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Considering Multiple Futures:

Scenario Planning to Address Uncertainty in Natural Resource Conservation

Cover photo: Moose in mist at Aroostook National Wildlife Refuge in Maine. Credit: Sharon Wallace

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Executive Summary

Conservation professionals face unprecedented challenges arising from changes in land use, invasive species, biodiversity, climate, and more. These changes interact in complex ways, introducing an array of uncertainties that confound natural resource decision-making. While uncertainty is not new to natural resource management, limitations in our ability to confidently predict the direction, rate, and nature of the effects of climate and other drivers of change on natural and human systems has reinforced the need for tools to cope with the associated uncertainties.

Scenario planning is one approach used to help inform natural resource management decision-making in light of uncertainties. With a long history of successful application in military strategy and land-use planning, scenario planning is particularly applicable in situations of high uncertainty and complexity. As a decision support method, it can inform a conscious approach to risk management, through the identification of strategies that are robust to uncertainty in future conditions. Applying scenario planning to a natural resource management challenge can provide insights into future trajectories that may unfold, and prepare managers to respond appropriately in the near and long term.

In this guide we present a broad synthesis of scenario planning concepts and approaches, focused on applications in natural resource management and conservation. The guide is intended to help natural resource and conservation professionals, including managers, planners, and researchers to:

- Understand the core elements of scenario planning;
- Identify situations for which scenario planning could be a valuable tool, and what distinguishes it from other decision support frameworks and methods;
- Understand the range of options for implementing scenario planning and identify approaches that fit their needs;
- Get started on their own scenario planning effort; and
- Find additional resources to support the application of a given scenario planning approach.

The guide includes numerous examples of how natural resource professionals are using scenario planning to consider the direct and interacting effects of climate change on conservation goals and actions.

Scenario Planning and its Application

Scenario planning is a comprehensive exercise that involves the development of scenarios that capture a range of plausible future conditions. That development is then followed by an assessment of the potential effects of those scenarios on a focal resource or decision, and the identification of responses under each scenario, with a focus on those that are robust across scenarios. Whereas predictions and forecasts are statements about what will happen in the future with some degree of certainty, scenarios are plausible, alternative characterizations of the future not intended to be associated with probabilities. Scenarios can be constructed as qualitative narrative storylines or quantitative expressions of future conditions, depending on the outcomes needed to achieve the goal of the planning effort. While there are a variety of ways to use scenarios in planning, this guide focuses specifically on the use of multiple future scenarios to embrace uncertainties in decision making as a means for managing risk and maintaining flexibility in current and future decisions.

Scenario planning is particularly appropriate in complex situations where uncertainties about future conditions and the effectiveness of management actions are uncontrollable and irreducible. This can be the case when elements of socio-ecological systems that provide the context for natural resource management have the potential to greatly influence decision outcomes. These elements, or drivers of change are external to the resource and beyond the direct control of managers (e.g., environmental factors, population growth and demographic changes, land use patterns, the availability of financial resources, etc.). Uncertainties that cannot be reduced within a decision timeframe because they are beyond managerial control or outside current scientific knowledge make it difficult or even impossible to develop informative predictive models. Scenario planning offers an alternative approach to considering future conditions as uncertainties and the level of complexity of a situation increases, the longer one looks into the future, and when there is a relatively low level of understanding about the issue.

Scenario planning has received increased attention as a tool to inform natural resource management decisions in light of climate change. Climate change uncertainties range from gaps in our understanding of how climate systems function; whether and how much humans reduce or increase greenhouse gas emissions; what the rate, direction and magnitude of climate changes might be; how natural and human systems may respond to those climate changes; and what will constitute effective management actions in light of those changes. There are also uncertainties surrounding how climate change will interact with other social, economic, political, and technological changes.

Scenario planning is just one method to support planning and decision making under uncertainty, and it can be used in complementary ways with other decision frameworks, methods and tools, such as adaptive management, structured decision making, and iterative risk management. It can be used to serve multiple purposes, including education and outreach, decision support, and research. While there are key steps in the process, there is no single established methodology for conducting scenario planning, or even discreet types of scenario planning approaches. It is a method that can be tailored to meet a wide variety of needs and available time, capacity, and financial resources.

Breaking Down Scenario Planning and Designing A Process

While scenario planning is a flexible decision support method, there is a standard set of elements essential to organizing and conducting a scenario planning effort. This guide groups the basic steps to scenario planning in three phases:

- Phase I: Preparation & Scoping;
- Phase II: Building & Refining Scenarios;
- Phase III: Using Scenarios.

Phase I (Preparation & Scoping) sets the stage for a scenario planning exercise, and involves four steps: identify the issue and establish a project team; articulate the purpose of using a scenario planning approach and anticipated outcomes; select or formulate a suitable approach; and complete the design and staging of the process. While generally common to most planning efforts, there are some special considerations for scenario planning. Outputs from this first phase are likely to include an improved understanding of the problem or issues to be addressed, a conceptual model of the key drivers in the focal system, a synthesis of available information, and a workplan, scoping documents, and budget. These steps and outputs help confirm that scenario planning is an appropriate approach, and provide information that feeds into the next two phases of scenario construction and application.

Phase II (Building & Refining Scenarios) distinguishes scenario planning from most other decision support methods, by seeking out and embracing uncertainties about the future. Steps include refining the scope and aim of the effort; identifying, assessing and prioritizing critical drivers; exploring and selecting scenario logics; developing scenario outlines and narratives; and evaluating scenarios. If quantitative maps or numerical simulations of the scenarios are deemed useful, this phase can also include a step to quantify the scenarios. The key outputs from this phase are scenario sets that may be represented by some combination of narratives, tables of comparative descriptions, visualizations (e.g., drawings, maps), or quantitative model outputs.

Phase III (Using Scenarios) uses the scenarios created in Phase II to support planning and decision-making. Steps include evaluating the potential implications of the scenarios for the focal resource, identifying potential actions options under each scenario, prioritizing and selecting actions for implementation, and designing monitoring and research to track changes and action effectiveness. There are a few aspects of this phase that differentiate scenario planning from many other decision-support methods. For one, the effects of future conditions on resources and the appropriateness of new and existing action options are examined for multiple scenarios, rather than the one most likely future. Scenario planning also helps explicitly articulate future decisions and their triggers, in addition to choosing some near term actions. Outputs for Phase III include summaries of scenario impacts on resources and implications for management decisions, a list of research needs and knowledge gaps, and an implementation plan which includes actions to take in the near term, a timeline for future decisions and contingencies, and a monitoring plan.

Examples of Scenario Planning in Natural Resource Management and Conservation

The guide provides 12 case studies of scenario planning for natural resource and conservation from across the United States. They represent a range of scenario planning approaches and issues. Although climate change is considered in each case study, it is often not the only driver of future scenarios. Most of these case studies represent "exploratory" exercises focused more on developing a clearer understanding of an issue and strategic-level planning than on making specific decisions. In these examples, there is widespread recognition of the role scenario planning plays in enhancing both social and institutional adaptive capacity to deal with uncertainty in general, and climate change specifically. This is arguably one of scenario planning's greatest strengths, as opportunities to increase understanding and foster creative thinking on climate change move organizations closer toward implementing climate-informed management strategies. Further application and refinement of scenario planning approaches in conservation and natural resource management is warranted given the challenges represented by climate change and its interaction with other stressors.

General Principles and Benefits of Scenario Planning

- Scenario planning is appropriate to use in situations of high uncertainty and low controllability, to examine different future trajectories and anticipate surprises
- Scenario planning explores plausible—not always the most probable--futures
    - Identifies key drivers of future change and the underlying assumptions to provide greater transparency
    - Assumes that future boundary conditions are not necessarily the same as those that currently influence a system
    - Builds awareness of multiple pathways toward the future
- Scenario planning is underpinned by strategic thinking on how decisions of today limit future options
    - Facilitates a move away from traditional single-outcome planning
    - Allows the exploration of plausible future developments of potential importance to current and future decision-making
    - Challenges thinking on current management actions
- Scenario planning is not a "one size fits all" approach; there are multiple ways to design a scenario planning exercise
    - Combines qualitative and quantitative information to describe changes to future environmental conditions
    - Synthesizes and integrates issues across sectors and scales in a common framework
    - Fosters consistency in characterizing future conditions across diverse studies, spanning different sectors, regions and scales of analysis, to enable direct inter-comparison of results
    - Provides a common logic to integrate key drivers of change, as well as their impacts and interactions
    - Outcomes may be very technical (e.g., computer simulation), as well as creative, depending on project needs
- Scenario planning facilitates participatory learning and understanding
    - Fosters improved learning and imagination
    - Can help participants collaboratively create a narrative or storyline
    - Moves away from a single dominant perspective toward acceptance of unfamiliar but valuable ideas
    - Can help create powerful stories to share with stakeholders outside of the planning process
- Scenario planning is a living process, requiring us to revisit key plausible futures to validate, replace, or remove them as we gain knowledge
    - Embeds a future-oriented perspective into organizational and individual thinking and operations

Sources: Alcamo and Henrichs 2008, Wiseman et al. 2011, Weeks et al. 2011, Settele et al. 2012

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Scenario planning or 'scenario thinking' increasingly is being applied in natural resource conservation, particularly for planning and taking action around the threats that climate change poses to natural and human systems. This guide was developed at the request of the Office of the Science Advisor to the USFWS Director to serve as a resource for its network of partners. The intent of the guide is to describe what scenario planning is, why a group might undertake a scenario planning effort, and the range of approaches for scenario planning.

The guide is the product of the authors, the core development team listed on the inside cover, and a host of other contributors who collectively improved the document content and structure throughout the project.

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In addition, we appreciate the contributions of those who authored case studies in Section 3 of the guide. The case studies represent a broad range of approaches for applying scenario planning in conservation, which could not be effectively illustrated in any other way. We greatly appreciate the efforts of the following individuals for allowing us to present their work and serving as lead authors on the summaries: Juan Carlos Vargas Moreno (GeoAdpative), Robert Winfree (National Park Service), Don Weeks (National Park Service), Koren Nydick (National Park Service), Samuel D. Veloz (Point Blue Conservation Science), Kristin Byrd (U.S. Geological Survey), Michal Russo (University of Washington), Amanda Babson (National Park Service), Jordan M. West (Environmental Protection Agency), Kathy Fallon-Lambert (Harvard University), and Bob Glazer (Florida Fish and Wildlife Conservation Commission). We are also grateful to Scott Bischke (Mountain Works, Inc.) for his thoughtful and efficient editing of the case studies.

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Section 1

Gerri Wilson

Joe-pye weed beside Blackwater River, Canaan Valley National Wildlife Refuge, West Virginia

Scenario planning and its application

1.1 What is scenario planning and why is it helpful?

1.2 When should scenario planning be used?

1.3 How does scenario planning fit in with other decision frameworks, methods and tools?

1.4 What scenario planning approach is best suited to the situation?

1.1 What is Scenario Planning and Why is it Helpful?

Key Messages

✓ There are many ways to deal with uncertainty in conservation and management, but each has tradeoffs.
✓ Scenario planning is a comprehensive exercise involving scenario development followed by discussion of the potential effects of those scenarios and how to respond.
✓ Scenarios are possible future states of the world that represent alternative plausible conditions under different assumptions; they are not predictions or forecasts.
✓ This guide focuses on scenario planning aimed at embracing uncertainty and exploring multiple futures for managing risk.

Conservation professionals face unprecedented challenges arising from the scale of human activity and its impacts. Changes in land use, invasive species, biodiversity, and climate characterize the modern era in which human activities continue to have a dominant impact on the Earth. These changes interact in complex ways introducing an array of uncertainties that complicate decision-making about both the natural and built environments. While uncertainty has always been pertinent to natural resource management, not knowing where, how and when the effects of climate will unfold has raised awareness of the influence of uncontrollable uncertainty in decision-making. The rate and magnitude of change already observed in some systems highlight the types of issues that will continue to prevail in future natural resource management (Box 1.1). Decision makers need help accounting for these growing uncertainties as they work to plot a sustainable course into the future. Scenario planning offers that help.

Box 1.1. Climate Change Effects on Natural Resources

The emerging and future impacts of climate change on biophysical and social systems add additional layers of complexity and uncertainty to the conservation and management of natural resources. The rate and magnitude of change already observed in some systems highlight the types of issues that will continue to prevail in natural resource management into the future:

- In parts of northern Minnesota, moose are in decline due to a series of very mild winters, an associated increase in ticks, other parasites and invasive pathogens, and heat stress related to the timing of spring coat shed.[1] The state wildlife agency faces questions such as: Should we close the moose-hunting season? How should we manage deer in light of their supposed role in predisposing moose to disease and parasites? How much funding should we put toward better understanding the factors underlying the moose decline?[2];
- Wolves of Isle Royale National Park are moving toward extirpation. Moose, their primary prey, are shrinking in number (see above), and the winter ice bridges that helped supplement the wolves' genetic pool and numbers are increasingly rare because of warmer winter temperatures.[3] The National Park Service must now decide whether and how to actively manage moose-wolf interactions.;
- Several National Wildlife Refuges along the North Carolina coast are being significantly altered by increased shoreline erosion, saltwater intrusion, a rising water table and rapid habitat changes associated with climate change. Adaptation actions including restoration of the area's natural water flow by plugging ditches and installing water control structures, planting native marsh grasses and trees to increase the coverage of flood-tolerant vegetation, and the creation of oyster reefs to increase shell-bottom habitat. These actions have been initiated at the Alligator River National Wildlife Refuge, and are now expanding to nine other refuges in the state.[4];

Continued

Fred Yost/USFWS

Hagen's bluet

- The combined effects of extended drought, disease and other pathogens are the suspected cause of the mortality in more than 13% of Colorado's aspen forest type from the early 2000s through 2010, a phenomenon that has become known as sudden aspen decline Aspen are important to the state, offering unique wildlife habitat, a forest products industry on which some communities rely, and serve as the backdrop to the tourist industry in the western part of the state.[5] Challenges include deciding whether and how aspen stands should be managed given the impacts.[6]

[1] *http://www.eenews.net/climatewire/2012/05/18/1*
[2] *http://www.dnr.state.mn.us/moose/index.html*
[3] *http://www.startribune.com/local/150255485.html*
[4] *http://www.fws.gov/alligatorriver/news/2011%20News/news-ClimateChange1.html*
[5] *http://www.smithsonianmag.com/science-nature/whats-killing-the-aspen-93130832/?page=2*
[6] *http://www.fs.fed.us/wildflowers/communities/aspen/managing.shtml*

Importance of incorporating uncertainty into natural resource management

Uncertainties are inherent to nearly all planning and decision-making around environmental issues of varying levels of complexity (Gregory et al. 2012). There are many ways to incorporate uncertainty into conservation and management, but each has tradeoffs:

Wait for more certainty before taking action ("staying the course"). Managers may miss opportunities to minimize risk or harm, or to take advantage of opportunities.

Proceed as though there were no uncertainty. Managers may be caught off guard when the single anticipated future on which they based their decisions fails to materialize.

Frame the problem as a lack of information rather than as one of making a good decision in the face of uncertainty. This can lead to "analysis paralysis" whereby the process remains stalled trying to increase understanding, rather than advancing actions.

Focus on better-understood problems, where uncertainty seems more manageable. Singular focus on what is most certain may shift attention away from the impacts or problems that ultimately matter most.

Understand and work with uncertainty within the problem or decision context. Although this may be an uncomfortable approach and does not provide a guarantee of achieving a desired outcome, it does build capacity for the type of flexible thinking an uncertain future demands. There are several methods, including scenario planning, that support this approach.

All of these approaches to uncertainty entail risk in both taking and not taking action; while merely ignoring uncertainty can increase the chances of "getting the future wrong" (Schwartz 1991) in non-stationary systems. The risk preferences of decision makers and their affiliate institutions play a fundamental role in the handling of uncertainty in decisions. Explicitly considering the effects of drivers that are not controllable and introduce irreducible uncertainty (FHWA 2011, Spangenberg et al. 2012, Bengston et al. 2012) can help reduce the risks associated with unanticipated consequences (Jones 2010, NRC 2011, Gregory et al. 2012). A structured consideration of unanticipated futures can provide multiple advantages by:

- Enabling transparent articulation of risks;
- Facilitating discussion of the values placed on the consequences associated with those risks;

> *"Although science allows some level of prediction about future events, scientific understanding is not absolute and so assumptions based on science carry some level of risk."–Shearer 2005*

- Delineating clearly between scientific uncertainty and the values associated with those consequences. This supports selection of a course of action that is most likely to achieve decided upon objectives and aligns most closely with the associated value structure; and
- Allowing for identification of alternatives that may avoid certain risks, reduce the probability of their occurrence, reduce any negative consequences, or otherwise strategically consider options given what is known about the risk and consequences.

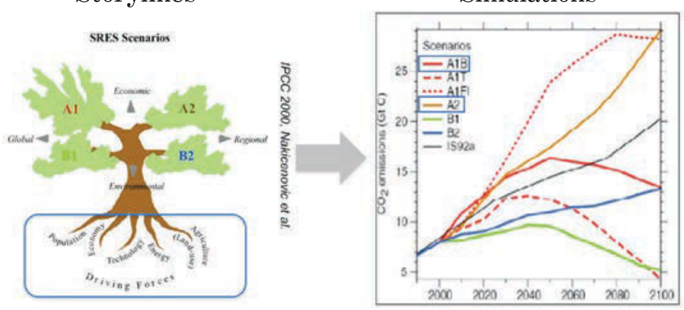
Scenario planning as a tool for dealing with uncertainty

Scenario planning is one decision support method that can help address uncertainties in natural resource management, including those associated with climate change (Peterson et al. 2003a, Dessai and van der Sluijs 2007, Alcamo and Henrichs 2008, Moss et al. 2011, Weeks et al. 2011, Price and Isaac 2012, Parris et al. 2012). With a long history of application in military and corporate business strategy and land use planning (Box 1.2), scenario planning is particularly applicable in situations of high uncertainty and complexity. It is a comprehensive exercise that involves scenario development followed by discussion of the potential effects of those scenarios and how to respond (Peterson et al. 2003a, Bishop et al. 2007, Mahmoud et al. 2009, Wiseman et al. 2011). The process is flexible but with a structure defined by three broad phases—Preparation & Scoping, Developing & Refining Scenarios, and Using Scenarios—each with several key steps (Figure 1.1). Although much of scenario planning is similar to elements of other decision support methods, it is distinguished by the explicit development of scenarios built around critical uncertainties. While scenario planning is not necessarily the best method at all times, it is especially relevant to consider when uncertain climate change effects will influence long-term policy and investment choices (Wiseman et al. 2011).

Box 1.2. A Brief History of Scenario Planning

The use of scenario planning in decision-making has a fairly long history (Alcamo and Henrichs 2008, Mietzner and Reger 2005). Its formal application for strategy development began with the military during World War II. The success of scenario planning in this context led to its rapid adoption by the business sector through the 1960s-1970s, most notably by Royal Dutch Shell during the oil crisis (Schwartz 1991). Scenario planning has also experienced broad application in land use planning and environmental assessment (e.g., Millennium Ecosystem Assessment) since the 1990s and earlier (MA 2003, Nassauer and Cory 2004, Peterson et al. 2003a, Wollenberg et al. 2000). More recently, the U.S. Federal Highway Administration integrated scenario planning into its traditional planning approach (FHWA 2011), and the National Park Service is applying it as part of its climate change response strategy (Weeks et al. 2011). Scenarios, themselves, have evolved through this period of formal usage, from a 1960s emphasis on predictions based on stable trends, to a shift toward coping with irreducible uncertainty in the 1970s-1980s, to a focus on broad participation and shared decision-making (Wollenberg et al. 2000). From a climate change perspective, the most widely recognized scenario exercise is the development of the greenhouse gas emission scenarios (also called the "Special Report on Emission Scenarios") (Nakicenovic et al. 2000) that underpin the projections of the Global Circulation Models published in the IPCC 4th Assessment (IPCC 2007). This is an example of the "storyline and simulation" approach to scenario planning (Moss et al. 2010), which builds quantitative representations of qualitative narratives.

"Storylines" "Simulations"



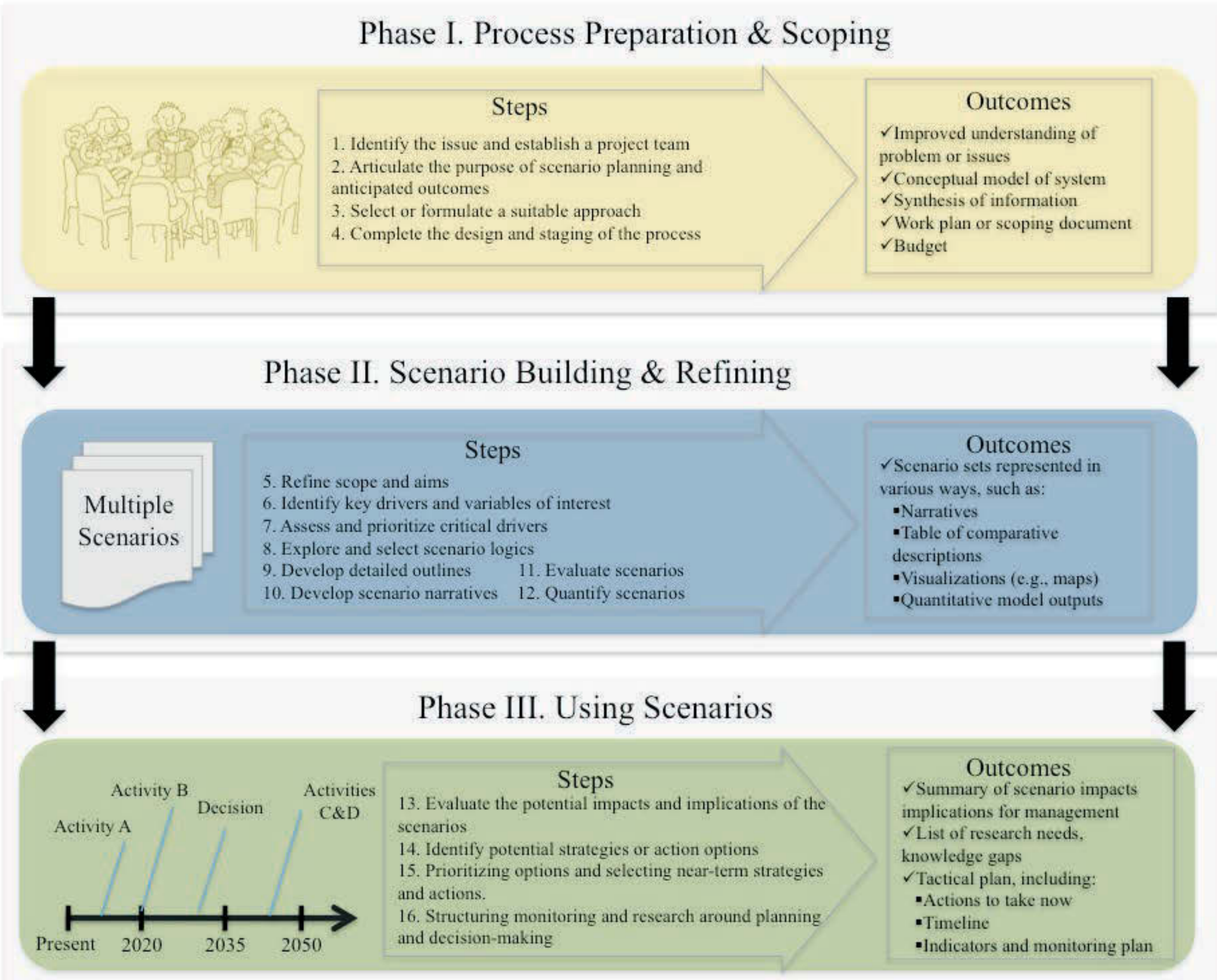


Figure 1.1. Three phases in the scenario planning process (modified from Wiseman et al. 2011 and others). More detail about the phases, the steps within each phase, and outputs for each phase can be found in Section 2.

Scenarios are possible future states of the world that represent alternative plausible conditions under different assumptions (Mahmoud et al. 2009). From a starting point of today, the future has the potential to follow several plausible trajectories that result in different conditions. The potential diversity of future states broadens as one moves farther away from the present (Figure 1.2). Scenarios attempt to capture this diversity linked to systems characterized by high levels of complexity and uncertainty, making them distinct from predictions and forecasts of the future (Figure 1.3). In keeping with this, they are not intended to be associated with probabilities of occurrence (e.g., Liu et al. 2008, Moss et al. 2011, but see Groves and Lempert 2007; see also Box 1.3). In some planning situations, improbable scenarios that represent low probability events that have high impacts (also known as "wild cards") are intentionally developed to broaden and challenge managers' perspectives on an issue (Schwartz and Ogilvy 1998, Perrottet 1998). Scenario planning allows practitioners to bring diverse kinds of information to bear on a complex problem in a transparent way (Thompson et al. 2012). The scenarios describe the "who, what, where, when and why" and provide specifics about how change might occur, in addition to the conditions that result. The pathways toward the different futures can reveal important implications for decision-makers (Shearer 2005).

> *"A scenario is a coherent, internally consistent and plausible description of a possible future state of then world. It is not a forecast; rather, each scenario is one alternative image of how the future can unfold." –IPCC 2007*

Box 1.3. Sorting Out Scenario Planning Terminology

'Scenario planning' and 'scenario analysis' (also 'scenario studies,' see Thompson et al. 2012 and 'scenario exercises,' see Alcamo and Henrichs 2008) are often used interchangeably in the literature (e.g., Bohensky et al. 2011). Some distinguish scenario planning as taking a more qualitative approach to understanding impacts and developing responses and scenario analysis as being defined by using quantitative methods and tools to represent potential futures and assess their impacts on resources. The perspective of others is that the quantifications of futures with no description of the pathways toward them and the assumptions underlying model outputs fall outside the realm of scenario planning altogether (Peterson et al. 2003a, Zhu et al. 2011). Mahmoud et al. (2009) refer to scenario analysis as the second step in a comprehensive scenario-planning framework that includes scenario narrative construction and scenario assessment. There is currently no consensus on the difference between scenario planning and scenario analysis. Because, this guide is aimed at using scenarios in adaptation planning and decision-making, we will use the term scenario planning when referring to the comprehensive process in which scenarios, qualitative and/or quantitative, are constructed to addresses a specific question or issue and strategy, and applied in various ways to generate action options (Morrison and Wilson 1997).

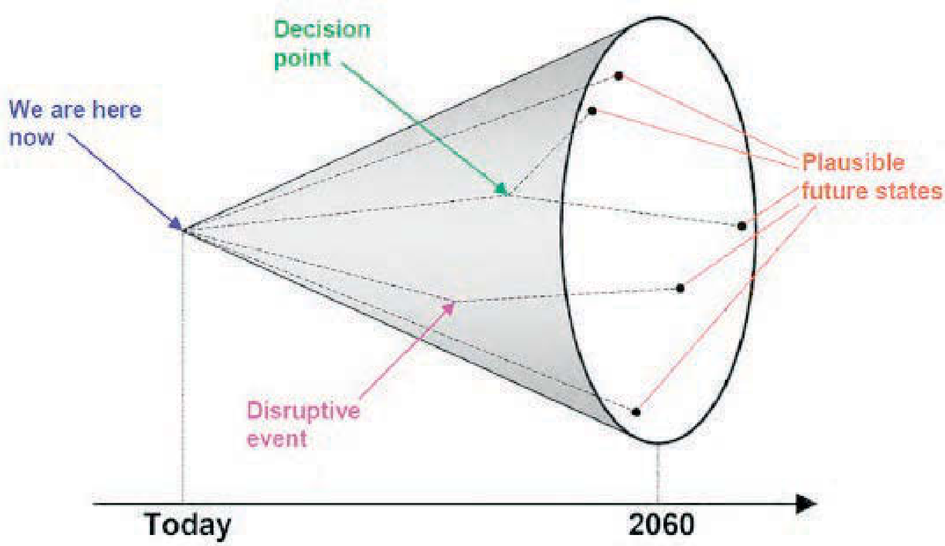


Figure 1.2. Conceptual diagram of the broadening range of plausible alternative futures as one moves farther away from the present and different events and decision points shift trajectories. (From BOR 2012, adapted from Timpe and Scheepers 2003).

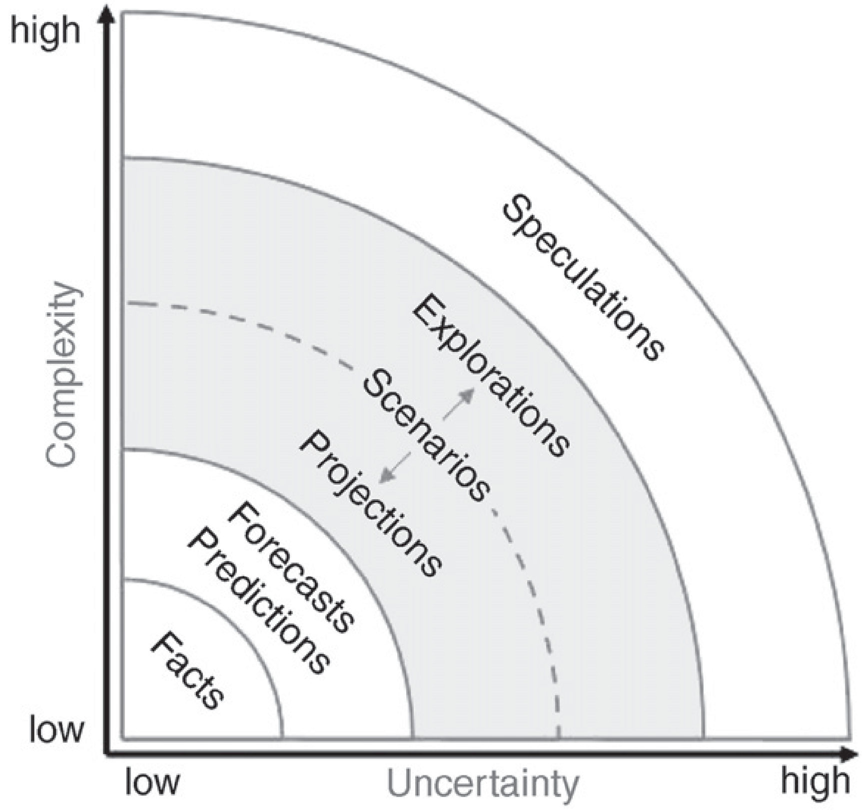


Figure 1.3. The levels of uncertainty and complexity in situations for which scenarios can be useful in comparison with other methods and tools for considering future possibilities (from Zurek and Henrichs 2007). Reprinted from Technological Forecasting and Social Change, Vol. 74, M. B. Zurek and T. Henrichs, Linking scenarios across geographic scales in international environmental assessments, pp. 1282-1295, 2007, with permission from Elsevier.

The use of scenarios in planning can help practitioners select actions that are robust across multiple, potentially divergent futures (Lempert et al. 2004). It can foster understanding of the near-term risks of taking particular actions should one or another future unfold. At the least, it can raise awareness about potential effects that otherwise may have been unforeseen. Scenario planning can also proactively identify decisions that may need to be addressed in the future. Coupling scenario planning with targeted monitoring can provide information on which trajectory is playing out, which further prepares managers to respond appropriately (Duinker and Greig 2007, Weeks et al. 2011).

"Many scenario practitioners argue that the main value of scenarios is in helping us to move away from the "one future" mentality and expose the inherent and sometimes irrational assumptions that lie behind our vision of the future."— Braithwaite 2010

As summarized by Wiseman et al. (2011) and others, scenario planning guides participants to:

- Develop an understanding of a set of plausible futures;
- Identify the uncertainties, vulnerabilities and risks to important resources under each of these futures;
- Consider strategies and actions to implement now and as the future unfolds; and,
- Examine how strategies and actions might fare in the face of many different potential changes.

"Managing rather than reducing uncertainty is particularly pertinent to climate change, where the rising complexity involved means a large part of the uncertainty about specific manifestations of climate change impacts is irreducible."—Wiseman et al. 2011

Scenario-planning approaches have been characterized in many ways (e.g., Borjeson et al. 2006, Wilkinson and Eidinow 2008). Here we distinguish three types of scenario planning based on the way they deal with uncertainties. First, scenarios may be used to characterize uncertainty. For example, climate change impacts to a system can be explored using multiple climate model projections in a research rather than planning setting, such as through sensitivity analysis (e.g., Iverson and Prasaad 2002, Williams et al. 2009, Wilsey et al. 2013). Second, scenarios can be used to reduce uncertainty in participatory exercises often aimed at identifying common values and a vision for the future of a place or an organization (Nassauer and Corry 2004, FWHA 2011, Andreescu et al. 2013). Lastly, scenarios can embrace and incorporate uncertainty in ways that enable flexibility in current and future decisions (Hartmann 2013).

This guide focuses on scenario planning efforts that are aimed at embracing uncertainty and exploring multiple futures as a means for managing risk (NRC 2011). Specific purposes for incorporating this kind of a scenario-planning approach into planning or decision-making might include (see Section 1.4):

- Broadening perspectives on problem or decision framing, refining goals and objectives, and considering who should participate in the process;
- Brainstorming about strategy or management options with respect to multiple futures;
- Evaluating the consequences of the alternatives under different future conditions;
- Laying out future decisions and the indicators and triggers for addressing them.

Applying scenario planning in a way that embraces key uncertainties that are either irreducible or irresolvable within the decision timeframe (see Section 1.2) may be most appropriate for climate and other drivers of system change. Exploring the effects of multiple future conditions can help pinpoint choices that can foster "success" across a diversity of futures. For some users, the combination of the explicit discussions of drivers of change, their relationships to system variables, and the assumptions underlying their understanding, provide greater transparency to a problem than output from models alone (e.g., Price and Isaac 2012).

USFWS

Snow geese

1.2 When Should Scenario Planning be Used?

Key Messages

- ✓ Complex systems influenced by external drivers that cannot be easily controlled are subject to significant uncertainties.
- ✓ There are different levels of uncertainty arising from diverse sources.
- ✓ Scenario planning is most appropriate when complexity is high, and one or more key uncertainties are uncontrollable and/or irreducible.
- ✓ Scenario planning can be useful for planning for the effects of climate change.

Natural resource management takes place in the context of complex, coupled human-natural, or socio-ecological, systems (Schoemaker 1993, Peterson et al. 2003a, Zurek and Henrichs 2007). There are many components of these systems that influence natural resources and management decisions (Figure 1.4), including environmental factors, future population growth, planning and development patterns, and financial resources available for conservation (Table 1.1). Sometimes these factors are : 1) external to the system, 2) operating at multiple scales, 3) difficult to predict, and 4) difficult to control (Zurek and Henrichs 2007, Walker et al. 2012). Complex systems with external drivers that are beyond direct control by managers can lead to significant uncertainties about future conditions and the effectiveness of management actions. It is in these situations where uncertainties are irreducible by their nature, or at least within the decision timeframe, that scenario planning can play a role in helping planners and decision-makers envision and prepare for the future. Therefore, understanding which uncertainties are relevant to a particular management situation, as well as their sources and magnitude (i.e., level), is important for determining whether or not scenario planning may be an appropriate or useful approach (Walker et al. 2003, Refsgaard et al. 2007, Williams and Brown 2012).

"....scenarios steer us on a middle course between a misguided reliance on prediction and a despairing belief that we can do nothing to envision the future and therefore cannot shape our future."—Morrison and Wilson 1997

Figure 1.4. Scenarios are typically built around external drivers that influence natural resource planning and decision-making. The arrow indicates that external forces beyond managerial control affect the system and are important considerations (modified from Lindgren and Banhold 2003).

Table 1.1. Broad categories of drivers of change and specific examples of each that represent the sources of uncertainty on which scenarios are based (adapted from McKenzie et al. 2012).

Category	Drivers
Environmental	Climate change Air and water pollution Invasive non-native species Environmental policy Fragmentation
Economic	Economic growth Commondity prices Demand and consumption patterns Income and distribution Market development Macroeconomic policy
Political	Land-use plans, zoning, management Governance Property rights and land tenure
Social & Demographic	Population growth/decline Migration Cultural values Education Religious values
Technological	Technological innovation Technology choice

Examples of Climate-Related Drivers
Frequency & magnitude of drought, flooding
Changes in seasonal patterns of rain & snow
Sea-level rise
Storm-surge, erosion & washover
Frequency of fire

Levels of uncertainties, controllability and their relevance to decisions

In some cases, the level of uncertainty about the future trajectory for a management target may be relatively low, the relevant system can be reasonably modeled, and the system response estimated within a high-to-low range with some confidence (Figure 1.5, Level 1). This situation might apply to a decision about the amount of fertilizer to apply to an agricultural crop, in which the crop's responses to different levels of fertilizer in a given soil condition and climate regime are well characterized. In other situations, there may be a moderate level of uncertainty related to the scientific understanding of the system and response of a resource to particular management interventions, but enough is known about the direction of change to put some bounds on the outcomes (Figure 1.5, Level 2). External drivers have the potential to exert little influence either because the decision timeframe is short or the problem addressed is narrowly scoped so that little to no change is anticipated to the decision or planning context. Efforts to control the spread of invasive buffelgrass that threatens the Sonoran desert ecosystem in southeastern Arizona offers one example (Frid et al. 2013). With limited resources available to control buffelgrass spread, managers needed to apply a control method that would be most effective at eradicating the buffelgrass threat, however little was known about the relative efficacy of the control options. In this case a modeling approach was applied to examine the potential response of buffelgrass to the different management options.

Climate change and other drivers that are external to the system and outside the control of management introduce a level of uncertainty that is irreducible (Box 1.4), at least in the near term, and typically with long-term consequences. Such situations can arise when drivers influencing the target resource are interacting in complex ways at multiple scales, when decision-makers have little or no empirical information, or when the unpredictable choices and actions of humans may significantly affect the resource (van der Sluijs 2002, Shearer 2005, Groves and Lempert 2007, Settele et al. 2012, Bengston et al. 2012). With uncertainty at this high level, it can be nearly impossible to envision a single, or even bounded, future with confidence (Figure 1.5, Levels 3 and 4). This is especially true when the direction of change is unknown, or the net effect of interacting drivers is unclear. For example, there is evidence that air temperatures are warming and permafrost is melting in the Arctic as a result of climate change. However, it is unclear whether the net effect of these two changes will cause an increase or decrease in soil moisture.

Box 1.4. Along a Gradient from Irreducible to Reducible Uncertainty

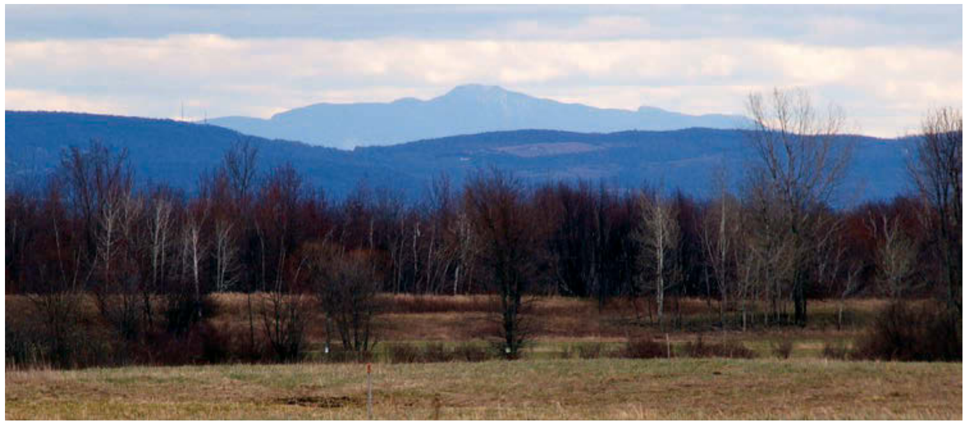
Some uncertainties are virtually impossible to reduce. For example, little progress has been made in the technologies for predicting volcanoes and earthquakes (and associated tsunamis and other impacts). In these cases, decision-makers simply have to accept the near-complete uncertainty and move forward, using approaches such as scenario planning.

Some uncertainties have been significantly reduced, such as the influence of atmospheric greenhouse gases on average global temperature. However, further reductions are likely to be fairly small or to take a lot of effort relative to the gain in certainty. In these cases, further reducing uncertainty may only be worthwhile if the value to making decisions is high.

Some uncertainties may still be further reduced, such as the influence of atmospheric greenhouse gases on precipitation patterns. In these cases, further measurement, modeling, or experimentation may improve the level of certainty. As in the previous case, decision-makers should weigh the cost of further reducing uncertainty against the benefits of doing so. ‘Value of information analysis’ is one way to weigh those costs and benefits (Moore and Runge 2012).

Even potentially reducible uncertainties may be *essentially* irreducible if they cannot be resolved during the window of time when a decision is being made.

In addition to assessing the level of uncertainty, it is also important to understand the relevance of a particular source of uncertainty to the decision at hand, since not all uncertainties are equally important. For example, consider the effect of springtime stream flow rates on a series of management decisions. Uncertainty around peak springtime flow rates in stream network may be critically important for decisions about road design or culvert size; but less relevant for decisions about what plants to use for riparian restoration projects, and largely irrelevant for decisions about deer management strategies.



Ken Sturm/USFWS

Mount Mansfield, Vermont

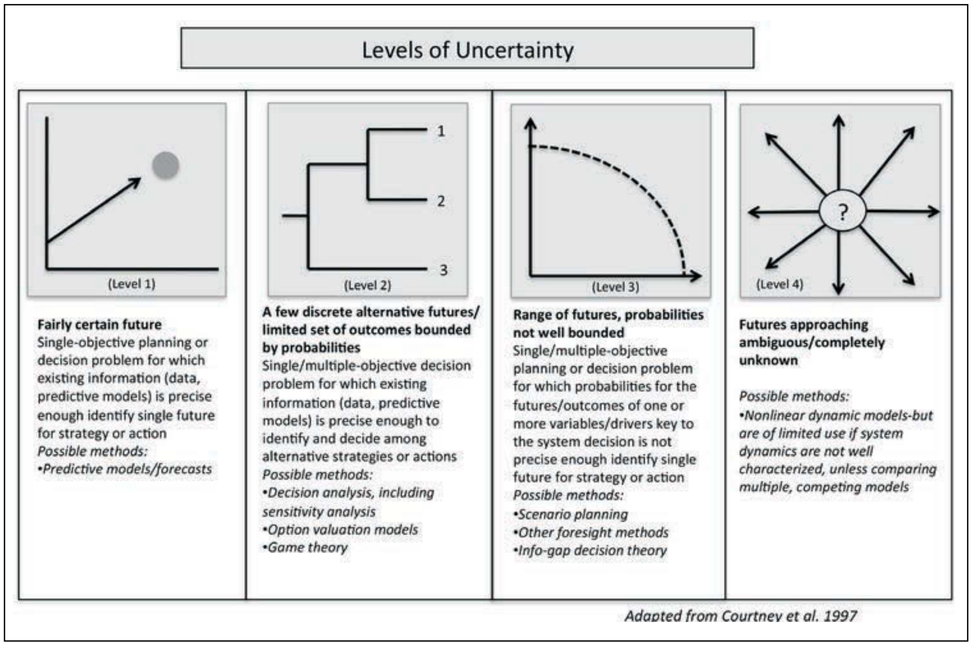


Figure 1.5. Levels of uncertainty and methods suggested for dealing with them in decision-making and planning.

Determining the appropriateness of scenario planning

Prediction and forecast methods for envisioning the future may be appropriate when drivers are relatively straightforward and controllable, and uncertainties are relatively low (Peterson et al. 2003a; Figure 1.5, Level 1). In the case where the uncertainty linked to within-system variables is high but system change can be manipulated, hypotheses and management alternatives might be developed and tested in an adaptive management framework (Williams and Brown 2012; Figure 1.5, Level 2).

In cases of high, irreducible uncertainties that cannot be controlled through management choices, practitioners typically do not know enough about system relationships and associated drivers of change to develop helpful predictive models (Figure 1.5, Levels 3 and 4). And, similarly, while probabilities can be assigned to potential outcomes, their distributions are typically too broad to effectively support decision-making. It is in these situations that scenario planning can play a valuable role in thinking about and embracing uncertainties about future conditions, and what they may mean for making near- and long-term management decisions. Explicitly identifying the relevance and level of uncertainties to the problem can help clarify whether scenario planning might improve the decision-making process. Some find that using a conceptual model or similar systems thinking approach helps sort out the number and relationships of key drivers, and their associated sources of uncertainty (see Sections 2.1 and 2.2).

In addition to diagnosing the sources and level of uncertainty, there are other conditions and situations that might favor scenario planning as a tool for envisioning future conditions. Figure 1.6 lays out a range of conditions under which scenario planning is likely to be appropriate. In general, scenario planning is expected to be even more useful as uncertainties and the level of complexity of a situation increase, the farther one looks into the future, and when the level of understanding about the issue is relatively low. It is also seen as particularly useful in the earlier stages of a planning or decision-making process.

Scenario planning can be challenging because the method often requires participants to move beyond empirical science and model projections (discussed further in Section 2.2). Both the attitude of leadership and the group dynamic needs to be supportive, and the planning or decision process needs to be at a point where participants are amenable to opening the discussion up to potentially widely divergent futures (Scearce et al. 2004). A group considering scenario planning should also be interested in:

- Fostering creativity;
- Enabling participants to view the system differently and uncover new insights;
- Providing new perspectives on outcomes of future actions;
- Developing triggers that align with particular scenarios and enable quick recognition of a specific trajectory and recommended action.

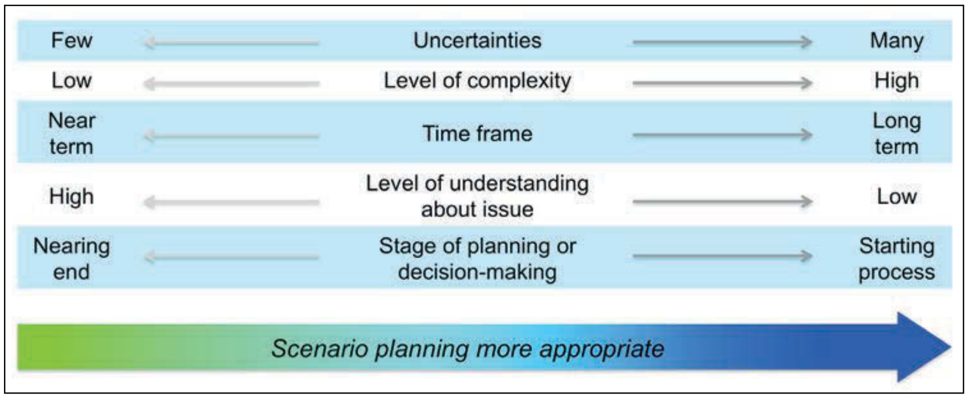


Figure 1.6. Factors to consider when deciding whether to embark on a scenario planning process (modified from Wiseman et al. 2011).

Scenario planning and preparing for the effects of climate change

Scenario planning has received increased attention as a tool to inform natural resource management decision-making in light of climate change (e.g., Glick et al. 2011, NCA 2012, National Fish, Wildlife, and Plants Climate Adaptation Strategy 2012, Parris et al. 2012). Climate change compels practitioners to consider highly unpredictable futures, often at longer time horizons than typically considered in natural resource management. For these reasons, scenario planning has and continues to be tested on resource issues for planning around climate change adaptation (Weeks et al. 2011, case studies in Section 3).

"More significantly, predicting the future conditions of the environment is complicated by the influence of human agency and the inability to forecast precisely the course of future actions."—Shearer 2005

Much of the discussion of uncertainty related to climate change centers on future climate projections: how much warmer will it get; will storms increase? Yet this is just one kind of uncertainty linked to climate change that has implications for resource management and conservation. Uncertainty about the ways that direct changes in climate will work their way through natural and human systems increases the level of uncertainty to a point where other decision support methods may not suffice in many planning contexts. There is also uncertainty about:

- How the climate system functions;
- How species or ecosystems will respond to climatic changes;
- How humans will respond to climatic or ecosystem changes;
- Whether and how much humans will reduce or increase greenhouse gas emissions;
- Whether existing or new policy, regulatory, or management actions will be effective at addressing impacts.

"When future possibilities are influenced by large but highly uncertain driving forces, a scenario approach is an appropriate tool."
—Dermawan et al. 2012

Uncertainties are not just about our knowledge of the biological and physical sciences and the limitations of models to predict them. Even when climate change is a focus of planning, the scenarios built may not always be limited to climate drivers only. They also stem from a wide range of socioeconomic, political, technological and other factors such as agency budgets, policies, social values, community preferences, human migration, institutional and policy flexibility.

There are several examples where planners have incorporated both climate and non-climate drivers in a scenario planning exercise, some of which can be found in greater detail as case studies in Section 3. For example, planners in southern Florida considered future population growth, land use planning and development patterns, and the availability of financial resources, in addition to sea level rise. These factors were combined using scenario planning to inform land acquisition priorities aimed at protecting an important coastally distributed species (Vargas-Moreno and Flaxman 2012). In a scenario planning exercise in northern Wisconsin, climate change, population shifts, invasive species and other drivers were all acknowledged as important. The scenarios constructed were organized around the societal response to these collective drivers and the sustainability of ecosystem services (Peterson et al. 2003b).

Another scenario planning effort focused on California rangelands is integrating habitat, hydrological and climate futures to examine changes to grazing lands, vegetation types, wildlife habitat, and water availability, as well as resulting economic impacts to local communities (see Case Study 3.7). In many of the National Park Service scenario planning exercises to date, scenarios based on uncertain climate futures are nested within scenarios of social and political uncertainties, and participants develop narratives around the combined scenarios of greatest concern (see Case Study 3.2).

While Wiseman et al. (2011) and others view scenario planning as an effective method for nearly all climate change adaptation efforts, it may not always be the best-suited decision support method. A scenario planning approach may not be warranted when examining the effects of a single climate change driver. It also might be inappropriate when the direction of change in a driver is known but not the magnitude, or the magnitude of change is known but not its impact on a target or variable. For example, with sea level rise, a purely research-driven investigation of how different amounts of sea level rise could impact a coastline might be more useful than scenario planning. The level of uncertainty might fall outside the realm of predictions, but still have a limited range of outcomes (what some call 'projections') (Figure 1.3). However, if there are thresholds in planning and management decisions, magnitude can be a serious concern. For example, some of the engineered adaptation options under consideration might only work up to 5 meters of sea level rise, in which case, the sea level rise scenarios might be defined in part by the threshold value of 5 meters (i.e., "under 5 meters" versus "5 meters and over"). In an example like this, different futures may need to be examined to understand how alternatives implemented in the near term might affect future options needed to address different magnitudes of change.

1.3 How does Scenario Planning fit in with Other Decision Frameworks, Methods and Tools?

Key Messages

- ✓ Scenario planning is one method to support planning and decision making under uncertainty.
- ✓ Scenario planning can be used in complementary ways with other decision frameworks, methods and tools.

Conservation practitioners can access multiple frameworks, decision support methods, and tools for planning and making decisions around complex and uncertain problems. There are several published reviews specifically comparing decision-support methods for dealing with uncertainties (Courtney et al. 1997, Dessai and van der Sluijs 2007, Means et al. 2010, Malik et al. 2010, Byer et al. 2011). While different decision support methods may be particularly appropriate for a given decision, many complex problems are most effectively tackled through an integrated set of methods applied at different points in the process (e.g., Ram and Montibeller 2012, Seidl and Lexer 2013). Scenario planning is one tool in the decision-making toolkit, and can be integrated within, complement, or be applied in sequence with other decision frameworks, methods and tools.

Decision Frameworks are structured processes used to work towards a decision, or a selection between two or more options or management actions (Figure 1.7). Criteria or objectives are the basis on which options are compared, ranked and selected (Means et al. 2010). A number of decision frameworks exist, some of which are relatively generalized with a set of required elements that can be achieved via different methods (e.g., NEPA-Environmental Impact Statement process). Decision frameworks like structured decision-making (Gregory et al. 2012) and adaptive management (Williams and Brown 2012) offer greater structure in terms of the steps and inputs used to make decisions ranging from simple to complex, with one or more objectives. These and other decision frameworks are supported by a long history of decision theory. They serve to break down decisions into components for analysis and are pertinent to issues where the objectives and tradeoffs between options are fairly clear (Possingham et al. 2001, Gregory et al. 2012).

One decision framework put forth as particularly relevant to climate change is an iterative risk management framework, such as that offered by the America's Climate Choices (NRC 2011) and patterned after the UK Climate Impacts Programme framework (Willows and Connell 2003). The iterative risk management framework can incorporate multiple forms of information (i.e., qualitative and quantitative from multiple sectors), is amenable to choices based on multiple criteria, and helps identify options either robust across a range of possible futures or a series of linked actions. A commitment by the decision-making institution to assess and revise choices as new information is put forth is a key aspect of this framework (NRC 2011).

Decision Support Methods provide input to decision frameworks by developing, bringing together, and presenting information from multiple sources in a transparent, structured and defensible way. That information can then help identify action options or apply decision criteria to determine which actions to implement (Figure 1.7). Scenario planning is generally considered a decision support method, along with expert elicitation, agent-based models, sensitivity analyses, vulnerability assessments, Bayesian statistical methods, and others.

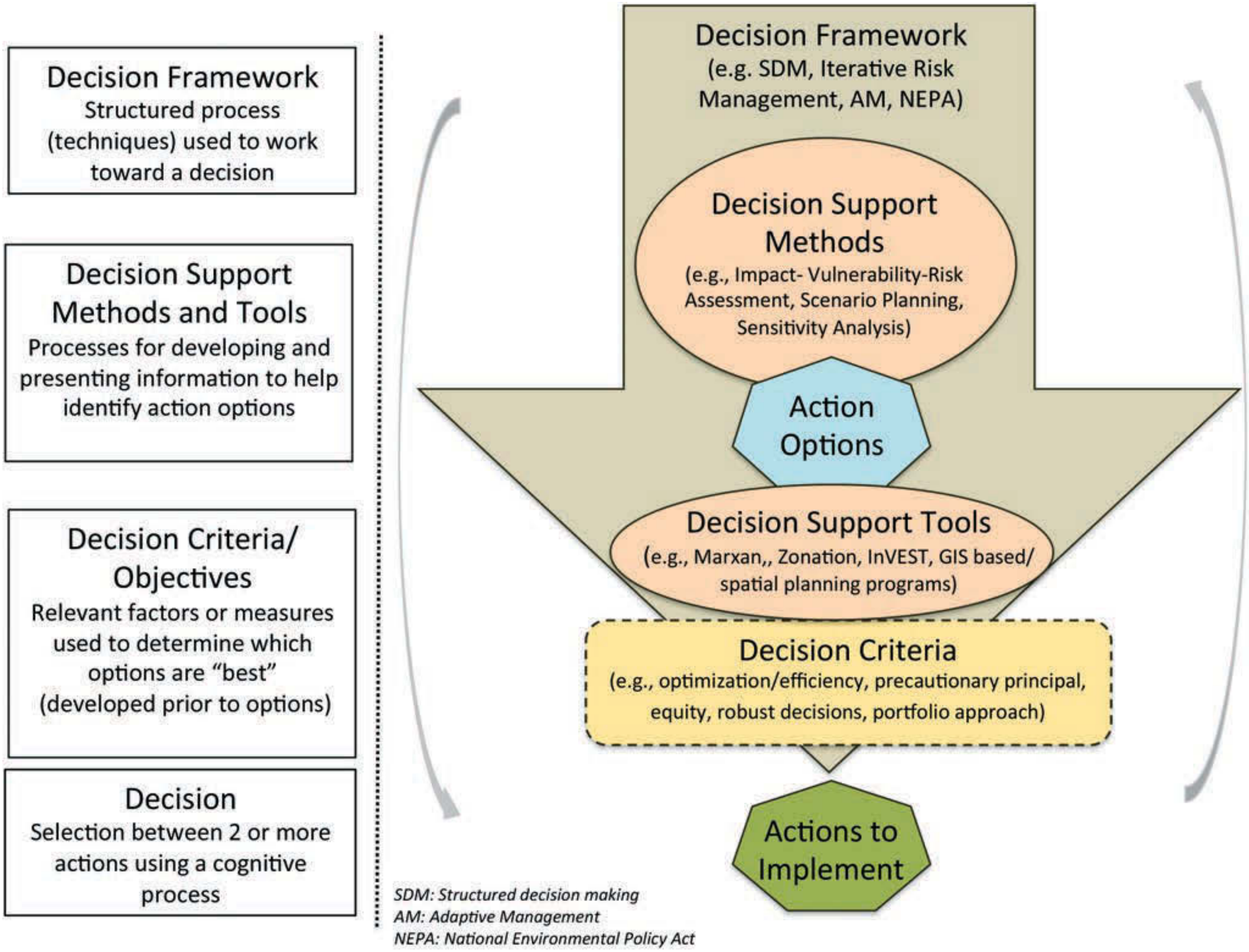


Figure 1.7. A generalized framework for linking decision support frameworks, methods, and tools, and decision criteria.

Planning and decision support tools are more specialized analytical constructs (e.g., GIS-based spatial planning programs, dynamic simulation models, state and transition models) that support data analyses and synthesize information (Bishop et al. 2007, Means et al. 2010).

The distinction among decision support frameworks, methods and tools is not universally defined, but all have a place in decision making and planning. As discussed in Section 1.2.2 selection of which to use is often driven by the level of uncertainties involved relevant to the decision context, as well as constraints associated with particular decision-making institutions and regulatory policy (e.g., Means et al. 2010, Gregory et al. 2012).

The following examples illustrate the links between frameworks, methods and tools:

1. One might use expert elicitation methods to inform parameters for a predicative model or inform probabilities in a decision tree tool, applied within a structured decision making framework.

2. An iterative risk management framework might employ a scenario planning method to identify potential options and use a spatially explicit simulation tool to visualize the potential impacts of the alternative scenarios.
3. A scenario planning method might be used to develop inputs to a decision-analysis model (tool) in order to consider irreducible uncertainty to examine the consequences of decision alternatives in an adaptive management framework.

Sheri Hagwood

Sub-alpine meadow

1.4 Which Scenario Planning Approach is Best Suited to the Situation?

Key Messages

✓ Scenario planning may be used for education, research, and decision support.
✓ Scenario planning may be used to explore possible future trajectories for a system, to consider the consequences of management alternatives, and to develop indicators of important future decision points.
✓ Scenario planning is not a "one size fits all" approach with a single, established methodology.
✓ Scenario planning can be tailored to fit a wide variety of needs and availability of resources.

Scenario planning is not a "one size fits all" approach with a single, established methodology (Wright et al. 2013). The decision support method allows for flexibility and invites creativity within some well-defined guidelines that are further discussed in Section 2. Practitioners have applied scenario planning in many ways, as evidenced by the diversity of the case studies included in Section 3. The structure of a scenario planning process depends largely on the purpose of the effort and the resources available to commit to the process (e.g., time, money, capacity, technical expertise, etc.).

For what purposes is scenario planning used?

The outputs of scenario planning are appropriate for informing the understanding, planning and acting stages that make up nearly all planning and decision-making frameworks, as well as in the context of climate change adaptation (Figure 1.8). While scenario planning does not eliminate all uncertainty, it can provide insights to determine whether or not different management options might be effective under one, several, or all alternative futures.

Alcamo and Henrichs (2008) recognize three broad purposes for scenario planning in environmental issues: 1) education and outreach, 2) science and research, and 3) decision support and strategic planning. These purposes are not mutually exclusive. Educational elements can be found in most environmental efforts, and science and research typically support decision-making and planning (Moss et al. 2010, McKenzie et al. 2012).

In some cases, the purpose of a planning effort may be largely exploratory, where scenarios are used to increase participants' understanding of potential impacts, vulnerabilities and management options under multiple plausible futures. In other cases, the purpose may be to use scenarios to inform specific decisions. While the purposes, outputs and the uncertain drivers for different efforts may require scenarios of differing content to achieve particular outcomes; often the outputs from an initial exploratory exercise can provide the framework and inputs for a subsequent decision-focused effort (Biggs et al. 2007, see Case Studies 3.4 and 3.11).

A key benefit of a scenario planning approach is that it enables the identification of important future decision points, as well as the development of indicators to recognize when decisions should be made (Tucson Water 2008, Wiseman et al. 2011, McKenzie et al. 2012). Specific applications for environmental problems include broadening perspectives on contentious issues and dealing with potentially catastrophic events, such as identifying the implications of climate change, and its interaction with other socio-economic drivers.

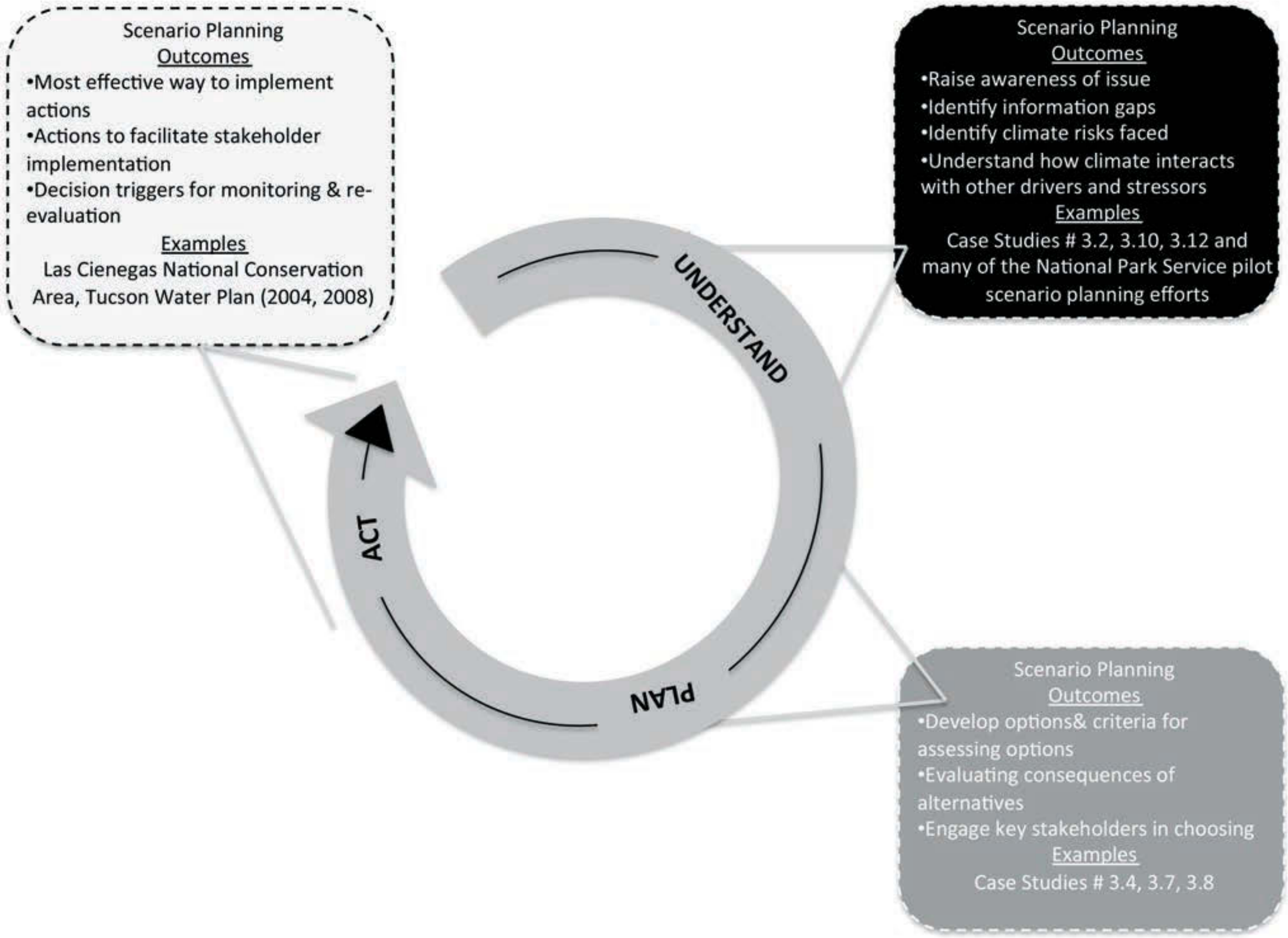


Figure 1.8. Outputs and outcomes for the use of scenario planning at different points in any planning process from a strategic habitat plan to a climate-adaptation process with natural resource examples (see Section 3 case studies and Caves et al. 2013).

How do scenario planning approaches differ and what resources are required?

Theoretically, scenario planning is most useful when it is an iterative process, offering the potential to start small and build in additional elements as needed. Scenario planning may be more effective when integrated with existing planning and decision-making frameworks, or used to broaden the perspective of participants in on-going projects (Mahmoud et al. 2009, Wright et al. 2012). For example, over the past several years a collaboration including the Bureau of Land Management, The Nature Conservancy and the Cienega Watershed Partnership has undertaken adaptive management of the Las Cienegas National Conservation Area and surrounding landscape in southeastern Arizona. The collaborative recently began applying scenario-planning approaches to its monitoring program to explore a range of potential futures at multiple scales. Its purpose is to generate indicators that help identify which trajectories of change the system is on, thereby enabling managers to adjust actions as needed (Bodner et al. 2011, Caves et al. 2013). In another example, the National Park Service has advanced some of its early pilot scenario work toward informing standard planning processes such as the Resource Stewardship Strategies created at the level of individual parks (e.g., see Case Study 3.3).

There are a range of approaches that are relevant to natural resource management and conservation:

- Partial-day "table-top" exercises are relatively quick runs through scenario planning that can provide the benefits of a more comprehensive effort without significant investment and often highlight needs (information, stakeholder involvement) and issues that can be addressed in a subsequent exercise. These may be internal to an organization or serve as a starting place for a small group of partners;
  - Example: As a precursor to the development of management alternatives for a USFWS Refuge Comprehensive Conservation Plan, a scenario planning effort was used to start conversations about the influence of the landscape outside of refuge boundaries (Granholm 2012, personal communication);
- Multi-day participatory workshops with partners and stakeholders typically require much greater investment in planning and information gathering, as well as in-meeting facilitation. Intended outcomes should be clear and agreed upon by the workshop organizers;
  - Example: The National Park Service and partners are developing and implementing participatory scenario planning workshops (2006-present) to inform climate change adaptation efforts within parks and across landscapes (Weeks et al. 2011; see also Box 1.5 and Case Studies 3.2, 3.3, 3.5, and 3.12);
- Multi-year large-landscape efforts with spatially explicit simulations are major undertakings that may begin with a "table-top" meeting and often include a series of multi-day workshops. A great deal of planning and a high level of technical capacity are essential;
  - Example: The Massachusetts Institute for Technology and US Geological Survey led a multi-year and evolving scenario planning effort in southern Florida examining multiple drivers and impacts on wildlife habitat (Vargas-Moreno and Flaxman 2012, Case Studies 3.1, 3.4, 3.8, and 3.10).

The purpose of the exercise and the number of key uncertainties being incorporated are probably the first-order considerations for defining the approach (see Section 2.2. for more details). Other common considerations include:

- Types of organizations involved and desired outcomes (i.e., ultimate goals);
- Types of desired outputs (e.g., spatial maps of impacts, ideas to inform a five-year strategic plan, high priority management actions for implementation);
- Number and types of drivers considered;
- How quantitative and spatially explicit scenario products need to be;
- Whether it is mainly expert-driven or stakeholder-driven;
- Number and diversity of participants.

As many of the case studies in Section 3 demonstrate, taking a scenario planning approach does not necessarily rule out the use of quantitative models, but rather informs how the models are developed and how outputs are applied in planning. Sometimes a combination of quantitative predictions and qualitative assessments will be needed to represent the futures, given the various levels of uncertainty that influence them. In the Bureau of Reclamation's Lower Colorado Basin study, both quantitative water supply and relatively qualitative water demand scenarios were developed to inform planning (BOR 2012). Scenario planning can blend both qualitative and quantitative inputs, and result in both quantitative and qualitative outputs. A single scenario planning effort might shift between qualitative or quantitative emphases as the process unfolds (e.g., Case Studies 3.1 and 3.4). Flexibility is a key strength of scenario planning, as focusing exclusively on quantitative scenarios may risk limiting the analysis to only those aspects of reality that readily lend themselves to quantification (Refsgaard et al. 2007, Seidl and Lexer 2013). But when a scenario planning approach is combined with other decision support methods and tools, it is important to clearly acknowledge which factors are associated with probabilities and how they have been assigned to assist in interpretation of the results of a scenario planning effort (van der Sluijs 2002).

Many factors influence the type of scenario planning approach needed for a given decision or planning situation, but using this decision support method does not necessarily require significant time and monetary resources. The resources and expertise needed to carry out a scenario planning effort will vary according to the approach chosen, and in particular on the relative emphasis on qualitative or quantitative outputs and the diversity of participation (Figure 1.9). A review of several metropolitan land use and transportation scenario-planning exercises revealed costs that ranged from $50,000 to more than $5 million (Cambridge Systematics 2009). Several of the case studies presented in Section 3 cost less than $50,000, although costs vary greatly. Many of the less expensive efforts used available information and existing models, and benefitted from voluntarily contributed time.

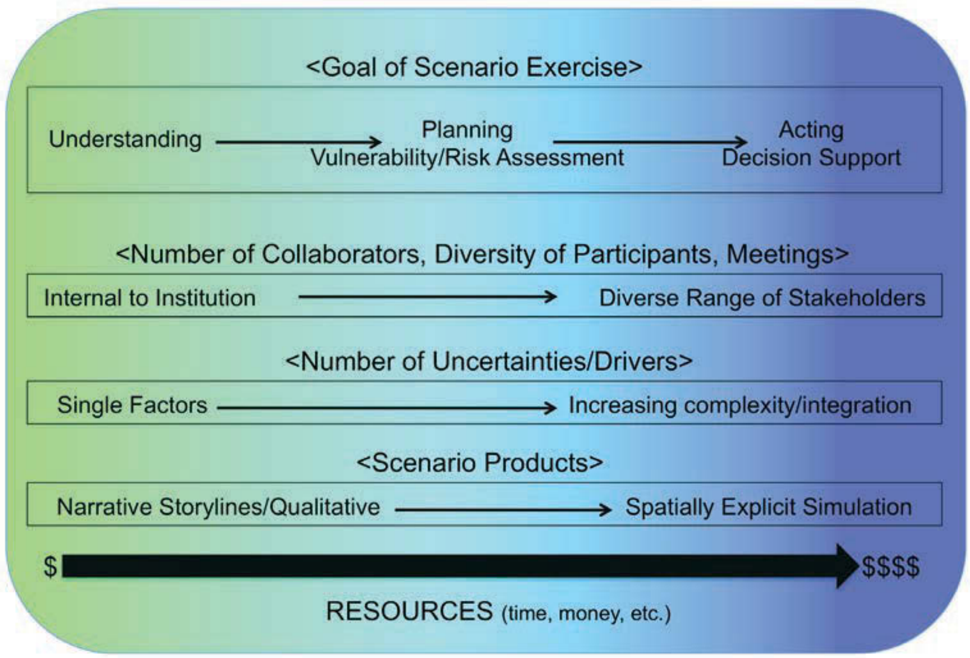


Figure 1.9. Several key factors that contribute to the resource demands of scenario planning exercises.

Box 1.5. National Park Service: participatory climate change scenario planning to inform planning and management efforts

Scenario planning is an important tool in the U.S. National Park Service (NPS) strategy for managing parks under conditions of climate uncertainty (NPS 2010). Within the NPS, scenario planning is a participatory process that engages a broad range of collaborators, including land managers from neighboring lands, climate scientists, and researchers from academic institutions. Guided by the needs and concerns of park managers, scenario planning synthesizes information and potential implications from climate change projections in a way that is relevant to the conservation of park resources and landscape values. Scenario planning in the NPS integrates quantitative, model-driven data with qualitative narratives to explore plausible futures that incorporate climate change, ecological responses, cultural resource impacts, and varying socio-political conditions (Weeks et al. 2011). The resulting scenarios represent divergent ecological, physical, social, political, and/or economic factors that define the decision environment for a given issue. The NPS and partners have been developing and implementing these techniques since 2006 for training, planning, and management decision making and have conducted 28 workshops to date, including:

Park Unit	Workshop Year	Key Insights/Outcomes
Joshua Tree National Park	2007	Initial scenario planning pilot project to develop and improve the process for National Park issues and to train managers and partners on its use and utility. Insights included changes to long-term interpretive and fire management plans
Assateague Island National Seashore	2009	Workshop identified groundwater as a potentially vulnerable resource and directly led to the initiation of a monitoring program. Scenarios were used to inform the park's General Management Plan
Southwest Alaska Network	2011	Managers prepared for key scenario components which manifest in subsequent years, including flooding from glacial meltwater and interannual climate variability (cool years). Coastal water monitoring was identified as a key need during the workshop, to assess the effects of melting ice on seawater chemistry and pH.
Catoctin Mountain Park	2012	Scenarios and climate data were directly incorporated into subsequent workshop to develop the park's Resource Stewardship Strategy
Isle Royale National Park	2013	Scenario planning is being used to help visualize plausible futures and inform the long-term efficacy of management actions within this wilderness park aimed at restoring ecosystem components directly or indirectly impacted by climate change.

Section 2


Alli Stewart

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Designing a scenario planning process

"The role of scenarios – the types of scenarios that are relevant, the methods used to develop them, the scale at which they are developed and applied – differs significantly depending on the orientation."— Wiseman et al. 2011

Scenario planning approaches can vary greatly depending on the purpose and objectives. While scenario planning is a flexible decision support method, there are some essential elements. This section of the guide outlines the steps in organizing a scenario planning effort, developing and applying scenarios to conservation resources issues, and integrating these results into decision making. Many of the steps are universal to planning, but we emphasize those aspects that set scenario planning apart from other decision support methods.

There are many variations in how the steps of scenario planning are presented in the literature. Fortunately, nearly all descriptions of the process possess common elements, which we divide into three phases (Figure 2.1):

Phase I. Preparation & Scoping (also called "Scenario Definition" in Mahmoud et al. 2009): This phase focuses on spending time at the outset to clearly identify what questions the exercise will help address, how these are related to decision and/or planning needs, and what the group is hoping to get out of the exercise (e.g., products and outcomes). It is also important to understand what information is available, who will need to be involved in the process, and whether the process will be managed in-house or by others such as outside consultants.

Phase II. Building & Refining Scenarios (also called "Scenario Construction and Analysis" in Mahmoud et al. 2009): In this phase key uncertainties are used to develop an initial set of scenario narratives, outlining the associated assumptions, translating narratives into quantitative and/or visual products (if appropriate/desired), checking scenarios for internal consistency, and revising scenarios as necessary.

Phase III. Using Scenarios (also called "Scenario Assessment and Risk Management" in Mahmoud et al. 2009): The final scenarios are now used to evaluate potential impacts on resources and implications for management, identify management options, select actions to implement, and identify future decision points and indicators for monitoring.

Revisiting the scenario planning process to update actions and indicators and timelines and to make the decisions that were intentionally delayed will be necessary as new information becomes available.

The remainder of Section 2 describes the steps within each of these phases (Figure 2.1), providing direction on how to work through each step and articulating anticipated outcomes. Project organizers may also wish to consult Wiseman et al.'s (2011) list of "best practices" for developing and using scenarios for climate change planning, which are relevant for efforts focused on a broad range of drivers (Table 2.1). Appendix 3 provides a number of useful resources for scenario planning, organized by the steps within each phase.

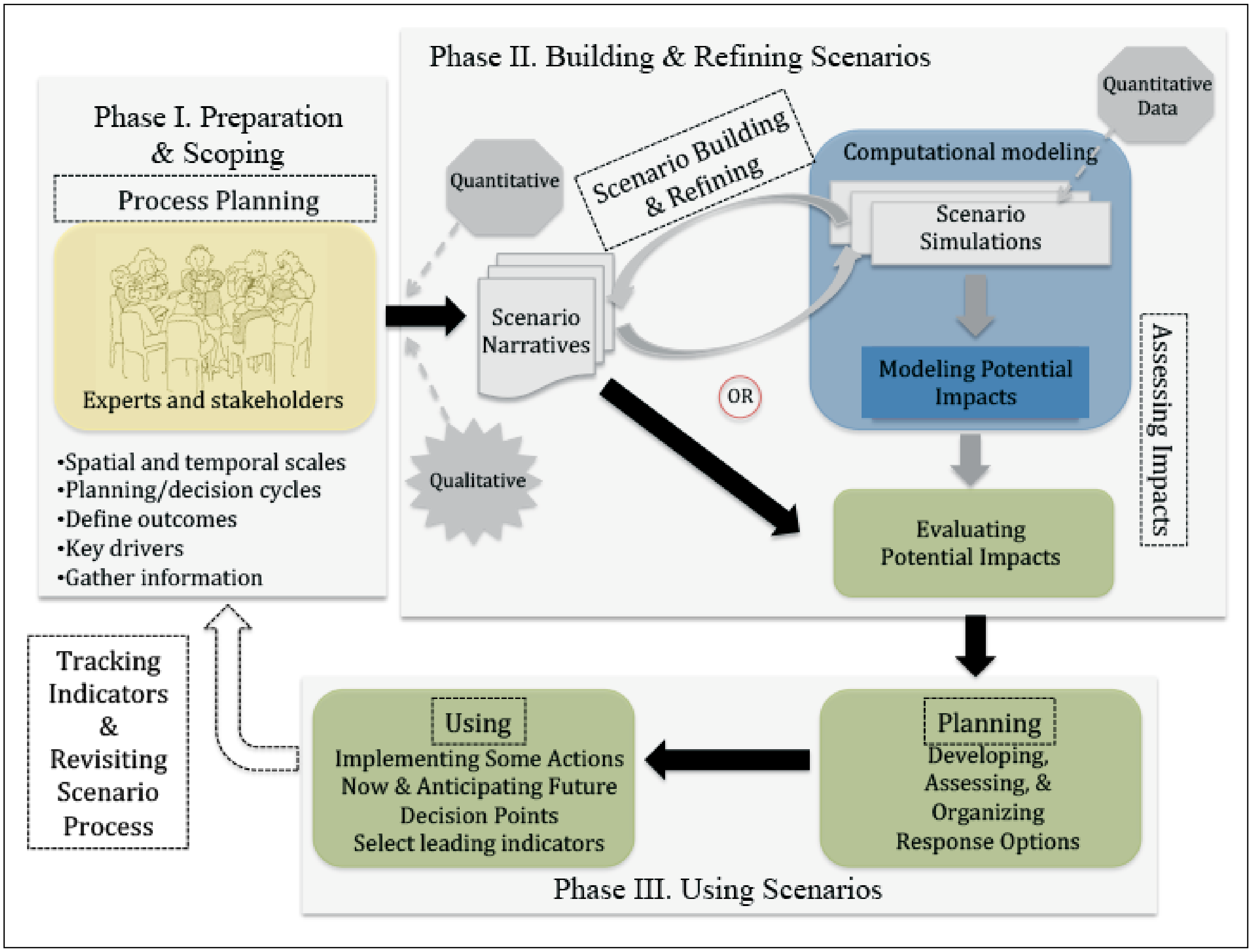


Figure 2.1. Steps in the scenario planning process (modified from Wiseman et al. 2011 and others). Although the phases are presented in a linear way, the process will not likely unfold in this manner. It may be necessary to learn as you go and revisit previous steps or even phases for the greatest effectiveness.

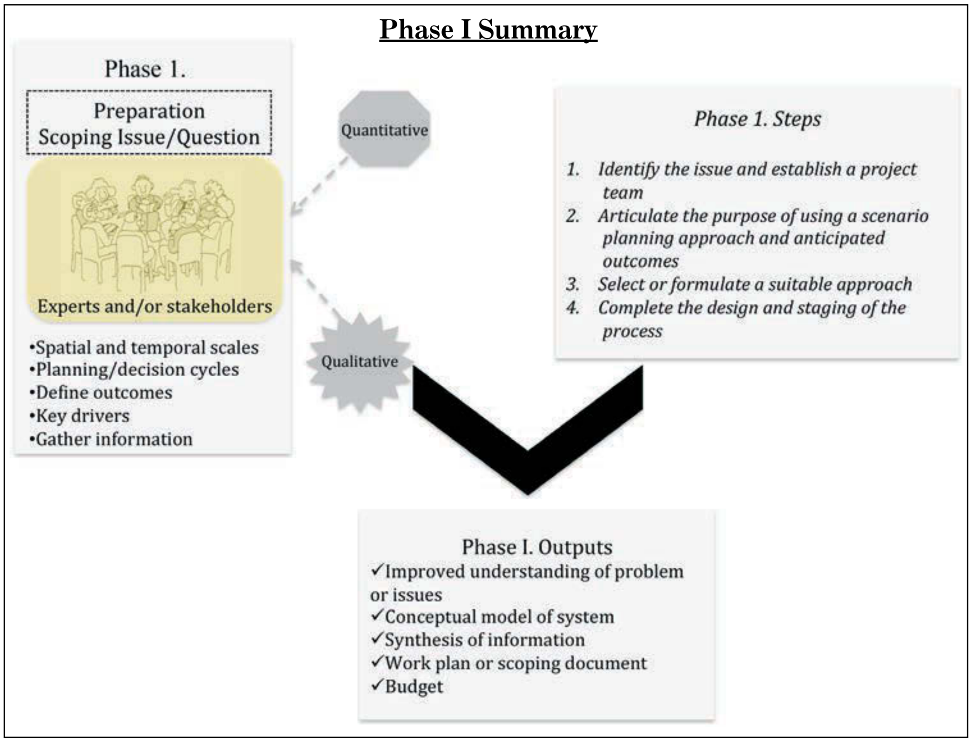
Table 2.1. "Best practices" for applying scenario planning to climate adaptation planning (from Wiseman et al. 2011).

1. Clear, shared framing of the climate change challenges and aims;
2. Clear, shared understanding of the strengths and limitations of scenario planning;
3. Clear, shared understanding of the primary goals of the specific scenario-planning process;
4. High-level support for the scenario planning process from key internal and external stakeholders and champions;
5. Time and resources invested in planning, preparing, and ensuring the right mix of skills and knowledge;
6. Broad range of relevant experience, expertise and evidence;
7. Identification and consideration of the full range of plausible drivers and pathways deliberately encouraged;
8. Scenarios sharply defined and capable of effective communication to key audiences;
9. Careful consideration of ways in which the outcomes of scenario planning process are to be integrated with strategic planning and decision-making;
10. Scenario planning embedded as an ongoing driver of organizational culture and decision-making.


Jim Mogen

Red Rock

2.1 Phase I: Preparation & Scoping



Project scoping defines how broadly or narrowly the issue is to be addressed and the types of scenarios needed. It can be challenging to effectively align a scenario planning approach with the purpose and objectives of the effort. Developing a clear problem frame and identifying the system drivers relevant to the issue set the scope and assist the choice of approach (see Table 2.2). This phase can be completed rapidly or in a more formal and detailed manner, depending on the nature of the effort envisioned. For example, a single-day exercise aimed at developing a clearer understanding of the issue may not require as much advance preparation as would a more complex, multi-stakeholder process with spatially explicit scenario simulations. If the scenario planning exercise is being integrated into an existing decision-making or planning process, much of the scoping work may have been previously completed.

The steps detailed below need not be tackled individually, but rather represent a breakdown of Phase I to ensure that the essential factors are included. There are several elements in particular that can be keys to the success of a scenario planning exercise (Wiseman et al. 2011):

- Clarity of purpose and objectives;
- Supportive organization culture;
- Existence of detailed, context-specific data;
- Effective engagement of relevant stakeholders;
- Optimized diversity of expertise and experience of participants;
- Skilled scenario planning facilitators.

The table below, taken from Wiseman et al. (2011), encapsulates most of the considerations critical to several of the steps in Phase I (Table 2.2).

Table 2.2. Key considerations for the preparation and scoping phase of a scenario planning exercise, with a focus on climate change adaptation planning (adapted from Wiseman et al. 2011).

Key Consideration	Response Options
1. Purpose of scenario planning	■ Understanding: a one-time exploratory, question-raising project; ■ Developing strategy: a one-time decision making project; ■ Anticipation: ongoing exploratory activities; ■ Action-based organizational learning: ongoing decision making activities (Wright et al. 2013).
2. Purpose of climate adaptation effort	■ Manage discrete climate risks, build general adaptive capacity and resilience, empower others, build relationships, question or justify existing policies.
3. Breadth of issues to consider	■ Biophysical climate change impacts and/or indirect economic, social, political, technological forces; ■ Possible effects of adaptation responses; ■ Present day vulnerabilities; ■ Challenges and opportunities to adaptation (e.g., research needs, existing policies, etc.).
4. Scales to consider	■ Long and/or short-term, with respect to climate change and decisions; ■ Changes at global, national, regional, and/or local geographic levels.
5. Contexts to consider	■ Existing and future developments at higher and lower government and society levels; ■ Influence of other organizations and sectors; ■ The influence of one's own adaptation efforts on the above.
6. Types of knowledge to include	■ Formal: climate science, economics, environmental and social science models and data, "predictive" or possibilities; ■ Informal: expert opinion, organizational knowledge, community; knowledge, imagination, traditional knowledge.
7. Participants and their roles	■ Internal to organization (which departments, management levels); ■ Participatory/external (which partners, stakeholders, community members, climate change adaptation or scenario experts).
8. Outlets for process outputs	■ Internal or external to organization ; ■ Published as report or website, static or interactive.
9. How process results will support climate adaptation	■ Used in early stages only or throughout adaptation planning efforts; ■ Used as a heuristic only, or as evidence to support selection and justification of options.

Step 1. Identify the issue and establish a project team

Like most management and research efforts, a scenario planning exercise should begin with the creation of a project team. The role of this group is to design the exercise and how the process will unfold, ideally capturing those details in a work plan. The project complexity and participant diversity can be used to gauge how detailed and formal a work plan needs to be.

To ensure a common understanding among participants, the work plan should indicate (Wiseman et al. 2011 and many others):

- The purpose and objectives for the effort;
- The scope (geographic and thematic), specific conservation target(s) and their associated conservation goals, and expected process outcomes;
- The intended audience for the products;
- The scenario planning approach to be used and who will participate;
- The time horizon (how far into the future is being considered);
- The intended completion date (i.e., length of process and time commitment); and
- Outlets for the process products, and with whom and in what form they will be shared.

Ideally the document would also define roles and expectations for leadership and involved stakeholders, as well as describe the anticipated technical support, research, and outreach activities (FHWA 2011, FOR-LEARN 2013; see BOR 2012 for an example).

Step 2. Articulate the purpose and anticipated outcomes

With a project team in place, the next step is to clearly state the purpose of using scenario planning to inform the issue or decision (see Table 2.2 for examples of purposes). Is the team using a set of scenarios to:

- Improve understanding of the issue or problem by examining the potential impacts to important conservation targets?
- Characterize the consequences of alternative adaptation options to make decisions between them?

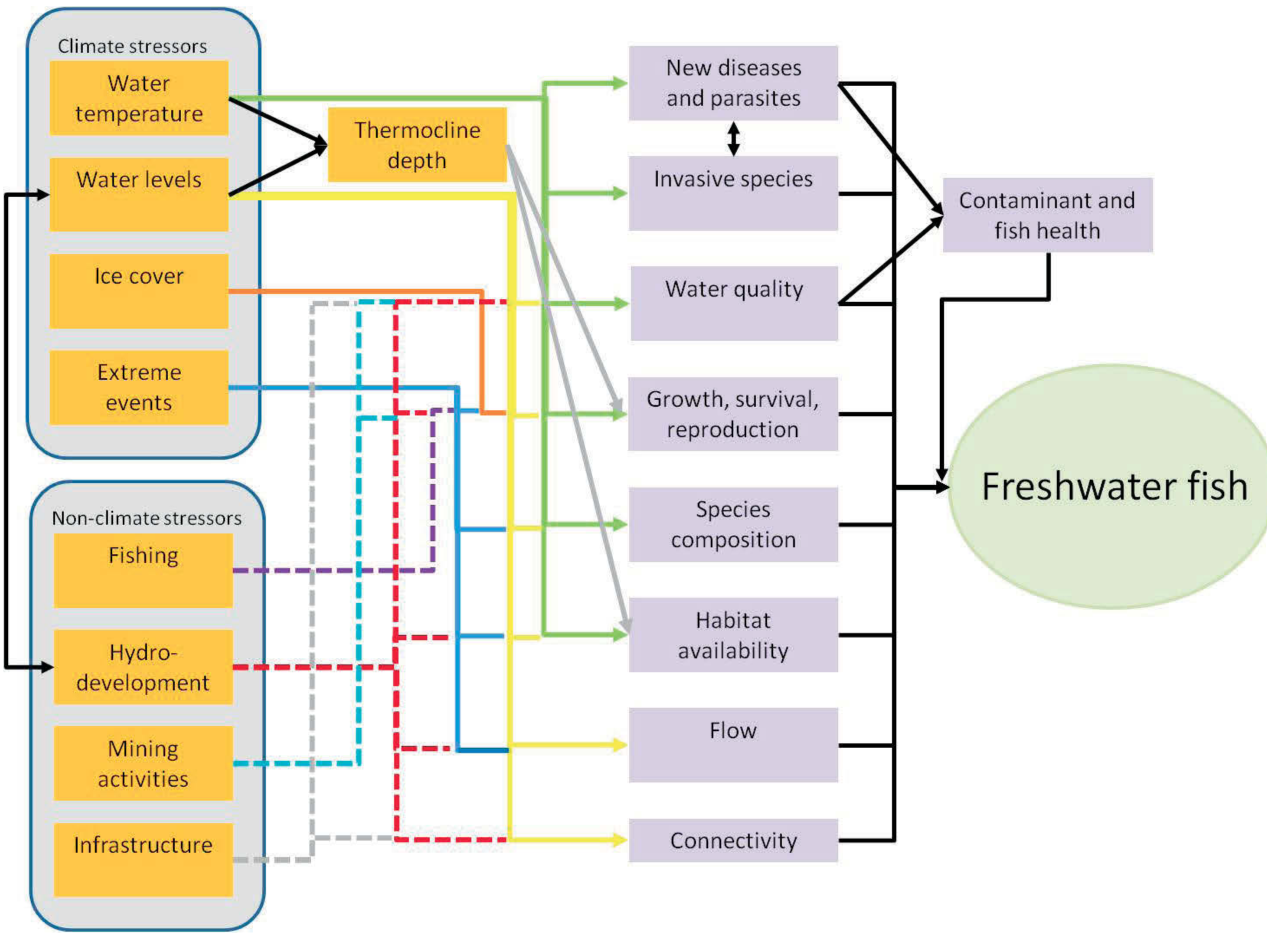
Articulating the purpose of the effort will contribute to refining the scope, developing and agreeing upon objectives, and identifying the outcomes to be achieved during the scenario planning effort (see Table 2.2 for considering breadth and scale of the issue and context).

Early on, participants might want to decide on which drivers of change the scenario planning effort will focus. One option is to look primarily or exclusively at climate change and other environmental factors. The group may also choose to integrate with other drivers. Socioeconomic and technological forces are some commonly recognized system drivers that are incorporated into scenario-planning exercises and help define the scope (Mahmoud et al. 2009, Moss et al. 2010). Given the anticipated global- and national-scale consequences of climate change (IPCC 2007), assuming that social, political, and economic drivers will remain fixed beyond mid-century may be unrealistic. It may therefore make sense to consider how these factors will vary alongside changing climate drivers. A key strength of scenario planning is its ability to integrate and jointly consider different types of system drivers.

Box 2.1. Using conceptual models

Participants often come to a planning or decision process with existing mental models about the system underlying an issue. Conceptual models are commonly used tools in decision-making and planning (Margoluis et al. 2009, Means et al. 2010, Gregory et al. 2012) and will be useful throughout many steps of any decision process, starting with problem framing and scoping. Such a model can also be a useful tool throughout each of the three phases of scenario planning described in this guide.

A conceptual model is high-level representation of important assumptions, inter-component flows, states, parameters, as well as uncertainties (Liu et al. 2008). These graphical representations of the system may depict controls and processes working across a range of temporal and spatial scales. They may also be used as a basis for numerical models (Liu et al. 2008, Chapin et al. 2009) and to show interactions or relationships between system variables and drivers, decision components, and outcomes (e.g., Cross et al. 2012). It is often helpful for the group to develop some type of graphical depiction of system components and relationships at the start of a process to reveal details of various individuals' models and allow the group to reach some level of agreement about the system and its boundaries (Liu et al. 2008, Mahmoud et al. 2009, Walker et al. 2012).



Conceptual model showing the potential pathways of influence of climate and non-climate drivers on freshwater fish species in watershed in northern Ontario Province, Canada (from Chetkiewicz et al. 2013).

At this time, it may be appropriate to develop or revisit a conceptual model or influence diagram (e.g., Margoluis et al. 2009, Gregory et al. 2012), to identify the system drivers whose impact is uncertain but potentially significant. A conceptual model will help the group think through many important considerations throughout the three phases of scenario planning (Box 2.1).

The group will also want to select the decision or planning timeframe. The timeframe of scenario planning might be short (e.g., 5-15 years) to assess the effects of climate on current actions, to assess the impacts of extreme climate-related events, or for near-term strategic planning. Timeframes more distant in the future (e.g., 50-100 years) are necessary to consider how actions we take now may influence our ability to respond to the long-term impacts of climate change (McKenzie et al. 2012). Scenarios aimed at longer timeframes can be described in shorter time steps or pathways toward those ultimate future conditions (Vargas-Moreno and Flaxman 2012).

Because climate change will occur over many decades, even planning for short time horizons should consider longer-term possibilities, in an attempt to ensure resulting decisions are not maladaptive, ineffective, or inadequate in the more distant future, or to avoid missing important options that require long-lead times to implement. The timeframe and drivers selected to consider will help focus information needs and availability. An assessment of information needs and availability will also suggest what kind of scenario planning approach may be feasible.

It is important to discuss early on who will be the end-users of the products to determine what outputs and products will be necessary. Decide who should be involved in the exercise, clearly identifying what they contribute (e.g., science content, technical expertise, stakeholder, implementer/manager), and whether and when to involve decision-makers. A conceptual model or influence diagram of the system can help identify stakeholders to include in the effort and at what points in the process to engage them (Vargas-Moreno and Flaxman 2012; Case Study 3.1). Outlining roles and responsibilities in the scenario planning exercise can also be helpful for considering potential participants (Table 2.3). Roles to consider include: a core group to provide continuity and consistency throughout the exercise, subject matter experts to involve at specific steps but not necessarily through the entire process, key participants from different organizations or departments within an agency, different levels of organizational management (e.g., executives, field managers), stakeholders, and the public. Based on this information and resource availability, indicate a reasonable expectation for the duration of the exercise (e.g., a day, several months, several years) and the approximate time commitments required of the different roles.

Table 2.3. Questions to address as organizers select participants and characterize their roles (see also Alcamo and Henrichs 2008, Mietzner and Reger 2005, Wiseman et al. 2011).

Participant Diversity Questions
Who needs to be involved in the decision to implement actions and meet objectives? Are stakeholders technically sophisticated? ■ Different management levels do different types of planning (executive level decision makers, mid-level planners, field-level managers). ■ Meetings, workshops, etc. take time that not everyone can give.
What is the function and influence of stakeholders in the system? How important is their involvement for enhancing the legitimacy and impact of the scenarios (i.e., getting "buy-in")? ■ Level of participation can vary between those involved, from active engagement, being regularly informed of progress, and providing expert consultation (Alcamo and Henrichs 2008). ■ Consider the function and scale of influence of each stakeholder group.
What internal capacity and expertise is available? What capacity and expertise does the scenario planning effort need? ■ Types of expertise might include modeling, meeting facilitation, etc. ■ Some participatory methods include workshops, interviews and surveys, focus groups, group mapping exercises, web-based discussions or forums (McKenzie et al. 2012).
Is there any concern that stakeholders will introduce bias to the exercise? ■ It is important to be aware of the motivation and potential biases of participants contributing to an exercise (Alcamo and Henrichs 2008, Rounsevelle and Metzger 2010).

Step 3. Select or formulate a suitable approach

Approaches to scenario planning vary in large part with respect to: 1) whether the effort is more or less qualitative, quantitative or some combination, 2) the nature and diversity of participation, 3) the type, number, and level of integration of the drivers of change included, and 4) where in the decision-making process scenario planning is integrated. The steps we describe for Phase II are largely devoted to developing your own scenarios, similar to the "tailored exploration" approach described by Wiseman et al. (2011).

Alternatively, the group might begin the effort with "off-the-shelf" scenarios. As "off-the-shelf" suggests, this approach involves using scenarios or scenario generation tools based on IPCC climate projections and other information previously developed externally by scientists or other experts and made available for others to apply in decision-making or planning with little modification (e.g., Climate Wizard, National Climate Assessment Scenarios for Climate Assessment and Adaptation). Using the IPCC Special Report on Emission Scenarios storylines and Global Circulation Model projections (Box 1.2) or recent projections based on the representative concentration pathways (RCPs, Moss et al. 2010) to consider the impacts of climate variables on a focal resource is one example of using an "off-the-shelf" approach. In another example of an "off-the-shelf" scenario planning exercise, Wyoming's Game and Fish Department and State Climate Office used climate information assembled for an earlier National Park Service scenario planning effort in the same region as the basis for their scenarios in an internal, 1.5-day workshop (Gray 2012, personal communication). These relatively rapid exercises are a sufficient starting place from which to pilot scenario planning methods and may be readily expanded into more comprehensive efforts if warranted.

Using existing scenarios may be attractive because they are convenient and may be considered highly credible depending on the underlying methodology and source. However, the scenarios' underlying assumptions may be poorly understood, they may not be considered legitimate by audiences not involved in their creation, and they may not be fully relevant (e.g., with outputs at different scales than desired). The available scenarios also may not be sufficiently different to challenge thinking, especially if based on modeling studies that focus on probable futures rather than plausible futures. Further, there is no central repository for scenarios developed to address climate change, although the National Climate Assessment, NOAA RISA projects, USGS Climate Science Centers, and Landscape Conservation Cooperatives are beginning to assemble information on existing scenario-based studies and their applications.

Other efforts build and apply scenarios customized to fit the specific context. Use of these tailored scenarios also has both advantages and disadvantages (Table 2.4). If creating tailored scenarios, earlier definition of the purpose of the exercise, decision context, relevant scope and associated drivers, and desired outcomes guide whether a more qualitative or quantitative approach is necessary or feasible. The choice between a relatively qualitative or quantitative emphasis will further inform what tools to apply and in what sequence. Time and information availability can act as constraints, as well as the necessity of engaging diverse participants and technical expertise (e.g., modelers) if the capacity does not exist in-house. Examine the groups of questions in Table 2.5 to determine whether qualitative or quantitative results will achieve the objectives of the scenario planning exercise (Alcamo and Henrichs 2008). Often, some combination of qualitative and quantitative inputs and outputs are use in scenario planning (see Section 3 cases studies for the diversity of ways scenario planning efforts use quantitative and qualitative inputs and outputs). The use of quantitative tools and approaches in scenario planning is discussed further in Box 2.2.

Table 2.4. Some potential strengths and weaknesses of constructing tailored, context-specific scenarios (modified from Wiseman et al. 2011).

Potential Strengths	Potential Weaknesses
✓ Recognizes and promotes the value of understanding systematic drivers of change and dynamic relationships between them as a foundation for better planning under uncertainty. ✓ Scenarios can be built at many different scales and tailor-made to suit the problem of interest. ✓ Value in learning through the scenario building process, exploring assumptions and diverse perspectives (including different sources of information). ✓ Capacity to consider broad range of futures, including non-linear responses and other surprises. ✓ Tailor-made scenarios can be made more explicitly relevant to key audiences.	✓ For a given scale, it can be difficult to determine boundaries and ways of factoring in drivers at scales beyond the sphere of influence of those building the scenarios. ✓ Possibility for confusion between descriptive approaches (i.e., describing what may be possible) and normative approaches (i.e., describing desirable futures). ✓ Challenges in establishing the credibility of scenarios from the point of view of those not involved in building them, especially getting buy-in from decision makers.

Additional considerations for designing a scenario planning approach include:

- The temporal and spatial scales of the processes that underlie system drivers and the decisions and actions being considered (Biggs et al. 2007, Zurek and Henrichs 2007, Alcamo and Henrichs 2008, McKenzie et al. 2012). The relevant scale will be determined by the degree to which the decision or problem is shaped by global (e.g., Nakicenovic et al. 2000, Moss et al. 2010), regional (e.g., MA 2003, Spangenberg et al. 2012) sub-regional, (e.g., Bohensky et al. 2011, Price et al. 2011) or local drivers (e.g., Wollenberg et al. 2000, Neff et al. 2007). Scenario sets can also be linked through time and across spatial scales. For example, global scenarios may be used to define the boundary conditions for finer scale efforts (Rounsevell and Metzger 2010, Dermawan et al. 2012). Greater detail about scale issues can be found in Phase II (Building & Refining Scenarios);

- Clear distinctions among the elements of the system that are subject to external driving forces and beyond the influence of management, and those that can be directly influenced through management actions. (Zurek and Henrichs 2007, Biggs et al. 2007). This can be difficult for groups to agree upon, because each person comes to the process with a distinct understanding of the system;
- The analysis tools that might be used to assess the impact of scenarios on the target natural resources, or on the effectiveness of management options under consideration. Options range from expert opinion to more technical methods (e.g., species distribution models, state and transition models, Bayesian methods, and others) (see case studies in Section 3 for diverse examples). If modeling is to be part of the process, the links between the scenario-building and quantitative representations should be identified as early as possible (see Box 2.2 for more information about quantitative approaches) (Mahmoud et al. 2009, Swetnam et al. 2011);
- Identifying the group who will administer the scenario products (e.g., GIS layers, storylines, interactive website, etc.) to end-users, store the scenario input and output data, and revisit and update the scenarios.

Table 2.5. Questions to consider when choosing between qualitative and quantitative approaches (see also Alcamo and Henrichs 2008, Mietzner and Reger 2005, Wiseman et al. 2011, Mackenzie et al. 2012).

Quantitative/Qualitative Products Questions
What kinds of outcomes are needed? ■ Who are the end-users or audience? ■ How important are quantitative results in meeting mandates and encouraging the use of outcomes? ■ Does the planning group want or need to generate detailed maps of expected change?
How will the results be used? Is a scenario planning effort contributing to an existing decision or planning process? At what stage of the existing process is the group? ■ If the existing planning process uses quantitative inputs or outputs, then it might influence how quantitative the scenario-planning component should be. ■ Some kinds of decisions might require or benefit from quantitative scenario planning outputs. ■ Does the scenario planning process need to be replicated?
What is the decision or planning timeframe? ■ Simulating qualitative narratives into quantitative, spatially explicit outputs can be relatively more time-consuming, challenging and expensive (Mahmoud et al. 2009, Walz et al. 2007).
What kinds of uncertain drivers are relevant to the focal issue or question being addressed? ■ If incorporating human dimensions, quantitative options may be limited. Do you have the data and capacity to support quantitative scenario modeling?

Box 2.2. Quantitative Modeling in Scenario Planning

Roles in Scenario Planning: Quantitative models and methods are often used to simulate scenarios and their effects on resources and other targets or indicators of interest. There are several roles that quantitative scenario development can play when implemented in combination with narrative storylines (from Kemp-Benedict 2004, see also Alcamo and Henrichs 2008):

1. Force clarification of the terms and mechanisms, ambiguities encountered and how they were resolved, particularly if the mathematical model is developed by a separate team than those using the outputs (van der Sluijs 2002).
2. Expose contradictions and test consistency in mental models underlying the narrative, both through process of developing the formal model or in its application (also see Mahmoud et al. 2009).
3. Provide a feel for the scope of possible outcomes represented by the narrative framework.
4. Expose limitations in quantitative assessment capacity (e.g., water levels fall outside the range of programmed in a reservoir management model, costs exceed values programmed in economic models).
5. Identify surprising systems responses.
6. Illustrate narratives to provoke and share insights.
7. Make a study more easily replicated and transferable.

Challenges & Cautions: The challenge for the developers of quantitative scenarios is to identify the model attributes (e.g., parameters, thresholds, state variables, input and output variables) implicit in the narrative through the causal connections described and to integrate datasets necessary to create the link. It is not uncommon to use multiple models, often including models that exist independently of the scenarios, having been developed for other purposes. But it is difficult to find or build models that: (i) represent the spatial and temporal scales of key process; (ii) reflect the fundamental constraints; and (iii) offer some management intervention points for the qualitative scenario developers and other potential users.

There are several important cautions:

- Temper the expectations (i.e., predictive capability) of scenario users for models, particularly when integrating them to create comprehensive views of the narrative (e.g., Walz et al. 2007);
- Assigning probabilities to plausible futures may suggest more certainty about the future than is actually known (Alacamo and Henrichs 2008);
- Statistical techniques, relying on past conditions to project response in the future, may be of questionable utility in climate change adaptation applications, given the non-stationarity of the system and their inability to represent non-linear responses (see Spangenberg et al. 2012).

Quantitative Techniques: There is no shortage of quantitative techniques and associated tools that may be appropriate for scenario planning exercises (e.g., Wilsey et al. 2013, McKenzie et al. 2012, Coreau et al. 2009, see Case Studies in Section 3). The major distinction is between statistical and process-based models. Statistical models are inextricably tied to the range of conditions under which they were developed; continued applicability of those models to scenarios that exceed historical envelopes or that represent novel regimes requires an assumption that the parameters controlling system relationships remain unchanged. Bayesian methods can offer more flexibility to address uncertainty in statistical model parameterization (e.g., Marcot et al. 2006, Choy et al. 2009). Process based models may also be tightly coupled to past conditions, when parameters are calibrated based on past observations.

In addition, there are likely multiple ecology models and management models that have been developed for a specific region or set of processes, in the same way that there are multiple global circulation models (GCMs) and multiple methods for downscaling global climate projections to regional projections (Mote et al. 2011, Daniels et al. 2012). The number of outputs that must be computed, evaluated, and communicated increases with respect to the number of models considered. Employing only one ecology model and one management model, however, neglects the uncertainties inherent in correctly identifying all the system relationships.

Further, models may be applied in two different ways to represent possible futures (Brekke et al. 2011). One is the “period-change” approach, which provides a snapshot of system conditions under specified conditions, averaged over a period (e.g., a 10-year average centered on 2030). The other is the “time-developing” approach, in which system conditions evolve over time (e.g., monthly conditions from the present to 2050).

Step 4. Complete the design and staging of the process

Before moving on to building the scenarios, you need to put the finishing touches on the design process may be needed and best documented in a work plan. Although participation likely has been considered early in the scoping and preparation phase, decisions about the scenario planning approach to be used will refine whom to involve (Table 2.3). Science and technical experts are a must for building scenarios and understanding potential impacts. But, if the intent of the scenario planning exercise is to move beyond learning, decision-makers and implementers (e.g., managers) are also required. Final selection of appropriate stakeholders should be guided by the relevance of stakeholders to the purpose of the scenario planning exercise, including their function with respect to the focal issue and their scale of interest and influence (Alcamo and Henrichs 2008, Mahmoud et al. 2009). Not everyone needs to be involved in all activities, so some staging of participation (e.g., when and in what role) should be included in the work plan. Do not avoid the inclusion of key stakeholders as early in the process as possible, even if they express concerns or resistance. Conflict can be reduced by early involvement—or delayed and exacerbated. As needed, engage the services of a third party neutral facilitator to allow full participation of all internal and external stakeholders.

Selecting who will facilitate the scenario planning process is another key decision. Many practitioners emphasize the importance of skilled facilitators familiar with scenario planning for generating useful outcomes and credibility (e.g., Mahmoud et al. 2009, Olabasi et al. 2010, Johnson et al. 2012). Keep in mind that facilitators also have the potential to introduce their own biases. Whether it is a single day exercise or a lengthy effort, internally facilitated processes can be successful (e.g., City of Tucson 2004). It also may be desirable to develop that capacity if the intention is to integrate scenario planning organizationally. The key is to make a choice informed by acknowledged needs (see Box 2.3).

It is difficult to manage time investment, and maintain consistent and effective engagement of stakeholders, in an exercise lasting more than 1-2 days. If there are multiple teams involved in the different scenario planning steps, the teams will need to come together and share results over a longer period. This will ensure that the entire group identifies common themes and messages for broader communication, resolves incompatibilities across scenarios or action options, and avoids solutions that create problems elsewhere within the system. In addition, because so few people have participated in this type of scenario planning, the need to introduce new participants to the project goals and the various choices and approaches that have been selected, can create a burden for the core project team and recurring participants. Box 2.4 (in Phase II below) lists some methods for communication beyond workshops.

Finally, this is also the time to think about how to evaluate the success of the process relative to the stated purpose and desired outcomes (Wiseman et al. 2011).

Box 2.3. The Importance of the facilitator–from UN Habitat 2012

All climate change planning often requires cooperation and collaboration among a wide range of stakeholders. Because of this – and the fact that stakeholders may disagree on issues and approaches – having a good facilitator is critical. A good facilitator creates a positive and cooperative working environment and helps maximize group productivity and participation.

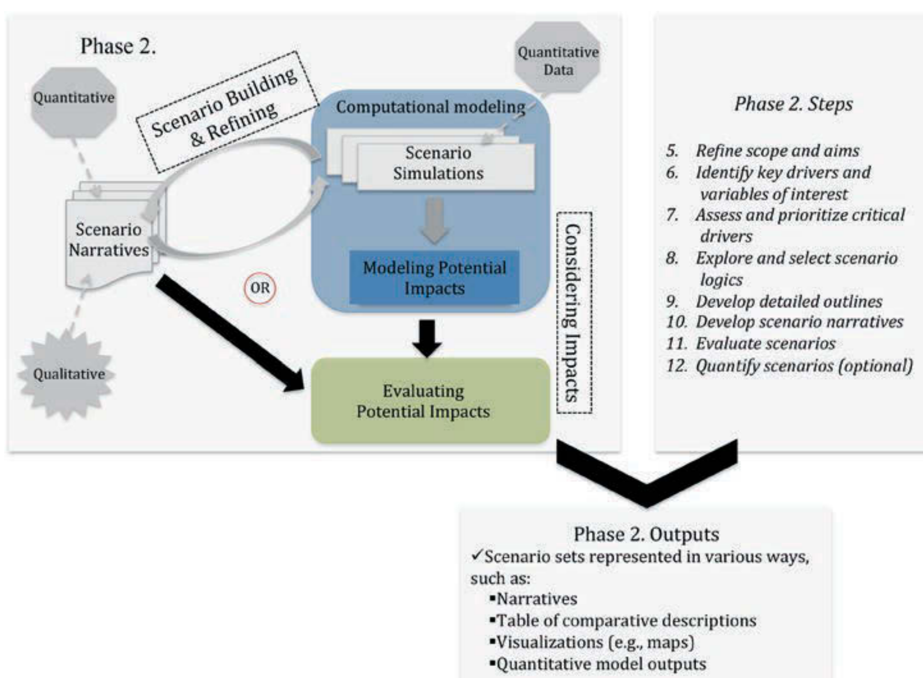
A facilitator performs four main functions:

1. Assists the group in establishing rules and procedures for the process;
2. States what the group wants to get done in the time available;
3. Ensures that stakeholder communication is effective and fair;
4. Maintains group progress toward the objectives.

Much of the success of the process depends on the skill of the individual(s) managing or facilitating it. Sometimes additional training may be required or an outside facilitator may be necessary.

2.2 Phase II: Building & Refining Scenarios

Phase II Summary




Doug Racine

Male wood duck

The preparation for scenario planning is not much different than for any other decision making process. However, the building and refining scenarios phase of scenario planning has a unique focus on seeking out and embracing uncertainties about the future by developing sets of scenarios. The methods described here do not characterize uncertainties in terms of probability or even relative likelihood. Neither do they attempt to reduce any uncertainties by seeking a common desired future. Management options and their consequences are evaluated against multiple plausible futures.

There are many ways to build and refine scenarios. No approach is right for all situations. All approaches mentioned here have been successfully used to support decision making – including relatively quick and inexpensive processes. While the approach needs to be matched with the resources available, an emphasis on time- and cost-efficiency is important because new scenarios will need to be built as scientific understanding of climate change and impacts, and other stressors, evolves. An iterative approach to developing scenarios is also necessary as community priorities, opportunities, and constraints change over time.

One key element of this phase is to create space for unusual or "out of the box" thinking, and to even think the unthinkable, an important role for the facilitator. This includes maintaining confidentiality in discussions and use of techniques that push people to think beyond their day-to-day concerns. There may be situations where separating supervisors and subordinates in breakout sessions is necessary, but keep in mind that this may impair the implementation of planning outcomes if ideas are not developed together to promote buy-in.

Aspects of building scenarios that are especially challenging for participants include:

- Prioritizing the issues to address;
- Structuring the collection and sharing of data and information about the forces of climate change and other stressors, and their impacts;
- Distinguishing external system drivers that are outside the control of local and regional decision makers from internal system responses that are subject to at least some local and regional influence and from management choices and actions;
- Conceptually linking external drivers of climate and other change with anticipated impacts; and,
- Creatively synthesizing the collective understanding and choices into scenario narratives.

Another challenge is that people are exploring conditions outside their comfort zones. This can engender strong personal responses from some participants. Other people simply are uncomfortable moving beyond facts or model projections, to the realm of scenarios or speculation. Explicitly discussing the differences among scenarios and other ways of considering future conditions, using the distinctions suggested by Zurek and Henrichs (2007), can be helpful (refer to Section 1.; see also Coreau et al. 2009). Scenarios are more speculative and complex than model-based projections, because models are necessarily limited in the variables and dynamic relationships they consider, while scenarios can be more integrative and flexible. Scenarios can make effective use of both projections and more exploratory analyses.

It can also be difficult to effectively and efficiently engage key participants. Building and refining scenarios can be completed within a workshop setting. However, it can also be completed as a group process through other methods, for example, conference calls, webinars, and small group meetings (Box 2.4). Building into the process enough time for extended discussion can be important to enable new concepts or problematic issues to be addressed and integrated into prior thinking that may be entrenched.

Box 2.4. Use of Webinars and Social Media

Problems can arise from conducting a scenario planning process only in a workshop environment. Scenario planning that focuses on widely divergent futures to embrace the irreducible uncertainties can be a difficult concept to grasp on first exposure. Recurrent conversations are often required to appreciate the perspective that the future is not well defined by a 'base case' of a 'normal' climate, or even a trio of projections for 'high', 'medium', and 'low' levels of change. A short workshop, alone, does not provide sufficient time for difficult issues to be grappled with, nor does it allow gathering of information to respond to questions. Further, cost and time involved in travel to recurring meetings can preclude participation. An alternative is to use online conference technology to conduct a series of web-based seminars (webinars) to address questions related to scenario planning and decision-making. This method allows people to participate remotely but efficiently and effectively in discussions about difficult questions. It has proved useful in the implementation of several scenario planning exercises for the National Park Service (Weeks et al. 2011). For a 23 organization scenario planning exercise for the northern Rocky Mountains, involving U.S., Canadian, and tribal members working far apart, Hartmann (2012) used a series of 12 webinars to build scenarios in preparation for a 2-day workshop. The webinars were supported by social networking capacity, through which information resources, meeting agendas, and discussion questions were shared. Webinar recordings were considered a valuable product of the project. The recordings allowed new participants as well as those who missed meetings to "catch up" and allowed later analysis of the process and discussion details.

Step 5. Refine scope and aims with key participants

The main objective of this step is to create an explicit common focus for the scenario building activities. Although questions of the contextual environment, geographical setting, timeframe for issues, and others are addressed in the preparation phase, it is worthwhile to review and refine the questions within the group of key participants. If the scope is too narrow, important issues may be missed, but if the scope is too broad, outcomes may not be relevant (Wiseman et al. 2011). Because the overall scenario development process is iterative, all answers in this step can be provisional, to be confirmed or revisited as the process proceeds. Identification of what elements remain ambiguous about the project scope and aims can provide useful insight and feedback about the evolution of the project.

This step includes identifying a focus question, or a series of questions. Initial selection of the focus questions can be tentative and refined during the process. Common climate-related focus questions at a regional scale (i.e., within a country) include:

1. What does climate change mean for the resources we manage?
2. Are our current approaches sufficient to manage our resources in the face of prospective climate change impacts?
3. How will we need to manage our resources in the face of prospective climate change impacts?
4. Do our management objectives need to change in the face of prospective climate change impacts? If so, how to they need to change?

Question 1 is often the first suggested within a group, but it is a question addressed by vulnerability or sensitivity analyses. Question 2 is also an often-posed question, but is typically too narrowly focused; without reframing, it leaves out consideration of new or modified approaches that may be needed. Question 4 is the most abstract, but may ultimately be the most useful to high-level managers because it accommodates significant changes that are beyond past experience. Questions 3 is more manageable for participants who might have difficulty relating to the more abstract question about management objectives and prefer to instead focus on changes in action at the field or operations management level.

Creation of an "Issue Tree" can help to refine the critical issues and focus questions for building scenarios in subsequent steps (Wiseman et al. 2011, Box 2.5). The language for this activity should be adapted to fit the group. For example, for the Las Cienegas scenario planning effort (Bodner et al. 2011), participants understood the exercise better when it was called "Mapping the Management Challenges". Developing an Issue Tree often highlights that different management levels and organizations may be focused on different issues and scales, and that individuals may have varying assumptions about the process. This activity ensures the group is operating at a common scale, while also providing a pathway for groups to move to other scales and scopes as needed without a sense of failing to identify the right questions the first time.

Box 2.5. Issue Trees

Purpose: Helps at the start of a project to clarify the overarching question needing to be answered and where it sits within a set of broader issues.

Participants: Best to involve topic experts and external stakeholders, but could also be carried out by the project team alone.

Time: Approximately 1-3 hours

Process:

1. Write an opening question that relates to the project's aims (layer 1).
2. Set out the key questions that need to be answered in order to answer the opening question (layer 2).
3. Repeat step 2 for each question in layer 2.
4. Carry on with the process until the group is satisfied that the fundamental question(s) at the heart of the project have been captured.

An advantage of this process is that it helps identify issues "above" and "below" the ideal scoping question. Doing this gives the participants a way of tracking how closely they are sticking to the main issue of concern.

Source: Waverly Management Consultants for UK Department of Transportation (2007); http://www.dft.gov.uk/pgr/scienceresearch/futures/secsceniss/ *(modified from Wiseman et al. 2011).*

Step 6. Identify key drivers and variables of interest related to the focus question

The purpose of this step is to identify and document the rationale for the choices that will be made in building the scenarios. Often the challenge is not one of too little information, but too much information spread across a large number of reports and in the scientific literature. Methods to synthesize and structure information are important for this phase. No single approach is best, and the choice of methods will depend on the experience and preferences of the facilitator and the group, as well as the time available for the activities. Regardless of the approach, there are several considerations that are detailed below:

- Consider external drivers of system change, that is, outside managerial control and typically acting at a regional or higher level;
- Assess potential impacts of changes in the external drivers;
- Consider linkages between drivers and impacts, with an emphasis on system attributes that enable a system to shift to a vastly different character.

Holly Gaboriault/USFWS

Pitcher plant

Many participants in building scenarios have difficulty distinguishing among external drivers of change for the system, the internal system elements that can be changed through decision-making, and impacts of either external drivers or internal choices. Clarity about the boundaries of the system relevant to the decision or planning effort, also known as the decision context, helps participants discern the difference between external forces and internal choices. One way to manage this problem is to consider the scales one step above and below the system under consideration. Using the Issue Tree exercise (Box 2.5) modified to address drivers of change rather than questions related to scoping scenario efforts can help participants sort internal system elements and external drivers.

For example, an Issue Tree for a hypothetical project has two layers of key questions:

Layer 1: How do we maintain biodiversity in our management unit through the year 2050?

Layer 2: How do we maintain wetland species X, Y, and Z in our management unit through the year 2050? How do we maintain upland species A, B, and C?

Drivers of change for Layer 1 might include climate change, land use change in the surrounding landscape, and regional public interest in the management unit. Factors influencing the questions in Layer 2 might include invasive species spread, road maintenance needs, and visitor access. The drivers listed for Layer 1 are also relevant to Layer 2 but would be external to a decision focused on questions at this layer.

Another important part of this step is to identify key assumptions underlying the understanding of external drivers, impacts, and their linkages. For example, a key assumption underlying much of the past decades' hydrologic analysis has been the concept of stationarity, whereby it is assumed that observations from a prior time period remain the same and can be used to model current or future time periods. However, that assumption is no longer valid, due to changes in climate, watershed condition (e.g., land cover, land use), and river hydraulics (e.g., diversions, river channeling). Other assumptions to question include those that underlie any single future about demographics, development, and economics (e.g., ever-shrinking or ever-increasing budgets, ever-increasing population or economic growth, dominant economic sectors). These are sometimes referred to as "official futures."

Finally, it is important to consider past change and current conditions in this step in order to identify what aspects of the current system represent "predetermined" or "legacy" aspects of the future. Examples of legacies might include some elements of urban infrastructure, transportation systems, or large dams that will persist into the future. However, it is also important to not get trapped into thinking that the issues of the future will be the same as those confronted in the past (Wiseman et al. 2011) or a magnification of current issues.

Ken Sturm/USFWS

Trail in fall at Missisquoi National Wildlife Refuge

This section describes several methods for identifying key drivers that can be used separately or together – asking an expert, considering past change, conducting a "STEEP" analysis, developing drivers and impacts tables, constructing conceptual models or influence diagrams, and considering cross-scale linkages.

Ask An Expert

One approach to identifying drivers of change is simply to have experts prepare a report or presentation specifically for the scenario building process. This approach would be especially useful if a scenario planning effort is limited to a short workshop, with little time or capacity within the organizing group for information gathering and synthesizing. The NOAA Regional Integrated Sciences and Assessment (RISA) programs, the Department of Interior Climate Science Centers, state climatologists, and the National Weather Service regional climate directors can provide connections to respected experts in regional climate change and impacts. Other sources for scenarios or information from which to build scenarios include the National and Regional Climate Assessments, reports from the RISA programs, and other known scenario planning projects in your region.

Consider Past Change

Every region of the country has experienced tremendous change throughout the 20th century, including technological changes, shifts in social values, dominant economic sectors, population, and agency regulations and policies. Considering the range of these past changes, how surprising some of the changes were, and the management challenges that emerged from the changes, can help a group step out of its day-to-day thinking about current challenges. It can also highlight that change has many causes, and help differentiate between driving forces outside the control of a region, internal responses, and management choices. A fast exercise is the History Wall (Wiseman et al. 2011), in which a timeline chart stretching back 30 years is placed on the wall and individual participants list information about past management challenges and responses.

"STEEP" Analysis

If non-climate factors are important for the scenario planning effort, constructing a "STEEP" analysis (STEEP = Societal, Technological, Environmental, Economic, Political drivers (Box 2.6)) can ensure participants are considering a sufficiently broad set of potential forces of change (see also conservation situation analysis in CMP v.3.0 2013). The STEEP analysis is helpful to clarify which types of drivers should be within or outside the scope of the scenarios. Climate change issues are included in a STEEP analysis within the environmental category. If climate drivers, impacts, and linkages have already been identified prior to a STEEP analysis, participants may desire that an equivalent level of effort be given to the other categories of drivers. This will expand the range of experts or participants to include in the scenario planning exercise.

Box 2.6. STEEP Analysis

Purpose: Helps to structure initial brainstorming sessions and to allow groups to focus on what is driving change in the external environment. This is done by considering a range of drivers, categorized as Social, Technological, Environmental, Economic and Political (STEEP), which may not seem to have immediate relevance to the groups or organizations involved, but which are often shaping future trends.

Participants: Any team or group of people

Time: Approximately 1-1.5 hours

Process:

1. Introduce STEEP concept, discuss what is driving change.
2. Participants each write approximately 5 drivers on post-it notes.
3. In groups of 2-3, participants discuss and group post-it notes into clusters.
4. Identify names for clusters.
5. Identify the most significant or highest impact driver in each cluster.
6. Discuss the likely impact and implications of the cluster and key drivers on the organizations' activities.

Source: Waverly Management Consultants for UK Department of Transportation (2007); http://www.dft.gov.uk/pgr/scienceresearch/futures/secsceniss/ *(From Wiseman et al. 2011).*

Drivers and Impacts Tables

Another approach useful in a variety of scenario planning efforts is a modified form of two tables from a climate change guidebook for local, state, and regional governments (see Tables 4.1 and 4.2 in Snover et al. 2007). The first table provides the structure for organizing information about external drivers of change, whether for climate or non-climate factors (Table 2.6), and a second table describes the impacts linked to the drivers (Table 2.7).

Table 2.6. A table developed for a National Park Service scenario planning workshop in June 2012 showing climate change drivers and the projected changes for the upper Colorado River basin.

Rocky Mountain Divide - Climate Change Driver Projections to 2050

Climate Variable	Trend	Relative Change by 2050	Projections for 2050s	Confidence	Uncertainty (HML)	Consequence (HML)	Source / Comments
Temperature (change from 1960-1990; x ± SD)	↑	Large	2.7 ± 0.7 C (4.9 ± 1.3 F) Warming greater in summer	Very likely	Trend: L Value: H		CMIP3 ensemble for 1 degree cell including RMNP*
Extreme high temperatures	↑	Large	1-in-20 year mean maximum temperature Likely to increases by 2-3 C (3.6 -5.4 F). 1-in-20 year maximum temperature events Likely to occur 1-in-2 to 1-in-4 years.	Likely	Trend: L Value: H		IPCC 2012
Mean precipitation (% change from 1960-1990; x ± 1 sd)	↔	Small	1 ± 7.2 %	About as likely as not	H		CMIP3 ensemble for 1 degree cell including RMNP*
Evaporation	↑	Moderate	Increase due to temperature; difficult to quantify	Likely	M		Evapotranspiration may increase 20-30% at higher elevations (BOR 2012)
Intense precipitation events	↑	Moderate	"Marked" increase in 24-hr precipitaton for 2040-2070 period. 50-70% increase in event maxima.	Likely	M		IPCC 2012; Mahoney et al. 2012
Snowfall (April 1 SWE)	↓	Moderate?	2050: -15 to -30%	Likely	M		Christensen & Lettenmaier 2006; BOR 2012; Gangopadhyay & Pruitt. 2011
Streamflow	↔	Small	No change to slight decrease	About as likely as not	H		BOR 2012; Evapotranspiration may increase 20-30% at higher elevations (BOR 2012: B57ff)
Drought	↑	Moderate?	Difficult to quantify. Likely result of higher temperatures, increased evaporation, and perhaps increased variation in precipitation.	Likely	H		IPCC 2012
Hail	↓	Large	Almost complete elimination of surface hail	Likely	M		Mahoney et al. 2012

* The CMIP3 ensemble includes 15 Bias-Corrected and Spatially Downscaled (BCSD) GCMs, at 1/8 degree resolution.

Table 2.7. This example is a portion of a table developed for a National Park Service scenario planning workshop in June 2012 describing potential impacts for components of the system in the upper Colorado River basin (Note: Publications cited in the example table are not reported in the reference section of the guide).

Impacts of Climate Change on Rocky Mountain Divide Resources

Category	Topic	Trend	Comments
Air Quality	N Deposition	↑	Excess N often favors invasive plant species, enabling them to outcompete native species. In Rocky Mountain National Park, N from atmospheric deposition has caused increased nitrate in lakes, increased N in vegetation and soils (Baron et al. 2000; Baron et al. 2003), and changes in aquatic biota (Baron 2006). Current levels of N deposition in the park are sufficient to alter alpine plant community composition (Bowman et al. 2006). Recent trends in the vicinity of the park are stable or very slightly increasing (NPS Air Resources Division, 2011). Effects of future rapid population increases are unknown.
	Ozone	↑	Ozone formation generally increases at higher temperatures due to increased gas-phase reaction rates (Aw and Kleeman 2003). Evidence suggests that the frequency and duration of ground-level ozone events will increase. Remote areas may be most affected by changes in the global background of ground-level ozone and by increases in particulate matter due to increases in fire frequency and drought (summarized by Ashton 2010).
Biota	Amphibians	↓	The effects of climate change on amphibians are expected to be multi-faceted and include direct physiological impacts as well as indirect impacts to the species' habitat, competitors, predators, and pathogens. Boreal toads appear to have experienced a population decline across the Rocky Mountains from north to south, a pattern potentially associated with the distribution of chytrid fungus. (summarized in Ashton 2010)
	Aspen Trees	↓	There has been some expansion of aspen into higher elevations, and aspen may be positively affected by global changes such as increasing fire frequency, beetle outbreaks, and rising CO2, however, aspen is expected to continue to decline at the landscape scale as a result of fire suppression and a recently-described phenomenon known as sudden aspen decline that may be associated with disease and other pathogens (Strand et al. 2009; Worrall et al. 2008). Aspen recruitment has been very limited since 1975 in areas of Rocky Mountain National Park, and heavy browsing by elk has reduced regeneration by up to 90%, although aspens have remained stable in areas with fewer elk, suggesting that herbivory plays a larger role than climate change in aspen decline (Binkley 2008).
	Birds	↔	Avian responses to climate change can be broadly categorized as changes in range and distribution, phenology, behavior, and morphology (Fiedler 2009; Van Buskirk et al. 2010). American Robins in the Colorado rocky Mountains are arriving earlier in spring than in previous decades (14 days earlier in 1999 than in 1981).
	Elk	↑	Reduced precipitation, especially less snow, has created more favorable conditions for elk population growth in Montana (Creel and Creel 2009) and is predicted to improve conditions for elk in Colorado, including a potential increase in the size of the equilibrium population (Wang et al. 2002).

Conceptual Models / Influence Diagrams

The use of conceptual model schematics (see Box 2.1 in Phase I), or influence diagrams, helps clarify relationships between external forces and impacts. The purpose of influence diagrams is to identify key aspects of the system that could produce very different future challenges. In particular, the key features to identify include:

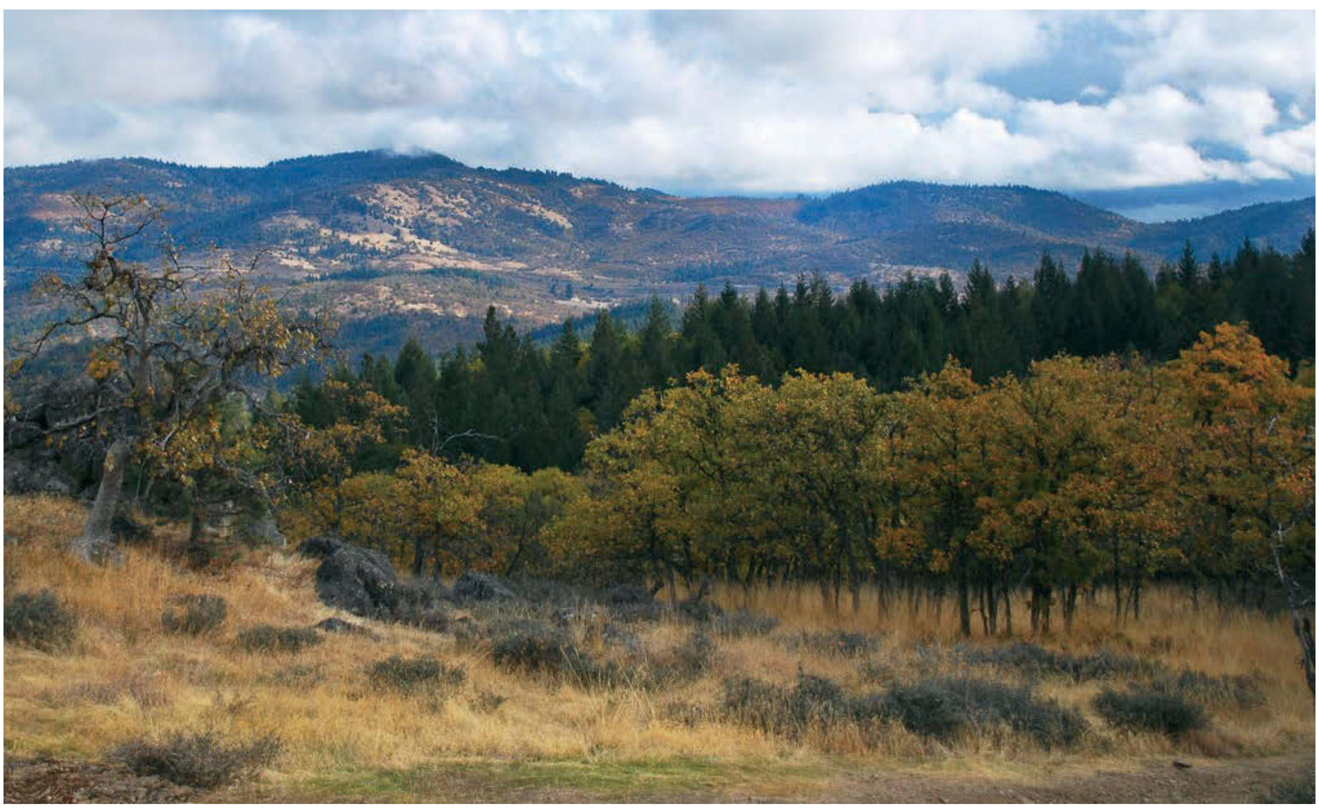
- Highly uncertain drivers;
- Highly uncertain relationships within the system;
- Amplifying (or positive) feedbacks, whereby several parts of the system are interconnected so that changes in any one of them will lead to self-reinforcing changes in the others;
- System cascades, whereby crossing a threshold in a single, "keystone" state variable will have consequences across many parts of the system. Common system cascades are related to drought, fire, flooding, invasive species, disease or other disturbances;
- System "pinch points," whereby a large number of system components can be lost from the system if thresholds are crossed. Examples include high alpine ecosystems that could be lost as the systems cannot migrate higher

with increasing temperatures, or the riparian systems associated with perennial streams as water stress increases and flow becomes ephemeral.

For some systems, conceptual models or influence diagrams may already exist, at least in an initial form that can be modified through discussion. This is especially likely in situations where conceptual models are already being used to support management processes. Sources for influence diagrams include the National Park Service's Inventory and Monitoring Program and the Bureau of Land Management's Rapid Ecoregional Assessments. Influence diagrams can be constructed if they do not already exist. If influence diagrams are not constructed prior to building the scenarios, they still can be useful for documenting, vetting, and using the scenarios (Dermawan et al. 2012). For this purpose, the diagrams are constructed by interpreting casual statements in the scenario narratives or discussions leading to the narratives and then seeking verification of those relationships in the literature or from experts (Dermawan et al. 2012).

Cross-scale linkages

It can be helpful to identify drivers and impacts across multiple scales, especially for regional scenario planning that includes multiple jurisdictions, organizations, or decision making and implementation roles. Zurek and Henrichs (2007) discuss making linkages across scales for scenarios, comparatively assessed in Table 2.8. Single scale and loosely linked multi-scale applications have been the most common and most practical to implement. Dermanwan et al. (2012) and scenario planning efforts by the National Park Service (e.g., Case Studies 3.2 and 3.5) provide examples of loosely linked multi-scale scenarios using nested scenarios described below in Step 8.



Matt Baun

Oak woodlands

Table 2.8. A comparison of the degrees of linkages between scenario elements across scales in scenario planning exercises that considers multiple scales (modified from Zurek and Henrichs 2007).

Types of Linkages	Single scale	Loosely linked scales	Tightly coupled (cross-scale)
Number of focal scales	*1*	*2+*	*2+*
Consistency across scales of storylines describing scenarios	Not relevant	Storylines describing scenarios usually differ and are inconsistent	Storylines describing scenarios are consistent across scales with explicit focus on down- and up-scaling
Consideration of drivers at other scales	Exogenous drivers with relevance to focal scale are included	The set of scenarios is often constructed within a common broad conceptual framework that incorporates similar types of drivers at different scales	Exogenous drivers and constraints from higher and lower scales are included via down- and up-scaling procedures
Consideration of feedbacks between scales	Not considered	May or may not be considered	Explicit linkages between scales and incorporation of feedbacks
Main advantages	Simple, no distractions by concerns from other scales	Allows stakeholders at each scale to frame the issues that are important to them	Allows for consideration of feedbacks between scales and evaluation of how an issue plays out at different scales
Main disadvantages	Important feedbacks between scales may be missed or important externalities at other scales may be overlooked	Scenario outcomes at different scales or at different places are not directly comparable	Very costly; may lose credibility because stakeholders at, especially, lower scales may not have much latitude to define the issues to be considered
Example	All of the Case Studies in Section 3 of this guide	Southern Africa Millenium Assessment scenarios (Biggs et al. 2004)	Med Action scenarios (Kok et al. 2006)

Step 7. Assess and prioritize critical drivers

The goal of this step is to identify document high impact, low predictability external driving forces. There may be some drivers with critical impacts that are relatively certain. They should be incorporated into scenarios, but they do not form the basis for creating divergent scenarios that embrace uncertainty. The prioritization and selection of critical drivers strongly influences the scenarios that are ultimately developed.

Prioritizing drivers can be difficult for a group. Sometimes groups resist prioritizing or making choices, preferring to keep all their options open in considering external drivers. Some in the group may struggle with adjusting their initial thoughts about the uncertainty of some drivers (e.g., temperature increases) relative to others. Others may have to ‘let go’ of a specific issue that has been important in other processes and discussions. In a group process, attempts to bypass or minimize this step are common. If the larger group has too much difficulty with this step, it may be possible to designate a smaller group or an external group (e.g., the facilitator or consulting firm) to perform this step.

The number of drivers to identify in this step is open-ended, although some practitioners suggest aiming for two to seven drivers (Wiseman et al., 2011). The number of critical drivers can inform the choice of methods to use in Step 8. If only one driver can be identified, the use of scenario planning may not be the most appropriate overall approach, unless the direction of change is divergent.

If many drivers are identified, it can be helpful to categorize them. Useful categories may be climate vs. non-climate drivers, the STEEP categories, or some other designation. Prioritization then can occur within categories (e.g., the most important climate drivers) and across categories (e.g., the most important STEEP categories). If some key drivers are clearly short-term concerns and others are long-term concerns, categorization by time horizon can be useful.

It may be useful to use a graphical approach to prioritizing key drivers. An example from a multi-agency scenario planning effort for the Crown of the Continent region of the northern U.S. Rocky Mountains illustrates a simple graphical approach (Figure 2.2). In this example, both key drivers and internal system responses were identified because participants had difficulty distinguishing between external forces of change that could not be changed by decisions made within the region, and intermediate variables that reflect internal system responses that are, more or less, able to be managed in some way. This type of graphical analysis identifies the high impact, high uncertainty (low predictability) drivers on the upper right of the graph. High impact, low uncertainty (high predictability) drivers are on the upper left, and should be included in all subsequent scenarios.

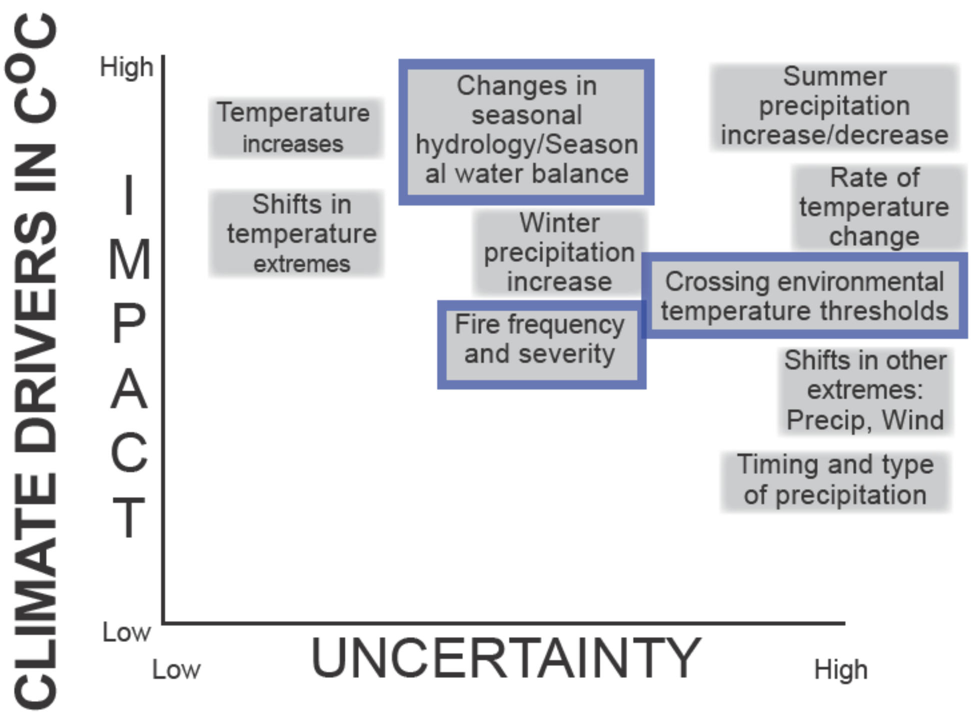


Figure 2.2. Example of a graphical approach for prioritizing critical drivers of change for drivers affecting the northern U.S. and southern Canadian Rocky Mountains. Blue boxes indicate internal system responses that participants wanted carried through in the discussion (adapted from Hartmann 2012).

Variants of this approach use four quadrants (Ratcliffe 2002, Figure 2.3). This approach more clearly identifies the significant trends that should be included in all scenarios, and the potential high impact situations that can emerge from indirect causal relationships that are highly uncertain (sometimes called "wild cards"). The disadvantage of the four-quadrant approach to prioritizing key drivers is its similarity with one of the most common approaches, the quadrant approach, for creating the logical structure of the scenarios, which is described in detail in the next step. While the similarity in form of these two graphical tools can be confusing for groups without experience in building scenarios, both can be helpful in organizing key pieces of the scenario development process.

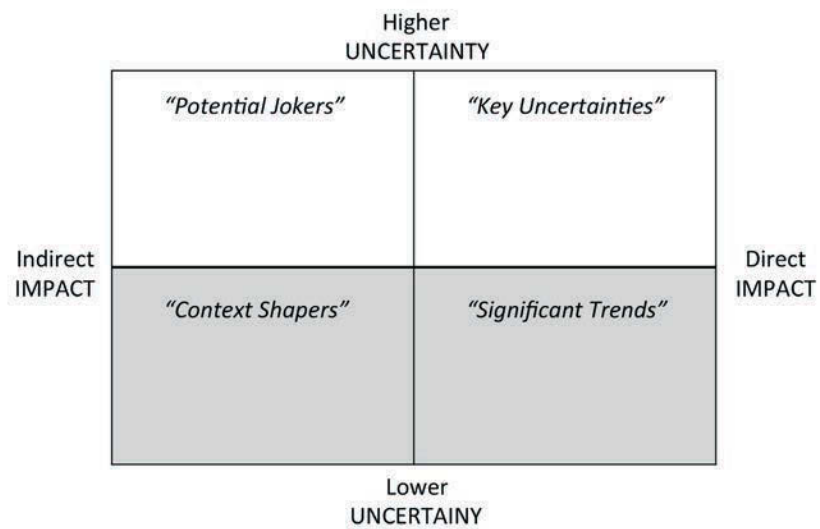


Figure 2.3. Four-quadrant approach for prioritizing and identifying critical drivers of change. The categories of the four quadrants suggest how each uncertainty might contribute to the overall scenario (modified from Ratcliffe 2002).

If a project team has the technical capacity and resources, the repeated visualization of scenarios derived from the larger pool of potential drivers can help narrow the list to a set of key drivers. Vargas and Flaxman (2012) used a series of workshops over an 8-month period to help stakeholders in southern Florida pinpoint the important drivers. Between each workshop, scenarios based on the information from the previous meeting were simulated and displayed at the next workshop for stakeholders to use to refine which parameters they considered to be most important.

Step 8. Explore and select scenario logics

This is the step in which the basic structure of the scenarios is developed and plausible and divergent scenarios emerge. There are many methods that can be effective. Several of these are summarized in Table 2.9 with more detailed descriptions in the text below. The specific method selected is not as important as a commitment to construct scenarios that are both divergent in character and magnitude. Thus, use of a single future bracketed with an upper and lower bound is not recommended. These types of scenarios are more appropriate for sensitivity studies (see Section 1) as they often do not result in divergent futures. Best case and worst-case combinations are also not advocated. A single future is rarely "all good" or "all bad," and even futures that pose many management problems can have "good" or "bad" aspects. Planning for "the worst" may seem easier than planning for the "very different," but this can limit strategic thinking.

Table 2.9. A summary comparison of methods for developing the structure of scenarios and the planning situations for which they are suited.

Method	Features
Basic Quadrants	■ Targets 2 key uncertain drivers generating 4 quadrants; ■ Intuitively straightforward; ■ Ensures scenarios are divergent;. ■ Can be expanded to >2 drivers (axes).
Nested Quadrants	■ Variant of Basic Quadrants; ■ Helpful for considering drivers at different spatial scales (giving context to initial driver); ■ Generates 16 quadrants that need to be reduced to 3-5 scenarios.
Chained Quadrants	■ Variant of Basic Quadrants; ■ Helpful for considering the interaction of near-term and long-term uncertainties (different temporal scales); ■ Chaining creates numerous scenario starting points that need to be reduced to 3-5 scenarios.
Dominant Themes	■ Helpful for considering multiple drivers or issues (>2); ■ Each scenario is developed around a driver or issue that dominates that future; ■ Allows inclusion of a "base case", official future, or continuation of current trends.
Decision Tree	■ Helpful if a specific future needs to be considered (managers have difficulty letting go of a preferred or least change future); ■ Scenarios branch off a base future, e.g., base case, official future, least change, preferred future; ■ Key uncertainties represent branches on tree.
State Change	■ Useful if interested in considering the linkages between drivers, thresholds, and system state changes; ■ Helpful for systems experiencing multiple stressors; ■ Comfort with influence diagrams/conceptual models recommended.
Flash Cards	■ End points of extreme values potential conditions for 5-10 key drivers represented on opposite faces of the cards; ■ Opportunity to consider futures based on several combinations of different drivers; ■ Can be fast-paced.

Although the number of scenarios to develop is not predetermined, often, development of three to five scenarios is recommended. Use of only two scenarios fosters perceptions of best case vs. worst case, or desired vs. undesired futures. The use of an odd number of scenarios can foster anchoring on a perceived middle ground as the most likely future. While use of more than three to five scenarios can be conceptually difficult for some, grouping scenarios into categories can help (Tucson Water 2004), and some applications can easily handle more scenarios


Ken Sturm/USFWS

Painted turtle

(e.g., Mahmoud et al. 2011, Case Study 3.1). Each of the scenarios can be given a creative and compelling name to facilitate engagement with stakeholders and the public. This is not essential (Tucson Water 2004), though, and naming can sometimes lead to preconceptions by decision makers.

All of the following methods require iteration to identify a strategic subset of scenarios to further develop. For each iteration, scenarios are developed as simple skeletons, bullet points, or outlines. The goal is simply to screen whether the scenario logics are plausible, internally consistent, and divergent, and will challenge current thinking related to the focus questions. Collectively, the scenarios should encompass the widest range of possible futures. Scenarios that seem unlikely but still plausible should not be dismissed. No method guarantees that the scenarios themselves are replicable (i.e., that the same scenarios would be developed by a similar group comprised of different individuals). However, the process used to create them can be replicated.

A range of methods for developing scenario logics is described below, including the basic quadrants, nested quadrants, chained quadrants, dominant themes, decision tree, state changes, and flash card approaches.

Basic Quadrants

The quadrant approach is one of the most commonly used methods for constructing scenarios. It is simple to implement and, if the axes are appropriately selected, ensures scenarios that are divergent in character. The basic approach is to use each of the highest priority external drivers as an independent axis with the divergent outcomes of those drivers represented by each end of the axis. Using two independent drivers and axes creates four quadrants, with each quadrant representing divergent conditions that form the basis for four scenarios. Use of three axes creates eight quadrants. Each additional axis increases the potential number of scenarios by another power of two, so the basic quadrant approach becomes unwieldy as more than two or three axes are considered.

The ordering and selecting of axes is iterative, with participants testing their choices by developing some simple scenario outlines and then evaluating which quadrants produce scenarios with the greatest diversity of conditions. With the final selection of the two or three dominant axes, participants outline the key characteristics of each of the four or eight scenarios and give them short, memorable names that encapsulate the essential nature of the scenarios. For the Crown of the Continent example (Figure 2.4) the scenarios selected were: Climate Complacency, Colorado Creeps North, Race to Refuge, and Volatile Surprise. Variants to the basic quadrant approach have emerged in different settings.

The basic quadrant approach can be implemented during a half-day workshop with little preparation or supporting information, but at a level that is useful simply as an introduction to the approach. When results are going to be used in the subsequent phase, participants typically need more time to iterate the process. Part of the difficulty in completing this step quickly is that the group is prioritizing only the two to three most important drivers, when it may have identified many critical external driving forces of change. The selection of the quadrant axes and making even simple statements about the resulting scenarios

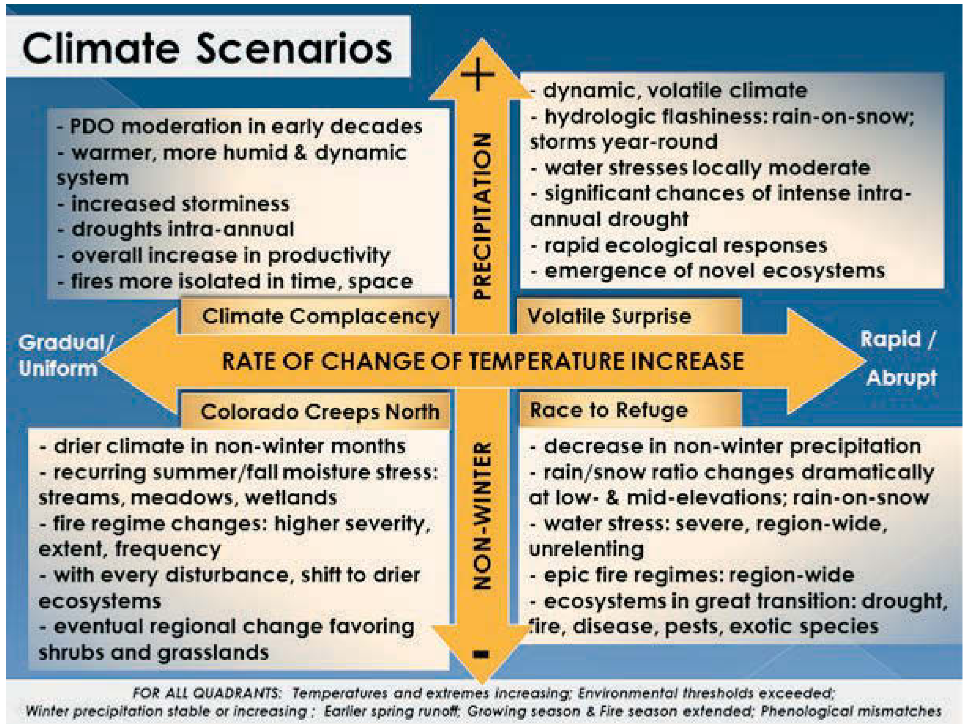


Figure 2.4. Basic climate scenario outlines developed using the quadrant approach based on the prioritized climate drivers in Figure 2.2. (from Hartmann 2012).

can require a lot of discussion about the drivers and their influence (Steps 6 and 7), and the participants have to bring sufficient background to the discussion. If this becomes problematic a decision tree approach may be more effective by allowing for multiple uncertainties and drivers to be addresses by different branches (see Figure 2.4).

Nested Quadrants
This approach was developed by the National Park Service and implemented through “train-the-trainer” workshops and several pilot applications in National Park Service units (Weeks et al. 2011). The nested quadrants approach starts with the basic quadrant method for two climate dimensions (NPS 2010). These four possible climate scenarios are then nested within a 2-dimensional matrix representing sociopolitical uncertainties that include federal leadership and national-scale social concerns (Figure 2.5). This produces 16 possible scenarios. Qualitative analysis of 16 scenarios is more than most groups can manage. Typically 3-5 scenarios are selected to be built out and assessed further. Transformation of the qualitative scenarios into quantitative scenarios can allow consideration of more scenarios (see Step 12), although that still requires developing basic outlines for each of the 16 scenarios and then transforming the outlines by linking them with quantitative models. The nested approach has proved useful for working with multiple jurisdictions that have different missions and objectives (Hartmann 2012), and in independent efforts to connect global, regional, and local scale issues (Dermawan et al. 2012).

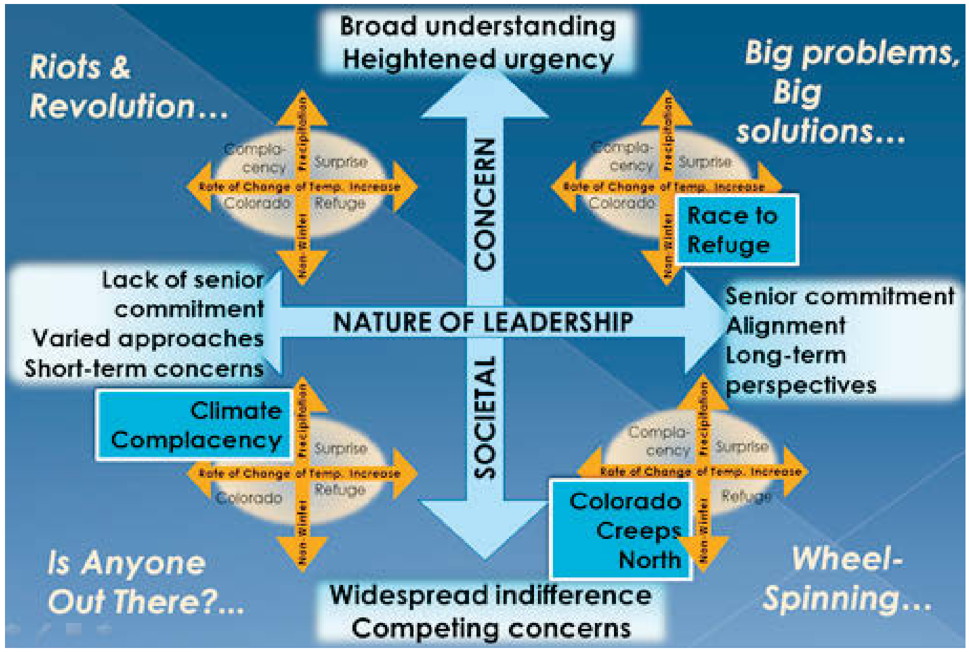


Figure 2.5. Climate scenario quadrants from Figure 2.4 nested within national socio-political quadrants, resulting in 16 potential scenarios.

Participants use an iterative approach in selecting the three scenarios they will build out in more detail, by screening each potential scenario for the essential characteristics listed below in Step 11 and Table 2.10. The aim is to seek scenarios that pose the most relevant and challenging situations for planners and managers to consider. The resulting scenarios can be given new names, or simple aggregations of the names within the nested quadrants. For example, the three scenarios selected from Figure 2.5 are named: Climate Complacency/ Is Anyone Out There; Race to Refuge/Big Problems-Big Solutions; and Colorado Creeps North/Wheel Spinning. They were selected by focusing on three frames that participants thought offered the most potential to challenge thinking about the future. The frames included: 1) If there are low levels of societal concern and leadership, can managers meet the challenge of even small, slow change?; 2) Even if managers are supported by the highest levels of leadership and societal concern, with concomitant resources and institutional flexibility, will that be enough to meet the challenges of abrupt change that will remake the regional landscape?; and 3) Would changes in policy alone offer enough flexibility to meet the challenges of inexorable climate change?

In the Crown of the Continent example, the nested scenario approach did not allow adequate consideration of the high impact and high uncertainty related to understanding ecosystem and cultural processes or estimating the effectiveness of management actions. For example, the processes and controls on invasive species, regional economic development, and wildfire management practices in the region are not understood with high certainty. Further innovation, experimentation, and testing to include these additional dimensions of uncertainty within the scenario planning process are needed. The Cienegas Watershed Partnership in southeast Arizona is exploring this type of additional nesting of scenarios to link regional climate scenarios with local management issues (Bodner et al. 2011, Caves et al. 2013).

Chained Quadrants
This is the approach used effectively by Tucson Water (City of Tucson 2004) and repeated shortly after completion to incorporate new uncertainties (City of Tucson 2008). This method uses the basic quadrant method, but for two time periods, one focused on key short-term uncertainties, and the other focused on long-term uncertainties (Figure 2.6). The two sets of scenarios are chained together, multiplying the number of scenarios to analyze. However, the scenarios can be grouped into "families" of scenarios for more efficient evaluation of adaptation options. One advantage of this approach is that it explicitly clarifies when to update, that is, as early uncertainties become resolved or as new uncertainties appear.

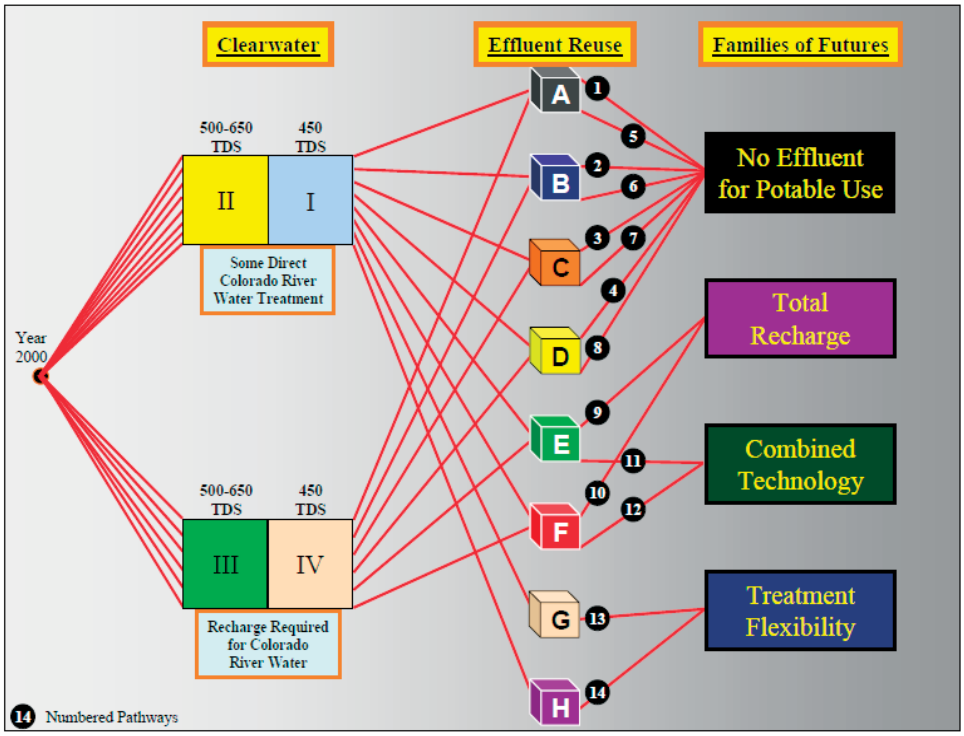


Figure 2.6. Chained quadrant scenarios created in the Tucson Water scenario planning exercise to address uncertainties that operate at different time horizons (Tucson Water 2004). The four Clearwater scenarios were produced using a 2x2 quadrant that reflects short-term uncertainties about preferred water treatment methods. The Effluence Reuse scenarios were produced from a 2x2x2 quadrant that reflects longer-term uncertainties about public acceptance of reused water, because implementation of this option could be delayed. The 14 plausible combinations were grouped into four families for use in considering water management options.

In a climate context, short-term uncertainties can reflect seasonal to interannual climate variability that can produce impacts that cross critical thresholds (e.g., loss of flowing water in key stream reaches, or the loss of a species). This is especially important as systems approach those thresholds, or produce cascading impacts (e.g., occurrence of extreme wildfire or sea level rise). In a non-climate context, critical short-term uncertainties may include the availability of funds to stem invasive species spread or approval of impending development activities.

Dominant Themes
The use of this approach may be preferred in some settings because it allows direct consideration of a "base case", that is, the continuation of current conditions into the future. Even though use of a "base case" is logically inconsistent with climate change science, some decision makers or planning processes may require this as an "official future." This approach focuses on a dominant issue in the construction of each scenario within a small suite of scenarios that collectively covers a wide range of issues, aligned with STEEP categories or some other meaningful themes (e.g., economics, environment, or climate change). For example, Denver Water used this approach to develop five scenarios, each with a different dominant theme (Yang 2009, see also Box 2.7).

Box 2.7. Denver Water Theme-based Scenarios

In 2009, Denver Water created five theme-based scenarios to support development of its Integrated Resource Plan. The group selected five planning futures with the goal of expanding their planning analyses:

1. Water Quality Rules: The public demands high quality of drinking water beyond current standards;
2. Hot Water: A mild climate change scenario brings ever-increasing temperatures and more severe droughts.
3. Green Revolution: environmental considerations are at the top of agency planning considerations.
4. Economic Woes: an energy crunch is combined with an economic downturn to pose challenges of affordability.
5. Old Future: a static climate, accompanied by recurrence of historically familiar and comfortable conditions.

All futures assumed that a permit for a new reservoir would be granted by the time the IRP was completed. However, the Integrated Resource Plan was subsequently delayed because the reservoir permit was not granted.

Decision Trees
Decision trees are variants of dominant themes or official futures, with branching that reflects key drivers and uncertainties. This approach can be useful when there are more critical drivers than can be accommodated by the other methods, or when key participants require use of an official future or some other specific future.

The National Park Service has been experimenting with a decision tree approach because some resource managers had difficulty considering management under the challenges posed by most of the climate change drivers and impacts. They begin with a "Least Change" scenario based on the smallest change produced from climate change projection studies. The purpose of the least change scenario is to establish that some level of climate change is inevitable and to bring managers to adaptation planning in an incremental way (NPS 2010, Gross 2012). A least change scenario is based on the smallest change in high impact climate drivers and the status quo of non-climate drivers. The state-change and flash card methods (described below) are then used to modify the least change scenario to produce additional scenarios. Case Study 3 in Section 3 describes an approach combining a least change future with flash cards to develop additional alternative scenarios.

State-Change Approach
In this method, influence diagrams are used to identify linkages among external drivers, thresholds, and state changes. Three scenarios are constructed on top of the "least change" scenario described above by modifying three different combinations of thresholds and state changes. The approach seems particularly


Ralph Tiner/USFWS

Riparian habitat

well-suited for systems experiencing multiple stresses (e.g., drought, invasive species, fire behavior changes), and for groups comfortable working with influence diagrams.

Flash Card Approach

In this method, a core group identifies 7-10 key external drivers and prepares flash cards with two extreme values or conditions for a given driver on each of the cards (e.g., GBN 2011, see also Case Study 3.3). Participants are asked to choose different combinations of the cards as the basis for developing 3-5 scenarios. In some groups, participants can have a difficult time focusing only on external drivers, and, therefore, keep trying to include uncertainties that are management choices or performance outcomes. In other groups, some individuals can dominate the process with their strongly held views about the importance of specific drivers. The flash card approach is a fast-paced exercise that deals with both problems by constraining the variables to be considered: the group works only with the variables presented on the flash cards. However, care must be taken to ensure that: 1) the combination of drivers produces internally logical plausibility; 2) any scenarios are divergent; and 3) the linkages between drivers, impacts, and management challenges are clearly described.

Step 9. Develop detailed outlines of the time evolution of scenarios

The objective of this step is to develop a causal chain within a scenario to move from the present through different periods of the future. This step fills in the "skeleton" outlines for the scenarios selected from the previous step. Some scenario planning efforts have focused on current conditions and scenario endpoints, omitting this step. However, articulating the pathways toward endpoints can help make scenarios more useful for considering time dependencies in decision-making, that is, identifying what actions might need to occur or what other decisions might need to be made and when. While different options exist for considering change in planning (e.g., the time-developing and period-change perspectives identified by Brekke et al. (2011)), both can benefit from development of scenarios that explicitly include a temporal change component.

Outlining the time evolution of scenarios provides additional transparency about how participatory input is incorporated into specific scenarios and the resulting narratives. It is common in this step for participants to want to immediately start identifying management responses. However, the outlines should focus on describing conditions that present management challenges, not the responses to those challenges. Facilitators can note ideas as they are mentioned for use in Phase III activities described below.

A good practice is to use an influence diagram to describe how changes are propagated throughout the system, such as by amplifying feedbacks and crossing thresholds that produce state changes that cascade throughout the system. However, it is also important to incorporate conditions that will be common across all scenarios. This includes driving forces with high certainty (e.g., temperature increases) and elements that change at a slower rate than the time period under consideration (e.g., highway networks or existing developments).

A simple approach for this step is to combine relevant information from the drivers and impacts tables and influence diagrams into a matrix, contrasting each scenario and subdividing the drivers and impacts into specific time periods (e.g., a beginning, middle, and an end period). The matrix helps ensure each scenario differs in character, even though some elements may be common across all scenarios (e.g., increased temperature). The time periods should correspond to periods that are meaningful for decisions. A creative, fast-paced way to prompt group thinking for this step is to develop a timeline with headlines, events, and key details (Olgilvy and Schwartz 1998).

Step 10. Develop scenario narratives

This step involves developing compelling stories for each of the scenarios, and is fundamentally a creative process of storytelling incorporating information from the drivers and impacts tables, and management issues and larger sociopolitical concerns raised in the group discussions. It also focuses on describing the meaning and reasoning behind the combination of drivers and their implications. Good scenarios provide decision-relevant insight, are plausible, internally consistent, divergent, memorable, and challenging to conventional thinking and assumptions.

The scenario narratives emerging from this step are stories. From a practical perspective, there are several ways to approach writing and telling the scenario stories, including:

- Assigning one individual to write all the stories;
- Having everyone in the group participate in developing the stories,;
- Having individuals or small groups write the stories, which are then modified by another individual or group in an editing process aimed at telling the stories in common narrative styles and consistent voice.

The stories can be fairly simple (e.g., a two page brief covering three management periods throughout the century) (Hartmann 2012) or relatively complex (Tucson Water 2004). If the purpose of the scenarios is to garner attention and support for consideration of uncertainties, the communication style might be different than for an internal organizational process.

In developing scenarios for public communication and consideration, it can be helpful to think of specific characters and plot lines describing challenges facing each character, and "good" aspects as well as "bad" aspects (i.e., they should present opportunities as well as challenges). Plot lines can take many forms (Duinker and Grieg 2007, Mahmoud et al. 2009), but some are more appropriate for business planning, others for emergency planning, and so on. Common plots lines particularly appropriate for climate change adaptation include: Winners and Losers, Crisis and Response, Perpetual Transitions, and New Generations/New Cultures. For each scenario, the story should provide a compelling description of the challenges and opportunities facing different characters within the system, due to external forces beyond their control.

Step 11. Evaluate scenarios

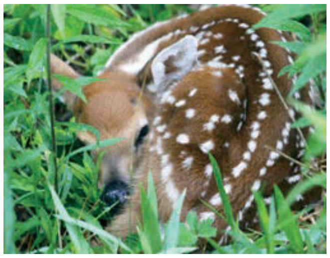
In this step, scenarios are reviewed and vetted by others to evaluate the quality and characteristics of the scenarios relative to the intended purpose. Creators of the scenarios may return to the key participants involved in the process and ask them to vet the scenarios. Alternatively, outside individuals may review the scenarios. A simple screening of scenarios aims to confirm that they embody the key characteristics of good scenarios recommended by Wiseman et al. (2011), including:

- Decision making power;
- Plausibility;
- Range of alternatives;
- Differentiation;
- Logical consistency;
- Memorability;
- Challenging to perception about future.

A more complex screening can be used to confirm both the process used to create scenarios and their characteristics. Table 2.10 shows a variety of characteristics of both process and outputs that make scenarios effective. Use of the scenarios also serves as a way to evaluate them, sometimes revealing flaws in the logic or management constraints not previously incorporated (Mahmoud et al. 2009, Wiseman et al. 2011). Thus, it may be appropriate to modify scenarios, either at this point or later in the process.

Table 2.10. Characteristics of scenarios and the processes used to create them that make these scenarios effective. Not all characteristics are relevant to all scenario planning efforts. Different situations may require a focus on different subsets (adapted from MacKenzie et al. 2012, Wiseman et al. 2011 and others).

Characteristic	Description	References
Relevant	Do the scenarios align with the problems and questions of interest? Are they relevant to the participants/managers? Scenarios that address issues of importance, contributing specific insights, are more likely to have an impact on policies, management choices and investments under consideration.	Mietzner and Reger 2005, Alcamo and Henrichs 2008, Lindgren and Bandholm 2009
Participatory	The process of scenario development and analysis can have as much—or more—impact on decision makers as the final results. Stakeholder engagement can build understanding, identify conflicts, help develop consensus, build broad ownership of results, facilitate negotiations, provide a platform for dialogue among differing interests, and ensure results are seen as legitimate.	Cash and Moser 2000, Wiseman et al. 2011
Legitimate	Was the range of experts and/or stakeholders involved in the process broad enough to be acceptable by potential users? Are the messages of the scenarios perceived to be fair, avoiding the promotion of specific beliefs or values? Are participants satisfied with the process used to develop and communicate the scenarios? Are varied and competing views represented to help participants appreciate others' perspectives and reevaluate their own assumptions and values?	Xiang and Clark 2003, Cash et al. 2003, Alcamo and Henrichs 2008
Plausible	Do the scenarios tell coherent stories that could conceivably happen? Scenarios may contain surprising or unexpected events, but need to be viewed considered plausible.	Mietzner and Reger 2005, Lindgren and Bandholm 2009
Understandable and Memorable	Are the scenarios accessible to the target audience? One of the main benefits of scenarios is that they tell compelling stories.	Lindgren and Bandholm 2009
Distinct	Are the scenarios sufficiently dissimilar to show contrasting climate change or other impacts? To show clear tradeoffs, scenarios need to be distinct, not represent variations on the same theme.	Mietzner and Reger 2005, Lindgren and Bandholm 2009
Scientifically Credible	Are scenario storylines and other outputs scientifically robust and credible? Are the relationships and content of the scenarios compatible with current understanding of the world? Are the different assumptions about drivers and resulting change in conflict? Was the development procedure transparent?	Cash et al. 2003, Alcamo and Henrichs 2008
Comprehensive	Do the scenarios consider all relevant drivers? Exogenous global drivers—such as demographic transformation, climate change, and economic growth—are beyond the control of decision makers, but are increasingly having impacts at regional and local scales.	Biggs et al. 2007, Carpenter 2009
Iterative	Are the scenarios refined and revised on the basis of emerging trends? An iterative scenario development process can improve the quality of the final scenarios, as well as cultivate understanding, trust and more detailed discussions among decision makers, scientists and technical experts.	Liu et al. 2007
Challenging	Do the scenarios challenge assumptions and broaden perspectives about unexpected developments? Scenarios can provoke creative thinking, challenge current views about the future, and inform people about the implications of uncertainty.	Mietzner and Reger 2005, Lindgren and Bandholm 2009


Ken Sturm/USFWS

Fawn

This step also considers how to present the scenarios to others, with the approach dependent on the key audiences who will be working with them. Some efforts have simply presented scenario outlines and schematics. Other efforts create immersive environments using more traditional community planning and visualization methods. Use of complex or expensive communication methods risks attributing more importance to the scenarios than is warranted. This is because the scenarios are only possibilities to expand thinking rather than predictions or projections (Duinker and Grieg 2007), and evolving science and observation requires frequent revision. Use of just a few pictures can be highly effective as can an analogous description of locations currently embodying the attributes or challenges facing your region in the future (e.g., drought in the Chihuahuan Desert in New Mexico and Texas in 2012 to represent possible future drought challenges in Arizona).

A more formal evaluation process can be helpful, especially in assessing and communicating perceptions about the scenarios, although very few scenario applications have incorporated formal scenario reviews. Alcamo and Henrichs (2008) offer several criteria for evaluating scenarios that can be used by participants involved in vetting or using scenarios, for example, via survey questions posed as part of the scenario review process. The criteria and their relative importance vary according to the intended use of the scenarios (education, research, strategic decision making), and some criteria may conflict. Hartmann (2012) used the criteria to test whether scenario narratives developed in advance by a small group were accepted later by a more diverse audience of workshop participants. Criteria for evaluating the scenarios, and their order of importance, were selected prior to the construction of the narratives, following the guidelines suggested by Alcamo and Henrichs (2008).

Creativity is a higher priority when scenarios are intended to:

- Challenge the views of participants, especially concerning whether future systems will generally look like the past;
- Challenge whether science can provide reliable predictability about future changes in climate or its impacts over the long term;
- Provoke new thinking about evolving objectives.

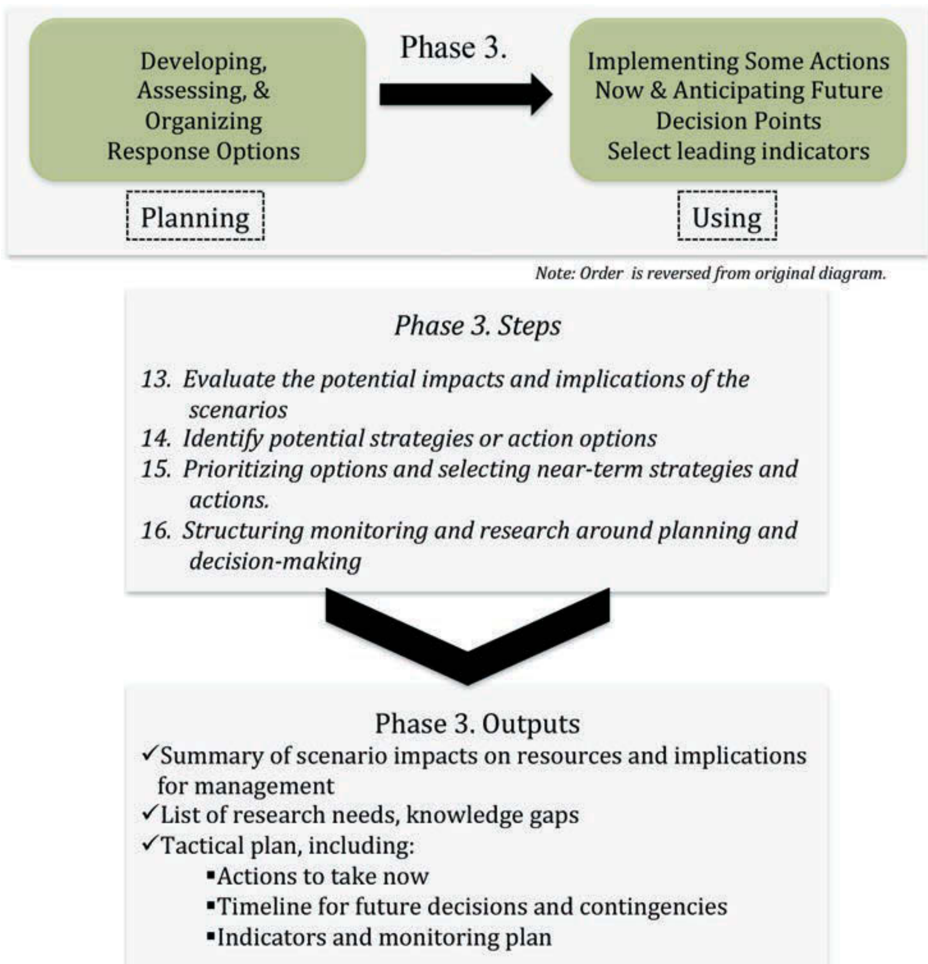
In settings where scenario planning involves a mix of agencies with different missions and management objectives, or where many participants cannot be involved in the creation of the scenarios, relevance and legitimacy are important criteria. Legitimacy is important when scenarios are used within a public planning process, while credibility is a priority when the scenarios must conform to scientific practice. At minimum, scenarios must be credible enough for participants to be willing to engage with them during Phase III (Using Scenarios).

Step 12. (Optional) Quantifying and simulating scenario narrative

This is an optional step in which elements of the scenario narratives that can be represented in quantitative models are quantified. Not every set of scenario narratives will need to be converted into quantified scenarios or run through simulation models. However, even the simplest scenarios can be used as input to simulation models, as long as there is some alignment between the variables considered by the simulation model and elements of the scenario narratives (see Box 2.2 above for more information about representing scenarios quantitatively). Mahmoud et al. (2011) show how scenario narratives based on high impact and low predictability climate, economic, and demographic dimensions can be interpreted to drive water management models, by mapping scenario narrative elements on model inputs, parameters, and calculated variables. Conceptual models and influence diagrams can help identify appropriate links between the quantitative model and the scenario narratives, while studies that have been synthesized into the drivers and impacts tables can be used to set model parameters or select input time series. If multiple models or time series are available to represent a given scenario, ensembles can be used to characterize a range of modeled conditions associated with a specific scenario narrative.

2.3 Phase III: Using Scenarios

Phase III Summary



"Crossing into the realm of risk assessment, scenario assessment uses techniques such as influence diagrams, event trees, outcome matrices, contingency planning, cost/benefit analysis, Delphi techniques, normative tables and vulnerability assessment, among others. Scenario assessment relies on extensive discussion among stakeholders and researchers."–Mahmoud et al. 2009

Phase III of scenario planning is the stage at which planning and decision-making become integral. During this phase, the scenarios are applied to assess potential impacts, consider implications for management, and develop responses. Several of the steps in Phase III are not unique to scenario planning. There are a few elements, however, that most differentiate scenario planning from many other decision-support methods:

- The effects of several plausible futures on resources, rather than simply the one most likely future, are examined;
- The appropriateness of new and existing actions or strategy options is tested against multiple future conditions;
- Future decisions and their triggers are explicitly articulated while choosing actions to implement in the near-term.

This effort to identify contingencies and triggers is explicitly linked with monitoring. While monitoring is a component of many decision frameworks, such as adaptive management (Williams and Brown 2012), the kinds of indicators highlighted by a scenario planning exercise may differ from those arising from other decision support methods, due to the nature of the uncertainties addressed.

Step 13. Evaluate the potential impacts and implications of the scenarios

The goal of this step is to evaluate the ways in which the different scenarios constructed in Phase II might directly and indirectly affect the natural resources of concern (Mahmoud et al. 2009). A table with the different scenarios listed as row headers, resources of concern as column headers, and the potential impacts of each scenario filling the cells, is often employed. The list of potential impacts could derive from expert opinion, literature reviews, the output of models used to assess specific impacts, other research, or some combination (Price et al. 2011). For example, Case Studies 3.1 and 3.6 employed quantitative methods to examine effects of sea level rise and other factors on coastal species in Florida and California, respectively. The results to this point could represent a climate change vulnerability assessment considering multiple future climate scenarios (Glick et al. 2011, Crist et al. 2012).

Participants then assess the implications of the scenarios and associated impacts for making management decisions. For example, in one climate change scenario developed for the National Park Service's Assateague Island National Seashore, increasing sea level rise is coupled with increasing storm frequency and intensity. Under this scenario, more frequent over-wash events and episodes of erosion on the barrier islands would likely occur. These impacts have the additional potential to deteriorate and reduce the freshwater ecosystems supported by the shallow freshwater aquifer. The implications of saltwater intrusion and land loss for the iconic wild horses and other priority wildlife species dependent on freshwater systems on the island include significant declines in the availability of potable water and habitat. This leads to management questions about sustainable population sizes for these species and how to maintain them (GBN 2009). Another example described in Case Study 3.6 looks at how different inundation scenarios might affect land conservation and restoration priorities for tidal marsh bird habitat in San Francisco Bay using a combination of quantitative tools.

Impacts and their implications are not always negative, and there is value in considering the potential opportunities that might arise under different scenarios (Wiseman et al. 2011). Thinking about implications related directly to the institutions, organizations, or stakeholders involved in the exercise is also important, especially for informing later steps aimed at identifying which groups would be responsible for making specific decisions or implementing specific actions (Wiseman et al. 2011).

Step 14. Identify potential strategies or action options

Managers and conservation practitioners play an especially key role in this step, in which participants identify potential strategies and actions to achieve management goals in light of each scenario. Some questions that should be addressed in this step include:

- Should we be thinking about this issue or resource of concern differently (i.e., revisit Phase I and defining the issue)?
- Do our current actions or strategies associated with this resource still make sense in light of the ways that the future might unfold? If not, how should we modify them?


Gary Tucker

Spanish moss

Should we be thinking about this issue differently?
Before moving onto action and strategy options, it may be valuable to reflect on whether the discussion of impacts alters how the group wants to frame the focal issue or problem. This might include asking:

- Do the management implications of the scenarios fall within the purview of the current participants, or should others be involved?
- Is there key information missing?
- Do we need to reassess our goal or management objectives for this resource?

Revisiting some of the previous phases or individual steps may be warranted at this point if key information or stakeholders are deemed missing. Alternatively, participants can continue through the remaining steps while documenting information gaps and other needs. A need to reframe the issue or reconsider objectives might argue for starting with a rapid, tabletop-style scenario planning exercise before investing heavily in a more time-consuming and comprehensive scenario planning effort.

Do the current actions or strategies associated with this resource still make sense in light of the ways that the future might unfold?
It is possible that new actions to achieve existing goals, or even revised goals, will be needed in response to the implications of one or more future scenarios. A group can consider this question in one of two ways, or a combination of both. One approach is to take a look at current strategies and actions (i.e., what we are already doing) to determine whether they will continue to be sufficient to achieve the goals and objectives for the conservation target under each of the future scenarios (e.g., Wiseman et al. 2011, Cross et al. 2012). From this assessment, decisions can be made about whether to keep implementing current actions without any modification, to cease unproductive or counterproductive activities or modify current activities. For example, changes in seasonal precipitation regimes may require a shift in the timing of prescribed burns to maintain effectiveness. Case Study 3.3 describes an example of how scenarios were developed to assess strategies in an existing resource plan to identify necessary revisions.

A more open-ended approach to this question is to start with goals and objectives, and broadly brainstorm the strategies or actions needed to continue to achieve them in light of each scenario. To help guide this discussion, it may be valuable to look for "intervention points"—places in the system where management actions or strategies can influence outcomes for the resource. Intervention points often can be identified within a conceptual model or influence diagram, and there may be one readily available if developed earlier in the process to guide scenario construction or the discussion about management options (Cross et al. 2012). This approach may be more likely to reveal novel strategies and actions than one focused primarily on examining current activities. Most useful is a combination of the two approaches so that current activities are re-evaluated and potential new activities can be identified.

Types of interventions for resource management might fall under categories such as land and water protection; land, water and species management; and regulatory and policy changes (e.g., Mawdsley et al. 2009, Cross et al. 2013). This approach can also lead to a re-examination of goals, if none of the activities suggested seem able to ease the impacts of the scenarios considered (Smith et al. 2011, Stein et al. 2013). A table illustrating the links between the potential impacts or implications of one or more scenarios, the intervention points, and response actions or strategies is often used for structuring the output of group discussions (e.g., see Degiorgio et al. 2010). It is good to be clear about which scenarios require which responses, and spell out how particular actions might influence trajectories of change in the resource to aid in the development monitoring indicators (e.g., CMP v. 3.0 2013).

Scenario planning efforts designed to broaden understanding of a decision problem and to consider impacts and vulnerabilities to help identify options for planning (e.g., many initial climate change adaption planning efforts) often stop at this point. However, scenario planning efforts that are structured to help practitioners make decisions about which actions to take should proceed to the next step.

Step 15. Prioritizing options and selecting near-term strategies and actions

Some scenario planning efforts aim to support decision making by prioritizing and selecting options for implementation. Long lists of options may be evaluated and prioritized based on any number of established criteria (Table 2.11). This step involves moving from *planning* to *managing*, and falls into the realm of decision-making (Figure 2.7). To be defensible, final choices should clearly reflect the objectives identified for the resources of interest by the groups participating in the process.

Table 2.11. Potential criteria for evaluating and prioritizing adaptation options (from the process to develop Washington State's Climate Response Strategy, http://www.ecy.wa.gov/climatechange/2010TAG.htm).

Criteria	Relevance
Importance	How important are the predicted climate change impacts addressed by this adaptation option? Are they likely to affect unique or valuable species, ecological functions, or other natural resources? What is at stake if we do nothing?
Urgency	What are the costs of delaying action? Is it likely to cost more to implement later rather than now? Will we lose species, resources, or options by delaying action? Are the consequences of not acting now irreversible?
Co-Benefits	Are there benefits to this action beyond the adaptation objective? Will the total benefits exceed the cost of implementation? Are costs and benefits equitably distributed?
Feasibility	How feasible is the proposed action given existing laws, regulations, policies and the political climate? How technically feasible is it? Is there an opportunity to adapt existing strategy/actions, or will entirely new initiatives be needed?
Robustness	What is the likelihood that the proposed action will be effective across the range of future scenarios? Does it allow for adaptive management?
Cost	How costly will this proposed action be in terms of time, money or other resources? Is there opportunity to adapt existing strategy/ actions?
Others	■ Consistency with national laws/policies; ■ Equity; ■ Impact on greenhouse gas emissions; ■ Economic efficiency; ■ Technical feasibility; ■ Scale specificity.

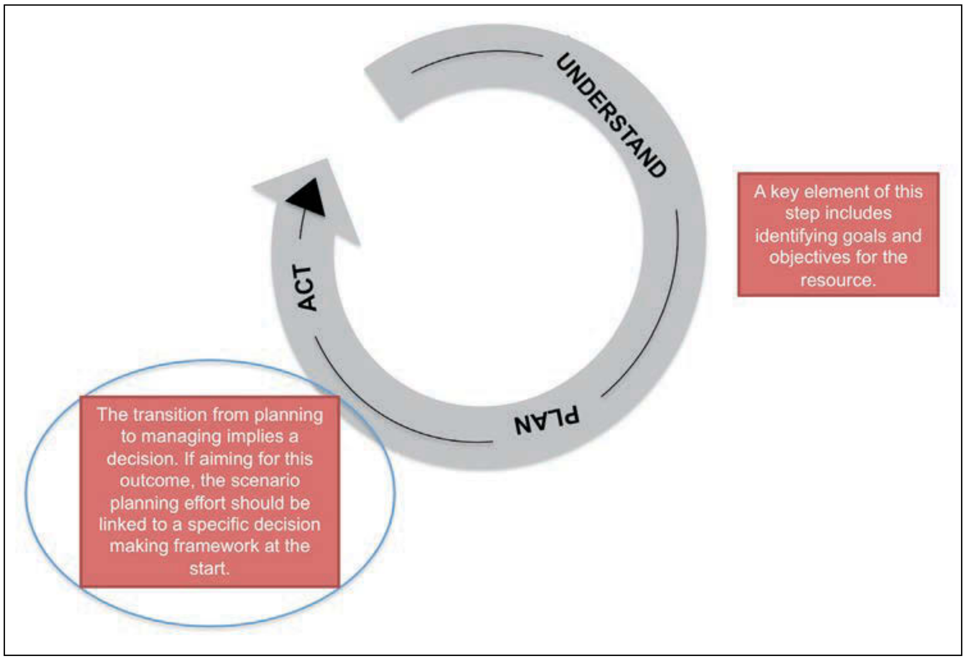


Figure 2.7. A slight modification of Figure 1.8 highlighting how the transition from assessing options to selecting and implementing actions for implementation requires making decisions, which may best be made within a specific decision making framework.

In addition to the criteria outlined in Table 2.11, it can be helpful to evaluate the likely effectiveness of proposed actions under changing conditions, and to categorize actions based on their applicability in the near- and- long-term under some or all future scenarios.

Evaluating options with existing or new scenarios

Up until this point the guide has mainly focused on developing scenarios of the future to generate management options or alternatives. Scenarios may also be used to assess the consequences of acting on the different alternatives. This might be done in the context of a structured decision making process (e.g., Ogden and Innes 2009, Gregory et al. 2012) or other decision-making framework (e.g., McKenzie et al. 2012, Ram and Montibeller 2012, Bhave et al. 2013). The scenarios used to assess the consequences of taking particular actions may be the same ones used to identify management options, or it may be necessary to create new scenarios.

In this situation, the planning group is taking a look back at the scenarios themselves to consider how the identified action options might alter the trajectories of the scenarios (Wiseman et al. 2011). This activity serves to confirm that the scenarios remain feasible, as well as to ensure unintended consequences do not result from the identified actions. This is particularly important if there is more than one objective to be met by the management alternatives. In this case, the exercise serves to highlight tradeoffs between meeting each objective under each scenario.

Endangered species recovery planning offers a hypothetical example. Under scenario A, the geography of interest becomes so dry that amphibian X is unlikely to persist in the region for many more decades. Under Scenario B, the climate remains within the tolerance range of amphibian X, but species recovery is still expected to be impaired because of concomitant increases in human land


USFWS

Karner blue butterfly

development and enhanced climatic suitability for a competing amphibian species. If planners mostly focus on Scenario B, a key strategy might be to take actions to minimize human development impacts within the current range of amphibian X. However, if climatic suitability for amphibian X is negatively affected (as described in Scenario A), focusing on land development prevention in the species' current range may inadvertently shift human populations into the region that turns out to be the most suitable for the species in the future. In this example, it is important to try to balance actions and gauge their effectiveness across multiple scenarios simultaneously.

If one of the proposed management options is associated with high uncertainty, it may be useful to craft new or additional scenarios that explicitly address those sources of uncertainty. For example, consider a hypothetical scenario planning exercise that examines the effects of climate change and increases in angling pressure (both recreational and commercial) on a highly prized trout fishery. Among other actions, the multiple scenarios considered may point to the need to install dams for water storage, but it may not be clear where to locate the dams because their effect on local hydrology and uncertain interactions between dams and climate change were not addressed in the original scenarios. In this case, a new set of scenarios specifically addressing stream hydrology may be helpful in deciding whether or not to take the action, and if so, where. An analysis conducted by Seidl and Lexer (2013) in the context of sustainable forest management in Austria offers another example. For this effort, the performance of two alternative management strategies is compared across a set of future scenarios with respect to established indicators of sustainable forestry. The scenarios integrate climate projections with alternative future social demands on sustainable forest management. In a land-use planning example, the consequences of three proposed adaptation strategies on multiple sectors (including biodiversity) are examined in a participatory scenario planning process (Albert et al. 2012). Participants, using spatially explicit simulations of what the future might look like under the different strategies, assess the impacts of the three options on the different sectors.

Characterizing action options

Scenario planning can help determine which current actions still make sense regardless of what the future holds. It can also help identify new near-term actions that may achieve objectives across all or most of the future scenarios. These options are typically referred to as being "robust" to uncertainty in knowing which scenario will actually unfold in the future.

In some cases, though, it may not be possible to identify many truly robust options; or it may not be desirable to pursue the robust actions. There may be reasons for implementing some options that are appropriate under only one or a few scenarios. Even if there are robust options available, they may be turned down because of the way they limit future opportunities (Wilby and Dessai 2010, Wiseman et al. 2011). For example, building a sea wall might be considered a robust strategy for curbing the negative effects of sea level rise on important natural and human resources under a wide range of future scenarios. An alternative might be to restore a natural ecological system to buffer that same coastline from the effects of sea level rise, but this option might not offer protection to valued infrastructure under some sea-level rise scenarios. While the sea wall may be considered a more robust option because of its applicability under all future scenarios, the sometimes irreversible damage that sea walls cause to ecological systems might have unanticipated consequences and limit the options for using natural systems in the future.

For these situations, "contingent" and "bridging" strategies and actions can be identified (e.g., Gilson et al. 2013). Contingent options are applicable to only one or a limited set of scenarios. The implementation of the contingencies occur over time and are linked to the results of monitoring efforts designed to help understand the course of the future as it unfolds or research conducted to fill information gaps.

Bridging or transition actions differ in that they are near-term choices that link to anticipated decisions, conditions, strategies and actions further in the future. These are not necessarily preferred or robust options, but they may be needed until something more effective or permanent can be implemented. The California Condor captive breeding program is an example of a bridging action. It was designed to maintain the genetic viability of the species until habitat and mortality issues could be better managed for wild populations. However, in order to develop bridging options, the scenario narratives and quantitative or spatially explicit simulations needed to describe pathways to and conditions at different time steps; that is, how one gets from current to future conditions (Alcamo and Henrichs 2008). Snap shots of end-points alone will not fully enable the consideration of links between near-term and long-term options.

By combining robust, contingent, and bridging options, scenario planning can suggest a portfolio of strategies and actions to implement immediately and at different points in the future in response to changing conditions. To do this, the group of response options initially generated for the different scenarios is separated into two categories: "what makes sense now" and "what we might consider a little down the road, if we make certain near-term choices or certain events take place." Sets of near-term and long-term options are then organized to articulate the links between the two and the associated decisions points.

Step 16. Structuring monitoring and research around planning and decision-making

Scenario planning is ultimately about embracing uncertainties linked to unpredictable change in a planning or decision-making context. While the uncertainty associated with some drivers may remain irreducible, monitoring programs and research can help fill information gaps related to other uncertainties. Designing and implementing monitoring is an undertaking requiring its own process, and there are numerous existing resources. A few key questions to consider in this step include:

- What decisions might need to be confronted in the future?
- What triggers should be monitored to help identify and shape decisions down the road?
- What are the research or information needs given the differences among scenarios?

As the future unfolds, scenarios should be reviewed and evaluated to determine whether the current plans should be modified or if new scenarios are needed. While the value of good scenarios includes their ability to help decision-makers avoid dangers and achieve desired objectives (Godet and Roubelat 1996), these attributes can only be tested at the conclusion of scenario development through scenario monitoring and post-audits, a process that is also widely referred to as adaptive management.—Mahmoud et al. 2009

What decisions might we have to confront in the future? What triggers should we be monitoring to help identify and shape decisions down the road?
When implementing management actions, it is important to monitor whether those actions are achieving their intended objective. This kind of monitoring is a widely recommended element of most natural resource management and is an especially critical part of adaptive management (Williams and Brown 2012) and structured decision-making processes (Gregory et al. 2012). Such a monitoring effort aims to select indicators that help to improve the understanding of mechanisms by which management actions affect the resource of interest. This is particularly useful for reducing uncertainties in predictive models of system relationships and management decisions (Williams and Brown 2012).

More specific to scenario planning, the identification of actions that might be enacted in the future requires the identification of decision points and the indicators and thresholds that might act as triggers for shifting course. The City of Tucson's water plan offers an example of how decision points and associated indicators can be represented and organized with an action timeline (Figure 2.8). The purpose of this kind of monitoring, particularly in the context of climate change, would be to assess the state of the system to understand which of the future scenarios appears to be unfolding and which predetermined actions may therefore become appropriate. Some indicators should be selected to measure those elements that differentiate among scenarios. Additional indicators related to unknowns about the responses of focal resources to the different scenarios can be chosen to help trigger the implementation of particular management actions. Fixed events, observable trends, and ongoing external processes may all serve as indicators (Mahmoud et al. 2009). In the Tucson Water example, water quality (measured by levels of total dissolved solids) acted as the indicator that triggered the first decision point identified in the scenario planning exercise (Tucson Water 2004).

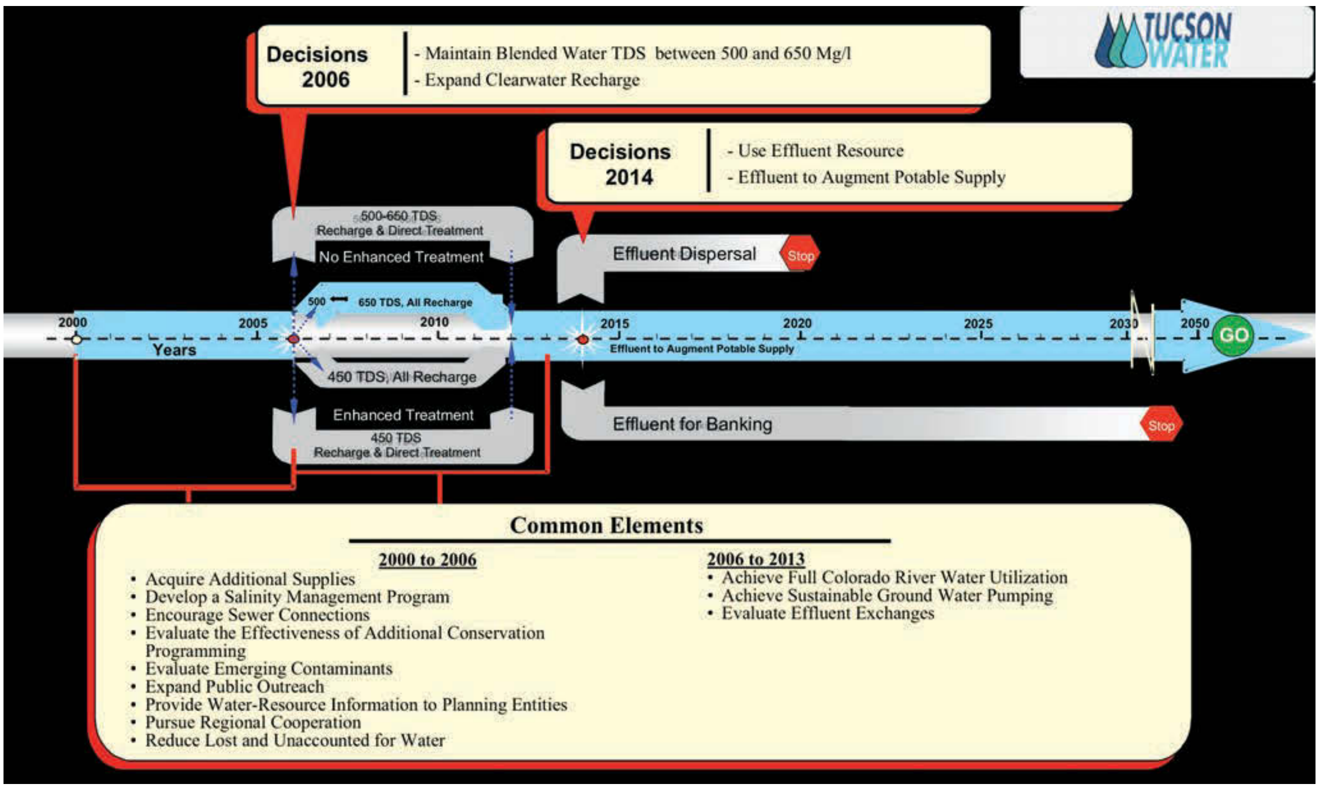


Figure 2.8. Example of a timeline from the City of Tucson's Water Plan for 2000-2050 that was developed using a scenario planning approach. It shows robust actions ("common elements") and future decision points to select between actions associated with particular scenarios (from Tucson Water 2004).

What are the research or information needs given the differences among scenarios?

Ideally, research and other information gaps are identified and documented as a planning group works its way through the scenario planning process. These may be related to uncertainties about the drivers of change and the biological response of the system, the effects of management alternatives on the natural resources of interest, as well as other missing information. Some of these research needs may be filled by a more thorough look for existing data or on-going research projects. Others may require investment in new analyses by the group or particular participants, either by conducting the research themselves or in collaboration with outside experts.

There will likely be no shortage of information needs identified during planning, but resources, both time and money, are always limited. The challenge is deciding which uncertainties are reducible over the timeframe of the decision, and will contribute most to informing decisions. The planning group can start by examining the list of research needs and the types of uncertainty they reflect (see Section 1.2). "Value-of-information" analysis, a type of sensitivity analysis, offers one tool for directing research efforts in natural resource decision settings (Runge et al. 2011). While often applied in situations in which some level of optimization is a decision criterion (i.e., selecting an option or set of options that satisfies the maximum number of objectives), this tool can also be appropriate for problems with substantial uncertainties (Moore and Runge 2012). Sensitivity analyses can contribute to understanding which components of the system are most responsive to changes in inputs. These types of analyses can help target information-gathering efforts towards resolving uncertainties with the greatest potential impacts on decision outcomes (Mumby et al. 2011).

2.4 Revisiting the scenario process

Several experts and practitioners suggest that although scenario planning is of some value as a stand-alone effort, it does not fulfill its full potential as a decision support method when it is conducted just once (e.g., Alcamo and Henrichs 2008, Mahmoud et al. 2009, Wiseman et al. 2011). Wiseman et al. (2011) suggest that at the outset of a scenario planning exercise "careful consideration should be given to the way in which…outcomes are to be integrated with strategic planning and decision making," and that scenario planning becomes "…embedded as an ongoing driver of organizational culture and decision making." Whether a long-term commitment to scenario planning is necessary to even pilot an exercise is debatable. However, the intent is for the process to be iterative and build on previous efforts by revising scenarios and the understanding of their impacts as new information becomes available. Changing conditions might require repeating particular phases or steps, or perhaps the entire process. Such revisions can identify emerging problems and inform adjustments to objectives for particular resources and shifts in priorities (Mahmoud et al. 2009).

The City of Tucson Water Department is one example in the realm of natural resource management where scenario planning was adopted and the process repeated as a decision point identified in the initial exercise was reached and important new uncertainties uncovered (Tucson Water 2008). Additional scenarios were created in response to the observed changes, the results of which were documented in a revision to the original water plan. Two other examples from the case study section (Case Studies 3.1 and 3.7) highlight scenario-planning efforts that have expanded on scenario planning work previously done in southern Florida (Vargas and Flaxman 2012).

2.5 Communicating scenario planning outputs and assessment

Whether an expert-driven or broadly participatory scenario planning exercise, there will likely always be stakeholders for whom the outcomes are relevant, but who were not included in the effort. One of the ascribed values of scenario planning is the potential to orient communication to a wide-ranging audience (e.g., Ogilvy and Schwartz 1998, Wright et al. 2013). Communications might take the form of written narratives or stories (GBN 2009, Soliva and Hunziker 2009), tables (Tucson Water 2008, Mahmoud et al 2011), images and 3-D visualizations (e.g., Burch et al. 2010, Cohen et al. 2011), and spatially explicit maps and graphics (e.g. Bolte et al. 2006, Galatowitsch et al. 2009, Sohl et al. 2012) depending on the target group. Communication is discussed in Phase I and again in Phase II, so this element is likely to have been addressed to some degree during early preparation of the scenario planning effort and the development of the scenario sets themselves. But, it is at the end of the process where the material needs to be packaged and presented to those not involved. For example, while the Tucson Water scenario planning work was internal to the institution, those involved devoted much energy to communicating the process and results to water customers, their primary stakeholders.

It may be beneficial to assess and document the success of the scenario planning effort to aid decisions about whether to apply this decision support method to inform another issue. The most straightforward way to accomplish this would be to examine results with respect to the stated purpose and desired outcomes of the process (Wiseman et al. 2011).

Tom LaPointe/USFWS

Nulhegan River

Section 3

Cactus

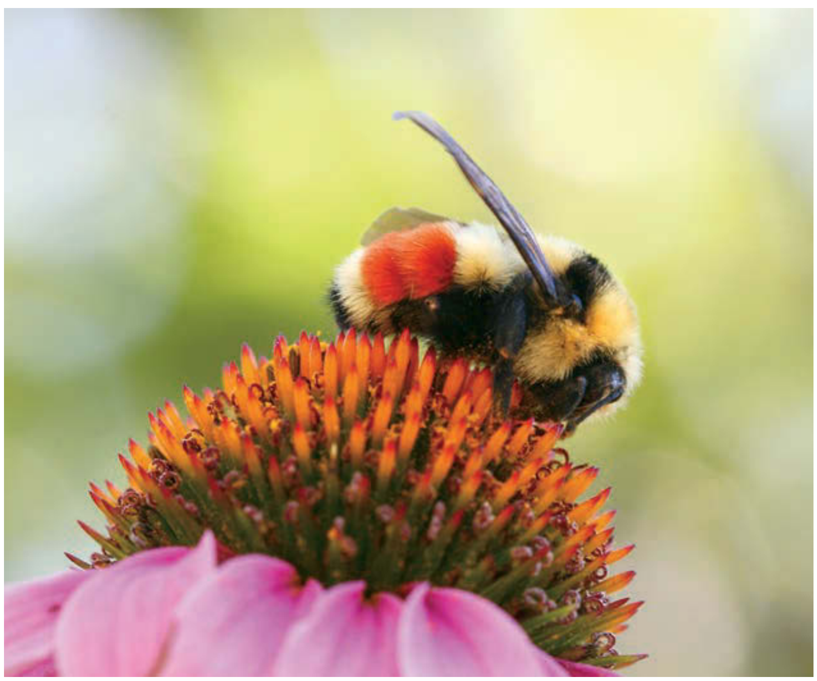
Examples of scenario planning in natural resource management and conservation

This section provides 12 nationwide case studies representing a range of scenario planning approaches and issues for natural resource and conservation decisions. Although climate change is considered in each case study, it is often not the only driver of future scenarios. Given that climate change planning for natural resources in the United States is relatively new, most of these case studies represent "exploratory" exercises focused more on developing a more clear understanding of an issue and strategic-level planning than on making specific decisions. In these examples, there is widespread recognition of the role scenario planning plays in enhancing both social and institutional adaptive capacity to deal with uncertainty in general, and climate change specifically; arguably one of scenario planning's greatest strengths. Scenario planning is useful for increasing understanding and fostering creative thinking on climate change, helping to move organizations closer toward implementing climate-informed management strategies. Further application and refinement of scenario planning approaches in conservation and natural resource management appears to be warranted given the challenges represented by climate change and its interaction with other stressors, such as land use change and urbanization.

Table 3.1 summarizes the 12 case studies to help direct readers to those that might be most relevant to their own situation. Each case study follows a common template to ensure consistent sets of information were included in each description:

- Background and objectives (the what, why, and how of the effort);
- Methods;
- Scenario development;
- Outcomes and applications;
- Lessons learned and next steps.

In addition to the case studies presented here, we reviewed more than 100 descriptions of exercises that included "scenarios" or "scenario planning" as a keyword descriptor published in a variety of journals. The methods and results of that analysis are summarized in Appendix 2. Additional summaries of scenario planning case studies can be found in Price and Isaac (2012) and Mackenzie et al. (2012).



Leah Lewis/USDA/ARS

Hunt's bumble bee

Table 3.1. Summary of the case studies included in the guide to help locate relevant examples for review.

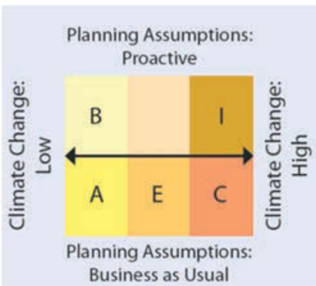
Case Study Title	Purpose	Participants	Drivers	Scenario Format	Outcomes	Method
3.1. Land Use and Climate Change Scenarios for the Peninsular Florida Landscape Conservation Cooperative (LCC)	Make strategic management decisions by quantifying the complex conditions under which conservation strategies may operate.	Massachusetts Institute of Technology, US Geological Survey, US Fish & Wildlife Service, Florida State Wildlife Commission, stakeholders	Climate change, population, resources, planning and regulation	Narratives quantified in land-use maps	Spatially explicit simulation of scenarios and potential impacts on seven species	Workshops, meetings, matrix technique, land-use change based simulation
3.2. Scenario Planning as a Tool for Climate Change Adaptation Planning: National Park Service, Alaska Region	Help park managers and employees, cooperators, and stakeholders understand climate trends; anticipate future changes that could affect resources, assets, and operations in and around parks; and identify possible climate change response strategies	Agencies, cooperators, stakeholders, community	Climate change and social-political context	Narratives	Potential climate impacts and response strategies	Web presentations, information syntheses, workshops; nested matrix approach
3.3. Climate Change Considerations in National Park Service Planning Pinnacles National Monument, California	Integrate climate change considerations into the planning process for Pinnacles National Monument, as mandated by the National Park Service's Resource Stewardship Strategy.	National Park Service employees	Climate change	Narratives	Framework for creating management strategies under multiple possible futures; better understanding of possible futures	Webinars, workshop
3.4. Alternative Fire Management Futures in the Southern Sierra Nevada ecoregion, California	1) Integrate climate change adaptation into fire management and planning; 2) Test scenarios as an approach for change adaptation for other resource management programs.	National Park Service, US Forest Service, US Geological Survey, University of California, and others	Climate change, fire regime, social-political context	Narratives, spatially-explicit model projections of future fire probability and climate-related vegetation stress	Inputs for developing climate-smart NPS Resource Stewardship Strategy and Fire and Fuels Management Plan. Others TBD.	Workshops, information synthesis, model output, interactive management simulation exercise

Case Study Title	Purpose	Participants	Drivers	Scenario Format	Outcomes	Method
3.5. Climate Change Scenario Planning in the Crown of the Continent Ecosystem (Montana, Alberta, British Columbia)	Guide development of National Park Service scenario planning template for autonomous implementation; test use of webinars for scenario development; test scenario acceptance by diverse organizations not involved in the scenario development; consider changes in management objectives; use scenarios to organize adaptation options.	Crown Management Partnership's 23 member organizations: US federal and state agencies, Canadian federal and provincial agencies, native nations; National Park Service	Climate, sociopolitical context	Narratives	Insight across organizations, template for adaptation by National Park Service	Information synthesis, nested matrix, 12 webinars, 2-day workshop
3.6. San Francisco Estuary, CA: Tidal marsh restoration and conservation planning in the face of uncertainty	Prioritize tidal marsh restoration projects for funding by identifying regions most robust and resilient under multiple scenarios	Academic and agency experts, with a focus on those with experience with field observations of marsh accretion in the area.	Climate change-sea level rise and sediment accretion, organic accumulation	Narratives, models of future bird distributions and conservation priorities, proposed restoration projects	Report, publication in press, website open to use by managers and public interested in utilizing scenarios for planning, web-based tool	Modeling software, expert-based internal discussion
3.7. Integrated Scenarios and Outreach for Habitat Threat Assessments on Central Valley and Inner Coast Range Rangelands, CA	Create decision support mechanisms to assist managers in maintaining ranchland and ranch ecosystem services in light of future integrated threats.	Expert driven with input from California Rangeland Conservation Coalition members	Land use, climate, hydrological change	Maps, quantified impacts of integrated scenarios; narratives for local applications.	Impacts to water and carbon, vegetation types, grazing lands, and related economic effects	Stakeholder workshops, land-use change model, on-line mapping tool
3.8. Adapting to an uncertain future: Decision Support for Long Term Provision of Ecosystem Services in the Snohomish Basin, WA	Assess the prospects for long-term provision of ecosystem services in the watershed that supplies a major urban area, taking into consideration numerous drivers	Broad team of experts	14 different environmental and socio-economic drivers considered, with a particular focus on climate change and social values	Narratives	Identify key strategies and drivers, framework for integrating predictive models, identification of gaps in data and future research directions, open house to present findings to public	Models, interviews, workshops, use of different teams for different aspects of scenario construction

Case Study Title	Purpose	Participants	Drivers	Scenario Format	Outcomes	Method
3.9. Vulnerability Assessments for Wetlands of the Massachusetts Bays Program and San Francisco Estuary Partnership	Assess the vulnerability of wetland processes and resources, and understand how climate change might affect management goals	Experts, EPA, Massachusetts Bays Program, San Francisco Estuary Partnership	Climate change	Quantitative models and narratives	Vulnerability assessments, identification of data gaps, research and monitoring needs, and management options.	Expert scenario construction, Expert elicitation workshops
3.10. Scenarios of Land Use, Climate Change and Transformations of Forest Landscapes in Massachusetts	Expand understanding of the potential consequences of global change on forest conditions and ecosystem services at landscape to regional scales and provide scientific resources to guide forest policy, conservation, and management.	Expert driven with input from multiple stakeholders	Climate mitigation, biomass energy, global markets, conservation and other themes	Narratives quantified in land-use maps	*Effort in progress* To date, simulation of "business as usual" forest change 2010-2060	Workshops, stakeholder dialogues, land-use change based simulations
3.11. Florida Keys Marine Adaptation Planning (KeysMAP) – A marine-based scenario-planning project	Provide a means of addressing uncertainty and a framework within which natural resource managers can conceptualize future conditions and develop possible management options to address those conditions.	Managers-state and national parks, Florida Keys National Marine Sanctuary, U.S. Navy, fishery authorities, USFWS refuges, local NGOs	Sea-level rise, sea surface temperatures, future fishing and tourism demand	Scenarios based on quantitative inputs (e.g., SLAMM modeling)	*Effort in progress* Management-relevant scenarios, the effects of the scenarios on focal habitats and species, management strategies	Series of three workshops
3.12. Climate Adaptation Planning for the Bear River Basin, UT	Use a structured framework for landscape-scale climate adaptation planning to identify and prioritize management options	The Nature Conservancy, the Southwest Climate Change Initiative, representatives of 20 public agencies and private organizations	Climate change, hydrology	Climate projections and hydrological model output	List of strategic actions, monitoring opportunities, and research needs for the Bear River system	Workshop-based, breakout sessions among experts
End						

3.1 Land Use and Climate Change Scenarios for the Peninsular Florida Landscape Conservation Cooperative

Juan Carlos Vargas-Moreno[a] and Michael Flaxman[a,b]
[a]GeoAdaptive LLC, [b]Florida Atlantic University



Background / Objectives

What.—The Peninsular Florida Landscape Conservation Cooperative (PFLCC) has supported creation of a set of five alternative futures for peninsular Florida[1,2]. These futures integrate possible future land use/land cover and sea level rise, represented as spatially explicit simulations, for the PFLCC region in 2020, 2040, and 2060. They significantly extend and update prior US Fish and Wildlife Service (USFWS) and US Geological Survey (USGS)-led Everglades scenario efforts in terms of geography and considered data[3].

The scenarios represent a wide but plausible range of parameter values organized around four important drivers of change for the PFLCC region identified by stakeholder groups in the earlier scenario planning effort:

- Sea level rise;
- Human population growth (human settlement patterns and future land use);
- Land use planning policies and constraints, and;
- Financial resources for conservation.

Each alternative future considers a unique combination of these drivers, as depicted in the graphic at left. Proactive planning assumptions were implemented in the development of scenarios B and I, which also represent the two extremes of climate change projections. Scenarios A, C, and E assume planning practices and funding availability will proceed according to Business As Usual, while covering the full range of climate change projections from low (Scenario A) to high (Scenario C). Unlike many prior studies for the region, which dealt with these drivers in isolation, the PFLCC scenarios include interactions among the various drivers. The scenarios, developed as individual GIS layers/raster grids, examine the displacement of human populations due to sea level rise and the opportunities for conservation lands. They also illustrate the interaction between land use policies and conservation budgets and techniques. Designed to support planning for voluntary conservation initiatives such as conservation easements and payments for ecosystem services, the scenarios also bound a likely range of conditions for the drivers considered.

Why.—These scenarios are intended to be used as (a) a set of "what-if" tools (not as predictions), and (b) to support the development and testing of conservation plans and policies within Peninsular Florida. For example, it is possible to look at the habitat of any particular species relative to likely future sea level rise and urbanization pressures, then design a reserve network robust to those pressures. Although the focus of these scenarios is landscape scale, it is also possible to use them to evaluate how individual proposed acquisitions fit into the broader context over time.

In the context of PFLCC conservation planning, a major focus is on private voluntary conservation and its interaction with ongoing fee-simple (i.e., owned lands, often in contrast to easement-based conservation) efforts. The three Business as Usual scenarios show how current broad prioritizations are expected to fare under various combinations of development, climate change, and budget. In contrast, the two Proactive scenarios developed in this work show alternatives that would much more deeply engage private voluntary efforts. One important use of such scenarios is to evaluate the adequacy of current plans and policies, and to adjust them as needed.

Scenario Development

The following section describes the information incorporated and key steps followed in the development of the scenarios. This involved either obtaining existing GIS digital data or developing the raw data sources to create the GIS layers required to represent the scenarios with spatially explicit simulations. The process is complex and captured in much greater detail in the PFLCC report[2]. The multiple data sources and the outputs of multiple models were used to develop inputs into the final simulations of the five alternative scenarios of future land use change.

Sea level rise.—Sea level rise (SLR) analysis was performed based on tidally corrected, high-resolution LIDAR data provided by Florida Atlantic University (FAU). The conceptualization of values used was identical to prior MIT Everglades scenarios[3] in that low, moderate, and high climate change steps were considered (Table 3.2). The low and moderate SLR values used are in accord with IPCC reports, specifically their B2 and A1F1 SRES scenarios, which did not account for glacial ice sheet melting. These values ranged from 18 to 59 cm by 2100. For this study, we revised these values upward based on the AR5 report, expected in 2014, and the uncertainty about the levels of glacial melt[3]. We used a value of 1 m by 2100, which is identical to that used in prior MIT Everglades scenarios.

Table 3.2 SLR values by time slice.

Sea Level Rise (cm)	2020	2040	2060	Precedent
PFLCC Low	2.0	7.8	13.6	IPCC AR5 Low (2.9mm/yr)
PFLCC Mod	5.7	22.1	38.5	IPCC AR5 High (8.2mm/yr)
PFLCC High	20.0	52.0	78.0	Vermeer and Ramsdorf 1m@2100

Values for 2100 were converted to average accretion rates in millimeters per year, and these were multiplied by the time from present year to estimate SLR at 2020, 2040, and 2060. While straightforward and replicable, this conversion provides a linear approximation of change that is expected to be non-linear. This procedure tends to overestimate SLR slightly in early years, and underestimate in later years. However the errors introduced are small relative to scenario differences; in fact well below the vertical precision of our terrain models.

Characterization of human settlement patterns and future land use.—We began our simulation of future land use in Florida by reviewing and quantifying past and recent settlement patterns, since these have a strong influence on likely futures. In particular, we looked at the types and categories of land use which are recognized and permitted, and then the spatial pattern of each type. Florida's land use pattern is highly influenced not only by land tenure, but also by its growth management and related planning activities.

We distinguish in our methods between design elements and planning zones, and where possible incorporate both:

- *A design element* is a significant land use feature or piece of infrastructure which is to be built or conserved in a particular location (e.g., a stadium, major road, or park). For design elements, we used estimates or plans which specify a specific footprint and timeframe;
- *Planning zones*, by contrast, are not prescriptive, but instead require willing buyers and free-market investment. We allocated zoned elements based on projections of future demand.

Manatee swims near Crystal River National Wildlife Refuge, Florida

Human population analysis.—The future demand for urban land uses was estimated based on three data sets:

- Existing land use as characterized by Florida Natural Areas Inventory (FNAI);
- Existing demographics as measured by the U.S. Census Bureau, and;
- Future demographic projections provided by the State and University of Florida.

Factors considered in this component of the analysis include the following:

- Business as Usual scenarios: historic/existing land cover demand and distribution
- Proactive scenarios: transit-oriented development, reduction in low density development
- Population projections:
  - Trend Demand: extrapolation of county-level decadal projections
  - High Demand: doubling of population in 50 years

Simulation of human population displacement under SLR.—Modeling urban growth jointly with sea level rise simulation allows for simulation of their interaction. We do not know how U.S. residents will respond to either gradual sea level rise, or storm surges combined with that rise, simply because we have no analogous prior experience.

Conceptually, there are three general possibilities: coastal armoring, reactive-retreat, and pro-active retreat. Despite the challenges, we have chosen to treat all three possibilities in these scenarios. When using regional- to state-scale GIS data, such estimates require coarse assumptions. We focused on three questions, as described below.

Question 1: Which areas are highly vulnerable to high water table or sea level rise, and who currently occupies those areas?

Answer: demographic vulnerability analysis using 2010 Census tracts, FNAI land cover, and SLR inundation grids to produce a household density grid of relatively fine and uniform spatial resolution (Figure 3.1).

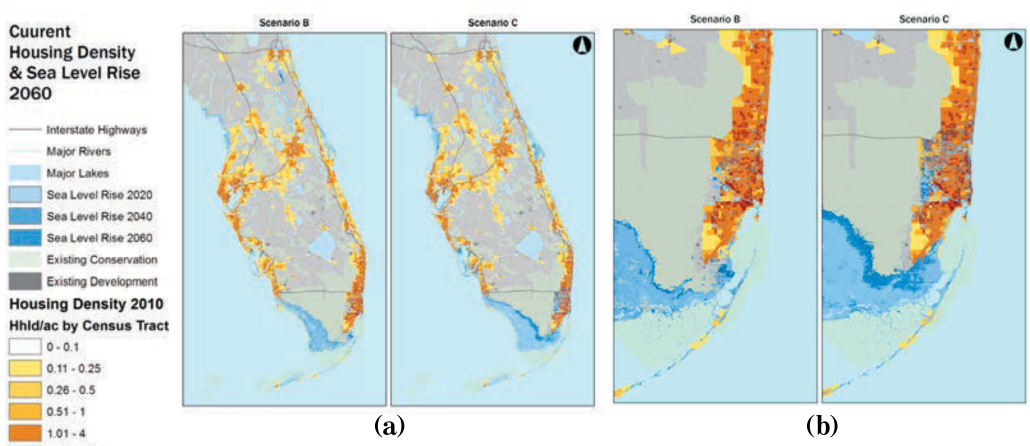


Figure 3.1. Current household density relative to potential future SLR for (a) Peninsular Florida Landscape Conservation Cooperative and (b) SE detail view.

Question 2: Given existing infrastructure and economic activities, which areas are most likely to be armored or adapted, even despite high costs?

Answer: high density locations most likely to be armored (threshold = 10 units/acre – based on Florida regulatory constraints), assumed that more resources would be dedicated to protecting these major investments

Question 3: How are different population and demographic groups likely to respond to SLR?

Answer: assumed higher density/urban infrastructure armored regardless of socioeconomic conditions, greater likelihood that single family homes/high vulnerability areas would be abandoned.

Consistent with the earlier scenario effort[3], 80% of coastal population assumed to relocate within Florida due to increased hazard risk, 20% would emigrate. Therefore, the high sea level rise scenarios reflect a re-settlement of 80,000 households by 2060.

***Simulation of potential redevelopment*.**—A challenging but important aspect of future land use simulation is the estimation of areas of potential development. Historically, the Florida real estate industry and Florida planning practices have concentrated on green field development. When and how change to development in Florida occurs will depend on a complicated mixture of transportation infrastructure spending, human preference, and public policies. Within our scenarios, these potential changes affect both the planning assumptions and public resources dimensions. Under Business as Usual we continue historic green field development and infrastructure investment policies. Under Proactive scenarios, we change these assumptions to reverse late-twentieth century practices.

These differences in planning assumptions are implemented using several mechanisms. The first is a change in the use of public resources. Under Business as Usual scenarios, we simulate continued auto-dependent infrastructure investment—primarily the continued expansion and widening of major arterial streets. Under Proactive scenarios, we simulate public investment in transit-oriented development. This involves three components which have been demonstrated to be important in development (sidebar).

Three key components for simulation of potential redevelopment

- **Access to transportation**, in particular public transportation.
- Two styles of transit-oriented development:
  - **Multi-modal transportation hubs** with adjacent or included high-density mixed use. *An excellent example is CityPlace in West Palm Beach, which includes a large amount of structured parking, a regional bus transit hub, two floors of retail, and additional residential on upper floors, free-market and civic anchor tenants such as movie theaters and an arts center. While this mixture is pedestrian-oriented within the center itself, the majority of users drive and park.*
  - **Linear transit-oriented development** *Typified by Portland, Oregon, which several decades ago pursued a joint land use and transportation strategy built around light rail corridors.*

***Attractiveness.*—**Attractiveness models were designed to identify priority lands for future conservation, agricultural, and residential uses. These models served as inputs to the series of future land-use scenarios for the entire state of Florida. The conservation priorities simulations are driven by the outputs of the attractiveness models run with different preference weightings:

- A 'Proactive' model run using stakeholder-suggested conservation factor weights (Proactive Stakeholder Weights);
- A 'Proactive' model run using equal conservation factor weights (Proactive Equal Weights), and;
- A 'Business as Usual' model run emphasizing high CLIP (Critical Lands and Waters Identification Project) priorities and representing a typical allocation of conservation effort in Florida.

***Conservation.*—**The conservation attractiveness model uses three inputs:

- *Florida Ecological Greenways Network* (developed by the University of Florida GeoPlan Center) is a spatial model intended to represent a prioritized network of ecological hubs and linkages designed to maintain landscape-scale ecological functions throughout the state of Florida;
- *Strategic Habitat Conservation Areas* (developed by the Florida Fish & Wildlife Conservation Commission) is a spatial model that prioritizes

aggregated suitable habitat for one or more rare or vulnerable vertebrate species in Florida;

- *Critical Lands and Waters Identification Project (CLIP)* was developed through a collaborative effort between the Florida Natural Areas Inventory, the University of Florida GeoPlan Center and Center for Landscape Conservation Planning, and the Florida Fish & Wildlife Conservation Commission. CLIP is a spatial model that indicates the statewide priorities for a broad range of Florida natural resources.

Because restoring the "River of Grass" in what is now the Everglades Agricultural Area is also a priority, an additional attractiveness factor was created which includes parcels that have been identified as potential acquisitions by the South Florida Water Management District, as well as half-mile buffers on existing canals in the area.

Figure 3.2 depicts models run for each of the three alternative weightings on conservation. Attractive areas are darker green, the darker the red the less attractive. Grey areas are either already protected, or are constrained by some other land use or regulation.

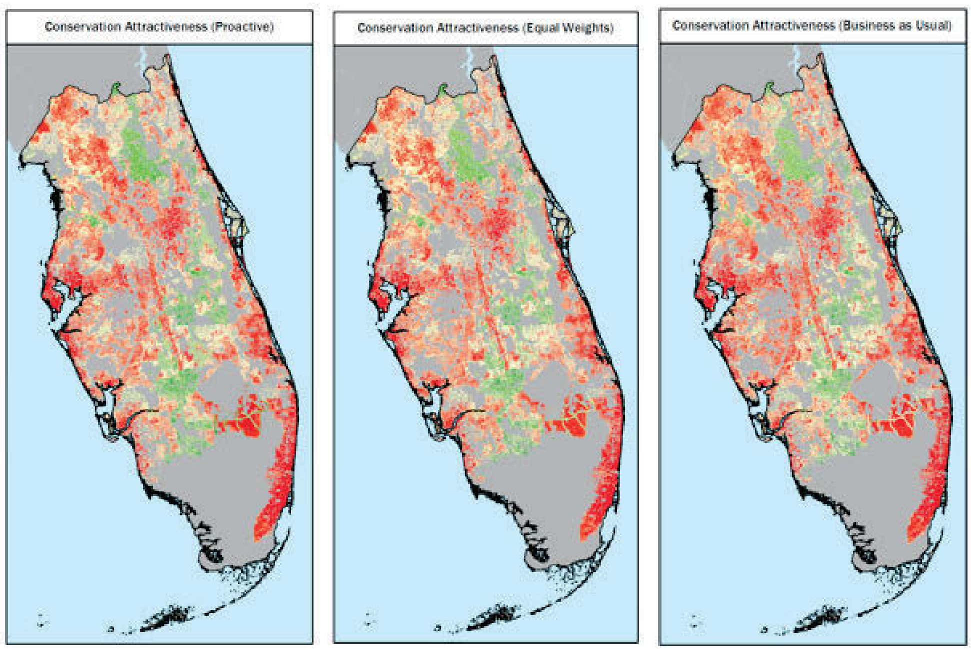


Figure 3.2. Conservation attractiveness showing three models from left to right: Proactive Stakeholder Weights, Proactive Equal Weights, and Business as Usual.

Agriculture.—Models were also developed to rank Florida lands in terms of attractiveness to agricultural land uses, specifically farming (crop and citrus) and cattle ranching. This model only provides input to the Proactive scenarios group land cover change analysis, since it was assumed that there will not be a significant conversion of non-agricultural land to agricultural land in a Business as Usual scenario group. For farming, each factor was weighted equally; for ranching, land cost and existing ranching were weighted higher than the other factors.

Residential.—Attractiveness models were developed for four categories of residential housing, to project urban growth patterns in each scenario. Each category was designated as a different housing type, representing market

NPS

Long Pine Key nature trail area, Everglades National Park, Florida

segments which combine median gross density and income information based on Census 2010:

- *Rural.*—Represents the lower quintile of household incomes and those living in rural areas;
- *Multifamily (or Affordable).*—Represents the lower quintile of household incomes, with residences of 0.1 acre and apartment buildings;
- *Suburban or Middle Income.*—The middle 60% of household income, quintiles (3) with residences on 0.25–1 acre lots in residential development;
- *Urban and Exurban (or High Income).*—The upper quintile of household incomes, with residences of 0.1 acre beach condominiums and golf course/ ranchette developments of 1-5 acres.

Multiple factors were considered when developing the attractiveness models for each housing type, such as, for example, travel time to employment centers and distance to public transit.

***Constraints.*—**Constraints represent a critical input to the modeling process for simulating future land use described above. Existing physical and regulatory factors (e.g., existing conservation areas, transportation infrastructure) that would present barriers to urban and agricultural growth were combined together to create a mask where development cannot occur. Two sets of constraints were developed:

- *For the Business as Usual scenario.*—Existing regulations are considered;
- *For the Proactive scenario.*—More restrictions would be put in place to limit development in sensitive or hazardous areas.

Outcomes and Applications

***Land cover change simulation under different scenarios.*—**Land cover change modeling was done separately for four socioeconomic regions of the state. These included the panhandle, northern, central and southern regions.

We used the AttCon model to simulate land cover change, using the GIS layers we developed and integrated as input, including:

1. Model simulations of human population displacement under SLR
2. Model simulations of re-development
3. Model simulations of attractiveness for conservation, agriculture, and residential development.

Prioritization for allocating land use demands in the AttCon model, based on willingness to pay

- *For Business as Usual scenarios:*
  urban > rural > agriculture > ranching > conservation
- *For Proactive scenarios:*
  conservation > urban > rural > agriculture > ranching

The model allocates requested land use demands onto the best available legal areas in a predetermined sequence (sidebar).

Under Business as Usual scenarios, development was simulated anywhere permitted by law and dry, based on current Florida coastal control lines and sea level projections for each future time step. For the Proactive scenarios, policy was simulated as looking ahead 40 years and prohibiting development in zones expected to be inundated in that time frame (from direct tidal inundation and/or high water tables).

Once all constraints are accounted for, each potential development or resource unit was ranked by determining the mean attractiveness of its component grid cells. Allocations were then performed in rank order, with each potential development or resource unit added in sequence. This process continued until all demand was satisfied, or until demand exceeded land supply.

Discussion of scenario results.—The five resulting alternative futures exhibit strong and interesting differences in potential land use patterns, the most apparent being between the two most extreme scenarios, B and C (Figure 3.2). Scenario B (Proactive) is for low climate change, trend population growth and pattern, a relatively high level of public resources devoted to redevelopment and conservation, and more sustainable public policies. Scenario C (Business as Usual), by contrast, postulates a world with high climate change, a doubling of population within the region, conventional planning policies, and an infrastructure controlled under tight government fiscal constraints.

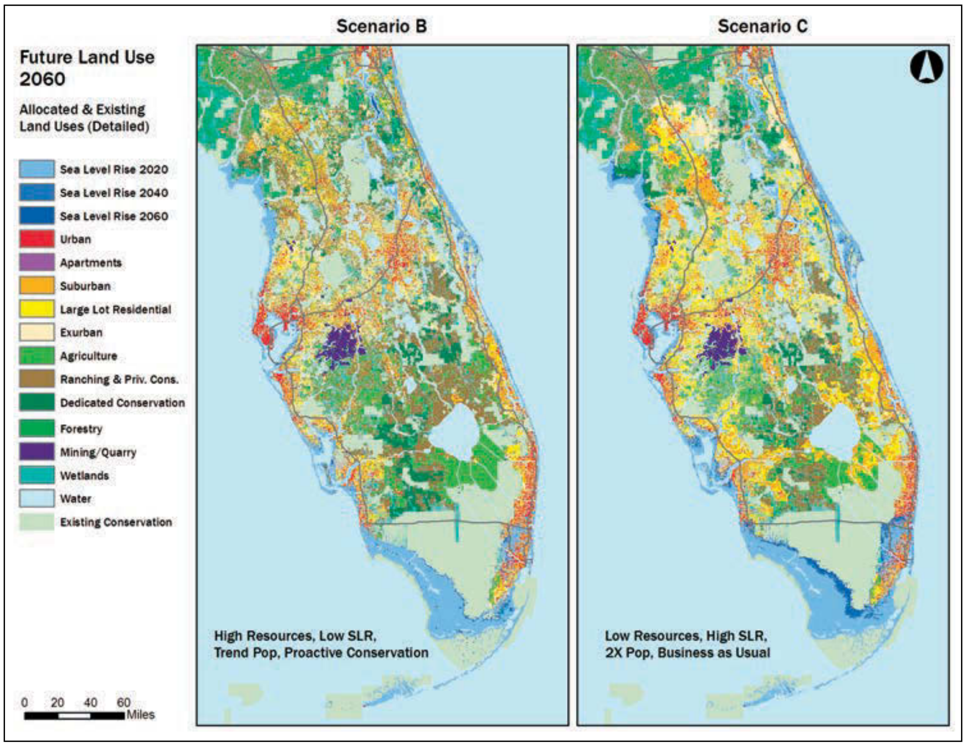


Figure 3.3. Allocated land uses for Proactive (left, here shown as Scenario B) and Business as Usual (right, Scenario C) example scenarios, combined with existing land use categories.

Perhaps the most dramatic difference between these two scenarios is in the total development footprint. For the full PFLCC under trend population assumptions and Proactive policies (scenario B), approximately 750,000 acres of residential land is needed to meet demand. Under doubling population assumptions and current land use density mix (scenario C), just over 2,000,000 acres are required to meet demand.

Lessons Learned / Next Steps

***Limitations and caveats.*—**As comprehensive as they are, these scenarios carry several caveats and limitations relative to their intended purposes:

- They are regional scenarios based on the best uniformly-available public data covering the full study area. They do not include all local plans and policies;
- No simulation method can predict with 100% confidence the timing or outcome of individual human decisions. These scenarios represent statistically probable decisions over decadal time periods, given willing buyers and sellers. No implication should be drawn about any particular parcel or single development decision;
- The scenarios do not account for temperature, precipitation, or species habitat shifts due to climate change. Such models have yet to be comprehensively generated for PFLCC species. However, these scenarios are being used by Watson, Romanach, and others at USGS in their climate envelope modeling efforts, so additional related work is expected;
- No hydrological simulation is performed. This is a significant limitation in a Florida conservation context. However, no spatially comprehensive water models exist for the PFLCC region. A five-year National Science Foundation effort led by Michael Sukoup at FIU will likely be adopting and integrating PFLCC scenarios, but only for a subset of the PFLCC geography;
- Sea level rise is modeled with high precision data (tidally corrected LIDAR) and methods, but as a bathtub. Therefore no storm surge—known to have major effects within the region—effects are considered. Additional PFLCC efforts, led by Paul Zwick at the University of Florida, are underway to consider storm surge and resultant urban infrastructure impacts for three counties.

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U.S. Army

Eastern indigo snake

3.2 Scenario Planning as a Tool for Climate Change Adaptation Planning: National Park Service, Alaska Region

Robert Winfree[a], Bud Rice[a], Nancy Fresco[b], Lena Krutikov[b], John Morris[a], Nancy Swanton[a], Don Weeks[a], Jeff Mow[a] and Don Callaway[a]
[a]National Park Service,
[b]Scenarios Network for Alaska Planning

Background / Objectives

What.—In April 2012, Alaska became the first region of the National Park Service (NPS) to complete climate change scenario planning exercises for every national park, preserve, and monument in the region. These areas collectively make up about two-thirds of the total area of the National Park System and are experiencing visible and measurable changes attributable to climate[1].

Why.—The Alaska Leadership Council, composed of the regional directorate and park superintendents, saw scenario planning as an educational process to help park managers and employees, cooperators, and stakeholders understand climate trends; anticipate future changes that could affect resources, assets, and operations in parks and surrounding areas; and help identify a range of possible climate change response strategies.

How.—The NPS Alaska Region was supported in this effort by the NPS Climate Change Response Program; Global Business Network (GBN); and the University of Alaska (UAF) Scenarios Network for Alaska and Arctic Planning (SNAP), who assisted with funding, scenarios process training, technical assistance, workshop facilitation, and reporting.

One training workshop and five regionally focused scenario planning workshops were undertaken during this project. The workshops were roughly organized around the geographic boundaries of Alaska's four natural resources Inventory & Monitoring (I&M) networks. Two superintendents volunteered their parks (Kenai Fjords and Bering Land Bridge) for pilot exercises during the August 2010 training workshop in Anchorage.

To maximize opportunities for participation of field staff, cooperators, and community residents, the five remaining workshops were scheduled between February and April in two consecutive years. Two workshops were held in the NPS regional office, two at UAF, and one at a US Forest Service visitor center in Juneau:

- *Southwest Alaska.*—Focused on Kenai Fjords National Park, Katmai National Park and Preserve, Lake Clark National Park and Preserve (NP&Pr), Aniakchak National Monument and Preserve, Alagnak Wild River (about 9.4 million acres). February 22-25, 2011. Anchorage, Alaska;
- *Northwest Coastal Alaska.*—Focused on Bering Land Bridge National Preserve and Cape Krusenstern National Monument (about 3.3 million acres). April 19-21, 2011. Anchorage, Alaska;
- *Southeast Alaska.*—Focused on Glacier Bay NP&Pr, Klondike Goldrush National Historic Park (NHP), Sitka NHP, and coastal Wrangell-St. Elias NP&Pr (about 3.3 million acres). February 21-24, 2012. Juneau, Alaska;
- *Interior Arctic Alaska.*—Gates of the Arctic NP&Pr, Noatak National Preserve, and Kobuk Valley National Park (about 16.8 million acres). March 27-29, 2012. Fairbanks, Alaska;
- *Central Alaska.*—Denali NP&Pr, Yukon-Charley Rivers National Preserve, and Wrangell-St. Elias NP&Pr. (about 21.8 million acres). April 16-18, 2012. Fairbanks, Alaska.

Daniel A. Leifheit/NPS

Denali and caribou

USFWS

Horned puffin pair, Alaska

Participants.—Workshop participation was by invitation in order to keep the workshops relatively small and highly participatory. The initial list of invited participants was designed for a highly diverse mix of knowledge holders, stakeholders, decision-makers, and creative and curious individuals, as suggested by GBN's Jonathan Starr, who led the training workshop. The invitations were sent by email several months before the actual workshops, but the participant lists remained fluid up to day of arrival to accommodate additional requests from agencies, organizations, and individuals asking for a seat at the table. On average, about 35 people attended each workshop, with two thirds of them having no prior experience with the scenario planning process. By design, about half came from the national parks and I&M networks, with the other half coming from cooperating agencies, organizations, and communities. More than 20 park-related technical specialties and career fields were also represented across the workshops, including the senior management for nearly all of the NPS areas in Alaska.

Methods

Preparations.—A core team of nine individuals developed and implemented the agenda for each workshop, with SNAP taking the lead for science and technical information and alternating with NPS for presentations and facilitation. Several subject matter experts such as climate scientists also participated in multiple workshops. When they were not presenting or facilitating discussions, all were encouraged to participate as equals in fleshing out scenarios, potential effects, and narratives. Also, it was helpful to have some people who were familiar with the process from previous workshops.

The initial lists of possible scenario drivers and effects were developed by SNAP and NPS staff, who had researched the issues, science, and literature. SNAP's Alaska climate models, which they had downscaled from IPCC global climate models, were used throughout the workshops for envisioning potential changes across broad areas and timescales. Anthropogenic and natural greenhouse gas (GHG) emissions were discussed as factors affecting uncertainty about the rate of future change, noting that different GHG emission scenarios could yield higher or lower projections. The models for these workshops used the "moderate" A1B GHG emissions scenario published in the IPCC Fourth Assessment[2], which some experts now think may underestimate recent trends. The projections were based on an average of five models determined to best match historic data for Alaska and the Arctic: Echam5, Gfdl2.1, Miroc3.2MR, HadCM3, and CGCM3.13.

NPS prepared two annotated bibliographies of the peer-reviewed literature related to climate change in Alaska[4,5], which proved helpful for background reading and for determining potential effects.

The focal question for each workshop was...

How can NPS managers best preserve the natural and cultural resources and other values within their jurisdiction in the face of climate change?

Each workshop was preceded by a series of webinars to prepare participants with an understanding of the scenario planning process, climate drivers and science, and climate change impacts in the area. SNAP provided each participant with access to a set of park-scaled maps with projected changes in temperature, precipitation, and permafrost at various intervals throughout the 21st century. During these webinars, participants also began the work of linking drivers to biological, social, and physical effects already occurring or likely to occur on the landscape. What started as five webinars for the first training workshop, evolved into two webinars by the final workshop.

Workshop overview.—Each three to four day workshop was designed to consider potential future changes spanning large landscapes over several decades, rather than to address immediate management issues. The scenario planning process could also be applied to uncertainties about pressing acute and localized effects of climate change, which many participants indicated they were already dealing with (e.g., flooding, erosion, wildland fire, ground movement or vegetation change). Although the workshops focused primarily on parks and waters, nearby communities and other land management units were included through the broad landscape focus.

To encourage collaboration, each workshop was divided into two groups, each of which would develop scenarios focused on a different park or ecosystem (e.g., coastal, marine, inland, freshwater). An effort was made to assure each group included a diverse range of the stakeholders present; for example, agency and academic scientists, senior management, climate specialists, and subsistence users. Also, by explicitly stating at the start that these scenarios would not be predictions of what *will* happen, but rather hypotheses, the participants were able to set aside any preconceptions about climate change science and instead focus on considering the scenarios from a "what if" mindset. The range of observations and interpretations put forward was highly interactive, dynamic, informative, and respectful.

Climate-related scenario drivers most commonly selected at the workshops were related to...

- Temperature
- Moisture
- Storms
- Seasonality
- Ocean acidification (for marine parks)

Scenario Development

The two work groups each had two assignments:

- assess the relative importance and uncertainty of a dozen or more physical climate-related scenario drivers;
- then select two drivers with both high importance (to maximize the relevance of resulting scenarios) and high uncertainty (to maximize divergence).

Crossing two drivers on a diagram yielded a 2x2 matrix with four quadrants, each of which represented a different future or scenario (Figure 3.4). The biophysical effects and implications of the four scenarios were then fleshed out by all workshop participants. Most participants felt comfortable considering scenarios that could develop within 20-40 years, capturing trends beyond natural climatic variability, while also maintaining relevance to their careers or those of immediate successors.

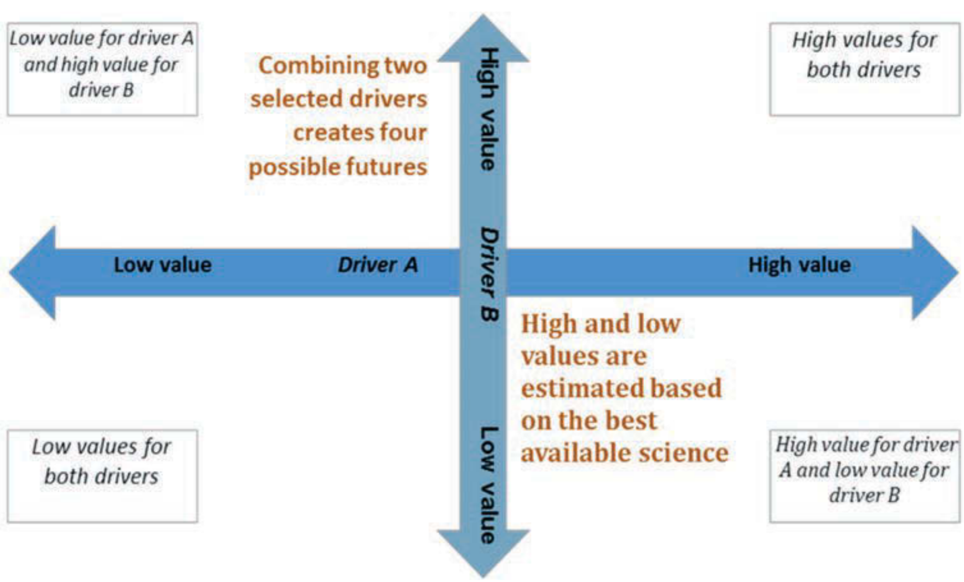

Figure 3.4. Creating a primary scenarios matrix. Two key climate-related drivers of change are crossed to create four possible futures.

Next, all four scenarios were nested into social and institutional matrix (Figure 3.5), which was adapted for Alaska from one previously used by GBN and NPS:

- *The selected social driver* envisioned broad understanding and heightened urgency at one end of the spectrum, with widespread indifference and competing concerns at the other extreme;
- *The institutional driver* envisioned strongly-committed senior leadership, international alignment and long term perspectives at one end of the spectrum, and a lack of commitment, varied approaches and short term concerns at the other end.

The groups considered situations under which each of the four social/institutional combinations could occur, and accepted the social/institutional drivers and their end points as plausible. Nesting each of the bio-physical scenarios into each of the four socio-institutional quadrants yielded 16 different combinations of potential future social and institutional environments and biophysical effects of future climate. Since 16 scenarios were too many for management to work with, the participants in each group selected two of the nested scenarios that fit the four selection criteria: *plausible, relevant, divergent,* and *challenging,* for further development.

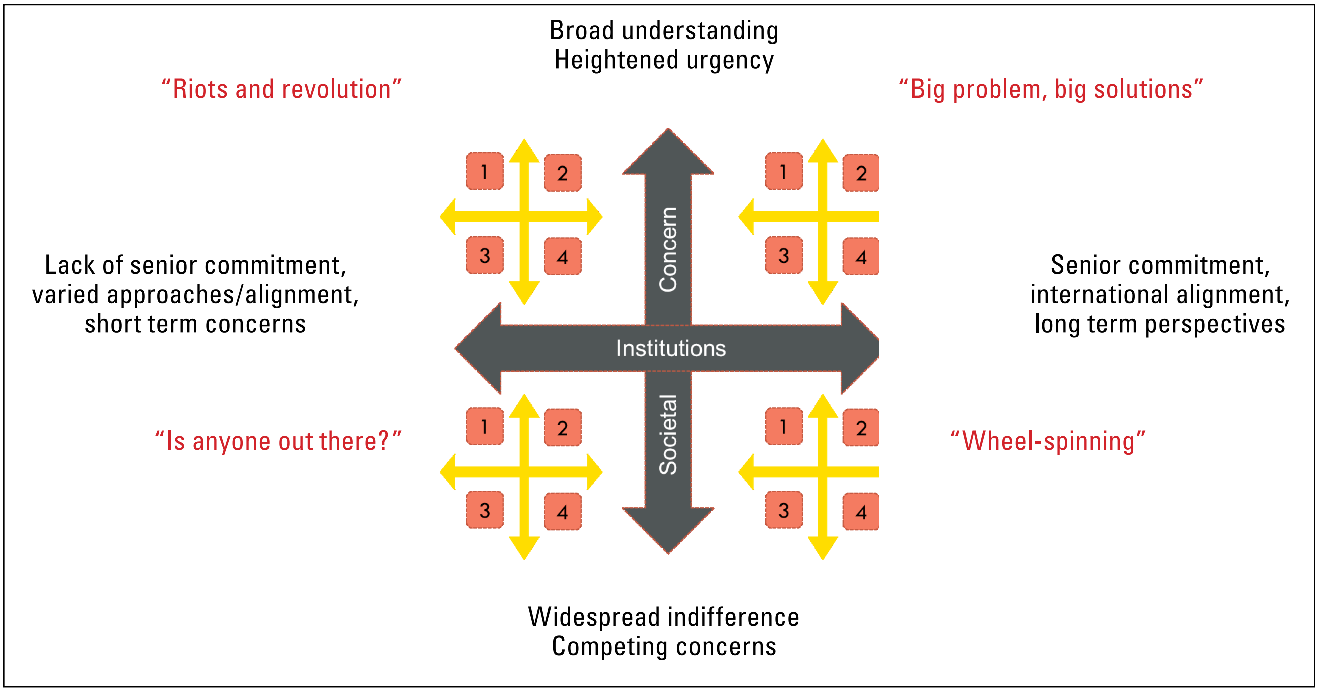

Figure 3.5. General design for a matrix that nests the four biophysical scenarios from Figure 1 into each quarter of a socio-political framework incorporating the degree of future societal concern and the nature of future leadership. Adapted from the Global Business Network (GBN).

The scenario planning process was fast moving, technically complex, and challenging. Large diagrammatic posters (up to about 4' x 8') were printed before each workshop and fastened to foam core boards to help walk through the following sequence of steps:

1. Developing biophysical scenarios (two drivers crossed on the x and y axes of a figure) and nesting the biophysical matrices into the four quadrants of a social/institutional matrix;
2. Identifying potential scenario effects and impacts;
3. Developing narratives to help visualize selected scenarios;

4. Assessing the implications for parks (e.g., natural resources; cultural resources; facilities and infrastructure; communications, education and interpretation; social, economic, community and subsistence, and visitor protection).

Completion of each step was followed by a plenary session for the groups to present and discuss their findings, and to identify commonalities among the groups.

Very few participants had engaged in similar processes before these workshops. A brainstorming tool—sticky notes on a large printed poster—was used for identifying implications and appropriate actions for preparing and responding to change. Facilitators cautioned participants not to belabor the details of individual proposed actions. The groups then sorted the charts, looking for high-level actions that would make sense to implement under most or all of the scenarios. Sometimes those "no regrets actions", actions that make sense under the range of plausible scenarios created, reaffirmed the importance of existing programs and other times they identified need for new or increased attention to other areas (e.g., new I&M vital signs).

Outcomes and Applications

The last of the planned workshops and webinars were completed in late April 2012. Final reports will be posted on the NPS Alaska Regional Office Climate Change website (http://www.nps.gov/akso/nature/climate/scenario.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

Scenario planning products included background materials, presentations, and summaries for webinars and workshops, climate map projections, and detailed final reports for each workshop, as well as a number of reports in scientific and technical journals. SNAP's energetic staff and student volunteers ensured rapid and detailed recording of workshop activities and products. Draft and final products were produced and posted on SNAP and NPS web sites[6]. Photography of the original flip charts and sticky notes enabled later comparison with summaries, to ensure that important details would not be lost.

At workshop close, participants were invited to provide feedback through post-webinar and post-workshop assessments via printed forms, Wi-Fi linked tablet computers available at the workshop, on-line survey tools (Survey Monkey), and a post-workshop webinar. Survey results from each activity were then used to make adjustments for subsequent activities.

SNAP, NPS, and the USGS Alaska Climate Science Center are also cooperating on climate change and scenarios-related educational products for multiple audiences, including posters and presentations for science and resource conferences, travelling displays, fact sheets, web pages, and video. Video was also taken in about half of the workshops, to record selected presentations and to interview a few participants before, during, and after the workshop, potentially for use in assessments and educational products.

The completion of scenario planning workshops across all NPS units in Alaska has resulted in discussions about climate change that span multiple program areas, and at high levels (Alaska Leadership Council, regional directorate and superintendents). Several cooperators with employees who participated in these workshops have also proposed additional scenario planning. These include the US Forest Service, US Fish and Wildlife Service, North Slope Science Initiative (NSSI), cooperators on the Kenai Peninsula, and the Central Council of the


NPS

Kenai Fjords National Park, Alaska

Tlingit and Haida Indian Tribes of Alaska. A coauthor of the Alaska Federal Lands Long Range Transportation Plan, who participated in a workshop, specifically addressed planning for climate change and using scenario planning to assess risks in their reports. The early products and information from two workshops (Southwest and Interior Arctic Alaska) have been requested for use in major planning efforts for two Alaska parks. Staff from several areas also remarked that they expected to use the workshop products in future planning or wished that their organizations had access to the scenarios for previous planning efforts. UAF and SNAP organized a short course on scenarios planning focused on energy development in August 2012, with many NSSI cooperators and BLM Alaska employees participating.

Lessons Learned / Next Steps

- Scenario planning ran smoothly in part because SNAP's scientists were already familiar with IPCC models, had downscaled and adapted GCMs to Alaska's topography, and were experienced and interested in working with agencies;
- Having project funding available to implement the workshops and develop pre- and post-workshop products was a great benefit to the success of the work described;
- The inclusion of a diverse group of participants, including those with Alaskan native, public outreach and storytelling backgrounds, provided for more compelling scenarios than would otherwise have been possible. Still, considerable encouragement and flexibility on both sides was sometimes required to involve local area residents, businesses, and nonfederal agencies in the multi-day commitment. Costs were mostly covered by the organizing or participating agencies, but some invitees declined participation because of the amount of time required for webinars, workshops, and travel, or perhaps internal agency policies;
- Several agency managers and participants expressed concern about the investment of time and travel. Thus, the workshop team considered several ways to shorten the time burden for participants in these and future workshops. Videoconferencing was available for people unable to travel to several workshops, but interaction was greatly reduced for remote


Tim Rains/NPS

Alaska fireweed and Arctic ground squirrel, Denali National Park, Alaska

participants. Live webinars were recorded and posted quickly on the internet. It became clear that participants who had not viewed the pre-workshop webinars or read recommended readings were the least prepared to participate fully in the workshop;

- The workshop's length might have been reduced by using organizer-selected scenario drivers and draft biophysical and nested matrices before the meeting, but group selection of drivers and effects helped to enhance the learning and to ensure broad "ownership" of the final scenarios by subject matter experts and other participants. With the completed scenarios, it might now be possible to present the results as shorter mini-workshops, to give additional participants (such as the residents of a remote community) an opportunity to focus their thinking on implications and actions for a particular area. Splitting the scenario development steps and implications and actions steps into two workshops could be effective where most participants live close to the venue, but was deemed infeasible for bringing together participants from multiple and extremely remote locations;
- Brainstorming, followed by recognition of common elements among multiple scenarios, helped identify actions appropriate to a wide range of conditions. Such "no regrets" actions can serve as an excellent starting point for consensus, but it is important to recognize that responding effectively to a particular scenario may require actions specifically tailored to that situation. Comparing observed trends to scenarios can help to identify which trends warrant closer attention or response strategies;
- Scenarios are proving to be a useful way to engage people with widely differing backgrounds and views in Alaska in discussing important and sometimes divisive topics. Consideration of multiple scenarios enabled the participants to set aside predetermined beliefs, to create and explore hypotheses about the future based on the best available science and the participants' own knowledge and experience. By employing a variety of analytical and interpretive tools (e.g., models, data, matrices, interpretive narratives, visualization), people with greatly differing ways of learning stayed engaged throughout the process;
- Developing methods for assessing the impact and effectiveness of this scenarios planning process; for incorporating scenarios thinking into planning, operations, and programs; and for continuing the learning process are all important future considerations.

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NPS

Gates of the Arctic National Park, Alaska

3.3 Climate Change Considerations in National Park Service Planning: Pinnacles National Monument*, California

**Pinnacles is now a National Park.*

Don Weeks and
Cat Hawkins-Hoffman
National Park Service

Background / Objectives

Why.—Since 2006, the National Park Service (NPS) has explored the use of scenario planning in the context of climate change and from that experience, several scenario-planning processes evolved that have application for National Park units. The NPS is now directed to consider climate change in planning projects, both via Department of the Interior[1] and 2010 NPS Climate Change Response Strategy[2], which in part states that NPS is to "…incorporate climate change considerations in all levels of NPS planning."

One of the primary planning documents prepared by National Park units for natural and cultural resources is the Resource Stewardship Strategy (RSS). The RSS is designed to (1) provide an objective basis for assessing the condition of natural and cultural resources relative to the "desired conditions", and (2) document science- and scholarship-based comprehensive strategies to achieve and maintain these desired conditions.

Where.—In an effort to bring climate change considerations into the RSS process, in 2012 Pinnacles National Monument (PINN) was selected as a prototype project. PINN is located in the Inner Coast Ranges of Central California at the southern end of the Gabilan Mountains, roughly 40 miles inland from the Pacific Ocean and 100 miles south of the San Francisco Bay Area. The national monument is a biological refuge for many California species, including the California Condor. Visitors come to the national monument for many reasons including the cultural history, hiking, rock climbing and viewing wildlife and the natural geologic formations known as Pinnacles Rocks.

How.—The National Park Service's Climate Change Response Program, working with the PINN's staff and RSS planning team, used climate change scenario planning as a tool to integrate climate change considerations into the planning process. For PINN, the scenario planning project objective was:

To explore a range of plausible, science-based climate change scenarios that are relevant and challenging to Pinnacles National Monument and to describe the associated impacts and management implications, with emphasis on the monument's fundamental resources and values.

Methods

Participants.—This scenario planning project, which took less than three months (Table 3.3), included only NPS staff. The NPS participants represented a variety of disciplines including management, planning, natural and cultural resources, facilities, interpretation, visitor use, and visitor protection.

Preparations.—A core team organized and facilitated the work. The team's primary function was to design the process, provide the climate science, select participants, and organize the effort. The core team consisted of 7 people who represented the NPS Climate Change Response Program, the national monument (e.g., the Chief of Resource Management), and some select NPS regional staff (e.g., a regional scientist and a cultural resource specialist).


Keir Morse/NPS

Crinkled onion, Pinnacles National Park, California

Process.—Participants attended two preparatory webinars in advance of the core scenario planning workshop. The webinars provided basic information on the scenario process, as well as the climate science required to build the climate change scenarios:

- *Webinar 1.*—An overview of scenario planning, project design, and schedule;
- *Webinar 2.*—An overview of historical climate change observations and the range of change projected for climate variables in the region under different assumptions about future greenhouse gas emissions (low emissions [B1], central emissions [A1B], and high emissions [A2])[3], as well as information on resource vulnerabilities and impacts based on observed and projected climate change information. A plausible climate scenario having minimal change relative to other modeled projections was also introduced.

The information and understanding developed during the webinars served as the basis for the planning workshop. Included with the workshop information were local population and land use demographic projections. At the workshop, participants explored a range of plausible climate change futures, associated impacts, management implications, potential management responses, and monitoring approaches to track the range of selected climate change scenarios.

Table 3.3. The NPS scenario planning project took roughly 2.5 months, from planning to final report.

Time Period	Effort
1 month	■ Pre-webinar organization: • Selection of the project core team. • Selection of participants/facility. • Accumulation of relevant information/data to support project.
1 week	■ Two 90-minute webinars on the scenario planning process and information/data that will be used in the workshop.
2.5 days	■ Workshop for the scenario planning process
1 month	■ Report that summarizes the process used and workshop outcomes

Scenario Development

Workshop participants initially discussed a scenario having minimal change from existing climate conditions. Dubbed “Subtle Shifts”, this scenario was developed by the NPS climate scientist Dr. Patrick Gonzalez and primarily based on the low emissions (B1)[3] climate model projection. The scenario had been presented in Webinar 2, and it provided a starting platform for the workshop. Participants identified impacts and management implications associated with the Subtle Shifts climate future.

Participants in the workshop went on to consider other climate scenarios, using cards as a tool to describe a range of potential future climate conditions. For example, the Temperature card had “2.5°F” on one side and “7.5°F” on the other side, representing the range of temperature projections by 2100 (IPCC 2007). The Precipitation card had “no change” on one side and “Increase (39%)” on the other side…and so on.

Using the cards, two breakout groups worked through different combinations of climate variable projections to create and explore additional climate change scenarios. The groups employed the following four criteria to select the scenarios for further development:


USFWS
California condor

1. *Plausible.*—Is the scenario possible?
2. *Relevant.*—Does it matter to the national monument?
3. *Challenging.*—Are there big consequences if this scenario becomes a reality?
4. *Divergent.*—Do the scenarios create a broad range of possibilities for how the future could unfold?

As a of result of their discussions, the breakout groups developed (and named) two additional climate change scenarios relevant to PINN: "Desert Dry" and "Wet and Wild(flowers)". The workshop participants felt that the three scenarios provide a wide range of plausible future conditions at the national monument, and thus could be used to support the development of management strategies in PINN's Resource Stewardship Strategy. The three scenarios were summarized as:

- Scenario 1.—The Subtle Shifts scenario represents a future with a gradual average annual temperature increase of 2.5°F by 2100 and no significant change in annual precipitation. Intense storms occur more frequently along with extreme warm temperature events;
- Scenario 2.—The Desert Dry scenario represents a future with an average annual temperature increase of 7.5°F by 2100 and an increase in extreme warm temperature events. Annual precipitation will decrease 39% by 2100 with storms occurring more frequently, including a 25% to 200% increase in 100-year storms;
- Scenario 3.—The Wet and Wild(flowers) scenario represents a future similar to the Subtle Shifts scenario but wetter with a 27% increase in average annual precipitation, including a 25% to 200% increase in 100-year storms.

Table 3.4 summarizes some of the impacts, management implications, and management strategies generated by the workshop participants for the three scenarios. Participants also generated a list of recommended monitoring to track and validate the scenarios.

Effects / Impacts	Implications
Scenario 1: Subtle Shifts	
■ Increase in fire frequency ■ Event driven shift to grasslands ■ Urban interface expanding closer to PINN ■ Decrease in aquifer recharge impacting seeps and spring habitat ■ Altered phenology	■ Vulnerability of water-dependent species such as red legged frog ■ Increased difficulty accommodating indigenous community needs ■ Loss of traditional ecological knowledge (T.E.K.) ■ Changes in fire management due to differing fuels and ignition sources ■ Facilities in flood-prone areas ■ Changes in visitation seasons with increased visitor conflicts and emergency response

Continued

Effects / Impacts	Implications
Scenario 2: Desert Dry	
■ Some perennial streams become ephemeral with a loss of some ephemeral systems ■ Increase in fire season, fire frequency and fire intensity ■ Potential loss of grey pines and important habitat for owls, raptors and condor ■ Increase in flash flood events with erosion and sedimentation impacts ■ Decrease in air quality ■ Extirpation of some water-dependent species ■ More open habitat, shift from shrubs to herbs	■ Need for alternative sources for potable water supply on the western side of the national monument ■ Decrease in feral pig population ■ More visitor pressure at talus caves due to cooler cave environment ■ Greater need for interagency coordination on watershed function ■ Challenges to maintain viable/harvestable populations of culturally significant plant and animal populations ■ Loss of wilderness character ■ Decreased viewsheds and night sky quality due to degraded air quality ■ Increased weathering of historic structures with greater exposure of paleontological/archeological sites from storms and fires ■ Opportunities to communicate/educate on climate change
Scenario 3: Wet and Wild (flowers)	
■ New seeps and springs with a wider distribution of water-dependent species ■ Changes in stream morphology, increases in sedimentation and turbidity ■ Increase in flooding ■ Increased fire fuel loads ■ Increase in mass wasting/debris flows/landslides ■ Higher cave humidity ■ Increase in regional agriculture and associated land development	■ Easier to manage cultural landscapes ■ Infrastructure impacted by increase in fires and flooding ■ Visitation patterns more dynamic with seasonally concentrated visitation ■ Increase in exotic species ■ Opportunities to communicate/educate on climate change

Outcomes and Applications

A summary report was completed describing outcomes from the Climate Change Scenario Planning project and provided to the participants and RSS planning team. The planning team used the outcomes from the scenario planning project in three ways when considering existing, or developing new, management strategies during the PINN RSS:

- *Wind tunnel testing.*—"Wind tunnel testing" refers to using the climate change scenarios to ask, "Does the strategy make sense under these scenarios?" Seen through the context of the three scenarios, it may be apparent that continuing some current activities is an unwise expenditure of time/resources, while other activities may warrant additional effort. In some cases, entirely new approaches may be prudent. Scenarios enable park managers to make better informed decisions regarding what level of risk they are willing to take with future park investments given an uncertain climate future;

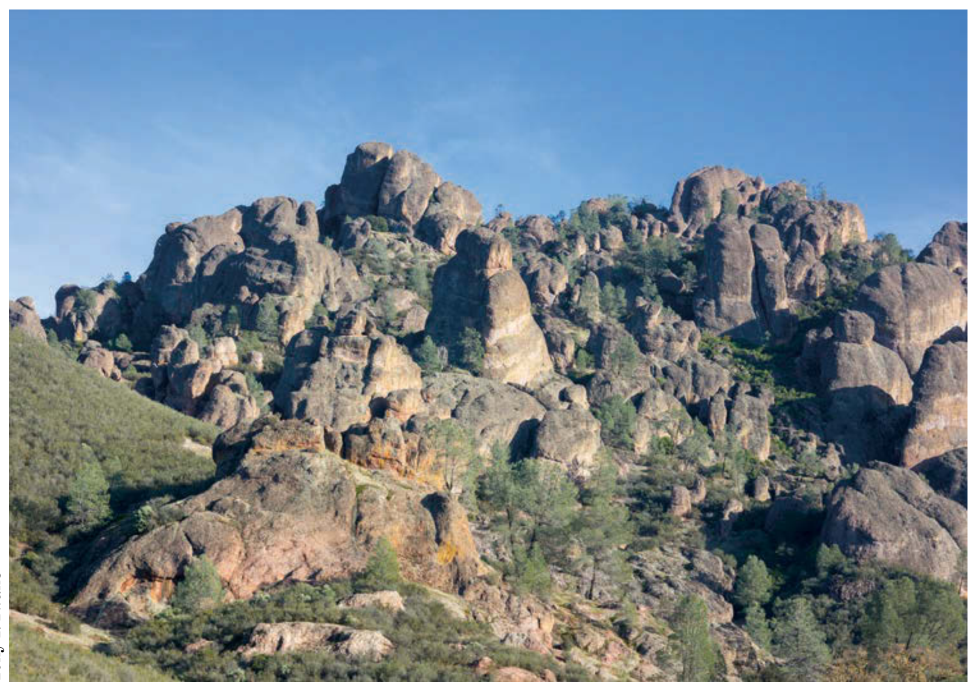
- *No regrets strategies.*—"No regrets strategies" that make sense for all three climate change scenarios were generated during the scenario planning project. These strategies provide good preparation for future events, and represent low risk with respect to influences from the three plausible climate change futures. Thus, they were considered in the RSS process;
- *Monitoring.*—Monitoring is another critical element in scenario planning. Climate change scenario work is a living process requiring review of new information and the understanding to further develop, validate, or potentially invalidate a given scenario(s). Monitoring climate variables (temperature, precipitation, storm events, etc.), as well as the responses to a changing climate (e.g., ecological changes), is important in tracking how the future unfolds relative to the scenario projections, so that decisions use the most current information possible. Thus, the monitoring recommendations from the scenario planning project were incorporated as strategies in the RSS.

References

[1] Secretarial Order No. 3289. 2009. Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources. Dept. of the Interior. Washington, D.C.

[2] National Park Service. 2010. National Park Service Climate Change Response Strategy. National Park Service Natural Resource Stewardship and Science, Climate Change Response Program. Ft. Collins, CO. 28 pp.

[3] Intergovernmental Panel on Climate Change (IPCC), 2007. Climate Change 2007: The Physical Science Basis. Cambridge University Press. Cambridge, UK.



Tony P. Iwane

Pinnacles National Park, California

3.4 Alternative Fire Management Futures in the Southern Sierra Nevada Ecoregion, California

Koren Nydick and Charisse Sydoriak
Sequoia and Kings Canyon National Parks

Background / Objectives

What.— Fire is an important ecosystem process in the southern Sierra Nevada of California. In Sequoia and Kings Canyon National Parks, climate change, coupled with a legacy of fire suppression, is projected to produce more severe and rapid effects on ecosystems than either disturbance acting alone. At the same time, fire management is one of the most potent resource management tools available as it can affect resources over large landscapes and timescales.

Why.—Incorporating climate change considerations into fire management can span a range of decision types from broad strategic problems to extensions of current strategy. The project focuses on the interactions of climate, fire and vegetation. It also combines a research focus—asking which resources are vulnerable to fire and climate change and where—and decision support, using the results of the research to develop potential management strategies.

The project's goal is to develop the capacity to manage fire under a "new lens" and to revise objectives, tools, and methods so that valued resources that are sensitive to climate change can be conserved at an appropriate scale. Project objectives include:

- Define a *range of plausible future* scenarios and make relevant to potential changes in climate, focal resources, and management policies;
- Identify *which* resources are likely to be most vulnerable to the interacting effects of changing climate, fire regimes, and other agents of change;
- Describe *where* biodiversity and other selected values are most likely to (a) remain stable without intervention, (b) survive if current fire management objectives and prescriptions are applied, and (c) suffer losses unless new fire management strategies are developed;
- Identify *what* federal partners' fire management objectives and prescriptions (coping strategies) should be to enable the conservation of valued fire-dependent ecosystems and to protect fire sensitive focal resources;
- Identify *how* and *where* fire management efforts may need to vary in the future as a consequence of changing climate;
- Share lessons learned from this project with the public and other federal land managers.

Figure 3.6 shows examples of decision types addressed by this project.

Where.—This project represents an ecoregional scale. We initially bounded the geography with the Southern Sierra Fire Management Planning Area, which is used by fire management programs across agencies. We later expanded the geographical scale northward to include more national forest land as well as Yosemite National Park. We used the Protected Area Centered Ecosystem (PACE) boundary developed for Sequoia, Kings Canyon and Yosemite National Parks as part of the National Park Service's (NPS) Park Analysis for Monitoring Support project. The PACE boundary contains an ecologically meaningful area for landscape analysis that integrates a number of important factors for the parks.

NPS

Giant sequoia, Sequoia and Kings Canyon National Park, California

Scenario Development

Collaborators.—The process was internal to federal agencies, but used cooperative university expertise. The core team included expertise in climate change science, forest ecology, fire ecology, conservation biology, resource management, fire management, and geographic information systems (GIS). However, social science expertise was missing. The participating agencies and management units on the core team were NPS-Sequoia and Kings Canyon National Parks and the Climate Change Response Program, USFS-Sequoia National Forest, and US Geological Survey. University technical expertise came

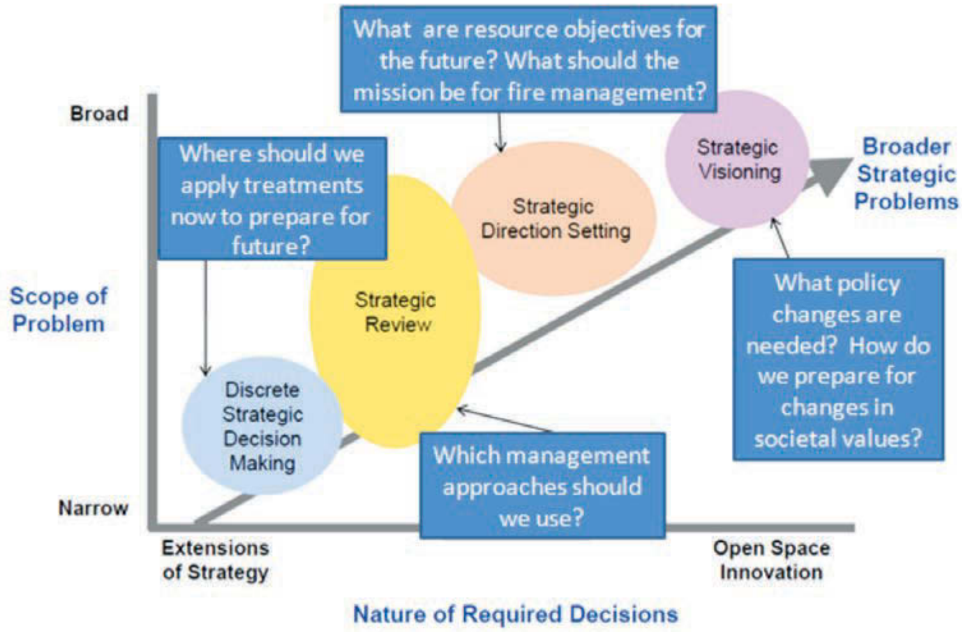


Figure 3.6. Examples of the range of decision types in fire management that were addressed in this project. Figure adapted from Global Business Network.

from University of California at Davis and Berkeley, where most of the modeling was conducted. The core project team and support staff fluctuated around 17 individuals in total. University experts and staff from Yosemite National Park, USFS Pacific Southwest Research Station, and the Bureau of Land Management participated in specific workshops. The last workshop was designed to present the project to line officers, and all federal managers in the southern Sierra Nevada were invited.

The project objectives and work plan were developed by Charisse Sydoriak, NPS-Sequoia and Kings Canyon National Parks's (SEKI) Division Chief for Resource Management and Science, in consultation with Dave Bartlett, SEKI's Fire Management Officer (now retired), and various other experts. A university cooperator was solicited through the California Cooperative Ecosystem Study Unit and Mark Schwartz at UC Davis was selected as the university co-lead. Koren Nydick was hired as SEKI's science coordinator and assigned as the agency co-lead. The project benefitted from a new partnership effort, the Southern Sierra Conservation Cooperative, and a related interagency agreement between Sequoia National Forest (SQF) and SEKI, which provided some of the funding. Sydoriak, Nydick, Bartlett, and Schwartz determined invitees for the initial workshop. While the original objectives and work plan steered the process initially, the core team reviewed and revised them iteratively throughout the project.

The project employed "science by committee", where core team members provided input on all stages of narrative scenario development and many aspects of the vulnerability assessment process and interpretation. When key decision points arose, the core team discussed the critical questions during workshops, meetings, phone calls, and in emails depending on the timing of the issue and its urgency. The team tended to be conservative and not use data or methodology with which any member found fault. Additional experts were contacted for consultation when needed.

Pre-workshop planning.—We initially planned five workshops over 1.5 years, but instead held eight workshops over two years. The workshops were either one or two day events, and encompassed topics ranging from initial scenario development, to application of scenarios to explore possible management strategies.

Narrative scenarios were constructed using the process developed by the NPS Climate Change Response Team in consultation with Global Business Network. Three members of the project team attended NPS climate change scenario planning training. We sought to create scenarios that were plausible, relevant, divergent, and challenging but also were based on science and internally consistent.

Workshop Process.—At workshop #1, we identified the critical issue as "How should we manage fire so that valued resources that are sensitive to climate change can be conserved?" Initial scenario construction occurred at workshop #2. We used a series of presentations, provided by core team members and experts, to review what we know and do not know about climate-fire-vegetation dynamics from the past, present, and into the future. We reviewed the NPS Climate Change Response Program's information on climatic and biotic projections. We also asked the agency fire management officers to discuss concerns about climate change and how it would affect their fire management decisions.

The core team and invited experts then brainstormed environmental drivers that play a critical role in regulating climate-fire-vegetation dynamics, but are uncertain in the future. From among twenty environmental drivers, the project team agreed on climate water deficit (later simplified to available moisture as a combination of temperature and precipitation change) and the frequency of fire ignitions as the most compelling combination of critical uncertainties. The two drivers were used as the two axes on a plot, which delineated four environmental scenarios.

At a later stage of the project, we incorporated social drivers by adapting four socio-political scenarios described by the National Park Service's Climate Change Response Program in collaboration with the Global Business Network. The four socio-political scenarios were constructed based on the interactions between the "nature of leadership" and "degree of societal concern." We used four from among the 16 combinations of environmental x socio-political scenarios, focusing on those that seemed reasonable based on the assumption that more severe and rapid change would result in more effective leadership and/or societal concern.

To flesh out the scenarios, we divided the workshop participants into four groups. Each group created an initial scenario description and name and presented their results. The project leads then developed a template to help guide each scenario group towards questions they should answer in their scenario. We used three elevation zones to standardize responses among the four groups. A leader was designated for each group and they were tasked with completing the template over email and phone calls. The NPS project lead used the completed templates to produce four draft scenario products:

- Graphic;
- Detailed scenario narratives;
- Senario summaries for three elevation zones in table format, and;
- Scenario comparisons for each elevation zone in table format.

The most compelling combination of critical uncertainties selected for scenarios…

- Climate water deficit
- Frequency of fire ignitions

Upon review, we found that the draft environmental scenarios were not as divergent as we desired. People had a difficult time describing a single narrative for the scenario, rather than describing various possible outcomes. Also, there were still gaps in some scenarios and we had to figure out how to deal with large-scale landscape die-off, which we thought was a possibility in any of the scenarios. Over the next three workshops (#3a, 3b, and 4), we further refined the narrative scenarios. To push towards more divergence we discussed the scenarios in a large group, as separating into small groups seemed to foster convergence among the scenarios.

We found that divergence among the scenarios often had to do with differences in the rate of change and the types of change that were predicted for earlier versus later in the century. Certain conditions, such as catastrophic wildfires, were common to multiple scenarios but occurred at different times along the trajectory of change. We specifically asked how a prolonged drought would affect resources if it occurred early versus later in the century.

By workshop five, the environmental scenarios were refined enough to use in an exercise. We separated participants into four groups that maximized diversity in expertise and agency representation within each group. Each group was assigned an environmental scenario and a socio-political scenario and was given maps of current condition and projected future climate vegetation stress and fire frequency that corresponded to the available moisture in their environmental scenario (Figure 3.7). Each group was tasked with merging its environmental and socio-political scenarios and describing the situation. We found that integrating the socio-political scenarios pushed the scenarios toward greater divergence and led to outcomes that were surprises to some participants who had not considered this driver of change.

Quantitative modeling.—In parallel to the narrative scenarios, quantitative modeling of future fire probability and vegetation climate stress was conducted to geospatially describe two scenarios varying in available moisture (i.e., approximating the x-axis of our narrative scenarios). We used two downscaled climate models with bioclimatic outputs available from a project supported by the California Energy Commission. These model outputs represented a much warmer/much drier future and a slightly warmer/wetter future. The latter was wetter than the first model, but had similar precipitation as a recent historical baseline. The projected temperature and precipitation change over the 21st century for these two models were compared to 16 other model predictions and the ensemble average using IPCC A2 emissions. This comparison helped us understand where our geospatial model scenarios fit within the universe of predictions.

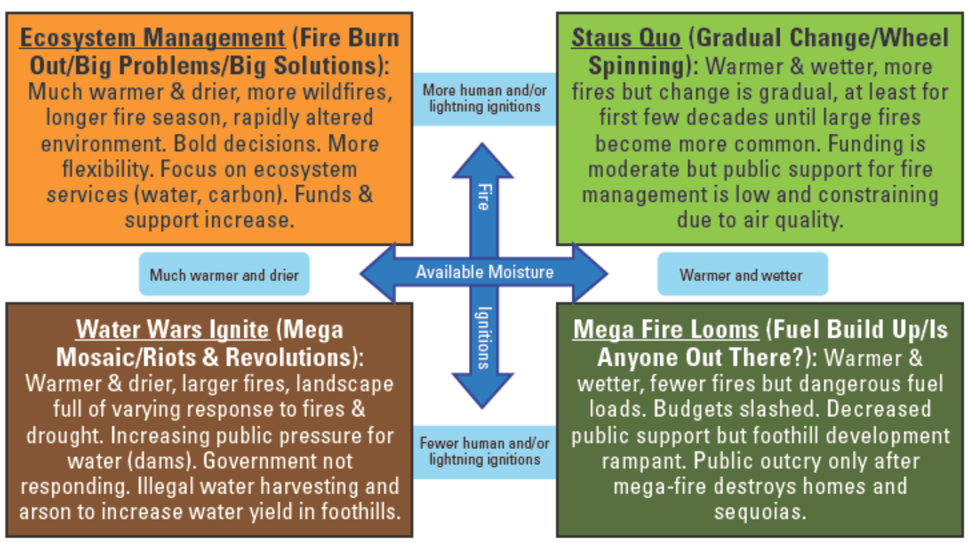


Figure 3.7. Integrated scenario summaries


David Iliff

Yosemite National Park, California

By selecting an ecoregional scale that spanned various jurisdictional boundaries, we were often forced to use statewide datasets known to be less accurate or detailed than datasets available for specific management units. In some cases, we analyzed geospatial data for the entire project area and compared it to results for specific management units (including SEKI and SQF, which were the main funders of the project).

Downscaled global circulation models output was used to drive multivariate hydroclimate envelope modeling of fire frequency (by Max Moritz, UC Berkeley), vegetation climate stress, and magnitude of change (by Mark Schwartz, UC Davis). Other geospatial data used include current conditions, namely fire return interval departure and potential flame length. The current condition and future projection data layers were combined into a vulnerability assessment. When the vulnerability assessment is combined with "values" data layers (i.e., locations of focal resources and human values) and the various data layers weighted according to management objectives and priorities, a decision support tool results.

Outcomes and Applications

Scenario application.—We applied the scenarios in two ways. First, we dissected them to understand the thresholds/changes of management concern predicted in each scenario, and whether they were unique or common to other scenarios. We brainstormed potential management options and information gaps that could be used to address the management concern. We categorized the management actions under broad strategies of resisting change, increasing resilience to change, facilitating transformation, anticipating change and planning a response (especially to extreme events), and monitoring change. This effort resulted in a reference tool, but suffered from being a "laundry list" of potential actions with little context.

Second, we designed an interactive exercise where groups "gamed" their integrated environmental/socio-political scenario on maps. Each team was charged with managing an inter-agency land area over the next 38 years, following a multi-step process:

- *Identify valued landscapes.—*First, they identified and prioritized, based on the situation in their scenario, what was most valued on the landscape (e.g., resources, ecosystem functions/services, or human values like infrastructure);
- *Develop management strategy.—*Next they came up with a management strategy to prioritize treatments (prescribed fire and mechanical thinning) for selected locations on their map to protect these values. Treatment capacity varied by scenario;
- *Apply treatments.—*Once treatment areas were drawn on the map, the team was given locations of fire ignitions and illustrated on their map where the fire burned (and if it was beneficial or damaging) taking into consideration the specific scenario. This cycle of treatments and fires was repeated several times;
- *Describe management response.—*Groups also mapped situations, such as landscape die off, invasive plant invasions, and increasing foothill development, that occurred in their scenario, and described their management response;
- *Assess future response.—*In 2050 the management team had to deal with a year of several large, intense and uncontrollable fires that had the potential to burn the entire management unit. They assessed how well their 38 years of management prepared the landscape for this event and what the consequences were for resources, ecosystem function/services, and human values. This "game" was later refined into a digital version that is run in a GIS.

Outcomes.—We did not engage stakeholders in the project because it was the agencies' first attempt at a collaborative climate change adaptation project. Our goal was to learn how to analyze information and use it to inform decision-making in the face of a changing and uncertain future. No resource management decisions were actually made as a result of the project. Public engagement will begin once official agency planning efforts begin, for example SEKI's Resource Stewardship Strategy and the USFS "early adopter" Forest Plans. The core team invited a representative from the Southern Sierra Partnership, a partnership of several non-profit organizations, to initial workshops so that they were aware of the effort.

How the information is used will depend on the value ascribed to different resources as well as the goals managers decide upon for these resources. Goal setting, however, will be informed by both scenario and vulnerability information. Therefore, the process of decision-making is expected to be iterative. How information is used will evolve over time as managers grapple with resource goals and the policy implications.

Lessons Learned / Next Steps

- *Insufficient divergence in scenarios.*—Because damaging fires, landscape die off, and type conversions were possible in any of our narrative scenarios, we had trouble making the scenarios sufficiently divergent. We had to come back together in a large group to understand that a major source of divergence was the rate of change and whether changes happened earlier or later in the century. We found that adding in socio-political drivers increased divergence substantially;
- *Funding and model constraints.*—Narrative scenarios enabled us to consider futures that were not readily modeled. We wanted to geospatially model all of our narrative scenarios but due to funding constraints and availability of existing model output, we were limited to modeling changes in temperature and precipitation represented by the GFDL and PCM models as these were the only two for which we had access to downscaled output. Neither of these models represented a significant increase in precipitation;
- *Data limitations.*—Taking a regional perspective means using data standardized across the region. Regional datasets often are less accurate, detailed, or up-to-date than local datasets, or they may not exist and require substantial effort to construct. For collaborative conservation to be effective, we need to collaborate to improve the standardization of high-quality datasets across jurisdictions;
- *Power in gaming.*—Combining narrative scenarios with maps of current and projected future conditions allowed us to "game" alternative futures. We were able to use the game to explore potential objectives, strategies, prioritization criteria, and consequences. This interactive format proved to be more valuable than simply brainstorming objectives and strategies for a scenario;
- *Scenario planning is exploratory, not decision making.*—Prioritization and decision-making requires setting resource goals and then assessing the likely consequences of various management options on these objectives. While scenario planning and vulnerability assessment can inform the setting of objectives, they do not include re-evaluating and setting of objectives as a part of the process. Scenario planning and vulnerability assessment therefore support more of an exploratory form of planning where options are developed rather than a decision-making process. We are investigating using a Structured Decision Making approach for the decision making part of the process;
- *Completing the project.*—The project spanned about two years, including three months leave for the project coordinator. The environmental scenarios

were described within the first year over three workshops. At the same time, we were developing methods for, and then conducting geospatial climate effects modeling and vulnerability assessment. In the second year, we combined the narrative and geospatial information in the context of an interactive exercise that helped us evaluate trade-offs, priorities, strategies, and consequences. The final workshop took place in the final year and reports are now available;

- *Future work and use of results.*—The results of this project will be used by SEKI to help develop the Resource Stewardship Strategy and eventually a revised Fire Management Plan. The USFS may incorporate some results into a regional bioassessment report that informs the "early adopters" forest planning process. We have not used the results for monitoring plans, but we may do so in the future. Brief summaries and presentations at conferences have been produced thus far. Fact sheets and formal publications will be produced. We are also developing a website to provide results.

USDA/Forest Service

The Rim Fire in the Stanislaus National Forest, California

3.5 Climate Change Scenario Planning in the Crown of the Continent Ecosystem (Montana, Alberta, British Columbia)

Holly Hartmann
University of Arizona

Background / Objectives

What.—Prior National Park Service (NPS) case studies, conducted from 2006-2009, demonstrated that scenario planning resonates with NPS managers and leads to identification of unique and creative ideas for proactively adapting to changes driven by climatic and non-climatic forces. These studies focused on management *within* a park unit. Recognizing that national parks exist within larger ecoregions managed by multiple jurisdictions with diverse missions and management goals, the NPS Climate Change Response Program (CCRP) established a case study centered on Glacier National Park and the Crown of the Continent ecoregion. The study was designed for all scenario development and assessment activities, including a culminating two-day workshop, to occur within a 12-week period.

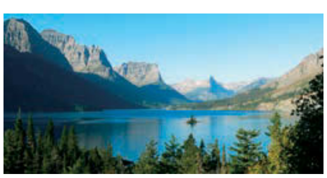
Where.—The Crown of the Continent ecosystem covers more than 16,000 square miles within Montana, British Columbia, and Alberta. A largely intact ecosystem with two national parks at its core, the region is experiencing sustained pressures, including fragmentation and loss of wildlife habitat, degradation of ecosystem goods and services, urban and rural residential development, invasive weeds, and resource extraction. The Crown Management Partners (CMP), a voluntary consortium of 22 agencies fostering trans-boundary approaches to environmental management, already had been collaborating to define ecological health in ways that can inform management by individual agencies, but they had not yet explicitly considered climate change.

Why.—This project had two sets of goals, one set for the NPS CCRP and one for the CMP. From the perspective of the CCRP, this project was intended to:

- Test and document a formalized remote engagement process and structure for scenario planning workshop preparations;
- Develop a scenario planning workshop structure to engage NPS staff and non-NPS land management organizations from the region, scaled to include two to three times more participants than prior NPS scenario planning workshops; and,
- Extend prior scenario planning efforts into new areas by exploring approaches for rapidly advancing discussion of adaptation strategies, and for connecting scenario planning with formal planning procedures.

For the Crown Management Partners, the Crown of the Continent Climate Change Scenario Planning (C4SP) project objectives focused on the scenario planning experience. The project was not intended to train participants in leading scenario planning activities, or to produce a climate change adaptation action plan. Rather, C4SP objectives were to:

- Raise awareness and build capabilities in scenario thinking for CMP managers to enable them to better address climate change issues;
- Extend scenario planning concepts developed in prior NPS case studies to the Crown of the Continent ecosystem and management concerns; and,
- Facilitate interagency discussions about how Crown of the Continent resources should be managed given prospective changes in climate and other forces over the coming decades.


Ken Thomas

St. Mary Lake, Glacier National Park, Montana

Methods

Planning.—A Steering Committee comprised of staff from the CCRP, Glacier National Park, Yellowstone National Park, Waterton Lakes National Park, and the Rocky Mountain Cooperative Ecosystems Studies Unit guided the project. Pre-workshop preparation, focused around a series of ten webinars conducted over six weeks, allowed selected participants to explore the range of potential impacts to park resources and operations, share their management challenges


©Isaac Rockwell

Lower Flathead River, Montana

and concerns, and begin thinking about viable management actions (Table 3.5). Webinars were chosen as a venue for collaboration because:

- Topic experts and personnel aligned with a specific park unit or region were located at great distance from each other. Thus even limited travel in preparation for a face-to-face workshop was too costly in time, money, and greenhouse gas impacts;
- The topics that needed to be addressed crossed multiple disciplines. Also, many topics challenged conventional thinking and agency approaches, requiring time to gather, process, and internalize new information and concepts.

The webinars were supported by a project website where participants could access the collection of resources used in the project, including webinar agendas and readings, a link to recordings of each webinar, and presentations made at the workshop.

Each 1.5-2 hour webinar included suggested readings, framing questions, invited presenters, and facilitated discussion. Participants heard from regional specialists on a variety of topics, shared their expertise, and provided input about management challenges, local and regional systems and issues, science and community activities, and data availability. Thus, the webinars provided a way to link scientific literature, expert judgment, and local knowledge for many topics.

Participants.—Each CMP organization was asked to nominate a workshop participant. Nominated individuals completed a form outlining their areas of interest, expertise, and management roles. The Steering Committee used this information to ensure diverse participation and identify potential conflicts (e.g., from individuals known to be skeptical about climate change, and/or individuals with history of cross-organizational conflict or poor workshop participation). Workshop attendance limits were increased from an original 35 participants, to 50, and then to 65 as interest in the workshop grew and the Committee desired to accommodate more NPS staff and other agency participation.

Table 3.5. Topics of the ten pre-workshop webinars

- The Scenario Planning Process
- State of the Art: Future Change in the Crown of the Continent
- Impacts on Terrestrial Ecosystems
- Impacts on Aquatic Ecosystems
- Impacts on Cultural Resources
- Impacts on Facilities and Services
- Feedbacks, Thresholds, and Cascades
- Building Scenarios
- Adaptation
- Policy Screening

Workshop invitations stressed that participants should be interested in exploring issues across several disciplines, considering both policy and management challenges, and connecting science and management, all through constructive dialog with others having diverse backgrounds and responsibilities. They also suggested participation would be most meaningful to individuals comfortable with uncertainty, complexity, and ambiguity. All participants were asked to prepare for the workshop, with preparation time estimated to require about five hours of reading or listening to webinar recordings. Informal evidence suggested that few people prepared for the workshop, although some participants did, for example reviewing the webinar recordings.

Workshop process.—Workshop goals are presented in Table 3.6. Not intended to train participants in leading scenario planning activities, nor to produce a climate change adaptation action plan, the workshop was scoped to fit within the larger context of CMP collaboration and coordination. That context includes many organizations and individuals primarily focused on resource management and ecological health rather than climate change adaptation, who would not be present at the workshop.

Table 3.6. Workshop goals

Primary Workshop Goals
Participation.—Fun, engaging, leading to new perspectives useful for further climate change-related planning and adaptation processes.
Strategic Planning.—Help CMPs "think big" about climate change over large time, space, and organizational scales, and about the interconnectedness of climate change with other forces of change. Use scenarios as a device to explore the role of policies and management objectives in preparing for climate change challenges.
Decision Support.—Identify and evaluate options for adaptation that can accommodate diverse futures, with a focus on the roles of scale and management objectives.
Secondary Workshop Goals
Exploration.—Bring together information from different disciplines and sectors to highlight the complexity and interconnectedness of climate change with other problems.
Scientific Assessment.—Combine qualitative and quantitative information about the future evolution of management challenges in the Crown of the Continent ecosystem. Help bridge scientific and political aspects of management challenges.
Tertiary Workshop Goals
Information.—Inform and consult with CMP managers about climate change and its challenges.

Scenario Development

Scenario Construction.—One principle in scenario planning for environmental decision making is that if stakeholders are not fully involved in development of the scenarios, the process used for creating the scenarios should be transparent[1]. Further, it was considered important for workshop participants to understand the scenario development process and consider it legitimate. Thus, the workshop allotted significant time for explaining the process of developing scenario narratives and presenting information used in their construction.

An important part of scenario assessment is placing the scenarios in a historical context[2]. An evening program was designed to incorporate tribal perspectives about climate, ecosystem, and socioeconomic variability in ways more flexible than in the necessarily highly structured workshop. Tribes have traditions and experience with large change and strong, uncertain external driving forces. The distinct evening program offered the opportunity to highlight those perspectives.

In prior NPS scenario planning efforts, the scenarios used to drive discussion of adaptation options were constructed within workshops, allowing development of only simplistic scenarios that were little more than lists of impacts and implications within one long time period. To better connect scenario narratives with planning processes that address different time periods, and to foster deeper discussion about adaptation options and time ordering or prioritization of potential responses, this project required more detailed scenario narratives.


NPS

Grizzly Bear, Glacier National Park, Montana

For this project, the scenario narratives were designed to serve the following specific purposes, in the following order:

- *Policy making.*—To help managers "think big" about climate change and other stressors, taking into account the large scales of the challenges, and the connection across scales from global to regional to local;
- *Long-term planning.*—To provide several scenarios which would provide managers with a wide range of potential futures that can be used to evaluate the consequences of potential management choices. This use of scenarios would necessarily occur after the workshop, on a manager's own initiative;
- *Exploration.*—To bring together information from different disciplines, including the natural and social sciences, to highlight the complexity and inter-connectedness of climate change challenges, especially for the long-term future;
- *Scientific assessment.*—To assess future developments of climate change and other stressors, combining qualitative and quantitative information about potential future events;
- *Public information.*—To raise awareness, inform, and consult managers and CMP partners about climate change challenges and other stressors.

Scenario development followed the general "four quadrant" approach used in the prior NPS case studies, but extended to produce narratives that would provide dynamic change throughout the planning horizon. Three scenarios were developed to challenge workshop participants' assumptions about the future of climate change and impacts in the Crown of the Continent region, as well as larger sociopolitical constraints or opportunities for adaptation. The basic steps used to create the narratives follow:

- *Exogenous drivers of regional change.*—A modified form of Table 4.1 from Snover et al. (2007)[3], provided the structure for constructing the climate change drivers table. Webinar participants chose to have a climatologist prepare the climate change drivers table. No tables were prepared for the non-climatic drivers, because those drivers were represented in the high-level sociopolitical matrix, developed in GBN-led case studies[4] and vetted in this project's webinar discussions;
- *Assessment of potential regional impacts.*—Impacts tables were completed by the University of Arizona project team based on a literature review, invited webinar presentations, and discussions by webinar participants. The impacts tables were limited to climate impacts on different NPS management sectors. Impacts of the sociopolitical drivers were discussed throughout webinars 2-8 and integrated directly into the scenario narratives;
- *Consideration of the linkages.*—This step made use of conceptual model schematics, or influence diagrams, developed by the Rocky Mountain Inventory and Modeling Network (Britten et al. 2007) for terrestrial landscapes, alpine systems, wetlands, and streams, and by one of the webinar topic experts for human migration;
- *Selection of climate variables for constructing quadrants.*—After the formal webinar series, several informal webinars were held to make choices required for the development of scenario narratives. These informal webinars involved a small number of webinar participants selected by Steering Committee members, along with outside topic specialists familiar with scenario planning. The ordering and selecting of climate axes was iterative, with the group testing their choices by developing some simple climate scenario outlines and then evaluating which quadrants produced scenarios with the greatest diversity of conditions;
- *Selecting scenarios to develop into detailed narratives, for climate change scenarios nested into the high-level sociopolitical matrix.*—The climate change scenario matrix was nested within the high-level sociopolitical matrix. Then the group iteratively identified five potential scenarios

that would stretch the thinking of management in different ways. Three scenarios were identified as priorities for using at the workshop;

- *Developing detailed outlines of the time evolution of scenarios.*—The University of Arizona team combined the literature reviews and webinar-based tables of climate drivers and impacts into a matrix contrasting each scenario and subdividing the drivers and impacts into specific time periods. The matrix helped ensure that each scenario differed in character, even though some elements were common across all three;
- *Development of scenario narratives.*—This effort was fundamentally a creative process of story-telling that incorporated information within the drivers and impacts tables, management issues, and the larger sociopolitical concerns raised in the webinar discussions. The narratives were ultimately created by a single individual and reviewed for consistency by other members of the project team. They were subsequently vetted by workshop participants.

Brief descriptions of the resulting scenarios are presented in Table 3.7. At the workshop, each scenario was described in a slide presentation and in a two-page briefing paper.

Table 3.7. C4SP scenarios.

Climate Complacency–Is Anyone Out There?— This scenario features local-scale climate volatility and ecosystem diversification, and increasing growth pressures due to climate change consequences occurring elsewhere. Lack of national leadership and inflexible policies, combined with public attention being focused on challenges elsewhere, severely restrict external assistance for the Crown of the Continent. The region must rely on its own creativity, flexibility, initiative, and resources.
Colorado Creeps North–Wheel Spinning.—This scenario features steady regional trends toward dryness and increasing growth pressures due to severe climate change consequences occurring elsewhere. While societal concern is focused elsewhere, national leadership and policies support a wide variety of options for adaptation.
Race to Refuge–Big Problems, Big Solutions.—The scenario features rapid climate change leading to transformative ecosystem changes in all parts of the Crown of the Continent region. This scenario used A1B climate projections from 2050 to represent conditions in 2020, and 2100 entries for 2050, with concomitant strong impacts on Southwestern drought and sea level rise producing extreme pressures on food production and human migration. However, society is focused on the region as the "last best place" and national leadership and policies support any innovations the region desires.

Scenario Evaluation.—Criteria for evaluation of the scenarios, and their order of importance, were selected prior to the construction of the narratives[1]:

- *Relevance.*—Are the scenarios relevant to the CMP managers? Do the scenarios address the concerns and needs of the CMP managers? Do they broaden the understanding of managers?
- *Creativity.*—Do they provoke new, creative thinking? Do they challenge current views about the future? Do they inform managers about the implications of irreducible uncertainty?
- *Legitimacy.*—Are the messages of the scenarios perceived to be fair, avoiding the promotion of specific beliefs or values? Are participants satisfied with the process used to develop and communicate the scenarios? Are there others that should have been involved in the scenario construction process?
- *Credibility.*—Are the scenarios plausible? Is their content compatible with current understanding? Was the development process scientifically rigorous?

Two workshop breakout sessions allowed participants to review the scenario narratives, via survey (results in Table 3.8) and discussion. Participants were asked to provide feedback about whether anything in the scenario narrative seemed not possible or plausible. Comments from participants during the workshop indicated that the climate elements of the Race to Refuge–Big Problems, Big Solutions scenario were not the source of the lower ratings. Rather, the increased availability of financial resources, especially through reprioritization of federal budgets, was considered implausible, if not impossible. However, all participants, when asked, were willing to continue working with that scenario for the purposes of considering adaptation options and continuing the workshop exercises.

Table 3.8. Workshop participant (n=25) rating of how well each scenario met the criteria (1=not at all, 2=somewhat, 3=mostly, 4=very well). Criteria are listed in order of their priority.

Evaluation Critera	Colorado Creeps North–Wheel Spinning	Climate Complacency–Is Anyone Out There?	Race to Refuge–Big Problems, Big Solutions
Relevant	3.5	3.6	3.1
Creative	3.3	3.3	3.2
Legitimate	3.1	3.1	2.6
Credible	3.3	3.2	2.3

Outcomes and Applications

At the workshop, participants were asked to focus on the two focal questions identified by webinar participants:

- *How do CMP management objectives need to change?* This question was to prompt consideration of new management objectives that might be more appropriate given the changes described in the narratives. The emphasis was on recognizing that some present-day management objectives may not be attainable, and considering that mandates and policies may be needed to give managers the flexibility, direction, or authorization they need;
- *How will CMP managers need to manage the region in the face of prospective climate change impacts?* This question recognized that for some participants a focus on management objectives was too abstract or different from their thinking about adaptation options.

Scenario assessment discussions focused on long-term changes, their implications and adaptation challenges, with participants addressing a single scenario. To foster creative thinking, we asked participants to begin by thinking about conditions described by the scenario narratives for 2100, and then think of management objectives and actions that needed to be in place by 2050 in order to prepare for 2100. Then they were asked to think of conditions described for 2050 and consider what management objectives and actions needed to be in place by 2020. Changes in management objectives were generated through group discussion, while adaptation ideas were contributed through posting of notecards by individuals working independently.

Post-workshop, distinction was made between options that build capacity to adapt and ideas that actually implement adaptation. In total, nearly 400 options were identified (106, 152, and 138 for the three scenarios in Table 3.8, respectively), including changes in management objectives needed by 2020 and 2050.

Subsequent discussions focused on evaluating a subset of suggested adaptation options related to the management of water and aquatic systems, presented without identifying which scenario(s) had sparked them. Participants were asked to identify options that were suitable for all three, two, or only a single scenario. The groups refined, expanded, and organized the options according to which scenario(s) each option was relevant, resulting in a different set of options from earlier discussions. The sequential ordering of adaptation options maximizes the flexibility of management decisions to be relevant for a wide range of possible futures (Figure 3.8).

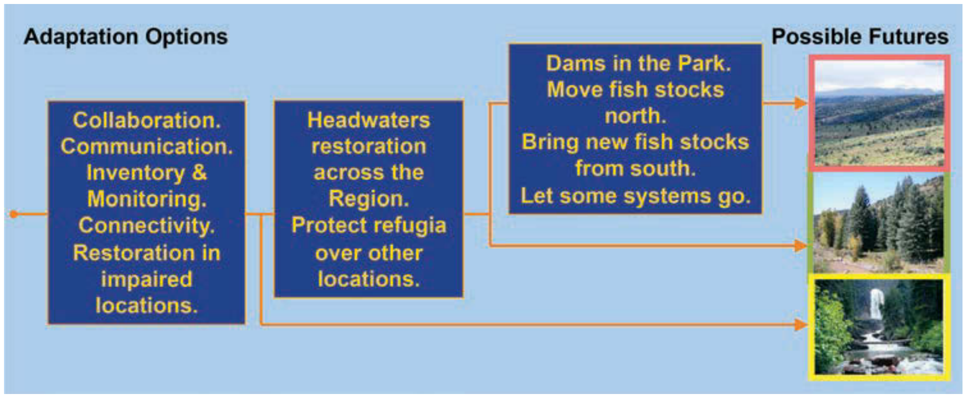


Figure 3.8. Organizations of a few potential adaptations options identified in response to C4SP scenarios (time is along the Y-axis).

Post-workshop evaluation of the nearly 400 adaptation ideas generated at the workshop identified options that were suggested for all scenarios. These "no regrets" options were few, including six options that develop capacity to adapt that should be implemented by 2020, four adaptation actions identified for implementation by 2020, two adaptation actions identified for implementation by 2050, and none identified for management objective changes for either time horizon.

Lessons Learned / Next Steps

- *Scenario planning.*—This project showed that the scenario planning process is practical for engaging with both larger groups of organizations with diverse missions and with participants who have not been involved in development of the scenario narratives. Further, the scenario planning process provides opportunity to address climate change and its high level of irreducible uncertainty over multi-decadal time horizons. It also has the potential for connecting with more formal planning processes and guiding other components within diverse adaptive planning frameworks. This case study confirms that multidimensional scenario planning takes significant pressure off specific global climate model outputs and the details of down-scaled model projections. Participants were able to focus on management challenges rather than the details of specific modeling and downscaling methods. However, the nested scenarios did not allow adequate consideration of the high impact and high uncertainty related to (1) understanding ecosystem and cultural processes, or (2) estimating the effectiveness of management actions. The methods for screening and structuring of the adaptation options resonated strongly with some participants, notably high-level management, including using the options to develop a management-driven research agenda;
- *Website.*—The project website was generally useful. It provided an easy way to manage invitations; provide directions for webinar participation; and provide controlled and structured access to webinar agendas, background reading material, webinar recordings, and workshop presentations. Participants indicated the most useful aspect of the website was access to workshop presentations, background readings, and recorded webinars;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- *Webinars.*—The webinars were practical to implement and essential to workshop preparation, especially because the scenario narratives were developed by outsiders, unfamiliar with the specific prospective changes and management challenges of the region. Each webinar allowed participants to address, in depth, a topic key to project requirements and discuss how it related to management concerns and challenges in the Crown of the Continent ecosystem. The webinar recordings offer a rich resource for understanding details of CMP challenges. Collectively, they include more than 18 hours of discussion. However, the rigorous schedule was problematic, and topics should either be reduced where practical (e.g., combining impacts topics, not addressing adaptation options or their screening), or conducted over an extended time period. In retrospect, creation of one-page summaries of webinar discussions would have provided an efficient way for people to connect with the webinars and conversations, and for updating the CMP;
- *Group involvement.*—This case study confirmed that group discussion is essential for making choices and developing the skeleton of the scenarios. The ranking process used to identify the primary scenario dimensions was important. When a suggestion was made to avoid the need to prioritize the important variables and use an ad hoc process to develop narratives, other participants voiced strong disagreement—having a structure for considering uncertainty was considered too important. Likewise, the process for prioritizing which scenarios to "build out" into narratives was important, requiring the group to seek scenarios that would pose the most relevant and challenging situations for current managers to consider. While creation of the scenario narratives is fundamentally a creative writing effort uncomfortable to some people, selection of elements to include in the narratives can involve anyone, as can review of the narratives to ensure they incorporate the full range of information and concerns expressed throughout a project;
- *Timeframe.*—For developing potential adaptation options, the approach of going backward in time, beginning with potential conditions in 2100, was successful. It kept the emphasis of discussion away from near-term "no regrets" actions that have already been identified, and instead focused on the challenges posed by long-term changes that may require irreversible commitments and long lead-times in decision making. Subsequent movement of discussion to shorter-term needs provided opportunity to highlight management options that may have long-term or irreversible consequences.

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3.6 San Francisco Estuary, CA: Tidal Marsh Restoration and Conservation Planning in the Face of Uncertainty

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[a]PRBO Conservation Science, [b]University of Alberta

Matt Ferner

China Camp State Park

USFWS

Suisun Marsh Overlook

Table 3.9. Tidal marsh bird selected for study in this case study[1]

- Black Rail *(Laterallus jamaicensis)*
- Clapper Rail *(Rallus longirostris)*
- Common Yellowthroat *(Geothlypis trichas)*
- Marsh Wren *(Cistothorus palustris)*
- Song Sparrow *(Melospiza melodia)*

Background / Objectives

What.—In the San Francisco Bay Estuary, tidal marsh restoration projects have been underway for years, with thousands of hectares restored and thousands more slated for rehabilitation. The marshes in the San Francisco Bay Estuary provide ecosystem services to the community, as well as important habitat for birds and other wildlife, but these regions have suffered substantial degradation due to filling, invasive species, development, and a host of other problems. A broad coalition of groups is working on restoration projects in an attempt to enhance natural communities within the estuary.

Why.—Tidal marshes show variable resiliency in the face of rising sea levels. With the prospect of climate change on the horizon, the California State Coastal Conservancy, which helps fund many of the restoration projects within the estuary, commissioned a study to use scenario planning to:

- assess the impacts of sea level rise on different parts of the estuary and;
- determine the likelihood of restoration success under different scenarios.

How.—The scenario building process outlined here is part of a broader project to help managers guide decision-making about wildlife in the face of climate change. In the first phase, the research team and their collaborators considered geomorphological change in the estuary. In the second phase described here, we built off the products of the earlier work to construct scenarios to assess the impact of climate change on wildlife species of interest. The goals of the project were to:

- assess impacts of climate change on estuary tidal marshes and bird populations;
- identify and prioritize sites for restoration and conservation;
- create a web-based mapping tool for use by managers (available at http://data.prbo.org/apps/sfbslr/), and;
- communicate conservation priorities to a broad constituency, including managers, conservation organizations, and the public.

This case study looks closely at the scenario process, which encompasses the first two goals, and considers how the scenario process fed into the third and fourth goals.

Scenario Development

Participants.—The San Francisco Bay Estuary project's scenario phase was expert-based and did not include stakeholders. The researchers sought to provide a tool that managers could use to think about future change and how to prioritize restoration projects in the face of uncertainty, rather than to build inclusion or participation around that process. The broader scope of the project, however, did seek to engage with a wider array of stakeholders, and the scenario process and the maps and models that it provided served as tools to do so.

Design.—Tidal marsh response to climate change was the key uncertainty for managers and researchers interested in the San Francisco Bay Estuary restoration case. The resilience of a tidal marsh in the face of climate change is very sensitive to two factors: the rate of sea level rise (SLR), and the input of mineral sediment. The rate of SLR under different climate change projections remains unclear, and the managers also lacked an understanding of the sediment dynamics within the estuary. Social factors, including policy and human behavior, added a secondary uncertainty to decision making about prioritizing different restoration projects.

For the sake of a streamlined process, the researchers involved in this study chose to consider only sea level rise and sediment input as factors in creating these initial scenarios[1].

The researchers used existing region-specific sea level rise and sediment scenarios, at 20 year intervals from 2010 to 2110, and adapted salinity projections from the USGS for consistency with the sea-level rise scenarios. The four local scenarios included a 'high sea level rise, high sediment input' scenario, a 'high sea level rise, low sediment input' scenario, a 'low sea level rise, low sediment input' scenario, and a 'low sea level rise, high sediment input' scenario. The SLR impacts of the four scenarios were quite divergent, with the high sedimentation/low SLR resulting in a large increase in tidal marsh habitat, while the low sedimentation/high SLR drives a nearly complete loss of tidal marsh.

The researchers selected five tidal marsh bird species as indicators of marsh structure and function, assuming that the presence and density of each of these species indicated the quality of different aspects of the tidal marsh ecosystem (Table 3.9). Subspecies of these birds are all of special conservation concern in California. The bird species were chosen partially because the researchers possessed adequate data on birds, but also because increasing avian biodiversity is a stated goal of many of the tidal marsh restoration projects in the San Francisco Bay Estuary and these species reflect unique facets of the tidal marsh ecosystem.

Researchers carried out bird surveys for some species, and also utilized a decade of existing data associated with monitoring for restoration projects. Researchers included marsh elevation and seasonal salinity as physical factors in creating a bird distribution and abundance model. They also included distance to the Bay and distance to nearest channel as non-varying factors. The models were created using boosted regression trees, resulting in presence/absence and abundance predictions for the estuary.

To identify areas of important bird habitat under each scenario, researchers employed the conservation planning software "Zonation," which ranks pixels within a landscape based on importance to species of interest.

Using six outputs of the Zonation software (Table 3.10)—one for current conditions with no reference to climate change, four for the different scenarios, and an "All" output that included current distribution maps and maps for the all of the scenarios—the researchers then ranked 97 current and proposed restoration projects based on the projections for each scenario. Each restoration project was represented by a polygon on the map (Figure 3.9), and the polygons with the highest summed rankings across scenarios were deemed most important, and most resilient to climate change. The researchers acknowledged that this granted an advantage to larger parcels, but felt this was appropriate since larger parcels inherently provide more habitat. They also tested several other methods of ranking, but found that the results were not substantially different from the simple ranking based on sums of habitat value across the Zonation scenarios.

Table 3.10. The six different strategies used to prioritize restoration projects for providing the best habitat for tidal marsh birds. The prioritization strategy lists which scenarios were included as inputs into the Zonation analysis to rank the landscape[1].

Prioritization strategy	Years included	Strategy Name
Current tidal marsh bird abundance	2010	Head in the sand
Current & High Sediment/ High sea level rise	2010, 2030, 2050, 2070, 2090, 2110	I feel lucky a
Current & High Sediment/ Low sea level rise	2010, 2030, 2050, 2070, 2090, 2110	I feel lucky b
Current & Low Sediment/ High sea level rise	2010, 2030, 2050, 2070, 2090, 2110	I feel lucky c
Current & Low Sediment/Low sea level rise	2010, 2030, 2050, 2070, 2090, 2110	I feel lucky d
Use all scenarios†	2010, 2030, 2050, 2070, 2090, 2010	Combined

† Variation in projections of tidal marsh bird abundance among future scenarios within each time period were used to down-weight pixels where variation is high for the All strategy.


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Clapper rail

The six different Zonation outputs allowed researchers to not only rank projects cumulatively across scenarios, but also to compare the effects of planning based on current conditions only, versus planning by taking uncertainty and different potential futures into account.

Across the scenarios, there was significant variation in the response of different species to different levels of sea level rise and sediment input. The black rail, for example, substantially increased in abundance in a low sea level rise, low sediment scenario, and substantially decreased in the a high sea level rise, high sediment scenario, whereas the clapper rail increased in a low sea level rise, low sediment scenario, and dramatically increased in a high sea level rise, high sediment scenario. These variations meant that the cumulative rankings performed much better for illustrating resilience of specific restoration project sites across all possible scenarios than the rankings based only on current conditions. The "All" scenario, which included current conditions and all four potential futures, offered the most robust insight into which parcels would perform well under whatever future conditions occur.

The researchers acknowledged that the scenarios included only the extremes—in other words "low" versus "high" rates of sea level rise and sedimentation, with no intermediate stages—and did not account for other sources of uncertainty that might have an impact on restoration project success.

Outcomes and Applications

The results of the scenario process were presented at seven conferences or meetings of stakeholders, along with instruction as to how to use the associated online decision assistance tool. The online program includes the maps that resulted from the modeling process (projected sea level rise, projected sedimentation levels, and bird and vegetation distribution, at different scales). Managers can view and search these maps to help envision the effects of climate change under different scenarios, and make decisions.

In addition, the online mapping tool and the Zonation results were incorporated into a vulnerability assessment (http://www.adaptingtorisingtides.org/wp-content/uploads/2012/09/Ch-7-NaturalShorelines.pdf), and are currently being applied in an update to the Bayland Goals Project to revise conservation and restoration priorities for the San Francisco Estuary (http://californialcc.org/projects/sustaining-healthy-ecosystems-face-sea-level-rise-ensuring-baylands-ecosystem-habitat-goals).

A number of publications have also come out of the project, including academic papers and technical reports. A list of these publications is available on the online mapping tool website, at http://data.prbo.org/apps/sfbslr/.

Lessons Learned / Next Steps

- Future endeavors for this particular system could include other species of interest beyond the five birds considered, since the needs of these five species might conflict with the needs of other species. The scenarios do provide a range of potential outcomes, however, and should therefore still be viable and useful tools;
- Using Zonation to rank restoration projects provides a more objective and potentially more accurate way to make decisions about prioritizing restoration projects in the face of climate change. The modeling process also offered (a) insight into the value of different regions for habitat for the five bird species, and (b) along with use for ranking restoration projects, the data could also be used to consider the impacts of development projects or other activities on these regions under different climate change scenarios.

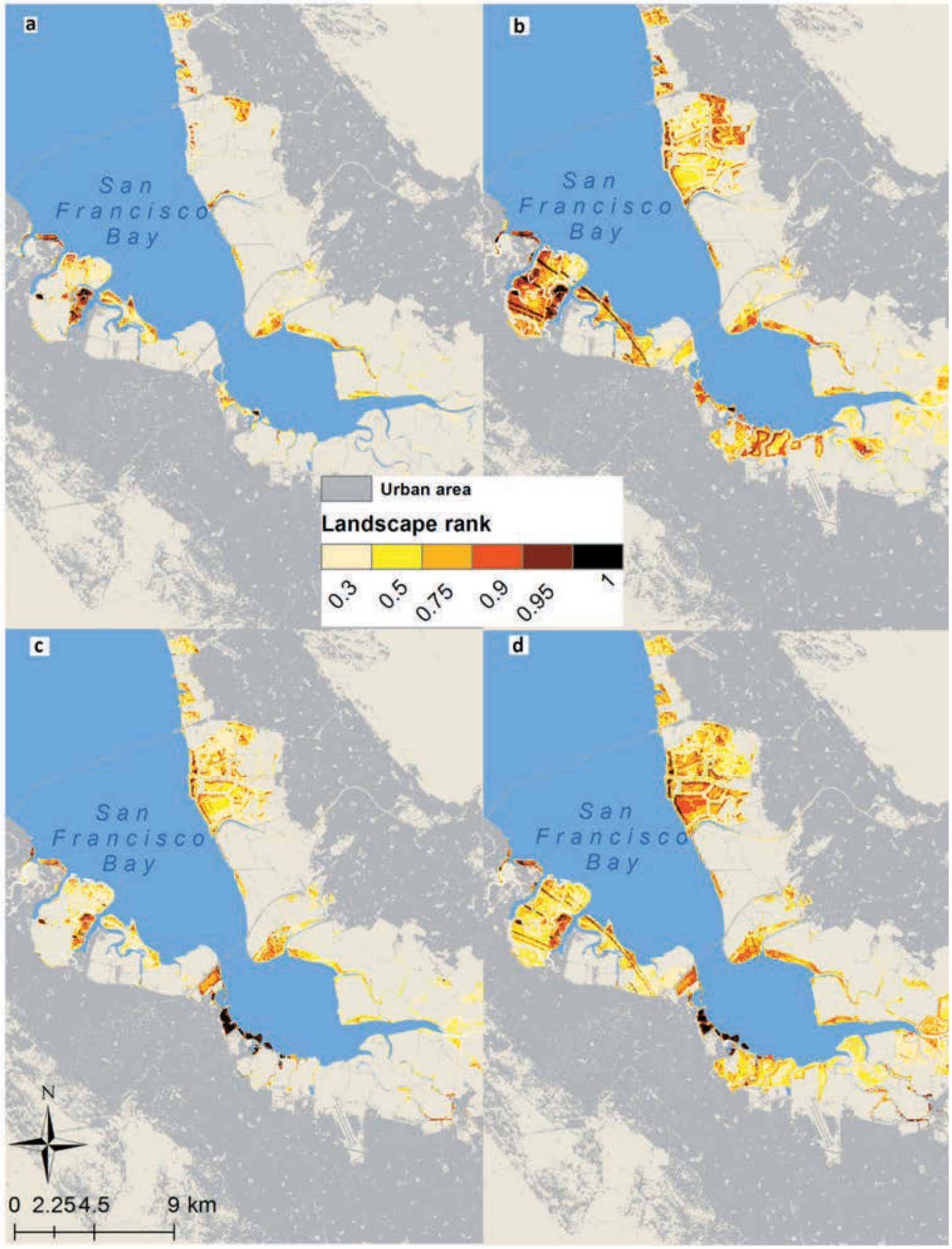

Figure 3.9. Maps of Zonation landscape conservation prioritization based on projections of abundance of five tidal marsh bird species for (a) current (2010) environmental conditions, (b) a future scenario of high sediment/low sea level rise, (c) a future scenario of low sediment/ high sea level rise, and (d) the "All" scenario prioritization which includes the four future scenarios. In all maps higher pixel values indicate greater habitat importance for tidal marsh birds (from Veloz et al. 2013).

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3.7 Integrated Scenarios and Outreach for Habitat Threat Assessments on California Rangelands

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Key management question for scenario development…

How can we maintain viable ranchlands and their ecosystem services in light of future integrated threats?

Carrizo Plain

California rangelands

Background / Objectives

What.—The Central Valley of California, the surrounding foothills, and the interior Coast Range include more than 11 million acres of grasslands, most of which are privately owned and managed as rangelands for livestock production. Grasslands are located in some of California's fastest-growing counties and are under severe threat from conversion and development. California lost 105,000 acres of grazing lands to urbanization between 1990 and 2004 and could lose 750,000 acres more by 2040[1]. In addition, climate change further stresses grasslands by potentially altering water availability[2] and distribution of species[3].

Why.—Maintaining a ranching landscape holds great potential for biodiversity conservation in the California Landscape Conservation Cooperative (LCC) region, as these privately-owned rangelands are the last remnants of open space providing corridors for wildlife to migrate and adapt to climate change. In addition to biodiversity conservation, ranches generate multiple ecosystem services—defined as human benefits provided by natural ecosystems—that carry considerable economic value, including livestock production, drinking and irrigation water, and carbon sequestration[4]. Ranchers, managers, conservationists and decision makers are seeking guidance on how future threats of climate change and land use change may impact the viability of a ranching landscape in California.

How and where.—We developed six scenarios organized around our management question: How can we maintain viable ranchlands and their ecosystem services in light of future integrated threats? The scenarios represent alternative futures of climate/land use/hydrological change for the California Rangeland Conservation Coalition (Rangeland Coalition) focus area (the foothills around the Central Valley and most of the southern Inner Coast Range) based on (a) consistent storylines of the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES)[5] and (b) downscaled global climate models (GCMs) that represent future possible climates ranging from a hot/dry future to a warm/wet future. We are using these scenarios to quantify benefits of rangeland conservation—wildlife habitat, water supply, and carbon sequestration—and to conduct an economic analysis associated with changes in ecosystem services. Scenarios are translated to land owners and land managers through an expanded outreach campaign led by the Defenders of Wildlife.

Scenario Development

Participants.—The project relied on input and collaboration facilitated by the Rangeland Coalition network. The Coalition is comprised of 120 organizations including landowner associations, government agencies and conservation non-profit organizations. The collaboration process involves multiple agencies and organizations, and includes both experts and diverse stakeholders. Stakeholder organizations include Defenders of Wildlife, US Geological Survey (USGS), cattle and sheep ranches, CA Department of Conservation, US Fish and Wildlife Service, Natural Resource Conservation Service, CA Department of Water Resources, California Rangeland Trust, Audubon California, University of California-Berkeley, and The Nature Conservancy.

Developing storylines.—Stakeholders were involved in developing narratives for scenario development, prioritizing key regions for detailed analysis, and identifying metrics for model output analysis. In the first year of the project, we held two workshops (November 1, 2011 and September 11, 2012), plus a focus group of ranchers to help refine the scenarios (January 24, 2012). Scenarios were presented to stakeholders during workshops and focus groups. Presentations and a facilitated discussion were aided by the use of maps.

Through workshops we received input that guided development of realistic storylines on how climate and socioeconomic changes may affect ranchers. In the rancher's focus group we invited ranchers to discuss the main pressures influencing change to California rangelands. Three of the key concerns expressed in the focus group were the limited availability of grazing land for lease, the fragmentation of grazing land from development, and forage quality and quantity.

Developing scenarios.—We developed three scenarios based on the storylines of SRES A2, A1B and B1. To develop scenarios we leveraged products from two USGS efforts: (a) downscaled land use change scenarios, and (b) downscaled California climate projections and related hydrologic data on climatic water deficit, runoff, and recharge. These scenarios differ by socioeconomic drivers that include population, economic development, rate of technological innovation, changes in the energy sector, the relative importance of environmental protection, and the degree of globalization. A comparison of each scenario is provided in Table 3.11.

To develop land use change scenarios logically consistent with greenhouse gas emissions scenarios, Sleeter et al. (2012)[6] used the Integrated Model to Assess the Global Environment (IMAGE)[7], which translates the SRES storylines, greenhouse gas emissions, and population projections into changes in land use and land cover (LULC), including forest, agriculture, and grasslands. The IMAGE model generates demand, or the area of land required for each LULC class, in five-year intervals from 1975-2100 on a national scale. National estimates are downscaled into regional estimates for EPA Level III ecoregions based on LULC histories from the USGS's Land Cover Trends project[8,9,10], as well as expert knowledge.

Two statistically downscaled GCMs were selected for each emissions scenario to provide representative future climate projections for California[11] (Table 3.11, Table 3.12). GCMs were selected that included variables for minimum or maximum temperatures, which were considered important determinants of vegetation distribution.

Table 3.11. Comparison of scenarios used in threat assessment for California rangelands

Scenario	Global Drivers	GCMs*	Local Translation
A2	■ High population growth ■ Medium GDP growth ■ Slow technology diffusion ■ Fossil fuel intensive ■ Conservation lower priority ■ Regional development	PCM GFDL	■ *Development*—low density ■ *Agriculture*—intensive, less innovation ■ *Conservation*—low priority; no active conservation planning
A1B	■ Moderate population growth ■ Very high GDP growth ■ Rapid technology diffusion ■ Energy balanced between several sources ■ Mixed-use based conservation ■ Global convergence	CSIRO MIROC	■ *Development*—low density ■ *Agriculture*—intensive, focus on high value perennial crops ■ *Conservation*—mixed use emphasis; 500,000 acres protected by 2100 near urban centers

B1	■ Moderate population growth ■ High GDP growth ■ Rapid technology diffusion ■ Rapid diffusion of green energy resources ■ Conservation high priority ■ Global convergence	PCM GFDL	■ *Development*—high density ■ *Agriculture*—moderate growth ■ *Conservation*—biodiversity high priority; 1 million acres protected by 2100 in high biodiversity areas

*See Table 3.12 for description of GCMs

Table 3.12. Description of Global Circulation Models (GCMs) used in this study.

Hot, dry scenarios	Warm, wet scenarios
GFDL = GFDL CM2.1 model, NOAA Geophysical Fluid Dynamics Laboratory	PCM = National Center for Atmospheric Research and Department of Energy Parallel Climate Model
MIROC = MIROC 3.2 (medres), Model for Interdisciplinary Research on Climate, Japan	CSIRO = CSIRO Mark 3.5, Commonwealth Scientific and Industrial Research Organisation, Australia

These representative projections were downscaled to 270 meter spatial resolution for monthly estimates of precipitation and maximum and minimum air temperature for application to the Basin Characterization Model, a regional water balance model[12,13]. The Basin Characterization Model relies on a rigorous calculation of potential evapotranspiration using solar radiation and topographic shading. These calculations provide energy forcings to calculate changes in snowpack, snowmelt, soil moisture, climatic water deficit, recharge, and runoff for all 270 meter grid cells. Climatic water deficit is quantified as the amount of water by which potential evapotranspiration exceeds actual evapotranspiration[14]. This term effectively integrates the combined effects of solar radiation, evapotranspiration, and air temperature on watershed conditions given available soil moisture derived from precipitation.

The USGS uses a probabilistic growth model, FORE-SCE, (FORecasting SCEnarios of future land cover) to model the distribution of each land cover type across a landscape[15,16]. FORE-SCE runs dynamically with future downscaled climate model outputs, meaning that LULC change is modeled based on socioeconomic demands, as well as changing climate. Climate variables—including 10-year averages of precipitation, summer maximum temperature, winter minimum temperature, potential evapotranspiration, and climatic water deficit—are updated in the model at 10-year intervals. All 270 meter grids of climate and hydrological variables were resampled to 250 meters to match spatial resolution of the growth model. The integration of climate and land use change in a single model allows us to study the combined effects of these stressors on dominant vegetation types.

We ran the FORE-SCE model for two EPA Level III ecoregions, Central Valley and Chaparral and Oak Woodland. The extent of these ecoregions matches the high priority conservation focus area map in use by the Rangeland Coalition (Figure 3.10). Model outputs are maps of LULC change generated yearly from 2006 to 2100 at a spatial resolution of 250 meters. Underlying climate and hydrological variables for each scenario are also available in raster format at 250 meter resolution.

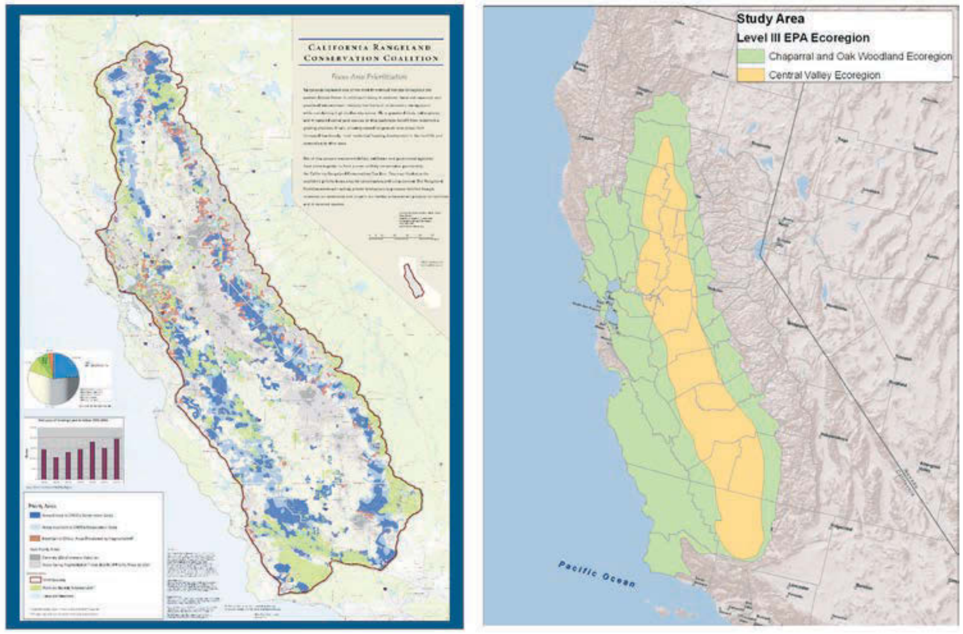

Figure 3.10. On the left is the California Rangeland Conservation Coalition Focus Area Map that identifies high priority conservation areas. The map on the right displays the boundaries of the EPA Level III eco-regions—Central Valley and Chaparral and Oak Woodland—which cover essentially all of the Rangeland Coalition focus area. We developed integrated climate/land use/hydrological change scenarios for these eco-regions for IPCC emission scenarios A2, B1, and A1B to assess future threats to wildlife habitat, water availability, and carbon in high priority conservation areas.

Outcomes and Applications

With workshop information, we developed narratives around our integrated scenarios that guided the choice of inputs to the land use change model FORE-SCE. Descriptive narratives were translated into spatially explicit variations in model runs; scenarios primarily varied by extent and distribution of developed land; extent and distribution of intensive, irrigated agriculture; and extent and distribution of future conservation lands.

To further distinguish scenarios, we incorporated future conservation scenarios into our land-use change modeling. By means of "conservation masks" we can compare and contrast the effects of land use change on rangeland ecosystem services, and we can de-couple climate effects from land use impacts. For the B1 scenario, we created a map of one million acres of presently unprotected land located in high priority conservation areas within the Rangeland Coalition boundary, where no land use change will occur in the model, but climate effects will still occur. This acreage was determined based on existing conservation goals and historical trends of conservation land protection. In the A1B scenario, we masked 500,000 acres of land from land use change, and in the A2 scenario, we did not identify any land explicitly for conservation. A brief description of the local narratives is provided below, and their implementation in the land use change model is summarized in Table 3.11, under the "Local Translation" column.

- *A2.*—Low public investment in conservation, low development density, especially around urban centers, intensive agricultural development;
- *A1B.*—Moderate public investment in conservation, protected lands are relatively near population centers, low development density, especially in Sierra foothills, expansion of high value perennial crops into rangelands;

- *B1.*—High public investment in conservation, especially for lands with high biodiversity, wildlife value, high development density and establishment of urban growth boundaries, moderate agricultural development.

Model outputs (maps) were analyzed at two scales, landscape and watershed, to compute impact assessments. We divided the Rangeland Coalition focus area into three regions: the Sacramento Valley and surrounding foothills, the San Joaquin Valley and surrounding foothills, and the Delta. Landscape level results were calculated for each region, and include change in extent of key rangeland land cover types; fragmentation of grazing land; change in bioclimatic distribution of oaks, grassland, and shrubland; change in runoff and recharge; change in wildlife habitat; and identification of water and wildlife hotspots, where changes in water availability and wildlife habitat coincide.

Six watersheds (two in each region of the Rangeland Coalition focus area) were selected for more detailed analysis on changes in wildlife habitat, carbon stocks and carbon flux, and in stream discharge. These watersheds contain high priority conservation areas and experience significant increase in either development or intensive agriculture in the scenarios. An economic impact analysis of the changing ecosystem services in these watersheds will also be conducted.

We have developed a web application that will allow users to compare and contrast results at the watershed scale for three scenarios simultaneously. Model results described above are available on the website in the form of maps. Identification of "water-wildlife hotspot" areas is a key feature of the website. The website, data and supporting materials are hosted by the California Climate Commons. The link to the web application is: http://climate.calcommons.org/aux/rangeland/index.html.

Comparison of analyses across scenarios will allow resource managers to identify potential risks and opportunities—both biological and economical—for rangeland across alternative futures. The Defenders of Wildlife will distribute this information through an outreach campaign directed at the Rangeland Coalition network of more than 100 partner organizations that includes land owners, land managers (local, state, and federal), researchers, and conservation organizations. Results from model outputs will enable:

- land trusts to target regions for land protection that are suitable for ranching and critical for biodiversity;
- water districts to assess future impacts to water supply and plan land acquisition and outreach to landowners to maximize watershed function; and,
- county planners to identify areas important to water supply and areas vulnerable to fragmentation, climate, and hydrological stressors.

Workshops continue to reach out to managers of public and private lands and decision makers in the Rangeland Coalition focus area. In addition to workshops printed materials including a factsheet has been created (http://pubs.usgs.gov/fs/)

Lessons Learned / Next Steps

- *Communicating with landowners.*—Climate change is a sensitive issue when working with landowner organizations. It was challenging to explain the need to downscale GCMs and combine them with land-use change models to be able to prioritize conservation actions and policies at the local level. It was also important to explain the role of scenarios as a tool to explore alternative actions and address large uncertainties that exist in the projection of future land use and climate, as opposed to ways to predict the future;

- *Importance of stakeholder engagement.*—Established relationships among organizations and individuals built over the years by the Rangeland Coalition helped the process since project organizers knew in advance what individuals and interests should be represented at the workshops. The final scenarios are more refined and realistic as a result of stakeholder involvement. In addition, stakeholders have started to think about potential applications of project results and were appreciative of the participatory approach. Having continuity of attendees was key for getting good feedback;
- *Get proper information on which to base the project* .—This project required that we reinterpret IPCC emission scenarios based on socioeconomic drivers of future emissions so that narratives reflected pressures that may influence change to California rangelands. We also required stakeholder input for developing a list of metrics derived from model outputs that were relevant to decision makers' needs;
- *Workshop lesson #1.*—In soliciting information from partners during workshops and focus groups, we found that adequate preparation of workshop materials was important, but not as essential as providing enough time and opportunity for participants to provide input and feedback. It was best to keep formal presentations short, and focus on one broad question to the group that could generate in-depth discussions. Details such as technical modeling information were usually not relevant to participants' concerns;
- *Workshop lesson #2.*—We found that the most valuable time was spent; listening to ranchers, and hearing anecdotes about changes individuals had witnessed over years of ranching, as well as pressures they currently faced. Individual stories provided the best opportunity to translate abstract maps generated from computer models into meaningful narratives about future threats to rangelands that land owners and land managers need to consider.

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California ranchlands

3.8 Adapting to an uncertain future: Decision Support for Long Term Provision of Ecosystem Services in the Snohomish Basin, WA

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University of Washington, Urban Ecology Research Lab


Spotted owls


Jeff Dillon/USFWS
Checker mallow

Background / Objectives

What.—The Snohomish Basin Scenarios 2060 project aimed to develop and assess hypotheses about the future trajectories of ecosystem service provision in the Snohomish Basin by characterizing the uncertainty associated with alternative future baseline conditions. The project culminated in four scenarios presenting unique and surprising sets of future conditions. Together the four scenarios are intended to provide decision-makers with essential information for testing, monitoring, innovating and prioritizing policies in light of potential opportunities and challenges that future conditions may present.

Where.—The Snohomish Basin is a rapidly urbanizing region on the west coast of Washington State. The predominantly forested landscape (66%) of the Snohomish Basin drains from the Cascade Range into Puget Sound. The Snohomish Basin encompasses the City of Everett and the large employment center at Boeing Field. The greater Seattle metropolitan area directly relies on the Snohomish Basin for ecosystem services including drinking water, recreation, wildlife habitat, large runs of salmon, and substantial carbon sequestration.

Why.—The Snohomish Basin faces many critical challenges in balancing social, economic and ecological health. Future conditions in the Snohomish Basin are controlled largely by external drivers which will change how effective regional strategies are at maintaining ecosystem service provision. The direction of technological innovation, the pace of climate change, the transformation of social values, the regulatory strength of government, global economic markets are all parts of the complex socio-ecological system governing ecosystem service provision in the basin.

Who.—The Urban Ecology Research Lab (UERL) led the project with funding from the Bullitt Foundation. The project incorporated a large number of regional experts and Basin representatives, including a steering committee, science team, and policy team. In total, individuals representing more than 50 agencies contributed over a thousand combined hours of time towards the project's completion.

Methods

Participants.—A 14-member ***steering committee***, comprised of representatives of municipalities, tribes, and local economic and environmental groups, directed the project's process and deliverables. The content of the scenarios were developed and tested with a science ***team*** of over 100 members including hydrologists, ecologists, economists, developers, utility analysts, naturalists, demographers, among several other disciplines. A ***stakeholder team*** consisted of representatives from 18 interest groups, including tribes, industry, and conservation groups, and supported the translation of project deliverables into effective policy directions.

Process.—The scenario planning process was the culmination of a two year research collaboration, starting in 2010. The iterative process incorporated Steering Committee meetings, action workshops, dozens of interviews and focus groups with the Science Team, and the integration of reviews at key stages:

- *Steering Committee Meetings:* The steering committee met to initiate the project and identified eight project directives. The same committee met to at the end and provided feedback on how to best leverage project outcomes with decision makers and the public.
- *Individual and Focus Group Meetings:* In a series of meetings throughout the project, science team members helped formulate the focal issue and

Figure 3.11. Map of Snohomish Basin in the state of Washington.

Table 3.13. Driving forces identified for project team scenarios

- Behavior
- Biophysical template
- Climate change
- Demography
- Development
- Ecology
- Economy
- Hydrology
- Infrastructure
- Institutions
- Governance
- Knowledge
- Resource management
- Values

identification of critical drivers, refine the scenario logics, and assess regional predictive models.

- *Four Workshops:*
  - Science team members collaborated on a common language for a conceptual model relating drivers, actors, assessments, and actions at a Conceptual Model Workshop;
  - Science team members formulated alternative hypotheses for the Basin's future by exploring the trajectories of climate change and human values at a Scenario Logics Workshop;
  - Modelers developed a blue print to explicitly link the inputs and outputs of eight predictive models forecasting conditions in the Snohomish Basin at an Integrated Model Workshop;
  - Basin representatives identified key questions to support more informed long-term critical decisions at a Policy Workshop.
- *Reviews:* Science team members provided focused feedback on the final scenarios. The Steering Committee provided feedback on the final package of project deliverables.

Scenario Development

Preliminary Products.—The project team, including members of the Urban Ecology Research lab working jointly with the Science Team to develop four scenarios that characterize different possible futures for the Basin out to 2060. The process evolved from four preliminary products:

- *Driving Forces:* The project team synthesized 78 interviews with science team members exploring past and future trends influencing the state of the Basin to identify 14 driving forces (Table 3.13). Each driver characterizes historical evidence and future predictions across multiple disciplines, theoretical foundations, and published literature;
- *Shared Conceptual Model:* The Shared Conceptual Model illustrates potential areas of agreement and disagreement in the relationships between driving forces influencing the future of the Snohomish Basin. The objective of the shared conceptual model is to link the various conceptual models supported by different disciplines and perspectives to support a more inclusive view of the system. The model is the product of individual and focus group interviews and the Conceptual Model Workshop;
- *Scenario Logics and Storylines:* The Snohomish Basin scenario logics represent the interactions among alternative trajectories of climate change and social values, creating four alternative frames, translating into the final four scenarios. The Science Team, subsequently refined the trajectories of each driver. For climate change, the team selected the magnitude of climate change and the variability of extreme events. For social values, the team selected a harmony versus mastery social disposition regarding the relationship to society and nature. In order to elucidate the implications for the Basin of the interactions between the two selected drivers and selected variables, the Project Team combined the divergent conceptualizations from the Science Team interviews, historical and forecast data on key trends of selected driving forces, and blueprints for integrating predictive models to assess ecosystem service conditions in the Basin. The final storylines characterize the plot of each scenario by navigating the initial hypotheses through four overarching dimensions, including worldviews and governance, employment, demographics and wealth, changes to the built environment and changes to ecosystem services;
- *Integrated Model Blueprint:* Given that future conditions cannot be described by past events along, the objective of model integration phase of the project was to complement the scenarios through two actions: 1) exploring potential relationships between systems represented by separate

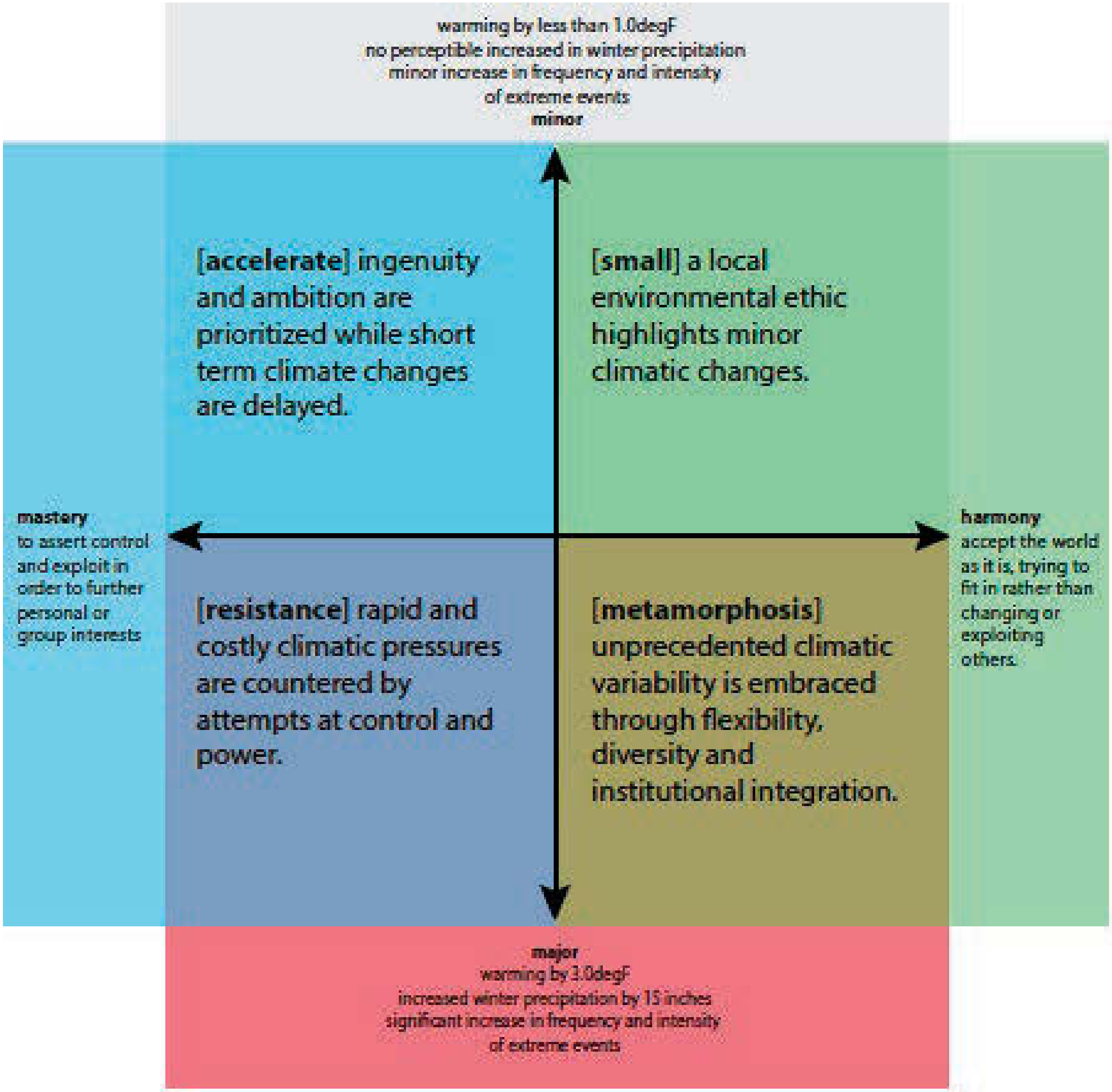

Figure 3.12. The Snohomish Basin scenario logics. The scenario logics represent the interactions among alternative trajectories of climate change and social values, creating four alternative frames, translating into the four scenarios

existent regional models, and 2) quantifying future baseline conditions associated with the alternative futures scenario hypotheses. A series of interviews and a workshop led to a summary of regional models in use, understanding of how current models address uncertainty, and suitability analysis for model integration and knowledge gaps.

Final Scenarios.—The four preliminary products were pulled together to create the final scenarios. The resulting four scenarios depict four alternative futures that can be characterized by four divergent trends:

- Faster than historical rate of economic growth with significant environmental consequences;
- Severe climatic challenges met with assertion of inequitable resource distribution and restrictive power;
- Economic downturn spurring a local, environmental ethic;
- Climate changes are embraced with experimentation and upfront investments.

Each scenario grew out of a consideration of the complex interactions among the 14 driversand highlights alternative decision contexts brought forth by different actors and power domains within the Basin. Each decision context supports new partnerships, highlighting different challenges of which to be aware, prioritizing different investment strategies, and reflecting different interests. The scenarios focus on Basin-scale challenges for decision makers by exploring the interactions of drivers at multiple scales from global climate changes and economic markets, to city-scale infrastructure investments and watershed water quality implications.

Outcomes and Applications

Based on Science Team input, the project provided initial hypotheses on the implications of alternative scenarios on ecosystem service provision. Services were limited to water provision (explored through indicators water quality and quantity), carbon cycling (explored through indicators carbon stocks and fluxes) and biodiversity (explored through indicators habitat and genetic diversity). Future changes to each of the six indicators were associated with the interaction of the selected driving forces. The divergent trajectories of these driving forces, as articulated by the scenarios, were used to hypothesize future changes to the indicators. The hypothesized effects on the services are intended to reflect potential uncertainty around future conditions and important relationships to consider when exploring the use of integrated predictive model to forecast future changes.

Basin planners expressed increasing interest in evaluating scenarios with new integrated models for the region to support a quantitative assessment of ecosystem services. One productive step in this direction would be to link operational models of climate, hydrology, urban development, ecological systems, and land cover change. The integrated model blueprint developed in the model workshop illustrated how models can be joined in a way that is both sensitive to differences represented in the scenarios and capable of simulating future baseline ecosystem service conditions. While the actual development and testing of an integrated predictive model is far beyond the scope of the project, there are efforts underway to implement this research venture.

Lessons Learned / Next Steps

Six key insights emerged from the project:

1) *Shift the focus to Resilience to consider the irreducible complexity and uncertainty of the system;*
2) *Redefine the Decision Context to expose multiple perspectives and shifting power domains;*

3) Support a blueprint for an Integrated Predictive Model to test the sensitivity of system components to expanded boundary conditions;
4) Highlight Risks and Opportunities that support a more creative and inclusive policy formation;
5) Illuminate Warning Signals to increase our anticipatory capacity and flexibility and;
6) Identify Robust Strategies that are effective across divergent yet plausible future conditions.

Project leaders identified three challenges persistent in scenario development approaches: gaps in data, subjectivity associated with participant representation, and the potential rejection of scenarios by nonparticipants in the process. To address these challenges, future research directions and improvements should include:

- *Data gaps.*—focus on (1) spatial and temporal linkages, (2) frameworks for interpretation across diverse disciplines, and (3) quantification of social values;
- *Representation.*—review of methods and outcomes by outside reviewers; and,
- *Buy-in.*—focus on communication of key concepts underlying scenario development (e.g., testing for robustness) as opposed to specific scenario narratives.

Project leaders optimistically noted: "from the various conversations over the last few years, it is clear that this project and report mark the beginning of an emergent transformation in institutional flexibility and natural capital investment towards a more resilient and anticipatory approach to long-term socio-ecological decisions."

The final report occurred in May 2013. Collaborations with the Tulalip Tribes, Snohomish Basin Salmon Recovery Forum, and Model Integration projects reflect a few of the potential future applications of this project. Project details have been made available on the project website at: http://urbaneco.washington.edu/wp/research/snohomish-basin-2060-scenarios/


Lance Koudele

Tule Fall Chinook salmon

3.9 Vulnerability Assessments for Wetlands of the Massachusetts Bays Program and San Francisco Estuary Partnership

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Background / Objectives

What.—In a pilot effort of the U.S. Environmental Protection Agency's (EPA) Climate Ready Estuaries Program, the EPA partnered with the Massachusetts Bays Program (MBP)[1] and the San Francisco Estuary Partnership (SFEP)[2] to carry out climate change vulnerability assessments for wetlands resources. For each assessment, two ecosystem processes were examined through an expert elicitation workshop. A critical element of these workshops was the presentation and discussion of a range of climate scenarios relevant to the estuarine systems being considered.

Where.—The focal ecosystem processes were sediment retention in salt marshes, and community interactions in salt marshes and mudflats. Community interactions explored for the Massachusetts Bays study focused on the implications of salt marsh grass interactions for provision of salt marsh sparrow nesting habitat, while the focus for San Francisco Bay was shorebird and mudflat prey interactions.

Methods

Participants.—The EPA, the MBP/SFEP, their partners and contractors, and academic experts (e.g., a specialist in decision analysis methods) contributed to the MBP and SFEP vulnerability assessment pilots at different stages. The collaboration for scenario construction included the EPA, the MBP/SFEP and an academic expert in regional climate modeling. Participants in the expert elicitation workshops included scientists and resource managers and were selected based on criteria to ensure extensive expertise in the local system, broad coverage of multiple scientific disciplines, experience in both science and management, and knowledge of both empirical and theoretical research.

Preparations.—In the month prior to the expert elicitation workshops, a small team developed two scenarios for each pilot project. The goal of the scenarios was to provide distinct, scientifically credible climate futures to assist workshop participants in assessing resource vulnerabilities and evaluating how to fulfill their management goals in a range of different futures.

Process.—The expert elicitation workshop approach to assessing climate sensitivities included:

- Selecting an interdisciplinary mix of participants with expertise in the local system and experience in science and management;
- Having participants create conceptual models of selected ecosystem processes;
- Characterizing the relative influences of physical and ecological variables that regulate the process;
- Assessing the relative sensitivity of the ecosystem process to key stressors under current conditions and future climate scenarios;
- Assessing the degree of confidence in judgments about these relationships; and,
- Synthesizing and reporting on the potential effects of the above on the ability to attain key management goals to inform adaptation planning.

Scenario Development

Dr. Katharine Hayhoe of Texas Tech University, an experienced climate scientist with an extensive background in regional climate assessments, led the pre-workshop scenario development. Scenario inputs came from published projections, primarily relying on the Northeast Climate Impacts Assessment[3] and work funded through the California Energy Commission[4]. Adapting the information from existing regional assessments proved to be an efficient process.

Proposed scenarios were distributed for review and revision, which involved several conference calls with EPA project leads and the key partner. Discussions between the EPA and Dr. Hayhoe over which model projections to include explored how best to balance scientific credibility with exploring a range of scenarios meaningful to management decisions. Additional discussion about what to call the scenarios also highlighted differences in use of language—partners settled on the terms "lower-range" and "higher-range," although the scenarios did not actually reflect the model extremes in future magnitudes of change.

The climate variables chosen for scenario development (Table 3.14) were chosen based on availability in published literature, as well as good agreement among the literature. The project used an iterative process to develop a handout and a presentation for the workshops in a format that could integrate qualitative descriptions while addressing different degrees and sources of uncertainty.

Each scenario was localized by using the model output from the grid point in each model nearest to Ipswich, MA for the MBP and Sacramento, CA for the SFEP. The values from multiple global climate models were averaged between one lower emissions scenario and one higher emissions scenario to generate the temperature and precipitation variables. Some additional analyses were also incorporated to develop analogs, such as relating the difference between local mean and spring tide levels to future sea level estimates.

Table 3.14. Scenario planning constraints selected as most relevant for management planning

	MBP	SFEP
Time period	2040-2069	2035-2064
Climate drivers	■ Sea level rise ■ Storms and wind ■ 4-6 temperature variables ■ 3-6 precipitation variables	

Assessment Workshops.—The pre-workshop scenario-building process resulted in a presentation and handout for the expert elicitation workshops. The scenarios were primarily quantitative, but not spatially explicit. Climate analogs as well as qualitative descriptions were provided where qualitative descriptions were more meaningful or the published literature was not conclusive on quantitative estimates.

At the expert elicitation workshops, participants assessed implications of the scenarios for each focal ecosystem process in a stepwise process, as follows:

- Dr. Hayhoe provided an overview of major climate drivers, regional trends, and sources of uncertainty through remote presentation at the start of each workshop. An additional climate expert was present to help answer questions;
- Participants created a conceptual model for each ecosystem process. Each conceptual model, which included no more than 15 biological, physical, and management variables, was used to assess the sensitivities of the system to the climate scenarios;
- Participants used the values provided under a lower range scenario and a higher range scenario to examine the relationships among ecosystem process variables reflected in the conceptual model. The discussion of impacts was focused on an example location within each estuary to ground this step in the process;
- Experts then identified management options that continued to achieve management goals in light of these impacts;

The group did not explicitly consider interactions between climate drivers in their exploration of the potential impacts of the climate scenarios to the wetland targets. In contrast, the sensitivity assessment did include consideration of

Saltmarsh sparrow

interactions between ecological and management drivers, though not in depth due to insufficient time.

Outcomes and Applications

As an outcome of each workshop, workshop participants:

- Identified an initial list of management options for the scenarios explored. MBP and SFEP resource managers, and/or those with relevant capacity and mission, were expected to further evaluate, refine, and prioritize the management options post-workshop, as well as share results with their broad stakeholder networks;
- Developed a list of research and monitoring needs based on (a) knowledge gaps and (b) areas of highest uncertainty, as identified through the scenario construction process. Examples include:
  - Developing a better understanding of the threshold after which accretion will no longer keep pace vertically with sea level rise by determining what the maximum level of vegetation growth is relative to sea level rise and monitoring future changes in rates of growth and sea level rise;
  - Tracking other potential thresholds, especially for birds and other mobile species that use multiple habitat types, by monitoring at the landscape scale.

This work demonstrated a pilot process for expert elicitation-based vulnerability assessments for coastal systems and the resulting implications for assessing climate adaptation options. The pilot process and results are published as a two-volume EPA report, available at http://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=241556 and http://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=241555. The descriptions of the climate scenarios used in each workshop are in Appendix C in each document.

Lessons Learned

Workshop participants identified multiple challenges with the process employed:

- *Choosing between alternative options* of basing scenarios on model means, versus exploring the broadest range of potential futures using maximum and minimum model outputs, proved to be a challenge. The two scenarios ultimately selected were based on mid-century model averages. This preference stemmed in part from the climate science community being cautious about methods that could be misrepresented as alarmist or cherry-picking. Concern about misinterpretation prevented selection of more distinct scenarios based, for example, on the results from the two most divergent models. As a result, the two scenarios used were not distinct enough to fully explore the impacts and management implications of each compared to the other, although it was possible to distinguish between current climate and future climate (the two scenarios) effects;
- *Matching expectations* between available quantitative information for physical variables and bridging to ecological variables that were the focus of the assessment offered another challenge. One participant suggested that more qualitative, ecologically-based scenarios might be more effective for planning; for instance, instead of trying to come up with options associated with specific future sea levels, managers could consider divergent futures, one in which a marsh is able to accrete vertically at the same pace as sea level rise, compared to a scenario representing a marsh no longer able to keep pace vertically where facilitating landward migration would become essential;
- *A clearer definition of scenario planning* and its purpose in the climate science community might help alleviate concerns of misuse, as well as increase comfort in exploring broader ranges of uncertainty in future efforts.

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USFWS

Oxbow National Wildlife Refuge, Massachusetts

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3.10 Scenarios of Land Use, Climate Change and Transformations of Forest Landscapes in Massachusetts

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Background / Objectives

What.—The New England Forest Scenarios Project led by the Harvard Forest, Harvard University is part of the Long Term Ecological Research (LTER) Future Scenarios Initiative begun in 2004. The Forest Scenarios Initiative, an expanding collaboration of the LTER Network, research institutions, and stakeholders, represents a series of studies focused on several forested regions across the United States[1].

Why.—The overarching purpose of the New England Future Scenarios Project is to expand understanding of the impacts of multiple drivers (e.g., socio-economic, policy, biophysical) of landscape change on forests and the ecosystem services they provide. In 2011, the key drivers of forest change (Table 3.15) were identified through leadership dialogues with representatives from federal agencies, conservation organizations, and landowner associations. While fundamentally research focused, the ultimate goal of the efforts was to generate information to guide forest policy, conservation, and management in the context of changing climate. Fundamental questions addressed through the LTER Future Scenarios Initiative include:

- What will be the relative influence of climate change, natural disturbance, forest conversion, forest management, and forest dynamics on ecosystems and service provision over the next 50 years?
- How will the relative influence of broad-scale processes vary along major social and ecological gradients across and among regions?
- How can scenarios and ecosystem service evaluation inform and motivate forest policy, management, and conservation at state to national scales?

Where.—A part of the New England Future Scenarios Project, a pilot was launched in 2009 focused on the forests of Massachusetts. Beginning in 2014, the knowledge and experience gained from the Massachusetts pilot will be used to shape an expanded regional effort extending to the states of Massachusetts, Maine, New Hampshire, and Vermont.

Participants.—The Massachusetts pilot is a joint effort led by the Harvard Forest and the Smithsonian Conservation Biology Institute[2]. For scenario development, these lead organizations convened a regional stakeholder group comprised of representatives of state agencies (conservation, planning, water and energy) and non-governmental organizations (forest management, land protection, and sustainability).

Preparations.—Priorto the scenario development workshop, stakeholders participated in a webinar where research goals, project approach, and findings to

Table 3.15. Key drivers of forest change

- Housing
- Competition for food production
- Energy development (e.g., biomass)
- Management for climate change mitigation
- Responding to disturbance (e.g., fire management).

date were outlined so that in-person time could be most efficiently used toward scenario creation.

Scenario Development

Scenario simulations.—The Massachusetts project began with an extensive data gathering effort to define current trends in forest harvesting and development. These land cover and land use trends were then simulated as a current trends scenario for the state's forest through 2060. The objective of this first step was to estimate the relative influence of growth, succession, climate change, forest conversion through development, and timber harvest on indicators such as aboveground biomass and tree species composition[3].

Regression trees were developed to create probability of conversion and probability of harvest zones based on landscape variables (e.g., population density, distance to cities, distance to roads). These probability zones were used to simulate future patterns of conversion using the LANDIS-II model designed for meso-scale forest dynamics (10^4-10^7 ha).

Once the model was parameterized, a series of eight different "treatments" or combinations of climate change, land conversion, and harvest were simulated and their impacts on biomass and species composition measured. Only a single climate change scenario was examined as part of the "business as usual" simulation. Published results from this first round of simulations for Massachusetts forests suggest that the effects of climate change might be small relative to those engendered by other regional drivers such as regeneration and growth of forests[3].

Workshops and webinars.—The current trends scenario simulated a linear continuation of the trends in land use under a single climate change scenario and served as a baseline for a broader range of plausible alternative futures. The regional stakeholder group's task was to create a suite of scenario narratives that stretched beyond the current trends and incorporated drivers reflecting their concerns to bracket the range of plausible futures for 2060[4].

The scenarios were developed for MA forests over the course of three, half-day workshops and three intervening webinars (1.5 hours in length), by eliciting stakeholder input on forest concerns and drivers of change and lumping the responses into a set of three coherent storylines. Each storyline was loosely based on a two-dimensional matrix of the degree of environmental regulation

Table 3.16. Massachusetts Land Use Scenarios (scenario names are preliminary)

Current Trends	Based on conservation, development and harvesting trends for 1999 to 2005.
Opportunistic Growth	Environmental regulations are rolled back; weakened zoning laws allow for proliferating sprawl, subdivisions, and a 125% increase in development; reduced funding for conservation; development of some former public lands; largely unrestricted forest harvesting.
Resource Self-Reliance	Important natural resources become scarce; oil prices skyrocket; regional demand increases for woody biomass and local food; development of tightly spaced low-income housing increases but large-lot residential development still occurs.
Forests as Infrastructure	Development is strongly targeted towards redevelopment of small cities; protection of forest is paralleled by an increase in sustainable harvesting, large forest reserves; pace of land conservation doubles and is targeted; use of woody biomass increases.


Bill Thompson
Ruby-throated hummingbird

and the extent of resource extraction (Table 3.16). For the purposes of the MA pilot, the scenario development was limited to expert elicitation from the stakeholder group.

The three alternative scenario narratives were then translated into rule-sets that provided the inputs to the landscape simulation model, LANDIS-II. The rule sets were developed by starting with the number of forest acres converted or harvested and the decision trees for spatially allocating those acres under the initial current trends scenario. Stakeholders helped translate the scenario narratives into rule-sets for modeling by modifying the land cover/land use acreages and probabilities for allocating these acres for each of the scenarios. The quantitative rule-sets for each of the scenarios were then used as inputs to LANDIS-II to simulate the influence of this land cover/land use change over a 50-year period. The modeling was conducted for current climate conditions and for conditions under the A1F1 climate scenario (640 ppm CO_2 by 2060) downscaled for the Northeast by Hayhoe and others[5]. For each scenario, LANDIS-II provides detailed information on forest composition and structure at a 1-hectare pixel and at annual time steps. The next step is to analyze the consequences of the resulting changes in forest composition and structure for critical ecosystem services (Table 3.17). The consequences for ecosystem services were quantified by modifying the InVEST model (Integrated Valuation of Environmental Services and Tradeoffs) created by the Natural Capital Project.

Table 3.17. Calculations planned as part of a future analysis of critical ecosystem services

- Changes in annual live aboveground biomass and associated carbon consequences;
- Timber harvest by species and associated economic return;
- Total annual water runoff;
- Total annual nitrogen export;
- Change in forest patch size;
- Degradation of forest habitat;
- Likelihood of development for high priority habitats identified through the MA state wildlife action plan (i.e., BioMap[6]).

Outcomes and Applications

In a final MA pilot workshop held in March 2013, project leaders worked with the stakeholders and policy makers who developed the scenario narratives to explore linkages to specific policy, conservation, and management decisions that will be in play over the next 3-5 years, including:

- Upcoming environmental bond act to provide public funding for land conservation;
- Land use sector guidelines and goals for the MA climate action plan to achieve the goals of the Global Warming Solutions Act;
- Thermal biomass harvesting guidelines for renewable energy tax credit program;
- Water sustainability plans and the role of forests as water supply and flood mitigation infrastructure.

At the final MA pilot workshop that group also defined and framed outreach products for the scenarios project and identified key audiences for outreach briefings. It is anticipated that outreach products will include a scenarios website, a color report for decision makers, case studies for specific iconic or vulnerable areas in the state, and a press release and supporting information for journalists. These outreach efforts will build on existing efforts, including:

- Future Scenarios website: http://harvardforest.fas.harvard.edu/other-tags/future-scenarios#
- Recent workshop August 2012 at the Harvard Forest in Massachusetts: “August Workshop and Webinar—Future Scenarios of Landscape Change”

- ESA Annual Meeting presentation 2012: "Collaborating with stakeholders to define land-use scenarios that inform landscape simulations in Massachusetts, USA"

Lessons Learned / Next Steps

- Time lags between stakeholder involvement workshops and scenario modeling at times made it difficult to sustain momentum and required substantial review of decisions and directions established in previous work sessions.
- Gaps between stakeholder defined land use prescriptions and limitations of the LANDIS-II simulation model required that we hire programmers to develop new modules to represent different configurations for development (e.g., clustered development) and different types of silviculture.
- An inherent tension exists between scenarios that depict specific, detailed policy and conservation decisions and scenarios that represent widely contrasting futures. The MA pilot struck a useful and informative balance between these two approaches, but this challenge will remain as the effort expands into northern New England.
- The informal scenarios process and relatively small group of stakeholders were appropriate for the MA pilot project, but we intend to ramp up these efforts by drawing on social science practitioners to design a group process and facilitate workshops with a larger group of diverse stakeholders when we expand the effort to northern New England.
- These lessons and others will inform the scenario development approach for the expanded northern New England project beginning in 2014.

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Leslie Karasin

Saranacs, New York

3.11 Florida Keys Marine Adaptation Planning (KeysMAP) – A marine-based scenario-planning project

Bob Glazer[a], Juan Carlos Vargas[b], Michael Flaxman[b], Roger Griffis[c], and Chris Bergh[d]

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Background / Objectives

What.—The Florida Keys are among the most highly vulnerable coastal areas in the U.S. with respect to a changing climate due to the high degree of endemism, the low-lying topography of the island chain, and the reliance of the economy on a fragile coral reef ecosystem.

Why.—The region is comprised of a complex mosaic of sub-tropical coastal and tropical marine ecosystems. Large expanses of mangrove forests with intermittent isolated beaches exist within the coastal zone. Further inland, pine rocklands and hardwood hammocks are common although development has greatly reduced the latter. Importantly, the majority of land within the Keys is less than 1-m in elevation—the highest point is 5.5 m on Windley Key—making the region highly susceptible to sea level rise and storm surge inundation.

The marine ecosystem is characterized by large expanses of seagrass meadows in close association with coral reefs. The reefs have been declining for decades due to a large number of documented stressors. Recently, they have been subject to increasing frequency of elevated sea surface temperatures, resulting in large-scale bleaching events and, ultimately, coral mortality.

Where.—The Florida Keys are located within or in close association with a number of administrative jurisdictions, including the Florida Keys National Marine Sanctuary, Everglades National Park, the USFWS National Wildlife Refuge System, as well as a number of state and county parks (Figure 3.13). Fisheries resources are managed by the Florida Fish and Wildlife Conservation Commission and the Fishery Service within the National Oceanic and Atmospheric Administration (NOAA).

How.—Despite the well-developed governance structure, the uncertainty related to climate change in the coastal and marine ecosystems makes natural resource planning a daunting challenge, particularly in the marine environment. Here managers generally have few alternatives and often default to seeking to increase resilience by reducing exogenous impacts. The KeysMAP (Florida Keys Marine Adaptation Planning) project, by contrast, provides a framework within which natural resource managers can conceptualize future conditions, factoring levels of uncertainty, and develop possible management options.

KeysMAP project, which is designed to be manager driven, is based on the development of a set of alternative future scenarios. It expands upon a method employed for terrestrial ecosystem planning, but not yet widely used for marine planning. The ultimate goals of the project are to enable ecosystem and resource managers to (a) develop scenarios they want examined, and (b) interpret possible outcomes so they may identify appropriate management strategies. Towards accomplishing the second goal, we tested the effectiveness of a set of potential management actions across the range of conditions. We selected a time horizon for this project out to 2060 to correspond with the 50-year horizon within which most planners are constrained.

Amanda Pollock

Coral

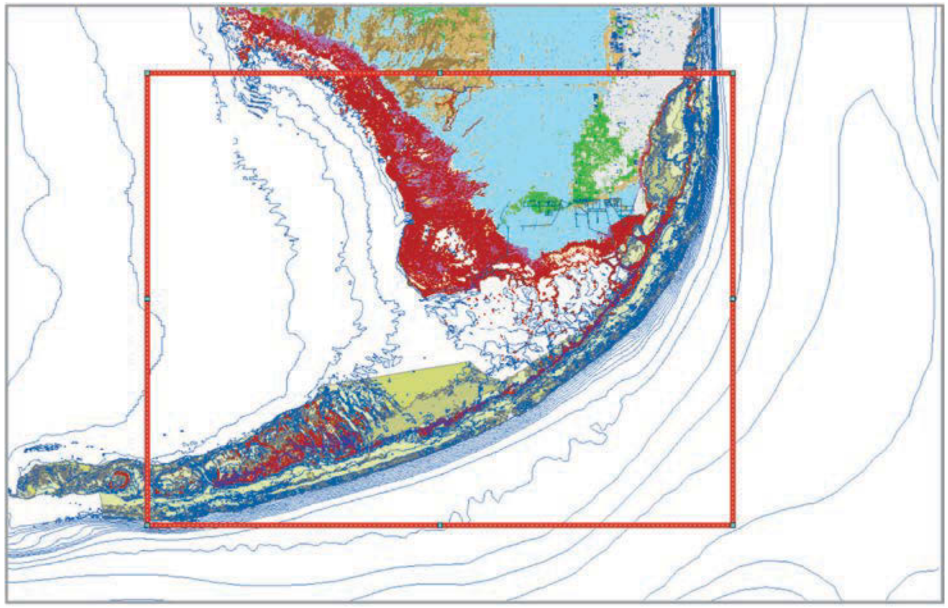

Figure 3.13. The spatial scope of the project includes the Florida Keys and southern peninsular Florida encompassed by red box south of 25.25° north latitude.

Scenario Development

Scenarios.—Three dimensions are incorporated into each scenario developed (Figure 3.14):

- *Biophysical (i.e., climate change associated variables).*—Within the biophysical dimension, we will examine two variables, both tied to IPCC emissions scenarios. The first variable is sea level rise (SLR), simulated using the Sea Level Affecting Marshes Model 6.0 (SLAMM[1]). SLAMM model runs were initialized to correspond with the lower, middle, and upper end of the range of SLR projected to occur by 2060 by the south Florida Four County Compact[2]. The lower and mid-point SLR scenarios were tied to IPCC AR4 scenarios; the lower end was based on the A1T max which estimates 196.6 mm SLR at 2060. The A1FI emission scenario represents the middle of the range with 297.5 mm estimated SLR at 2060. The upper end of the range was simulated directly from the Four County Compact extreme projection of 1-m SLR by 2100, which equates to 419.4 mm by 2060. The second biophysical variable we are examining is sea surface temperature (SST), by NOAA's AOML, using their downscaled, high-resolution, spatially-explicit ocean model[3]. Surface warming will be coupled with IPCC AR5 carbon emission scenarios at 1° latitude/longitude spatial resolution that corresponds as closely as possible with the AR4 emission scenarios defined for the SLR projections. This spatial resolution will help ensure cross-compatibility between the two biophysical components. The expert working group we convened on coral reef ecosystems declared that sea surface temperature will be far more important than ocean acidification in our 2060 time horizon, thus the latter is not included as a variable.
- *Socio-economic.*— The socio-economic dimension includes variables related to commercial fishing, recreational fishing, and tourism. For the purposes of developing scenarios, these activities are further refined based on their possible future demand relative to current demand (i.e., lower, higher, or trending). A number of historical datasets are used to examine and project the status of those activities, including spatially-explicit boat use data and fishing catch and effort data.
- *Management.*—For this project, the management dimension is focused solely on marine protected areas. In a process similar to the socio-economic dimension, the possible future importance of this dimension is based on reduction of existing zones, no change to current policy (business as usual), and policies which increase protection.

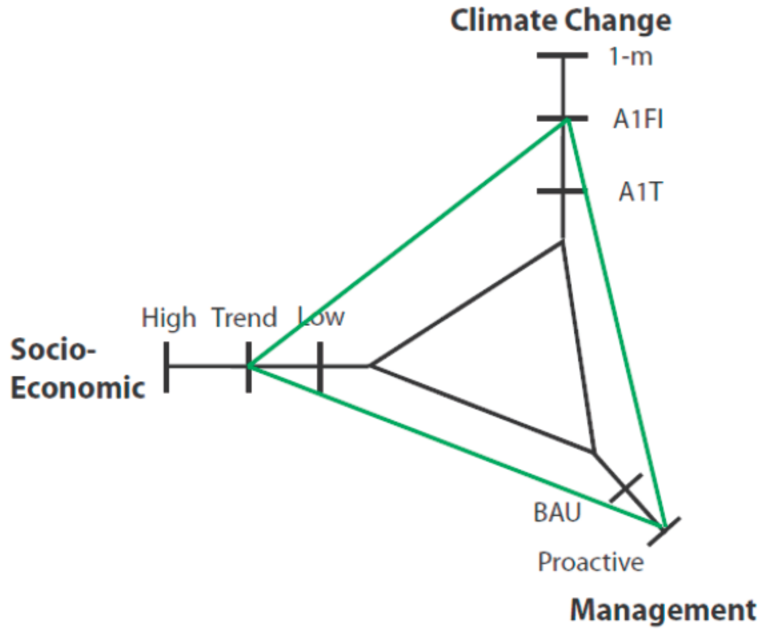

Figure 3.14. Dimensions associated with the KeysMAP scenario-planning project. The climate change dimension details three carbon emission scenarios. The socio-economic dimension relates to commercial and recreational fishing and tourism. The management dimension is marine protected area development—"BAU" is business as usual and "Proactive" is increased protected area development. The green triangle represents one possible scenario: medium sea level rise and sea surface temperature, continued fishing and tourism demand, and increased appetite for using marine protected areas.

Ultimately, each scenario will include information from each dimension based on manager needs. For example, one scenario may include medium SLR and the associated SST (biophysical), trend in fishing and diving demands (socio-economic), and proactive approaches to marine protected area development (management).

The scenarios to be developed are to be tested against a set of indicator species and associated habitats chosen to represent a diversity of habitats and species within the coastal and marine habitats within the Keys (Table 3.18). The spatial scope of the project includes the Florida Keys and southern peninsular Florida south of 25.25° north latitude and we have selected 3 zones within this larger region as representative areas (Figure 3.13).

Table 3.18. Habitats and species selected for scenario simulation.

Habitat	Species	Reason for species selection
coral reef	Goliath grouper	a protected yet recovering species that uses both mangroves and coral reef for different stages of its life-history
mangroves	spiny lobster	a commercially and recreationally fished species using coral reefs
beaches	loggerhead turtle	an ESA listed species which uses beaches for nesting

Workshops.—This project uses four workshops where managers and scientists provide input related to the development of management-relevant scenarios and then examine the possible resulting outcomes from those scenarios on focal habitats and species. As previously described, the scenarios are tied to IPCC emissions scenarios.

The first workshop, conducted in the summer of 2012, was comprised of managers from state and national parks, the Florida Keys National Marine Sanctuary, the U.S. Navy, national wildlife refuges, fisheries authorities, and from the local NGO community. The managers evaluated habitat maps under different SLAMM simulations for their accuracy. They also defined the variables used as input within each dimension (Figure 3.14).

The second workshop was structured around expert working groups of scientists. The scientists focused on the three habitats under consideration. They provided background information and inputs on how they expected the habitats to respond under changing environmental conditions.

Next Steps

The third workshop will examine the three focal species (Goliath grouper, spiny lobster, and loggerhead turtle). We will convene working groups of species experts who will provide their expertise to determine how each species may respond under the different scenarios.

The fourth and final workshop will reconvene the managers from workshop one to brainstorm management strategies to address the differing conditions under each scenario. We expect them to develop a discrete set of possible options at the habitat, species, and ecosystem scale.

We hope that this project will serve as a baseline from which we can add data to the dimensions as they become available, plus additional dimensions and/or variables. For example, two important variables not under consideration in this study, but will have large ramifications on future management include Everglades' restoration (biophysical and management dimensions) and the longevity of the Naval presence (socio-economic dimension). In future iterations of the project, we also intend to integrate other programs that are modeling physical, biological, and social systems within this framework.

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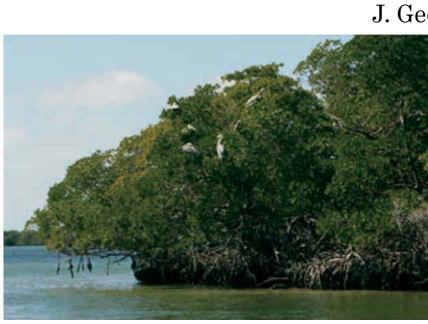

Steve Hillebrand/USFWS

Brown Pelicans in mangrove tree, Florida

3.12 Climate Adaptation Planning for the Bear River Basin, Utah

Molly S. Cross
Wildlife Conservation Society

Background / Objectives

What.—The Adaptation for Conservation Targets (ACT) framework is a simple yet structured process for deriving place-based climate change adaptation actions for particular species, ecosystems, and ecological functions[1]. The ACT framework integrates elements from familiar decision support methods (e.g., adaptive management, Structured Decision-Making, Open Standards for the Practice of Conservation) into a process that is tailored to considering the effects of climate change. The ACT framework is designed to motivate collaborative planning by a multi-disciplinary group of experts and practitioners through a series of steps (Figure 3.15).

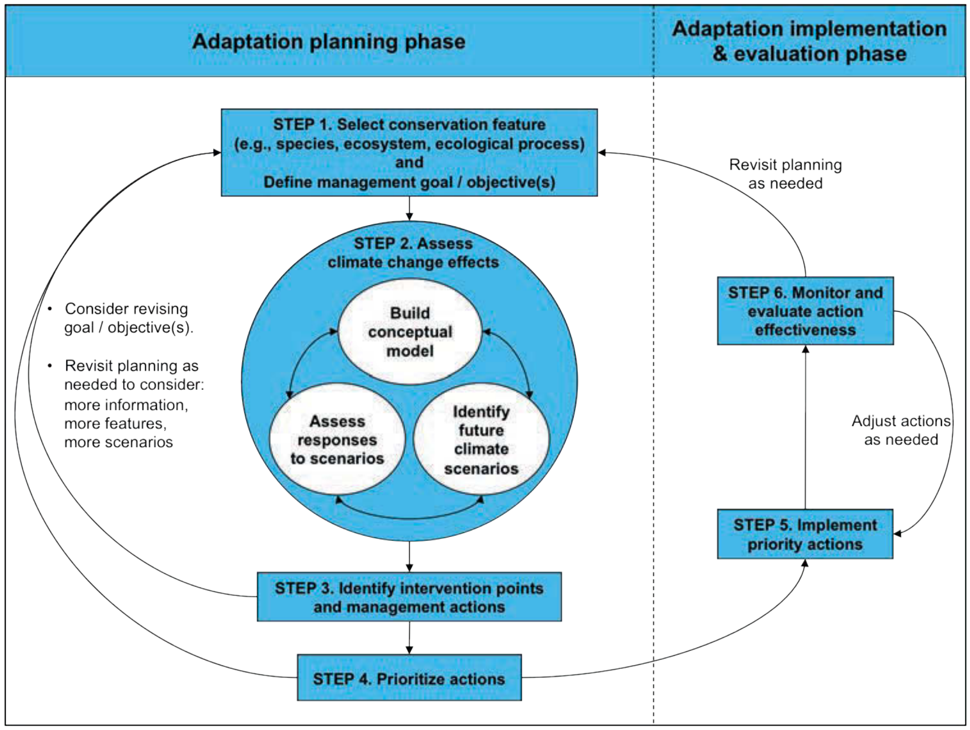

Figure 3.15. The Adaptation for Conservation Targets (ACT) framework for natural resource management planning in light of climate change.

Why.—To address irreducible uncertainties in projecting future climate and ecological conditions, ACT uses scenario-based planning techniques to identify management actions that would be justified under multiple plausible future climate scenarios. While the approach does not necessarily result in a single solution for addressing the effects of climate change, it can identify options to be explored, evaluated, and tested.

Winter at Bear River Migratory bird Refuge, Utah

Jason St. Sauver/USFWS

How.—The ACT framework has been used to initiate adaptation planning for more than 18 conservation features (e.g., species, ecosystem, or ecological processes) in 11 landscapes[2]. Summary reports detailing how future climate scenarios were developed and the content of workshop discussions on climate change impacts and adaptation strategies are available for download[2]. Here we provide a few of those details from one particular landscape, the Bear River Basin in Utah, Wyoming and Idaho.

Methods

Where.—The Nature Conservancy (TNC) convened a two-day climate adaptation workshop for the Bear River Basin in 2010. The goal of the workshop was to identify management strategies that will help native ecosystems adapt to a changing climate, and lay the groundwork for adaptation action. This workshop was the last in a series of four pilot workshops organized by the Southwest

Climate Change Initiative (SWCCI), a collaboration involving TNC, Wildlife Conservation Society, Climate Assessment for the Southwest (CLIMAS) at the University of Arizona, Western Water Assessment at the University of Colorado, University of Washington, U.S. Forest Service, and the National Center for Atmospheric Research (NCAR).

Workshop overview.—The objectives of the workshop were to:

- Provide information about the observed and projected effects of climate change in the Bear River Basin;
- Introduce the ACT framework;
- Assess the impacts of climate change on high-priority species and ecosystems;
- Identify strategic actions to reduce the adverse impacts of climate change; and
- Identify opportunities for ongoing learning and collaboration for climate adaptation in the Bear River Basin.

Over the course of two days, managers, scientists and conservation practitioners identified adaptation strategies under two climate scenarios for two conservation features: abandoned oxbow wetlands on the Bear River and the Bonneville cutthroat trout (*Oncorhynchus clarki utah*). Information for this case study is drawn from the workshop summary report[3] and a paper describing preliminary lessons learned in applying the ACT framework during the four SWCCI workshops[4]. While similar discussions were held for abandoned oxbow wetlands and Bonneville cutthroat trout, we focus here on the wetlands to illustrate the approach and outcomes.

Participants.— Workshop participants were selected on the basis of the relevance of their expertise to the conservation features under consideration, involvement of their organizations in informing or undertaking natural resource management actions, their ability to influence and lead decision-making within their organizations or agencies, and/or their interest in addressing climate change in regional and local planning and management. Thirty-nine participants representing 20 public agencies, private organizations, and academic institutions attended the Bear River workshop[3].

Scenario Development

For the Bear River workshop, future climate and hydrology scenarios were developed by Dr. Linda Mearns, Director of the Weather and Climate Impacts Assessment Science Program and senior scientist at NCAR, and Dr. Joe Barsugli, Research Scientist at the NOAA Western Water Assessment and the Cooperative Institute for Research in the Environmental Sciences at the University of Colorado, Boulder. Dr. Mearns and Dr. Barsugli participated in a number of discussions with workshop organizers to determine which types of climate and hydrology scenarios were of interest, and which specific climate variables were likely to be of greatest importance to the selected features (e.g., summer precipitation, summer temperatures, winter snow accumulation, timing and magnitude of spring snow melt).

Based on these discussions, Dr. Mearns developed two climate change scenarios for 2040-2060, and Dr. Barsugli developed scenarios of hydrological change (e.g., snowpack, seasonal flows, and timing of spring runoff) that would be associated with those climate scenarios[3]. Dr. Mearns based the climate scenarios on: (1) dynamically downscaled climate model projections using the high A2 greenhouse gas emissions scenario from the North American Regional Climate Change Assessment Program (NARCCAP), and (2) global climate model projections using the medium-high A1B greenhouse gas emissions scenario from the IPCC Fourth Assessment Report. Dr. Barsugli created the hydrological scenarios by running the two scenarios of temperature and precipitation changes through the Variable Infiltration Capacity (VIC) hydrologic model[5,6], using parameters appropriate to the Bear River. Dr. Barsugli's analyses only considered natural flows unaltered by diversions and reservoir storage, and likely do not apply to reaches of the river where groundwater interactions are important. This process resulted in two scenarios (Table 3.19).

Table 3.19. Two scenarios developed for the Bear River basin study for 2040-2060.

Scenario #1	Scenario #2
Annual temperature increases by 3.5°C, with an increase in winter precipitation but a decrease in spring and summer precipitation. Summer streamflow drops drastically, as does snow accumulation, and an earlier timing of spring runoff leave longer dry periods in the summer[3].	**Annual temperature increases by 2.7°C**, with increased precipitation in the spring but much less precipitation in the summer. Spring precipitation helps to buffer effects of decreased summer precipitation in some areas, but overall expect to see declines in summer streamflow, earlier spring melt and increased spring flooding[3].

Assessing the effects of the climate scenarios.—The abandoned oxbow wetland breakout group collaboratively defined the management goal that would be the focus of discussions—*to maintain current wetland acreage and a diversity of wetland types in at least fair or good condition, and to maintain wetland functions including: bird and wildlife habitat, flood control, water storage, water infiltration, carbon and other nutrient sink, and connectivity for wildlife movement and ecological processes.*

A conceptual model (Figure 3.16) was used to help facilitate the group discussion about the potential impacts of each future climate scenario on the condition and size of oxbow wetlands in the Bear River Basin. The conceptual models were also used to identify "intervention points" where management or conservation actions could influence the system in ways that might help achieve the management goal under the two scenarios.

USFWS

Avocets landing at Bear River Migratory Bird Refuge, Utah

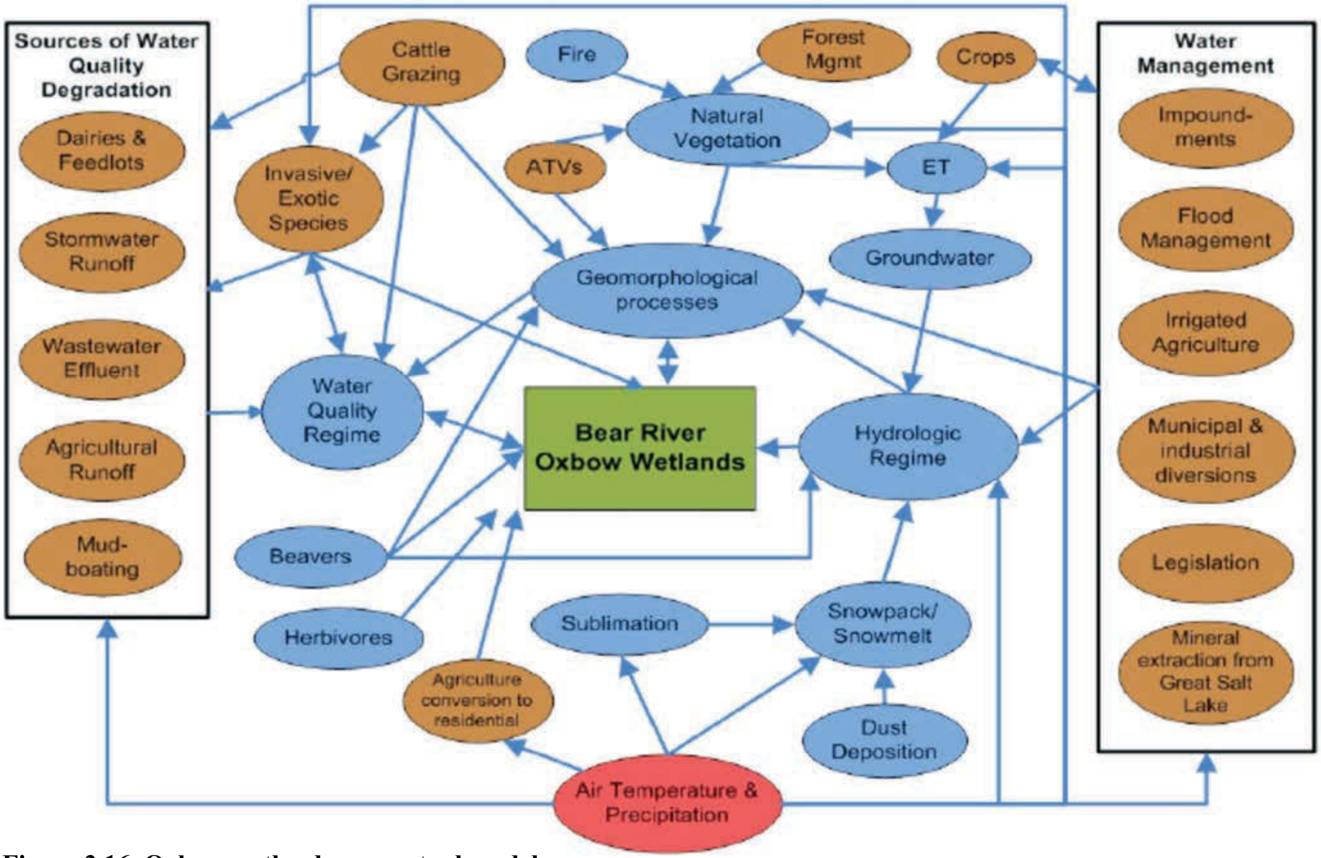

Figure 3.16. Oxbow wetlands conceptual model.

Under both climate scenarios, participants expect to see a decrease in the areal extent and the condition of abandoned oxbow wetlands in the Bear River Basin. For Scenario #1, the drying effect of decreased precipitation and streamflows in the spring and summer is likely to lead to: (a) a shrinking of the areal extent of abandoned oxbow wetlands, and (b) a shift in wetland vegetation species composition from wetter to drier species.

Scenario #2 is also expected to result in drier conditions and a loss of wetland acreage. However, it is possible that the losses will be less dramatic than for Scenario #1 since the effect of drier summers on plant productivity and water availability may be buffered by an added pulse of moisture in the spring. Participants also identified ways that Scenario #2 might differentially affect plant community composition and the provision of habitat for migratory birds.

Outcomes and Applications

After assessing the potential impacts of each scenario, participants identified actions that might be necessary to achieve the stated management goal in light of those climate change effects. Some of the top priority strategic actions that were recommended under both of the scenarios considered included:

- Address declines in water delivery to the wetlands as summer streamflows decline by:
  - Establishing water conservation laws that provide incentives for water conservation and changes in use (e.g., that provide financial incentives for users to leave some water instream).
  - Restoring and maintaining healthy upland watershed vegetation communities to improve watershed function and increase water retention and recharge.

- Reduce the risk of land conversion from agriculture to urban uses as wetlands dry out by:
    - Establishing a Bear River land trust to hold easements, push for education about the benefit of easements, find funding, and manage some of the land.
- Improve land use planning, such as through the creation of special area management plans.
- Undertake education and marketing activities related to understanding and communicating the true value of wetlands (and the avoided cost of losing wetlands), and informing the agricultural community about wetland conservation incentive programs. Such action would provide incentive and motivation for caring about the loss of wetlands, and is necessary to encourage more dramatic changes in land use policy.

Efforts are underway in the Bear River and the other three SWCCI landscapes to expand on the initial workshops to conduct further planning, and to move from planning to implementation of on-the-ground adaptation strategies[7].

Lessons Learned / Next Steps

Participants noted that this two-day session should be considered a starting point for what will need to be a long-term process for understanding and responding to the challenge of climate change for the species, habitats, and ecosystems of the Bear River Basin. The group emphasized that more time, thought, and energy will be required to build consensus for—and begin implementing—resilience-building strategies. Specifically, the group wanted to explore alternative climate change scenarios in more depth. They wanted deeper discussion, and more testing, of projected effects of those alternative scenarios on natural resources of the Bear River Basin.

This issue of having insufficient time to consider both climate scenarios in great detail was encountered at all four of the SWCCI workshops[4]. Most breakout groups were able to have at least a general discussion of whether and how climate change impacts and adaptation actions might differ across the scenarios, but some groups were not able to address the second scenario at all. When more than one scenario was considered, many of the adaptation actions identified by workshop participants were recommended under both scenarios. In a few cases, however, participants did identify a need for different, additional, or modified actions under the second scenario. One reason why the same actions were often recommended under each scenario may be that there was not enough time at the workshops for sufficient discussions along these lines. Another reason could be that the differences between scenarios were not great enough to result in notable differences in impacts given the relatively qualitative nature of the impacts assessment conducted by workshop participants. Continued discussions between experts and decision-makers beyond what can be covered in a two-day workshop would allow for a more thorough consideration of the consequences of multiple plausible future scenarios (including the inclusion of more than just two scenarios) on management decisions.

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Mike Guyant

Coots at Bear River Migratory Bird Refuge, Utah

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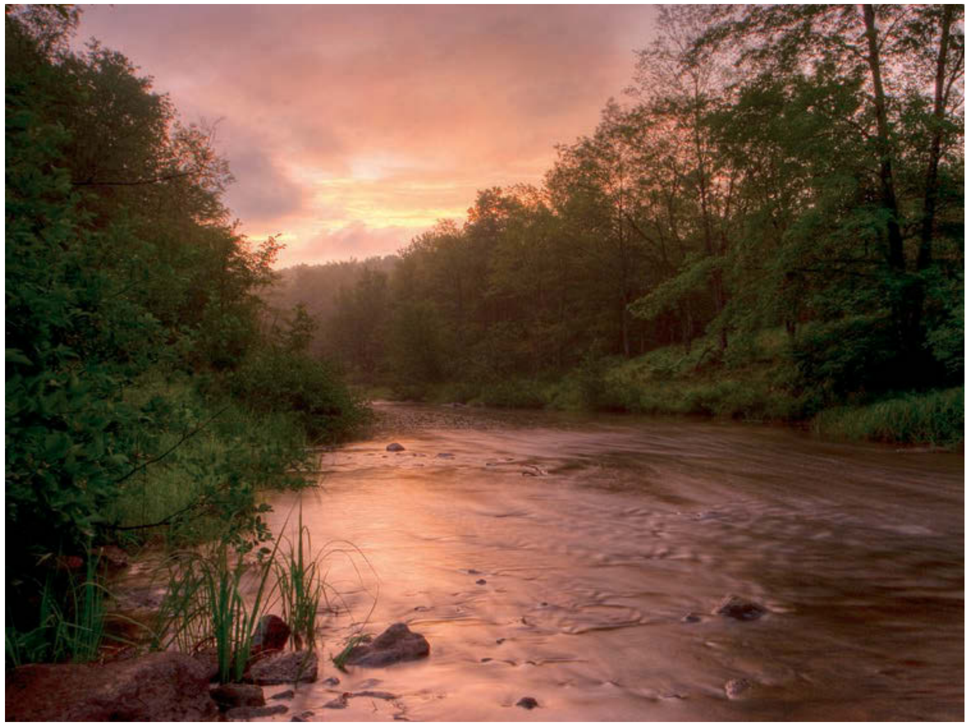
Cache Valley, Utah

Section 4



Frank Ceravalo

Blackwater River, Canaan Valley National Wildlife Refuge,West Virginia

Appendices

4.1 Appendix 1. Glossary

Confidence- The level of confidence in the correctness of a result

Decision context-Clearly defines what question or problem is being addressed by the planning or decision process and establishes the scope and limits of the effort (Gregory et al. 2012)

Discontinuities-Events or consequences that cannot be extrapolated from prior actions or events and are unpredictably new

Drivers- Underlying causes of system change that are external from the system of analysis. They come from higher scales and are not affected by what happens within the system (Walker et al. 2012)

Foresight-Set of methods to better understand the range of possible futures (Mietzner and Reger 2005); gathering anticipatory intelligence from a wide range of knowledge sources in a systematic way and linking it to today's decision making to meet future challenges proactively. Scenario planning is one foresight approach.

GCM-General Circulation Models represent physical processes in the atmosphere, ocean, cryosphere and land surface and are currently the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations

IPCC-Intergovernmental Panel on Climate Change

Irreducible uncertainty- Uncertainty that cannot be reduced. Situations characterized by irreducible uncertainty can arise is different ways. Uncertainty may be irreducible due to the inherently unpredictable variation in natural systems over space and time (environmental) or in human systems (linked to behavior). Changes in driving forces external to the system (e.g. related to social, economic, and technological choices) are uncontrollable, often resulting in irreducible uncertainty. Finally imperfect knowledge can also contribute to irreducible uncertainty if unresolvable within a decision timeframe (Shearer 2005, Walker et al. 2004, Bengston et al. 2012).

Level of uncertainty-Where the uncertainty manifests itself along the gradient between deterministic knowledge and total ignorance (Walker et al. 2004)

Likelihood-The likelihood of an occurrence, an outcome, or a result, where this can be estimated probabilistically. The IPCC developed a standard for their reports:

Terminology	Likelihood of the occurrence / outcome
Virtually certain	>99% probability of occurrence
Very likely	>90% probability
Likely	>66% probability
More likely than not	>50% probability
About as likely as not	33 to 66% probability
Unlikely	<33% probability
Very unlikely	<10% probability
Exceptionally unlikely	<1% probability

Monitorable Indicators (for scenarios)-variables that can be tracked through time to determine the occurrence of regimes, triggers, cascading events, discontinuities, and wild cards.

Source or type of uncertainty- whether the uncertainty is due to the imperfection/lack of our knowledge or is due to the inherent variability (non-linear dynamics) of the phenomena being described (Walker et al. 2004)

Narrative-see "Storyline"

Non-linear response- a system for which the effects or responses (outputs) are not proportional to their causes (inputs) and cannot be modeled with linear equations

Prediction/Forecast-A statement about what will happen in the future with some degree of certainty often associated with probability distribution; focus on one future, considered most likely.

Projection-A potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Projections are distinguished from predictions in order to emphasize that projections involve assumptions concerning, for example, future socio-economic and technological developments, future socio-economic and that may or may not be realized, and are therefore subject to substantial uncertainty.

Reducible uncertainty- Sources that could, feasibly, be controlled or refined to reduce or eliminate the particular uncertainty, scientific understanding (epistemic) and linguistic. Epistemic includes measurement error, sampling error, systematic error or bias (from measurement, sample selection, etc.), model uncertainty (potentially reducible), and reliance on subjective judgment. Note that these sources may or may not be reducible within a given timeframe and may need to be treated as irreducible in some decision contexts.

Regimes- the persistent status of a system

Risk-The probability of an event occurring and magnitude of the consequences

Risk Management-Deciding what to do (how to reduce risk) in light of imperfect knowledge

Scale-Description of the spatial extent of an area or temporal extent time period

Scenarios (for scenario planning)-Plausible futures of a system under different conditions; “scenario’” as a “hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points” (Kahn and Wiener, 1967, page 6).

Scenario dimensions-Uncertainties around which scenarios are constructed, represented as axes in some methods

Scenario logics-Methods for structuring the relationships between different drivers and assumptions in scenarios

Scenario planning-Comprehensive process for strategic planning that involves the development scenarios, consideration of their impacts, and implications for strategy and action choices

Stationarity-The assumption that natural systems fluctuate within an unchanging envelope of variability through time (Milly et al. 2008)

Storyline- A narrative description of a scenario (or family of scenarios), highlighting the main scenario characteristics, relationships between key driving forces and the dynamics of their evolution

Storyline and simulation-Combination of qualitative narrative development and quantitative modeling (scenario construction-sensu Mahmoud et al. 2009, Wollenberg et al. 2000)

System-Defined by (composed of) its state variables, and it is the relationships among them that are of central interest. The system changes as a consequence of both these internal relationships and the effects of external drivers (Walker et al. 2012)

Thresholds-Conditions in time and space that produce notably different experiences in a system’s state or response

Triggers-particular combination of conditions that lead to a change in a system’s regime

Uncertainty- An expression of the degree to which a value or outcome is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many sources, from quantifiable errors in the data or limited ability to characterize/model system, to ambiguously defined concepts or terminology, or uncertain projections of human behavior, environmental variation and stochasticity.

Wild Cards-major surprises caused by low probability events that have high impacts

Sources: Regan et al. 2002, IPCC 200b7, Refsgaard et al. 2007, Dessai and van der Sluijs 2007, Coreau et al. 2009, NRC 2011, Williams and Brown 2012, Rounsvell and Metzger 2011, Varum and Melo 2010, Bishop et al. 2007, Liu et al. 2008.

4.2 Appendix 2. Review of Published Scenario Planning Efforts

In addition to the case studies presented in the guide, we reviewed over 100 published descriptions of exercises that included "scenarios" or "scenario planning" as a keyword descriptor. Articles came from a variety of journal types focused on topics from business and risk management to land use planning and global change (Table 4.1). We also read through approximately 30 theoretical or process oriented papers on the topic, surveyed published reports, existing guidebooks on scenario planning and other grey literature, and engaged in discussions with scenario planning experts. Our review generally informed the content of the guide and populated a spreadsheet that compiles information using the same template upon which the case studies are based.

We attempted to encompass the range of ways in which scenario planning has been applied, including an array of environmental assessment applications, as well as applications in other sectors when they offered a relevant approach not otherwise characterized. Note that the review was not exhaustive. The following is a summary of the findings from our review of ~70 published examples of scenario-planning efforts:

- Many of the articles reviewed were conservation or natural resources applications of scenario planning (e.g., biodiversity, fisheries, forestry, or water management). Agriculture, transportation, emergency planning, tourism were other sectors represented;
- The geographic scale considered included ecological communities, watersheds, landscapes and regions.
- Nearly all articles identified decision support as a purpose but few processes ended with a decision. Most articles described how scenario planning enhanced participants' understanding of the issue.
- The majority of the scenario planning exercises focused on drivers of change other than climate change (e.g., policy and land use). Several articles incorporated climate change with other drivers; only a few (5) solely addressed climate change;
- The examples were about an equal mix of internal, expert-driven efforts and participatory exercises that included diverse stakeholders;
- A few of the articles made reference to the value of (professional) facilitation or facilitators, but were not specific about who served that role;
- The lengths of processes were only indicated in 15 examples. These varied from 3 hours, several days, weeks, months and years. The longest durations (i.e., multiple years) were typically part of larger planning projects.
- Only a few exercises resulted in purely qualitative scenarios. Most efforts quantified narratives to at least some extent through simulations and other techniques;
- While GIS-based software was often used to visualize scenarios, diverse modeling approaches were employed to generate the information;
- The cost of scenario-planning exercises was not specified, although some made general comments about the value of the process qualified by the need to reduce costliness.

Table 4.1. Journals covered in the literature review

Agriculture, Ecosystems and Environment	Environmental Impact Assessment Review	Journal of Sustainable Tourism
Advances in the Economics of Environmental Resources	Environmental Modelling and Software	Land Use Policy
Bioscience	Environmental Impact Assessment Review	Landscape & Urban Planning
Climatic Change	Environmental Resource Economics	Landscape Ecology
Computers, Environment and Urban Systems	Environmental Science & Policy	Mitigation and Adaptation Strategies for Global Change
Conservation Biology	Forest Policy and Economics	Mountain Research & Development
Conservation Ecology	Forests	PLOS One
Current Issues in Tourism	Futures	PNAS
Ecological Applications	Global Ecology & Biogeography	Society and Natural Resources
Ecological Economics	Global Environmental Change	Sustainability
Ecological Economics of Sustainable Watershed Management	Journal of Environmental Planning & Management	Technological Forecasting & Social Change
Ecology and Society	Journal of Marine Biology	

4.3 Appendix 3. Other Scenario Planning Guides and Useful Resources

Other Scenario Planning Guides	
Scenarios for Climate Adaptation: Guidebook for Practitioners Victoria Center for Climate Change Adaptation Research/http://www.vcccar.org.au/content/pages/scenarios-climate-adaptation	Step-by-step guide to developing and using scenario planning in climate adaptation planning, informed by recent experiences of policy makers and practitioners in Victoria, Australia. Includes natural and human systems.
Towards Guidelines for Environmental Scenario Analysis Alcamo and Henrichs 2008	The guidelines include "definitions of key terms, an overview of the basic steps in a scenario exercise, a description of the existing types of environmental scenarios, hints on how to assess the quality of environmental scenarios, and some recommendations about "best practice" for the development and analysis of environmental scenarios."
Guidelines for Constructing Climate Scenarios Mote et al. 2011/EOS 92(31):2	How to select, treat, and combine the vast amount of climate model output into useful climate scenarios
Using Scenarios to Explore Climate Change: A Handbook for Practitioners NPS 2013	This handbook describes a five-step process for developing multivariate climate change scenarios taught by the Global Business Network, a strategy consulting firm, during a series of training workshops hosted by the National Park Service in 2010 and 2011.
Adapting Sustainable Forest Management to Climate Change: Scenarios for Vulnerability Assessment Price and Isaac 2012	It examines how scenarios can be constructed to assess the impacts of climate change and other stressors on managed forest systems for application at local scales (such as a forest management unit), using both top–down (downscaling from global and regional projections) and bottom–up (accounting for local trends and projections) approaches. Practical examples of using scenarios for impact assessment in forestry are briefly reviewed in four case studies from across Canada.
A Formal Framework for Scenario Development in Support of Environmental Decision-Making Mahmoud et al. 2009	The paper reviews the state-of-the-art of scenario development and proposes a formal approach to scenario development in environmental decision-making.
Developing Scenarios to Assess Ecosystem Service Tradeoffs: Guidelines and Case Studies for InVEST Users McKenzie et al. 2012	Drawing on case experiences, it provides guidance on scenario types and methods, engaging stakeholders, and creating scenario maps. The guide highlights key issues and questions for reflection, along with tools, case studies, references and resources for those who want to learn more.
Federal Highway Administration Scenario Planning Guidebook FHWA 2011	The guidebook assists transportation agencies with using scenario planning to address transportation issues, land-use changes, population changes, as well as other topics that are important to the state, region, community, or study area, including climate change and uses of alternative energy.
The On-Line Foresight Guide FOR-LEARN (European Commission)	It guides users throughout the critical steps of design, implementation and follow-up of a Foresight project and gives a description of the main methods that can be used. Clear and easy-to-access information is provided, with real case illustrative examples.
Scenario Planning for Climate Change Adaptation: A Guidance for Resource Managers Moore et al. 2013	This is a guide based largely on the NPS scenario planning work and published by PRBO Conservation Science and the California Coastal Conservancy.

Useful Resources for Phase I

Step 1. Identify the issue and establish a project team

- Tools in the Appendix of Planning for Climate Change: A strategic values-based approach for urban planners (UN-HABITAT)
- http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3164
- FOR-LEARN's Scoping a Foresight Exercise-http://forlearn.jrc.ec.europa.eu/guide/3_scoping/index.htm
- The Conservation Partnership Center-www.conservationpartnerships.org
- The Scenario Toolkit, created by staff of the Stockholm Environment Institute for developing scenarios for sustainability studies, includes the Scenario Manager for organizing information about scenarios for individual or collaborative scenario development and other tools.
- http://scentools.sourceforge.net/aboutscen.html

Step 3. Select or formulate an approach

- Table on p. 31 in Wiseman et al. (2011) in their "Scenarios for Climate Adaptation: Guidebook for Practitioners"-Matching Objectives with Approach

Useful Resources for Phase II

Step 6. Identify key drivers and variables of interest related to the focal question

- Link to Issue Tree tool –(http://evaluationtoolbox.net.au/index.php?option=com_content&view=article&id=28&Itemid=134)
- PESTLE/STEEP analyses – (http://www.jiscinfonet.ac.uk/tools/pestle-swot)
- Guidebook for Local, State, and Regional Governments --www.cses.washington.edu/db/pdf/snoveretalgb574.pdf
- Tools for constructing influence diagrams:
    - CMAP: http://ftp.ihmc.us/
    - Tufts VUE: http://vue.tufts.edu/

Step 8. Explore and select scenario logics

- Climate Wizard-visualize and download climate projections for lower 48 states and the globe (http://www.climatewizard.org/)
- Scenarios Network for Alaska Planning (http://www.snap.uaf.edu/)
- IRI/LDEO Climate Data Library (http://iridl.ldeo.columbia.edu/)
- World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) --http://www-pcmdi.llnl.gov/projects/cmip/index.php
- Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections (http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/#Welcome)
- NOAA RISA program (http://www.climate.noaa.gov/cpo_pa/risa/)
- Climate Impacts Group (http://cses.washington.edu/cig/)
- DataBasi*n (*www.databsin.org*)*
- LCC tools and data portals (e.g., LC-MAP -- http://greatnorthernlcc.org/lcmap)
- Nation al Climate Assessment (national, regional, state, etc.) (www.globalchange.gov/what-we-do/assessment)

Useful Resources for Phase III

Step 1. Evaluate the potential impacts and implications of the scenarios

- Impact assessment guides and tools (e.g., Refuge Vulnerability Assessments and Alternatives guides-https://connect.natureserve.org/publications/rvaa)
- Scanning the Conservation Horizon: A guide to climate change vulnerability assessment (Glick et al. 2011)
- Structured Decision-Making and Adaptive Management Materials and Courses at NCTC (http://nctc.fws.gov/courses/sdm/home.html
- TNC expert elicitation presentation (https://nethope.webex.com/nethope/ldr.php?AT=pb&SP=MC&rID=64529297&rKey=232a6cb06aa75d34)
- Yale Mapping Framework (http://www.databasin.org/yale/using/matrix)
- National Fish, Wildlife and Plants Climate Change Adaptation Strategy (http://www.wildlifeadaptationstrategy.gov/)

Step 3. Prioritizing options and selecting near-term strategies or actions

- Structured Decision-Making and Adaptive Management Materials and Courses at NCTC (http://nctc.fws.gov/courses/sdm/home.html
- Prioritization matrix (http://www.jiscinfonet.ac.uk/tools/prioritisation-matrix)
- Decision Matrix (http://asq.org/learn-about-quality/decision-making-tools/overview/decision-matrix.html)
- Multi-criteria analysis (http://forlearn.jrc.ec.europa.eu/guide/4_methodology/meth_multi-criteria-analysis.htm)

Step 4. Monitoring and research for decision-making

- Timeline templates (http://www.vertex42.com/ExcelTemplates/excel-project-management.html)

Additional Resources – Tools, Consultant Groups, Researchers, University Courses

Tools: community planning tools, spatial modeling tools, web-based tools

- ENVISION-a GIS-based tool for scenario-based community and regional planning and environmental assessment; a framework for policy-driven alternative futures analyses (http://envision.bioe.orst.edu/); example application: Willamette Water 2010 (http://water.oregonstate.edu/ww2100/)
- Carpe Diem West Academy: Carpe Diem West Academy helps western water and energy managers make sense of the vast array of available tools that might help them make better decisions in the face of climate uncertainty (http://carpediemwestacademy.org/tools)
- Lincoln Institute of Land Policy and Sonoran Institute: Opening Access to Scenario Planning Tools (developing website) http://scenarioplanningtools.org/
- On-line guide to applying foresight efforts to issues, including scenario planning: http://forlearn.jrc.ec.europa.eu/guide/4_methodology/methods.htm
- Scenarios Network for Alaska Planning-http://www.snap.uaf.edu/planning.php
- Natural Captial InVEST tool/toolkit: http://www.naturalcapitalproject.org/database.html
    - http://naturalcapitalproject.org/scenarios.html
    - Prominent examples of scenario models include Metronamica, PoleStar, IMAGE, WaterGAP, AIM, T21, GLOBIOM, Mirage, CLUE, GTAP/MAGNET, LandSHIFT and the International Futures Model
- Gordon (Adam) 2008- http://www.slideshare.net/adgo/scenario-building-workshop-how-to-build-and-use-scenarios
- Kamloops Future Forest Strategy- Validating Impacts, Exploring Vulnerabilities, and Developing Robust Adaptive Strategies-model simulations and experts (http://k2kamloopstsa.com/k2-introduction/)
- The Path Landscape Model: The purpose of this vegetation modeling tool is to assist land managers in predicting how vegetation may change over time, in response to possible future natural processes and anthropogenic activities, as part of landscape-level ecological restoration and planning.
- Landis II is a forest landscape simulation model. Forest landscape simulation models estimate forest change over large spatial scale (typically > 10 ha) and longer time scale (> 10 years). Forest landscape models simulate succession (changing species composition) and disturbances. http://www.landis-ii.org/
- The tool uses state-and-transition models, such as those developed using the Vegetation Dynamics Development Tool (VDDT), to simulate vegetation conditions on a landscape into the future by considering the interaction between succession, unplanned disturbance and planned actions.
- Three key user groups – The Nature Conservancy, the U.S. Forest Service and the LANDFIRE project – have joined forces to support the development of a common approach for running state and transition models across a landscape. The result of this combined effort is a new generic state-and-transition modeling platform, referred to as the Path Landscape Model. The Path Landscape Model has been developed jointly by Apex Resource Management Solutions and ESSA Technologies, and continues to be updated and improved (http://essa.com/tools/path/). (Also other ESSA Technologies simulation tools)
- 3-D Visualization tools-landscape based models using Visual Nature Studio 2-Example: "Downscaling and visioning of mountain snow packs and other climate change implications in North Vancouver, British Columbia" (Cohen et al. 2012)

- VenSim (http://www.vensim.com/customers.htm) and Climate Interactive (http://climateinteractive.org/)
- Integral Ecology Group-Experience working with ALCES Group (simulation modeling) to conduct cumulative effects-land use planning scenario exercises. http://integralecologygroup.com/
- BEACONs Conservation Matrix Model: CONSERV is a landscape simulation model designed to evaluate the long-term efficacy of reserves. http://www.beaconsproject.ca/conserv

How researchers and intermediaries can support scenario planning

- Long-Term Ecological Research and Future Scenarios of Climate and Land-use Change (summary in Thompson et al. 2012)
- National Weather Service guidance (Holly Hartman)
- NOAA Scenarios of Global Sea Level Rise Scenarios for the US (Parris et al. 2012)
- MIT water tool (Climate Wire 12/19/2012)

University groups teaching scenario planning

- Scenario Planning Institute-Colorado State University: Thomas Chermack (http://scenarioplanning.colostate.edu/)
- LTER Future Forests collaborative
- University of Wisconsin (Biggs et al. 2010)
- University of Minnesota - Innovation Studies (http://www.cce.umn.edu/Innovation-Studies-Certificate/index.html)
- North Dakota State (http://www.ndsu.edu/nrm/faculty/jack_e_norland/)

4.4 Appendix 4. References

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