U.S. Department of the Interior
U.S. Geological Survey

Northeast Climate Science Center
Strategic Science Agenda 2013-2018

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Introduction

The Department of the Interior (DOI) recognizes and embraces the unprecedented challenges of maintaining our Nation's rich natural and cultural resources in the 21st century. The magnitude of these challenges demands that the conservation community jointly develop integrated adaptation and mitigation strategies that address the impacts of climate change and other landscape-scale stressors. On September 14, 2009, DOI Secretary Ken Salazar signed Secretarial Order 3289 (amended February 22, 2010) entitled, "Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources." The Order establishes the foundation for two partner-based conservation science entities to address these unprecedented challenges: DOI Climate Science Centers (CSCs) and Landscape Conservation Cooperatives (LCCs). CSCs and LCCs are the Department-wide approach for developing and applying scientific tools to increase understanding of climate change and to coordinate an effective response to its impacts on tribes and the land, water, ocean, fish and wildlife, and cultural-heritage resources that DOI manages. Eight CSCs have been established and are managed through the National Climate Change and Wildlife Science Center (NCCWSC); each CSC works in close collaboration with its neighboring CSCs, as well as those across the Nation to ensure the best science is produced. This close collaboration ensures that the CSCs provide partners with the tools necessary to respond to climate change by sharing resources and information across boundaries.

In the January 2011 DOI draft guidance for both CSCs and LCCs the following excerpt outlines the relationship between CSCs and LCCs:

> *"Much of the information and tools provided by the CSCs, including physical and biological research, ecological forecasting, and multi-scale modeling, will be in response to the priority needs identified by the LCCs. Working closely with the LCCs, the CSCs will help develop statistically sound sampling programs and processes to monitor climate change effects and help develop adaptive management approaches. The CSCs will be partnership-based regional entities functioning with LCCs, as well as, the regional management community, scientific entities, and other stakeholders."*

The Northeast Climate Science Center (NE CSC or the Center) was established in 2012 to address the regional challenges presented by climate change and variability in the Northeast and Midwest United States (US). As such, the Center's focus is on science needs that apply across the entirety of the NE CSC region. The Center will provide regional-scale science products that can inform the local needs of the LCCs and other partners. The NE CSC is supported by a consortium of partners that include the University of Massachusetts Amherst (lead/host), College of Menominee Nation, Columbia University, Marine Biological Laboratory, University of Minnesota, University of Missouri Columbia, and University of Wisconsin (Figure 1A). This consortium combines the expertise of federal and university scientists, as well as Federally recognized American Indian tribes to address the priority needs of federal, state, non-governmental, and tribal resource managers relative to the challenges associated with climate change. The purpose of the NE CSC is to provide scientific information, tools, and techniques that managers and other parties interested in land, water, wildlife, and cultural resources can use to anticipate, monitor, and adapt to climate change. The Center will actively engage LCCs and other partners to identify science that best informs management needs in a changing climate, and will help translate science results into management decisions, and adaptation strategies. Coordination across CSC regions will ensure that issues are addressed on an ecological basis, and are not limited by regional or administrative boundaries; thus each CSC can shift its geographic domain as the science dictates. The ultimate goal is a seamless science network across the CSCs, LCCs, and the Nation (Figure 1B).

This document is the first Strategic Science Agenda (2013-2018) for the NE CSC. Using the DOI guidance as a model, it describes the role and interactions of the NE CSC among its partners and stakeholders, clarifies the responsibilities of the Center to its partners, defines a context for climate impacts in the NE CSC region, and establishes the science priorities that the Center will address through research. The Science Agenda is intended to be reevaluated and progressively refined as the science and policy landscape evolves, research tools and products are developed, management actions are taken or decisions

made, and partner needs change. The recommendations outlined in this document provide a framework to guide the science activities conducted and funded by the NE CSC over the next 5 years. The NE CSC may not accomplish all of these goals, but will strive to address as many as possible through stakeholder-driven research, consortium activities, and leveraging opportunities.

Background

The NE CSC Region, as defined by the U.S. Geological Survey (USGS) for its DOI Regional Climate Science Center, is an area of enormous diversity in geography, climate, biological diversity, land-cover, and human land-use. The NE CSC region covers 22 states encompassing all or part of the northeastern and midwestern United States. It includes multiple ecoregions, some portion of six of the 22 regions established for the LCC Program, and a human population of 131,000,000 (41% of the US population) (Table 1, Figure 1). Land ownership in the the NE CSC region is largely dominated by private land holders; this poses challenges different than for other areas of the Nation such as the western United States, which contains a greater proportion of Federal and public lands. Stakeholders and partners in the Northeast region are remarkably numerous (Appendix A); thus, the need for cooperative climate science is critically important to inform agile and effective management decisions. Indeed, the public demand for understanding climate change effects and possible responses is becoming increasingly more urgent as environmental conditions continue to change in this highly populated area.

Climate Change Impacts

Climate change is already affecting the physical and biological environments of the Northeast US Region, and is expected to intensify in coming decades. Temperatures have risen by approximately 0.7°C over the last century and are projected to increase by another 3-5°C under forecasted greenhouse gas emission scenarios (Hayhoe et al., 2007; Karl et al., 2009). Largely as a consequence of human activities, sea level is projected to rise by approximately 1 meter in the 21st century, with even greater coastal impacts from storm surges, especially in areas that have seen major population increases (Parris et al., 2012). In the Great Lakes, increases in surface water temperatures and significant decreases in ice cover will bring changes in water levels and circulation patterns with many models projecting lake level fluctuations that could disrupt natural and human communities (Horton et al., 2012).

The Northeast region has recorded higher amounts of precipitation over the last 50 years, with a greater frequency of extreme events. Many climate model simulations for the future suggest wetter winters and springs, but drier summers and falls. These changes will increase overall runoff but shift the timing of peak flows of rivers to earlier in the spring, with longer periods of low flows in the summer months (Groisman et al., 2004; Karl et al., 2009). Warmer springs with increased precipitation and runoff are also expected to produce and mobilize more contaminants into aquatic ecosystems across the upper Midwest and eastern United States (Bradley et al., 2011; Brigham et al., 2009; Evers et al., 2011).

All of these changes will have profound effects on terrestrial, aquatic, and coastal ecosystems across the region, changing habitat types and affecting community structure and function. Multiple climate drivers (e.g., temperature, precipitation, and soil moisture) have also affected latitudinal, altitudinal, and other geographic range shifts in biota throughout the region and the nation (Staudinger et al., 2012). Many species are responding to climate change through shifts in phenology; for example, numerous taxonomic groups including migratory birds, amphibians, and insects are shifting the seasonal timing of life events such as migrations to breeding sites (Parmesan and Yohe, 2003; Parmesan 2006; Bellard et al., 2012). As the velocity of climate change continues to increase, shifts in species' range and phenology are becoming more widespread and occurring at faster rates, leading to novel species interactions and ecological communities (Loarie et al., 2009; Mahlstein et al., 2013). Altered patterns of species dominance and community composition have the potential to affect ecosystem services, or the benefits that humans derive from natural resources, through changes in the production of food and forest resources, regulation of clean water, coastal protection, pest and disease control, as well as the enjoyment and enrichment that cultural and recreational experiences bring to society (Mace et al., 2012).

Understanding how climate change affects habitats and other conditions for fish and wildlife populations will be essential to inform decision makers challenged with balancing multiple land-uses and objectives, including agriculture, forestry, conservation of trust species, maintenance of migratory pathways, recreational use of natural and cultural resources, water allocations, energy production, and transportation. Obtaining the best regional estimates for a range of probable climate change scenarios is a critical task to aid natural resource managers and other stakeholders.

The NE CSC region poses many unique challenges for understanding, adapting to and mitigating the combined effects of climate change and landscape-scale stressors, including:

- Significant warming, especially during the winter and spring seasons, has increased the number of frost-free days and decreased snow pack and ice coverage. Combined with increased precipitation, extreme events, and rising sea level along the Atlantic coast, this warming is projected to continue and will have wide-ranging impacts on the natural and cultural resources of the NE CSC region (Kunkel et al., 2013). Uncertainty stemming from the range of future projections of the amount and frequency of seasonal precipitation and extreme events poses challenges to management and planning in the region.

- The large geographic size, extent of urbanization and development, and diversity of ecosystems in the NE CSC region create extreme gradients in environments and threats manifested over relatively small spatial scales. From rapidly expanding and developing coastal regions and urban areas to depopulating rural communities, the common thread is that the natural resources of the region are inextricably intertwined with human use and human infrastructure – both past and present.

- A pattern of land ownership and administration in most of the region that is dominated by relatively small, privately owned parcels, and limited federal or other public lands. Consequently, the interactions between land-use and climate change adaptation and mitigation will be complex and largely depend on the participation, cooperation, and successful coordination of a wide array of stakeholders and decision makers with different cultural values, priorities, responsibilities and needs. Because many critical ecological processes inherent to the Northeast region operate across jurisdictions and landscapes, local decisions will also need to be balanced with the needs and decisions made in neighboring CSC regions and Canada.

- A long ethno-ecological history, intensive land-use practices, and urban development that have led to species extirpations, invasions, range extensions, and restorations. Regional climate changes and the associated responses of species and ecological communities will be complicated by multiple stressors, including a range of historical anthropogenic influences that are difficult to predict. In many cases, patterns and composition of species and habitats will change due to immigration, emigration, and local extinctions of native and invasive species, potentially altering ecosystem services within the region

Consideration and analysis of the factors listed above, as well as the complex risks and uncertainties that climate change and human actions will continue to have in the region, require interdisciplinary and structured approaches that weigh alternative scenarios and outcomes for decision making and planning (e.g., Brown et al., 2011; Brown and Wilby, 2012; Rowland et al., In press). Formal methods for prioritizing information and informing actions (Decision analysis approaches) in the face of global change will be a running theme throughout this document. Helping stakeholders in the region balance the costs and benefits of different types of information and translating those data into actions is a key mission of the NE CSC. An expanded discussion of the NE CSC's strategy for using decision frameworks is presented in Theme 7.

Northeast Climate Science Center Operational and Strategic Planning

The NE CSC receives funding and oversight from NCCWSC, located at the USGS National Center in Reston, Virginia. NCCWSC provides guidance for national science priorities as part of the USGS Climate and Land-Use Change Mission Area. The NE CSC Director also reports to NCCWSC. Although NCCWSC manages CSC general operations, the NE CSC Director receives guidance on *regional* science priorities from a "Stakeholder Advisory Committee (SAC)" that is composed of federal, state, and tribal senior-level executives, natural/cultural resource managers and coordinators throughout the region. The SAC is chaired by USGS Regional Director for the Northeast/Midwest, and current membership is listed in Appendix B.

The roles and responsibilities of the SAC include 1) providing counsel for the development and periodic updating of the regional science agenda (5 year) for the CSC; 2) providing counsel on the development of CSC planning and implementation documents, including periodic short-term science plans and strategic solicitation documents for periodic funding opportunities; and 3) providing and facilitating feedback concerning how effectively CSC products meet the needs of stakeholders.

While SAC input is extremely important, final authority for program direction and project selection, funding and portfolio management rest with the USGS CSC Director, and will be shaped by multiple factors, including SAC-identified priorities, the creation of a balanced scientific portfolio, the needs of ongoing scientific activities, and funding constraints. Revised guidance for SAC Charters (specific roles and responsibilities, guidance on membership, tenure, governance and terms of reference) are under development by NCCWSC in concert with USGS leadership, to be applied across all CSCs.

The NE CSC Director serves as Chair and will also convene a Science Implementation Panel (SIP) annually, which will be responsible for peer and technical review of all proposed projects, and will recommend how to utilize available scientific assets of the CSCs and LCCs to address regional science priorities. Key staff from LCCs and other partners (for example, LCC Science Coordinators or other appropriate staff) associated with the NE CSC will serve on the SIP. The NE CSC Director may chose a variety of means to engage the SIP, including on-line proposal review programs developed by NCCWSC and virtual meeting activities such as webinars. Close collaboration between the NE CSC and the six associated LCCs enhances the functional capacities of both groups to develop meaningful and effective conservation adaptation strategies for the NE CSC regional landscape. The following LCCs have part or all of their geography within the boundaries of the NE CSC: Appalachian LCC, Eastern Tallgrass Prairie and Big Rivers LCC, Gulf Coastal Plains and Ozarks LCC, North Atlantic LCC, Plains and Prairie Potholes LCC, and Upper Midwest and Great Lakes LCC (Table 1; Figure 1B).

The NE CSC Director provides leadership and oversight of the Center's operations, including the structured processes used to develop the annual workplan and the administration of the CSCs financial resources. The NE CSC Director works closely with the University/Academic Director of the NE CSC, based at the host institution, University of Massachusetts Amherst. The NE CSC employs a Program Manager, Science Coordinator, and Communication and Outreach Manager; these additional NE CSC staff work closely with the NE CSC Directors, Consortium, and partners to coordinate university consortium research and outreach activities, and ensure the CSC is providing the best available science to stakeholders responding to climate change impacts throughout the region. In addition, the Consortium includes a number of talented scientists and leaders in the climate science community, under the leadership of the University Director of the NE CSC.

The NE CSC will leverage these resources and science capacity with partners in both the research and resource management communities within and across CSC boundaries, including through hiring permanent scientists and postdoctoral fellows (as funding allows) in compatible areas to build and leverage the collective science capacity of the NE CSC. Consortium members (primarily the host institution) and NCCWSC will share administrative support responsibilities for the NE CSC. The NE CSC Director will also be responsible for ensuring timely release of scientific information that is both accessible and functional for use by resource managers across the region.

Science Capacity of the Northeast Climate Science Center Consortium

The NE CSC, in cooperation with its seven academic partners, will collaborate with stakeholders and partners across the NE CSC region to provide climate science and global change research that assists resource managers in developing management and adaptation plans that address current and predicted changes at both regional and local scales. The NE CSC is hosted by the University of Massachusetts Amherst and is supported by a consortium that includes the College of Menominee Nation, Columbia University, Marine Biological Laboratory, University of Missouri Columbia, University of Minnesota, and University of Wisconsin (Figure 1A). The NE CSC Consortium has expertise in a wide variety of research topics that will help meet the regional needs of stakeholders and partners throughout the Northeast region. Researchers with the NE CSC Consortium are recognized locally, nationally, and internationally as experts in fields that include but are not limited to:

- *aquatic ecosystems*
- *Big River ecosystems*
- *boreal and temperate forest ecosystems*
- *citizen science outreach*
- *climate adaptation science*
- *climate dynamics*
- *climate modeling & scaling*
- *coastal ecosystems & processes*
- *conflict resolution*
- *cultural resources*
- *decision analysis*
- *ecosystem modeling*
- *fisheries management*
- *Great Lakes ecosystems*
- *groundwater hydrology*
- *human dimensions*
- *invasive species ecology & management*
- *landscape ecology*
- *migratory fishes*
- *Native Nations & the environment*
- *paleoclimate analyses*
- *renewable energy*
- *ecosystem management & restoration*
- *resource policy & economics*
- *riverine ecology*
- *sea level change*
- *spatial analysis & remote sensing*
- *surface water hydrology*
- *sustainable forestry*
- *terrestrial ecosystems*
- *traditional ecological knowledge*
- *wetlands ecology & mapping*
- *wildlife management*

NE CSC Consortium members lead major stakeholder-driven research initiatives and data centers at regional, national, and international levels, including agreements and projects currently supported by federal programs such as Department of Energy (DOE), National Oceanic and Atmospheric Administration (NOAA), National Park Service (NPS), National Science Foundation (NSF), National Aeronautics and Space Administration (NASA), U.S. Department of Agriculture (USDA), U.S. Geological Survey (USGS), and U.S. Fish & Wildlife Service (USFWS). This collective knowledge and experience of the diverse ecological communities and fish and wildlife resources throughout the Northeast extends from the Atlantic Coast to the Appalachians, west to the Ozarks, and north to the Great Lakes. The Consortium offers extensive research, education and outreach relationships with communities, state and federal resource management agencies, nongovernmental organizations (NGOs), and tribal nations both on- and off- its campuses. These extensive collaborations, including with the U.S. Forest Service (USFS), The Nature Conservancy (TNC), USFWS, the U.S. Army Corps of Engineers, NOAA, and the DOE are grounded in the diversity of DOI-resource management issues throughout the Northeast and Midwest. Consortium institutions are pioneering new analytical, science support and decision analysis tools for landscape-scale analyses of climate change effects. They are engaging with regional conservation networks for developing climate adaptation and mitigation strategies by diverse stakeholders. Facilities and computing infrastructure exist at Consortium institutions, as well as the extensive resources and experiences necessary to train climate science professionals and to meet the continuing education/training needs of resource managers and the public.

Education and Training

An important element of the NE CSC, and a focus at all Consortium institutions, is the education and training of graduate students and postdoctoral associates in the science of climate and global change, as well as public outreach and education associated with climate change. NE CSC partners recognize the importance of increased awareness and climate literacy throughout society, as well as the growing need to incorporate climate science into everyday decisions by natural resource managers, conservation practitioners, and policy makers. The NE CSC will provide research opportunities for early career scientists including graduate students and postdoctoral fellows (called "NE CSC Fellows") to learn and contribute to the science of climate and global change, engage with stakeholders, and develop communication skills necessary to foster public dialogue and education. Publically-accessible webinars and community engagement opportunities will strengthen interactions within the NE CSC research community as well as continue to expand it. NE CSC staff will participate in the training of graduate students and post-doctoral researchers through mentoring and research opportunities that will span the CSC network. As part of an Education and Training program, the NE CSC will:

- Maintain an intellectually active culture for its undergraduate and graduate student and postdoctoral "NE CSC Fellows", including discussion and research-sharing using regular meetings, retreats, webinar technologies, and focused workshops to promote regular NE CSC as well as cross-CSC interactions;

- Support new NE CSC researchers in gaining a wide variety of skills in preparation for interdisciplinary careers in climate science and assist in circulating career opportunities;

- Offer a regular, publically-accessible webinar series that presents NE CSC research and related topics appropriate for a wide audience;

- Develop NE CSC products and tools such as web-resources, fact sheets, periodic newsletters, and an annual report that will increase awareness of climate impacts and be accessible to the public.

Information Management and Data Sharing

The NE CSC will generate, integrate, and disseminate data that helps resource managers develop adaptation and mitigation strategies in response to climate change. The NE CSC's science program will be of the highest quality, with results viewed as unbiased, based on sound science, and useful to resource managers. To maintain high-quality research, the NE CSC will implement strict procedures for reviewing proposals, avoiding conflicts of interest, and protecting confidential and timely information. The NE CSC data-management activities will comply with the guidance, policies, and standards identified in the national NCCWSC/CSC Data Management Policy and the NCCWSC/CSC Data-Sharing Policy, both of which build on DOI and other government-wide policies (*https://nccwsc.usgs.gov/content/data-policies-and-guidance*). To this end, the NE CSC will:

- Adopt national web-based data management systems such as Sciencebase to serve and archive data, provide open access to products, and to ensure data protection and distribution;

- Support interdisciplinary data management, sharing, and training;

- Ensure timely data progress, release schedules, and transition of data to the final repository; and

- Host web-based seminars to facilitate interactions between consortium member institutions, and provide outreach opportunities to the greater NE CSC region including the public.

Monitoring and Observation

Data from monitoring networks are a critical resource for the NE CSC and LCC partners; scientific research, management decisions, and the evaluation of management outcomes all depend on data collected at the appropriate scale and frequency. Historical and contemporary observations of climatic and biophysical factors, ecosystem conditions, and species distributions and diversity across the range of terrestrial and aquatic ecosystems of the NE CSC are critical for evaluating and refining models; detecting changes in physical conditions, assessing the vulnerability of ecosystems and populations; and monitoring the outcomes of management, adaptation, and restoration activities. Although the CSCs are not tasked with maintaining monitoring programs, they will assist and collaborate with LCCs and other partners by identifying monitoring priorities and strategies for the regions that build upon the current monitoring and assessment activities, and promote an awareness of current and future information needs associated with science, management decisions, and evaluation needs. The NE CSC will:

- Work with partners to inventory existing monitoring network activities and protocols; use decision frameworks to develop standardized monitoring protocols and identify monitoring gaps to improve data integration and sharing across the region;
- Work with partners to evaluate the effectiveness of existing monitoring networks to track ecological and environmental variables across varying temporal and spatial scales, and answer novel questions brought about by climate change as well as interactions with other landscape-scale and anthropogenic stressors (e.g., land-use change, pollution, exploitation);
- Identify key environmental drivers and ecological response variables necessary to build and improve predictive models that forecast the effects of climate change, and assess the outcomes of adaptive management, conservation, and policy in the region; and,
- Develop robust decision frameworks for building monitoring networks and models.

Northeast Climate Science Center Science Agenda

The development of this Strategic Science Agenda involved as many groups as practical in both its formulation and review. Continued involvement from partners in the science agenda process will ensure that this document and its science priorities are consistently responsive and relevant to the needs of the conservation community into the future, and build on existing efforts including those of the State Wildlife Action Plan (SWAPS), the Association of Fish and Wildlife Agencies, the National Fish, Wildlife and Plants Climate Adaptation Strategy, and the US Global Change Research Program.

Seven Science Themes (Figure 2) were developed through review of existing NE CSC stakeholder and partner publications (Appendix C), including LCC operational plans and annual reports, telephone interviews with LCC coordinators and other stakeholders, and a meeting of the NE CSC Consortium in June 2012. Additionally, other partner resources and publications were evaluated including those from NPS, USFS, USFWS, NOAA, Environmental Protection Agency (EPA), US Army Corps of Engineers (USACE); regional partnerships such as Atlantic Coastal Fish Habitat Partnership and Association of Fish and Wildlife Agencies; and conservation organizations such as American Rivers, Northeast/Midwest Foundation, Conservation Wilderness, TNC, and The Field Museum. Priority science needs were drawn from these and other resources and organized within seven overarching themes as a first draft of the NE CSC Strategic Science Agenda. The SAC (Appendix B) is helping define and validate stakeholder-identified science needs for the five-year planning cycle, with annual priorities and project selection determined by the NE CSC Director with input from technical reviewers (SIP and others) and in coordination with NCCWSC to identify complementary opportunities across the CSC network.

Early drafts (Draft 0: Nov 2012; and Draft 1: Oct 2013) of the NE CSC Strategic Science Agenda were modified to reflect NCCWSC review, partner input and evolving directions in response to research developed as part of the NE CSC annual science plan process. The NE CSC will produce an Annual

Science Plan that outlines the process and development of research goals for each fiscal year, which will be cooperatively developed with stakeholders (e.g., the SIP) and rely on partner input in the solicitation of research proposals and development of directed research projects. The Annual Science Plan process will typically address priority issues identified in the five-year Strategic Science Agenda. There may be instances where a new issue or need evolves prior to the five-year Agenda update and these instances will be accounted for in the annual planning process.

The seven Science Themes (Figure 2) focus on climate change issues that NE CSC partners have previously defined. Appendix C illustrates how these priority issues were emphasized by the partners throughout the NE CSC region in relation to climate change. This partner input was critical to the development of the Science Agenda described below. The NE CSC will work closely with partners, and use decision analysis tools (Theme 7) to address the regional impacts of climate change on natural and cultural resources outlined in Themes 2-6.

Science Themes

Science Theme 1: Climate projections and assessments

Science Theme 2: Climate impacts on land-use and land-cover

Science Theme 3: Climate impacts on freshwater resources and ecosystems

Science Theme 4: Climate impacts on Atlantic and Great Lakes coastal and nearshore environments

Science Theme 5: Ecological vulnerability and species response to climate variability and change

Science Theme 6: Impacts of climate variability and change on cultural resources

Science Theme 7: Decision frameworks for evaluating risk and managing natural resources under climate change

Science Theme 1: Climate change projections and assessments

Temperature, precipitation, and related observational records provide a century or more of data on climate variability and change in the Northeastern and Midwestern United States. Paleoclimate data (tree rings, sediments record, and other sources) offer an even longer perspective that can be used to evaluate modern climate shifts as well as characterize past baselines of earth-system behavior in the region. The combination of different temporal data (decadal to million year scales) types reveals the strong role of natural variability in the region, and the fact that human activities are shifting climate statistics. For example, extreme events such as heat waves are often associated with natural circulation pattern anomalies (such as El Niños or the North Atlantic Oscillation) and an understanding of how the region is affected by such patterns is useful information for resource managers. Superimposed on these complex patterns of variability, climate change is leading to more frequent extreme heat events, an increasing number of frost-free days, and more frequent intense storm and precipitation events. Since future climate may have few analogs in the past, reliable projections should combine instrumental and paleoclimate data analysis with climate model simulations, the basic tools used to assess how climate may change under different scenarios of anthropogenic forcing.

General circulation models (GCMs) are used to forecast the impact of current and future greenhouse gas emissions on the climate across the globe (IPCC, 2007). In addition, regional climate

models (RCMs), with substantially increased spatial resolution (grid spacing of 25-50 kilometers) are becoming available. These are embedded or nested within GCMs and can provide a more highly resolved picture of how climates vary at local and regional levels. However, both GCMs and RCMs are far from perfect, even in simulating current climate conditions. A first step is therefore to assess the biases in these models with respect to the climate of the northeast region and identify regional variations in climate across the domain of the NE CSC.

Another approach to obtain highly resolved spatial data from GCMs is to use statistical methods to establish the existing relationships between the large-scale atmospheric circulation features (which global climate models are able to reproduce) and climate at a particular location (which is beyond the spatial scale of GCMs) based on historical relationships. This approach, typically denoted as statistical downscaling, uses GCMs to forecast general trends and past spatial correlations and to apply these to fine scale locations. Both statistical downscaling and the application of RCMs (i.e., dynamical downscaling) are widely used in climate studies that have resource management implications. Evaluations need to be conducted to determine which of these approaches offers the most promise to natural resource managers in both the near and long-term. Decision-making and adaptation relies on the best available information, yet it is crucial that stakeholders also understand the limitations and uncertainties associated with these data. The possibility of climate changes that fall outside the range suggested by climate models and standard anthropogenic forcing scenarios should be assessed as well. The NE CSC will seek guidance from stakeholders on the information generated by climate models (e.g., specific variables and spatial and temporal resolution) that is of most value to their communities.

The Center will build on existing climate models that are specifically tailored to the geographical domain of stakeholders in the NE CSC region. Generation of climate scenarios is an objective that interacts with all subsequent themes and science needs. Areas of climate data generation that are particularly important to resource managers include 1) projections of climate extremes, primarily temperature and rainfall extremes; 2) spatial distribution of climate data at various scales, ranging from local to national scales; 3) information on how hydrological systems will change as temperature, precipitation, and extreme events change, and 4) projections of sea level rise and changes in the frequency and intensity of coastal flooding.

The NE CSC recognizes that conducting regional downscaling requires significant resources and support. Therefore the NE CSC will rely on the leadership and guidance of the NCCWSC on how best to approach this area of research and deliver products to our stakeholders. In addition, the NE CSC will work strategically with partners to address the climate change projections and assessments needs of the region by conducting the following activities:

Recommendations

- Provide a critical assessment of available climate projections (e.g., GCMs, RCMs, and statistical downscaling models) including a) their resolution, extent, time horizon, climate endpoints, b) information on limitations, strengths, confidence, and uncertainties, and c) the possibility of climate changes outside the ranges projected by GCMs and emission scenarios (e.g., Representative Concentration Pathways) (Moss et al. 2010).

- Assess major needs for climate projections in terms of impacts on ecosystems and human communities, including seasonal conditions, extreme events, and the degree to which available products (e.g., data and models) meet these needs.

- As gaps in regional data and modeling efforts are identified, work with partners to develop complementary tools and activities, and determine what information is needed to conduct future evaluations, best inform decision making and conduct the activities in NE CSC Science Themes 2-7.

- Work with regional partners (e.g., NOAA, Northeast Regional Climate Center (NRCC)) to better understand how climate variability responds to different modes of circulation and patterns of

natural climate variability (e.g., the Arctic Oscillation, the El Nino Southern Oscillation, and the Atlantic Multidecadal Oscillation).

- Provide improved modeling of seasonal conditions, precipitation, hydrological regimes, and extreme events that can be used to identify where the greatest probability of impacts and change will occur, and that can be used to inform partner/stakeholder planning processes (e.g., State Wildlife Action Plan (SWAPS; Association of Fish and Wildlife Agencies; LCC strategic plans for ecologically sustainable landscapes; the National Fish, Wildlife and Plants Climate Adaptation Strategy)) and adaptation strategies in the region.

- Develop and support partner decision support tools, guides, and directories of experts that translate information on the uncertainties and confidence in available approaches (e.g., modeling historical and future changes) and applicability across various scales to non-climate experts and the public.

Science Theme 2: Climate impacts on land-use and land-cover

Understanding the interactive and cumulative effects of climate and land-use changes are a priority for the NE CSC as it will affect the distribution, composition, condition and vulnerability of regional biomes including forests, grasslands, shrublands, prairies, alpine tundra, and human managed systems (e.g. agricultural lands and forestry) (Grimm et al., 2013). Impacts from agriculture, urbanization, energy and infrastructure development have already and will continue to directly modify land-cover through habitat loss, degradation, and fragmentation (Sala et al., 2000; Staud et al., 2013) with additional indirect impacts that radiate to freshwater systems (Theme 3), and ultimately, coastal and nearshore environments (Theme 4). To date, human activities have been the primary source of land-use and land-cover changes; however, climate change is expected to exacerbate and accelerate impacts on terrestrial, hydrological and climatic regimes, as well as increase the vulnerability of species (Theme 5) and cultural (Theme 6) resources (Staudinger et al., 2012; Staud et al., 2013). Adaptation and mitigation strategies that account for climate change interactions with multiple anthropogenic stressors will be critical to minimize further loss of terrestrial habitats that support important ecosystem services such as primary production, nitrogen and carbon cycling (Nelson et al., 2013a).

Predicted increases in precipitation and temperature extremes will exacerbate the impacts of many landscape-scale stressors on natural and cultural resources. For example, increasingly warmer and shorter winters due to climate change in the Northeast are conducive to the proliferation of biological disturbances. Invasive species, diseases, and insects such as recent outbreaks of hemlock woolly adelgid, Asian longhorn beetle, and emerald ash borer have already caused widespread damage and loss of forests throughout the region (Paradis et al., 2008). Such large-scale disturbances across the forest-rich landscapes of the NE CSC region can have important negative feedbacks on the carbon and mitigation benefits currently provided by this region (cf. Kurz et al. 2008). In addition, systems that are already stressed from biological disturbances, exploitation, or pollution are likely to be more sensitive to the impacts of climate change, potentially amplifying the effects of these multiple stressors (Staud et al., 2013).

Management agencies in the NE CSC region have prioritized the development of robust land-use change projections and models to design landscapes that are sustainable in the face of climate and landscape changes. This is in part due to shifts in temporal and spatial land-uses driven by urbanization and human development as well as natural and human responses to climate change (e.g., shifts in seasonal and latitudinal planting zones). Areas that are relatively vulnerable to climate change or have high ecological value have also been identified as being particularly important research targets. Heterogeneous land-cover caused by development and agriculture, numerous privately owned parcels of private land, patchwork jurisdictions, and relatively limited federal and public lands in this region make these issues even more

complicated and require participation, cooperation, and successful coordination of diverse stakeholders.

Simple models based on the climate associated with current species distributions (e.g., climate envelope models) have been helpful in giving initial or first-order estimates of the effects of climate change. However, this coarse-filter approach can lead to either over or underestimates of the rate and extent of landscape change, particularly in strongly human-influenced landscapes or in those with a high degree of fine-scale variability in climate conditions (e.g., mountainous or near-coastal regions). A key element of this science theme is the development of models which incorporate the response of the vegetation communities that constitute diverse natural communities (e.g., forests, shrublands, grasslands), human responses (urban and residential development, agricultural, forestry, wildlife management practices, mining impacts, and bioenergy development), and changes in natural disturbance regimes (fire, wind, flood, drought, and insects and disease). Studies of historical impacts in the Northeast can help inform these models, but understanding the changes in land-use and land-cover over recent time and how they impacted other systems (such as sediment flux, nutrient transfer, wildlife distribution, etc.) are also very important to linking together landscape-scale impacts of climate and land-use.

Progress along these lines requires assessing a range of approaches including both habitat capability and ecological integrity models that are under development at several NE CSC partner institutions (UMO, UMass, UMN, UWI). The habitat capability models are focused on a suite of surrogate species that link fish and wildlife population dynamics (survival, reproduction, dispersal) with habitat changes. The ecological integrity models focus on a suite of ecological systems to be used as a coarse filter for evaluating landscape and climate change scenarios. Models with greater spatial resolution that address build-out or grow-out can be used to simulate changes, particularly in human-dominated landscapes, associated with regulatory practices and socio-economic drivers, such as human population growth or changes in agricultural or forestry practices. Acknowledging the uncertainty inherent in all of these modeling efforts, the goal of the NE CSC is to provide managers with a well-supported set of alternative scenarios largely through decision analysis frameworks (Brown et al., 2011; Rowland et al., In press).

Because urban areas are generally warmer than surrounding (less developed) lands, they may serve as models to examine and evaluate the potential impacts of climate change. In some cases, current within-city temperature differences can be as large as projected warming at multi-decadal to centennial scales (Horton et al., 2011). Consequently, microclimates within existing and expanding urban areas, created by a phenomenon known as the heat island effect (Oke, 1987), can improve our understanding of how, for example, urban forests respond to extreme temperatures. In addition, urban watersheds may be used to evaluate the combined impacts of human stressors, such as pollution, and extreme precipitation and flooding events. The responses of different types of lands within the urban areas of the Northeast CSC region will provide important comparisons of impacts on biodiversity and ecosystem functioning in surrounding rural areas (Imhoff et al., 2010).

The NE CSC will work closely with federal agencies and other partners in the region (e.g., Eastern Geology and Paleoclimate Science Center, USFS Northern Institute of Applied Climate Science, and the newly established USDA Regional Climate Hubs) to complete the following:

Recommendations

- Work with partners (e.g., USDA Climate Hubs) to characterize and model regional impacts of land management practices (i.e., agriculture, urban, and energy development) and climate changes on ecological integrity.

- Assess the current and future capacity of landscapes to support ecological functions and sustainable fish, wildlife, forestry and agricultural resources.

- Work with the USFS and other partners to improve the understanding of forest management practices and strategies that maximize resilience to changes in climate and natural disturbance regimes.

- Partner with existing efforts in the region (e.g., Northern Institute of Applied Climate Science) to develop decision support tools that assist Federal, State, Tribal, NGO, and private landowners design and manage sustainable landscapes for increased resilience, connectivity, and conservation under climate and landscape changes.

- Use decision analysis tools to identify climate and landscape-scale impacts, risks, and uncertainties and provide guidance on key decisions in the region.

Science Theme 3: Climate impacts on freshwater resources and ecosystems

The impacts of climate change on freshwater resources (both surface and groundwater) will be one of the most important and far reaching impacts felt by individuals, ecosystems, and institutions. As noted by the Intergovernmental Panel on Climate Change in their Fourth Assessment Report, "observed warming over several decades has been linked to changes in the large-scale hydrological cycle such as: increasing atmospheric water vapor content; changing precipitation patterns, intensity and extremes; reduced snow cover and widespread melting of ice; and changes in soil moisture and runoff." Recent extreme weather events (e.g., inland flooding, hurricanes, and droughts) in the US cannot be directly attributed to climate change; however, these events are consistent with events that climate change models suggest will be more frequent in the future.

There is a diversity of important freshwater resources in the Northeast CSC region. These include the Laurentian Great Lakes ecosystems, which contain myriad habitat types from open-lake, to coastal wetlands and tributaries (Dodge and Kavetsky, 1995), to other smaller freshwater lakes (e.g., Lake Champlain), ponds, and vernal pools. Also of high importance are wetlands and their intrinsic mosaic of hydric soils, as well as multifaceted stream and river systems. Together, these freshwater resources support numerous ecologically, economically, and culturally important species and ecosystem services, including clean drinking water, agriculture, fisheries, and recreational activities.

Changes in snowpack depth and extent, seasonal shifts in the timing and volume of runoff, transitions in the peak and base stream flows, and changes in stream and river temperatures are extremely important throughout watersheds and ecosystems. This is especially true in the Northeast where precipitation and extreme storm events are increasing flow extremes and impacting hydrologic networks. Timing and volume shifts will significantly impact species that rely on hydrologic regimes for important transitions in their life cycle. In addition, increasing stream, river, and lake temperatures will impact water quality, stream, river, and lake chemistry, as well as the composition and vulnerability (Theme 5) of aquatic species ranging from microorganisms to commercially important fishes and other associated riparian flora/fauna. The combined impacts of climate change and anthropogenic activities (e.g., agricultural practices and urban development) will bring about shifts in the hydrological cycle that effect the transfer of sediments and nutrients, production and transport of pollutants including pesticides and heavy metals (e.g., methyl-mercury), and influence salinity concentrations of lower watersheds and coastal habitats (Theme 4) (Groisman et al., 2004). These changes in hydrological and thermal regimes may increase the risk of disease outbreaks in aquatic systems, impact eutrophication, hypoxic and dead zones, as well as lead to community transitions that alter ecosystem structure and function. Recent and future climate changes are occurring on a backdrop of historical geologic influences such as glacial-related events and physiographic effects (such as slope and mass wasting). Consequently, paleoclimate studies may be useful in assessing long-term fluxes and responses of stream networks to modern changes in the environment.

The Great Lakes will be a particular focus for the NE CSC. Containing 84% of North America's surface freshwater, the Great Lakes region supports a variety of resources such as agricultural lands, coastal marshes, mineral deposits, forests, fens, wetlands, dunes, and other ecosystems unique to the region. Considering that the Great Lakes supply drinking water to more than 26 million people, and have billions

of dollars in economic impact, climate change impacts on the Great Lakes will reverberate throughout the region. Projected increases in temperature, changes in precipitation, fluctuating ice cover, and water levels possibly accompanied by increasing prevalence of drought, will lead to a variety of impacts. Concurrent and interrelated impacts from invasive species, eutrophication, and other environmental stressors, could directly affect the lakes, but also have indirect effects on streams, wetlands, forests, and agriculture as well as ecological and human communities across the region. Although there are issues unique to the Great Lakes system, research into issues that will affect coastal, limnological, and fisheries systems can help inform the impacts of climate change throughout the greater region. For example, the link between climate change, eutrophication, and harmful algal blooms (HABs) are important emerging issues in the Great Lakes as well as for regional inland lakes, and Atlantic and Gulf of Mexico coastal environments (Theme 4) (Nelson et al., 2013b).

Also of particular interest are the impacts of climate change on the headwaters of watersheds. Studies of headwaters in the NE CSC region are particularly effective in identifying the potential impacts of climate impacts on (inherent and downstream) vulnerable aquatic communities. As an area of maximum terrestrial/aquatic interaction, headwaters are an ideal location to assess how land management affects persistence of aquatic and riparian species under a changing climate. These habitats have already been noted as critical priorities by several of the Center's LCC partners.

Evaluating current and future climate changes on freshwater resources is an important theme not only for the NE CSC, but a range of federal agencies and other partners in the region (e.g., NOAA Great Lakes Integrated Sciences and Assessments Center, EPA Great Lakes Restoration Initiative (GLRI), Upper Midwest and Great Lakes LCC). The NE CSC will work collaboratively with existing efforts to develop protocols for assessments of the impacts of climate change on freshwater fisheries, lake level fluctuations, hydrology, water quality, and water availability.

Recommendations

- Identify the impacts of climate (Theme 1) and land use/land cover change (Theme 2) on freshwater resources including the occurrence, magnitude, and frequency of flooding events across varying elevation, soil types, and other scales; susceptibility to drought, and changes in seasonal water availability.

- Identify the impacts of climate (Theme 1) and land use/land cover change (Theme 2) on freshwater quality, including agricultural runoff, nutrient loading, methyl-mercury production and transport, and waterborne disease outbreaks across the region.

- Identify the impacts of climate change on freshwater ecosystems, particularly regional headwaters, ephermal wetlands and other intermittent habitats (e.g. seasonal and temporary wetlands; vernal pools), and the temperature ranges of coldwater streams.

- Characterize potential consequences of hydrological and thermal regime changes on water resource budgets, requirements for ecological flows, and the implications of widespread loss of (vulnerable) habitats on biodiversity and ecosystem services.

- Characterize the resulting vulnerabilities from the combined impacts of climate and land use/land cover change, particularly in the form of habitat degradation and increased exposure to pollution, on human health, economic, fish, wildlife, and cultural resources.

- Assist partners that collect and monitor water quality data to better understand landscape changes across the region.

- Collaborate with partners (e.g., NOAA GLERL, GLISA, RISA) to improve models and predictions of climate impacts on physical processes unique to the Great Lakes, particularly the direction and magnitude of lake level fluctuations, fluctuating seasonal ice cover, and how changes affect ecological, socio-economic and cultural interests.

- Use decision analysis frameworks to identify major risks and uncertainties in model predictions for freshwater resources across the region and develop alternatives for management decisions that are focused on different outcomes (e.g., decisions effected by the direction and magnitude of seasonally, and annually fluctuating lake levels and ice cover).

- Work with partners and stakeholders to develop adaptation strategies that decrease vulnerabilities from the impacts of climate and land use/land cover change, and increase the resilience of changing water resources.

Science Theme 4: Climate impacts on Atlantic and Great Lakes coastal and nearshore environments

The Northeast CSC region is unique in that it contains two coastal regions: the Atlantic Ocean and the Laurentian Great Lakes Basin. While there are some inherent differences (e.g., salt water influence of the Eastern Seaboard; 10,000 miles of freshwater coastline of the Great Lakes), both contain a wide array of estuaries (e.g., tidally-driven Hudson River Estuary, Narragansett, Delaware, and Chesapeake Bays) and bays/marshes (e.g., freshwater Black River Bay, Cecil Bay Marsh) that provide protection from hazards (e.g., reduction of flooding), and support highly valuable commercial fisheries. Coastal habitats including low-lying beaches, rocky shores, marshes, nearshore and barrier islands, have been identified by management agencies and interdisciplinary work-groups as being particularly vulnerable to climate change impacts. Climate-change associated sea level rise (Atlantic), and lake-level fluctuations (Great Lakes) in combination with more frequent and intense precipitation, drought, and extreme storm events (e.g., increasingly stronger coastal storms and more intense hurricanes), may strongly increase the risk of coastal flooding, shoreline instability, and erosion throughout the two coastal regions.

Of primary importance on the Atlantic coast, are the impacts of sea level rise and extreme storm events, which threaten to flood coastal habitats, displace or eradicate some species, and increasingly place people and property at risk (Arkema et al., 2013). Saltwater intrusion into groundwater systems, exacerbated by groundwater withdrawal as coastal populations increase, is another concern. As mentioned in Theme 3, changes in climate are predicted to have significant effects on river discharge that will impact salinity levels, as well as sedimentation, contaminant, and nutrient inputs into coastal and nearshore habitats. Changes in freshwater inputs to coastal habitats can also exacerbate seasonal episodes of stratification, and the formation of dead zones, which have already been observed in major coastal water bodies in the region (e.g., Long Island Sound, Chesapeake Bay) as well as neighboring downstream systems (e.g., Gulf of Mexico hypoxic zone). The projected joint effects of these physical processes along with climate change-associated chemical changes such as ocean acidification and hypoxic or low oxygen events are expected to result in degradation or permanent loss of some habitats. Since many coastal habitats serve as nursery grounds and essential habitat to commercially and culturally valued fishes and invertebrates (e.g., shellfish), impacts are likely to be widespread and have economic consequences for the region (Griffis and Howard, 2012; Staudinger et al., 2012).

Nearly one-quarter of the US population lives in the Northeast CSC region. The strong and increasing human footprint of coastal cities and residential areas plays an important role in the sustainability and resilience of surrounding Atlantic and Great Lakes coastal ecosystems. Urban development exacerbates nutrient inputs and increases the frequency and magnitude of runoff associated with impervious surfaces. In addition, commercial ports increase the spread of pollutants and invasive species, further stressing biotic assemblages already at risk to growing climate impacts. At the same time, an increasing human population along the two coasts places more people at risk of catastrophic storm and flood events, and significant property damage. Recent extreme weather events including Tropical Storm Irene (2011) and Hurricane Sandy (2012) have revealed how vulnerable coastal infrastructure and communities are to flooding and storm surge, causing billions of dollars in damages (Horton et al., 2012). Human responses to climate change can often have unintended consequences and exacerbate the impacts of climate change. For example, building seawalls and other structures that harden the coastline can impede the inland migration of coastal habitats and species trying to keep pace with sea level rise, as well as reduce the amount of protection that natural systems provide to people. Therefore, it will be increasingly important

to raise local awareness (e.g., through decision analysis of the risks and uncertainties associated with different response strategies) and emphasize adaptation planning that decreases vulnerability, and improves resiliency without further compromising or exacerbating the impacts of climate change and other anthropogenic stressors on ecological systems.

Predicting these effects and adapting to these vulnerabilities will drive NE CSC research in coastal and nearshore environments throughout the Atlantic and Great Lakes regions. A motivating question for this Science Theme is the extent to which management actions particularly in urban and suburban areas (e.g., reduction in nitrogen inputs, decreases in impervious surface, improved stormwater management) can buffer climate impacts to the coasts. Answering this question requires increasing the accuracy of sea level rise projections, runoff, and lake level fluctuations, and linking them to critical elements of Atlantic and Great Lakes coastal ecosystems such as the structure and function of estuarine wetlands. Resource managers need to understand the extent to which coastal zones can continue to provide habitat for valuable fisheries and at-risk wildlife under a changing climate (see Theme 5) and how management actions including conservation design and restoration can promote sustainability of natural systems while decreasing risks and increasing quality of life for human communities.

Recommendations

- Evaluate the synergistic impacts of sea level rise (Atlantic) or lake level fluctuations (Great Lakes), flooding, extreme events, and anthropogenic stressors (e.g., land use/land cover change) on coastal and nearshore resources including wetlands, marshes, estuaries, beaches, and associated fish and wildlife populations.

- Evaluate the synergistic impacts of sea level rise (Atlantic) or lake level fluctuations (Great Lakes) and anthropogenic stressors (e.g., urban development) on water quality including nutrient-, sediment-, and contaminant-loading, and the resulting impacts on the structure and function of coastal and nearshore ecosystems.

- Understand the combined impacts of climate-associated physical (e.g., increased stratification and coastal erosion) and chemical changes (e.g., increased acidification and hypoxia) on coastal and nearshore ecosystems.

- Characterize and evaluate risks and uncertainty (e.g., through the use of decision analysis approaches) of increasing precipitation and extreme storm events on coastal ecological and human communities.

- Assess and predict the combined impacts of climate change and anthropogenic activities (e.g., urban development) on coastal and nearshore environments (e.g., rates and magnitude of wetland loss in coastal systems).

- Work with regional partners to develop decision support tools, alternative scenarios, and adaptation strategies that aid government and coastal landowners respond to the combined impacts of climate change and urban development, and increase resistance and resilience to future global change through selection and adoption of Best Management Practices as well as strategic coastal planning, conservation, restoration, and engineering efforts.

Science Theme 5: Ecosystem vulnerability and species response to climate variability and change

Climate change is expected to cause stressful environmental conditions for the majority of global biodiversity in the coming decades, and there is concern that many species will not be able to keep pace with direct and indirect impacts (Loarie et al., 2009). Biological responses to climate change are occurring as shifts in time (e.g., phenology), space (e.g., geographical range) and organism (e.g., physiology) throughout terrestrial, aquatic, and marine habitats in the Northern Hemisphere and across the northeast region (Staudinger et al., 2013). Species-specific responses to multiple climate drivers (e.g., temperature,

water availability) are causing changes in the timing, direction, and magnitude of movements and life events among biota and regions and may have adverse impacts on the distribution and viability of biological communities, species and populations. Changes in species' range and phenology are also altering trophic relationships, shifting community assemblages, and increasing the potential for asynchronies, disruptions, and novel biotic relationships between dependent species (Miller-Rushing et al., 2010). Ultimately, the reshuffling of communities and declines of flora and fauna in northeast/midwest habitats have the potential to impact ecosystem structure, function, and productivity, threatening the many goods and services that humans depend on (Leadley et al., 2010; Mace et al., 2012). Biodiversity and ecosystem services are intrinsically linked, and biodiversity is often considered an ecosystem service in itself. However, in many cases, the relationships between biodiversity, ecosystem processes, and ecosystem services are complex and not well understood, making predictions of how the delivery of ecosystem services in the Northeast region will be altered due to climate change uncertain (Mace et al., 2012).

The characterization and modeling of ecological impacts and projected future changes across the region is the ultimate goal of much of the work of the NE CSC. Research on wildlife and fisheries habitats, populations and communities are the traditional focus of most natural resource agencies (often targeted towards vulnerable or other trust species), but requires a broad and deep research program at all levels of organization from individual organisms to ecosystems.

The vulnerability of species and habitats to climate change is dependent on the degree (character, rate, and magnitude) of exposure to changing conditions, sensitivity (or responsiveness) to those changes, and inherent adaptive capacity to adjust to those changes (IPCC 2007; Glick et al 2011). Understanding what traits make some species and habitats relatively more vulnerable to regional climate changes (e.g., increasing temperature and precipitation extremes) than others will be critical to designing adaptation strategies in the northeast CSC region. Populations and habitats already under stress from land-use change, exploitation, pollution, and biological disturbances are likely to be more vulnerable to the impacts of climate change and at risk for declines (Staudt et al., 2013). Therefore, approaches that improve our understanding of how climate drivers are expected to change in the Northeast region (Theme 1), as well as the synergistic and interactive effects of land-use change (Theme 2) are needed to inform conservation, restoration, and adaptive management approaches.

Research conducted under this theme will incorporate historical datasets, on-going broad-scale monitoring efforts by both management and research agencies, targeted field and laboratory experiments, comparative analyses, and modeling studies. Results of this wide range of studies will be used to establish baselines, track population shifts, identify critical thresholds, and improve our understanding of the physiological, behavioral, and ecological mechanisms that cause populations and habitats in the Northeast CSC region to respond to climate change in variable ways. Improved modeling approaches that incorporate these types of data as well as information on species demographics, dispersal abilities, evolutionary processes, and trophic interactions will help improve forecasts of which species will be successful and those that may decline under future climate scenarios. In addition, the parameterization of a new generation of linked climate, population, and ecological models will provide science support for management decisions (e.g., to evaluate connections or corridors among terrestrial, aquatic, and coastal systems). The NE CSC is committed to adaptive management approaches that are flexible and manage for future changes rather than solely focusing on maintaining or restoring historical conditions and ecological communities (Stein et al., 2013). Ideally, management actions resulting from NE CSC research will be used to reduce uncertainties in ecological responses and vulnerabilities, increase resiliency, and inform the next generation of tools and techniques to best manage habitats and species under climate change.

Recommendations

- Document how species and ecosystems were historically distributed, how they have adapted to past global change, and use this information to evaluate the relative vulnerability or resilience of specific natural resources to potential future changes.

- Determine the synergistic effects of climate change and other environmental and anthropogenic stressors prevalent in the northeast region, including changes in land-use and habitat connectivity, disturbance regimes, non-native invasive species, disease, and pollution.

- Characterize climate change impacts on priority, endangered, and threatened (Federal and State) freshwater and migratory (e.g., anadromous and catadromous) fishes, fisheries, and wildlife resources.

- Improve the understanding of relationships between regional biodiversity, ecological systems, and ecosystem services.

- Assess how climate change impacts on fish, wildlife, and ecosystems will affect the delivery of regional ecosystem services, and identify approaches to increase resilience and the sustainability of ecosystem services across the northeastern region.

- Work with partners to develop predictive models (e.g., abundance, range, and distribution changes; population viability) and promote tools to identify habitats, species, and populations that are either particularly resilient or vulnerable to climate change in the northeast region (e.g., barrier islands, Great Lakes islands, headwaters, mountain and alpine habitats, prairies, coastal wetlands and their associated fish and wildlife populations).

- Work with partners to link models of specific climate drivers (e.g., temperature, precipitation, lake or sea level changes) with population (e.g., survival and size-structure) or ecological (e.g., production and food-web dynamics) models to better understand temporal (e.g., seasonal) and spatial (e.g., distribution) changes in plants and animals.

- Work with partners to develop products (e.g., databases, maps, and factsheets) that summarize habitat and species transitions predicted by downscaled climate and linked population and ecological models.

- Use decision analysis frameworks to identify and prioritize restoration and adaptive management approaches and discern their relative effectiveness and necessary implementation thresholds that can help to improve the resilience of populations and habitats, including assisted migrations of populations, increasing habitat connectivity, maintenance of genetic and life-history diversity, and changes in harvest or habitat management techniques.

- Advise and work collaboratively with LCCs, State, Tribal, and other partners (e.g., Association of Fish & Wildlife Agencies) to link fish and wildlife adaptation management plans (e.g., State Wildlife Action Plans; National Fish, Wildlife and Plants Climate Adaptation Strategy) across state and LCC boundaries to adequately respond to multiple anthropogenic and climate stressors, as well as shifting populations and geographic ranges.

Science Theme 6: Impacts of climate variability and change on cultural resources

The NE CSC region includes many cultural resources that are increasingly vulnerable in a changing climate, including the traditional practices and heritage (i.e., Traditional Ecological Knowledge) of federally recognized tribes; sites within our vast National Parks, National Wildlife Refuges, National Forests, and other federally managed and tribal lands (e.g., Independence Hall, PA); as well as social processes, aesthetic experiences, recreational opportunities, and other cultural (ecosystem) services that natural resources provide. Managing cultural services and lands under the impacts of climate change poses a grand challenge to managers who are entrusted to preserve a variety of resources for the education, enjoyment, and livelihood of future generations. For example, climate change in the northern regions of the NE CSC threaten a long-established ‘winter culture’ involving a suite of activities, often associated with public lands and the responsibility of resource managers, and essential to the economies and cultures of northern communities. Understanding how these changes will be manifest will help managers identify which aspects of winter culture will be most vulnerable, and how responses to these vulnerabilities will in turn affect natural resources.

According to its mission, "The National Park Service preserves unimpaired the natural and cultural resources and the intrinsic values of the National Parks system". In order to tackle the challenge of climate change, the NPS Climate Change Response Program has outlined a four-part strategy, including climate science, adaptation, mitigation, and communication. Many of the primary NPS science priorities are in line with the objectives of the NE CSC, and partnerships between NPS and the NE CSC will increase the effectiveness of responses to climate threats on cultural resources and lands throughout the region.

Secretarial Orders such as No. 3289 have identified climate impacts on tribes, tribal lands, and cultural heritage, as a priority for the DOI. The NE CSC is responding to this call by collaborating with other federal agencies to engage tribes and evaluate options for adapting to climate change impacts. Tribal and indigenous communities have a tremendous interest in building capacity for resilience to the impacts of climate change on their lands and communities. These communities are also some of the most vulnerable to climate change because available land is confined to reservation boundaries and tribal communities often lack the financial resources needed to invest in adaptation measures (Berenfeld, 2008; Rinkevich et al. 2011). Nineteenth century treaties between tribes and the United States, upheld by the Federal Courts, also guarantees tribes access and use of many natural resources in off-reservation ceded territories beyond reservation boundaries. Climate change impacts to the continued availability of these and other resources (e.g., birch, maple, and ash trees; blueberries; moose; wolves) threaten the vitality of some tribal cultures.

Traditional ecological knowledge (TEK) that is shared by tribal and indigenous communities may also contribute to a better understanding of climate change impacts on natural resources at finer spatial scales than are detected by some monitoring systems (e.g., weather stations), and provide natural and climate histories of local habitats that may not be documented elsewhere (Reidlinger and Berkes 2001; Nakashima et al. 2012). These sources of information and the knowledge of how native communities have responded to changing environmental conditions can inform adaptation strategies. It is important to note that TEK is culturally sensitive and sacred. Therefore knowledge exchange between tribes and scientists should always be informed and respectful of the history and purpose of TEK, the risks and benefits tribes face when sharing TEK (Williams and Hardison 2013), and observe the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), as well as other relevant federal policies on tribal consultation (e.g., Executive Order 13175).

The NE CSC Consortium represents tribal interests primarily through the participation of the College of Menominee Nation. It is committed to working with the tribal community to build awareness, increase education, and develop research networks to improve the understanding of how climate change impacts tribes, TEK, and the natural resources they depend on while preserving and respecting their sacred and intellectual properties. The NE CSC is also developing a tribal consultation and engagement strategy that will reach out to tribal representatives, their natural resource councils and associations to address their interests, and work to develop climate change adaptation strategies for their necessary cultural and ecological resources.

Recommendations

- Partner with federally recognized tribes, municipalities, States, NGOs, and other entities to assess the breath of cultural resources in the Northeast region threatened by climate change, and to develop and recommend adaptation strategies.

- Collaborate with partners to communicate the impacts of climate change on trust resources on and off Indian reservations, and the potential impacts on tribal cultures, particularly in areas that may be effected by sea level rise, lake level changes in the Great Lakes, ephemeral freshwater habitats, and extreme events (e.g., flooding).

- Characterize the impacts of climate change on subsistence activities including hunting, fishing, forestry, and agriculture, and work with Tribal Nations and the public to identify adaptive and mitigative measures to sustain these cultural aspects of these activities.

- Develop methods, protocols, and policies to incorporate tribal knowledge into natural resource and climate change research to make tribal cooperation efforts with science more of a knowledge exchange. However, free, informed, and prior consent should be used for all research with tribes and be respectful of each tribe's individual cultural heritage.

- Work with partners (e.g., NPS) that have cultural resource responsibilities and vested interests to identify priority cultural resource targets vulnerable to climate change (e.g., man-made structures, species, or other natural resources), and incorporate adaptation strategies into land management and planning.

Science Theme 7: Decision frameworks for evaluating risk and managing natural resources under climate change

The NE CSC strives to become a valued source of emerging information and tools for evaluating the impacts of climate change, and for developing systematic approaches that learn from, inform, and improve resource management (i.e., adaptive management) strategies that cope with climate change within the region. This final crosscutting and interdisciplinary theme has implications for many of the science needs and priorities outlined in Themes 1-6. The NE CSC will become a national leader in risk-based impact analysis. We endeavor to create decision frameworks and tools that integrate the best available science about historical and future impacts on natural and cultural resources as well as their associated uncertainties into frameworks that are meaningful and relevant to resource managers and decision makers. Approaches will be interdisciplinary and collaborative, so that both ecological and social sciences are integrated, and stakeholders are involved in all phases of planning and adaptation strategies.

One approach that will be explored is "Structured Decision-Making," 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 the decisions that must be made by resource managers and the potential objectives, alternatives, quality of information available, uncertainty, and outcomes that they encounter. The approach recognizes the iterative component of natural resource decision-making and the ability to update decisions in the future. The NE CSC has particular interest and expertise in the application of structured decision-making to climate change and natural resource management, and consortium members have a long history of working with stakeholders in addressing climate impacts in decision frameworks (e.g., Brown et al., 2011; Brown and Wilby 2012). Examples of the application of decision frameworks include: 1) on-going studies of management strategies to address change in the Great Lakes, 2) the development of indicators of ecological integrity of wetland systems in the northeast region, and 3) the integration of harvest models for horsehoe crabs that acknowledge potential impacts on migrating red knots in Delaware Bay (McGowan et al., 2011; Converse et al., In press). The NE CSC will work closely with the LCCs and other managers and management partners to assess decision needs and develop decision-support tools to address myriad climate impacts in the region on natural and cultural resources. The NE CSC envisions a complementary role with these partners, where the NE CSC focuses on the science of decision frameworks, while the LCCs and other entities ensure that the tools are available and useful to managers and other stakeholders.

Other frameworks that will be of high interest in evaluating risk, vulnerability, and planning for future climate changes include Vulnerability Assessments, Ecosystem-Based-Management, Adaptive Resource Management, Strategic Habitat Conservation, and Scenario Planning (Glick et al., 2011; Nelson et al., 2011; Failing et al., 2012; Nelson et al., 2013b; Rowland et al., In Press). These tools represent holistic, iterative, interactive, and transparent processes that are intended to foster collaborative processes when developing conservation priorities, planning, and climate change adaptation responses. The NE CSC will work with regional partners and stakeholders (e.g., LCCs) to support and coordinate these types of

evaluations, with the ultimate goal of delivering the most relevant science to managers to assist responses to climate change impacts across the region.

Consideration of how human social processes and behaviors will be impacted by climate change and contribute additional risks to natural resources (e.g., from landscape-scale anthropogenic stressors) will often be important components of decision frameworks and tools. This is largely because depending on their willingness to participate and adopt conservation practices, stakeholder networks can have a significant influence on the success of protective, restorative, and other management actions involving natural resources. Therefore considering human attitudes and including stakeholders, as well as engaging constituents that effect conservation efforts (e.g., the private sector) in the development and implementation of adaptation strategies and policies may increase the effectiveness of management efforts in the region.

Recommendations

- Sponsor trainings and workshops (e.g., in partnership with the National Conservation Training Center) to promote decision-support approaches among stakeholders.

- Work with stakeholders and partners with shared goals (e.g., State Wildlife Action Plans; National Fish, Wildlife and Plants Climate Adaptation Strategy; US Global Change Research Program) to develop frameworks and decision-support tools for planning and implementing adaptation strategies and policies (including both "top-down" and "bottom-up" approaches) in response to climate change.

- Use decision frameworks and tools to assess the resistance, resilience, vulnerability and sustainability of natural and cultural strategies to inform climate change adaptation strategies.

- In cooperation with stakeholders and partners, use decision frameworks to identify key sources of uncertainty and information gaps in resource monitoring and assessment systems, and develop statistically-valid monitoring protocols for application by resource managers.

- Collaborate with stakeholders and partners to use decision frameworks to develop tools that improve data sharing, encourage research collaboration, standardize data collection and management protocols, and maximize limited resources to achieve sustainable resource management and conservation in the context of changing climate throughout the region.

- Partner with social scientists to understand how aspects of human dimensions are influenced by climate change impacts, and how social factors may aid or impede conservation and adaptation strategies.

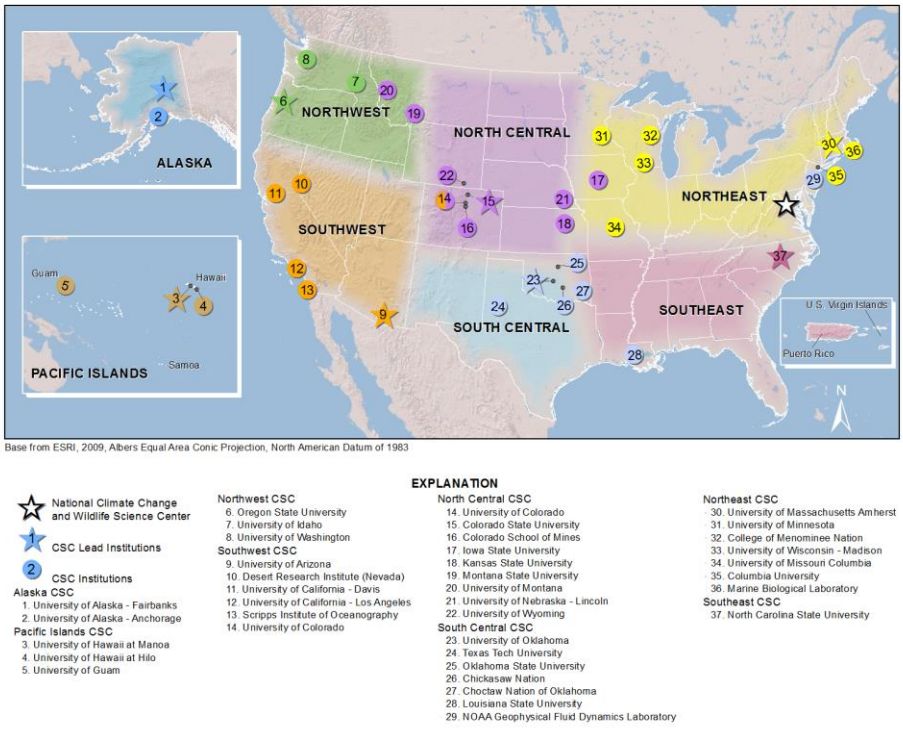
- Incorporate human dimensions considerations (e.g., public opinion and policy, ecosystem services, economic implications) into decision frameworks and climate change recommendations.

Table 1: List of Ecoregions, States, and LCC Programs included in the Northeast Climate Science Center region.

Ecoregions	**States**	**LCCs**
Central Appalachian Forest	Connecticut	Appalachian
Central Tallgrass Prairie	DC	Eastern Tallgrass Prairie & Big Rivers
Chesapeake Bay Lowlands	Delaware	Gulf Coastal Plains and Ozarks
Great Lakes	Illinois	North Atlantic
High Allegheny Plateau	Indiana	South Atlantic
Interior Low Plateau	Iowa	Upper Midwest and Great Lakes
Lower New England / Northern Piedmont	Kentucky	
North Atlantic Coast	Maine	
North Central Tillplain	Maryland	
Northern Appalachian-Boreal Forest	Massachusetts	
Northern Appalachian-Boreal Forest	Michigan	
Northern Tallgrass Prairie	Minnesota	
Piedmont	Missouri	
Prairie-Forest Border	New Hampshire	
Prarie-Forest Border	New Jersey	
St. Lawrence-Champlain Valley	New York	
Superior Mixed Forest	Ohio	
Western Allegheny Plateau	Pennsylvania	
	Rhode Island	
	Vermont	
	Virginia	
	West Virginia	
	Wisconsin	

Figure 1: A) Map showing the boundaries of the DOI Climate Science Centers and Consortium Institutions, B) Map of the Climate Science Centers and Landscape Conservation Cooperative boundaries.

A



B

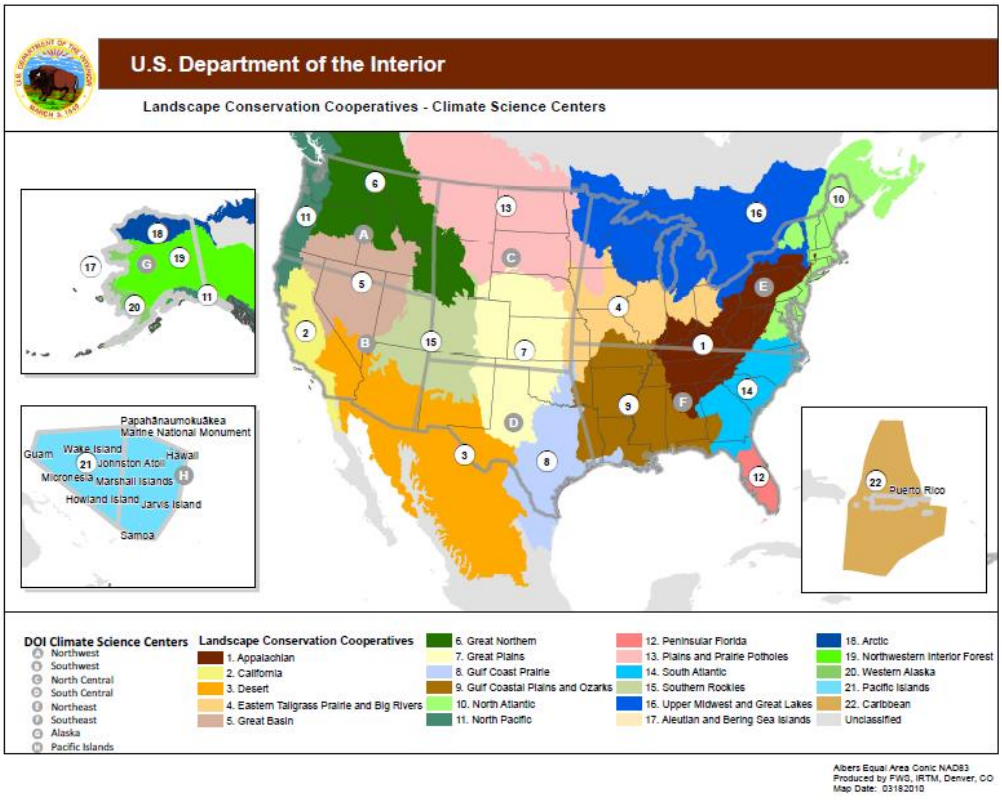
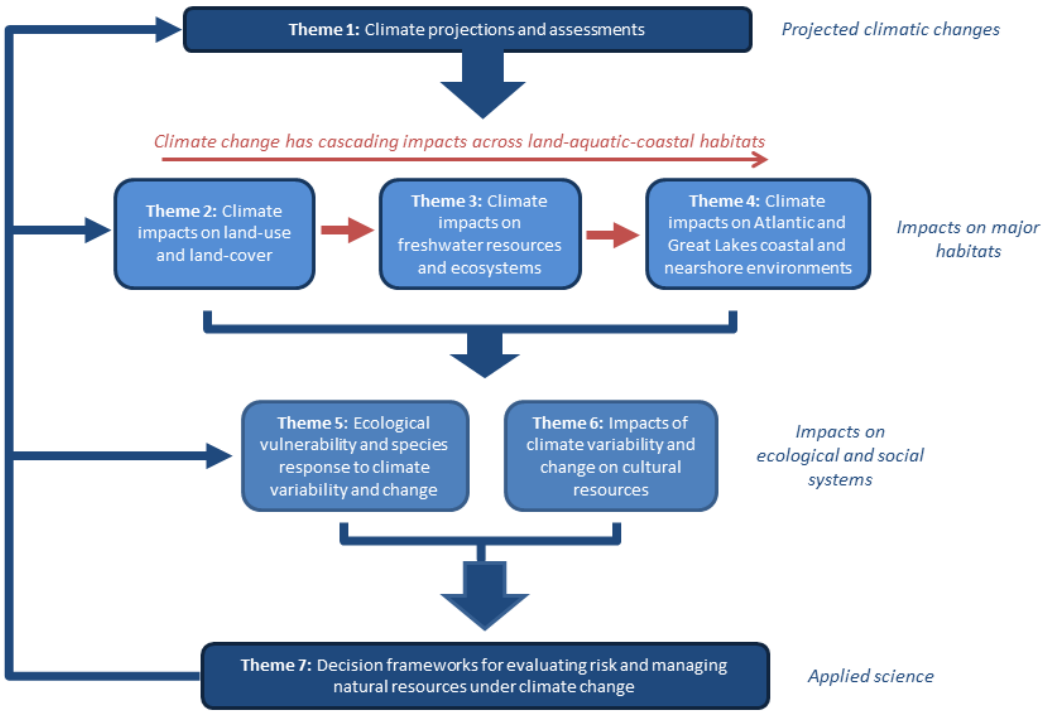


Figure 2: Hierarchical presentation of Science Themes depicts the flow of information achieved from work in Theme 1 (projections and assessments) that will support advances in the large landscapes of Themes 2 – 4 (impacts on major habitats), and in turn, inform detailed disciplinary work in Themes 5 and 6 (impacts on ecological and social systems). All research supported by the NE CSC is intended to support the needs of natural resource managers and other stakeholders in our region; thus Theme 7 (applied science) feeds into and is integrated across all themes.



Appendix A. Partner List (Note: Our Partner List continues to expand)

- Canada Conservation Data Center
- Chicago Wilderness
- Consortium on Climate Risk in the Urban Northeast (CCRUN)
- Cooperative Marine Education and Research Program (CMER)
- Department of Energy (DOE)
- Environmental Protection Agency (EPA)
- Intergovernmental Panel on Climate Change (IPCC)
- Landscape Conservation Cooperatives (LCCs)
    - Appalachian LCC
    - Upper Midwest and Great Lakes LCC
    - North Atlantic LCC
    - Eastern Tallgrass Prairie & Big Rivers LCC
    - Gulf Coastal Plains and Ozarks LCC
    - Plains and Prairie Potholes LCC
    - South Atlantic LCC
- Mass Audubon
- Massachusetts Division of Fisheries and Wildlife
- Massachusetts Executive Office of Energy and Environmental Affairs
- Michigan Institute of Fisheries Research
- Michigan State University
- Minnesota Department of Natural Resources
- National Oceanic and Atmospheric Administration (NOAA)
- National Park Service Cooperative Ecosystem Study Units (CESUs)
- National Park Service Inventory and Monitoring Program
- National Sea Grant College Program
- Nature Conservancy Canada (NCC)
- NatureServe
- New York Department of Environmental Conservation
- Northeast Fisheries Science Center (NEFSC)
- Ohio Division of Wildlife
- River and Stream Continuity Project
- Sustainable Development Institute (SDI)
- The Nature Conservancy (TNC)
- The Pennsylvania State University
- The Wildlife Conservation Society
- University of Georgia
- University of Maine
- US Army Corps of Engineers (USACE)
- US Fish and Wildlife Service
    - USFWS Midwest Office (Region 3)
    - USFWS Northeast Office (Region 5)
    - US Fish and Wildlife Service National Wetlands Inventory
- US Geological Survey (USGS)
    - National Climate Change and Wildlife Science Center

    - USGS Mission Areas
    - State Water Science Centers
    - Northeast and Midwest USGS Regions
    - Patuxent Wildlife Research Center (PWRC)
    - Leetown Science Center and Labs (LSC)
    - Columbia Environmental Research Center (CERC)
    - Eastern Geology and Paleoclimate Science Center
    - Cooperative Research Units
    - National Biological Information Infrastructure
    - National Wetlands Research Center (NWRC)
    - National Wildlife Health Center Fish and Wildlife Service Science Support Program
    - Upper Midwest Environmental Sciences Center (UMESC)
- USDA Forest Service National Forest System
- USDA Forest Service Northern Research Station (NRS)
    - Northern Institute of Applied Climate Science
- USDA Climate Hubs
- Water Resources Research Institutes (WRRIs)
- Wisconsin Department of Natural Resources

Appendix B – Northeast Climate Science Center Stakeholder Advisory Committee

Member Affiliation	Member SAC Position	Member SAC Role	Member Contact Information	Official SAC Designee	Comments
U.S. Department of Interior					
USGS – Northeast Region	• Committee Chair (rotational) • Voting Member	Represents USGS Northeast Region Executive Leadership; regional science needs and climate change research activities	Dr. David P. Russ Northeast Regional Director U.S. Geological Survey 12201 Sunrise Valley Drive MS 953 Reston, VA 20192-0002 703-648-6660 druss@usgs.gov		Chair may rotate between USGS NE and MW Regions; support staff Rachel Muir
USGS – Midwest Region	• Committee Chair (rotational) • Voting Member	Represents USGS Midwest Region Executive Leadership; regional science needs and climate change research activities	Dr. Leon M. Carl Midwest Regional Director U.S. Geological Survey 1451 Green Road Ann Arbor, MI 48105 734-214-7207 lcarl@usgs.gov		Chair may rotate between USGS NE and MW Regions; support staff Jeffrey Stoner and Randy See
NPS – Northeast Region	• Voting Member	Represents NPS Northeast Region Executive Leadership; regional science needs and climate change research activities	TBD (Dennis Reidenbach [previous SAC member] retired as of January 2013)	Maryanne Gerbauckas Associate Regional Director, Resource Stewardship Northeast Region - National Park Service 200 Chestnut Street Philadelphia Pa. 19106 215-597- 0137 Maryanne_Gerbauckas@nps.gov	Regional Directors may designate ARDs or other staff to represent or support them

NPS – Northeast Region	• Voting Member	Represents NPS Northeast regional science needs and climate change research activities	Dr. Mary Foley Regional Chief Scientist National Park Service Northeast Region 15 State Street Boston, MA 02109-3572 617-742-3094 mary_foley@nps.gov		Science Support for NPS Northeast Regional Director
NPS – Midwest Region	• Voting Member	Represents NPS Midwest Region Executive Leadership; regional science needs and climate change research activities	Michael Reynolds Midwest Regional Director National Park Service 601 Riverfront Drive Omaha, NE 68102-4226 402-661-1736 Michael_Reynolds@nps.gov	Jerrilyn L Thompson Research Coordinator Great Lakes Northern Forest CESU 115 Green Hall, 1530 Cleveland Av N St. Paul, MN 55108 612.624.3699 jerrilyn_thompson@nps.gov	Regional Directors may designate ARDs or other staff to represent or support them
NPS – Midwest Region	• Voting Member	Represents NPS Midwest regional science needs and climate change research activities	Robert Krumenaker Superintendent National Park Service Apostle Islands National Lakeshore 415 Bayfield Ave. Bayfield, WI 54814 715-779-3397 x101 Bob_Krumenaker@nps.gov		Science Support for NPS Midwest Regional Director
FWS – Northeast Region 5	• Voting Member	Represents FWS Northeast Region Executive Leadership; regional science needs and climate change research activities	Wendi Weber Northeast Regional Director Northeast Regional Office U.S. Fish and Wildlife Service Northeast Region 5 300 Westgate Center Drive Hadley, MA 01035-9587 413-253-8200 Wendi_Weber@fws.gov	Rick Bennett, Ph.D. Regional Scientist U.S. Fish & Wildlife Service 300 Westgate Center Drive Hadley, MA	Regional Directors may designate ARDs or other staff to represent or support them

				01035 413-253-8305 (Office) 413-531-5467 (cell) rick_bennett@fws.gov	
FWS – Midwest Region 3	• Voting Member	Represents FWS Midwest Region Executive Leadership; regional science needs and climate change research activities	Tom Melius Midwest Regional Director U.S. Fish & Wildlife Service Midwest Region 3 5600 American Blvd West. Ste 900 Bloomington, MN 55437-1458 612-713-5360 Tom_Melius@fws.gov	Craig Czarnecki Assistant Regional Director – Science Applications U.S. Fish & Wildlife Service 2651 Coolidge Road East Lansing, MI 48823-5202 517-351-8470 FAX: 517-351-1443 Email: Craig_Czarnecki@fws.gov	Regional Directors may designate ARDs or other staff to represent or support them

Member Affiliation	Member SAC Position	Member SAC Role	Member Contact Information	Official SAC Designee	Comments
U.S. Department of Agriculture					
FS – Eastern Region 9	• Voting Member	Represents USFS Executive Leadership; Eastern regional science needs and climate change research activities	Dr. Thomas L. Schmidt Assistant Director Northern Research Station U.S. Forest Service 1992 Folwell Ave St. Paul, MN 55108 651-649-5216 tschmidt@fs.fed.us		
USDA ARS, NRCS or USDA Climate Hub	• Voting Member	Represent USDA regional science needs and climate change research or extension activities	TBD		
National Oceanic and Atmospheric Administration					
NOAA – Northeast Region	• Voting Member	Represents NOAA and RISA Northeast regional science needs and climate change research activities	Ellen Mecray Regional Climate Services Director National Oceanic and Atmospheric Administration NESDIS/NCDC/CSD 630 Johnson Avenue, Suite 202 Bohemia, NY 11716 508-824-5116 x263 Ellen.L.Mecray@noaa.gov		
NOAA – Great Lakes Region	• Voting Member	Represents NOAA and RISA Midwest regional science needs and climate change research activities	Heather Stirratt Great Lakes Regional Coordinator National Oceanic and Atmospheric Administration National Ocean Service 1735 Lake Drive West Chanhassen, MN 55317 952-361-6610 Heather.Stirratt@noaa.gov		

U.S. Environmental Protection Agency					
EPA – Northeast Region 1	• Voting Member	Represents EPA regional science needs and climate change research activities	Norman Willard Coordinator U.S. Environmental Protection Administration Region 1 New England 5 Post Office Square Mail Code: OEP Boston, MA 02109-3912 617-918-1812 Willard.norman@Epa.gov		EPA Regions could rotate (Regions 1, 2,3, and/or 5)
EPA – Region 2, 3 and 5			TBD		
Tribes					
Native American Tribal Governments	• Voting Member	Represents tribal regional science needs, priorities, and research activities	Dr. John Daigle (Penobscot Indian Nation; University of Maine) is Northeastern Tribal representative		
Native American Tribal Governments	• Voting Member	Represents tribal regional science needs, priorities, and research activities	TBD (second representative from Midwest)		

Member Affiliation	Member SAC Position	Member SAC Role	Member Contact Information	Official SAC Designee	Comments
Landscape Conservation Cooperatives					
LCC – Appalachian	• Voting Member	Represents LCC strategic goals and priorities	Dr. Jean Brennan Coordinator Appalachian LCC Virginia Tech Conservation Management Institute 1900 Kraft Drive Blacksburg, VA 24061 540-231-7121 Jean_Brennan@fws.gov		LCC Science Coordinators provide more detailed technical expertise via Science Implementation Panel
LCC – Eastern Tallgrass Prairie and Big Rivers	• Voting Member	Represents LCC strategic goals and priorities	Glen Salmon Coordinator Eastern Tallgrass Prairie & Big Rivers LCC U.S. Fish and Wildlife Service 620 S. Walker St. Bloomington, IN 47403 812-334-4261 ext 1211 Glen_Salmon@fws.gov		LCC Science Coordinators provide more detailed technical expertise via Science Implementation Panel
LCC – North Atlantic	• Voting Member	Represents LCC strategic goals and priorities	Andrew Milliken Coordinator North Atlantic LCC U.S. Fish and Wildlife Service 300 Westgate Center Drive Hadley, MA 01035 413-253-8269 (office) 413-835-5538 (mobile) andrew_milliken@fws.gov		LCC Science Coordinators provide more detailed technical expertise via Science Implementation Panel
LCC – Upper Midwest and Great Lakes	• Voting Member	Represents LCC strategic goals and priorities	John D. Rogner Coordinator Upper Midwest and Great Lakes LCC 1250 S. Grove Ave., Suite 103 Barrington, IL 60010 847-381-2253 ext 12 (off) 847-650-2514 (cell) John_rogner@fws.gov		LCC Science Coordinators provide more detailed technical expertise via Science Implementation Panel

State Agencies and Associations					
AFWA –Northeast Region	• Voting Member	Represents AFWA Northeast regional science needs and priorities, and climate change research activities	John O'Leary State Wildlife Action Plan Coordinator Massachusetts Division of Fish & Wildlife 100 Hartwell Street, Suite 230 West Boylston MA 01583 508-389-6359 john.oleary@state.ma.us		
AFWA – Midwest Region	• Voting Member	Represents AFWA Midwest regional science needs and priorities, and climate change research activities	Katherine DonCarlos Deputy Director Minnesota Dept. of Natural Resources Division of Fish and Wildlife 500 Lafayette Road, Box 20 St. Paul, MN 55155-4020 651-259-5224 Kathy.DonCarlos@state.mn.us		
Great Lakes Fisheries Commission	• Non-Voting Member		Dr. Marc Gaden Communications Director and Legislative Liason Great Lakes Fisheries Commission 2100 Commonwealth Boulevard, Ste 100 Ann Arbor, MI 48105 734-669-3012 marc@glfc.org		

Appendix C – Priority Science Needs and Issues for Northeast Climate Science Center Partners organized by Science Theme

	NE CSC Science Theme						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Stakeholder and partner publications	Climate projections and assessments	Climate impacts on land-use and land-cover	Climate impacts on freshwater resources and ecosystems	Climate impacts on Atlantic and Great Lakes coastal and nearshore environments	Ecological vulnerability and species response to climate variability and change	Impacts of climate change on cultural resources	Decision frameworks for evaluating risk and managing natural resources under climate change
Appalachian LCC	1	1	1		1		1
Eastern Tallgrass Prairie and Big Rivers LCC	1	1	1		1	1	1
North Atlantic LCC	1	1	1	1	1		1
Upper Midwest and Great Lakes LCC	1	1	1	1	1		1
Plains and Prairie Potholes LCC	*1*	*1*			*1*		*1*
Gulf Coastal Plains and Ozarks LCC		1	1		1		
USGS Global Change SSPT	1	1	1	1	1		
National Fish Wildlife and Plants Climate Adaptation Strategy	1				1	1	1
USFWS Strategic Plan	1				1		1
USGCRP, 2009, Global Climate Change Impacts in US, Northeast	1	1	1	1	1	1	1
USGCRP, 2009, Global Climate Change Impacts in US, Midwest	1	1	1		1	1	
NPS Climate Climate Change Response Strategy	1				1	1	1
Great lakes Integrated Science Assessment	1	1					1
US Forest Service Climate Change Resource Program (National Roadmap for Responding to Climate Change)	1				1	1	1
NOAA Regional Integrated Sciences and Assessments	1						1
National Research Council: Americas Climate Choices	1	1			1	1	1
Northeast Climate Impacts Assessment, 2007, Synthesis Report	1	1	1	1	1	1	1
USDA Climate Change Science Plan	1	1	1	1			1
Cumulative mention of Science Priority	**17**	**13**	**10**	**6**	**15**	**8**	**15**

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