e.*, without major shifts to entirely  
 4 redefined systems). It is important to note at this point that promoting resilience may be a  
 5 management strategy that is useful only on shorter time scales (*i.e.*, 10–30 years) because as  
 6 climate change continues, various thresholds of resilience will eventually be exceeded.  
 7 Therefore, each confidence estimate is based solely on how effectively—in *the near term*—the  
 8 adaptation approach will be at achieving positive ecological outcomes with respect to increased  
 9 resilience to climate change. On longer time scales, as ecosystem thresholds are exceeded, these  
 10 approaches will cease to be effective, at which point major shifts in ecosystem processes,  
 11 structures and components will be unavoidable. This eventuality is discussed in a later section  
 12 (9.5.3, *Manage for Change*), where adaptation strategies associated with planning for major  
 13 shifts are presented.

#### 14 **9.3.4 Adaptive Management**

15 Once adaptation approaches have been selected after taking into account confidence levels,  
 16 adaptive management is likely to be the most attractive method for implementing those  
 17 approaches. It emphasizes managing based on observation and continuous learning and provides  
 18 a means for effectively addressing varying degrees of uncertainty in our knowledge of current  
 19 and future climate change impacts. Adaptive management is at heart an experiment, with data on  
 20 the effects of various management interventions collected to measure the effectiveness of those  
 21 interventions and to determine the best way to move forward. Examples include flood release  
 22 experiments in the Grand Canyon (Chapter 4, National Parks) and at the Glen Canyon dam  
 23 (National Research Council, 1999). Releasing water from a dam allows for the application of  
 24 highly regulated experimental treatments and assessments of effects.

25  
 26 Adaptive management to address climate change is an iterative process that involves the  
 27 consideration of potential climate impacts, the design of management actions and experiments  
 28 that take those impacts into account, monitoring of climate-sensitive species and processes to  
 29 measure management effectiveness, and the redesign and implementation of improved (or new)  
 30 management actions (Figure 9.2). To maximize the implementation of climate-sensitive adaptive  
 31 management within federal systems, managers can focus on (1) previously established strategies  
 32 that were designed for other management issues but have strong potential for application toward  
 33 climate change impacts and (2) new strategies that are not yet in place but appear to be feasible  
 34 and within reasonable reach of current management structures. In other words, at a minimum,  
 35 managers need to vigorously pursue changes that are relatively easily accomplished under  
 36 existing programs and management cultures.

37

38

39 **Figure 9.2.** The process of adaptive management.

40

41 Even in the absence of an ability to experimentally manipulate systems, rapid, climate-induced  
 42 ecological changes provide excellent opportunities to observe the effects of climate change in  
 43 relatively short time frames. Managers and scientists can design studies to take advantage of  
 44 increased climatic variability and climate trends to inform management. Some examples of such  
 45 studies could include determining which riparian plant species are best adapted to extreme

1 variations in flow regime and flooding, observing how increased variability in climatic  
2 conditions affects population dynamics of target insect pests or focal wildlife species, and  
3 determining the effect of marine reserve size on recruitment and survival of key species. Using  
4 climate-driven changes as treatments *per se* will be much less exact and less predictable than  
5 controlled experiments, so taking advantage of such situations for adaptive management studies  
6 will require increased flexibility, foresight, and creativity on the part of managers and scientists.  
7

8 Another key element of adaptive management is monitoring of sensitive species and processes in  
9 order to measure the effectiveness of experimental management actions. In the case of adaptive  
10 management for climate change, this step is critical, not only for measuring the degree to which  
11 management actions result in positive outcomes on the ground, but also for supporting a better  
12 scientific understanding of how to characterize and measure ecological resilience. Most resource  
13 agencies already have monitoring programs and sets of indicators. As long as management goals  
14 are not changed (see section 9.5.1), then these existing monitoring programs should reflect the  
15 outcomes of management actions on the ground. If management goals are altered because  
16 climate change is perceived to be so severe that historical goals are untenable, then entirely new  
17 indicators and monitoring programs may need to be designed. Whatever the case, monitoring is  
18 fundamental to supporting the reevaluation and refinement of management strategies as part of  
19 the adaptive process.  
20

21 The same monitoring can also foster an improved understanding of how best to characterize and  
22 quantify resilience. For some systems, the ecology of climate stress (*e.g.*, coral bleaching) has  
23 been studied for decades, and resilience theory continues to develop rapidly. For other  
24 ecosystems, the negative impacts of climate change are less well understood, and understanding  
25 resilience is more difficult. In any event, while there may be some good conceptual models that  
26 describe resilience characteristics for species and ecosystems, there is generally a paucity of  
27 empirical data to confirm and resolve the relative importance of these characteristics. Such  
28 information is needed for the next generation of techniques and tools for quantification and  
29 prediction of resilience across species and ecosystems.  
30

31 The idea of “adaptive management” has been widely advocated among natural resource  
32 managers for decades but is still not applied as widely as it should be. Yet, the prospect of  
33 uncertain, widespread, and severe climatic changes may represent a tipping point that spurs  
34 managers to embrace adaptive management as an essential strategy. Climate change creates new  
35 situations of added complexity for which an adaptive management approach may be the only  
36 way to take management action today while allowing for increased understanding and refinement  
37 tomorrow.

## 38 **9.4 Barriers and Opportunities for Adaptation**

39 Although there may be many adaptation strategies that could be implemented, a very real  
40 consideration for managers is whether all of the possibilities are feasible. Factors limiting or  
41 enhancing managers’ ability to implement options may be technical, economic, social, or  
42 political. As noted previously in this chapter, the climate community refers to such opportunities  
43 and constraints (or barriers) as adaptive capacity. It may be helpful to understand the types of  
44 barriers to implementation that exist in order to assess the feasibility of specific adaptation  
45 options, and even more so to identify corresponding ways in which barriers may be overcome.

1 The barriers and opportunities discussed below are based on the expert opinions of the authors of  
2 this report and feedback from the stakeholder workshops, and are associated with  
3 implementation of adaptation options today, assuming no significant changes in institutional  
4 frameworks and authority.

5  
6 A useful way of thinking about both barriers and opportunities is in terms of the following four  
7 categories: 1) legislation and regulations, 2) management policies and procedures, 3) human and  
8 financial capital, and 4) information and science (see Tables 9.5–9.8). All of the federal land and  
9 water management systems reviewed in the preceding chapters are mandated by law to preserve  
10 and protect the nation’s natural resources. Specific management goals vary across systems,  
11 however, due to the unique mission statements articulated in their founding legislation, or  
12 organic acts. Organic acts are fundamental pieces of legislation that either signify the  
13 organization of an agency and/or provide a charter for a network of public lands, such as the  
14 National Park Service Organic Act that established the National Park System. Accordingly, goals  
15 are manifested through management principles that could either narrowly interpret the goals and  
16 thus hinder adaptation, or could broadly interpret the goals and thereby facilitate adaptation.

17  
18 No matter how management goals are approached, achievement of goals may be difficult even  
19 without climate change. For example, in the case of the National Forest System, managers are  
20 asked to provide high-quality recreational opportunities and to develop means of meeting the  
21 nation’s energy needs through biofuel production while reducing the risk of wildfire and invasive  
22 species and protecting both watersheds and biodiversity. Successful management requires not  
23 only significant resources (*e.g.*, staff capacity and access to information), but also the ability of  
24 managers to apply resources strategically and effectively (*e.g.*, for monitoring and management  
25 experiments) (Kelly and Adger, 2000).

26  
27 The growing need for more management resources is ubiquitous across federal agencies as the  
28 ramifications of a growing human population put new and expanding pressures on the manager’s  
29 ability to meet management goals. Examples of these existing pressures include economic  
30 development near management unit boundaries (Chapter 5, National Wildlife Refuges), air  
31 pollution (Chapter 4, National Parks), increased wildfire-related costs and risks (Chapter 3,  
32 National Forests), habitat degradation and destruction (Chapter 8, Marine Protected Areas),  
33 pollutant loading (Chapter 7, National Estuaries), and excessive water withdrawals (Chapter 6,  
34 Wild and Scenic Rivers). The added threat of climate change may exceed the capacity of the  
35 federal management systems to protect the species and ecological systems that each is mandated  
36 to protect. However, as many of the previous chapters point out, this threat also represents an  
37 opportunity to undertake strategic thinking, reshape priorities, and use carefully considered  
38 actions to initiate the development of management adaptations to respond to climate change.

39  
40 Adaptation responses to climate change are meant to reduce the risk of failing to achieve  
41 management goals. A better understanding of the barriers and opportunities that affect  
42 implementation of adaptation strategies could facilitate the identification of critical adjustments  
43 within the constraints of management structures and policies, and subsequently could foster  
44 increased adaptive capacity within and across federal management systems as those constraints  
45 are addressed in the longer term (see section 9.5).

## 1 **9.4.1 Legislation and Regulation**

### 2 **9.4.1.1 Barriers**

3 While original organic acts represented progressive policy and management frameworks at the  
4 time they were written, many reflect a past era (Table 9.5). For example, the first unit of the  
5 National Wildlife Refuge System, Pelican Island, was designated in 1903 to protect waterfowl  
6 from being over-hunted when that was the greatest threat. At that time, the U.S. population was  
7 half of what it is now, and the interstate highway system decades away from establishment  
8 (Chapter 5, National Wildlife Refuges). In addition, ambiguous language in enabling legislation  
9 poses challenges to addressing issues related to climate change, such as determining what  
10 “impaired” means (Chapter 4, National Parks). It also has been recognized that specific  
11 environmental policies such as the Endangered Species Act, National Environmental Policy Act,  
12 and the National Forest Management Act are highly static, making dynamic planning difficult  
13 and potentially impeding adaptive responses (Levings, 2003). Even recently implemented  
14 legislation and management plans have not directly addressed climate change (Chapter 7,  
15 National Estuaries). In general, while coarse-filter or community-focused approaches are more  
16 adaptive, many existing laws force a species-specific approach to management (Chapter 3,  
17 National Forests), limiting agency action to address issues related to climate change.

18

19 Furthermore, organic acts and pursuant enabling legislation have failed to provide sufficient  
20 capacity to effectively manage resources. For example, the chief legal limitation on intensive  
21 management to adapt to climate change for the National Wildlife Refuge System is the limited  
22 jurisdiction of many refuges over their water (Chapter 5, National Wildlife Refuges). Both the  
23 timing of water flows as well as the quantity of water flowing through refuges are often subject to  
24 state permitting and control by other federal agencies. Similarly, legal frameworks such as the  
25 Colorado River Compact establish water rights, compacts, and property rights that all serve to  
26 constrain the ability to use adaptive strategies to address climate change (Chapter 6, Wild and  
27 Scenic Rivers).

28

29 Protected areas have political rather than ecological boundaries as an artifact of legislation.  
30 These boundaries may pose a barrier to effectively addressing climate change. Climate change  
31 will likely lead to shifts in species and habitat distribution (Chapter 3, National Forests; Chapter  
32 4, National Parks; Chapter 7, National Estuaries; Chapter 8, Marine Protected Areas), potentially  
33 moving them outside the bounds of federal jurisdiction or introducing new species that cause  
34 changes in animal communities, such as changing predation and competition (Chapter 5,  
35 National Wildlife Refuges). Agencies often do not have the capacity or authority to address  
36 issues outside their jurisdiction, which could hamper efforts to adapt to climate change. This  
37 could affect smaller holdings more acutely than others (Chapter 5, National Wildlife Refuges).

38

39 Despite historical interpretations, existing legislation does not prohibit adaptive management.  
40 The obstacle to implementing adaptive management is rarely legal—but rather political—  
41 opposition both from within and from outside the agencies. Additionally, the uncertainty  
42 surrounding its use has led to costly and time-consuming challenges from particular stakeholders  
43 or the public (Chapter 3, National Forests). Fuel treatments and other adaptive projects that have  
44 ground-disturbing elements, such as salvage harvest after disturbance and use of herbicides  
45 before revegetation, have been strongly opposed by the public (Levings, 2003). While using

1 adaptation approaches in management poses the risk of spurring costly litigation from  
2 stakeholders, every chapter in this volume concludes that inaction with regard to climate change  
3 may prove more damaging and costly than acting with insufficient knowledge of the outcomes.

#### 4 **9.4.1.2 Opportunities**

5 Federal land and water managers can use existing legislative tools in opportunistic ways (Table  
6 9.5). Managers can strategically apply existing legislation or regulations at the national or state  
7 level by applying traditional features or levers in non-traditional ways. For example, while still  
8 operating within the legislative framework, features of existing legislation can be effectively  
9 used to coordinate management outside of jurisdictional boundaries. Generally, the USFWS has  
10 ample proprietary authority to engage in transplantation-relocation, habitat engineering (including  
11 irrigation-hydrologic management), and captive breeding to support conservation (Chapter 5,  
12 National Wildlife Refuges). These activities are especially applicable to managing shifts in  
13 species distributions and in potentially preventing species extirpations likely to result from  
14 climate change. Portions of existing legislation could also be used to influence dam operations at  
15 the state level as a means of providing adaptive flow controls under future climate changes (*e.g.*,  
16 using the Clean Water Act to prevent low flows in vulnerable stream reaches, adjusting thermal  
17 properties of flows). As these examples suggest, managers can influence change within the  
18 legislative framework to address climate change impacts.

### 19 **9.4.2 Management Policies and Procedures**

#### 20 **9.4.2.1 Barriers**

21 Most management systems have a history of static policies and procedures that are counter to the  
22 dynamic and flexible management actions called for now (Table 9.6; Chapter 3, National  
23 Forests). Thus, although adaptive management is encouraged, its implementation is rarely fully  
24 embraced (Lee, 1999; Stankey *et al.*, 2003). Part of the problem is that some agency policies do  
25 not recognize climatic change as a significant problem or stressor (Chapter 3, National Forests).  
26 In many cases agency policies do not allow for sufficient flexibility under uncertainty and  
27 change. Without flexibility, existing management goals and priorities—though potentially  
28 unrealistic given climate change—may have to be pursued without adjustments. Yet, with  
29 limited resources and staff time, priorities need to be established and adaptation efforts focused  
30 to make best use of limited resources. There are several specific hindrances to such management  
31 changes that are worth mentioning in detail.

32  
33 First, addressing climate change will require flexible and long-term planning horizons. Existing  
34 issues on public lands, coupled with insufficient resources (described below), force many  
35 agencies and managers to operate under crisis conditions, focusing on short-term and narrow  
36 objectives (Chapter 4, National Parks). Agencies often put priority on maintaining, retaining, and  
37 restoring historic conditions. These imperatives can lead to static as opposed to dynamic  
38 management (Chapter 3, National Forests) and may not be possible to achieve as a result of  
39 climate change. Additionally, place-based management paradigms may direct management at  
40 inappropriate spatial and temporal scales for climate change. Managing on a landscape scale, as  
41 opposed to smaller-scale piecemeal planning, would enable greater adaptability to climate-  
42 related changes (Chapter 3, National Forests).

43

1 A number of factors may limit the usefulness of management plans. The extent to which plans  
2 are followed and updated is highly variable across management systems. Further, plans may not  
3 always adequately address evolving issues or directly identify actions necessary to address  
4 climate change (Chapter 3, National Forests; Chapter 8, Marine Protected Areas). If a plan is not  
5 updated with regularity, or a planning horizon is too short-sighted in view of climate change, a  
6 plan's management goals may become outdated or inappropriate. To date, few management  
7 plans address or incorporate climate change directly. Fortunately, many agencies recognize the  
8 need for management plans to identify the risks posed by climate change and to have the ability  
9 to adapt in response (Chapter 6, Wild and Scenic Rivers). Some proactive steps to address  
10 climate change will likely cost very little and should be included in policy and management  
11 plans (Chapter 7, National Estuaries). These include documenting baseline conditions to aid in  
12 identifying future changes and threats, identifying protection options, and developing techniques  
13 and methods to help predict climate related changes at various scales (Chapter 3, National  
14 Forests; Chapter 6, Wild and Scenic Rivers).

15  
16 Last, even if the plan for a particular management system addresses climate change  
17 appropriately, many federal lands and waters are affected by neighboring lands for which they  
18 have limited or no control (Chapter 4, National Parks). National wildlife refuges and wild and  
19 scenic rivers are subject to water regulation by other agencies or entities. This fragmented  
20 jurisdiction means that collaboration among agencies is required so that they are all working  
21 toward common goals using common management approaches. Although such collaboration  
22 does occur, formal co-management remains the exception, not the rule. Despite this lack of  
23 collaboration, there is widespread recognition that managing surrounding lands and waters is  
24 important to meeting management objectives (Chapter 5, National Wildlife Refuges; Chapter 8,  
25 Marine Protected Areas), which may lead to more effective management across borders in the  
26 future.

#### 27 **9.4.2.2 Opportunities**

28 Each management system mandates the development of a management plan. Incorporating  
29 climate change adaptation could be made a requirement and could be accomplished at the level  
30 of individual units or collaboratively with other management units. This might encourage more  
31 units in the same broad geographical areas to look for opportunities to coordinate and collaborate  
32 on the development of regional management plans (Table 9.6). A natural next step would then be  
33 to prioritize actions within the management plan. Different approaches may be used at different  
34 scales to decide on management activities across the public lands network or at specific sites. If  
35 planning and prioritizing occurs across a network of sites, then not only does this approach  
36 facilitate sharing of information between units, but this broader landscape approach also lends  
37 itself well to climate change planning. This has already occurred in the National Forest System,  
38 where the Olympic, Mt. Baker, and Gifford Pinchot National Forests have combined resources to  
39 produce coordinated plans. The Olympic National Forest's approach to its strategic planning  
40 process is also exemplary of an entity already possessing the capacity to incorporate climate  
41 change through its specific guidance on prioritization.

42  
43 In some cases, existing management plans may already set the stage for climate adaptation. A  
44 good example is the Forest Service's adoption of an early detection/rapid response strategy for  
45 invasive species. This same type of thinking could easily be translated to an early detection/rapid

1 response management approach to climate impacts. Even destructive extreme climate events can  
2 be viewed as management opportunities by providing valuable post-disturbance data. For  
3 example, reforestation techniques following a fire or windfall event can be better honed and  
4 implemented with such data (*e.g.*, use of genotypes that are better adjusted to the new or  
5 unfolding regional climate, use of nursery stock tolerant to low soil moisture and high  
6 temperature, or use of a variety of genotypes in the nursery stocks) (see Chapter 3, National  
7 Forests).

8  
9 Management plans that are allowed to incorporate climate change adaptation strategies but that  
10 have not yet done so provide a blank canvas of opportunity. In the near term, state wildlife action  
11 plans are an example of this type of leveraging opportunity. Another example is the Forest  
12 Service's involvement with the Puget Sound Coalition and the National Estuary Program's  
13 involvement in Coastal Habitat Protection Plans for fish, an ecosystem-based fisheries  
14 management approach at the state level. Stakeholder processes, described above as a barrier,  
15 might be an opportunity to move forward with new management approaches if public education  
16 campaigns precede the stakeholder involvement. The issue of climate change has received  
17 sufficient attention that many people in the public have begun to demand actions by the agencies  
18 to address it.

19  
20 As suggested by the many themes identified by the federal land and water management systems,  
21 the key to successful adaptation is to turn barriers into opportunities. This should be possible with  
22 increased availability of practical information, corresponding flexibility in management goals, and  
23 strong leadership. At the very least, managers (and corresponding management plans) may need to  
24 recognize climate change and its synergistic effects as an overarching threat to their resources.

### 25 **9.4.3 Human and Financial Capital**

#### 26 **9.4.3.1 Barriers**

27 Consistent under-funding and lack of staff capacity (or regular staff turnover) pose significant  
28 barriers to adaptation to climate change (Table 9.7). Agencies may also lack adaptive capacity  
29 due to the reward systems in place. Currently, in some agencies a reward system exists that  
30 focuses primarily on achieving narrowly prescribed targets, and funding is directed at achieving  
31 these specific activities (Chapter 3, National Forests). This system provides few incentives for  
32 creative project development and implementation, instead creating a culture that prioritizes  
33 projects with easily attainable goals. This comes at the expense of adaptive, forward thinking  
34 approaches to management.

35  
36 Budgetary constraints can also curtail adaptation efforts. National and regional budget policies  
37 constrain the ability to alter or supplement current management practices that would enable  
38 adaptation to climate change. Managers often lack sufficient resources to deal with routine  
39 needs. Chronic budget shortfalls have reduced the ability or restricted the implementation of  
40 monitoring programs (Chapter 5, National Wildlife Refuges). Managers have even fewer  
41 resources available to address unexpected events, which will likely increase as a result of climate  
42 change. Exacerbating the problem of limited budgetary support is the lack of adequate staff  
43 capacity. National and regional budget policies pose a significant barrier by constraining the  
44 potential for changing current management practices that would enable adaptation to climate



1 change (Chapter 3, National Forests). While climate change stands to increase the scope of  
2 management by increasing both the area of land requiring active management and the planning  
3 burden per unit area (because of adaptive management techniques), agencies such as the USFWS  
4 face decreasing personnel in some regions. Even if time and sufficient resources exist, minimal  
5 institutional capacity exists to capture experience and expand learning (Chapter 4, National  
6 Parks). As a result, many agency personnel do not have adequate training, expertise, or  
7 understanding to effectively address emerging issues related to climate change, something that  
8 staff education programs could serve to remedy (Chapter 3, National Forests). The legacy of past  
9 practices and long-term institutional status quo may also make it difficult to increase capacity to  
10 address climate change. When other threats have been seen as higher priorities by historical  
11 leadership, then it may be difficult to attract and train the most innovative managers for  
12 adaptation to climate change.

### 13 **9.4.3.2 Opportunities**

14 Agency employees play important roles as crafters and ultimate implementers of management  
15 plans and strategies. In fact, with respect to whether the implementation of adaptation strategies  
16 is successful or unsuccessful, the management of people can be as—or more—important than  
17 managing the natural resource. A lack of risk-taking coupled with the uncertainty surrounding  
18 climate change could lead to a situation where managers opt for the no-action approach  
19 (Spittlehouse and Stewart, 2003). On the other hand, climate change could cause the opposite  
20 response if managers perceive that risks must be taken because of the uncertainties surrounding  
21 climate change. Implementation of human resource policies that minimize risk for action and  
22 protect people when mistakes are made will be critical to enabling managers to make difficult  
23 choices under climate change (Table 9.7). A “safe-to-fail” policy would be exemplary of this  
24 approach (Chapter 4, National Parks). A safe-to-fail policy or action is one in which the system  
25 can recover without irreversible damage to either natural or human resources (*e.g.*, careers and  
26 livelihoods). Because the uncertainties associated with projections of climate change and its  
27 effects are substantial, expected outcomes or targets of agency policies and actions may be  
28 equally likely to be correct or incorrect. Although managers aim to implement a “correct” action,  
29 it must be expected that when the behavior of drivers and system responses is uncertain, failures  
30 are likely to occur when attempting to manage for impacts of climate change (Chapter 4,  
31 National Parks).

32  
33 Tackling the challenge of managing natural resources in the face of climate change may require  
34 that staff members not only feel valued but also empowered by their institutions. Scores of  
35 federal land management employees began their careers as passionate stewards of the nation’s  
36 natural resources. With the threat of climate change further compounding management  
37 challenges, it is important that this passion be reinvigorated and fully cultivated. Additional  
38 human resources also would add new energy and passion that could lead to successful  
39 implementation of existing, new, and future adaptation strategies. In fact, it could be argued that  
40 by increasing funding, staff capacity, and access to new information and tools, the overall  
41 adaptive capacity of each management institution would be enhanced. Specifically creating new  
42 employment opportunities that include duties associated with or entirely focused on climate  
43 change could further build upon this capacity.  
44

1 Conversely, it may also be argued that existing employees could be effectively trained for  
2 tackling climate change issues within the context of their current job descriptions and  
3 management frameworks (Chapter 3, National Forests). For example, the National Park Service  
4 has recently implemented a program to educate park staff on climate change issues, in addition to  
5 offering training for presenting this information to park visitors in 11 national parks. Called the  
6 “Climate Friendly Parks” program, it includes guidelines for inventorying a park’s greenhouse  
7 gas emissions, park-specific suggestions to reduce greenhouse gas emissions, and help for setting  
8 realistic emissions reduction goals. Additionally, the Park Service’s Pacific West Regional  
9 Office has been proactive in educating western park managers on issues related to climate  
10 change as well as promoting messages to communicate to the public and actions to address the  
11 challenge of climate change (Chapter 4, National Parks). Such “no regrets” activities offer a cost-  
12 effective mechanism for empowering existing employees with both knowledge and public  
13 outreach skills.

#### 14 **9.4.4 Information and Science**

##### 15 **9.4.4.1 Barriers**

16 Adaptive management is predicated upon research and scientific information. Addressing  
17 emerging issues that arise as a result of climate change will require new research and information  
18 to use in developing strategic management plans. However, in some agencies a disconnect exists  
19 between management and scientific personnel. Critical gaps in scientific information, such as  
20 understanding of ecosystem function and structure, coupled with the high degree of uncertainty  
21 surrounding potential impacts of climate change, hinder the potential for effective  
22 implementation of adaptation (Table 9.8; Chapter 8, Marine Protected Areas). A lack of climate-  
23 related data from monitoring precludes managers from assessing the extent to which climate has  
24 affected their systems. Staff and budget limitations not only constrain the ability to monitor but  
25 also often preclude managers from analyzing data from the monitoring programs that do receive  
26 support. Without adequate monitoring, it remains impossible to move forward confidently with  
27 appropriate adaptation efforts (Chapter 6, Wild and Scenic Rivers).

28  
29 Distinguishing the causes and effects of climate change from other natural phenomena has proven  
30 difficult, particularly at certain scales (Chapter 3, National Forests). In general the uncertainty  
31 associated with climate change at sub-regional and local levels has caused managers to take  
32 minimal action. Where agency managers are keen to apply adaptive management and are fully  
33 aware of the challenges posed by climate change, they are constrained by an absence of  
34 provisions for management experiments, by a lack of financial support, and by an absence of  
35 training in what to look for and how to respond.

36  
37 Even if managers had sufficient information, decision-making would still prove problematic.  
38 Managers often lack sufficient support and decision-making tools to help guide them in selecting  
39 appropriate management approaches that address climate change. The complexity of climate  
40 models poses a barrier to adequately understanding future scenarios and how to react to them, and  
41 gaps in tools and resource availability limit the ability of managers to prioritize actions to address  
42 climate change (Chapter 3, National Forests). Of particular importance is the need to establish  
43 decision support tools to help identify tradeoffs in different management decisions and understand

1 how those tradeoffs would affect particular variables of interest (*e.g.*, air quality levels from  
2 prescribed fires versus high-intensity natural fires).

3  
4 Another gap exists between stakeholder information and expertise compared with that held by  
5 resource managers and scientists. Stakeholders often do not have full information, sufficient  
6 expertise, or a long-term perspective that allows them to evaluate the relative merit of adaptation  
7 options. Therefore, they may act to inhibit or even block the use of adaptation in management  
8 planning. Strong local preferences can contradict broader agency goals and drive non-optimal  
9 decision-making, all of which act to limit or preclude acceptance of proactive management  
10 (Chapter 3, National Forests).

#### 11 **9.4.4.2 Opportunities**

12 Although barriers exist, effective collaboration and linkages among managers and resource  
13 scientists are possible (Table 9.8). Scientists can support management by targeting their research to  
14 provide managers with information relevant to major management challenges, which would enable  
15 managers to make better-informed decisions as new resource issues emerge. Resource scientists  
16 have monitoring data and research results that are often underused or ignored. Monitoring efforts  
17 that have specific objectives and are conducted with information use in mind would make the data  
18 more useful for managers. The need for monitoring efforts combined with a shortage of funds may  
19 provide impetus for a more unified approach across agencies or management regions. This would  
20 serve to not only provide more comprehensive information but would also serve to minimize costs  
21 associated with monitoring efforts.

22  
23 A unified effort is also needed to invest resources and training into the promotion of agile  
24 approaches to adaptation management across all federal resource agencies and land or water  
25 managers. This would include producing general guidance in terms of the likely impacts of  
26 concern, and the implications of these impacts for ecosystem services and management. It would  
27 also mean expending efforts to develop “climate science translators” who are capable of  
28 translating the projections of climate models to managers and planners who are not trained in the  
29 highly specialized field of GCMs. These translators would be scientists adept at responding to  
30 climate change who help design adaptive responses. They would also function as outreach staff  
31 who would explain to the public what climate change might mean to long-standing recreational  
32 opportunities or management goals.

33  
34 Many federal lands and waters provide excellent opportunities for educating the public about  
35 climate change. The national parks and wildlife refuges already put extensive resources into  
36 education and outreach for environmental, ecological, and cultural subjects. There are several  
37 ways in which the agencies can inform the public about climate change and climate-change  
38 impacts. The first of these uses traditional communication venues such as information kiosks and  
39 signs, documentaries, and brochures. Interactive video displays are well suited to demonstrating  
40 the potential effects of climate change. Such displays could demonstrate the effects of different  
41 climate-change scenarios on specific places or systems, making use, for example, of photos or  
42 video documenting coral bleaching and retreating glaciers, or modeling studies projecting  
43 changes in specific lands or waters (*e.g.*, Hall and Fagre, 2003).

1 The second major way that agencies can inform the public is to provide examples of sustainable  
2 practices that reduce greenhouse gas emissions. The National Park Service’s Climate Friendly  
3 Parks program is a good example of such an outreach effort. The program involves a baseline  
4 inventory of park emissions using Environmental Protection Agency models and then uses that  
5 inventory to develop methods for reducing emissions, including coordinating transportation,  
6 implementing energy-saving technology, and reducing solid waste. Similar programs could  
7 easily be developed for other agencies.

## 8 **9.5 Advancing the Nation’s Capability to Adapt**

9 Until now, we have discussed specific details and concepts for managers to consider relating to  
10 adapting to climate change. When all of these details and case studies are pulled together it is the  
11 opinion of the authors of this report that some fundamental strategic foci are needed. Those foci  
12 are: 1) have a rational approach for establishing priorities and triage, 2) make sure the  
13 management is done at appropriate scales and not necessarily simply the scales of convenience  
14 or tradition, and 3) manage expecting change. In order to make progress on these foci, the  
15 authors believe greater collaboration and integration among federal agencies is a necessity.  
16

17 In order to understand how these conclusions were reached, one needs only to appreciate that for  
18 virtually every category of federal land and water management, one is likely to find situations  
19 that exist in which currently available adaptation strategies will not enable a manager to meet  
20 specific goals, especially where those goals are related to keeping ecosystems unchanged or  
21 species where they are. The expert opinion of the report authors and stakeholders is that these  
22 circumstances may require fundamental shifts in how ecosystems are managed. Such shifts may  
23 entail reformulating goals, managing cooperatively across landscapes, and looking forward to  
24 potential future ecosystem states and facilitating movement toward those preferred states. These  
25 sorts of fundamental shifts in management at local-to-regional scales may only be possible with  
26 coincident changes in organizations at the national level that empower managers to make the  
27 necessary shifts. Thus, fundamental shifts in national-level policies may also be needed.  
28

29 Even with actions taken to limit greenhouse gas emissions in the future, such shifts in  
30 management and policies may be necessary since concentrations resident in the atmosphere are  
31 significant enough to require planning for adaptation actions today (Kerr, 2004; 2005).  
32 Ecosystem responses to the consequences of increasing concentrations are likely to be unusually  
33 fast, large, and non-linear in character. More areas are becoming vulnerable to climate change  
34 because of anthropogenic constraints compounding natural barriers to biological adaptations.  
35

36 The types of changes that may be needed at the national level include modification of priorities  
37 across systems and species and use of new rules for triage; enabling management to occur at  
38 larger scales and for projected ecological changes; and expansion of interagency collaboration  
39 and access to expertise in climate change science and adaptation, data, and tools. Although many  
40 agencies have embraced subsets of these needed changes, there are no examples of the full suite  
41 of these changes being implemented as a best practices approach.

**1 9.5.1 Re-Evaluate Priorities and Consider Triage**

2 Climate change not only requires consideration of how to adapt management approaches; it also  
3 requires reconsideration of management objectives. In a world with unlimited resources and staff  
4 time, climate adaptation would simply be a matter of management innovation, monitoring, and  
5 more accessible and useable science. In reality, priorities may need to be re-examined and re-  
6 established to focus adaptation efforts appropriately and make the best use of limited resources.  
7 At the regional scale, one example of the type of change that may be needed is in selected  
8 estuaries where freshwater runoff is expected to increase and salt water is expected to penetrate  
9 further upstream. Given this scenario combined with the goal of protecting anadromous fishes,  
10 models could be used to project shifts in critical propagation habitats and management efforts  
11 could be refocused to those sites (Chapter 7, National Estuaries). In Rocky Mountain National  
12 Park, because warmer winters are expected to result in greatly increased elk populations, a plan  
13 to reduce elk populations to appropriate numbers is being prepared with the goal of population  
14 control (Chapter 4, National Parks).

15  
16 In the situations above, the goals are still attainable with some modifications. However, in  
17 general, resource managers could face significant constraints on their authority to re-prioritize  
18 and make decisions about which goals to modify and how to accomplish those modifications.  
19 National-level policies may have to be re-examined with thought toward how to accommodate  
20 and even enable such changes in management at the regional level. This re-examination of  
21 policies at the national level is another form of priority-setting. Similar to regional-level  
22 prioritization, prioritization at the national level would require information at larger scales about  
23 the distribution of natural resources and conservation targets, the vulnerability of those targets to  
24 climate change, and costs of different management actions in different systems. Prioritization  
25 schemes may weight these three factors in different ways, depending on goals and needs.  
26 Knowing where resources and conservation targets are is relatively straightforward, although  
27 even baseline information on species distributions is often lacking (Chapter 5, National Wildlife  
28 Refuges; Chapter 6, Wild and Scenic Rivers). Prioritization schemes that weight rare species or  
29 systems heavily would likely target lands with more threatened and endangered species and  
30 unique ecosystems.

31  
32 Because climate-driven changes in some ecological systems are likely to be extreme, priority-  
33 setting may, in some instances, involve triage (Myers, 1979; Chapter 3). Some goals may have to  
34 be abandoned and new goals established if climate change effects are severe enough. Even with  
35 substantial focused and creative management efforts, some systems may not be able to maintain  
36 the ecological properties and services that they provide in today's climate. In other systems, the  
37 cost of adaptation may far outweigh the ecological, social, or economic returns it would provide.  
38 In such cases, resources may be better invested in other systems. One simple example of triage  
39 would be the decision to abandon habitat management efforts for a population of an endangered  
40 species on land at the "trailing" edge of its shifting range. If the refuge or park that currently  
41 provides habitat for the species will be unsuitable for the species in the next 50 years, it might be  
42 best to actively manage for habitat elsewhere and, depending on the species and the  
43 circumstances, investigate the potential for relocation. All of the changes in management  
44 approaches discussed throughout the rest of this section would likely require fundamental  
45 changes in policy and engagement in triage at the national level.

**1 9.5.2 Manage at Appropriate Scales**

2 Experience gained from natural resource management programs and other activities may offer  
3 insights into the application of integrated ecosystem management under changing climatic  
4 conditions. Integrated ecosystems management seeks to optimize the positive ecological and  
5 socioeconomic benefits of activities aimed at maintaining ecosystem services under a multitude  
6 of existing stressors. One lesson learned from this approach is that it may be necessary to define  
7 the management scale beyond the boundaries of a single habitat type, conservation area, or  
8 political or administrative unit to encompass an entire ecosystem or region. Currently,  
9 management plans for forests, rivers, marine protected areas, estuaries, national parks, and  
10 wildlife refuges are often developed for discrete geographies with specific attributes (species,  
11 ecosystems, commodities), without recognition that they may be nested within other systems.  
12 For example, marine protected areas are often within national estuaries; wild and scenic rivers  
13 are often within national parks. With few exceptions (see section 9.4.2), plans are not developed  
14 with the ability to fully consider the matrix in which they are embedded and the extent to which  
15 those attributes may vary over time in response to drivers external to the management system.  
16 Climate change adaptation opportunities may be missed if land and water resources are thought  
17 of as distinct, static, or out of context of a regional and even continental arena. A fundamental  
18 reconsideration of national lands and waters as a national network to be managed for climate  
19 disruption may be advantageous. To achieve this, the spatial and biological scope of  
20 management plans would have to be systematically broadened and integrated. Although a single  
21 national park or national forest may have limited capacity for adaptation, the entire system of  
22 parks and forests and refuges in a region may have the capacity for adaptation. When spatial  
23 scales of consideration are larger, federal agencies often have mutually reinforcing goals that  
24 may result in the enhancement of their ability to manage cooperatively across landscapes  
25 (Metzger, Leemans, and Schröter, 2005).

**26 9.5.3 Manage for Change**

27 Agencies have established best practices based on many years of past experience. Unfortunately,  
28 dramatic climate change may change the rules of the game, rendering yesterday's best practices  
29 tomorrow's bad practices. Experienced managers have begun to realize that "best practices" and  
30 "standard protocols" need to be devised so they can anticipate changes in conditions, especially  
31 conditions that might alter the impacts of grazing, fire, logging, harvesting, park visitation, and  
32 so forth. Such anticipatory thinking will be critical, as climate change will likely exceed  
33 ecosystem thresholds over time such that strategies to increase ecosystem resilience will no  
34 longer be effective. At this point, major shifts in ecosystem processes, structures and components  
35 will be unavoidable, and adaptation will require planning for management of major ecosystem  
36 shifts.

37  
38 For example, some existing management plans identify a desired state (based on structural,  
39 ecosystem service, or ecosystem process attributes of the past) and then prescribe practices to  
40 achieve that state. While there is clarity and accountability in such fixed management objectives,  
41 these objectives may be unrealistic in light of dramatic environmental change. A desirable  
42 alternative management approach to systematically infuse into all resource planning may be to  
43 "manage for change." For example, when revegetation and silviculture are used for post-  
44 disturbance rehabilitation, species properly suited to the expected future climate could be used.

1 In Tahoe National Forest, white fir could be favored over red fir, pines could be preferentially  
2 harvested at high elevations over fir, and species could be shifted upslope within expanded seed  
3 transfer guides (Chapter 3, National Forests). It is also possible that, after accounting for change,  
4 restoration may cease to be an appropriate undertaking. Again, in Tahoe National Forest,  
5 warming waters may render selected river reaches no longer suitable for salmon, so restoration  
6 of those reaches may not be a realistic management activity (Chapter 3, National Forests). The  
7 same applies to meadows in Tahoe National Forest, where restoration efforts may be abandoned  
8 due to possible succession to non-meadow conditions. Management will not be able to prevent  
9 change, so it may also be important to manage the public’s expectations. For example, the goal  
10 of the Park Service is to maintain a park exactly as it always has been, composed of the same tree  
11 species (Chapter 4, National Parks), and the public may not recognize the potential impossibility  
12 of this goal. Some additional examples of adaptation options for managing for change are  
13 presented in Box 9.9.

14  
15 Scenario-based planning can be a useful approach in efforts to manage for change. As discussed  
16 in Section 9.2.3.2, this is a qualitative process that involves exploration of a broad set of  
17 scenarios, which are plausible—yet very uncertain—stories or narratives about what might  
18 happen in the future. Protected-area managers, along with subject matter experts, can engage in  
19 scenario planning related to climate change and resources of interest and put into place plans for  
20 low-probability, high-risk events. Development of realistic plans may require a philosophical  
21 shift concerning when restoration is an appropriate post-disturbance response. It is impractical to  
22 attempt to keep ecosystem boundaries static. Estuaries display this poignantly. There is often  
23 intense post-flooding pressure for restoration to the pre-flooding state (Chapter 7, National  
24 Estuaries). To ensure sound management responses, guidelines for the scenarios under which  
25 restoration and rebuilding should occur could be established in advance of disturbances. In this  
26 sense, disturbances could become opportunities for managing toward a distribution of human  
27 population and infrastructure that is more realistic given changing climate. Scenario-based  
28 planning may be difficult to use at the regional level unless national-level policies are changed to  
29 permit this approach. One option may be to legislatively mandate a policy that calls for all  
30 agencies to address climate change in the development of their management plans. This approach  
31 has many advantages, one of them being to foster the use of scenario-based planning.

#### 32 **9.5.4 Expand Interagency Collaboration, Integration, and Lesson-Sharing**

33 The scale of the challenge posed by climate disruption and the uncertainty surrounding future  
34 changes demand coordinated, collaborative responses that go far beyond traditional “agency-by-  
35 agency” responses to stressors and threats. Every chapter in this volume has noted the need for a  
36 structured, interagency effort and for partnerships and collaboration in everything from research  
37 to management and land acquisition. Scientists and managers across agencies and management  
38 systems would benefit from greater sharing of data, models, and experiences. The need to better  
39 integrate research and management across agencies is not a new idea, but the current lack of  
40 extensive integration and collaboration indicates that it may be necessary to develop formal  
41 structures and policies that foster and even mandate extensive interagency cooperation.

42  
43 To enhance the incorporation of climate information into management, each agency could  
44 designate two or more climate experts to advise agency scientists and managers on climate  
45 change related issues. At least one of the experts could be a high-level manager and at least one

1 could be a PhD scientist with extensive expertise in climate change. The team could advise  
2 agency scientists and managers both at the national and at the site level, providing guidance,  
3 translating climate-impact projections, and coordinating interagency collaborations. In addition,  
4 the lead manager and scientist could be members of an interagency climate change advisory  
5 group.  
6

7 A mechanism that might augment current collaboration across agencies could be to develop an  
8 interagency group or task force to coordinate climate change management efforts across  
9 agencies. Throughout the chapters of this Synthesis and Assessment Product, there has been an  
10 unequivocal call for the establishment of such an entity to strengthen the existing capability to  
11 address climate change. Several examples of interagency initiatives established to address  
12 universal threats to resources include the National Invasive Species Council and the Joint Fire  
13 Science Program and National Interagency Fire Center. The central responsibility of an  
14 interagency climate change council would be to advise managers and scientists in each of the  
15 agencies on both general and specific management issues. The council could help to interpret  
16 research findings, set priorities, and disseminate data and tools. The council could also help build  
17 collaborations among agencies.  
18

19 One interagency program established specifically to address climate change research is the U.S.  
20 Climate Change Science Program (CCSP). The goals of this program are to develop scientific  
21 knowledge of the climate system; the causes of changes in this system; and the effects of such  
22 changes on ecosystems, society, and the economy; and also to determine how best to apply that  
23 knowledge to decision-making. Climate change research conducted across 13 U.S. government  
24 departments and agencies is coordinated through the CCSP. As currently established, the CCSP  
25 would not entirely fulfill the needs called for in this report because few agency management  
26 program representatives participate, and consequently only a small number of direct management  
27 perspectives are voiced through the CCSP on climate change research. Without management  
28 representation, it would be difficult to bridge the gap between resource management needs and  
29 scientific research priorities. However, since one of the goals of the CCSP is to apply existing  
30 knowledge to decision-making, a natural step may be for the CCSP to expand its structure to  
31 explicitly incorporate management interests. One option for expanding the CCSP might be to  
32 include as representatives to the CCSP the management arms of each agency in addition to the  
33 research programs. Another option might be to add an interagency council focused on resource  
34 management that oversees and advises the CCSP on management-related research and decision  
35 support. Regardless of the form in which the CCSP might be expanded, a valuable change to the  
36 functioning of the CCSP would be to add the ability to evaluate research in light of the degree to  
37 which it supports resource management.  
38

39 Further, collaborative interagency initiatives of all kinds would benefit greatly from the creation of  
40 a regional or national database with scientific and monitoring data that could increase the capacity  
41 to make informed decisions related to climate-induced changes. Such a system could support all  
42 federal resource agencies and be a shared financial responsibility. Pooling resources would allow  
43 for more effective data generation and sharing. Easily accessible databases housed in a single  
44 location that can readily provide comprehensive information would serve to better inform  
45 managers and decision-makers in their efforts to adapt to climate change. This information center  
46 also could serve as a central repository for climate-change projections and climate-change-related



1 research. Ideally, this would be a web-based clearinghouse with maps, a literature database, and  
2 pertinent models (*e.g.*, sea level projection models such as the Sea Level Affecting Marshes  
3 Model [SLAMM] and hydrology models such as those developed and used by the USGS (U.S.  
4 Geological Survey, 2007b) and EPA (U.S. Environmental Protection Agency, 2007). All maps,  
5 data, models, and papers could be easily downloaded and updated frequently as new information  
6 becomes available. To be most useful, the website would be constantly updated with new  
7 literature and model projections incorporating the latest climate-change projections from both  
8 GCMs and regional models.

9  
10 Collaborations through national councils or interagency efforts may gain the greatest momentum  
11 and credibility when they address on-the-ground management challenges. There are several  
12 nascent collaborative networks that may provide models for success, such as the Greater  
13 Yellowstone Coalition and some collaborative research and management coalitions built around  
14 marine protected areas and wild and scenic rivers. These sorts of networks are critical to  
15 illustrating how to overcome the challenges posed by lack of funding, and how to create critical  
16 ecological and sociological connectivity. With strong leadership, a systematic national network  
17 of such coalitions could lead to increased adaptive capacity across agencies and may set  
18 precedents for coordinating approaches among regional, state, and local-level management  
19 agencies.

## 20 **9.6 Conclusions**

21 Information on climate trends and climate impacts has increased dramatically within the last few  
22 years. The public, business leaders, and political leaders now widely recognize the risks of  
23 climate change and are beginning to take action. While a great deal of discussion has focused on  
24 emissions reductions and policies to limit climate change, many may not realize that—no matter  
25 which policy path is taken—some substantial climate change, uncertainty, and risk are  
26 inevitable. Moreover, the climate change that is already occurring will be here for years to come.  
27 Adaptation to climate change will therefore be necessary. Although there are constraints and  
28 limits to adaptation, some adaptation measures can go a long way toward reducing the loss of  
29 ecosystem services and limiting the economic or social burden of climate disruption. However, if  
30 the management cultures and planning approaches of agencies continue with a business-as-usual  
31 approach, it is likely that ecosystem services will suffer major degradation. It is the report  
32 authors' and stakeholders' expert opinion that we may be seeing a tipping point in terms of the  
33 need to plan and take appropriate action on climate adaptation.

34  
35 These experts believe that the current mindset toward management of natural resources and  
36 ecosystems may have to change; the spatial scale and ecological scope of climate change may  
37 necessitate that we broaden our thinking to view the natural resources of the United States as one  
38 large interlocking and interacting system, including state, federal, and private lands. The most  
39 effective course may be to manage the nation's lands and waters as one large system, with  
40 resilience emerging from coordinated stewardship of all of the parts. To achieve this, institutions  
41 may have to collaborate and cooperate more. Under conditions of uncertain climatic changes  
42 combined with uncertain ecosystem responses, agile management may have to become the rule  
43 rather than the exception. While energy corporations, insurance firms, and coastal developers are  
44 beginning to adapt to climate change, it is essential that federal agencies responsible for  
45 managing the nation's land and water resources also develop management agility and deftness in

1 dealing with climate disruptions. Maladaptation—adaptation that does not succeed in reducing  
2 vulnerability but increases it instead—must be avoided. Finally, to adapt to climate change,  
3 managers need to know in advance where the greatest vulnerabilities lie. In response to a  
4 vulnerability analysis, agencies and the public can work together to bolster the resilience of those  
5 ecosystems and ecosystem services that are both valuable and, with apt management, capable of  
6 remaining viable into the future.

7  
8 It is crucial to emphasize that adaptation is not simply a matter of managers figuring out what to  
9 do, and then setting about to change their practices. All management is conducted within a  
10 broader context of socioeconomic incentives and institutional behavior. This means it is essential  
11 to make sure that policies that seem external to the federal land and water resource management  
12 agencies do not undermine adaptation to climate change. One of the best examples of this danger  
13 is private, federal, and state insurance for coastal properties that are at risk of repeated storm  
14 damage or flooding. So long as insurance and mortgages are available for coastal building, coasts  
15 will be developed with seawalls and other hardened structures that ultimately interfere with  
16 beach replenishment, rollback of marshes, and natural floodplains. At first glance one would not  
17 think that mortgages and insurance had anything to do with the adaptation of national estuaries to  
18 climate change, but in fact these economic incentives and constraints largely dictate the pattern  
19 of coastal development.

20  
21 In addition, federal lands and waters do not function in isolation from human systems or from  
22 private land or water uses. For this reason, mechanisms for reducing conflict among private  
23 property uses and federal lands and waters are essential. For example, the National Park Service  
24 is working cooperatively with landowners bordering the Rio Grande in Texas to establish  
25 binding agreements that offer them technical assistance with measures to alleviate potentially  
26 adverse impacts on the river resulting from their land-use activities. In addition, landowners may  
27 voluntarily donate or sell lands or interests in lands (*i.e.*, easements) as part of a cooperative  
28 agreement. In the absence of agreements with private landowners, withdrawals from rivers and  
29 loss of riparian vegetation could foreclose opportunities for adaptation, potentially exacerbating  
30 the impacts of climate change.

31  
32 One adaptive response is large protected areas and replicated protected areas. But this strategy  
33 also runs up against political and social constraints. In particular, protected areas are often  
34 associated with taking areas of land or ocean away from productive activities (such as ranching,  
35 farming, or fishing). In order to gain support for expanded networks of protected areas, it is  
36 essential that connections be made between the addition of protected areas and beneficial effects  
37 on the economy. For example, in the Florida Keys it has been shown that total annual spending  
38 by recreating visitors to the Florida Keys was \$1.2 billion between June 2000 and May 2001  
39 (Leeworthy and Wiley, 2003).

40  
41 Society can adapt to climate change through technological solutions and infrastructure, through  
42 behavioral choices (altered food and recreational choices), through land management practices,  
43 and through planning responses (IPCC, 2007). Although federal resource management agencies  
44 will tend to adapt by altering management policies, the effectiveness of those policies will be  
45 constrained by or enhanced by all of the other societal responses. In general, the federal  
46 government's authority over national parks, national forests, and other public resources will not  
47 be effective unless management is aligned with the public's well-being and perception of well-

1 being. Experienced resource managers recognize this and regularly invest in public education.  
2 This means that education and communication regarding managing for adaptation needs just as  
3 much attention as does the science of adaptation.  
4  
5 Repeatedly in response to crises and national challenges, the nation’s executive and  
6 congressional leadership have provided fiscal resources, mandated new collaboration among  
7 agencies, extended existing authorities, and encouraged innovation. The report authors, consulted  
8 experts, and stakeholders conclude that this is exactly what is needed to adapt to climate change.  
9 The security of land and water resources and critical ecosystem services requires a national  
10 initiative and leadership. More agility will be required than has ever before been demanded from  
11 major land or water managers. The public has become accustomed to stakeholder involvement in  
12 major resource use decisions. This involvement cannot be sacrificed, but decision-making  
13 processes could be streamlined so that management approaches do not stand still while climate  
14 change proceeds rapidly. The specific recommendations for adaptation that emerge from studies  
15 of national forests, national parks, national wildlife refuges, wild and scenic rivers, national  
16 estuaries, and marine protected areas will not take root unless there is leadership at the highest  
17 level to address climate adaptation.  
18

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25

## 9.8 Appendix: Resources for Assessing Climate Vulnerability And Impacts

### NCAR's MAGICC and SCENGEN

<http://www.cgd.ucar.edu/cas/wigley/magicc/index.html>

Coupled, user-friendly interactive software suites that allow users to investigate future climate change and its uncertainties at both the global-mean and regional levels.

### WALTER

<http://java.arid.arizona.edu/ahp/>

Fire-Climate-Society (FCS-1) is an online, spatially explicit strategic wildfire planning model with an embedded multi-criteria decision process that facilitates the construction of user-designed risk assessment maps under alternative climate scenarios and varying perspectives of fire probability and values at risk.

### North American Regional Climate Change Assessment Program

<http://www.narccap.ucar.edu/>

### Regional Hydro-Ecologic Simulation Tool

<http://geography.sdsu.edu/Research/Projects/RHESSYS>

### U.S. Climate Division Dataset Mapping Tool

<http://www.cdc.noaa.gov/USclimate/USclimdivs.html>

<http://www.cdc.noaa.gov/cgi-bin/PublicData/getpage.pl>

This tool can generate regional maps.

### ISPE/Weiss/Overpeck climate change projections for West (based on IPCC)

[http://www.geo.arizona.edu/dgesl/research/regional/projected\\_US\\_climate\\_change/projected\\_US\\_climate\\_change.htm](http://www.geo.arizona.edu/dgesl/research/regional/projected_US_climate_change/projected_US_climate_change.htm)

### High Plains Regional Climate Center

<http://www.hprcc.unl.edu/>

### Intergovernmental Panel On Climate Change

<http://www.ipcc.ch/>

Climate change reports, graphics, summaries.

### The Hadley Centre

<http://www.metoffice.gov.uk/research/hadleycentre/index.html>

Coarse scale global temperature, soil moisture, sea level, and sea-ice volume and area projections.

### National Center for Atmospheric Research (NCAR)

<http://www.ucar.edu/research/climate/>

Coarse resolution climate-change projections, regional climate model.

- 1
- 2 **Pew Center on Global Climate Change**
- 3 [http://www.pewclimate.org/what\\_s\\_being\\_done/](http://www.pewclimate.org/what_s_being_done/)
- 4 Background on climate change, policy implications.
- 5
- 6 **NOAA Earth System Research Lab (Climate Analysis Branch)**
- 7 <http://www.cdc.noaa.gov/>
- 8 Current climate data and near-term forecasts.
- 9
- 10 **The Climate Institute**
- 11 [http://www.climate.org/climate\\_main.shtml](http://www.climate.org/climate_main.shtml)
- 12 Basic background information on climate change.
- 13
- 14 **U.S. Global Change Research Information Office**
- 15 <http://www.gcrio.org/>
- 16 Reports and information about climate change.
- 17
- 18 **Real Climate**
- 19 <http://www.realclimate.org/>
- 20 In-depth discussions with scientists about many different aspects of climate change.
- 21
- 22 **EPA Sea level Rise**
- 23 <http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsSeaLevel>
- 24 [RiseIndex.html](http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsSeaLevel)
- 25 Reports and impact projections.
- 26
- 27 **CLIMAS, Climate Assessment for the Southwest**
- 28 (<http://www.ispe.arizona.edu/climas/>)
- 29 A source for climate change related research, short-term forecasts and climate
- 30 reconstructions for the southwestern United States.
- 31
- 32 **Climate Impacts Group, University of Washington**
- 33 <http://www.cses.washington.edu/cig/>
- 34 Climate-change research and projections for the Pacific Northwest.
- 35

1 **9.9 Boxes**

2 **Box 9.1.** An example framework for incorporating climate change information into impact  
 3 assessments.

**Step 1 – Define decision context:** Clarify management goals and endpoints of concern, as well as risk preferences and tradeoffs, time horizons for monitoring and management, and planning processes related to established endpoints.

**Step 2 – Develop conceptual model:** Develop the conceptual model linking the spatial and temporal scales of interaction between and among drivers and endpoints to determine the most important dependencies, sensitivities, and uncertainties in the system.

**Step 3 – Assess available climate data:** Determine whether available climate data are adequate for achieving the specified goals and endpoints. Data sources that may be used include historical weather observations, palaeoclimate data, and data from climate model experiments (the focus of this framework).

**Step 4 – Downscale climate data:** Develop finer resolution datasets from coarser scale data using statistical relationships (“statistical” downscaling) or computer models (“dynamical” downscaling) to drive impacts models. For guidance on downscaling techniques, see IPCC-TGICA reports (Mearns *et al.*, 2003; Wilby *et al.*, 2004) on <http://www.ipcc-data.org/guidelines/index.html>.

**Step 5 – Select impact assessment models:** Review and select physical models that capture the processes and causal pathways represented in the conceptual model.

**Step 6 – Conduct scenario and sensitivity analyses:** Specify a number of climate scenarios that are consistent with associated global-scale scenarios, physically plausible, and sufficiently detailed to support an assessment of the specified endpoints. Use these scenarios to learn the potential ranges of the system’s response to changes in the climate drivers.

**Step 7 – Use risk management to make adaptation decisions:** Evaluate the information generated to determine potential management responses, recognizing that the consequences of decisions are generally not known and hence decisions are made to reduce the effects of risk.

4  
 5 Source: Johnson and Weaver (In Press)  
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- 1 **Box 9.2.** Examples of adaptation actions that focus on protection of key ecosystem features as a
- 2 means of supporting resilience.

| <b>Adaptation Approach: Protect Key Ecosystem Features</b>  |
|---|
| <p><b>National Forests</b></p> <ul style="list-style-type: none"> <li>✓ Maintain species with strategies such as supplying needed nutrients and water, removing competing understory, fertilizing young plantations, and developing cover species.</li> <li>✓ Conduct thinning and fuels abatement treatments to reduce crown fire potential and risk of insect epidemics.</li> <li>✓ Identify high value areas and take special measures to protect them.</li> <li>✓ Monitor non-native species to be able to take early, proactive, and aggressive action against them.</li> <li>✓ Proactively promote stand resilience with silvicultural techniques (<i>e.g.</i>, widely spaced thinnings).</li> <li>✓ Promote connected landscapes to facilitate migration.</li> </ul> <p><b>National Parks</b></p> <ul style="list-style-type: none"> <li>✓ Prevent establishment of invasive non-native species that threaten native species or current ecosystem function.</li> <li>✓ Allow the persistence of non-native species that maintain or enhance ecosystem function.</li> <li>✓ Minimize the spread of disease and alteration of natural disturbance regimes.</li> <li>✓ Maintain species migration corridors.</li> </ul> <p><b>National Wildlife Refuges</b></p> <ul style="list-style-type: none"> <li>✓ Manage risk of catastrophic fires through prescribed burns.</li> <li>✓ Reduce or eliminate stressors on conservation target species.</li> <li>✓ Strictly preserve the core of a reserve, and have multiple use management reflect decreasing degrees of preservation in concentric buffer zones.</li> <li>✓ Improve the matrix surrounding the refuge by partnering with adjacent owners to improve/build new habitats.</li> <li>✓ Install levees and other engineering works to alter water flows to benefit refuge species.</li> <li>✓ Remove dispersal barriers and establish dispersal bridges for species.</li> <li>✓ Use conservation easements around the refuge to allow species dispersal and maintain ecosystem function.</li> <li>✓ Facilitate migration through the establishment and maintenance of wildlife corridors.</li> </ul> <p><b>Wild &amp; Scenic Rivers</b></p> <ul style="list-style-type: none"> <li>✓ Manage dam flow releases upstream of the WSR to save flora and fauna in drier downstream river reaches.</li> <li>✓ Use drought-tolerant plant varieties to help protect riparian buffers.</li> <li>✓ Establish agreements with private partners to ensure that flows during droughts remain sufficient to protect critical habitats and maintain water quality.</li> <li>✓ Remove undesirable non-native species.</li> </ul> <p><b>National Estuaries</b></p> <ul style="list-style-type: none"> <li>✓ Protect the water quality of tidal marshes with oyster breakwaters and rock sills.</li> <li>✓ Use “managed alignment” to reorient existing engineering structures affecting rivers, estuaries, and coastlines.</li> <li>✓ Preserve the structural complexity of vegetation in tidal marshes, seagrass meadows, and mangroves.</li> <li>✓ Adapt protections of important biogeochemical zones and critical habitats as the locations of these areas change.</li> <li>✓ Prohibit engineered structures to delay the loss of shallow-water habitats by permitting their inland migration.</li> <li>✓ Connect landscapes with corridors to enable migrations to sustain biodiversity across the landscape.</li> </ul> <p><b>Marine Protected Areas</b></p> <ul style="list-style-type: none"> <li>✓ Identify ecological connections among marine ecosystems and use them to inform management decisions.</li> <li>✓ Manage functional species groups necessary to maintaining the health of reefs and other ecosystems.</li> <li>✓ Protect resistant areas to ensure a secure source of recruitment to support recovery in damaged areas.</li> <li>✓ Design dynamic boundaries and buffers to protect breeding and foraging habits, migratory and pelagic species.</li> </ul> |

- ✓ Create buffer zones to accommodate ecosystem shifts in response to sea level rise and temperature change.
- ✓ Monitor ecosystems and have rapid-response strategies prepared to deal with disturbances.

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**Box 9.3.** Examples of adaptation actions that focus on reduction of anthropogenic stresses as a means of supporting resilience.

**Adaptation Approach: Reduce Anthropogenic Stresses**

**National Parks**

- ✓ Move or remove human infrastructure to minimize the ecological effects of sudden changes in system state.
- ✓ Minimize sources of pollution and the alteration of natural disturbance regimes.

**National Wildlife Refuges**

- ✓ Reduce human water withdrawals to restore natural hydrologic regimes.

**Wild & Scenic Rivers**

- ✓ Claim or purchase more water rights.
- ✓ Manage water storage and withdrawals to smooth the supply of available water throughout the year. Re-evaluate institutional mechanisms governing water use and management with an eye toward increasing flexibility (*e.g.*, apply forecasting to water management, improve water monitoring capabilities).
- ✓ Consider shifting access points or moving existing trails for wildlife or river enthusiasts.

**National Estuaries**

- ✓ Conduct integrated management of nutrient sources and wetland treatment of nutrients to limit hypoxia and eutrophication.
- ✓ Manage water resources to ensure sustainable use in the face of changing recharge rates and saltwater infiltration.

**Marine Protected Areas**

- ✓ Manage human stressors such as fishing and inputs of nutrients, sediments, and pollutants within MPAs.
- ✓ Create buffer zones between intensive human activity and fully protected marine reserves.

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1 **Box 9.4.** Examples of adaptation actions that focus on representation as a means of supporting  
 2 resilience.

| <b>Adaptation Approach: Representation</b>  |
|---|
| <p><b>National Forests</b></p> <ul style="list-style-type: none"> <li>✓ Hedge against change by modifying genetic diversity guidelines to increase the range of species, maintain high effective population sizes, and favor genotypes known for broad tolerance ranges in forest ecosystems.</li> <li>✓ Use disturbances as opportunities (<i>e.g.</i>, reforest with species tolerant to low soil moisture and high temperatures, move species into the disturbed area from other seed zones).</li> </ul> <p><b>National Parks</b></p> <ul style="list-style-type: none"> <li>✓ Allow the establishment of species that are non-native locally, but maintain native biodiversity in the overall region.</li> </ul> <p><b>National Wildlife Refuges</b></p> <ul style="list-style-type: none"> <li>✓ Strategically expand the boundaries of NWRs to increase ecological, genetic, geographical, behavioral and morphological variation in species.</li> <li>✓ Facilitate the growth of plant species more adapted to future climate conditions.</li> </ul> <p><b>Wild &amp; Scenic Rivers</b></p> <ul style="list-style-type: none"> <li>✓ Increase genetic diversity through plantings or via stocking fish.</li> <li>✓ Increase physical habitat heterogeneity in channels to benefit aquatic fauna.</li> </ul> <p><b>National Estuaries</b></p> <ul style="list-style-type: none"> <li>✓ Maintain high genetic diversity through strategies such as the establishment of reserves specifically for this purpose.</li> <li>✓ Maintain complexity of salt marsh landscapes, especially preserving marsh edge environments.</li> </ul> <p><b>Marine Protected Areas</b></p> <ul style="list-style-type: none"> <li>✓ Maximize habitat heterogeneity and consider protecting larger areas to preserve biodiversity, biological connections among habitats, and ecological functions.</li> <li>✓ Include entire ecological units (<i>e.g.</i>, coral reefs with their associated mangroves and seagrasses) in MPA design to maintain ecosystem function and resilience.</li> <li>✓ Ensure that the full breadth of habitat types is protected (<i>e.g.</i>, fringing reef, fore reef, back reef, patch reef).</li> </ul> |

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 5 **Box 9.5.** Examples of adaptation actions that focus on replication as a means of supporting  
 6 resilience.

| <b>Adaptation Approach: Replication</b>   |
|---|
| <p><b>National Forests</b></p> <ul style="list-style-type: none"> <li>✓ Spread risks by increasing ecosystem redundancy and buffers in both natural environments and plantations.</li> </ul> <p><b>Marine Protected Areas</b></p> <ul style="list-style-type: none"> <li>✓ Replicate habitat types in multiple areas to spread risks associated with climate change.</li> </ul> |

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1 **Box 9.6.** Examples of adaptation actions that focus on restoration as a means of supporting  
 2 resilience.

| <b>Adaptation Approach: Restoration</b>  |
|--|
| <p><b>National Forests</b></p> <ul style="list-style-type: none"> <li>✓ Have ready deliberate and immediate plans to encourage the return of desired species to a site post-disturbance.</li> </ul> <p><b>National Parks</b></p> <ul style="list-style-type: none"> <li>✓ Restore ecosystems with vegetation that is no longer present locally, but is native to the overall region.</li> </ul> <p><b>Wild &amp; Scenic Rivers</b></p> <ul style="list-style-type: none"> <li>✓ Replant native riparian vegetation with drought-resistant vegetation in areas with higher temperatures and less precipitation.</li> <li>✓ Restore the natural capacity of rivers to buffer climate-change impacts (<i>e.g.</i>, stormwater management in developed basins, land acquisition around rivers, levee setbacks to free the floodplain of infrastructure, riparian buffer repairs).</li> <li>✓ Conduct river restoration projects to stabilize eroding banks, repair in-stream habitat, or promote fish passages from areas with high temperatures and less precipitation.</li> </ul> <p><b>National Estuaries</b></p> <ul style="list-style-type: none"> <li>✓ Restore the vegetational layering and structure of tidal marshes, seagrass meadows, and mangroves to stabilize estuary function.</li> <li>✓ Restore native species and remove invasive non-natives to improve marsh characteristics that promote propagation and production of fish and wildlife.</li> <li>✓ Direct restoration programs to places where the restored ecosystem has room to retreat as sea level rises.</li> </ul> |

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 4 **Box 9.7.** Examples of adaptation actions that focus on the use of refugia as a means of  
 5 supporting resilience.

| <b>Adaptation Approach: Refugia</b>   |
|---|
| <p><b>National Forests</b></p> <ul style="list-style-type: none"> <li>✓ Identify environments “buffered” against climate change and consider them as sites for new plantations or long-term conservation.</li> <li>✓ Protect populations that currently exist in climatically buffered, cooler, or unusually mesic environments.</li> </ul> <p><b>National Parks</b></p> <ul style="list-style-type: none"> <li>✓ Create refugia for valued aquatic species at risk to the effects of early snowmelt on river flow.</li> </ul> <p><b>National Wildlife Refuges</b></p> <ul style="list-style-type: none"> <li>✓ Reforest riparian boundaries with native species to create shaded thermal refugia for fish species in rivers and streams.</li> <li>✓ Identify climate change refugia and acquire necessary land.</li> </ul> <p><b>Marine Protected Areas</b></p> <ul style="list-style-type: none"> <li>✓ Identify, protect, and restore areas observed to be resistant to climate change effects or to recover quickly from climate-induced disturbances.</li> </ul> |

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2 **Box 9.8.** Examples of adaptation actions that focus on relocation as a means of supporting  
3 resilience.

| <b>Adaptation Approach: Relocation</b>  |
|---|
| <p><b>National Parks</b></p> <ul style="list-style-type: none"> <li>✓ Assist in species migrations and transplant species.</li> </ul> <p><b>National Wildlife Refuges</b></p> <ul style="list-style-type: none"> <li>✓ Facilitate long-distance transport of threatened endemic species.</li> <li>✓ Facilitate interim propagation and sheltering or feeding of mistimed migrants, holding them until suitable habitat becomes available.</li> </ul> <p><b>Wild &amp; Scenic Rivers</b></p> <ul style="list-style-type: none"> <li>✓ Establish programs to move isolated populations of species of interest that become stranded when water levels drop.</li> </ul> |

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5 **Box 9.9.** Adaptation options for managing in the context of major climatic and ecological  
6 changes.

| <b>Adaptation Options for Managing for Change</b>   |
|---|
| <ul style="list-style-type: none"> <li>✓ Assist transitions, population adjustments, and range shifts through manipulation of species mixes, altered genotype selections, modified age structures, and novel silvicultural techniques.</li> <li>✓ Rather than focusing only on historic distributions, spread species over a range of environments according to modeled future conditions.</li> <li>✓ Proactively manage early successional stages that follow widespread climate-related mortality by promoting diverse age classes, species mixes, stand diversities, genetic diversity, etc., at landscape scales.</li> <li>✓ Identify areas that supported species in the past under similar conditions to those projected for the future and consider these sites for establishment of “neo-native” plantations or restoration sites.</li> <li>✓ Favor the natural regeneration of species better adapted to projected future conditions.</li> <li>✓ Realign management targets to recognize significantly disrupted conditions, rather than continuing to manage for restoration to a “reference” condition that is no longer realistic given climate change.</li> <li>✓ Manage the public’s expectations as to what ecological states will be possible (or impossible) given the discrepancy between historical climate conditions and current/future climate conditions.</li> <li>✓ Develop guidelines for the scenarios under which restoration projects or rebuilding of human structures should occur after climate disturbances.</li> </ul> |

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2 **9.10 Tables**3 **Table 9.1.** Examples of climate change-related effects on key ecosystem attributes upon which  
4 management goals depend.

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| Federal lands             | Ecosystem attributes critical to management goals  | Potential climate-related changes that could influence management goals  |
|---------------------------|--|--|
| National forests          | <ul style="list-style-type: none"> <li>• Fire tolerance</li> <li>• Insect tolerance</li> <li>• Tolerance to invasives</li> </ul>   | <ul style="list-style-type: none"> <li>• Altered fire regimes</li> <li>• Vegetation changes</li> <li>• Changes in species dominance</li> </ul>   |
| National wildlife refuges | <ul style="list-style-type: none"> <li>• Persistence of threatened and endangered species</li> <li>• Wetland water replenishment</li> <li>• Coastal wetland habitat</li> </ul> | <ul style="list-style-type: none"> <li>• Threatened and endangered species decline or loss</li> <li>• Altered hydrology</li> <li>• Sea level rise</li> </ul>                             |
| Marine protected areas    | <ul style="list-style-type: none"> <li>• Structural “foundation” species (e.g., corals, kelp)</li> <li>• Biodiversity</li> <li>• Water quality</li> </ul>                      | <ul style="list-style-type: none"> <li>• Increased ocean temperatures and decreased pH</li> <li>• Increased bleaching and disease</li> <li>• Altered precipitation and runoff</li> </ul> |
| National estuaries        | <ul style="list-style-type: none"> <li>• Sediment filtration</li> <li>• Elevation and slope</li> <li>• Community composition</li> </ul>  | <ul style="list-style-type: none"> <li>• Altered stream flow</li> <li>• Sea level rise</li> <li>• Salt water intrusion/species shifts</li> </ul>   |
| Wild and scenic rivers    | <ul style="list-style-type: none"> <li>• Anadromous fish habitat</li> <li>• Water quality</li> <li>• “Natural” flow</li> </ul>   | <ul style="list-style-type: none"> <li>• Increased water temperatures</li> <li>• Changes in runoff</li> <li>• Altered stream flow</li> </ul>   |
| National parks            | <ul style="list-style-type: none"> <li>• Fire tolerance</li> <li>• Snow pack</li> <li>• Community composition</li> </ul>   | <ul style="list-style-type: none"> <li>• Vegetation shifts</li> <li>• Changes in snow pack amount</li> <li>• Temperature-related species shifts</li> </ul>                               |

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1 **Table 9.2.** Examples of hypothesis-driven monitoring for adaptive management in a changing  
 2 climate.  
 3

| Chapter   | Monitoring target                             | Hypothesis (why monitored)   | Management implications (how used).   |
|---|---|--|---|
| Forests (Chapter 3)                                       | Invasive species                              | Climate change will alter species distributions, creating new invasive species (Lovejoy and Hannah, 2005).   | <ul style="list-style-type: none"> <li>• Inform proactive actions to remove and block invasions</li> </ul>  |
| Parks (Chapter 4) / National Wildlife Refuges (Chapter 5) | Species composition                           | Species are shifting ranges in response to climate change (Parmesan, 1996).  | <ul style="list-style-type: none"> <li>• Manage for species lost from one park or refuge at a different site</li> <li>• Inform translocation efforts</li> </ul> |
| Wild and Scenic Rivers (Chapter 6)                        | River flow                                    | Increased temperatures will decrease snow pack and increase evaporation, changing the timing and amount of flows (Poff, Brinson, and Day, Jr., 2002).  | <ul style="list-style-type: none"> <li>• Manage flows</li> <li>• Increase connectivity</li> </ul>   |
| National Estuaries (Chapter 7)                            | Ecosystem functioning and species composition | As sea level rises, marshes will be lost and uplands will be converted to marshes (Moore <i>et al.</i> , 2003).  | <ul style="list-style-type: none"> <li>• Facilitate upland conversion, species translocation</li> </ul>   |
| Marine Protected Areas (Chapter 8)                        | Water quality                                 | Changes in temperature and runoff will affect acidity, oxygen levels, turbidity, and pollutant concentrations (Behrenfeld <i>et al.</i> , 2006; Guinotte <i>et al.</i> , 2006; Portner and Knust, 2007). | <ul style="list-style-type: none"> <li>• Address pollution sources</li> <li>• Inform coastal watershed policies</li> </ul>                                      |

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1 **Table 9.3.** Levels of biodiversity and associated management options.

|                                      | <i>Definition</i>  | <i>Management activities that support diversity</i>  |
|--------------------------------------|--|--|
| <b>Genetic Diversity</b>             | Allelic diversity and the presence/absence of rare alleles (foundation for all higher level diversity) | <ul style="list-style-type: none"> <li>▪ Transplantation: re-introduction of lost genes (<i>e.g.</i>, transplanting and/or releasing hatchery-reared larvae/juveniles)</li> <li>▪ Protected areas and corridors</li> </ul> |
| <b>Species Diversity</b>             | Quantity of species in a given area  | <ul style="list-style-type: none"> <li>▪ Captive breeding programs</li> <li>▪ ESA listings</li> <li>▪ Protected areas</li> </ul>   |
| <b>Functional Diversity</b>          | Full representation of species within functional groups.   | <ul style="list-style-type: none"> <li>▪ Special protections for imperiled species within functional groups (<i>e.g.</i>, herbivorous fishes)</li> <li>▪ Protected areas</li> </ul>  |
| <b>Ecosystem/Landscape Diversity</b> | All important habitats represented as well as appropriately large scale of metapopulations             | <ul style="list-style-type: none"> <li>▪ Large protected areas</li> <li>▪ Networks of protected areas</li> </ul>   |

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**Table 9.4.** Confidence levels associated with seven different adaptation approaches, examined across six management system types. Estimates reflect the expert opinions of the authors and are based on the literature, personal experience, and stakeholder discussions.

| <b>Adaptation Approach</b>  | <b>National Forests</b> | <b>National Parks</b> | <b>National Wildlife Refuges</b> | <b>Wild &amp; Scenic Rivers</b> | <b>National Estuaries</b> | <b>Marine Protected Areas</b> |
|---|-------------------------|-----------------------|----------------------------------|---------------------------------|---------------------------|-------------------------------|
| <b><i>Protect Key Ecosystem Features</i></b><br>Is strategic protection of key ecosystem features an effective way to preserve or enhance resilience to climate change? | Medium                  | Medium                | High                             | High                            | High                      | High                          |
| <b><i>Reduce Anthropogenic Stresses</i></b><br>Is reduction of anthropogenic stresses effective at increasing resilience to climate change?                             | High                    | High                  | Very High                        | High                            | Medium                    | High                          |

|  |        |        |           |          |        |          |
|--|--------|--------|-----------|----------|--------|----------|
| <b>Representation</b><br>Is representation effective in supporting resilience through preservation of overall biodiversity?  | High   | High   | Very High | Low      | Medium | High     |
| <b>Replication</b><br>Is replication effective in supporting resilience by spreading the risks posed by climate change?  | High   | NA     | Very High | Low      | NA     | High     |
| <b>Restoration</b><br>Is restoration of desired ecological states or ecological processes effective in supporting resilience to climate change?  | Medium | Medium | Medium    | Medium   | Medium | Low      |
| <b>Refugia</b><br>Are refugia an effective way to preserve or enhance resilience to climate change at the scale of species, communities or regional networks?                                  | High   | NA     | Low       | Medium   | NA     | Medium   |
| <b>Relocation</b><br>Is relocation an effective way to promote system-wide (regional) resilience by moving species that would not otherwise be able to emigrate in response to climate change? | Low    | Medium | Low       | Very Low | NA     | Very Low |
| <b>Confidence Levels</b>   |        |        |           |          |        |          |
| <b>Very High</b> = 95% or greater  |        |        |           |          |        |          |
| <b>High</b> = 67-95%   |        |        |           |          |        |          |
| <b>Medium</b> = 33-  |        |        |           |          |        |          |

|                              |  |  |  |  |  |  |
|------------------------------|--|--|--|--|--|--|
| 67%                          |  |  |  |  |  |  |
| <b>Low =</b> 5-33%           |  |  |  |  |  |  |
| <b>Very Low =</b> 5% or less |  |  |  |  |  |  |

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**Table 9.5.** Examples of legislation and regulation as barriers to and opportunities for adaptation.

| <b>LEGISLATION AND REGULATION</b>  |   |   |
|--|---|---|
| <b>Barrier</b>   | <b>Opportunity</b>  | <b>Examples</b>   |
| Legislation and agency policies may be highly static, inhibit dynamic planning, impede flexible adaptive responses and force a fine-filter approach to management. | Re-evaluate capabilities of, or authorities under, existing legislation to determine how climate change can be addressed within the legislative boundaries. | <ul style="list-style-type: none"> <li>• Use state wildlife action plans to manage lands adjacent to national wildlife refuges to enable climate-induced species emigration.</li> <li>• Re-evaluate specific ecosystem- and species-related legislation to use all capabilities within the legislation to address climate change.</li> <li>• Incorporate climate change impacts into priority setting for designation of new wild and scenic rivers (see Chapter 6 section 6.3.4).</li> </ul> |

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2 **Table 9.6.** Examples of management policies and procedures as barriers to and opportunities for  
3 adaptation.

| <b>MANAGEMENT POLICIES AND PROCEDURES</b>   |  |  |
|---|--|--|
| <b>Barrier</b>  | <b>Opportunity</b>   | <b>Examples</b>  |
| Seasonal management activities may be affected by changes in timing and duration of seasons   | Review timing of management activities and take advantage of seasonal changes that provide more opportunities to implement beneficial adaptation actions.  | <ul style="list-style-type: none"> <li>Take advantage of shorter winter seasons (longer prescribed fire season) to do fuel treatments on more national forest acres (see Chapter 3 section 3.4.6.2, Tahoe National Forest).</li> </ul>   |
| Agency policies do not recognize climatic change as a significant problem or stressor.  | Take advantage of flexibility in the planning guidelines and processes to develop management actions that address climate change impacts.  | <ul style="list-style-type: none"> <li>Where guidelines are flexible for meeting strategic planning goals (<i>e.g.</i>, maintain biodiversity), re-prioritize management actions to address effect of climate change on achievement of goals (see Chapter 3 section 3.5.5, Olympic National Forest).</li> </ul>  |
| Political boundaries do not necessarily align with ecological processes; some resources cross boundaries; checkerboard ownership pattern with lands alternating between public and private ownership at odds with landscape-scale management (see Chapter 3 section 3.4.6.1). | Identify management authorities/agencies with similar goals and adjacent lands; share information and create coalitions and partnerships that extend beyond political boundaries to coordinate management; acquire property for system expansion | <ul style="list-style-type: none"> <li>Develop management plans that encompass multiple forest units such as the Pacific Northwest Forest Plan that includes Olympic National Forest-Mt. Baker-Gifford Pinchot National Forest (see Chapter 3 section 3.5.5).</li> <li>Implement active management at broader landscape scales through existing multi-agency management processes such as (1) the Herger-Feinstein Quincy Library Group Pilot and the FPA Adaptive Management project on Tahoe National Forest (see Chapter 3 section 3.4.6.2), (2) the Greater Yellowstone Coordinating Committee, and the Southern Appalachian Man and the Biosphere Program with relationships across jurisdictional boundaries (see Chapter 4 section 4.3.3), (3) The Delaware River, managed cooperatively as a partnership river (see Chapter 6 section 6.4.3).</li> <li>Coordinate dam management at the landscape level for species that cross political boundaries using dam operations prospectively as thermal controls under future climate changes (see Chapter 6 section 6.3.4.2).</li> <li>Coordinate habitat and thermal needs for fish species with entities that control the timing and amount of up-stream water releases (see Chapter 6 section 6.3.4.2).</li> </ul> |

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1 **Table 9.7.** Examples of human and financial capital as barriers to and opportunities for  
 2 adaptation.  
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| <b>HUMAN AND FINANCIAL CAPITAL</b>  |   |   |
|---|---|---|
| <b>Barrier</b>  | <b>Opportunity</b>  | <b>Examples</b>   |
| Lack of incentive to take risks, develop creative projects; reward system focuses on achieving narrowly prescribed targets; funds allocated to achieve targets encourage routine, easily accomplished activities.   | Shift from a culture of punishing failure to one that values creative thinking and supports incremental learning and gradual achievement of management goals.   | <ul style="list-style-type: none"> <li>• Develop incentives that reward risk taking and innovative thinking</li> <li>• Build into performance expectations of a gradient between success and failure</li> <li>• Set up a systematic method for (1) learning from mistakes and successes, and (2) eliciting the experience and empirical data of front line managers, resource management personnel, and scientific staff</li> </ul> (Drawn from Chapter 4 section 4.3.2.)   |
| Little to no climate expertise within many management units at the regional and local level; disconnect between science and management that impedes access to information   | Use newly created positions or staff openings as opportunities to add climate change expertise; train resource managers and other personnel in climate change science   | <ul style="list-style-type: none"> <li>• Use incremental changes in staff to “reinvent and redefine” organizations’ institutional ability to better respond to climate change impacts (see Chapter 3 section 3.4.6.2, Tahoe NF)</li> <li>• Develop expertise through incorporation into existing Forest Service training programs like the silvicultural certification program, regional integrated resource training workshops, and regional training sessions for resource staffs (see Chapter 3 section 3.7.2.3)</li> <li>• Develop managers’ guides, climate primers, management toolkits, a Web clearinghouse, and video presentations (see Chapter 3 section 3.7.2.3).</li> </ul>   |
| National and regional budget policies/processes constrain the potential for altering or supplementing current management practices to enable adaptation to climate change (see Chapter 3 section 3.5.5; general decline in staff resources and capacity (see Chapter 3 section 3.4.6.1) | Look for creative ways to augment the workforce and stretch budgets to institute adaptation practices ( <i>e.g.</i> , individuals or parties with mutual interests in learning about or addressing climate change that may be engaged at no additional cost). | <ul style="list-style-type: none"> <li>• Augment budget and workforce through volunteers from the public or other sources such as institutions with compatible educational requirements, neighborhood groups, environmental associations, etc., such as the Reef Check Program that help collect coral reef monitoring data (see Chapter 8 sections 8.2.3, 8.3.4.1 and 8.4.4.2).</li> <li>• Identify organizations or private citizens that benefit from adaptation actions to share implementation costs in order to avoid more costly impacts/damages.</li> <li>• Use emerging carbon markets to promote (re-) development of regional biomass and biofuels industries, providing economic incentives for active adaptive management; funds from these industries could be used to promote thinning and fuel-reduction projects (see Chapter 3 section 3.4.6.2).</li> </ul> |

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1 **Table 9.8.** Examples of information and science as barriers to and opportunities for adaptation.

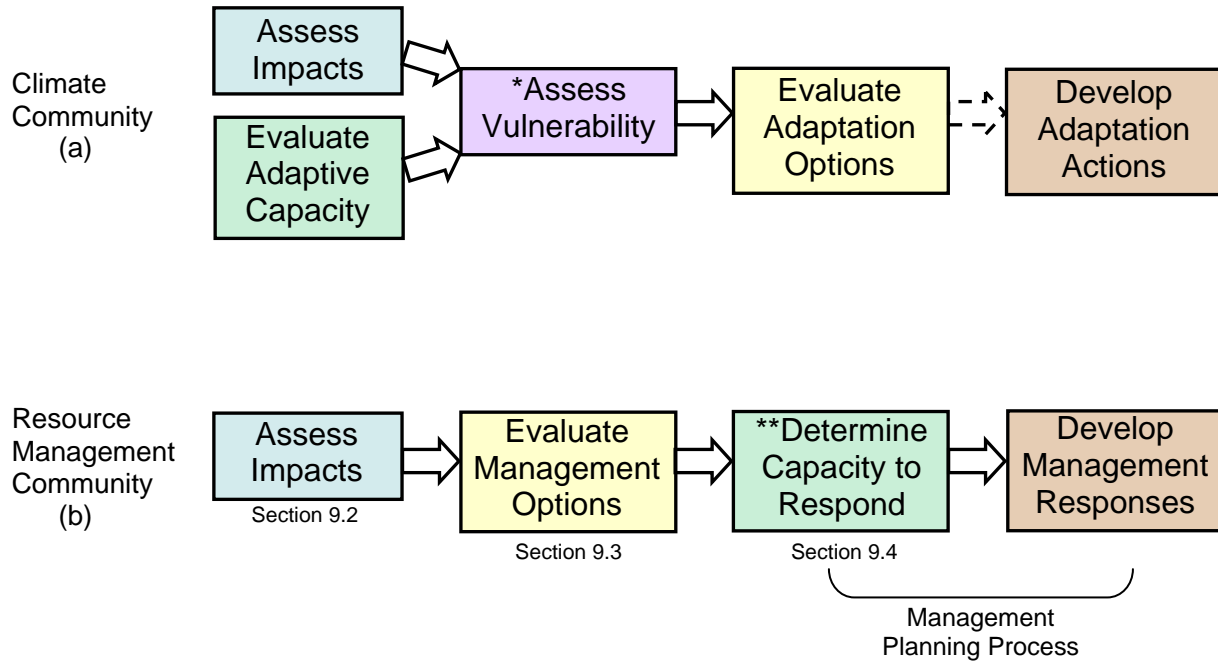
| <b>INFORMATION AND SCIENCE</b>  |  |   |
|---|--|---|
| <b>Barrier</b>  | <b>Opportunity</b>   | <b>Examples</b>   |
| Often no inventory or baseline information on condition exists, and nothing is in place to detect climate change impacts.   | Identify existing monitoring programs for management; develop a suite of climate change indicators and incorporate them into existing programs.  | <ul style="list-style-type: none"> <li>Use monitoring programs such as the NPS vital signs for the Inventory and Monitoring Program, Global Fiducial Program, LTER networks, and NEON to monitor for climate change impacts and effectiveness of adaptation options (see Chapter 4 section 4.3.3).</li> </ul>   |
| Historic conditions may no longer sufficiently inform future planning ( <i>e.g.</i> , “100-year” flood events may occur more often and dams need to be constructed accordingly).  | Evaluate policies that use historic conditions and determine how to better reflect accurate baselines in the face of climate change; modify design assumptions to account for changing climate conditions. | <ul style="list-style-type: none"> <li>Change emphasis from maintenance of “minimum flows” to the more sophisticated and scientifically based “natural flow paradigm,” as is happening in some places (see Chapter 6 section 6.2.4.2).</li> </ul>   |
| Lack of decision support tools and models, uncertainty in climate change science, and critical gaps in scientific information that limits assessment of risks and efficacy and sustainability of actions.   | Identify and use all available tools/mechanisms currently in place to deal with existing problems to apply to climate-change related impacts.  | <ul style="list-style-type: none"> <li>Use early detection/rapid response approaches (such as that used to manage invasive species) to respond quickly to the impacts of extreme events (<i>e.g.</i>, disturbances, floods, windstorms) with an eye towards adaptation (see Chapter 3 section 3.5.4).</li> <li>Diversify existing portfolio of management approaches to address high levels of uncertainty</li> <li>Hedge bets and optimize practices in situations where system dynamics and responses are fairly certain</li> <li>Use adaptive management in situations with greater uncertainty</li> </ul> (See Chapter 4 section 4.3.3).  |
| Occurrence of extreme climate events outside historical experience.   | Use disturbed landscapes as templates for “management experiments” that provide data to improve adaptive management of natural resources.  | <ul style="list-style-type: none"> <li>After fire, reforest with genotypes of species that are better adjusted to the new or unfolding regional climate with nursery stock tolerant to low soil moisture and high temperature, or with a variety of genotypes in the nursery stock (see Chapter 3 section 3.3.1.2).</li> </ul>  |
| Stakeholders/public may have insufficient information to properly evaluate adaptation actions, and thus may oppose/prevent implementation of adaptive projects ( <i>e.g.</i> , such as those that have ground-disturbing elements like salvaging harvests after disturbance and using herbicides before revegetating). Appeals and litigation from external publics often results in the default of | Inform public and promote consensus-building on tough decisions; invite input from a broad range of sources to generate buy-in across stakeholder interests.   | <ul style="list-style-type: none"> <li>Conduct public outreach activities with information on climate impacts and adaptation options—including demonstration projects with concrete results—through workshops, scoping meetings, face-to-face dialog, and informal disposition processes to raise public awareness and buy in for specific management actions (<i>e.g.</i>, like Tahoe NF, Chapter 3 section 3.4.6.2 and Partnership for the Sounds (the Estuarium) and North Carolina Aquariums, Chapter 7 sections 7.4.5).</li> <li>Use state and local stakeholders to develop management plans to gain support and participation in implementation and oversight of planning activities, as the National Estuary CCMPs do (see Chapter 7 section 7.1.2), the Coastal Habitat Protection Plans do for fisheries</li> </ul> |

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| no action. (See Chapter 3 sections 3.4.4.2, 3.4.6.1, and 3.7.2.4). |  | management (see Chapter 7 section 7.4.4), and some National Forests do (Chapter 3 section 3.4.6.2). |
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1 **9.11 Figures**

2 **Figure 9.1.** Two conceptual models for describing different processes used by (a) the resource  
 3 management community and (b) the climate community to support adaptation decision making.  
 4 Colors are used to represent similar elements of the different processes.  
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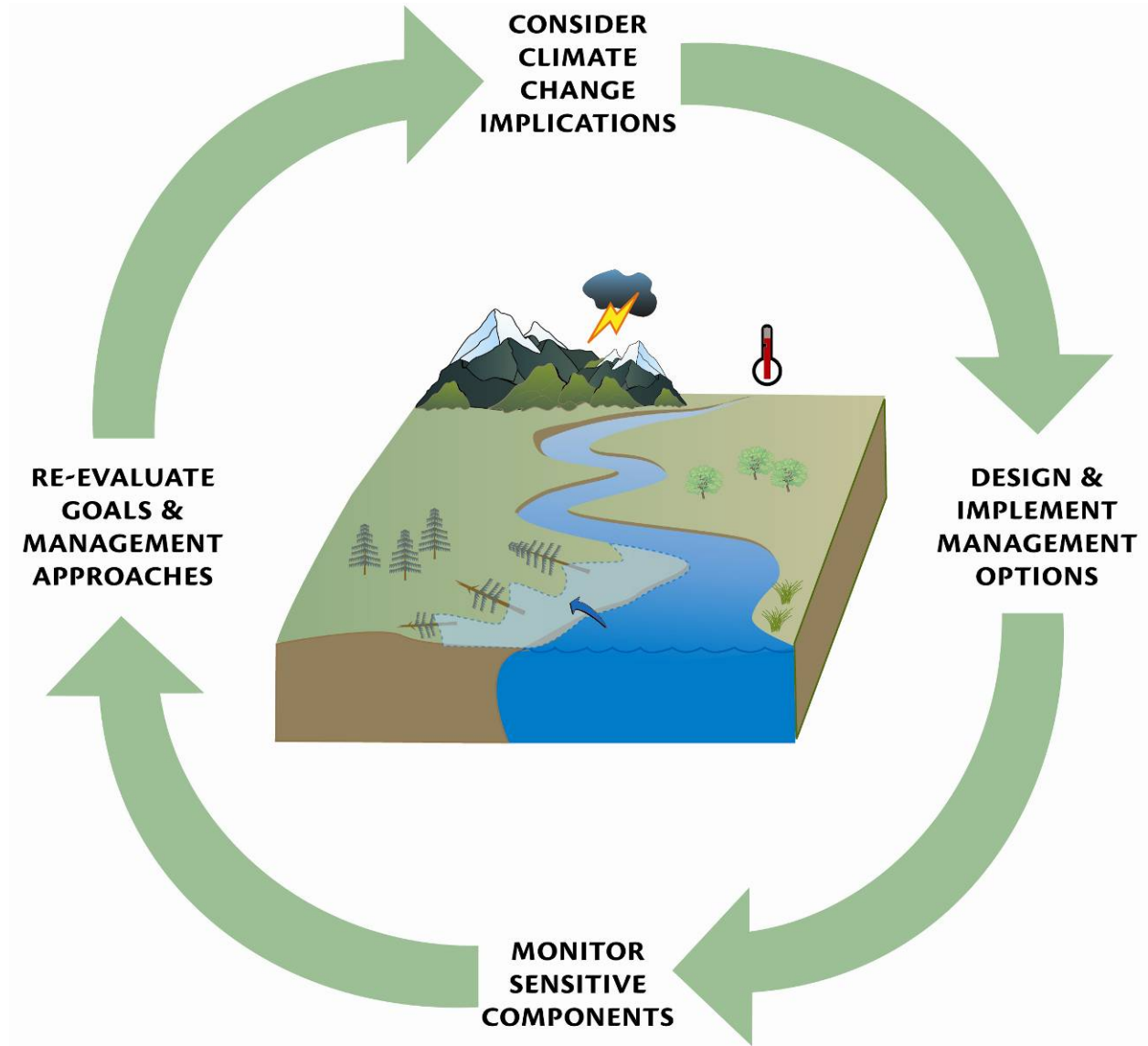
\*Vulnerability is the sum of projected impacts and adaptive capacity; this step is done by managers when they evaluate the projected impacts and their capacity to respond during their planning process

\*\*Assessing the capacity to respond in the management community is equivalent to assessing adaptive capacity in the climate community

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**Figure 9.2.** The process of adaptive management.



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