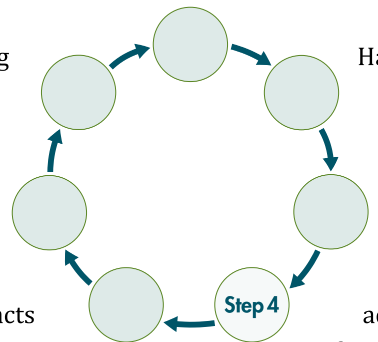
Chapter 8. The Art of the Possible: Identifying Adaptation Options[22]



Armed with an understanding of climate vulnerabilities in the context of climate-informed goals, the next step is to identify a full range of possible adaptation responses. Bridging the gap between vulnerabilities and potential options to address those impacts is at the heart of climate-smart conservation, through linking actions to climate impacts. This challenging task requires a concerted effort to consider knowledge gleaned from vulnerability assessments in the context of one's relevant decision-making processes and goals (Mastrandrea et al. 2010).

While the general toolbox of conservation and management approaches may remain fairly constant, it is not sufficient to simply apply the same practices "better" (more effectively) or "more" (in greater amount). Rather, the risks associated with climate change may require changes to some of the assumptions that go into conservation project design, as well how these approaches and strategies are used in given situations. For example, climate change may require managers to re-prioritize which existing stressors to focus on and which options to use to address them. Existing management practices and approaches may need to be adjusted for place, time, technique, or other aspects in order to be effective at meeting climate-informed goals. There may also be some entirely novel management approaches that emerge, which may either complement or supplant current-day "best practices."

Having a good list of options available is central to effective conservation priority setting and natural resource decision-making (Game et al. 2013). Step 4 in the climate-smart cycle (Figure 4.1) is the stage at which the broadest array of possible adaptation options should be generated for subsequent evaluation (step 5) and possible implementation (step 6). An important aim should be to avoid constraining identified adaptation options to a limited set of "popular" or familiar choices, without regard to whether they are really the most appropriate or sufficient for the particular need in question. At this stage in the process it is more useful to be creative rather than prescriptive, and to embrace innovative thinking. Even if some policy or management approaches may not currently be viewed as technically, financially, or socially feasible, what may be impossible today may change in the not-too-distant future. For example, while planning for managed retreat and abandonment of coastal areas in response to sea-level rise generally was considered unthinkable just 20 years ago, such approaches are now becoming a reality in certain early-adopter coastal states (NOAA 2013).

This chapter focuses on a process for using vulnerability information as the basis for generating specific adaptation options. The chapter also considers the applicability of these options in the context of the dual pathways of managing for change and persistence, and the interrelationship and cycling between the two. The concentration

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at this stage is on generating management options suitable primarily from the perspective of achieving ecological outcomes. A broader evaluation that brings in social, political, financial, institutional capacity, and other factors is also necessary, and the subject of step 5 in the climate-smart cycle (Chapter 9). In contrast, this chapter focuses on generating a broad array of options, or the "art of the possible."

8.1. Moving from Vulnerability to Adaptation

Climate change vulnerability assessments, conducted in the context of established goals, form an important basis for generating adaptation options. The link between vulnerability and adaptation is clearly evident in the IPCC (2007a) definition of adaptation as "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects." As discussed in Chapter 6, vulnerability assessments can help managers identify *which* of their conservation targets are most vulnerable, as well as *why* they are vulnerable. Understanding the "why" of vulnerability is of particular importance for generating relevant adaptation options. Vulnerability assessments may also reveal beneficial or positive changes that adaptation strategies and actions might take advantage of (such as the fact that invasive cheatgrass is likely to be stressed in portions of its existing range) (Rivera et al. 2011). Vulnerability assessments thus provide critical inputs for thinking about and identifying adaptation options. In particular, adaptation can be a means of addressing one or more of the three components of vulnerability (i.e., exposure, sensitivity, and adaptive capacity), either explicitly or implicitly. And while vulnerability assessments provide the context for identifying the scientifically important issues to consider in designing adaptation strategies, identification of "key vulnerabilities" can focus the generation of adaptation options even further on the most critical issues for meeting agreed-upon conservation goals.

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8.2. Identifying Adaptation Strategies and Options

How does one move from an understanding of vulnerabilities to specific and actionable adaptation options? This section describes an approach based on a set of general adaptation strategies that can serve as a framework for brainstorming more specific adaptation options and management actions (other types of framing approaches will be touched upon in Section 8.2.3). Next, a series of case studies, focused on different levels of ecological organization, illustrate how these adaptation strategies and options may be used to address specific climate change vulnerabilities. Ultimately, however, the options generated in this way will need to be assessed against context-specific "climate-smart design considerations" to ensure that they address relevant impacts and vulnerabilities, or take advantage of appropriate opportunities.

8.2.1. General Adaptation Strategies

As a framework for generating adaptation options in this chapter, we use a modified version of the adaptation framework developed by the U.S. Climate Change Science Program (CCSP 2008b). The strategies that comprise the original CCSP framework have been updated and further refined based on a number of more recent contributions to

Table 8.1. General adaptation strategies. While these general strategies also apply to traditional conservation efforts, "climate-smart" application takes into account future as well as current conditions and makes explicit links to climate-related impacts and vulnerabilities in order to generate specific adaptation options.

Adaptation Strategy	Definition
Reduce non-climate stresses	Minimize localized human stressors (e.g., pollution) that hinder the ability of species or ecosystems to withstand or adjust to climatic events
Protect key ecosystem features	Focus management on structural characteristics (e.g., geophysical stage), organisms, or areas (e.g., spawning sites) that represent important "underpinnings" or "keystones" of the current or future system of interest
Ensure connectivity	Protect, restore, and create landscape features (e.g., land corridors, stream connections) that facilitate movement of water, energy, nutrients, and organisms among resource patches
Restore structure and function	Rebuild, modify, or transform ecosystems that have been lost or compromised, in order to restore desired structures (e.g., habitat complexity) and functions (e.g., nutrient cycling)
Support evolutionary potential	Protect a variety of species, populations, and ecosystems in multiple places to bet-hedge against losses from climate disturbances, and where possible manage these systems to assist positive evolutionary change
Protect refugia	Protect areas less affected by climate change, as sources of "seed" for recovery (in the present) or as destinations for climate-sensitive migrants (in the future)
Relocate organisms	Engage in human-facilitated transplanting of organisms from one location to another in order to bypass a barrier (e.g., urban area)

the field (e.g., Galatowitsch et al. 2009, Heller and Zavaleta 2009, Joyce et al. 2009, West et al. 2009, Groves et al. 2012, Yale Working Group 2012).

A few words about terminology: there are various terms used to describe different types and levels of adaptation efforts, including approach, strategy, option, action, and tactic, with varying applications (Janowiak et al. 2011). There is no consensus on a hierarchy for such terms, and for purposes of this guidance, we generally refer to adaptation "strategies" as those at the broadest level, with adaptation "options" at the next level of specificity. Ultimately, both strategies and options will need to be translated to specific actions for implementation (Game et al. 2013).

Table 8.1 presents seven general adaptation strategies ranging from very familiar approaches for which managers already have a large degree of experience and confidence (e.g., reducing non-climate stressors) to those for which there is less experience and greater uncertainty about effectiveness (e.g., relocating organisms) (West et al. 2012). Note that most of these strategies represent existing "best practices" derived from the management community's long history of experiences with non-climate stressors such as pollution, habitat destruction, and invasive species, as well as unpredictable and extreme events such as hurricanes, floods, pest and disease outbreaks, and wildfires. As such, many are important for conservation regardless of climate change. The key question is how effective the strategies will be for meeting particular goals given the magnitude and timing of climate change impacts on the system. Even though multiple benefits may result from continuing with today's practices using these strategies, it is not enough to simply continue their use in a business-as-usual way. Rather, it is necessary to consider how climate change will affect both the need for and effectiveness of each adaptation option within the context of all relevant stressors. This should include what adjustments in timing, location, and intensity of effort may be necessary for the greatest positive (i.e., desired) effect on the management target. Note that each of these general strategies may be applicable whether one is focused on managing for change or for persistence. The relationship between these general strategies and the dual pathways is discussed in more detail in Section 8.3.

Reduce non-climate stressors. Reducing "non-climate" stressors (i.e., existing threats that are not specifically related to climate change) is a commonly cited adaptation approach, largely because climate change is not happening in isolation from the many other challenges we face in conservation (Hansen et al. 2003, Lawler 2009, Mawdsley et al. 2009, West et al. 2009, Hansen and Hoffman 2011). In fact, it is the combined effects of climate change and other problems, such as habitat fragmentation, pollution, and invasive species that ultimately pose the greatest threat to natural systems and the fish, wildlife, and people they support (Root and Schneider 2002, Glick et al. 2009, Staudt et al. 2013). This does not mean that addressing non-climate stressors *writ large* will be appropriate or sufficient in all cases. Rather, understanding where and how climate change may exacerbate (or may be exacerbated by) non-climate stressors is necessary to help identify relevant management actions. As described in Chapter 6, non-climate stressors can themselves be important factors in determining the degree to which a species or ecological system is sensitive to climate change. For example, management practices such as fire suppression may increase the sensitivity of a forest system to drought and disturbances associated with climate change. And, often, other anthropogenic stressors (e.g., the existence of coastal armoring) are important factors in reducing a system's or organism's adaptive capacity. Climate change is also likely to exacerbate some of the other problems managers must currently deal with, such as heavier downpours that increase pollutant loadings into aquatic habitats. In each of these cases, asking the climate question (i.e., showing your work) is essential.

Protect key ecosystem features. Within ecosystems, there are likely to be a number of key features that will be especially important for enhancing resilience to climate change (West et al. 2009). For example, there is clear scientific evidence that maintaining biological diversity across a range of functional groups can improve the ability of many ecological systems to recover from disturbances such as wildfires and disease outbreaks—in other words, because such systems have greater functional redundancies, they may be less sensitive to climate change and/or have greater adaptive capacity (Elmqvist et al. 2003, Luck et al. 2003, Folke et al. 2004, Worm et al. 2006, Kareiva et al. 2008, Peters 2008). Another key feature can be geophysical land facets or "enduring features" that, because they are likely to remain relatively static over time in contrast to predicted species distribution shifts, will support future diversification (Hagerman et al. 2009, Anderson and Ferree 2010, Beier and Brost 2010). Here, the focus is on protecting the ecological "stage" (e.g., distinctive combinations of geophysical features, such as elevation, slope, and substrate), not just particular "actors" (e.g., particular plant and animal species). Beier and Brost (2010), for example, cite numerous studies that found a strong correlation between species distributions and topographic features; understanding these key features can assist in the design of migratory corridors (see below) that are more likely to support range shifts under climate change.

Ensure connectivity. Maintaining or enhancing habitat connectivity is another adaptation strategy that has received considerable attention in recent years (Heller and Zavaleta 2009). Traditionally, habitat connectivity has been fostered as a way to enhance gene flow among isolated populations and promote recolonization of species into historical habitat areas (Krosby et al. 2010). Interest in connectivity in the context of climate change is both because of these capabilities as well as to facilitate species movements over the landscape in response to changing conditions—again, a factor that can be associated with the adaptive capacity of a species. Many approaches to maintain or enhance habitat connectivity focus on expanding protected area networks and protecting or restoring corridors

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among these protected areas (Monzón et al. 2011). Mapping corridors among currently suitable habitat patches to areas with similar conditions may be insufficient for the purpose of addressing climate change since those currently suitable conditions may change (Cross et al. 2012a). Rather, managers should take projected climate change into consideration when identifying and designing potential corridors for species movement. Various studies have suggested using: (1) projected shifts in habitat suitability (Williams et al. 2005); (2) identification of locations where climate is expected to remain within species' tolerances (Rose and Burton 2009); and (3) modeling of spatial temperature gradients along with land-use changes (Nuñez et al. 2013) to map potential routes and stepping-stone "refugia" that species might take to track shifting climates (see also discussion of refugia below). In addition to focusing on corridors, managers may also consider increasing the permeability of the landscape through actions focused on improving the suitability of human-dominated lands and waters, such as farms, grazing lands, and urban areas, to better support populations of native species (Manning et al. 2009, Mawdsley et al. 2009, Schloss et al. 2012).

Restore ecological structure and function. Climate-smart conservation necessitates greater emphasis on biodiversity processes and ecological function in the context of dynamic threats, recognizing that climate change will make it increasingly difficult to maintain or control species composition (Harris et al. 2006, Pressey et al. 2007, Hagerman et al. 2010, Prober and Dunlop 2011). Here the focus is on preserving processes that ensure the continuation of diverse and functioning ecosystems, even if the particular compositional and structural attributes may be strikingly different. Traill et al. (2010) suggest that a logical approach is to focus on the specific mechanisms by which climate change is likely to affect a host of factors, including "species behavior, physiological and evolutionary response, population- and species-level interactions, and consequent effects for species diversity, system resilience, and function." Based on this information, fundamental functions such as primary productivity, gene flow, decomposition, and nutrient cycling can be targeted for management, either through restoration of the original system, or through transformation to a new system state that fulfills the same functions. Although the term "restoration" conjures images of an emphasis on historical conditions or species assemblages, modern restoration ecology recognizes the importance of maintaining or restoring those processes and functions that will confer resilience even with shifts in system state or composition (Harris et al. 2006, Jackson and Hobbs 2009).

Support evolutionary potential. If managing biodiversity under climate change will largely be about "facilitating nature's response" (Prober and Dunlop 2011), then having explicit strategies for allowing adaptation in an evolutionary sense to proceed will be important, as will maintaining the distinctive evolutionary character of regional plants and animals. Evolutionary processes have been, and will continue to be, a significant factor influencing the patterns and rates of species' responses to climate change (Parmesan 2006). Indeed, preliminary evidence indicates that populations of some species are already demonstrating genetic changes (e.g., in traits that contribute to increased temperature tolerance) in response to climatic shifts (Parmesan 2006, Skelly et al. 2007, Berg et al. 2010, Hoffmann and Sgrò 2011). Managers can help improve the evolutionary adaptive potential of target species through actions that conserve or increase genetic diversity. This can include enhancing the abundance and genetic diversity of individual species, protecting diverse populations of species within and across habitat ranges (i.e., increasing redundancy), facilitating gene flow, and actively managing genetic composition of species (e.g., such as plants in forest management or restoration projects) (Harris et al. 2006, Millar et al. 2007, Joyce et al. 2009, Kremer et al. 2012).


USFS Kaibab National Forest

Protect refugia. The term "refugia" in the context of climate change adaptation typically refers to areas that are likely to experience relatively less change than others and thus serve as "safe havens" for species, either currently or in the future (Noss 2001, West et al. 2009, Keppel et al. 2011). For example, tributaries fed by glaciers may offer cold-water refugia for aquatic species when other parts of their stream habitat become adversely warm (i.e., it can help reduce exposure to climate change impacts). Refugia can be within a species' current distribution (in situ refugia) or outside of a species' current distribution but likely to be suitable in the future (ex situ refugia) (Ashcroft 2010). For management purposes, identifying and protecting in situ refugia may be especially important for species with limited dispersal ability. Yet, it also may be useful to protect potential ex situ refugia, even if associated species ultimately might need to be translocated to those areas (see below). Identifying and protecting potential refugia in the near term can help ensure that they will not be lost to land-use change or other factors before climate change comes into play. For both in situ and ex situ refugia locations, an important consideration is whether human structures such as dams or cities might restrict the ability of species to access otherwise available refugia, necessitating managed relocation (see below).

Relocate organisms. One of the more controversial climate change adaptation strategies is the translocation or, more specifically, "managed relocation" of species (i.e., actively moving a species from its current range into a novel area expected to have more suitable climate conditions in the future) (Schwartz and Martin 2013). This could be considered an option, for instance, for species with limited dispersal capabilities, whose ranges have become highly fragmented, and whose current habitats are disappearing (Hoegh-Guldberg et al. 2008, Thomas 2011). While some scientists (e.g., Ricciardi and Simberloff 2009, Seddon et al. 2009) cite risks such as the potential that the newly introduced species may erode biodiversity and disrupt ecosystems, others argue that those risks need to be weighed against the likelihood that, without such action, the target species may become extinct (Hoegh-Guldberg et al. 2008, Schwartz et al. 2009). It is important to note that translocation of species is not an entirely new concept. Species reintroductions generally follow a similar process, although usually those are intended to replenish species within their historic range (Lawler 2009, Green and Pearce-Higgins 2010). Yet even those native habitats may have changed over time due to anthropogenic stressors, so reintroductions may well be creating different species assemblages than had occurred before those target species had been extirpated. Ultimately, decisions about which adaptation approaches to take, from reducing existing stressors to relocating organisms, will require consideration of a range of values-based criteria, as discussed further in Chapter 9.

8.2.2. Generating Specific Adaptation Options

The set of general adaptation strategies described above can be used as a structure for identifying and discussing a wide array of more specific adaptation options using the climate-smart lens. Here the aim is to be creative and expand the range of possible options beyond those that are commonly used or already underway. Box 8.1, presents some available techniques and methods to help with the brainstorming and idea generation process. All of these require participatory processes in recognition of the valuable information and insights that come from engaging stakeholders and resource users with local or traditional knowledge. Most emphasize the need to engage people from

Box 8.1. Techniques for generating adaptation options.

Expert elicitation. A range of techniques to systematically elicit judgments from experts (either individually or in groups), usually through the use of some form of conceptual modeling that aids in structuring a series of questions about the system of interest. See example applications by McDaniels et al. (2012) and Doria et al. (2009), and a methods review by Martin et al. (2012).

Brainstorming groups/buzzing groups/ideation. A process for generating ideas in a participatory manner, often through workshops, using a mix of individuals with different backgrounds and roles to develop and propose ideas. “Buzzing groups” refers to smaller subgroups broken out from a larger group. “Ideation” typically involves intense preparation prior to a session to develop ideas. For a general guide to brainstorming, see Baumgartner (2005).

Analysis of Interconnected Decision Areas (AIDA). A structured format in which decision areas are identified (along with corresponding options) and compatibility is explored across decision areas in order to generate a list of possible option portfolios. Decision areas and options may be visually depicted (e.g., through circles and dots within circles) as an aid to check for interactions or incompatibilities. See Sayers et al. (2003) for an example for flood management.

Charrettes. A group-based approach that employs a period of intensive, collaborative problem solving to quickly generate appropriate options using groups of people with diverse disciplinary backgrounds, abilities, and interests. Typically, charrettes are held over multiple days and are conducted on or near the site for which planning is occurring. For example, see San Francisco Public Utilities Commission (2010).

Focus groups. An approach for gathering feedback from people with a variety of backgrounds who all have a stake in the issue at hand. Participants are provided with detailed information and asked to respond through a particular exercise. A trained moderator then analyzes participant responses and the internal dynamics of the group to identify the central elements of the issue and the reasoning behind different viewpoints. See Carmody (2010) for an example application.

Literature/case study reviews. Use of literature or case study databases for summaries of analogous management situations that illustrate selection and application of adaptation measures or that provide lists of adaptation options to consider. Online repositories such as the Climate Adaptation Knowledge Exchange (CAKE; http://www.cakex.org/) and the U.S. Forest Service’s TACCIMO (www.forestthreats.org/taccimotool) provide access to such resources from which adaptation options can be drawn.


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different backgrounds, abilities, and interests to collaborate in the option development sessions. Expert elicitation is an exception in that only individuals with specific knowledge are engaged. This approach is suitable when very specialized information is needed from an idea generation session. Other aspects that distinguish the different methods can include: whether to use large groups or smaller breakout groups or some combination; whether the format is a workshop or focus group; and the types of visual tools used. Selecting a method or technique may be as simple as going with the one that is most familiar. However, if a range of methods and techniques is possible, it is worth spending time to consider which is most appropriate given the characteristics of the problem and people involved in the planning process.

For adaptation options to be considered climate smart, a clear line of logic must be drawn that begins with the conservation target and its key vulnerabilities, and describes the mechanism by which the implementation of an option can be expected to reduce the vulnerability of the system or species to the climate-related stress. For example, salmon (the conservation target) is threatened by warming water (the exposure), which leads to greater mortality of eggs given critical temperature thresholds (the sensitivity). Adaptation options developed in response to this critical threat would need to demonstrate how each specifically designed action would either decrease exposure, decrease sensitivity, or increase adaptive capacity of salmon eggs in light of these changes. Table 8.2 provides a few example adaptation options for each general adaptation strategy that could arise from a brainstorming session.

8.2.3. Alternative Frameworks for Generating Options

The application of these general adaptation strategies in designing adaptation options for specific places and systems is elaborated on and illustrated in Section 8.4. It is important to note, however, that alternative frameworks are also in use for generating adaptation options in conservation planning efforts. In addition to the “general adaptation strategies” approach described above, other adaptation framings for generating adaptation options make use of “components of vulnerability” and “intervention points” as underlying structures. Table 8.3 provides descriptions of alternative frameworks along with example applications. These different approaches are not mutually exclusive, and can be used either individually or in concert to help structure the exploration of a full array of potential adaptation options. Indeed, step 4 of the climate-smart cycle focuses on identification of an array of possible adaptation alternatives to use as the basis for subsequent steps in the cycle (i.e., evaluation selection [step 5] and implementation [step 6]).

Table 8.2. Illustrative adaptation options. For any particular option to be considered climate-smart, it would need to explicitly address vulnerabilities of the conservation targets. More detailed and specific examples of how to apply such climate-smart considerations to the design of options are presented in Section 8.4.

General Adaptation Strategy	Example Adaptation Options
Reduce non-climate stressors	• Work with watershed coalitions to promote best practices for agricultural and stormwater management to reduce non-point sources of pollution • Institute flexible zoning in marine protected areas to minimize tourism and fishing impacts • Remove structures that harden the coastline to allow inland migration of sand and vegetation
Protect key ecosystem features	• Update protections for key biogeochemical zones and habitats as their locations change with climate • Maintain natural flow regimes to protect flora and fauna in drier down stream river reaches • Manage functional species groups (e.g., grazers) necessary for maintaining the health of coral reefs and other ecosystems
Ensure connectivity	• Design marine protected area networks of resilient habitats connected by currents • Remove barriers to upstream migration in rivers and streams • Create linear reserves oriented longitudinally
Restore structure and function	• Restore the natural capacity of rivers to buffer climate-change impacts through land acquisition around rivers, levee setbacks to free the floodplain of infrastructure, and riparian buffer repairs • Restore estuarine habitat in places where the restored ecosystem has room to retreat as sea level rises • Favor the natural regeneration of species better-adapted to projected future conditions
Support evolutionary potential	• Manage for a variety of species and genotypes with tolerances to low soil moisture and high temperatures • Distribute species over a range of environments according to modeled future conditions • Facilitate evolution by managing disturbances to initiate increased seedling development and genetic mixing
Protect refugia	• Create side-channels and adjacent wetlands to provide refugia during droughts and floods • Restore oyster reefs along a depth gradient to provide shallow water refugia for mobile specie during climate-induced deep water hypoxia/anoxia events • Identify areas that supported species in the past under similar conditions to those projected for the future and consider those sites for establishment of "neo-native" plantations or restoration sites
Relocate organisms	• Move isolated populations of species of interest that become stranded when water levels drop • Relocate or re-introduce captively bred species to restored habitats and refugia • With sufficient information, move germplasm in the anticipated adaptive direction

Table 8.3. Alternative frameworks for identifying adaptation options. Several different framing approaches currently are in use for generating possible adaptation options, including the three broad frameworks detailed here. These general approaches can be used in combination to assist in thinking through and generating sets of potential adaptation strategies and actions.

Framework	Description	Example application of framing approach	Other examples for approach
General adaptation strategies	Use a list of "general" adaptation strategies to identify specific adaptation options that would help achieve goals and objectives	Using the U.S. Forest Service Climate Change Response Framework Adaptation Workbook (Swanston and Janowiak 2012), adaptation options such as the following can be identified for retaining paper birch stands where possible, and regenerating white pine (*Pinus strobus)* when paper birch regeneration is not possible as climate changes: • *Reduce the impact of existing stressors (e.g., invasives):* Ensure adequate overstory is retained so as not to encourage the establishment of sun-loving invasives • *Maintain and enhance species and structural diversity:* Employ silvicultural techniques (e.g., shelterwood harvest) to encourage growth of white pine in overmature paper birch forests • *Sustain fundamental ecological functions:* Adjust rotation age to achieve age class distribution goals and increase ability of forests to resist pests and pathogens	SAP 4.4 (West et al. 2009); TACCIMO (Treasure et al. 2014); Conservation Action Planning for Climate Change (TNC 2009); Yale Framework (Schmitz et al. In press)
Components of vulnerability	Using the three components of vulnerability, target actions toward one or more of the following: reduce exposure, reduce sensitivity, enhance adaptive capacity	Using a guide for the design and implementation of climate-smart restoration projects for the Great Lakes region (Glick et al. 2011b), adaptation options such as the following can be identified to restore fish habitat along the Black River of Ohio (see Section 3.4.1., Chapter 3): • *Reduce exposure:* Restore riparian tree canopy to provide shading over open water to moderate exposure to warmer air temperatures • *Reduce sensitivity:* Select more southerly tree species for use in site restoration to decrease sensitivity to future temperature increases and precipitation changes • *Enhance adaptive capacity:* Construct fish shelves at multiple levels to increase availability of breeding habitat at variable water levels	Application of Climate Change Vulnerability Index by Defenders of Wildlife (Dubois et al. 2011); Adaptation for conservation reserves by Magness et al. (2011); Mangrove adaptation by World Wildlife Fund (Ellison 2012)
Intervention points	Use conceptual models or other methods to identify "intervention points" (components of the target system that can be influenced through conservation actions) to identify possible adaptation options	Using the Adaptation for Conservation Targets (ACT) Framework (Cross et al. 2012b), adaptation options such as the following can be identified for managing stream flows for native cold-water fish as temperatures warm and flows decline: **Intervention points** — **Potential Adaptation options** • Withdrawals — Reduce withdrawals by leasing in-stream water rights • Snowpack management — Build snow fences to retain snow in key areas for longer • Riparian vegetation — Restore riparian areas that provide shading to streams	Conservation Action Planning (CAP) for Climate Change (TNC 2009); Open Standards for the Practice of Conservation (CMP 2013); NOAA (2010)

It does not, however, prescribe the process for generating those options, and adaptation planning teams may elect to use one or more of these framing approaches as appropriate.

Regardless of the framing approach used, all options would then be designed according to whether the intent is to: (1) preserve the current set of system conditions (e.g., maintain natural flow regimes to protect flora and fauna in drier downstream river reaches), or (2) facilitate system changes in a desirable direction (e.g., manage for a variety of species and genotypes with tolerances to low soil moisture and high temperatures). In practice, even if the current intent is to "manage for persistence," experience indicates that change is inevitable and it will be necessary to think about and prepare to "manage for change" as well.

8.3. Adaptation for Persistence and Change: Dual Pathways

As discussed in Chapter 2 and above, climate change will increasingly necessitate that the conservation community move from a paradigm of not just preservation and restoration to historical conditions (i.e., managing for persistence), but one that is simultaneously open to anticipating and actively facilitating transitions (i.e., managing for change). This notion has previously been described in the adaptation literature in the form of a continuum of strategies that move from resistance, to resilience, to transformation (Millar et al. 2007, Glick et al. 2009). Here we choose to focus on "outcomes" (change/persistence) rather than "strategies" (resistance/resilience/transformation) because any particular adaptation action could contribute to change or persistence depending on context, scale, and application.

In the case of managing for persistence, the aim generally is to prevent systems from crossing thresholds of major change for as long as possible by protecting them from stress and by supporting their recovery after major disturbances (e.g., Hansen et al. 2003, Marshall and Schuttenberg 2006, West et al. 2009). This remains a viable goal where: (1) there is potential for long-term success; or (2) a high priority is placed on "buying time" to prepare for longer-term changes (Hansen et al. 2003). However, managing for persistence will become an increasingly difficult challenge as climate change progresses. In some cases changes in the mean and extremes of precipitation and temperature already have led to ecological transitions. For example, threshold behaviors have been documented in grasslands throughout arid and semiarid areas as woody plants have encroached into perennial grasslands (Zavaleta et al. 2003, Sherry et al. 2011, Yang et al. 2011) and in coral reef ecosystems as seawater temperatures and ocean acidification have increased (Marshall and Schuttenberg 2006, Hoegh-Guldberg et al. 2008).

Thus, equally as important as persistence is the concept of managing for change, which involves assessing where unavoidable changes in ecological systems may be about to happen and preparing for a different management regime for the altered state. Since thresholds will continue to be crossed as climate change progresses, it will be necessary to revisit and sometimes revise conservation goals and objectives, as covered in Chapter 7. For example, a national wildlife refuge established to protect a particular species might see that species' habitat range shift farther north outside of refuge boundaries, while more southerly species move in. Accordingly, the refuge may need to reconsider its goal of maintaining the original species (Griffith et al. 2009).

Based on the existing or revised goals, there are two primary approaches to managing for change. The first is to allow regime shifts to occur without management interference (which may be unavoidable where there is not enough information to know a shift is occurring); and the second is to anticipate potential shifts, establish the new goal of the desired future state, and manage to affect the trajectory toward that state as climate changes. The second approach is still in the realm of the experimental since there are significant uncertainties associated with trying to project regime shifts. This is where sustained research, monitoring, and evaluation will be critical in order to continuously improve the knowledge base about system dynamics (see Chapter 11). In the meantime, managers and researchers have already begun to explore ways to anticipate and manage transitions using existing information and theory, with the same techniques that are used to manage for persistence, but applied differently to manage for change.

For example, management techniques involving manipulation of genetic composition of communities (e.g., forests) can be used to preserve the existing type of system; or they can be used to manage succession to a different type of system (Joyce et al. 2009). As another example, one could imagine that for cold-water fish, we might maintain natural flows and riparian buffers to support persistence of current species; but if invasion/replacement by warm-water fish becomes unavoidable, we might use the same techniques (e.g., manipulation of flows) to now manage for the new species assemblage. The challenge is deciding when it is time to shift to a new objective, either based on some indicator of impending transition or in rapid response to an observed transition as it is occurring. In the meantime, it will be important to practice the climate-smart characteristic of "employing agile and informed management" by brainstorming and designing options for both persistence and change simultaneously, as a dual pathways approach to planning.

8.4. Examples of Linking Adaptation Options with Impacts

Below, we highlight this dual pathways concept through four case studies of specific management options for targets representing a range of ecological scales: individual species; ecosystems; protected area networks; and multi-ecosystem mosaics (Tables 8.4–8.7). Each table provides a specific example of a management target and associated conservation goal, along with an identified set of key climate change vulnerabilities that are specific to the targets (and could affect attainment of the goal). An explicit understanding of the mechanism by which a key vulnerability relates to an impact on the target is needed to make the link from vulnerabilities to specific options that address those vulnerabilities. Each option must then be subjected to "climate-smart design considerations" in order to determine how, when, and where a conservation action can be applied to be truly effective for adaptation (this is where to "show your work"). Some of the questions surrounding these design considerations can be difficult to answer, particularly in cases where current data and scientific knowledge are incomplete. Yet it is not in society's best interest to put off adaptation while waiting for perfect information. The key is to couple available information (whether meager or abundant) with logical reasoning to shed new light on today's management choices, while also being open to adjusting this reasoning through time as new information becomes available.

These examples are meant to be illustrative rather than comprehensive. Each case study table presents one example of a specific option under each general strategy, along with a set of climate-smart design considerations for that option. The case studies illustrate the crosswalk from target, to vulnerabilities, to strategies, to options to actions. In order to generate a complete

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table of options, however, one would need to examine each key vulnerability—and consider it from the perspective of each general strategy—in order to systematically brainstorm a full list of possible options in response.

8.4.1. Species Level: Chinook Salmon on the U.S. West Coast

In this example, the conservation goal is to ensure viable spawning habitat to maintain populations (i.e., support the persistence) of Chinook salmon *(Oncorhynchus tshawytscha)* on the U.S. West Coast (Table 8.4). Under the "restore structure and function" general strategy, one option is to increase spawning habitat containing clean gravel beds through restoration. Looking at the identified key vulnerabilities, the line of logic is that climate change will cause increased sedimentation rates, increased temperatures, and decreased flows in salmon spawning habitats—all of which will be detrimental to the survival of eggs given their sensitivity to changes in those variables. This is where the essential application of the climate-smart design considerations comes into play. Restoring clean gravel beds may only make a positive difference if they are strategically located based on questions such as: How will climate change affect temperature, flow, and sedimentation rates in historic locations of spawning habitats versus other locations (i.e., are there areas where exposure to relevant climate change factors can be reduced or eliminated)? What are the best locations for restoring clean gravel beds in terms of their long-term viability as salmon spawning habitat given climate change? Besides location, climate-smart adjustments for other options may also involve timing and intensity. For example, under the "maintain key ecosystem features" general strategy, water temperature and flow can be managed through scheduled dam releases to maintain suitable habitat conditions during spawning and migration. Yet, this will only be effective if implementation is based on asking: How will climate change affect the timing and magnitude of peak temperatures and low flows during spawning and migration? What volume and timing of water releases will maintain temperatures and flows within tolerance ranges?

Besides looking at adaptation options individually, it is also helpful to consider them in concert. In some cases it may be necessary for multiple actions to be combined in order for any individual

Table 8.4. Species-level example of adaptation options and climate-smart considerations: Chinook salmon, U.S. West Coast.

Target, goal, and key vulnerabilities	General adaptation strategy	Specific management option (example)	Key climate-smart design considerations
Conservation Target Chinook salmon **Conservation goal:** Ensure viable spawning habitat to maintain salmon populations on the West Coast **Key climate-related vulnerabilities:** • Increased stream temperatures - Lethal temperatures - Reduced dissolved oxygen **• Altered flows** - Erosion/sedimentation - Habitat fragmentation	Reduce non-climate stressors	Reduce withdrawals and remove infrastructure to maintain minimum flows during spawning to ensure sufficient oxygenation of eggs	How will climate-related alterations in hydrology, together with changing water demands, affect flows during spawning? What combination of reduction in withdrawals and removal of infrastructure will maintain minimum flows during spawning?
	Protect key ecosystem features	Schedule dam releases to maintain suitable habitat temperatures during spawning and migration	How will climate change affect timing and magnitude of peak temperatures during spawning and migration? What volume and timing of water releases will maintain temperatures within tolerance ranges?
	Ensure Connectivity	Re-establish side channel connections with freshwater and estuarine wetland habitats to improve low flows and lessen the negative impacts of peak flows	How will climate change continue to affect hydrology in historic floodplains? Where are the locations for re-establishment of side channels that will be most viable in the long term given climate change?
	Restore Structure and Function	Restore spawning habitat containing clean gravel beds in areas with suitable temperatures and flow s (also see refugia example below)	How will climate change affect sedimentation rate, temperature and flow in historic locations of spawning habitats? Where are the best locations for restoring clean gravel beds that will be viable in the long term given climate change?
	Support Evolutionary Potential	Maintain diversity (genetic replicates) within and across populations	How will climate change affect the genetic diversity of native salmon populations? What is the best way to identify, capture, breed and restock appropriate genotypes within and across populations?
	Protect refugia	Create streamside riparian vegetation to provide shaded areas (thermal refugia) and buffer gravel beds from sediment runoff	How will climate change affect temperatures, flows and land-based sedimentation of existing gravel spawning beds? Taking into account flows, what kind and how much vegetation should be placed in what locations to provide effective thermal refugia, free of excessive erosion and sedimentation?
	Relocate Organisms	Relocate hatchery-bred fry to most appropriate stream habitats	How will climate change affect the relative likelihood that natal streams will become intermittent and disrupt native salmon runs? From which streams should salmon be captured and bred in hatcheries, and in which streams should the fry be released?

Based on Battin et al. (2007), Yates et al. (2008), and Beechie et al. (2013).

action to be fully effective. For example, projects to restore clean gravel beds for spawning habitat may only be worthwhile if carried out in concert with other activities such as creation of refugia through planting streamside riparian vegetation to provide shaded areas. Note that these activities could span both managing for persistence (since natural populations of salmon are being preserved) and managing for change (since refugia may need to be created in entirely new areas where viability of conditions such as temperature limits can be maintained). Thus we are managing for persistence (of salmon) at the scale of the overall river reach, while at the scale of individual habitat patches we are managing to account for unavoidable change.

8.4.2. Ecosystem Level: U.S. East Coast Salt Marshes

The issue of scale invokes another key climate-smart characteristic that is relevant to this discussion: considering the broader landscape context. This refers to how best to design on-the-ground actions in the context of broader geographical scales to account for likely shifts in species distributions and to sustain ecological processes. We illustrate this using an ecosystem-level case study for salt marshes (Table 8.5). Here, the conservation goal is to maintain healthy, functioning salt-marsh ecosystems along the U.S. East Coast. Based on the identified list of vulnerabilities, the logic model is that climate change will lead to altered hydrology and increased sea level, with consequent negative impacts on salt marshes due to altered inundation regimes and marsh "drowning." Under the "protect refugia" general strategy, one option is to identify and acquire (or acquire easements for) areas in the upper estuary that will serve as locations where favorable conditions are anticipated as sea-level rise continues. This requires modeling and planning at the scale of the entire watershed to identify appropriate upper estuarine habitat, even though salt marshes are currently present only in the lower estuary.

Similarly, under the "ensure connectivity" general strategy, considering the broader landscape context may also apply to actions aimed at maintaining appropriate inundation regimes in areas where marshes currently are present, through manipulation of tidal connectivity. For example, it

Table 8.5. Ecosystem-level example of adaptation options and climate-smart considerations: U.S. East Coast salt marshes

Target, goal, and key vulnerabilities	General adaptation strategy	Specific management option (example)	Key climate-smart design considerations
Conservation target: East coast salt marshes **Conservation goal:** Maintain healthy, functioning, East coast salt marsh ecosystems **Key climate-related vulnerabilities:** • Sea level rise - Marsh drowning - Saltwater infiltration • Altered hydrology - Increased nutrient runoff - Altered inundation regimes	Reduce non-climate stressors	Work with watershed coalitions to reduce non-point sources of pollution that favor invasive *Phragmites*	How will climate change affect inputs of non-point source pollution (e.g., through effects on timing and flashiness of precipitation)? Given the nature of these effects, what are the best options (e.g., permeable pavements, rain catchers, sewer system upgrades) for reducing runoff of pollutants onto the marsh?

(continued on p. 134)

Table 8.5. Continued.

Target, goal, and key vulnerabilities	General adaptation strategy	Specific management option (example)	Key climate-smart design considerations
	Protect key ecosystem features	Modify ditches to re-establish natural hydrology and maintain appropriate salinities and sediment transport	How will climate change affect salinities and sediment transport through effects on hydrology? How many, what type, and what locations of ditch modifications will enable sufficiently "natural" hydrology for appropriate salinities and sediment transport?
	Ensure Connectivity	Reinstate tidal connections to support appropriate inundation regimes	How will climate change affect tidal inundation regimes through sea level rise and changes in hydrology? What number and locations of restored tidal connections will be sufficient to support appropriate inundation regimes?
	Restore Structure and Function	Plan timing of restoration projects (i.e., incorporate known climatic oscillations) to maximize likelihood of success	How will climate change have implications for the success of restoration projects, in terms of the need to take into account inter-annual (e.g., El Nino/La Nina) or seasonal (e.g., wet/dry season) oscillations? What is the optimal timing for restoration projects in order to maximize successful establishment of restored salt marsh?
	Support Evolutionary Potential	Ensure high clonal diversity of salt marsh plants used in restoration	How will climate change affect or change the top stressors of salt marshes? What is the clonal diversity of salt marsh plants found at sites that already experience these stressors to a high degree, and how do we ensure a high diversity of these types of clones for use in restoration?
	Protect refugia	Model, identify, and acquire (or set up easements for) areas in the upper estuary that will serve as refugia, i.e., locations where favorable conditions such as tidal inundation are anticipated as sea level rise continues	How will climate change shift the future locations of appropriate salt marsh habitats in the upper estuary based on sea level rise projections? Where do these locations correspond with areas that are available or can be acquired/set aside as refugia? What preparations (e.g., installation of larger culverts) can be made to ready these locations for unimpeded tidal inundation?
	Relocate Organisms	Not applicable	Not applicable

Based on Richards et al. (2004), Erwin (2009), Derwent Estuary Program (2011), and U.S.EPA (2012a, 2012b).

may be possible to support/enhance the adaptive capacity of marshes to keep pace with sea-level rise by enhancing sources of sediments to the marsh from upstream and/or tidal sources. Asking how climate change will affect engineering of hydrology and tidal inundation regimes is a watershed-scale question. In short, whether the intent is to enable existing marshes to stay in their current locations (managing for persistence) or facilitate the migration of marshes to new locations up-watershed (managing for change), success will not be possible without proper modeling and analysis at the broader landscape scale.

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8.4.3. Network Level: Central Flyway

Looking across adaptation options also helps with identifying potential conflicts and trade-offs. This is the "avoid maladaptation" key climate-smart characteristic: ensuring that actions taken to address climate change impacts do not exacerbate other vulnerabilities or undermine conservation goals and broader ecosystem sustainability. An illustration can be found in the case study on networks of protected areas (Table 8.6). This case study focuses on the conservation goal of ensuring appropriate Central Flyway feeding habitats to sustain waterfowl populations during migration.

One line of thinking or logic model is that climate change will cause altered precipitation patterns that will in turn result in increased runoff of nutrients into wetland feeding habitats, with consequent negative impacts due to eutrophication. Accordingly, under the "reduce non-climate stressors" general strategy, one option would be to work with farmers to reduce agricultural runoff into wetland-feeding habitats through the use of riparian buffers or improved irrigation scheduling. Yet at the same time, under the "protect key ecosystem features" strategy, a possible option for maintaining key feeding habitats is to mimic natural disturbance regimes (e.g., through controlled burns) in order to counteract the negative effects of climate change on the natural processes that shape these ecosystems. A problem arises in that controlled burns can have the negative side effect of increasing runoff during rain events, which could negate the nutrient reductions made under the other strategy through sheer volume of flow. In other words, even if nutrient concentrations have been reduced through riparian buffers or improved irrigation scheduling, the volume of runoff may be so great during intensified rain events that total nutrient inputs are just as high or higher. Therefore, part of the calculation in using these options might be to time controlled burns so that they will not coincide with periods of greatest fertilizer use in adjacent portions of the watershed.

Table 8.6. Network-level example for adaptation options and climate-smart considerations: Central Flyway.

Target, goal, and key vulnerabilities	General adaptation strategy	Specific management option (example)	Key climate-smart design considerations
Conservation target: Central Flyway feeding habitats for migratory waterfowl **Conservation goal:** Ensure appropriate Central Flyway feeding habitats to sustain migratory waterfowl populations **Key climate-related vulnerabilities:** • Changes in precipitation - Altered flows - Increased runoff - Eutrophication - Reduced extent and number of wetlands and lakes • Increases in temperature - Species distribution shifts - Asynchronous phenological changes and shifts in resource availability	Reduce non-climate stressors	Work with farmers to reduce agricultural runoff into wetland feeding habitats to improve water quality, groundwater recharge, and hydrologic function	How will climate change affect runoff of non-point source pollution from agricultural lands into feeding habitats? What are the best options (e.g., riparian buffers, improved irrigation scheduling) for reducing runoff of pollutants into water bodies, and when and where should they be implemented?
	Protect key ecosystem features	Maintain disturbance regimes (e.g., controlled burns, pasture rotation, periodic flooding) to augment natural processes and mimic natural patterns	How will climate change, in combination with other human activities, alter historic disturbance regimes (e.g., distribution, frequency, area disturbed) that shape ecosystems providing feeding habitat for waterfowl? How, when and where can human-assisted practices be used to best mimic natural patterns?
	Ensure Connectivity	Conserve corridors and transitional habitats between ecosystem types through land exchanges, conservation easements and other approaches	How will climate change affect species with special connectivity needs (e.g., area-, resource-, dispersal-limited)? Where will the connectivity gaps in the landscape be, and how can priority areas be conserved to maintain transitional habitats and corridors, considering ecosystem functions and physical barriers?
	Restore Structure and Function	Restore or enhance areas that will provide essential feeding habitat and ecosystem services during ecosystem transitions under a changing climate	How will climate change affect ecosystems that have been identified as providing key food resources for migratory waterfowl under the current climate? What areas, if restored, will provide the necessary feeding habitat to sustain waterfowl species as ecosystems change, and where and when should they be restored?
	Support Evolutionary Potential	Conserve areas representing the full range of geophysical settings (e.g., bedrock geology, soils) to maximize future biodiversity	How will climate change affect the full range of habitats and associated land cover and geophysical settings that support migratory waterfowl species? What areas need to be conserved that will maintain that full range under climate change?
	Protect refugia	Identify/protect wetland habitats that will serve as refugia, i.e., where precipitation is projected to stay the same or increase	How will climate change affect wetland water levels and extent? Which wetland areas in or near feeding habitats are projected to persist or increase in size? What should the placement and size of buffer strips be to maintain/protect these areas from development?
	Relocate Organisms	Assist in the translocation of limited-dispersal species to repositioned habitats	How will climate change affect food sources such as fish and submerged aquatic vegetation, and are their dispersal capabilities sufficient for them to adjust? Which species should be moved, and to which sites according to projections of favorable future conditions (see refugia discussion above)?

Based on information from CCSP (2008b), Griffith et al. (2009), and NFWPCAP (2012).

Identifying such trade-offs in order to avoid maladaptation should be a consideration not only for maintaining current feeding sites (managing for persistence) but also when considering selecting from among a list of potential new sites/refugia (managing for change). In the case of managing for change, it is important to note that over time, migratory waterfowl are likely to have range shifts in their nesting areas and/or may not go as far in migration (or even need to migrate); and this will have implications for where to locate climate-smart efforts to restore, protect, and manage feeding habitats of the future.

8.4.4. Multi-Ecosystem Mosaic: Alligator River National Wildlife Refuge

Currently, one of the best examples of a place where managers have fully embraced the dual pathways concept of managing for both persistence and change is the Alligator River National Wildlife Refuge in North Carolina (Table 8.7) (Gregg 2010, Tucker 2010). In this refuge, which consists of bogs, freshwater and brackish marshes, and hardwood and Atlantic white cedar *(Chamaecyparis thyoides)* swamps, climate change impacts already are being seen. The refuge is experiencing greater rates of shoreline erosion, saltwater intrusion into the interior via ditches, a rising water table, some disintegration of peat soils, and more frequent inundation events. In response, managers have begun planning and implementing adaptation options for both persistence and change simultaneously, in order to preserve the extant system for as long as possible while also preparing for inevitable shifts. For the near term, in an effort to preserve refuge area for as long as possible while also adjusting to ongoing changes, the U.S. Fish and Wildlife Service and The Nature Conservancy have joined with other partners to among other things: restore natural hydrology (i.e., reduce exposure to climate-related shifts in hydrological conditions) by installing water control structures equipped with flashboard risers and tide gates to reduce the impact of saltwater intrusion (a persistence option under "protect key ecosystem features"); and plant salt-tolerant (i.e., less climate sensitive) black gum (Nyssa sylvatica) and bald cypress *(Taxodium distichum)* where land has been cleared to ensure shore stability as the shoreline transitions inland (a change option under "restore structure and function"). In the longer term, as sea-level rise reaches a threshold after which current coastal refuge land becomes permanently inundated, managers are preparing to create migration corridors (i.e., enhance adaptive capacity) through which wildlife can safely reach inland conservation areas (a change option under "ensure connectivity"). As these currently freshwater inland systems transform into brackish bog/swamp systems characteristic of the refuge today, there will be a concomitant transformation of the current refuge area to either salt marsh or open water. Therefore, to fully complete the process of managing for change, refuge managers could also develop strategies to facilitate the trajectory of state change to favor full salt marsh as a "new" component of this refuge.

8.5. Cycling Between Persistence and Change

The case studies above provide examples of adaptation options for managing along the dual pathways of persistence and change. Until recently, the conservation and management communities have mostly focused on managing for persistence, and there will continue to be a place for this focus, especially when thinking at large scales. Indeed, distinguishing between managing for persistence and change can often be scale dependent (e.g., when change is being managed at the local scale to achieve persistence at the regional scale).
At the same time, it is clear that it is becoming increasingly important to plan explicitly for change, that is, to identify and implement techniques to manage during and after unavoidable ecological shifts to facilitate and then manage a new state. Indeed, the changing nature of ecosystems through

Table 8.7. Ecosystem-mosaic example for adaptation options and climate-smart design considerations: Alligator River National Wildlife Refuge.

Target, goal, and key vulnerabilities	General adaptation strategy	Specific management option (example)	Key climate-smart design considerations
Conservation targets: Bogs, fresh/brackish marshes, hardwood and Atlantic white cedar swamps **Conservation goal:** Protect and preserve unique wetland habitat types and associated wildlife species (fish, birds, bears, wolves) **Key climate-related vulnerabilities:** • Sea-level rise - Shoreline erosion - Saltwater intrusion - Periodic inundation - Increased sediment runoff • Altered hydrology - Rising water table	Reduce non-climate stressors	(Persistence) Mitigate runoff of sediments and pollutants from surrounding croplands by preventing further losses (and/or replacing) bottomland hardwood forests	How will climate change related shifts in precipitation patterns and hydrology affect overland runoff of sediments and pollutants? In what locations should priority management of forests be focused to minimize runoff?
	Protect key ecosystem features	(Persistence) Mimic natural hydrology by installing water control structures to reduce the impact of saltwater intrusion	How will sea level rise and changes in the intensity and frequency of large storms affect coastal hydrology? What are the implications for the number, placement and viability of water control structures to mimic natural hydrology?
	Ensure Connectivity	(Change) Work with outside organizations to convert surrounding cropland to nonalluvial hardwoods .to provide corridors and habitat for wildlife	How will climate change affect the viability of nonalluvial hardwoods? What amount of hardwood habitat is needed and where should it be located to ensure sufficient corridors for migration?
	Restore Structure and Function	(Change) Restore structures for coastal soil stabilization by planting flood-tolerant tree species on cleared land	What cleared areas along the coastal edge are most impacted by erosion from sea level rise and storm surge? Which tree species (e.g., black gum, bald cypress) would be most effective as well as least sensitive to climate change?
	Support Evolutionary Potential	(Change) Acquire land to connect the nine coastal Refuges in North Carolina to protect multiple present and future coastal habitats as destinations for species	How will sea level rise shift the locations of appropriate coastal habitats? What land protections/ acquisitions and hydrologic changes will be needed to facilitate unimpeded tidal inundation?
	Protect refugia	(Change) Identify and protect a suite of potential sites within the path of connected Refuges (see above) that provide future refugia for endangered species	How will temperature, precipitation, sea level rise and resulting changes in vegetation and predator-prey relationships shift endangered species habitat along the refuge corridor? What number, location and size of sites is needed for continued provision of habitat?
	Relocate Organisms	(Change) If corridors between refuges do not yet exist/are not possible, manually transport species with limited dispersal capabilities to destination habitats	See climate-smart questions for refugia. Relocate species to appropriate locations identified/ protected.

Based on USFWS (2008a), Gregg (2010), and Tucker (2010).

time will require that management be prepared to iteratively cycle between managing for persistence and managing for change.

The shift of a wetland system from salt marsh to mangroves illustrates the concept of cycling between persistence and change (Krauss et al. 2011). The original salt marsh system initially can be managed for persistence using adaptation options that target maintenance of sediment supplies for vertical marsh buildup and implementation of rolling easements to facilitate upslope migration with sea-level rise. At some point, a combination of marsh edge erosion and sea-level rise may surpass the ability of the system to remain as salt marsh, however, with different ecological trajectories possible resulting in multiple new system states: open water, mudflats, or mangroves. In this instance, the ability of the mangroves to become established would depend on such factors as their proximity to the salt marsh, their migration capabilities, suitability of the topography left behind by the salt marsh, and how fast sea level is rising. If decision-makers considered mangroves to be the desired endpoint, compared to open water or mudflat, then managers could employ a variety of adaptation options to facilitate a successful transition to a mangrove system (e.g., planting mangrove seedlings at the onset of the transition from salt marsh). Following establishment of the new system, there would be an opportunity to return to a focus on persistence, this time for the mangrove system. Underlying this process would be a need to define new management targets (species, processes) on which managing for persistence would focus.

While managing for persistence tends to be better understood, actions on the "managing for change" side are largely experimental at this point because so little is known about the magnitude and degree of climate change and how ecosystems will respond in the future (CCSP 2009, Burkett and Davidson 2013). More research is needed on the mechanisms underlying ecosystem responses that determine their trajectories of change, as well as the factors that trigger such changes (Briske et al. 2006, CCSP 2009, Fleishman et al. 2011). Currently, this knowledge is highly variable and in many cases nonexistent. Other gaps affecting the ability to plan include whether an ecosystem transformation will be abrupt and rapid versus gradual and incremental, and whether early warning signals or indicators of an impending transition exist and provide enough advance notice to implement management actions (Groffman et al. 2006, Scheffer et al. 2009, Burkett and Davidson 2013). Finally, there are situations in which no knowledge exists about the kinds of changes that may happen in the future, in which case the only option for managers is to be prepared to react to changes after they occur.

There are some cases where regime shifts have occurred in the past and can inform subsequent management planning (Suding and Hobbs 2009) (such as coral ecosystems flipping to algal-dominated ecosystems [Hoegh-Guldberg et al. 2007]); but in other instances this information is not yet known, and it is difficult to know how to proceed. One way forward is to focus on the planning process itself, making sure that it reflects the climate-smart characteristics described in Chapter 3. Particularly important in the context of managing for change will be: (1) emphasizing management approaches that are robust in the face of uncertainty and provide benefits under a range of possible future climate changes; and (2) maintaining flexible planning processes that continuously incorporate new information and make adjustments to accommodate rapid or unexpected climatic and ecological changes (see Chapter 5). Information continues to be generated through studies of underlying mechanisms, cross-system comparisons, deliberate ecosystem manipulations, and long-term observations (Walker and Meyers 2004). Experimenting with management strategies where possible to help test and generate new information will be important.