

# CHAPTER 4: SCALE-APPROPRIATE ADAPTATION STRATEGIES AND ACTIONS IN THE NORTHEAST AND MIDWEST UNITED STATES

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## Contents

I. INTRODUCTION .....	5
A) Adaptation concepts .....	5
B) Adaptation actions: broad goals to specific tactics.....	8
II. IMPLEMENTING ADAPTATION ACTIONS.....	10
A) Process for adaptation planning and implementation .....	10
B) Monitoring.....	20
III. REGIONAL CASE STUDIES .....	23
A) Landscape and ecoregion.....	24
B) State .....	30
C) Local.....	31
IV. LITERATURE CITED .....	43

## Tables

<b>Table 1:</b> Total numbers of species and habitat-specific adaptation strategies and tactics listed in <b>Appendix 4.1</b> .....	31
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## Figures

<b>Figure 1:</b> Actions for adaptation actions become increasingly specific along a continuum of options, strategies, approaches, and tactics. ....	8
<b>Figure 2:</b> Structured Decision Making in the context of other decision support approaches.. ...	11
<b>Figure 3:</b> Five steps of the structured process outlined in The Adaptation Workbook. ....	12
<b>Figure 4:</b> Diagram of the five core elements of the PrOACT decision model.....	14
<b>Figure 5:</b> Three phases in the scenario planning process.....	18
<b>Figure 6:</b> The parts of a decision-making process or adaptive management to which scenario planning might contribute .....	20
<b>Figure 7:</b> Map of the 7 Landscape Conservation Cooperatives contained within Northeast Climate Science Center geography. ....	25
<b>Figure 8:</b> Map showing potential areas of high permeability for upslope range shifts under future climate change and considering anthropogenic barriers and fragmentation.....	29
<b>Figure 9:</b> Diagram of the primary inputs used to predict future land elevations and coastal responses to sea level rise and storm surge.....	38
<b>Figure 10:</b> Restoration ahead of climate change.....	39

## Boxes

<b>Box 1:</b> Regional examples of the scenario planning approach applied to address climate, ecological, and other changes for natural resources across the Northeast and Midwest. <b>Appendix 4.3</b> contains expanded descriptions of each project and its partners.....	17
<b>Box 2:</b> Regional examples of ongoing Landscape Conservation Design initiatives being led by the Landscape Conservation Cooperatives. Expanded descriptions of each project and its partners can be found in <b>Appendix 4.4</b> .....	26

## **Appendix**

**Appendix 4.1:** Synthesis of 960 adaptation strategies by scale, target resource, and climate stressor from nine regional adaptation studies.

**Appendix 4.2:** A selection of regional websites offering resources and decision support tools for climate change adaptation.

**Appendix 4.3:** Regional examples of scenario planning applied to address climate, ecological and other changes for natural resources, both completed and ongoing.

**Appendix 4.4:** Examples of current Landscape Conservation Design initiatives being undertaken across the Northeast and Midwest by the Landscape Conservation Cooperatives (LCCs). More information can be found at each LCC's website.

## CHAPTER 4: SCALE-APPROPRIATE ADAPTATION STRATEGIES AND ACTIONS IN THE NORTHEAST AND MIDWEST UNITED STATES

### Summary Points

- *Climate Change Adaptation* is a growing field within conservation and natural resource management. Actions taken toward climate change adaptation account for climate impacts and ecological responses, both current and projected into the future. These actions attempt to accomplish a number of goals, including the conservation of wildlife and ecosystems by reducing vulnerability and increasing resilience.
- Climate change adaptation strategies and approaches for natural resources can be thought of as part of a continuum of potential actions ranging from 1) options or goals to 2) strategies, 3) approaches, and 4) tactics.
- There are a range of decision support tools and processes to aid climate change adaptation. This document highlights several including the Adaptation Workbook, Climate Change Vulnerability Assessments, Structured Decision Making, Adaptive Resource Management, and Scenario Planning. It will also provide case studies on the application of these tools across the Northeast and Midwest.
- Improved, better-integrated, and increasingly coordinated monitoring systems would be helpful to detect, track, and attribute species and habitat shifts to climate change over spatiotemporal scales. We highlight regional examples of projects and programs addressing these challenges.
- Illustrative case studies of climate change adaptation efforts are presented across landscape/ecoregion, state, and local scales.
- **Appendix 4.1** provides a synthesis of over 900 general, species and habitat-specific adaptation strategies and tactics from 9 regional studies being considered or implemented across the region.

The study of climate change adaptation is a relatively new and rapidly growing field focused on preparing for and responding to the current and future impacts of climate change. The goal of this chapter is to highlight different approaches, processes, and tools currently being used across the region through illustrative case studies at varying scales. In addition, we provide a synthesis of numerous species and habitat-specific adaptation strategies and actions from existing assessment reports and management plans, which is intended to showcase a range of possibilities for natural resource management under future global change. This report does not prescribe one specific approach to taking action; instead, we outline a range of adaptation

tactics, which will require thoughtful consideration of the needs of the species, habitat, and location, the stakeholders and partners involved, the scale that a decision or policy is being implemented at, and the financial and personnel resources available to managers.

## **I. INTRODUCTION**

### **A) ADAPTATION CONCEPTS**

#### *i. Overview of Climate Change Adaptation*

Climate change adaptation is a growing field within conservation and natural resource management focused on preparing for and responding to current and future impacts of climate change, and reducing related vulnerabilities (IPCC 2007; Parry et al. 2007; Heller & Zaveleta 2009; Glick et al. 2011). Ecological systems are subject to natural variability over short and long time scales, but climate change is increasingly pushing species and systems to surpass historical ranges of fluctuations. Therefore, managers are being encouraged to embrace a new paradigm of managing for change rather than persistence (Milly et al. 2008). This requires goals and actions that consider not only how a system or population has already changed, but also what conditions it is expected to experience as climate change continues (Stein et al. 2013). In addition, conservation and management initiatives that act broadly across the landscape to increase connectivity among refugia and protected habitats, and sustain ecological functioning and processes, are increasingly necessary (Stein et al. 2013).

Information on what factors contribute to a species or habitat's vulnerability to climate change is increasing, and managers are searching for ways to realistically use this information in planning and implementation to meet specific needs on-the-ground (Millar et al. 2012; Janowiak et al. 2014). However, challenges still remain in putting high-quality scientific information within reach of most natural resource professionals and making the information understandable and actionable (Vose et al. 2012; Seppälä et al. 2009).

Climate change adaptation is largely about balancing goals and trade-offs, and there are many lessons to be drawn from ecosystem-based management approaches, which have been challenged with similar complex issues (Larkin 1996). Climate change also introduces high uncertainty to the decision making process as we are unable to exactly predict future climate

conditions, how species and systems will respond to climate change and other stressors that act synergistically or cumulatively, as well as human response and behavior. Therefore managers are considering actions and making informed decisions that consider a range of possible futures and associated risks. Fortunately, planning approaches have been developed to help managers account for that uncertainty (e.g., scenario planning), as presented in this chapter. Finally, managers may consider their available resources and weigh decisions and actions that have the greatest chance of success under future climate conditions.

Climate change adaptation requires thinking over multiple temporal and spatial scales to sustain fish and wildlife populations and the habitats they depend on. Over the short-term and small scale, regardless of whether further assessment and information is needed, there are things that can be done now to minimize the effects of climate change on both ecosystems and humans. Over the long-term and large scale, responses to climate change can take advantage of existing and emerging knowledge to identify areas that are more resilient, more likely to adapt, or conversely, that are at highest risk. Efficient and effective adaptation plans and actions that can engage and form collaborations and partnerships among government agencies, NGOs, planners, researchers and municipalities to achieve common goals will be helpful (New Hampshire Fish & Game Department 2013).

Many broad recommendations for adapting ecosystems to climate change have already been suggested and synthesized (e.g., Heinz Center 2008; Heller & Zaveleta 2009; Millar et al. 2007; Ogden & Innes 2008). The purpose of this chapter is to highlight goals, approaches, processes, and actions being considered and implemented across the Northeast and Midwest for fish and wildlife species and their habitats through illustrative case studies at landscape, ecoregion, state, and local scales. Various case studies highlight how different researchers and organizations are confronting complex issues related to climate change. Because of the relatively emergent nature of the adaptation field and regional programs that support adaptation, many of the initiatives we highlight are ongoing. Our intention is to increase awareness of these initiatives and facilitate connections between researchers and managers across the region who may have specific interests in the process or outcomes of these projects. These examples may provide guidance for the development of adaptation plans that

incorporate existing knowledge of the effects and ecological responses to climate change, as well as associated uncertainty.

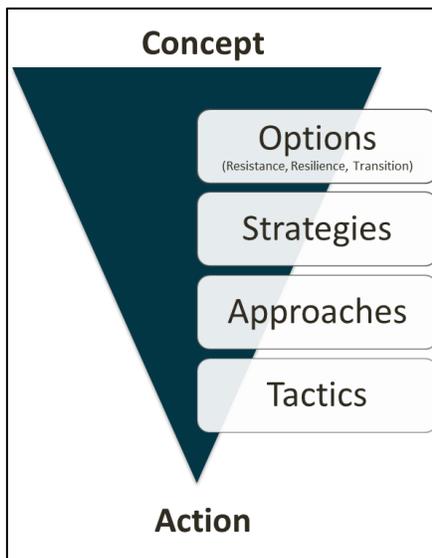
### *ii. Principles of Adaptation*

A great deal of work has occurred to provide conceptual frameworks (e.g., Millar et al. 2007; Peterson et al. 2011), compile adaptation strategies (e.g., Heinz 2008; Heller & Zavaleta 2009; Ogden & Innes 2008), and provide tools to support natural resource management decision making (e.g., Cross et al. 2012; Morelli et al. 2012; Swanston & Janowiak 2012). The following principles can serve as a starting point for incorporating a climate change adaptation perspective into an existing management framework (Joyce et al. 2008; Millar et al. 2007; Swanston & Janowiak 2012; Wisconsin Initiative on Climate Change Impacts 2011):

- **Prioritization and triage** – It will be increasingly important to prioritize actions for adaptation based both on the vulnerability of natural resources and on the anticipated effectiveness of actions that attempt to reduce vulnerability.
- **Flexible and adaptive management** – Adaptive management provides a decision-making framework that maintains flexibility and incorporates new knowledge and experience over time.
- **“No regrets” decisions** – Actions that result in a wide variety of benefits under multiple scenarios and have little or no risk may be initial places to consider re-prioritization and look for near-term implementation.
- **Precautionary actions** – Where vulnerability is high, precautionary actions to reduce risk in the near term may be extremely important, even when long-term uncertainty is high.
- **Variability and uncertainty** – The effects of climate change go far beyond increasing temperatures; increasing climate variability will lead to equal or greater impacts that will need to be addressed as well.
- **Integrating mitigation** – Many adaptation approaches complement actions to mitigate climate change; for example, adapting forests to future conditions can help maintain and increase their ability to sequester carbon.

## B) ADAPTATION ACTIONS: BROAD GOALS TO SPECIFIC TACTICS

Climate change adaptation strategies and approaches for natural resources can be thought of as part of a continuum of potential actions (**Figure 1**). At the highest level are the broad and largely conceptual *options* of resistance (forestall change in ecosystems), resilience (enhance resilience of ecosystems to change), and transition (transition ecosystems into alignment with anticipated future conditions) (Millar et al. 2007). Adaptation *strategies* and *approaches* provide intermediate “stepping stones” that enable managers to translate broad concepts into targeted and prescriptive tactics for implementing adaptation (Janowiak et al. 2010; Swanston & Janowiak 2012).



**Figure 1:** Actions for adaptation actions become increasingly specific along a continuum of options, strategies, approaches, and tactics.

- **Options or Goals** – The options of resistance, resilience, and transition serve as the broadest and most widely applicable level of a continuum of management responses to climate change (Janowiak et al. 2011).
- **Strategies** – Adaptation strategies begin to illustrate the ways that adaptation options could be employed, and are abundant in recent literature and reports. Strategies, however, are still very broad, and can be applied in many ways across a number of landscapes and species.
- **Approaches**– Provide greater detail in how managers may be able to respond to changing environmental conditions; differences in application among species and habitat types and management goals start to become evident.
- **Tactics** – Ultimately, tactics are the most specific adaptation response on the continuum, providing prescriptive direction in how actions can be applied on the ground.

A national perspective on climate change adaptation for natural resources is provided in the National Fish, Wildlife and Plants Climate Adaptation Strategy (NFWPCAS 2012). Information is organized under seven broad goals for adaptation, which as a whole address resistance,

resilience, and transition with options at finer scales; yet NFWPCAS goals (presented below) are still broader than strategies (as outlined above).

1. **Conserve habitat** to support healthy fish, wildlife, and plant populations and **ecosystem functions** in a changing climate.
2. **Manage species and habitats** to protect **ecosystem functions** and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.
3. **Enhance capacity** for effective management in a changing climate.
4. Support adaptive management in a changing climate through **integrated observation and monitoring** and use of **decision support tools**.
5. **Increase knowledge** and information on **impacts** and **responses** of fish, wildlife, and plants to a changing climate.
6. **Increase awareness** and motivate action to safeguard fish, wildlife, and plants in a changing climate.
7. **Reduce non-climate stressors** to help fish, wildlife, plants, and ecosystems adapt to a changing climate.

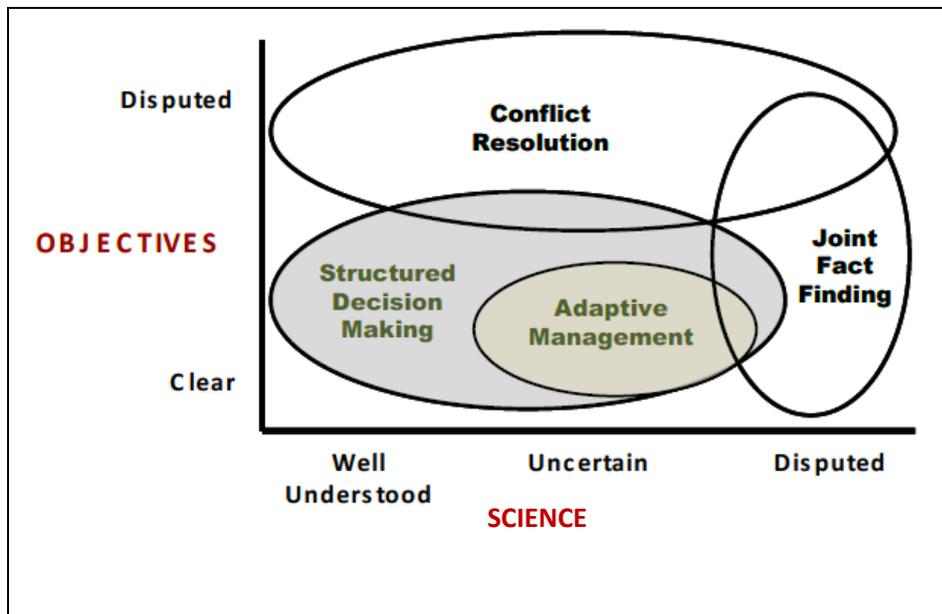
In addition, ten strategies and 39 more specific approaches were synthesized from dozens of scientific papers that discussed adaptation actions at a variety of scales and locations and are presented in Butler et al. (2012) (extracted strategies are listed in **Appendix 4.1**). Although the list was originally developed with a focus on forest ecosystems in northern Wisconsin, the strategies and approaches have proven to be broadly applicable to a variety of terrestrial ecosystem types across the Midwest and Northeast. By stating an intention to promote options of resistance, resilience, or transition and explicitly linking the strategies and approaches to on-the-ground tactics, managers are better able to specify how they will meet management goals through adaptation.

## II. IMPLEMENTING ADAPTATION ACTIONS

### A) PROCESSES FOR ADAPTATION PLANNING AND IMPLEMENTATION

Several processes are available to support planning and decision-making in resource conservation. They offer frameworks and structured steps aimed at enhancing transparency and participation in planning and decision making, and directly address sources of uncertainty from climate change (e.g., possible future conditions, model projections), human response behaviors, and other sources (e.g., land use change). Some approaches, such as structured decision-making, adaptive resource management, scenario planning, and risk assessment could be applied broadly, with a climate change component incorporated into the framework. Other approaches have been developed in response to the novel challenges that climate change brings to natural resource management through specific adaptation strategies that bring together familiar elements of existing processes with new climate-relevant concepts (e.g., multi-looped learning, resistance, resilience, and transition) and tools (e.g., vulnerability assessments). These are not necessarily mutually exclusive options; many if not all can work in a complementary fashion (**Figure 2**). For example, a vulnerability assessment is an initial step in the adaptation planning process that identifies where the greatest risks and uncertainties are while scenario planning and other decision support approaches can be used as part of, and to inform, the vulnerability assessment.

Below we describe several adaptation and decision support processes. Regional Case Studies (**Section III**) provide illustrative examples of the application of many of these methods.



**Figure 2:** Structured Decision Making in the context of other decision support approaches. Extracted from USGS and U.S. Fish and Wildlife Service National Conservation Training Center course module materials, and modified from Williams & Brown (2012).

*i. Adaptation Workbook*

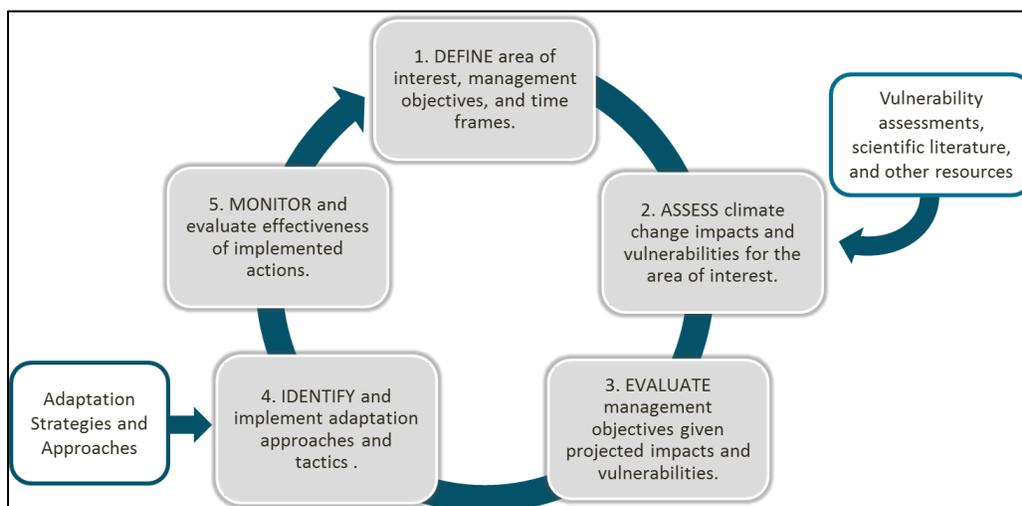
The [Adaptation Workbook](#) from *Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers* (Swanson & Janowiak 2012) outlines a conceptual five-step process to assist natural resource managers in integrating climate change into natural resource management plans and actions. It provides a structured process for managers to work through and draws upon region-specific information such as Climate Change Vulnerability Assessments (CCVAs). It is designed to incorporate climate change considerations into resource management at a variety of spatial scales (parcels to large reserves) and many levels of decision-making (e.g., planning, implementation). It is not intended to provide specific solutions, but rather draws upon the expertise of natural resource professionals and complements already existing processes for developing plans and projects. It provides step-by-step instructions for managers to translate the adaptation strategies and approaches, described above, into on-the-ground management tactics that are expected to help ecosystems adapt to climate change. Finally, it helps managers to consider how a suite of forest management actions can be implemented

over long time periods (often through the year 2100) to maintain desired ecosystem functions and benefits across a range of plausible future climates.

The Adaptation Workbook is a structured process to consider the potential effects of climate change on ecosystems and design management and conservation actions that can help prepare for changing conditions. The process is completely flexible to accommodate a wide variety of geographic locations, scales, habitat types, management goals, and ownership types.

The Workbook consists of 5 basic steps (**Figure 3**):

1. Define goals and objectives
2. Assess climate impacts and vulnerabilities
3. Evaluate objectives considering climate impacts
4. Identify adaptation approaches and tactics for implementation
5. Monitor effectiveness of implemented actions both in the short and long-term



**Figure 3:** Five steps of the structured process outlined in The Adaptation Workbook Modified from Swanson & Janowiak 2012.

## *ii. Climate Change Vulnerability Assessments*

Chapter 2 of this report provides an overview of Climate Change Vulnerability Assessments (CCVAs), outlines a range of CCVA frameworks being implemented regionally and nationally (e.g., NatureServe Climate Change Vulnerability Index (CCVI) and the Climate Change

response Framework (CCRF)), and synthesizes information on approximately 1,000 fish and wildlife species, and 82 habitats evaluated across 21 studies in the Northeast and Midwest. Briefly, climate change vulnerability assessments determine which species are relatively more or less vulnerable to the direct and indirect impacts of climate change, and to identify the specific elements of exposure, sensitivity, and adaptive capacity that contribute to their overall vulnerability. The process of conducting a vulnerability assessment can be nested within other frameworks (e.g., Structured Decision Making), and can also include other adaptation processes and approaches (e.g., scenario planning) (Glick et al. 2011). There are a variety of qualitative and quantitative approaches to assess vulnerability (**see Chapter 2, Table 2; Chapter 3** results related to the [Designing Sustainable Landscapes project](#) (DeLuca & McGarigal 2014)). As part of the vulnerability assessment process, information about what is known and uncertain about a species or system is amassed as well as the confidence levels in the existing information. Clear reporting of uncertainties is one outcome of a CCVA that can inform and help prioritize adaptation strategies such as targeted monitoring of specific biological and ecological attributes, or coordinated monitoring of paired biological and environmental monitoring systems to better detect and attribute responses to climate drivers and ecosystem shifts. Please refer to **Chapter 2** for additional information on regional CCVAs.

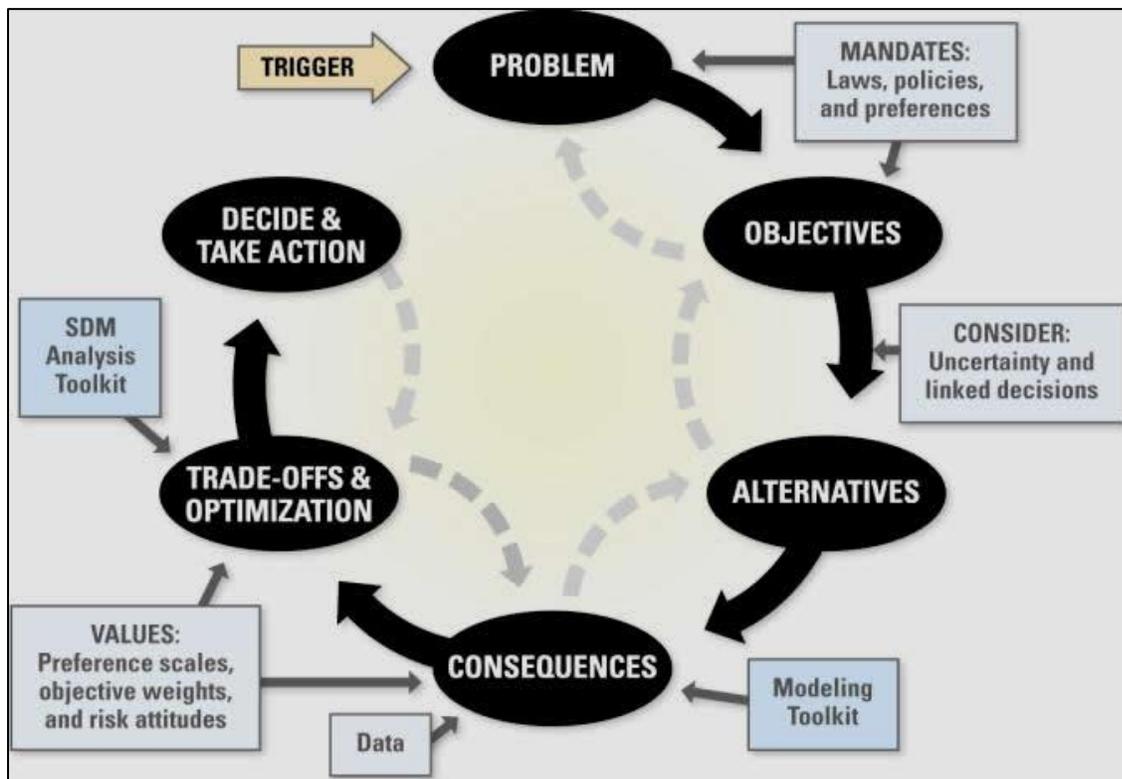
### *iii. Structured Decision Making*

Structured Decision-Making (SDM) is the application of decision theory, risk analysis, and stakeholder engagement in the analysis of natural resource management decisions. In this process, special attention is devoted to decisions made by natural resource managers and to the potential alternatives and outcomes, quality of information available, and uncertainty they encounter trying to achieve their objectives. The approach recognizes the iterative component of natural resource decision-making, and the ability to update decisions as more information becomes available about how a species or system is responding to management actions. The SDM process breaks the decision that needs to be made into components that separate science and policy issues. The SDM process is deliberate, transparent and replicable. Managers are

more likely to achieve their objectives through SDM because stakeholders are involved throughout the process and all viewpoints are represented in the decision (Gregory et al. 2012).

The SDM approach has recently become very popular within natural resource and conservation communities of practice, and is currently being utilized in numerous initiatives across the Midwest and Northeast. Case studies outlined in the next section of this report (**Section III. A.**) show SDM being used at the landscape scale by the Landscape Conservation Cooperatives (LCCs) as part of their Landscape Conservation Design project development, and also provides an example of SDM use at the watershed scale (**Section III.i.i.:** [Headwater Stream Ecosystem Conservation](#)).

Trainings on how to apply the SDM approach using the ProACT decision model (**Figure 4**) are offered by the [U.S. Fish and Wildlife Service National Conservation Training Center](#).



**Figure 4:** Diagram of the five core elements of the ProACT decision model. Figure modified from Hammond et al. 2002.

#### *iv. Adaptive Resource Management*

Adaptive Resource Management (ARM) is another decision tool and a special case of SDM. ARM was developed for recurrent decisions regarding dynamic resources that are subject to high but potentially reducible uncertainty (Williams & Brown 2012). Through this process, management actions provide feedback to decision makers of how the system or resource is responding to actions, helps verify or disprove competing hypotheses, and informs more refined, improved decisions over time (Walters 1986). The ARM approach reduces uncertainty through a collaborative approach that involves managers and scientists. The ARM process includes five elements (adapted from Williams & Brown 2012):

1. *Stakeholder involvement* – includes the different perspectives, preferences and values related to the decision and resource being considered. Even when conflicts are present among stakeholders, this process generally increases acceptance and compliance with the decision outcome.
2. *Objectives* – development of clear goals that serve as benchmarks to compare and contrast alternative management actions and the effectiveness of their implementation.
3. *Management alternatives* – alternatives are developed from which an action is selected at each decision point, which has direct or indirect effects on the target resource.
4. *Predictive models* – describe or quantify resource dynamics, ecological and environmental relationships, and the costs and benefits of the alternative actions being considered.
5. *Monitoring protocols* – provide feedback and learning about how the resource is responding to the alternative actions being implemented. To be effective, the attributes of the resource being monitored should be as closely linked as practically possible to the management action.

A case study of this approach was recently highlighted by Nichols et al. (2015), which described the process of decision-making regarding harvest regulations for mallards (*Anas platyrhynchos*), one of most economically important waterfowl species in North America. The

U.S. Fish and Wildlife Service used the ARM approach to maximize mallard harvests over the long-term and set goals that devalued harvest when the population size was below a specified threshold set by the North American Waterfowl Management Plan. The ARM approach is currently being considered and applied to other migratory waterfowl through the [US Flyways](#) collaborations.

#### *v. Scenario Planning*

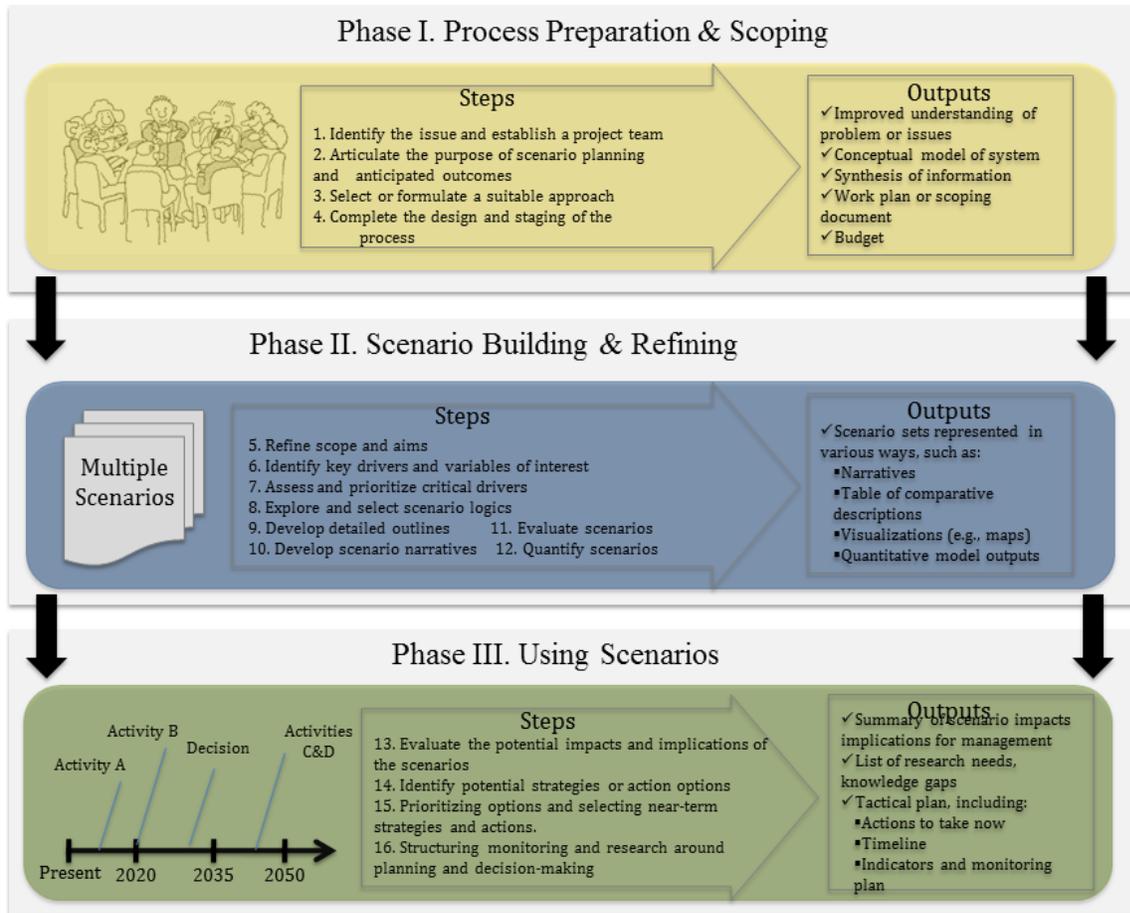
Scenario planning and other scenario-based approaches contribute to climate change adaptation as a tool for explicitly incorporating uncertainties into planning and decision-making that are difficult to address with predictive methods alone. Natural resource management takes place in the context of complex systems influenced by forces (or “drivers”) that are often beyond direct control by managers (Peterson et al. 2003; Zurek & Henrichs 2007; Walker et al. 2012). These can lead to significant uncertainties about future conditions, which have implications for the management decisions being made today (e.g., Beach & Clark 2015).

Climate change, which has direct and indirect influences on natural systems and interacts with other conservation threats and stressors, is creating increasingly unpredictable futures. Additionally, it requires consideration of longer time horizons than those typically considered in natural resource management. Scenario planning can provide insights into future trajectories, and prepare managers to respond appropriately to challenges in both the short- and long-term (e.g., Duinker & Greig 2007; Weeks et al. 2011; Price and Isaac 2012; **Box 1**). Scenario planning also has the ability to identify triggers (e.g., in environmental conditions) that can guide monitoring and management decisions and actions (e.g., targets that can help managers recognize when certain thresholds are imminent or have been past, thus prompting actions).

**Box 1:** Regional examples of the scenario planning approach applied to address climate, ecological, and other changes for natural resources. **Appendix 4.3** contains expanded descriptions of project goals, narratives, and partners.

- 1) **Isle Royale National Park** (Lake Superior, Michigan): the National Park Service (NPS) is developing qualitative scenario narratives to explore how climate change will impact future park conditions (Fisichelli et al. 2013).
- 2) **Northern New England** (Massachusetts, Maine, New Hampshire and Vermont): the New England Landscape Futures network is developing qualitative narratives and quantitative simulations to evaluate impacts on stakeholder identified ecosystem services ([S3 Research Coordination Network](#); Duvenek et al. 2015).
- 3) **Lake Ontario Ecosystem** (New York and Ontario, Canada in the Lake Ontario watershed): New York Sea Grant is using qualitative scenarios to explore uncertain trajectories of ecosystem processes and expand the perspectives of lake stakeholder groups (Ongoing, NY Sea Grant, [dbm4@cornell.edu](mailto:dbm4@cornell.edu)).
- 4) **North Woods and moose** (Northern New England, New York, Adirondacks): The Wildlife Conservation Society, USGS, and others are testing a scenario-planning approach with State and other managers to develop future scenarios of moose in the transition zone of the Northern Hardwood and Boreal forests (Ongoing, WCS, [erowland@wcs.org](mailto:erowland@wcs.org)).

Scenario planning is a flexible yet structured process. There is no single established methodology for conducting scenario planning, and the process has been depicted in different ways in its more recent application to climate change adaptation (e.g., Mahmoud et al. 2009; Wiseman et al. 2011; NPS 2013). Regardless of the specific techniques used, the process is generally characterized by three broad phases: 1) preparation and scoping, 2) developing and refining scenarios, and 3) using scenarios, each with key steps that are common between approaches and similar to other decision support methods (**Figure 5**; Rowland et al. 2014). Scenario planning efforts can assist with understanding, planning for, and implementing actions, and can be tailored to available time, capacity, and financial resources.



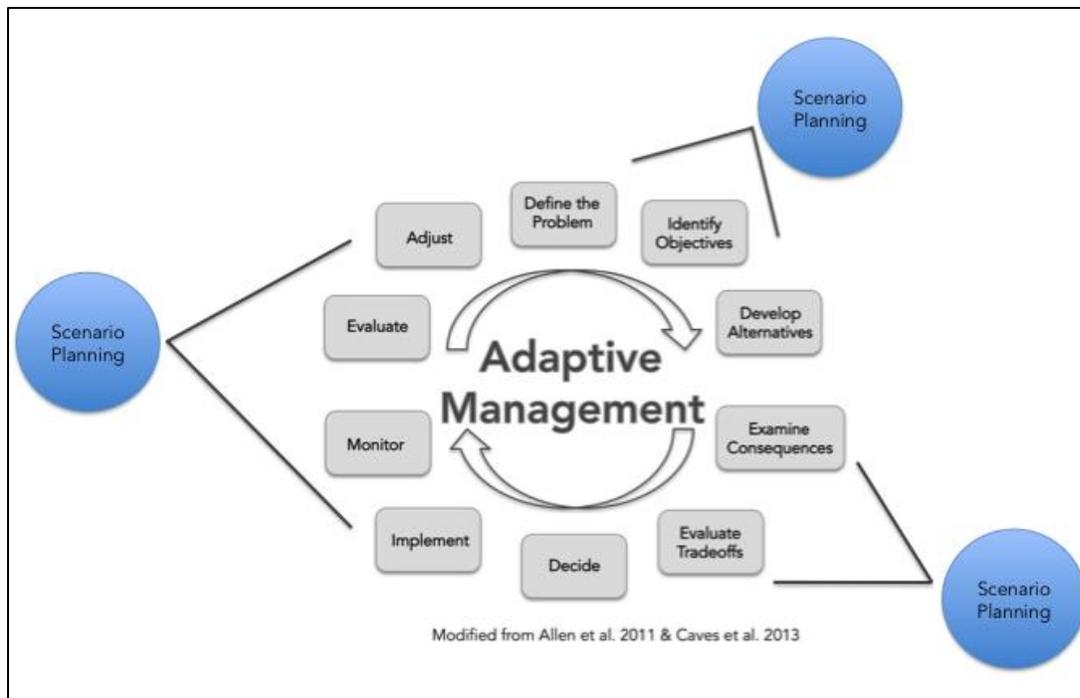
**Figure 5:** Three phases in the scenario planning process, including the steps and outputs for each phase (modified from Wiseman et al. 2011 and others).

While similar in many respects to other decision support methods, scenario planning is distinguished by the explicit development of scenarios built around critical uncertainties, for which the magnitude or direction of change have the potential to create diverse future conditions with different management challenges. The structured process allows practitioners to bring varying kinds of information to bear on a complex problem in a transparent way (Thompson et al. 2012; NPS 2013). Both quantitative and qualitative inputs are used to characterize ecosystem changes, and potentially economic and social changes, for a chosen time period (e.g., 2050, 2100). Scenarios describe more than just endpoints by including logically consistent, temporal pathways or sequences of events needed to arrive at those future conditions. The scenarios are often initially represented by realistic narratives or stories that capture the “who, what, where, when, and why” of the problem and portray both the positive

and negative consequences of the future conditions. While the scenarios are structured around uncertain drivers of change, they should also incorporate more certain elements that different futures may have in common (NPS 2013).

Whether qualitative, quantitative, or some combination, the resulting scenarios are possible future states of the world that represent alternative plausible conditions under different assumptions. Scenario planning does not end with scenario development. The intent is to use the scenarios to explore potential effects or consequences and how to respond (Peterson et al. 2003; Mahmoud et al. 2009; Wiseman et al. 2011). Applying the scenarios becomes a “what if” exercise through which management options for the different future conditions are considered (NPS 2013). Scenario planning enables the identification of robust management strategies, if they exist, as well as those specific to the unfolding of particular conditions. It can also support the development of new strategies or the revision of existing conservation goals and objectives in cases where current actions cannot achieve the goals regardless of future conditions (e.g., Caves et al. 2013; Beach & Clark 2015). Completing the process helps recognize future decision points, as well as the development of indicators that might determine when decisions can be made (Weeks et al. 2011; Wiseman et al. 2011). Coupling scenario planning with targeted monitoring can provide information on how a particular trajectory is playing out, allowing managers to respond quickly with proactively identified actions.

Scenario planning is one method to support planning and decision-making under uncertainty and can complement other decision frameworks, methods, and tools, including adaptive management, structured decision making, and iterative risk management (e.g., Caves et al. 2013; Miller & Morrisette 2014; **Figure 6**). Scenario planning can engage stakeholders, explore possible future trajectories for a system, assess the vulnerability of conservation resources, consider the consequences of management alternatives, and develop indicators of important future decision points. In some cases, the outputs from an initial exploratory exercise can provide inputs for subsequent existing planning and decision-focused efforts, helping to frame issues and suggest management alternatives (Biggs et al. 2007; Rowland et al. 2014).



**Figure 6:** The parts of a decision-making process or adaptive management to which scenario planning might contribute. Modified from Allen et al. (2011) and Caves et al. (2013).

### *vii. Web tools*

There are numerous interactive web-based climate change adaptation tools being developed and released on a daily basis. **Appendix 4.2** lists a selection of adaptation decision support tools focused on a variety of natural resources with short descriptions and website links. Many of these tools can be used to generate information to be included in the decision support approaches outlined in this section. There are many more tools available that are not listed in **Appendix 4.2**, but this list serves as a starting point to demonstrate the range of resources available for aiding in decision making and taking action.

## **B) MONITORING**

Climate change will require novel management decisions with unknown outcomes; thus monitoring is essential to tracking successes and failures, helping refine future actions and approaches, and identifying effective adaptation strategies and management practices (West et al., 2009; Lawler et al. 2010). Monitoring also reduces uncertainty by providing baseline data as

well as insight on how species and habitats are responding to climate change and other stressors. In many cases, monitoring programs were not designed with climate change impacts in mind and may need to be adjusted to accommodate new challenges and information needs (Heinz Center 2008). This includes identification of key indicators and metrics that track ecological responses, including certain demographic parameters and the seasonal timing of life history events (phenology) across components of biodiversity (species, ecosystems, and biomes). Monitoring can also provide advance warning of the direct and indirect impacts of climate change and other stressors (Heinz Center 2008; Staudinger et al. 2012).

A recent report that served as input to the National Climate Assessment (Staudinger et al. 2012) made a series of recommendations on monitoring in the context of climate change, and are summarized here:

- Improved, better-integrated, and increasingly coordinated monitoring systems are needed to detect, track, and attribute species and habitat shifts to climate change over varying spatiotemporal scales.
- Existing long-term monitoring sites provide a historical context of the underlying trajectories of fish and wildlife populations and dependent habitats, and are useful in detecting drivers of change, the places where ecological systems are adapting (or not), as well as novel shifts in range, phenology and species interactions.
- Locally based observation networks can be “nested” within a larger-scale network to deliver information to a wider range of managers and policy makers in order to better detect changes due to climate and interactions with other anthropogenic stressors.
- Inserting monitoring protocols with consistent metrics into projects will be critical to make inferences across studies and document large scale trends in impacted fish and wildlife species.
- Ecological monitoring of transition zones between ecosystems may provide early warning of potential biome shifts.

- Increased monitoring is needed to detect and subsequently eradicate invasive species before they become established in new locations or expand their range into new territories.

Here we provide examples of a regional project and national program that are addressing these recommendations for monitoring. In addition, **Appendix 4.1** provides numerous examples (searchable by Source Document Descriptor) of how monitoring can address climate change and other anthropogenic stressors through specific adaptation strategies and tactics.

*i. NorEaST - A coordinated regional monitoring initiative*

One example of how individual disparate monitoring locations can be linked together to inform landscape and regional scale adaptation is showcased by the NorEaST project. Climate change is expected to alter stream temperature and flow regimes over the coming decades, and in turn influence distributions of aquatic species in those freshwater ecosystems. To better anticipate these changes, there has been a need to compile both short- and long-term stream temperature data for managers to gain an understanding of baseline conditions, historic trends, and future projections. Pooled data from many sources, even if temporally and spatially inconsistent, can have great value both in the realm of stream temperature and aquatic response. Unfortunately, many agencies lack sufficient resources to compile, conduct quality assurance and control, and make accessible stream temperature data collected through routine monitoring.

The [NorEaST web portal](#) was developed to serve as a coordinated, multi-agency regional framework to map and store continuous stream temperature locations and data for New England, Mid Atlantic, and Great Lakes States. Stream temperature monitoring locations and metadata contributed by 47 different organizations can be viewed for over 10,000 monitoring locations across 22 states. Stream temperature sites can be viewed on the NorEaST mapper. Ultimately the goal of this project and portal is to make these data available to managers and the public to aid in adaptation and management planning and actions.

The NorEaST web portal was built to map stream temperature locations, store stream temperature data, and deliver stream temperature data through webservice to stakeholders, including easy access through R software. Preliminary applications of this project have allowed evaluations of seasonal associations of fish species with stream thermal conditions (e.g. range of summer and fall temperature ranges), the identification of thermally sensitive fish species, and potential differences of fish-temperature associations across regions that were previously unknown. Updates on this project can be found on the [NE CSC website](#).

### *ii. National Phenology Network*

The [National Phenology Network](#) (NPN) provides national standardized protocols for collecting phenology observations, advice and education materials for the collection and organization of new phenology data, and supports the development of tools and approaches for natural resource decision-making. NPN developed *Nature's Notebook* as a citizen science tool to gather phenology observations on plants and animals nationally. Citizen Science is a growing way to monitor and track changes in species responses to climate change, and supplement existing scientific monitoring networks (Newman et al. 2012). Public engagement increases awareness of conservation and climate adaptation issues and can help extend limited resources for activities like monitoring. There are numerous institutions across the Northeast and Midwest using NPN's *Nature's Notebook* tool and contributing to a larger network of monitoring programs to inform our understanding of phenological responses to climate change.

## **III. REGIONAL CASE STUDIES**

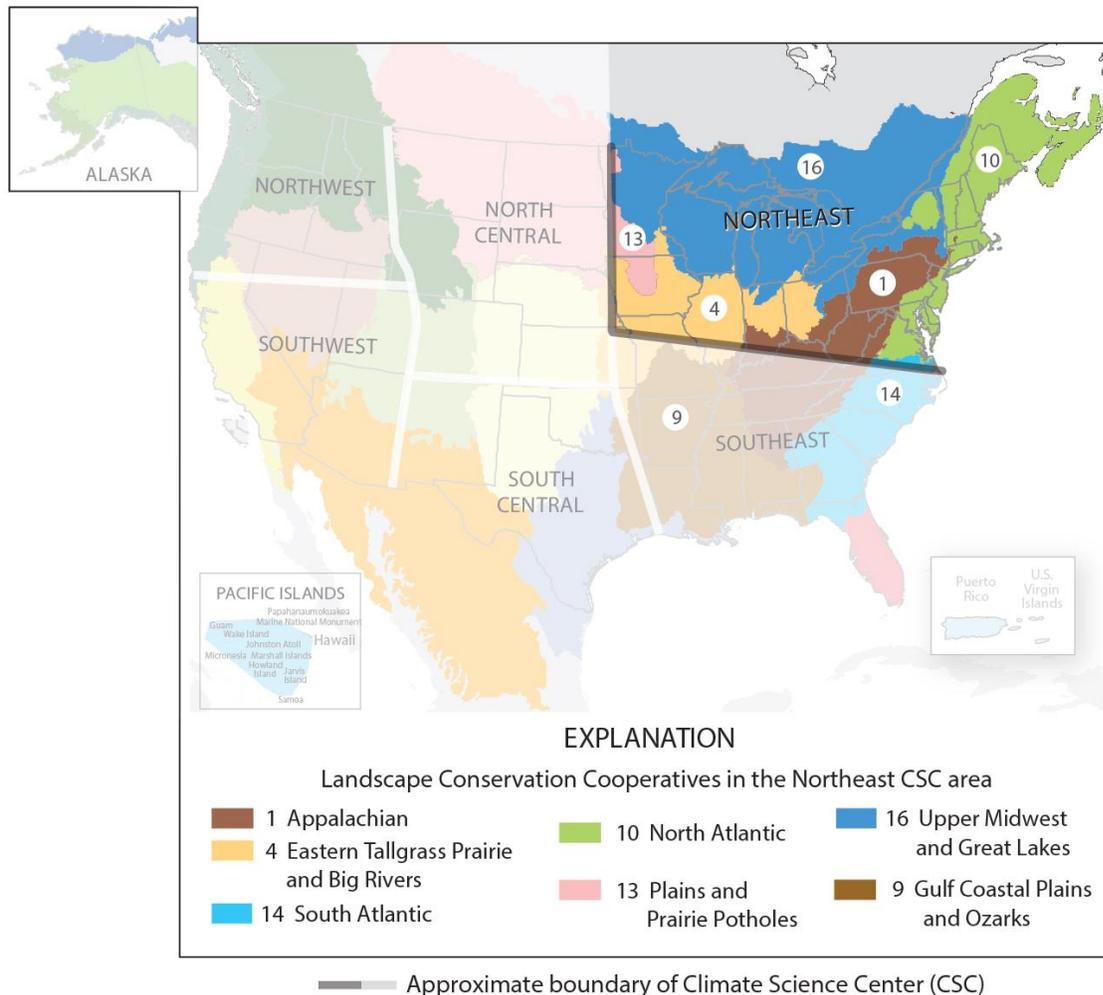
In this final section, we provide illustrative case studies of adaptation strategies, approaches, and tactics being implemented at the ecoregion, state, and local scales. Many of these projects are being conducted by the Northeast Climate Science Center (NE CSC) and diverse partners. At the local scale we include examples of ongoing or recently completed projects focused on aquatic systems, forests, terrestrial wetlands, coastal, and tribal lands. In addition, **Appendix 4.1** synthesizes over 900 adaptation strategies by scale (national, ecoregional, state, and local), target resource (major taxonomic group or habitat type), and

climate stressor (temperature, precipitation, sea level rise) from nine regional adaptation studies. Each of the adaptation strategies listed in **Appendix 4.1** is also organized by the seven overarching goals listed in the National Fish, Wildlife and Plants Climate Adaptation Strategy (NFWPCAP 2012). Our intention in presenting these materials is to provide searchable examples ranging from large scale, broad goals to local scale, species or habitat-specific actions and implementation.

## **A) LANDSCAPE AND ECOREGION**

### *i. Landscape Conservation Cooperatives and Landscape Conservation Design*

The Landscape Conservation Cooperatives (LCCs; <http://lccnetwork.org/>) were established by the Department of the Interior as part of Secretarial Order No. 3289 to better integrate science and management of natural and cultural resources across large spatial and temporal scales as well as to address complex stressors such as climate change. There are 22 LCCs across the nation, and 7 within the Northeast and Midwest (as defined by the footprint of the NE CSC) including: North Atlantic (NA), Appalachian (APP), Upper Midwest and Great Lakes (UMGL), Eastern Tallgrass Prairie & Big Rivers (ETPBR), Gulf Coastal Plains and Ozarks (GCPO), Plains and Prairie Potholes (PPP), and South Atlantic (SA) LCCs (**Figure 7**).



**Figure 7:** Map of the 7 Landscape Conservation Cooperatives contained within Northeast Climate Science Center geography. Figure modified from NE CSC 2012.

An emerging core initiative of the LCCs is to implement a Landscape Conservation Design (LCD) approach to inform refuge and conservation area planning. This collaborative and partnership-driven strategy to address large scale stressors encompasses both the process and products for designing sustainable landscapes and ecosystem services. LCDs guide landscape-scale restoration, protection, and adaptation of target resources (**Box 2**).

**Box 2:** Regional examples of ongoing Landscape Conservation Design initiatives being led by the Landscape Conservation Cooperatives. Expanded descriptions of each project and its partners are found in **Appendix 4.4**.

1. [North Atlantic](#): *The Connecticut River Watershed LCD Pilot* is a collaborative effort to plan a landscape with intact, resilient, connected natural areas providing habitat for fish, wildlife and plants and many other natural benefits that support people and communities within the Connecticut River Watershed.
2. [Eastern Tallgrass Prairie & Big Rivers \(ETPBR\)](#): *The Mississippi River Basin / Gulf Hypoxia Initiative* is an initiative undertaking a systematic and transparent process to create an integrated framework that supports planning, design, configuration, and delivery of wildlife conservation practices within the Mississippi River watershed.
3. [Gulf Coastal Plains and Ozarks \(GCPO\)](#): *The Ozark Highlands Comprehensive Conservation Strategy* is a cooperative effort to take an ecoregional approach to designing landscapes capable of sustaining healthy plant and animal communities in the Ozark Highlands.
4. [Upper Midwest and Great Lakes \(UMGL\)](#): The primary goal of the *Great Lakes Coastal Wetland LCD* is to guide landscape scale restoration/protection of historical, existing, or potential wetlands that are, or could be hydrologically influenced by levels of Great Lakes and their connecting channels.
5. [Appalachian \(App\)](#): The goal of the Appalachian Conservation Modeling project is to use data and models to develop a regional conservation plan and LCD that supports natural and cultural resources in the Appalachian region.
6. [Plains and Prairie Potholes \(PPP\)](#): The PPP LCC is currently developing a strategic plan that will help determine how and when to undertake LCD from a partnership perspective using decision analysis techniques, land use change, and human dimensions as priorities.

## ii. USDA Northern Forests Sub Hub

The Northern Forests Sub Hub tiers to and expands the work of the Midwest and Northeast [USDA Regional Climate Hubs](#). The primary goals of the Northern Forests Sub Hub are to ascertain and meet the needs of the forest sector through 1) ongoing engagement and

networking with a wide array of landowners, organizations, universities, and interests related to the sector, 2) creation and distribution of sector-relevant climate information and resources for natural resource professionals and landowners, and 3) establishment of adaptation planning and implementation, with associated promotion of peer-to-peer learning where appropriate. The Sub Hub is coordinated by the Northern Institute of Applied Climate Science (NIACS), a regional multi-institutional partnership that has focused on delivery of climate change and carbon science to the forest sector for more than 5 years. Deliverables and products identified in the Sub Hub work plan include: 1) vulnerability assessments; 2) adaptation resources, tools, and demonstrations; 3) science delivery, training, and technical assistance; and 4) outreach and communication demonstrations, materials, and tools.

### *iii. Northern Institute of Applied Climate Science*

The Northern Institute of Applied Climate Science (NIACS) has been designed as a collaborative effort amongst the Forest Service (Northern Research Station, Eastern Region, Northeastern Area State & Private Forestry), Michigan Technological University, National Council for Air and Stream Improvement, and the Trust for Public Land. NIACS provides information on managing forests for climate change adaptation, enhanced carbon sequestration, and sustainable production of bioenergy and materials. As a regional, multi-institutional entity, NIACS builds partnerships, facilitates research, and synthesizes information to bridge the gap between carbon and climate science research and the management needs of land owners and natural resource professionals, policymakers, and members of the public. Through its work to integrate climate change considerations into natural resource management, NIACS is central to the coordination of the Forest Service's Climate Change Resource Center (CCRC) as well as the Climate Change Response Framework (CCRF).

**[Climate Change Resource Center \(CCRC\)](#)** – The US Forest Service CCRC is a web-based, national resource that connects land managers and decision makers with useable science to address climate change in planning and application. The CCRC addresses the land manager's question "What can I do about climate change?" by providing information about climate change impacts on forests and other ecosystems, and approaches to adaptation and mitigation in

forests and grasslands. The website compiles and creates educational resources, climate change and carbon tools, video presentations, literature, and briefings on management-relevant topics, ranging from basic climate change information to details on specific management responses. The CCRC is a joint effort of the US Forest Service Office of the Climate Change Advisor and US Forest Service Research and Development.

[Climate Change Response Framework \(CCRF\)](#) – The CCRF is a highly collaborative approach to helping land managers integrate climate change considerations into forest management. Since 2009, the Framework has bridged the gap between scientific research on climate change impacts and on-the-ground natural resource management. Currently, there are six Framework projects encompassing 19 states, including 14 National Forests and millions of acres of forestland and 75+ partners (e.g., federal, state, tribal, private). Each regional project interweaves four components: science and management partnerships, vulnerability assessments (see **Chapter 2**), adaptation resources, and demonstration projects.

#### *iv. Southeast Conservation Adaptation Strategy*

The [Southeast Conservation Adaptation Strategy](#) (SECAS) is a regional conservation and management partnership driven effort seeking to develop coordinated planning and adaptation across the southeast region of the United States. Conservation priorities and actions are being targeted at the landscape scale and informed by a range of approaches including future climate change and sea level projections, and interactions with other anthropogenic stressors, particularly urban growth. Leveraged and collective resources are being coordinated across state fish and wildlife agencies, regional LCCs and CSCs, joint ventures, and a range of other organizations invested in conservation and adaptation of natural resources.

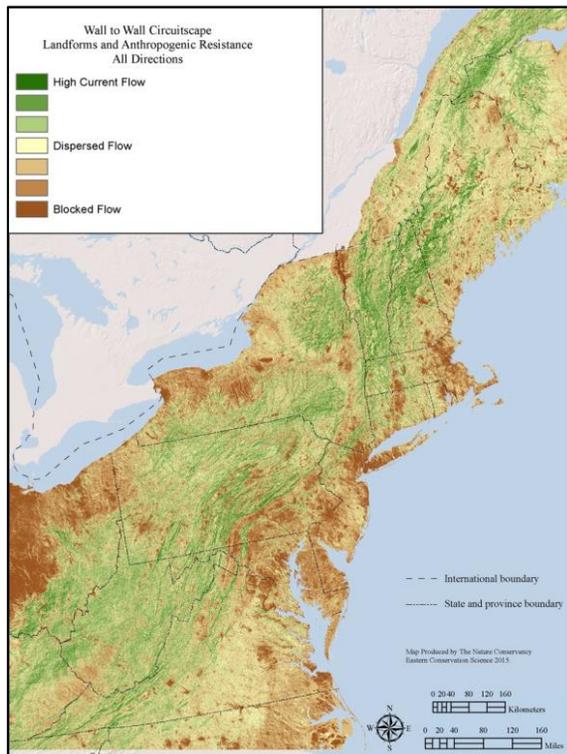
Examples of conservation and adaptation strategies underway through SECAS efforts at the landscape-scale include:

- Increasing connectivity among fragmented habitats and populations so that fish and wildlife can shift their ranges or migrations to follow optimal environmental conditions under future climate and land-use changes.

- Developing predictions of urban growth patterns and rates across the region to identify areas where fragmentation will increase and potentially have negative impacts on ecosystem health (Terando et al. 2014).
- Conducting regional multi-species and large-scale vulnerability assessments of fish, wildlife and habitats.

*v. Conservation Opportunity Areas*

Conservation Opportunity Areas (COAs) are spatially delineated places where actions to support or enhance populations of Regional Species of Greatest Conservation Need (RSGCN) and/or their habitats are likely to be most effective. State fish and wildlife agencies are



**Figure 8:** Map showing potential areas of high permeability for upslope range shifts under future climate change and considering anthropogenic barriers and fragmentation. Modified from Anderson et al. (2015) and used with permission from The Nature Conservancy.

partnering to establish COAs across the Northeast and Midwest. This process requires the development of a methodology to document and map COAs across the region to achieve fundamental objectives (**Figure 8**). A recent workshop (March 2015) convened by the North Atlantic LCC, discussed how COAs could be developed to inform State Wildlife Action Plans, evaluate possible fundamental objectives, and identify a refined set of alternatives for consideration by the Northeast Fish and Wildlife Diversity Technical Committee (NEFWDTC). The types of information included as part of this process included indices of ecological integrity, resilience, barriers to fish and wildlife movements and migration, and spatial data layers on habitat species distributions. Workshop participants then scored different alternatives for their inclusion in the development of COA objectives.

One study that was unanimously scored for inclusion was a new landscape permeability study led by The Nature Conservancy (Anderson et al. 2015). Building on previous work by Anderson et al. (2012), which documented climate-resilient sites, new methods were used to evaluate patterns of regional landscape permeability most likely to facilitate fish and wildlife movements as they respond to climate change through geographical range shifts. Spatially explicit data layers highlight areas where northward and upslope movements are most likely across terrestrial landscapes, as well as riparian corridors, such as intact floodplains, that would allow moisture-dependent species to track optimal habitat conditions under future climate change (**Figure 8**; Anderson et al. 2015). The Appalachian Mountain chain was one area identified as highly important for thermal corridors of movement in the Northeast. Next steps for this work are to integrate species range and movement data with the landscape layers to gain a better understanding of actual occupied habitats and prioritize specific areas for conservation.

## **B) STATE**

Several State Wildlife Action Plans have already begun the process of including adaptation strategies in their planning. **Appendix 4.1** provides a synthesis of adaptation strategies and tactics recommended in five State Wildlife Action Plans including Connecticut (Adaptation Subcommittee to the Governor's Steering Committee on Climate Change 2011), Massachusetts (Climate Change Adaptation Advisory Committee, 2011), New Hampshire (New Hampshire Fish and Game Department, 2013), Vermont (TetraTech, Inc. 2013), and Rhode Island (Rhode Island SWAP Wildlife Action Plan 2015 ).

**Table 1:** Total numbers of species and habitat-specific adaptation strategies and tactics listed in Appendix 4.1.

Target Habitat or species	N
Alpine	5
Coastal, Marine	85
Forest	285
Freshwater Aquatic	202
General	277
Terrestrial Wetland	83
Urban/Developed/Agriculture	21
<b>Total</b>	<b>958</b>

**C) LOCAL**

*i. Aquatic systems*

**Landscape Scale Decision Making for Headwater Stream Ecosystem Conservation:**

Researchers from the USGS Patuxent Wildlife Research Center, USGS Massachusetts Cooperative Fish and Wildlife Research Unit, and University of Massachusetts Amherst are working together to understand the impediments to landscape scale conservation of headwater stream ecosystems which are managed by multiple stakeholders in watersheds across the Northeast. The project uses decision theory and tools, specifically SDM (see **Section II.A.iii**) to evaluate how stakeholders can collaboratively create adaptive strategies that protect headwater ecosystems from various threats and stressors, including future climate and land use changes. Since headwater stream ecosystems are differentially valued by organizations for their species diversity, recreational opportunities, and/or ecosystem services (i.e., water quality and supply as well as flood control), and individuals and agencies are often working with limited resources (i.e., funding, staff), trade-offs may be inevitable, and can be explicitly incorporated into the decision framework to find an optimal solution for collaboration which best satisfies multiple stakeholder objectives. By working with federal, state and local governmental agencies and non-profit organizations from two watersheds (Deerfield and Merrimack in New England), this project will provide an example of when collaboration can improve effectiveness and efficiency of conservation actions. Using decision-theory approaches, this project is explicitly incorporating critical uncertainties (i.e., environmental variation, partial controllability,

structural and parameter uncertainty), risk preferences, and scenario planning tools to generate insights into the range of potential future outcomes under alternative management strategies. Solutions to other such landscape-scale conservation problems will require a similar decision framework that incorporates diverse stakeholder objectives, scientific and management uncertainty, and risk tolerance into large-scale conservation efforts across the Northeast and beyond. Updates on this project can be found on the [NE CSC website](#).

**Assessing aquatic vulnerability through storm transposition**: Risk assessment is a process used across many disciplines, agencies and institutions to evaluate the likelihood of harmful impacts that may occur or are occurring as a result of exposure or vulnerability to climate change and other stressors. Storm transposition is a modeling approach to help communities and land managers assess and prepare for the risk of extreme rainfall. Climate scientists project heavier and more frequent extreme rainstorms for the Northeast and Great Lakes regions in the future (see **Chapter 1**). Many communities plan for and design infrastructure using “synthetic” storms (e.g., the 10, 50, 100 year storms). Storm transposition makes use of high-resolution rainfall data from actual extreme rainfall events and applies them to inform flood risk assessment and stormwater management in nearby locations that have not recently experienced extreme rainfall. Researchers at the University of Wisconsin-Madison (David Liebl and Ken Potter) developed the software tool TranStorm to facilitate hydrologic modeling with transposed storms (additional information available on the [U.S. Climate Resilience Toolkit site](#)). Land managers and municipalities can use such modeling to identify potential vulnerabilities and plan for future extreme events. The use of a well known actual storm rather than a “synthetic” storm is more likely engage the public and may well lead to increased support and resources for restoration and adaptation actions. To date this modeling approach has involved stormwater ordinances and lake management, but can be applied to other issues involving extreme precipitation risk, including sediment and nutrient pollution, ecosystem damage, and bridge and culvert vulnerability.

The software tool TranStorm enables users to transpose a storm to a watershed of interest. The model also computes time series of rainfall amounts for subwatersheds for use in watershed modeling. The software is currently being shared with users to get their feedback.

## ii. Forests

**Modeling effects of climate change on spruce-fir forest ecosystems and associated priority bird populations:** The primary focus of this project is on forecasting both the future distribution of spruce-fir forest ecosystems in northern New England, as well as associated priority bird species. Deliverables and tools being developed from this project for informing adaptive responses to climate change impacts on these systems include fine-scale (900 m<sup>2</sup> resolution) maps for the entire Green and White Mountain National Forests and surrounding region (~500,000 ha landscapes) that depict the location of potential refugia for spruce-fir forests under different climate and management scenarios. Importantly, these maps include the future distribution of all forest habitat types for these areas, allowing for evaluations of ecosystem vulnerability and associated adaptive response for all forests in this region. In addition, bird distribution models are also being developed to determine the relative suitability of these vegetation refugia for priority birds, including Bicknell's thrush (*Catharus bicknelli*) (Millar et al. 2007).

The forest modeling work is informing three different adaptive strategies for sustaining forest habitats in northern New England, which are designed to achieve the broad objective of maintaining forest habitat conditions under future changes in climate and disturbance regimes for the region. These adaptive strategies are to: 1) identify and protect climate refugia for spruce-fir forest and associated birds across the region, to minimize incompatible land uses; 2) restore and encourage spruce-fir habitats through forest management practices on portions of the Green and White Mountain National Forest that contain biophysical and localized climate conditions with the potential to support future habitat refugia; and, 3) sustain forest habitat conditions broadly across the diverse forest types found in the Green and White Mountains. In many cases, spruce and fir were selectively harvested from these areas in the past. This project is helping inform where on the landscape active restoration of this species may provide long-term refugia, despite projections for the regional decline of this forest type under climate change. This work is being completed with partners from the Vermont Agency of Natural Resources, White and Green Mountain National Forest, and NIACS, to develop forest management practices that span a spectrum of adaptation objectives. Through stakeholder

input, a suite of adaptation prescriptions will be designed that range from “resistance treatments” (i.e., maintain current conditions in light of climate and forest health impacts) to “transition treatments” (i.e., intentionally accommodate projected changes by increasing representation of future-adapted species). Treatments will be implemented in several locations throughout the region, but will also use the landscape models developed to identify refugia to simulate the effectiveness of active, adaptive management at sustaining forest conditions across the region under climate change.

**Linking forest landscape change models and wildlife population models to assess climate change impacts on forest habitats and wildlife populations:** Forest landscape models incorporate site-scale succession and landscape-scale processes to simulate forest change at landscape scales (He 2008). They have been used to examine the importance of succession, landscape-scale processes, and climate change in affecting forest change. Forest landscape models are linked to different downscaled climate scenarios to investigate the effects of climate change on forests. For example Scheller & Mladenoff (2005) and Thompson et al. (2011) used the LANDIS II forest landscape model to investigate effects of climate change and other landscape processes on changes in forest in Wisconsin and Massachusetts, respectively. Recent advances in forest landscape models have expanded their simulation capacity and the relevance of the types of model outputs available for assessing wildlife habitat. The LANDIS PRO models forest composition and structure based on species-specific tree densities, basal areas, importance values, and biomasses, and can make simulations relevant for wildlife across the region at scales of 90-270 meters (Wang et al. 2014). Forest parameters can be used as direct indicators of wildlife habitat or as inputs to wildlife habitat, abundance, or population models. Forest landscape models can be used to simulate forest change under different climate and management scenarios to investigate tree species vulnerability and indirectly ecosystem or habitat vulnerability to climate change (Butler et al. 2015).

Outputs from forest landscape models can be linked with wildlife suitability models and population models to assess the impacts of landscape change on wildlife (Larson et al. 2004). For example, Bonnot et al. (2011) developed a spatially-explicit demographic model for several

migrant songbirds that structured the regional population into ecological subsections on the basis of habitat, landscape patterns, and demographic rates to assess species viability in the Midwest. Bonnot et al. (2013) then used this approach to evaluate the response of prairie warbler (*Dendroica discolor*) and wood thrush (*Hylocichla mustelina*) populations in the Central Hardwoods Bird Conservation Region to simulated conservation scenarios. The authors also assessed the relative effectiveness of habitat restoration, afforestation, as well as increased survival, differed placement, and levels of effort for implementing those approaches; however, these approaches could also be used to assess species vulnerability under different climate scenarios or to evaluate the effectiveness of adaptation plans.

### *iii. Terrestrial wetlands*

**Novel management approaches for a vernal pool breeding salamander:** Mole salamanders of the northeastern United States, including spotted salamanders (*Ambystoma maculatum*) and marbled salamanders (*Ambystoma opacum*), are vernal pool breeders and important species in the upland forest habitats surrounding these vernal pools. Marbled salamanders are a Regional Species of Greatest Conservation Need (see **Chapter 3** for full list and additional information on this species) that may require novel management approaches to reduce vulnerability due to the effects of climate and land use changes. Climate change is expected to lead to reduced vernal pool hydroperiod due to temperature effects on evaporation, evapotranspiration rates, and changes in seasonal precipitation rates (Brooks 2009).

Populations of vernal pool breeding salamanders have historically been focused at the individual vernal pool level, but recommendations are broadening monitoring and management actions to the metapopulation scale. Some vernal pools act as source populations with more persistent populations (e.g. those vernal pools with optimal hydroperiod regimes), while other vernal pools have lower numbers of breeders, and can periodically go extinct, but are often recolonized by individuals dispersing from nearby source vernal pools. At the landscape scale, individual vernal pools encompass a network of vernal pools and act as stepping stones across the environment allowing for salamander gene flow which is important for maintaining genetic

diversity. Unfortunately, such networks, as well as surrounding upland habitat, have been and continue to be, severely fragmented or degraded by human development (Compton et al. 2007; McGarigal 2008)

Adaptation efforts that identify and prioritize the protection of important pool networks will be important for allowing populations to track future environmental change (see Compton et al. 2007). Individual vernal pools and networks of pools could be conserved in a landscape scale network of refugia and corridors through future land acquisition and conservation areas. Marbled salamander network connectivity and population size could also be improved by restoring vernal pools that were previously filled or by creating new vernal pools on the landscape (Windmiller & Calhoun, 2007). Another potential adaptation tactic that could be implemented is to control the vernal pool hydroperiod at individual vernal pools within a network to improve breeding conditions and increase marbled salamander fecundity. This would require baseline monitoring of hydroperiod to determine which vernal pools on the landscape would be most suitable for hydroperiod alteration for marbled salamanders and how these pools might fit into a larger landscape scale network.

Assisted migration is another adaptation approach that has been proposed for species not able to track environmental change due to fragmentation or if rapid environmental change makes such environmental tracking unrealistic (Minteer & Collins, 2010). Before assisted migration could be successfully applied to marbled salamanders, vernal pools with optimal vernal hydroperiod and suitable upland habitats would need to be identified.

A long-term marbled salamander monitoring project at the [University of Massachusetts](#) is currently working on gathering the needed information to help guide adaptation strategies for marbled salamanders. Updates on this project can be found on the [NE CSC website](#).

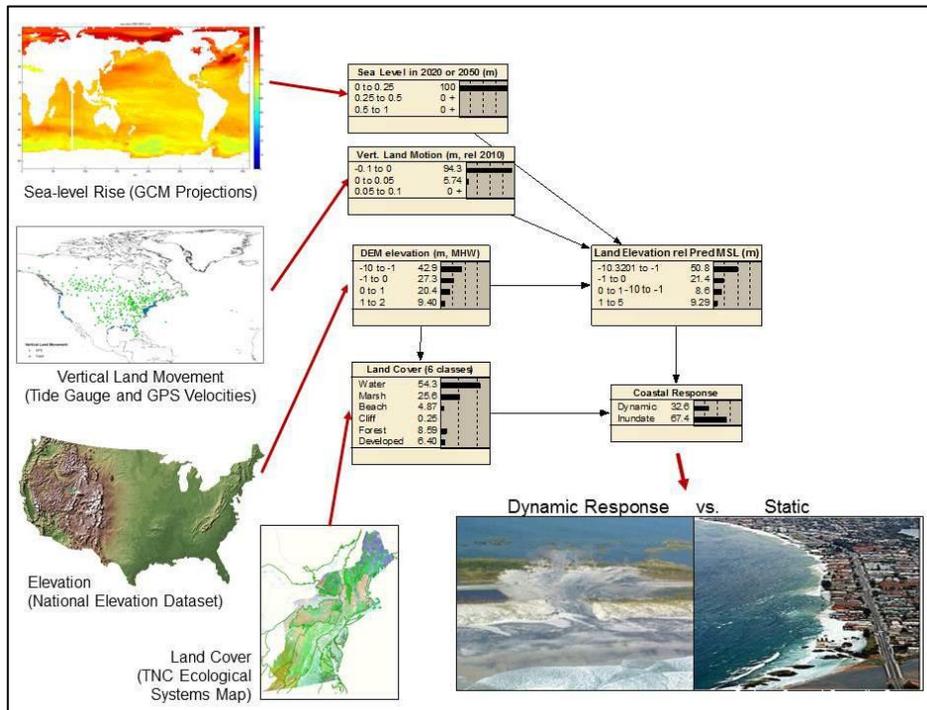
#### *iv. Coastal habitats*

Coastal regions in the Northeast are diverse, and face a variety of climate hazards including coastal flooding due to sea level rise and storm surge (**Chapter 1**). The combination of diversity and variety of climate hazards are fostering a diverse set of adaptation strategies along our coasts. The coastal region of the Northeast has high, and growing, vulnerability to coastal

flooding (Horton et al. 2014). Whereas global sea levels have risen by about 8 inches since 1900 (IPCC 2013), much of the Northeast has experienced approximately 1 foot. By mid-century, much of the region could see between 8 inches and 2.5 feet of sea level rise (Lentz et al. 2015); at the high end, this could lead to a several fold increase in the frequency of coastal flooding even if coastal storms remain unchanged in a changing climate (Sweet & Park, 2014).

Coastal adaptation strategies include hard infrastructure investments (e.g., sea walls and storm surge barriers; some of the region's examples are more than 50 years old), green infrastructure (e.g., oyster beds, and marsh and dune restorations that minimize wave impacts and retain sediment and sand), and policy actions (e.g., changes in building codes and insurance to reflect changing risks to health and assets). Given the scope of the adaptation challenge, many regions are employing hybrid strategies (For examples see the [Rebuild by Design Program](#)).

**Tools to assess coastal landscape response to sea-level rise for the Northeastern United States:** Recently researchers at USGS and Columbia University developed a new method to help support coastal adaptation to the threats of sea level rise and flooding (Lentz et al. 2015). This method distinguishes coastal areas along the Atlantic coast, from approximately Virginia to Maine that will predominantly experience inundation, from those that have the capacity to respond dynamically, for example through habitat shifts (e.g., inland). The probabilistic model goes beyond the traditional “bathtub” models by combining sea level rise projections, coastal elevation, vertical land movement, and coastal land cover as inputs (**Figure 9**). Model outputs include land cover-specific forecasts of the probability of inundation or dynamic coastal change. The model also produces an adjusted land elevation with respect to forecast sea levels.



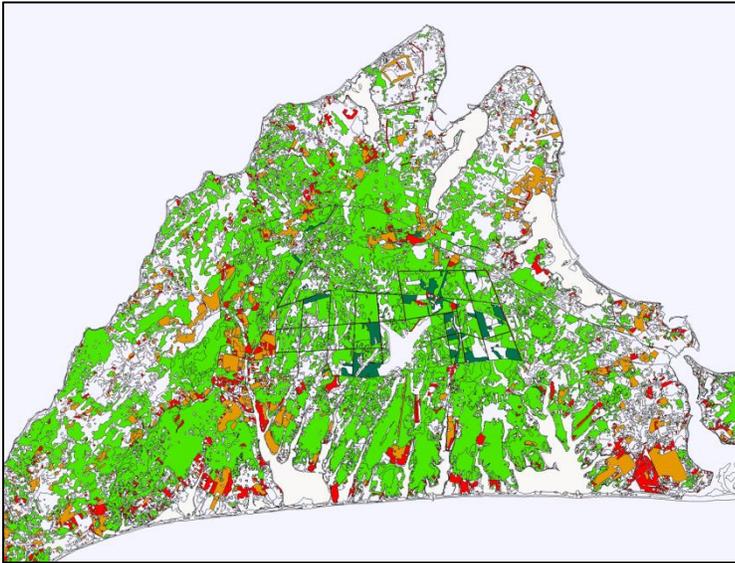
**Figure 9:** Diagram of the primary inputs used to predict future land elevations and coastal responses to sea level rise and storm surge. Modified from Lentz et al. 2015.

The interactive [project website](#) currently makes available for download, data layers on predicted land elevation ranges, likelihoods of observing the predicted elevation changes, and probabilities of static or dynamic change (Lentz et al. 2015). The website also anticipates providing decision support tools that allow users to explore and identify which areas may be best suited to meet their land adaptation or management requirements for a variety of planning horizons.

**Coastal sandplain grassland habitats:** Coastal sandplain grassland habitats are regional hotspots for biodiversity in the Northeast. These native-species rich and disturbance-influenced habitats are particularly important for regionally declining grassland birds and for habitat-restricted Lepidoptera that depend on food plants that reach their greatest abundance in these areas. Most of the highest quality grasslands occur on sandy, drought-prone glacial outwash soils that reach their greatest extent near the current coastline where they are highly

vulnerable to pressures from housing development, woody regrowth caused by fire suppression, and shoreline erosion caused by sea level rise and storm surge.

One approach to sustaining these habitats in coastal landscapes is to "create" these habitats in places where proper conditions exist but that do not support these habitats today.



**Figure 10:** Restoration ahead of climate change on Martha's Vineyard Island, Massachusetts. Light green is oak woodland, red is sandplain grassland, and orange is agricultural grassland. Data from Huber 2000 and Huber & Polzen 2003.

The available lands on which to do this fall in to two general categories: (1) areas that are currently woodland, and (2) areas that are currently grassland, but dominated by non-native species that are not a high conservation priority. But creating native species-rich grassland habitats requires a different land management toolkit and

presents a different set of barriers to implementation in the two categories outlined above. Use of forested areas requires forest clearing that can be

controversial with the public because it brings a large structural change. It also can require collection and distribution of seeds and follow-up suppression of regrowth. Use of already-cleared non-native agricultural land requires less structural change but could generate opposition because it would remove land from active local agriculture. It may also require active management of soil properties that encourage native species growth. Developing the toolkit for successful adaptation requires experimentation to guide actions in each of these cases.

The Marine Biological Laboratory and The Nature Conservancy conducted two large management experiments to address these cases. In the first, oak woodland habitat was surveyed for habitat characteristics and plant species composition, and then cleared and seeded with locally-collected sandplain grassland seeds (**Figure 10**). The recruitment of sandplain-associated plants was tracked for seven years in large (3+ hectare) management units

in the cleared area and in uncleared control units. The experiment created increased total cover of sandplain-associated plants and increased total plant species diversity from 27 to 89 species and almost exclusively native species (Lezberg et al. 2007). However, this management approach also required mechanical clearing of regrowing trees that added significant effort and cost.

In a second experiment, an agricultural grassland was subjected to large number of manipulations to test methods of removing existing non-native species, manipulating soils (e.g., reducing pH) to benefit native species, and establishing desired sandplain grassland species. An establishment technique that combined multiple tillings in one growing season with seed addition led to the greatest increases in native species cover and richness (Wheeler et al. 2015). Lowering soil pH also increased cover of native sandplain species (Neill et al. 2015). These new native-species rich grasslands can be relatively easily maintained by mowing or burning.

At the landscape scale, there are opportunities for both of these adaptation strategies. Currently, sandplain grasslands on Martha's Vineyard, MA, cover a small total area and occur in vulnerable areas near the coast. Agricultural grasslands cover a similar area on Martha's Vineyard, and can be converted to sandplain grassland using adaptation experiments as a prescription for action. Conversely, oak woodlands cover a wider area, and present opportunities to create new sandplain grasslands.

#### *v. Tribes and tribal lands*

##### **Tribal engagement and climate adaptation stories in the Northeast CSC Region**

The [2014-2018 Northeast Climate Science Center Strategic Agenda](#) included a set of recommendations to identify impacts and help develop culturally appropriate resources to assist Northeast and Midwest Tribes with adaptation planning. This was in response to [Secretarial Order 3289](#), which set this as a priority within the Department of the Interior. The College of Menominee Nation's (CMN) Sustainable Development Institute has been working to address these recommendations through several related initiatives. In the fall of 2014, the CMN hosted the [Shifting Seasons: Building Tribal Capacity for Climate Change Adaptation Summit](#), which brought Tribes together with federal, state, academic and non-profit groups to facilitate

a better understanding of regional climate change and adaptation needs and initiatives, and support the development of a best management practices approach for tribal engagement. Part of the Summit focused on giving examples of existing climate adaptation efforts within the Northeast, including the St. Regis Mohawk Tribe and the Grand Portage Band of Lake Superior Chippewa.

The people of Akwesasne (St. Regis Mohawk Tribe) located in upstate New York created a climate change adaptation plan framed by Tribal teachings, blended with terminology and concepts specific to climate science. Through this framework, the plan identifies culturally relevant species and habitats (i.e. Mother Earth, Fish, Three Sisters, Birds, Four Winds ) to provide context for the introduction of climate science information, existing or proposed adaptation strategies, and existing or proposed collaboration with federal and state agencies (St. Regis Mohawk Tribe 2013). Another important component is the education of its membership on climate change within this cultural context. The resulting plan is an adaptive effort that begins the specific work of climate change adaptation based on culturally appropriate understandings.

The Grand Portage Band of Lake Superior Chippewa in Minnesota is currently participating in a multi-agency research project ([Grand Portage Indian Reservation Project](#)) related to moose and moose habitat in Minnesota. For the Tribe, interest in this project is based on the importance moose play in cultural subsistence and how climate change may impact this way of life (Grand Portage Band of Lake Superior Chippewa 2012). This example of Tribal adaptation differs from the previous example because it focuses on a specific species and its habitat. It also differs because at this point, research is focused on the development of climate mitigation strategies with specific trigger points for management of the target species (moose).<sup>1</sup>

Another ongoing initiative led by the College of Menominee Nation has involved relationship-building site visits to several Tribes within the Northeast and Midwest and giving presentations to inter-tribal organizations such as the Native American Fish and Wildlife, and the [United Southern and Eastern Tribes](#) (USET). These efforts are aimed at building culturally

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<sup>1</sup> Dr. Seth Moore, ""Shifting Seasons Summit. October 2014. Keshena WI

appropriate relationships to better understand Tribal needs across the region, and to help Tribes communicate those needs to federal, state, academic partners working at the regional level. Results of these efforts are expected to identify climate change impacts unique to individual Tribes, and help guide solutions for adaptation and mitigation that are relevant for a number of locally-based climate scenarios targeting Tribes and Tribal lands. Anticipated products include a website providing guidelines for Tribal-Federal interactions and will be linked to the [NE CSC website](#).

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