Rapid Assessment of New Conservation Science in the Northern Appalachian-Acadian Ecoregion

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August 2019

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List of Abbreviations and Acronyms

2C1Forest	Two Countries, One Forest
CARTS	Conservation Areas Reporting and Tracking System
CBD	Convention on Biological Diversity
EPA	United States Environmental Protection Agency
FPIC	Free Prior and Informed Consent
GIS	Geographic Information Systems
ICE	Indigenous Circle of Experts
IPA	Indigenous Protected Areas
IUCN	International Union for the Conservation of Nature
KBA	Key Biodiversity Areas
NAPA	Northern Appalachian-Acadian Ecoregion
NALCC	North Atlantic Landscape Conservation Cooperative
NCC	Nature Conservancy of Canada
NEAFWA	Northeast Association of Fish and Wildlife Agencies
OECM	Other effective area-based conservation measure
PAD-U.S.	Protected Area Database of the United States
RCP	Regional Conversation Partnerships
SCI	Staying Connected Initiative
SDG	Sustainable Development Goals
TNC	The Nature Conservancy
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
UNEP-WCMC	United Nations Environment Programme World Conservation Monitoring Centre
USGS	United States Geological Survey

Acknowledgments

This rapid assessment was made possible by Two Countries, One Forest, with funding provided by the Open Space Institute. We thank Jessica Levine for her superb management and support of this assessment and Dirk Bryant for providing oversight. We also thank Conrad Reining for providing several datasets. The Nature Conservancy of Canada-Quebec (Maude Benny Dumont, Kateri Monticone, Hubert Pelletier-Gilberte, Steve Kentsa, and Pascal Hebert,) provided maps and GIS support for the analysis detailed in Annex 3, and we are very grateful for this assistance. Lastly, special thanks to the interviewees, Mark Berry, Bill Labich, David MacKinnon, Josh Noseworthy, Scott Schwenk, Shelby Semmes, Eric Sorenson, and Abby Weinberg for their time and insight.

Executive Summary

The Northern Appalachian-Acadian (NAPA) Ecoregion of Canada and the United States encompasses the largest intact broad-leaved temperate forest in the world. It is also home to millions of people who love, live in, and make a living from this rich complex of woodlands, farms, lakes, rivers, and shoreline.

Two Countries, One Forest (2C1Forest) is a cross-border conservation collaborative of Canadian and American members who share a stretch of land, a sense of responsibility, and a powerfully effective tool: science-based landscape conservation. The 2C1Forest strategy works from the landscape to the local level, to protect the extraordinary natural heritage of the Northern Appalachian-Acadian ecoregion. We strive to provide science that informs the activities of a host of groups, including state and federal agencies, policy makers, conservation organizations, communities, and landowners.

At 2C1Forest we strive to bring knowledge that will assist in a greater rate of protection and conservation of high priority habitat. Past work collated and presented by 2C1Forest has laid the foundation for identifying those places at great risk of loss to development and conversion. A key document, issued in 2008, was *Priority Locations for Conservation Action,* which identified key areas warranting protection based on their ecological importance and vulnerability to development. The information developed in 2008 has been used in the last 10 years by non-profit organizations, government agencies, and others to make the case for conservation and protection both locally and regionally. It has also served as a springboard for the implementation of much new conservation work on the ground, including in areas necessary to maintain connectivity among large blocks of intact habitat.

The Rapid Assessment undertaken here has three objectives: 1) synthesize key conservation challenges and opportunities that have emerged in the last decade in the Northern Appalachian-Acadian Ecoregion (NAPA), 2) provide an overview of what new conservation science tells us about the ecoregion, and 3) make recommendations about conservation priorities and next steps that 2C1Forest and its partners can undertake.

The first sections of the report provide an overview of the region, followed by an extensive review of science and conservation work since 2008. Significant advances in science, technology, and collaboration have been made since this time. These include expanded geospatial analyses, a substantial increase in the understanding of freshwater and riparian systems, consideration of climate change and habitat connectivity, and the emergence of widespread collaborative networks of organization working for similar goals. The latter, exemplified by entities like the Staying Connected Initiative, may be the most significant and perhaps least expected of the outcomes from the initial work. The nexus between the biological sciences and social science is both a success and a challenge.

Indeed, a key conclusion of this report is that there has been a shift in priorities over the past decade in the NAPA from a focus on the conservation of irreplaceable and vulnerable areas to the identification of priority terrestrial and aquatic networks for protection that are better connected, more climate-resilient, and include considerations such as economic valuation and other environmental benefits and ecosystem services like water security. Moreover, the past decade has also seen a new emphasis on ensuring broad participation of stakeholders who have a vested interest in applying the best science to prioritize land protection and who are invested in communicating results and information including making geospatial data and other datasets freely and widely available.

The assessment then summarizes conservation challenges and opportunities that have emerged in the last decade, ranging from continued habitat loss and conversion to climate change and declines in public funding for conservation. With a detailed background established, the report considers how recent developments in science can inform future work, including setting targets and goals, identifying biodiversity surrogates, accounting for climate change, and integrating aquatic and riparian conservation into future work.

Conclusions and recommendations are woven throughout the document, and key ones are consolidated into the final two sections of the assessment. Notable recommendations include the following:

1. Establish a set of shared conservation targets, goals, and definitions across the region. These should at a minimum adhere to international standards and conventions (e.g., Aichi Targets), but could be much more aspirational.
2. Agree on a set of metrics to measure the impacts of conservation and development. These metrics should include the positive effects of protected areas, such as avoided biodiversity loss and maintenance of ecological integrity. Ensure that measurement data are incorporated in policy, planning, and management decisions, and that they are regularly updated.

3. Move from prioritization exercises to action on the ground. There are already many prioritization analyses in the NAPA and some have only had limited distribution and uptake in the region. Options are diminishing to acquire land in priority areas and thus action must be accelerated.
4. Maximize limited resources, both human and financial, by increasing collaboration among government agencies, conservation organizations, community groups, municipalities, private landowners.
5. Expand the parameters and data for science-based work to include more socio-economic variables, including valuation of ecosystem services and environmental benefits and factors transforming the land (e.g., development, water issues, in-migration and rural de-population, and transportation infrastructure).
6. Continuously evaluate the scale of analyses and interventions to ensure local priorities are being met, and that they fit into the larger regional perspective of a well-connected and resilient ecoregion.
7. Ensure all ecoregion data and analyses are shared in one platform—or at least linked to one platform—to make all products more accessible and useful. Some products are already on 2C1Forest's space on the Data Basin platform, which could be the ideal location to share all data, in addition to organization specific websites.
8. Re-assess or cross-walk various analyses and determine where these correlate, or not. Doing a GIS analysis of various priorities and results of analyses would help clarify if various analyses are identifying the same priorities.

The results of the 2008 *Priority Locations* study were also compared with those identified by The Nature Conservancy in its 2016 report entitled *Resilient and Connected Landscapes for Terrestrial Conservation.* Although these planning efforts use different methods (see Annex 1 for descriptions of the two analyses), they both identify spatially explicit conservation priorities at the scale of the NAPA region. Moreover, because they were conducted nearly ten years apart, they may offer insights into whether priorities have changed over the last decade.

Annex 3 summarizes the results of the comparison, and several important areas of overlap emerge. Key places include the Adirondacks, mountainous regions of Vermont and New Hampshire, northern and "downeast" Maine, northern and coastal New Brunswick, the Gaspé Peninsula, and large portions of Nova Scotia.

The overlapping areas represent about 30% of the ecoregion, or more than 26 million acres (nearly 11 million hectares). An additional 17 million acres (7 million hectares) were identified as high priority by the TNC study, and a further 16 million acres (6.7 million hectares) emerged as important in the 2C1Forest analysis. Overall, nearly 68 percent of the ecoregion can be classified as biologically important in some way.

These results are in stark contrast to the current state of conservation in the ecoregion. Today, less than 10% of the region is strictly protected. Another 25% has some degree of protection, but many areas are subject to intensive management practices that erode biodiversity values.

The threat data developed as part of the 2008 *Priority Locations* study provide further insights into potential conservation priorities within the overlapping areas (the threat data should be viewed with caution because of their relative age).

Over the coming years, the pressures to the NAPA region will only increase. The goal for 2c1Forest and its partners is to accelerate the pace of conservation while the opportunity exists. Climate change, population growth, exploitive harvesting, and poor land use decisions are just some examples of the challenges we face. A clear message of the study is the need to incorporate the objectives of everyone in the region, including tribes/First Nation, small woodlot owners, industry, the recreation community, land use planners, and others in conservation planning and action.

Climate change and its effects are increasingly recognized as perhaps the most important stressor in the ecosystem. The threats, however, are more locally defined, whether the area is an intact forest block pressured by exploitive harvesting or a coastal region facing a rising ocean. The common theme of climate change could nevertheless be the appropriate lens in which to build broad collaborations among stakeholders. Exemplary forest management strategies, restoration of degraded lands, and thoughtful land use planning are actions that empower by showing success.

Going forward, 2C1Forest will seek to provide the best scientific data available to its partners and to collaborate with them to further conservation efforts and enhance on-the-ground management practices. Per this assessment, there is a vital role to play in helping establish a shared set of conservation goals at the local and regional levels. In addition, it is important to develop robust conservation evaluation metrics to track progress towards goals, monitor threats, and diversify the evaluation parameters available to stakeholders.

1. Introduction

The objective of the consultancy "Rapid Assessment of New Conservation Science in the Northern Appalachian-Acadian Ecoregion" was to synthesize key conservation challenges and opportunities that have emerged in the last decade in the Northern Appalachian-Acadian Ecoregion (NAPA), provide an overview of what new conservation science tells us about the ecoregion, and make recommendations about conservation priorities and next steps for Two Countries, One Forest (2C1Forest). This consultancy was undertaken by a team comprised of Karen Richardson and Wynet Smith.

This rapid assessment is the first step to take stock of conservation work to date, identify the highest priority places for land conservation in the NAPA, and harness new financial mechanisms to underwrite conservation efforts. It is based on a review of reports, spatial data, datasets and analyses in the region (Annex 1), structured interviews with eight experts in the NAPA (Annex 2), and research on current conservation practices in the region.

2. Rapid Assessment

In 2008, Two Countries, One Forest issued a report, *Priority Locations for Conservation Action,* which identified key areas in the Northern Appalachian-Acadian Ecoregion (NAPA) warranting protection based on their ecological importance and vulnerability to development. That report, and key reports and analyses that followed, represent a synthesis of scientific thinking about large-scale conservation needs in the NAPA and surrounding region.

This rapid assessment examines some of the challenges and opportunities that have emerged in the last decade in terms of land protection priorities in the NAPA, along with key developments in conservation science and recommendations for further work. We use the term "land protection" and "land protection priorities" to mean land protected from conversion and development that is either formally protected as part of a network of protected areas or secured from conversion and development through other means such as private land trusts, easements, community forests and other kinds of securement.

Specifically, this rapid assessment consists of:

1. A brief summary of the NAPA and initial land protection priorities for the NAPA stemming from the Trombulak *et al.* report (2008) and other earlier reports.
2. Science and conservation advances in the NAPA since 2008.
3. Conservation challenges and opportunities that have emerged in the last decade in the NAPA.
4. General developments in conservation science that could inform future work in the NAPA.
5. Conclusions.
6. Recommendations.

While we recognize there may be a lot more data, reports, analyses and experts to interview, this rapid assessment provides a high-level review of conservation science advancements over the last decade, challenges, opportunities and gaps.

3. The Northern Appalachian-Acadian Ecoregion

The Northern Appalachian-Acadian Ecoregion encompasses over 330,000 km^2 (nearly 82 million acres) in the northeastern U.S. and southeastern Canada, including all or a portion of western Massachusetts, northern New York, Vermont, New Hampshire, Maine, southern Québec, New Brunswick, Nova Scotia, and Prince Edward Island (Figure 1). It is ecologically diverse, dominated by spruce-fir and northern hardwood forests, extensive coastlines, inland mountain ranges, and glacially carved landscapes. It is also an ecological transition zone between northern boreal and southern temperate forests (Trombulak *et al.* 2008).

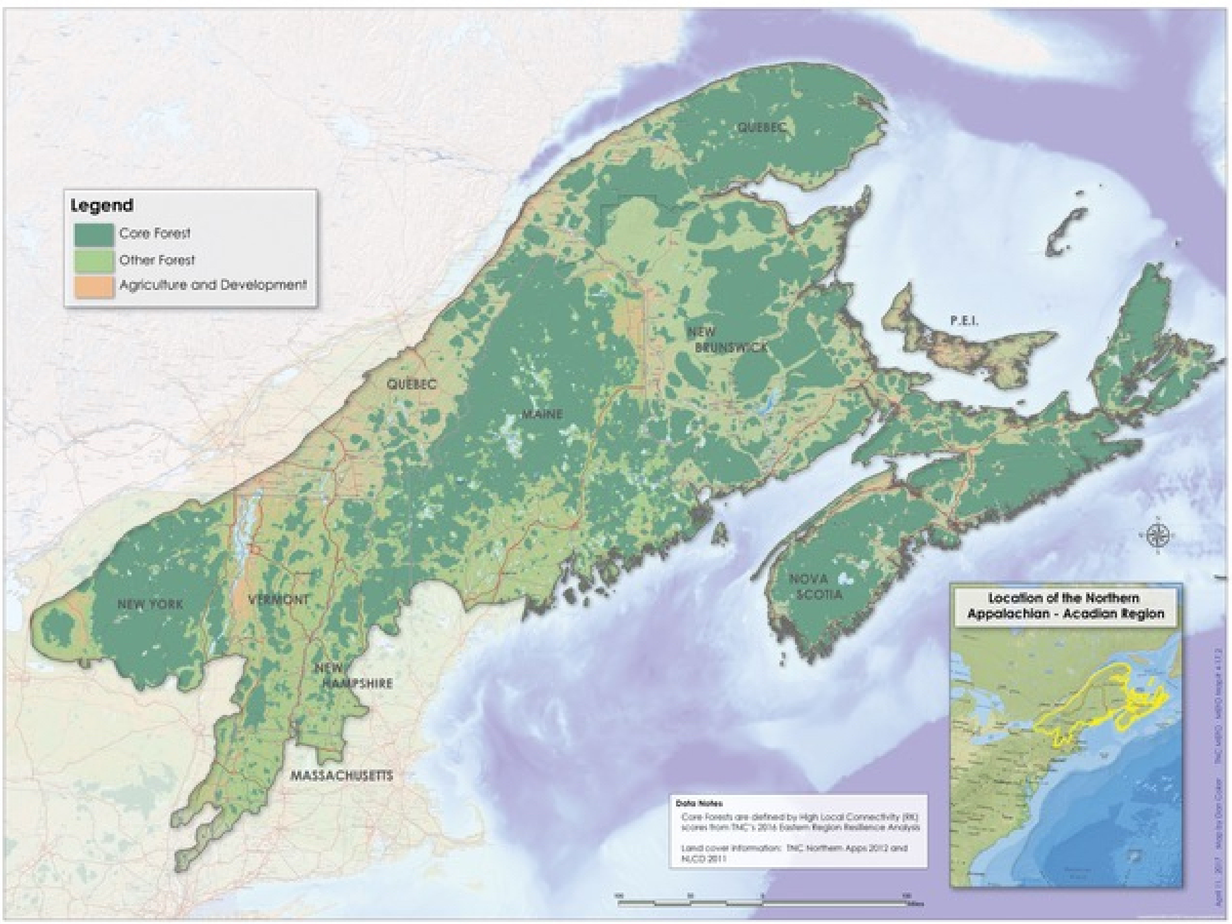

Figure 1. Northern Appalachian Acadian Ecoregion. Map courtesy of The Nature Conservancy-Maine

The NAPA is the most intact ecoregion in the eastern United States and contains the broadest extent of nearly contiguous natural forest. Forest cover has been increasing since extensive deforestation in the 19th century so that the remaining areas with over 80% natural cover amount to over 50 % of the region (Anderson *et al.* 2006). It also contains diverse aquatic, riparian, wetland, and coastal habitats, including floodplains, marshes, estuaries, peatlands, and sandy beaches (Anderson *et al.* 2006). There are still large, intact forest blocks in the NAPA with few roads and diverse flora and fauna.

The NAPA supports approximately 470 vertebrate species and over 2,700 species of plants, some of which are local endemics and rare (Anderson *et al.* 2006). Large mammals include moose, black bear, red fox, bobcat, and lynx. Large carnivores such as wolves and mountain lions have been extirpated from the region (Trombulak *et al.* 2008).

In 2006, 7% of the region was exclusively devoted to biodiversity protection while another 28% was secured from conversion to development (Anderson *et al.* 2006). Most of the protected lands were in the mountainous areas, while coastal regions and lowland valleys were the least protected. Overall, private conservation efforts accounted for 4-6% of the total secured lands (Anderson *et al.* 2006).

In 2008, Trombulak *et al*. (2008) noted that the emerging threats to the ecoregion included atmospheric deposition, climate change, invasive species, and forest tree pathogens. At the same time, the ecoregion was less threatened by housing development than other regions in the east, although coastal and floodplain habitats were vulnerable to intense pressure (Anderson *et al*. 2006, Trombulak *et al.* 2008).

Lastly, over the past decade, there has been a significant amount of cross-border cooperation, including scientific exchange in the NAPA that serves as a model for transborder collaborative work.

4. Land Protection Priorities in the Northern Appalachian-Acadian Ecoregion

Over the past two decades, several reports and analyses have identified various land protection priorities for the NAPA. For this assessment, we reviewed three important reports from just over a decade ago: *The Northern Appalachian/Acadian Ecoregion: Conservation Assessment, Status and Trend* (Anderson *et al.* 2006), *From the Adirondacks to Acadia: A Wildlands Network Design for the Greater Northern Appalachians* (2006), and *The Northern Appalachian/Acadian Ecoregion: Priority Locations for Conservation Action* (2008) and over 30 reports since 2008, along with recent conservation science literature. There is a substantial amount of geospatial data to support the findings in these reports (see Annex 1 for descriptions of the databases and analyses). Many of these datasets include detailed maps of priority areas for conservation actions.

As stated above, in this assessment we use the term “land protection” to mean land that is formally protected in a protected area as defined and reported by the Canadian and American governments through their protected area databases (CARTS and PAD-U.S. respectively) and land that has been permanently secured from conversion and development through easements, private land trusts, or other means. While we recognize these terms may be problematic (Anderson *et al.* 2006), and that secured lands may be managed for extraction and/or recreation, we apply the term only to understand past, current, and possibly future efforts to maintain viable habitats that can continue to maintain, in perpetuity, the region’s biodiversity.

We also recognize that earlier reports identified priority areas for protection based on a significant amount of work to classify the ecoregion, map and model important species and habitats, examine corridors and linkages, and measure compositional variability (e.g., Anderson *et al*. 2006, Reining *et al.* 2006) however, for the purpose of this assessment, we start with the *Northern Appalachian/Acadian Ecoregion: Priority Locations for Conservation Action* report by Trombulak *et al.* (2008) to assess advancements, challenges and opportunities over the past decade in the ecoregion.

In brief, the *Northern Appalachian/Acadian Ecoregion: Priority Locations for Conservation Action* report summarized an analysis to identify irreplaceable and vulnerable locations in the NAPA for the purpose of identifying priority areas for conservation action. Vulnerability was characterized through an analysis of the ecoregion's Human Footprint, a relative measure of the degree of landscape transformation from its completely natural condition using data on human population, transportation and energy distribution networks, and changes in land cover—and projections of future Human Footprints under alternative scenarios of future population growth rates and settlement patterns. Irreplaceability was characterized through a process of systematic conservation planning, identifying sets of locations that together satisfy targets established for protection of threatened and endangered species and ecosystems, source habitat for focal carnivores, and abiotic landscape features. The entire ecoregion was subdivided into sub-regions and irreplaceability and vulnerability scores were assessed for each sub-region to identify those with (a) high irreplaceability and high vulnerability (signifying a high priority for conservation action), (b) high irreplaceability but low vulnerability, and high vulnerability but low irreplaceability (moderate priority), and (c) low irreplaceability and low vulnerability (low priority) (Trombulak *et al.* 2008).

Trombulak *et al.* (2008) noted that while the NAPA is still one of the most forested ecoregions in eastern North America, it may be one of the most vulnerable simply because so much undeveloped land is unprotected and within reach of densely populated areas. They observed that most of the vulnerable areas in the NAPA were concentrated in settled landscapes, but these could rapidly expand outwards given changes in social or ecological conditions that would encourage rapid human population growth and settlement (e.g., climate, location of large industries, and availability of land with high amenity value). They noted that even with low target levels for conservation based on threatened and endangered species and ecosystems, source habitat for focal carnivores, and abiotic landscape features, 27% of the region was found to be irreplaceable and warranted some type of protection. These analyses however, did not include a comprehensive assessment of priorities to achieve functional connectivity across the ecoregion, either for ecological needs in the present time (e.g., movement of wide-ranging species) or in the future (e.g., ecosystem response to climate change). They did however, include priority areas important for structural connectivity, linking large regions with low degrees of transformation.

5. Science and Conservation Advances Since 2008

The past decade of work in the NAPA expanded on the 2006-2008 groundbreaking work, in six general focal areas:

Key Terms Used

- **Conservation action:** Purposeful action to protect land from conversion and development to conserve biodiversity and ecological integrity.
- **Land protection:** Land protected from conversion and development that is either formally protected as part of a network of protected areas or secured from conversion and development through other means such as private land trusts, easements, community forests and other kinds of securement.
- **Land protection priorities:** Priority areas identified for land protection.
- **Priority areas:** Areas of land identified as priorities for protection based on a stated target or goal.
- **Protected areas:** Land protected from conversion and development that is formally protected and legally gazetted as part of a network of protected areas.
- **Secured lands:** Land secured from conversion and development through other means such as private land trusts, easements, community forests and other kinds of securement.

1. Improved and complete terrestrial and freshwater habitat classification.
2. A substantial increase in attention to and understanding of freshwater and riparian systems and challenges for conservation. This includes the addition of geospatial data and information on freshwater and riparian habitats, including the classification of streams and rivers in both countries, and lakes and ponds in the U.S., an evaluation of condition and fragmentation by dams and culverts in the U.S. (with work underway in Canada), an assessment of critical floodplains in the U.S., and the identification of connected stream networks that will maintain a high level of biological diversity and ecological integrity in light of a changing climate.
3. Inclusion of connectivity, connectedness, and pinch point analyses.
4. Consideration of climate change and future climate and development scenarios that may influence resiliency of different habitats in the region.
5. Consideration of landscape integration, environmental benefits, ecosystem services, and economic valuation.
6. Development of strong partnerships and collaborative efforts across the border, within states and provinces and amongst conservation organizations, including the strengthening of Regional Conservation Partnerships (RCP), the North Atlantic Landscape Conservation Cooperative (NALCC), and the Staying Connected Initiative (SCI). This includes the involvement of a wide breadth of stakeholders in analyses and

planning exercises/workshops and the sharing and dissemination of geospatial datasets, reports and analyses through free and transparent means.

Examples of substantial work on these topics include the below reports and analyses (for details and links to the reports and datasets see Annex 1). Some of these cover several focal areas listed above, however, they are listed here under a particular focal area to illustrate an example of developments over the past decade. Many of these also borrow from/build on each other, thus are not necessarily stand alone products (see Annex 1 for details).

a) **Terrestrial and Freshwater Habitat Classification**: In the past decade, there has been substantial progress/work on classification of habitats for the NAPA, often within the context of broader studies. Terrestrial classification for northeast United States and eastern Canada is complete and now exists for all of NAPA in a seamless dataset (Ferree and Anderson 2013). Initial classifications for freshwater systems in the eastern U.S. only included streams and rivers (Olivero and Anderson 2008); scientists then simplified the classes and developed habitat guides (Anderson *et al*. 2013a). Scientists also did further work to classify lakes and ponds for the eastern U.S. (Olivero and Anderson 2016 a and b). Freshwater streams and river classification have now been developed for the Canadian portion of the NAPA as well (Millar and Olivero 2017).

b) **Freshwater Ecosystem Climate Resiliency:** *Assessing Freshwater Ecosystems for their Resilience to Climate Change* (Anderson *et al.* 2013b) examined connected stream networks in the Northeast of the U.S. for seven characteristics correlated with climate resilience—freshwater systems that continue to sustain diversity and ecological services as they adapt to climatic change. These characteristics (network length, number of size classes, number of gradients classes and number of temperature classes, risk of hydrologic alterations, natural cover in the floodplain, and amount of impervious surface in the watershed) ensure a stream network encompasses a diversity of environments, allows aquatic species to migrate and find suitable habitat, has clean water delivered to the channel, and that water, nutrients and sediment are stored on the floodplain. The results are being used to guide land acquisition, inform watershed management, and prioritize dam removals towards the goal of sustaining or increasing the resilience of freshwater systems. This analysis builds on stream/river classification in the northeastern U.S. and the aquatic connectivity, initially completed in 2011 (updated in 2017, as described in Martin and Levine 2017). Nature Conservancy of Canada has no plans for a freshwater resiliency analysis in the Canadian portion of the NAPA at this time (J. Noseworthy, pers. comm.) and we are unaware of any other planned studies.

c) **Aquatic Connectivity:** *Northeast Aquatic Connectivity Assessment Project - Version 2.0: Assessing the ecological impact of barriers on Northeastern rivers* (Martin and Levine 2017) explored the barriers (dams and road crossings) to aquatic connectivity in thirteen northeastern states. First completed in 2011 and revised in 2017 to incorporate road-stream crossings as well as dams, the project assessed over 200,000 barriers in these states for their potential benefit to anadromous fish if removed or mitigated. Thirty-eight ecologically-relevant metrics were calculated and used in the barrier prioritization. As not all road-stream crossings are equal barriers to fish and other aquatic organisms, barrier severity was split into 5 classes: Severe, Significant, Moderate, Minor and Insignificant. Nature Conservancy of Canada is currently developing a barrier analysis tool for the Maritime and Quebec based on the approach of The Nature Conservancy (TNC) so there will eventually be NAPA-wide coverage, even though there will be some differences in methods/results between the U.S. and Canadian analysis (J. Noseworthy, pers. comm.).

d) **Terrestrial Connectivity and Connectedness:** Over the past decade, conservation scientists have applied various approaches to analyzing and identifying connectivity and connectedness.

   - *A Measures Framework for Staying Connected in the Northern Appalachians* (Coker and Reining 2013) present a system for measuring the status of landscape connectivity in eight landscape linkage areas across the NAPA. The framework provides a set of relatively simple and repeatable GIS-based status measures, as well as an initial snapshot of the status of structural connectivity (with baseline numbers and maps), for each linkage area and the important pathways, or fine-scale landscape connections. These connections seek to maintain, enhance and restore landscape connectivity for wide-ranging mammals, bear, moose, bobcat and others, across the NAPA to mitigate the impacts of habitat fragmentation and climate change.
   - In *Resilient and Connected Landscapes for Terrestrial Conservation in Eastern North America*, Anderson *et al.* (2016b) focus on identifying a connected network of climate-resilient sites with confirmed biodiversity and connectivity values. This report expands prioritizing sites by biological features and types of regional flow, such as diffuse intact areas and riparian climate corridors, that are expected to facilitate range shifts under climate change. The resilient and connected landscapes analysis brings together resilience, permeability, and diversity to develop a connected network of sites that both represents the full suite of geophysical settings and has the connections necessary to support the continued rearrangement of species in response to change. The most climate-resilient sites are buffered from the effects of climate change because the site offers a wide range of micro-climates within a highly connected set of areas with diverse topography, bedrock, and soil, that are more likely to sustain native plants, animals, and natural processes into the future, becoming natural strongholds for diversity. This analysis complements other conservation tools that assess species and habitats because it focuses on the properties of the land itself. The results may help decision-makers ensure that the places conserved today will support a diversity of plants and animals in the future.
   - The North Atlantic Landscape Conservation Cooperative (NALCC) and the Northeast Association of Fish and Wildlife Agencies (NEAFWA) coordinated a team of partners from different states, the U.S. Fish and Wildlife Service, nongovernmental organizations, and universities, who developed a regional conservation design, *North Atlantic Landscape Conservation Cooperative's*

Nature's Network (2017). The Nature's Network conservation design - a conservation plan that uses the most recent research and data to identify areas of high biological value for very large regions, integrating core protected areas with wildlife linkages and economically active stewardship lands - identifies a network of places that help define the highest conservation priorities in the region to sustain natural resources and benefits for future generations and an interconnected network of lands and waters that, if protected, will support a diversity of fish, wildlife, and natural resources that the people of the Northeast region depend upon. The landing page map (www.naturesnetwork.org) serves as the "cover page" for the Nature's Network suite of products, outlining some of the most important natural areas in the region and provides an entry point to learn more about the information used to identify them. The conservation design represents a combination of three Nature's Network products: 1) a terrestrial core connector network, 2) aquatic core areas, and 3) core habitat for imperiled species. Each of these products have various components.

- The Eastern Wildway, a continental-scale vision for an extensive wildlife corridor linking eastern Canada to the Gulf of Mexico, expands earlier analysis and conservation visions for Maine and the NAPA (Reining *et al.* 2006; wildlandsnetwork.org/wildways/eastern). The Eastern Wildway traverses a wide array of ecoregions and climates, with the latter ranging from Arctic to tropical. Central to the vision of the Eastern Wildway are wilderness and other core reserves. National parks and other public wild places are essential core areas, as are large, strictly protected private lands—especially given that so much property in eastern North America is privately owned. Cores are where the protection of biodiversity, ecological integrity, and wilderness are given highest priority. The vision recognizes that securing wildlife corridors between Eastern core reserves is vital to sustaining biodiversity. The Wildlands Network has identified 16 locations throughout the Eastern Wildway where immediate action must be taken to restore and protect habitat connectivity and a number of these areas are within the NAPA.

e) **Resiliency**: *The Resilient Sites for Terrestrial Conservation in Eastern North America* (Anderson *et al.* 2016a) report notes that climate change is creating an increasingly dynamic natural world and conservationists need a way to identify important areas for protection that does not assume that the locations of existing plants and animals will stay the same. A team of scientists, led by TNC, identified land with sufficient variability and microclimate options to enable species and ecosystems to persist in the face of climate change, which will maintain this ability over time, and are more likely to sustain native plants, animals, and natural processes into the future. They then identified sites across all geophysical settings that had these characteristics, along with local connectedness that may increase resilience to climate change.

f) *Designing Sustainable Landscapes: Project Overview* (McGarigal *et al.* 2017). This project focuses on identifying the highest priority areas for sustaining the long-term ecological values of the landscape, based on currently available, regional-scale information. In this product the terrestrial core areas represent the following: 1) areas of relatively high ecological integrity across all terrestrial and wetland ecosystem types and geophysical settings, emphasizing areas that are relatively intact (i.e., free from human modifications and disturbance) and resilient to environmental changes. Integrity has the potential to remain high in these areas, both in the short-term due to connectivity to similar natural environments, and in the long-term due to proximity to diverse landforms and other geophysical settings; 2) areas of relatively high current landscape capability for a suite of representative (a.k.a. surrogate species) terrestrial wildlife species, emphasizing areas that provide the best habitat and climate conditions today; and 3) areas of rare terrestrial natural communities that support unique biodiversity, regardless of their landscape context. These areas were expanded to encompass surrounding areas that provide additional ecological value and resilience to both short- and long-term change, where resilience in seen as a weighted linear combination of two core metrics: connectedness and similarity (McGarigal *et al*. 2017).

g) **Landscape Integration, Environmental Benefits, Ecosystem Services and Economic Valuation:** *Wildlands and Woodlands: Farmlands and Communities Broadening the Vision for New England* (Foster *et al.* 2017) is an update to the 2010 Wildlands and Woodlands vision for New England. In the first report, scientists reported that after more than 150 years of forest regrowth following the regional decline in agriculture, New England reforestation had ended and forestland was being lost to development in every New England state. The authors called for retaining and permanently protecting at least 70% of the landscape (30 million acres) in forestland and another 7% (2.8 million acres) in farmland by 2060. Most of the forests would be managed as woodlands for wood products and other benefits, while at least 10% would be designated as wildland reserves. The 2017 report outlines actions that people can take to help reach these ambitious goals over the next half century. The broadened vision recognizes the interdependent role that forests, farms, rural communities, suburbs, and cities play in shaping the New England landscape. In this vision, protected forests dominate the region, even within settled areas, well managed farmlands diversify the landscape, and robust rural economies enable individuals and families to share in the region's prosperity. The report notes that the landscape faces the increasing loss of forest and farmland to residential and commercial development; ongoing fragmentation of land; declines in state and federal land-protection funding; deterioration of iconic tree species from introduced pests and pathogens; unsustainable forest and farm management in some areas; and, the challenge of maintaining public support for land protection and traditional uses of land amidst competing socioeconomic demands. Today, New England is one-third of the way toward the Wildlands and Woodlands forestland goal.

This report also provides some data on the human value of protecting land, including $550 million in health benefits from associated improvements in air quality reducing respiratory illness; 760,000 tons of air pollution removed through forests each year; clean drinking water to millions of households; support for a $10 billion annual tourism industry; and offsetting more than 20 % of the region's carbon dioxide emissions.

h) **Climate Change:** *New England and Northern New York Forest Ecosystem Vulnerability Assessment and Synthesis: A Report from the New England Climate Change Response Framework Project* (Janowiak *et al.* 2018) is an assessment of the best available scientific information on climate change and forest ecosystems to evaluate the vulnerability of forest ecosystems across the New England region under a range of future climates. The authors synthesized and summarized information on the contemporary landscape, provided information on past climate trends, and described a range of projected future climates. The information was used to parameterize and run multiple vegetation impact models, which provided a range of potential vegetative responses to climate. Model projections suggest that many northern and boreal species, including balsam fir, red spruce, and black spruce, may fare worse under future conditions, but other species may benefit from projected changes in climate.

i) **Strong partnerships and collaborative efforts:** Some of the multi-objective analyses are being met through Regional Conservation Partnerships (RCP), which consist of conservation organizations, state and local governments, private industry, conservation districts, water districts, universities and many others. It was noted that the number of RCPs in the U.S. rose from 4 to 43 over the past 25 years (Foster *et al.* 2017), along with the creation of 30 new community forests co-managed by different community stakeholders.

Overall, the review of these reports, datasets and analyses show a shift in priorities over the past decade in the NAPA **from** a focus by 2C1Forest on the conservation of irreplaceable and vulnerable areas, characterized through an analysis of the ecoregion's Human Footprint and irreplaceability (Trombulak *et al.* 2008), and a wildlands network design based on the location and extent of existing core protected areas, proposed core areas, and areas of high biological significance (Reining *et al.* 2006) **to the identification of priority terrestrial and aquatic networks for protection that are better connected, more climate-resilient, and stem from a more collaborative approach that includes other considerations, including economic valuation and other environmental benefits and ecosystem services, such as water security.**

In recent reports and analyses, there is a noticeable absence of prioritization based on the notion of irreplaceability, which was one of the key metrics in the 2006 and 2008 reports (Reining *et al.* 2006, Trombulak *et al.* 2008). Both of these reports used MARXAN, a systematic conservation planning tool to identify areas of high to low irreplaceability across the landscape. There was also a shift from using composite dataset such as the Human Footprint which uses the best and most recently available data on human population, transportation and energy distribution networks, and changes in land cover combined—and projections of future Human Footprints under alternative scenarios of future population growth rates and settlement patterns to datasets that model individual metric such as species-specific regime shifts under different climate change scenarios and land use changes under different development scenarios (Anderson *et al.* 2016 b, McGarigal *et al.* 2017, Thompson *et al.* 2017). This shift has resulted in land protection prioritizations that are hard to compare across the NAPA, as they address different challenges and opportunities. In addition, recent analyses have capitalized on conservation science that reinforces protecting connectors between large contiguous and resilient areas, especially in light of changing conditions, along with the importance of protecting aquatic and riparian networks.

Lastly, **the past decade has also seen a new emphasis on ensuring broad participation of stakeholders who have a vested interest in applying the best science to prioritize land protection and who are invested in communicating results and information including making geospatial data and other datasets freely and widely available.** It was noted in the expert interviews that past prioritization exercises were limited in terms of participation and this led to a reduced uptake at the local level (see Annex 2 for synthesis of interviews). As noted above, some of the challenges and opportunities that have emerged or developed over the last decade have had a considerable influence on the work funded and carried out in the NAPA on priority land protection. Theses are summarized below.

6. Conservation Challenges and Opportunities that have Emerged in the Last Decade

The following section summarizes the key challenges and opportunities gleaned from the review of the reports and analyses listed in Annex 1 and from interviews with experts in the region (see Annex 2 for synthesis). These are divided into data related challenges and opportunities and political will and funding challenges and opportunities.

Data-Related Challenges

Goals and Targets

An overarching challenge with the documents reviewed was the various and differing targets and goals used for land protection prioritization. This included targets covering a range of important topics from protecting areas with high value biodiversity to areas that are climate-resilient; areas that provide corridors for large mammals; areas that protect both aquatic and terrestrial biodiversity, ecological integrity, and connectedness; and core areas that protect ecological integrity and are predicted to remain intact and functional over the long-term. These goals and targets may all sound similar, however very few of the resulting priority setting exercises had the same root data and/or metrics to quantify and assess areas. In addition, most were not sufficiently specific in terms of an outcome and lacked the accompanying key actions necessary for achieving stated targets and goals. This is compounded by the use of different terminology in the various reports such as "ecological importance," "ecological integrity." "biodiversity value," "representativeness," "connectedness," "structural and functional integrity," "core areas," and "wilderness areas." In several cases, it is not clear if the same target or goal was intended but different terminology was used to define the parameters. To confuse the issue further, different suites and measures of biodiversity surrogates are used in almost every report and in some cases within a report (e.g., McGarigal *et al.* 2017x). Although most reports and analyses stress a three-pronged approach that has some measure of ecological representation, focal species habitat, and rare species, this varies greatly between analyses (see Annex 1 for complete set of reports reviewed). **The lack of a common definition of "what" to protect makes it potentially difficult to unify the various stakeholders in the region to implement joint actions**, as each group could have a valid list of priority lands to protect that bears little resembles to other lists.

Scale of Analysis

Another related challenge is the different scales of analysis. A considerable number of reports and analyses were done at the ecoregional level of the NAPA or part of the NAPA (note: there is a clear bias in the number of analyses done for the United States versus cross-border analyses or Canada only), however many were also done at a large scale across the northeast of the United States or at a more local scale. Experts interviewed noted the usefulness of an ecoregional perspective and the importance of being able to situate local land protection priorities within a regional context, and thus understand where local priorities fit into the bigger picture. It was reported that grids cells of multiple kilometers in size used in some ecoregional level analyses were larger than the planning scale at which most local conservation organizations work. Grid cells of 30 m x 30 m, most commonly used in regional analyses, were described as useful for coarse scale analyses but not that useful for finer and more local-scale analyses. In addition, in many cases the boundaries used for decision-making, including those needed for the inclusion of private conservation lands and municipalities, were not available, and this rendered the data less useful for on-the-ground decision-making. Conversely, it was observed that local data and higher resolution data could not be aggregated and substituted for data collected for regional analyses, as they did not provide an adequate "big picture." In most reports reviewed, there was a balance of localized data, primarily on biological conditions, species, species at risk, and local-level impacts such as development, industry use, and land ownership, and regional data on geophysical elements, land cover, and land use.

Threats

The main threats to biodiversity across the ecoregion are **habitat loss and permanent habitat conversion** (Coker and Reining 2013, Foster *et al.* 2017; McGarigal *et al.* 2017, NALCC 2017, Annex 2). This includes fragmentation from habitat loss and parcelization from development. These threats however, are not uniform across the NAPA, and there are local threats that impede the protection of land in specific areas within the region. These include residential and commercial development; sprawl development around urban centers; hardening of coastal areas, lakes and river banks, primarily for second homes; rural de-population; unstainable forestry practices; competition for land with the forestry industry and agriculture; mining operations; changing ownership; water extraction; road expansion on wildlife movement and habitat connectivity; new energy infrastructure; invasive and pest species and pathogens; climate change and sea-level rise (Coker and Reining 2013, Foster *et al.* 2017; McGarigal *et al.* 2017, NALCC 2017, Annex 2).

It is widely recognized that **climate change** is and will continue to be a stressor across the ecoregion and will present challenges for species with limited capacity to migrate or adapt to a changing climate. It is also understood that climate change will alter composition of species in the NAPA area, along with the magnitude and variation of ecosystem functions (Mokany *et al.* 2015). There will be shifts in the distribution of species and composition of communities and the changing climate will create options for species to move within an area or migrate permanently to another area. Moreover, climate change may alter human migration in the region.

There are several parts of the region that are presently experiencing rural de-population and this is a challenge in some areas. Several reports and experts interviewed, however, highlighted the challenge of in-migration to the region as people seek new areas to populate to escape coastal regression due to sea-level rise, and potentially less favorable climates in the south. Some of this in-migration may be welcome in areas where rural de-population is currently a serious challenge to sustainable livelihoods, although it may challenge natural resources and land protection in terms of water resources and land development (Foster *et al.* 2017, Annex 2).

The distribution of most of the above threats is not evenly distributed across the region; most notably, the distribution of new development, unsustainable forest management, and conversion to agriculture are skewed. Several analyses reviewed incorporated geospatial data and information on threats into their prioritization exercises, such as a measure of vulnerability (Trombulak *et al.* 2008); and data and analyses on the permeability of a landscape, including analyses on the flow and resistance across natural, agricultural/modified and developed areas of the NAPA (Anderson *et al*. 2016a). In general, the threats were well articulated in the various reports, but there was a **lack of quantifiable data to identify areas of high vulnerability to different threats**, the exception being climate change and the extensive work of Anderson *et al.* (2016 a and b) to map climate-resilient sites. Since development and harvesting decisions are expected to be the largest drivers of change, it was noted that **good data were needed on land use and land use change to identify areas vulnerable to loss and conversion**.

Aquatic and Riparian Habitat Data and Considerations

As noted in the section above, the past decade has seen a huge increase in the attention to aquatic and riparian habitats within the NAPA, although the data are not even across the ecoregion. The challenge is now to develop compatible data and information and then use it in a systematic way in land protection prioritization so that aquatic and riparian habitats are recognized and valued across the ecoregion. Another challenge is that land protection isn't necessarily the best tool for conserving aquatic and riparian habitat and there are several related issues to aquatic protection, including water quality, withdrawals, land use practices, and in-stream structures.

Type of Protection

In many of the reports, the term "land securement" is used to define land that is not formally protected as a legal protected area but is secure from development or conversion. This includes land on private properties that is secured from conversion or development through a land trust program or a conservation easement and Crown (Canada) or Federal (U.S.) land managed by the federal government for forestry. These lands are very important in ensuring land protection is adequate to meet stated goals and targets.

One challenge is to guarantee that secured lands and, in some cases, formally protected lands in the NAPA will not be degraded or subject to natural resource practices that decrease the biodiversity value of an area. It was reported that some of the Crown land in Canada designated as "secured land" may nonetheless be subject to intensive silvicultural practices, such as plantations, genetically engineered trees, and liberal use of pesticides, that may not be compatible with the goals and targets of conservation actions (Coker and Reining 2013). This also includes inadequate management of the land either though formal management plans or other measures. This topic is discussed in more detail below.

Water

One the biggest challenges for the NAPA is and will continue to be water management. This challenge was not specifically addressed in the initial 2006 and 2008, but its importance as a challenge has evolved over the past decade. The NAPA benefits from abundant and clean water throughout the region, and it is thought that water quality and security may become an issue as water becomes scarce in surrounding regions (Annex 2). Extraction of water for bottling (e.g., in Maine) and other uses may also become unsustainable. This may impact the quality of aquatic and riparian habitats and water supply to urban center within and surrounding the ecoregion (Annex 2). Another challenge is to maintain and, in some instance, restore floodplains to abate flooding in the ecoregion which is predicted to increase in a changing climate (Smith *et al.* 2008, McGarigal *et al.* 2017, NALCC 2017).

Funding and Political Challenges

Funding and Political Will

A challenge, and also a possible opportunity, is sufficient funding to implement the conservation actions required to protect the necessary land identified. Several experts interviewed and reports noted that there had been **a serious decline in the amount of federal, provincial, and state funding for conservation over the past decade** (e.g., Foster *et al*. 2017). In some areas within the NAPA, there had a decline of 50% in federal funding since 2008, and the impact on the ground with regards to the amount of land that could be secured for protection has declined over the decade (Annex 2). Funding from private foundations and organizations has not been tracked as closely, but experts interviewed noted that there would have to be a significant increase in private funding to meet the challenge of the funding needs to achieve on the ground conservation (Annex 2).

Another challenge, and opportunity, is **mustering adequate political will to secure and designate lands for protection.** Experts interviewed noted that this was variable across the NAPA and fluctuated with different political administrations. Several new initiatives such as the New England Governors and Eastern Canadian Premiers Resolution on Ecological Connectivity, Adaptation to Climate Change, and Biodiversity Conservation demonstrate commitment and an understating of the issues in the region, however there is no direct funding yet associated with this initiative. Recent changes in several administrations have resulted in significant decreases in funding and interest in land protection overall (Annex 2).

Data-Related Opportunities

Despite the noted challenges above, recent reports and experts identified several encouraging opportunities in the NAPA.

Connectivity, Connectedness, and Pinch Points

Recognition over a decade ago of the necessity to connect large forest blocks in the NAPA to improve wildlife movement and plan for climatic changes has presented an enormous opportunity for improved science-based analyses and data collection, especially high resolution geospatial data (see Annex 1 for details of these datasets). This has led to rigorous analyses of priority corridors to protect areas between cores; permeability of the landscape; measures of connectedness; identification of pinch points; and calls for better management of roads, railways, dams and culverts to mitigate their impacts and maintain or restore movement and flow of species (Anderson *et al.* 2016 a and b, Martin and Levine 2017).

It has also provided a significant opportunity to consider connecting more private lands and involving private landowners in conservation efforts to connect adjoining lands and lands buffering core protected and other secured lands. Lastly, it has provided an opportunity to restore degraded land that can be secured as connectors between cores and/or provide high quality habitat for species across the NAPA.

Trombulak *et al.* (2008) acknowledged that an explicit analysis of functional connectivity was not part of the prioritization exercise, however connectivity was an essential element to consider and that it would be responsive to intra and interspecies variations in migration throughout the region. Many of the reports examined since 2008 include comprehensive analyses of connectivity, in particular the work by Anderson *et al.* (2016 a and b) that look at linking climate-resilient sites across the landscape. Experts interviewed also raised the importance of connectivity across the landscape and the importance of looking at "pinch points" which may restrict the movement of species. The work of Anderson *et al.* (2016 a and b) has also advanced the state of knowledge on connectedness. They used the permeability of a site's landcover as a measure of local connectedness, along with the degree to which specific landscape features facilitated or impeded the movement of a species (for example the ability of a species to cross a developed area or area under agricultural production). Reports examined and discussion with experts highlighted the necessity for good land cover data to assess connectivity in areas across the NAPA and noted the **lack of adequate land cover change data for the entire region**. It was also noted that there was **a need to better define the terms, measures, and standards used to assess terrestrial and aquatic connectivity and connectedness**.

As mentioned above, the recognition of the importance of connectivity in the NAPA led to a resolution at the 40th gathering of New England Governors and Eastern Canadian Premiers Conference in 2016, the Governors and Premiers — 40-3 Resolution on Ecological Connectivity, Adaptation to Climate Change, and Biodiversity Conservation — which explicitly "acknowledges the need to work across the landscapes and borders to advance efforts to restore and maintain ecological connectivity" and resolves to "identify priority connectivity zones that connect and expand existing protected area…" amongst other instructions to regionally and mobilize resources effectively (NEG-ECP 2016). Through this resolution, the New England Governors and Eastern Canadian Premiers recognized that connected habitats provide natural pathways necessary for wildlife, plant and fish to move to meet their life needs and to find suitable habitat as climate conditions change (NEG-ECP 2016).

Wildlife Movement

A substantial amount of data and information has been collected over the past decade on wildlife movement across the NAPA, including the location and types of barriers (e.g., Coker and Reining 2013, Ferree and Anderson. 2013, Martin and Levine 2017). There is a **huge opportunity to continue to use this information to better assess and develop structural connectivity and functional connectivity indicators for focal species which also reflect climate change considerations.**

Aquatic and Riparian Habitats

The past decade has seen a purposeful inclusion of aquatic and riparian habitats in conservation science in the NAPA that has presented an opportunity to raise its profile and ensure its consideration in future work. The various analyses and comprehensive geospatial datasets to support this are summarized in Annex 1.

Resiliency

The notion of resiliency—the capacity to recover from disturbance and stress; more specifically, the amount of disturbance and stress a system can absorb and still remain within the same state (e.g., resistance to permanent change in the composition, structure and function of the system)—has been introduced in several analyses in the NAPA (e.g., Anderson *et al.* 2016 a and b, McGarigal *et al*. 2017). This has been important in the identification of climate-resilient sites that should be protected and areas that are naturally more resilient to disturbance and stress (e.g., a small isolated forest block is less resilient to species loss than an extensive and well-connected forest block because the latter has better opportunities for recolonization of constituent species). Although there are different methodologies to integrate resiliency—McGarigal *et al.* (2017) used a weighted linear combination of two core metrics: connectedness and similarity, whereas Anderson *et al.* (2016 a and b) used the capacity of a site to adapt to climate change while maintaining diversity and ecological function and a variety of microclimates— there are new opportunities to further **develop the metrics of resiliency and methodologies to incorporate them** into future work to improve the our understanding of how disturbance and stress impact the NAPA.

Indigenous Lands and Other Effective Area-Based Conservation Measures

To date, **an underdeveloped opportunity in the NAPA is the consideration and inclusion of Indigenous lands and Other Effective Area-based Conservation Measures (OECMs).** None of the experts interviewed were aware of comprehensive data on the condition and extent of land under Tribal or First Nation governance that could be seamlessly included in prioritization exercises. Information of this kind seems to be forthcoming in the next 3-5 years in several parts of the region, but there was no overt mechanism to consider and integrate these data and information. Similarly, the consideration of OECMs, along with formal protected areas is gaining momentum in Canada, where a new national agenda is providing the opportunity to widen the scope of land protection (Environment and Climate Change Canada 2018). Most of the experts interviewed stated that Indigenous groups were involved in regional workshops and planning exercises and there were new efforts to integrate local and traditional ecological knowledge more systematically into planning, although this appeared to be *ad hoc* for the time being.

Integration of Environmental Benefits and Ecosystem Services

Several reports recognized the additional environmental benefits and ecosystem services protected lands in the NAPA provided. For example, Anderson *et al.* (2016b, p. 110) stated: "Eastern forests provide an essential ecosystem service in the form of carbon sequestration: the uptake and storage of carbon in forest soils, standing biomass, and wood products. This service is becoming more valuable as the impacts of greenhouse gas emissions are more fully understood. Because the conversion, degradation, or unsustainable management of forests leads to the release of carbon to the atmosphere, the management of ecosystems for carbon is now widely considered to be a key climate change mitigation strategy. The greater Appalachian region has some of the highest forest biomass in the United States. These forests can also be managed for reduced carbon emissions using techniques such as longer harvest intervals and reduced harvest levels." Other benefits and services mentioned included water supply and quality, flood resiliency, health, recreation, energy siting, food production, and wood products (Anderson *et al.* 2016a, NEG-ECP 2016, Foster *et al*. 2017). **There is an opportunity to continue to identify environmental benefits and ecosystem services to local communities**, and where possible attribute economic valuation in terms of clean air, clean water, nature-based tourism, carbon storage and sequestration, recreation, and other benefits. This opportunity could easily be expanded to include key benefits and services across the NAPA in a more systematic manner.

Funding and Political Opportunities

Innovative Financial Mechanisms

Almost all of the reports stated the **need for additional funding in the NAPA for adequate land protection**, either for land acquisition, management or additional scientific work. Several new financial mechanisms have emerged over the last decade in the NAPA, including tax exemptions, transfer taxes, capital gain exemptions, matching funds, carbon markets, Crown trusts, and conservation funds from items such as license plates (Annex 2). Other mechanisms discussed included: ecosystem-based carbon credits; biodiversity or conservation offsets, in particular those associated with environmental impact assessments; water funds, especially in watersheds near urban area; and smart growth initiatives.

Funding and Political Will

As mentioned above, **funding is both a challenge and an opportunity**. At certain times over the past decade, innovative trusts such as the Nova Scotia Crown Share Land Legacy Trust established in 2008, have allowed for large amount of land protection through direct purchases, matching funds and leveraging other sources (Annex 2). Other large investments in land acquisition for conservation has resulted in significant acquisitions from private landowners, especially those managed by TNC and NCC. Although funding has significantly decreased in most jurisdictions across the NAPA, recent budget commitments at the federal level in Canada could greatly improve funding in the Canadian portion of the NAPA.

The experts interviewed were optimistic about the 2016 New England Governors and Eastern Canadian Premiers Resolution on Ecological Connectivity, Adaptation to Climate Change, and Biodiversity Conservation and the potential resources it could bring to the region (Annex 2).

This political commitment could unite the NAPA to work on connectivity and other conservation issues in a unified and systematic manner.

Why these Challenges and Opportunities are Important

The past decade saw an exponential increase in the amount of geospatial data available for the NAPA, most of it freely available, albeit primarily at the ecoregional or "coarse" scale. Several land protection prioritization exercises were carried out by scientists, conservation planners and managers in the region, and these form an important basis for the implementation of conservation actions. To date, experts noted that only 1/3-1/2 of priorities identified a decade or more ago have been acted upon. **Although there have been significant increases in the amount of land formally protected and secured, it is uneven across the ecoregion and still falls short of what has been identified as necessary to maintain the ecological integrity and biodiversity** of the NAPA. In addition, **the management effectiveness of the protected lands has yet to be systematically evaluated,** however both Canada and the U.S. suffered from decreased budgets over the past decade for land protection (although this is hopefully changing in Canada) which has translated into few personnel and resources on the ground. It is now important to weigh the challenges and opportunities to now find in-roads to implement identified priorities for more effective conservation action.

7. General Developments in Conservation Science to Inform Future Work

The NAPA has benefitted from some of the most cutting-edge and forward-thinking conservation science. This includes the 2006 and 2008 work on systematic conservation planning using various measures of irreplaceability and vulnerability as discussed previously and more recent work to integrate climate-resilience, wildlife barriers and connectors, aquatic and riparian habitats, and some economic valuation (Annex 1). A significant amount of the work has been published in the peer-reviewed literature, and it serves as a model of both an ecoregional approach and transborder cooperation.

Several recent advances in conservation science and planning could help inform and possibly improve conservation action in the NAPA over the next decade. This is not an exhaustive list by any means, rather a summary of some the key advances in conservation science that could be considered. Where possible, we call out why it's important, how it applies to the NAPA and in some cases specific recommendations.

Target and Goals Setting

The Aichi Biodiversity Targets under the Convention on Biological Diversity (CBD) have set a global target (Target 11): "By 2020, at least 17 % of terrestrial and inland water areas and 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape" (CBD 2010).

Canada, as a signatory to the Convention on Biological Diversity, signed on to the 2010-2020 Aichi Biodiversity Targets to protect biodiversity, including Target 11. Canada is also guided by the federal targets laid out in the 2020 Biodiversity Goals and Targets for Canada (Environment and Climate Change Canada 2018) stemming from the Canadian Biodiversity Strategy (Environment Canada 1995) and its commitment made to the Aichi Biodiversity Targets. In light of this, Canada has developed its own targets, and Canada's Target One states:

> "By 2020, at least 17% of terrestrial areas and inland water, and 10% of marine and coastal areas of Canada are conserved through networks of protected areas and other effective area-based measures and that these are areas of particular importance for biodiversity and ecosystem services, conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape"(Environment and Climate Change Canada 2018).

This overall target guides decision making at the national and provincial levels in Canada.

There are no overall national biodiversity conservation goals and targets for the United States *per se*, however several agencies guide the formal protection of land. These include the National Parks Service, the United States Forest Service and the United States Geological Survey that manages the United States Protected Area Database (PAD-U.S.), Bureau of Land Management, United States Agency for International Development, amongst others. The stated goals for the establishment of protected areas and parks include:

1. Preservation unimpaired of the natural and cultural resources and values for the enjoyment, education, and inspiration of this and future generation;
2. Natural resource conservation (biodiversity, wilderness, water/ocean ecosystems) — areas that are important for their habitat/species value now or in the future, lands that safeguard aquifers or watersheds, lands that are wild;
3. Recreation;
4. Managed resource production including their ecosystem service functions;
5. Economic contributions, including products (food, wood, fish, etc.);
6. Health benefits;
7. Cultural;
8. Shaping development including buffers and greenbelts; and
9. Human well-being.

These sets of national guidance provided a platform for a significant amount of conservation science over the last decade. For example, in Canada, there has been a national effort to develop and map measures of ecological representativeness and ecosystem services, along with assessing how much land is already protected in Canada (Government of Canada 2018). There have also been substantial resources directed at understanding what other effective area-based conservation measures (OECMs) mean in a Canadian context, where they apply across the country, including how international guidelines developed by IUCN can be applied in Canada (Environment and Climate Change Canada 2018 and IUCN WCPA 2018). Lastly, Canada has started to invest more in the science related to the state of connectedness of its protected lands to better address its commitment to a “well-connected systems of protected areas” (Environment and Climate Change Canada 2018).

In the U.S., the past decade has seen the transformation of its national protected area database (PAD-U.S.) to now include is a spatial (GIS) database covering over three billion acres of land owned and managed by thousands of federal and state agencies and non-governmental organizations, as well as private lands protected via conservation easement and land trusts. The U.S. has also invested a significant amount into re-categorizing its protected areas by IUCN categories so that it can now report to the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) World Database on Protected Areas (Gergely and McKerrow 2016, PAD-U.S. 2016) using a science-based approach under direction of the United States Geological Survey’s Gap Analysis Program (Gergely and McKerrow 2016, PAD-U.S. 2016). This has also included articulating the benefits of a national protected area system such as:

1. Managing public lands to better protect biodiversity.
2. Providing improved recreation access and supporting public health campaigns.
3. Ensuring effective siting for renewable energy facilities and other infrastructure.
4. Developing action strategies to mitigate climate change impacts.
5. Helping Americans find every type of outdoor recreation opportunity.
6. Supporting local economic development through improved parks information that helps build tourism businesses and supports outdoor recreation suppliers and guides.
7. Improving public health by enabling policy makers and researchers to learn more about parks and people nationally and in local areas, and to design programs that encourage active living.
8. Ensuring sound development of road, energy and other infrastructure.
9. Managing wildfire response, reducing the impacts of flooding and other natural disasters.
10. Ensuring military bases have compatible surrounding areas.

Recently, the Gap Analysis Program has also directed research on several science-based questions such as:

- Where are the biodiversity conservation lands, who manages them and how much habitat is protected?
- Which areas host the most species?
- Where should habitat mitigation corridors be placed to help species with changing climatic conditions?
- How can renewable energy projects best balance habitat conservation and much-needed energy production?

- How to improve land management practices that support continued biodiversity conservation?
- How to include aquatic areas such as rivers, lakes and coastal areas? (USGS 2016)

These national-level efforts are important for the NAPA, as they guide national conservation science and management directives, funding and political engagement.

Why It's Important

If there is only general agreement amongst scientists and conservation planners on ecoregional priorities for land protection (e.g., biodiversity, ecoregional representation, ecological integrity or climate resiliency), and targets and goals are not well situated in national and state/provincial targets and goals, then scientists and planners may derive different priority maps based on individual preferences for surrogate measures of biodiversity and landscape variables. This is the case in the NAPA, where **different actors have mapped priority areas for a series of different targets and goals and at various spatial scales**. Products are then not necessarily comparable and/or useful for ecoregional planning.

How Does This Apply to the NAPA?

An important observation from the review of reports, analyses and interviews is that **there are multiple, and not always compatible, stated conservation targets and goals for the NAPA**. As stated previously, part of the issue may be in the use of different terminology and definitions and some of this may be in part due to access to data, especially comprehensive and complete datasets for local and ecoregional variables. Examples of these different recommendations include:

1. Identify priority conservation areas based on ecological importance (Trombulak *et al.* 2008).
2. Ensure a portfolio of conservation sites that includes geographic distribution, stratification by ecoregion and geophysical representation that represent a set of resilient climate sites (Anderson *et al.* 2016a).
3. Identify a network of connected, intact, and resilient areas encompassing various types of lands and waters representing important habitats for key species. These are priority places for future sustainable human and natural communities in the Northeast (Nature's Network).
4. Identify priority sites to maintain ecological integrity and function (NAP 2018)
5. Identify highest priority areas for maintaining ecological integrity and protecting and enhancing ecological function into the future (Sorenson and Zaino 2018).
6. Protect the geophysical stages, "Nature's Stages" that created diversity in the first place at local and regional scales (Anderson and Ferree 2010).
7. Conserve all types of geophysical settings and using site resilience criteria to select places where conservation could expand in a portfolio of climate resilient and connected sites (Anderson *et al.* 2016b)

8. Retain and permanently protect of 70% of forest and 7% of farmland by 2060; of that 10% as wildlands and 60% as managed forest (Foster *et al.* 2017).
9. Other reasons such as to conserve historical and current ecological communities; manage for natural processes and trajectories of change; and manage for change based on projected future conditions.

Although many of these are very similar if not the same, there are subtle variations in the data used to derive and measure them. This also means that although the maps and datasets associated with these goals and targets tend to repeatedly show the same or similar areas for protection, including remaining forest blocks, riparian habitats, and connecting areas, there are differences which may be important on the ground. Since the identification of lands for protection is primarily based on two sets of surrogates: those representing biodiversity and/or ecological integrity; and those landscape variables used for modelling land cover, land use, permeability and suitability, amongst other elements, the results of all the prioritization exercises can only be taken as the best approximation with the best available data. (Note: A formal analysis of the overlap of areas from the different reports and analyses was not part of this assessment.)

Similarly, many of the reports state multiple goals that address a wider range of issues related to conservation and land protection in the region, although few had comprehensive datasets to include them as variables in prioritization exercises. These include:

1. Nature-based tourism;
2. Outdoor recreation;
3. Nature resource production;
4. Local food and wood;
5. Water quality, including clean drinking water;
6. Flood protection;
7. Air filtration;
8. Carbon storage and sequestration;
9. Ecosystem and environmental benefits;
10. Socio-economic benefits;
11. Research and education; and
12. Cultural values.

It was noted that several Regional Conservation Partnerships (RCPs) and community forests were addressing some of these multiple goals (e.g., Foster *et al.* 2017, Annex 2).

Specific Recommendation: **Efforts should be made to agree upon NAPA-level goals and targets for conservation. Since Canada is guided by national targets, NAPA-level targets should be compatible with these. A short GIS-based study on the overlap of previous prioritization**

exercises could also assist with an assessment of where and why differences are occurring using different targets and goals.

Biodiversity Surrogates

As noted above, in most cases different surrogates for biodiversity were used in the reports and analyses examined. These included: a) geophysical diversity; d) ecoregion/habitat diversity; c) abiotic environmental classifications; d) species diversity; e) species rareness and endemism; and f) focal species habitat. Although much work has been on the effectiveness of different biodiversity surrogates to date (Anderson *et al.* 2015, Beier *et al*. 2015, Forest 2017, Lawler *et al.* 2015), no one surrogate has been shown to effectively represent all the biodiversity in an area and most areas are limited by available data anyway. Most places are limited by species data and use some form of environmental classification of vegetation or climate as a surrogate for underrepresented taxonomic groups (Ferrier and Guisan 2006). Several modelling tools have been developed to look at compositional turnover (β-diversity) as a surrogate for species diversity (Ferrier 2002, Ferrier *et al*. 2007). Similarly, new techniques have been developed to model vulnerability from land use data and resilience and connectivity from high resolution land cover data (e.g., Luque *et al.* 2012, Mallampalli *et al.* 2016).

Why It's Important

This is important because it is very hard to compare the biodiversity "gain" of one conservation prioritization exercise with another if the "units" of measure for biodiversity are different. This is not a criticism of the extensive amount of science and data collection that has been developed by the organizations involved which is world-class, it is merely to point out that where different surrogate measures of biodiversity are used, it is difficult to compare outputs and design an optimal plan for conservation action.

How Does this Apply to the NAPA?

In the NAPA, a large amount of data has been collected to measure and report on important biodiversity areas. This includes, but it not limited to extensive geospatial data (Annex 1) on geophysical features; ecological integrity including structural, composition and functional elements of the various habitats in the region; species diversity and movements across the landscape; rare and endangered species and focal species habitats. Most of the reports and analyses reviewed either developed their own measure of biodiversity or incorporated measures developed by others to arrive at their own measure. Although this may be an effective approach to address the stated targets and/or goals at the spatial scale of the exercise, recent advances in conservation science and global agreements on biodiversity protection (e.g. Aichi Biodiversity Targets, CBD 2010) advocate for a network of protected areas that are ecologically representative, well-connected that protect biodiversity and ecosystem services, although no one-stop global standards for measuring biodiversity are proposed. To be effective, land protection in the NAPA needs to contribute to these national and global conservation targets and goals.

Specific Recommendation: **Similar to targets and goals, general NAPA-wide principles on biodiversity surrogates for different scenarios (e.g., ecoregional planning, local planning,**

species habitat modelling, etc.) could be developed with at a minimum data standards and common definitions.

Adequacy of Land Protection

Over the past decade, many definitions of protected areas and secured lands have appeared in the literature. Canada formally defines protected areas as "lands and waters where use is limited for the purpose of conserving nature. Protection does not always isolate areas from use, including industrial activity and the harvest of biological resources. Nature conservation, however, must be the primary purpose." (Environment Canada 2017). The United States defines protected areas as "national features or sites that the U.S. federal government has determined to be significant and worthy of protection." (USGS 2016). There are also formal definitions from the Convention on Biological Diversity (CBD) and the International Union for the Conservation of Nature (IUCN), as well as others. An important distinction is that protected areas are formally designated, whereas other types of land securement for conservation are not formally designated, as discussed previously. These definitions may have the same end goal of protecting land, but their slight difference may mean a different emphasis on what is measured.

Recently, new analyses have pointed at the need to include more "key biodiversity areas" (KBAs)—sites contributing significantly to the global persistence of biodiversity, in terrestrial, freshwater and marine ecosystems—in protected land networks (IUCN 2016). KBAs are presently being identified across Canada and the U.S. using global guidelines that use criteria with quantitative thresholds developed through an extensive consultation. Sites qualify as KBAs if they meet one or more of 11 criteria, clustered into five categories: threatened biodiversity; geographically restricted biodiversity; ecological integrity; biological processes; and, irreplaceability (IUCN 2016).

Canada's effort "to conserve at least 17% of terrestrial areas and inland waters of Canada by 2020 through protected areas, Indigenous protected and conserved areas, and other effective area-based conservation measures" will require a more inclusive approach to considering these lands (Environment and Climate Change Canada 2018). A significant amount of guidance is now available on the integration of Indigenous protected areas and how they can be systematically included in national networks to achieve equitably management (CBD 2010, Environment and Climate Change Canada 2018).

Lastly, adequate land protection requires effective management. A 2013 assessment by the Canadian Commissioner of the Environment and Sustainable Development reported that in Canada only 10% of formal protected areas (80% of network examined) were deemed to be under "effective and sound management" (CESD 2013). The majority of them had significant deficiencies because of insufficient resources and personnel (CESD 2013). There is no similar study for the U.S., however it is clear from decades of experience in protected area management worldwide that management intent and effectiveness are important concepts in protected area and secured land designation and ultimately determine the conservation outcomes for a region (Hockings *et al.* 2006). Effective management also applies to the areas surrounding a protected area and the larger landscape it is situated in as the permeability of protected area boundaries to external threats can impact its effectiveness (Hockings *et al*.

2006). Lastly, effective management should include practices that ensure the persistence of biodiversity into the future in light of changing climate conditions.

Why It's Important

This is important because it implies that meeting the target or goal for biodiversity and full ecological representation is nearly, if not, impossible in the ecoregion unless a significant effort is made to acquire a portion of the most productive lands for conservation. **It is also important that tribal and Indigenous protected areas and OECMs are considered using rigorous criteria laid out in available guidelines to determine whether they contributed to targets and goals for protecting land and could hence accelerate the achievements of these in the NAPA**. In Canada, as part of a national commitment for reconciliation with Indigenous peoples, an Indigenous Circle of Experts (ICE) was formed to provide advice and recommendations on achieving Canada Target 1 (ICE 2018). A recent report from ICE, *We Rise Together Achieving Pathway to Canada Target 1 through the creation of Indigenous Protected and Conserved Areas in the spirit and practice of reconciliation*, provides a vision for Canada's entire system of protected areas to be identified and managed in partnership with Indigenous governments, consistent with the principle of Free Prior and Informed Consent (FPIC) as expressed in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) (ICE 2018). Recommendations and directives from this process need to be part of any NAPA-wide guidelines to be consistent with Canada's path forward.

Lastly, without measures of the effectiveness or impact of land securement, it is hard to understand what would have happened without the intervention to protect land. In order to attribute apparent changes in the condition of biodiversity to protection (e.g., could have increase in native species in region due to climate change and not reduction in habitat loss), it is necessary to have appropriate indicators and methods to measure impact and management effectiveness.

How Does this Apply to the NAPA?

For the NAPA, there is no agreed upon ecoregional definition of a "protected area" that is applied uniformly across the region, however most prioritization exercises recognize that stated conservation targets or goals will require a significant amount of formally "protected areas" as well as "secured lands," defined as land permanently secured against conversion or development which is not formally protected (Anderson *et al.* 2016a). A significant amount of this secured land is projected to come from private lands in the form of easements and trusts and land currently being managed for forestry and other natural resource activities. Currently private land conservation only contributes between 1-6 % to the total amount of land protected both through formal protected areas and secured lands measured at the jurisdictional-level in the NAPA in both Canada and the U.S. **To achieve some of the stated targets and goals of the various prioritization plans for the region, this will have to increase several-fold and it will be important to have a collective understanding of "protection".**

Several of the reports examined and interviewees also noted that the current protected areas of the NAPA may not be in the right locations to maximize biodiversity protection and are biased to areas with acidic soils, at high elevations and with steep slopes where there is the least potential for extractive activities and agriculture. There is also a lack of protected areas with productive soils, at low elevation that are flat or with a gentle slope (Anderson *et al.* 2016a, Annex 2).

In addition, none of the reports or analyses examined included consideration of or provisions for including tribal or Indigenous lands as part of a network of protected and secured lands this included the lack of geospatial maps for the NAPA with no or little tribal or Indigenous lands (Annex 1). There was also no mention of how these lands could be included to meet conservation targets.

Reports recognized that actions such as avoided deforestation and agricultural land abandonment do not necessarily mean a positive impact for all ecosystems and species. Other reports recognized the need to plan for future changing climatic conditions and understand how climate change will impact ecosystems and species through the consideration of diversity, representation and flow (e.g., Anderson *et al.* a and b). However, none of the reports examined had any provisions for ensuring and measuring effective management or measuring the impact, biodiversity loss avoided, afforded by managing either formal protected areas or secured lands. While most of the reports and analyses contained maps of key areas needed to fulfill the stated targets or goals, few, if any, had indicators to measure the impact if and once the highest priority lands were secured and managed for protection.

Specific Recommendations:

1. **Efforts should be made accelerate the consideration of Indigenous Protected Areas (IPAs) as part of the network of protected lands and ensure that Indigenous groups are part of the decision-making process across all of the NAPA.**
2. **Conduct a GIS-based analysis of the amount (percent) of each distinct ecological unit (measured by an agreed surrogate such as geophysical setting) protected to set goals for those underrepresented. Include information on KBAs to ensure if they are also being captured in the network of protected lands.**
3. **Include in the above analysis the amount of private land for each biodiversity surrogate unit and if possible, using land cover and land use data (which is becoming more rapidly available for both sides of the border at the spatial scale of 30m or finer), a measure of the condition of those private lands.**

Climate Smart

Although there is still much uncertainty on how climate change will play out in the NAPA, it is already having significant impacts on species and habitats, and these effects are projected to increase over time (Anderson *et al.* 2016b). Over the past decades, several groups of scientists working in the NAPA and surrounding regions have addressed some of the current and projected changes attributed to a changing climate and have collected data and developed methodologies to identify climate-resilient sites and connectors (Annex 1). In addition to these pioneering approaches, several emerging principles on being "Climate-Smart" may be applicable to the NAPA. Stein *et al.* (2014) developed comprehensive guidelines for climate-smart conservation and how to put adaptation principles into practice. Some of these principles have already been incorporated into analyses in the NAPA, such as the identification of resilient examples of geophysical settings, critical connectors for species movements, connected and climate resilient sites (Anderson *et al.* 2016 and b) however, more will have to be done to monitor the impacts of climate change.

Why It's Important

This is important in planning, prioritizing and evaluating land protection going forward to **ensure that current plans are well designed to include areas of refugia, connection to other large core areas, as many microclimates and geophysical features as possible** and to adjust methodologies and planning techniques to ensure that conservation targets, outcomes, and timeframes are as "climate-smart" as possible.

How Does this Apply to the NAPA?

In light of emerging work on the northern migration of species in the NAPA, NAPA as a north-south corridor, and the predicted upslope migration of certain species in the NAPA (Anderson *et al.* 2016b), several science-based questions could be asked that complement the already on-going work in the NAPA (Stein *et al.* 2014):

1. What should we be doing differently and what actions continue to make sense?
2. How should we manage for change, as well as persistence?
3. What are the key climate vulnerabilities for species and habitats in the NAPA?
4. Are the protected lands and management actions having the desired ecological response, if not why?

Specific Recommendations:

1. **Encourage research on the above climate-smart oriented questions.**
2. **Document and share any data and information species' migrations north and upwards, as well as species that are declining due to lack of suitable habitat that can be attribute to climate change.**

Aquatic and Riparian Habitats

The fragmentation of river habitats through dams and poorly functioning culverts is one of the primary threats to aquatic species in the United States. The impact of fragmentation on aquatic species generally involves loss of access to quality habitat for one or more life stages of a species. For example, dams and impassable culverts limit the ability of anadromous fish species to travel from the sea to their preferred freshwater spawning habitats (Martin and Levine 2017). The most recent analysis of Canada's efforts to conserve biodiversity concurs that there has not been an adequate focus on these systems (Environment and Climate Change Canada 2018) and the United States Environmental Protection Agency (EPA) has developed extensive guidelines for the functional restoration of riparian habitats to protect biodiversity and maintain water flows (EPA 2005, Swanson *et al.* 2017). The importance of adequately protecting aquatic and riparian habitats was highlighted in several reports as critical to maintaining drinking water for communities, flood protection, water quality and security. and reducing the impact of severe weather events when associated floodplains were protected. In addition, fishing is an integral part of the outdoor recreation so sought after in the region, and although the consideration of fish species diversity as a target for conservation may still be lacking in the region, access to clean lakes and healthy rivers was an important driver of protection goals in certain areas (Annex 2).

Why It's Important

Aquatic and riparian habitats have been underrepresented in the various prioritization and conservation plans in the region and need to be brought in systematically to address the threats that are unique to these habitats and the role they play in flood mitigation, water security and recreation.

How Does this Apply to the NAPA?

In the NAPA, there is a clear recognition that a focus on freshwater aquatic and riparian habitats has been slower to materialize than for terrestrial habitats. Several studies in the region state that protecting wetlands and riparian corridors are the single best actions in promoting resilience and sustaining biodiversity in the region and that the conservation of riparian corridors should be based on their degree of permeability and flow (Anderson *et al.* 2016 and b).

Specific Recommendation: **Prioritize work that brings freshwater and riparian habitats work into prioritization exercises in a purposeful and systematic manner and that allows the associated science to advance rapidly to catch up the terrestrial science.**

Ecosystem-based Carbon

In Canada, addressing climate change is a shared jurisdiction between the federal and provincial/territorial governments. Canada has committed to a 17% reduction in emissions below the 2005 level by 2020 and by 2030 to a 30% reduction below the 2005 level (Government of Canada 2017). The 2017 Pan-Canadian Framework on Clean Growth and Climate Change is one of the key policies at both levels of government that will be implemented to achieve Canada's international commitments. It calls for the forest sector to be part of mitigation efforts. About 90% of Canada's forest is under provincial or territorial jurisdiction, with the remainder owned by Aboriginal peoples, the federal and municipal governments, and private landowners (Government of Canada 2017). The Paris Agreement, to which Canada is a signatory, and the U.S. was a signatory (several states are still adhering to the Agreement) calls for increased natural carbon sinks to achieve a balance between anthropogenic greenhouse gas emissions and removals in the second half of this century (Paris Agreement, Articles 4 and 5). A significant portion of these natural carbon sinks will be forests and tidal wetlands, both abundant in the NAPA. Several new methodologies have also been developed for the voluntary carbon market through the Verified Carbon Standard (VCS) to credit the restoration and conservation of tidal wetlands (VCS 2015).

In 2017, the New England Governors and Eastern Canadian Premiers signed a resolution, Resolution 41-2: Resolution Concerning The Regional Climate Change Action Plan, that will hopefully support cross-border solutions to reduce greenhouse gas emissions, including ecosystem-based solutions (NEG-ECP 2017). Plans on the implementation of this resolution are still being developed, however this resolution provides another framework to develop innovative strategies.

Why It's Important

The maintenance and possibly increased capacity of the NAPA's ecosystem-based carbon is an important component of a comprehensive conservation strategy that recognizes ecosystem services and environmental benefits along with the conservation of biodiversity and ecological integrity. Ensuring that the latest schemes to value and incorporate ecosystem-based carbon across the landscape should be part of any future conservation science work in the NAPA.

How Does this Apply to the NAPA?

Over the past decade, carbon sequestration and storage by forest, tidal wetlands, and other ecosystems in the NAPA have been recognized as an additional environmental benefit and ecosystem service to biodiversity protection for protected lands. Recent efforts to calculate the amount of carbon sequestered and stored in NAPA forests have yielded approximations that the forests offset 20% of the region's carbon dioxide emissions (Foster *et al*. 2017).

Carbon credits could be an effective incentive for private landowners to protect their forested lands and offset emissions, along with improved and sustainable forest management practices. In terms of forest carbon credits, Keeton *et al.* (2018) published: *Vermont Forest Carbon: A Market Opportunity for Forestland Owners* which is intended to encourage landowners and other entities in Vermont to consider market participation through generation of forest carbon credits (see Annex 1 for details). The report notes there are two types of carbon markets: 1) compliance schemes; and 2) the voluntary market. The authors note that the California Air Resources Board's (CARB) cap-and-trade program is the main compliance carbon market but that it requires large (e.g. 5,000 acre) forest holdings while aggregation of smaller properties is acceptable under voluntary market standards (Keeton *et al.* 2018). A modeling exercise for a hypothetical project of seven properties totaling 5,900 acres in northern Vermont estimated revenue to the landowners (after expenses) over 10 years was $943,284. This equates to $16 per acre per year for each landowner— income that could be layered on top of other revenue streams, cost share, and tax incentives.

Lastly, tidal wetlands in the NAPA contain thousands of years of stored carbon in their salt marshes and more attention should be paid to their role in sequestering and storing carbon.

Specific Recommendations:

1. **Explore the feasibility of landowners joining forces for forest carbon credits in areas that are *also* beneficial for conservation.**
2. **Compile, assess and where necessary develop finer scale carbon data, including soil carbon for the region to improve estimates and assessments. This should include both forest and "blue" (tidal wetland) carbon.**
3. **Encourage more work on the contribution of protected lands and conservation actions to avoided emissions as part of greenhouse gas mitigation plans.**

Mainstreaming

The need to mainstream biodiversity into different economic sectors, including forestry, fisheries, agriculture, mining, manufacturing, health, and tourism amongst others has been recognized for over 20 years as an effective way to highlight the importance of biodiversity in national economies (OECD 2018, Petersen and Huntley 2005). It is also seen as a mechanism to ensure the 2030 Sustainable Development Goals (SDGs) make enough references and links to maintaining global biodiversity and ecological integrity. Tools that facilitate the integration of mainstreaming consideration are now more readily available and could assist with building political buy-in for conservation efforts.

Why It's Important

The disconnect between the long-term value of protecting and securing land from exploitation and development, including intensive forestry practice to ultimately protect the biodiversity that provides clean air, water, and food and short-term economic gain is ubiquitous within governments and significant parts of the private sector. It is important to demonstrate the necessity of maintaining biodiversity for human existence. Making biodiversity a "mainstream" component of related sectors and assigning financial resources to include its consideration in sectorial plans is an important way of raising the profile and importance of conservation.

How Does this Apply to the NAPA?

In the NAPA, healthy forests and coasts are essential for the natural resource and tourism-based economies of the various jurisdictions. Cross-border nature-based tourism is a significant economic driver in the region, along with agricultural trade.

Specific Recommendation: **Where possible, encourage linkages and explicit connections to sectors that depend on and use biodiversity for economic gain in future developing conservation actions.**

Natural Climate Solutions

"Natural solutions "or "natural climate solutions" is an expression being applied more and more to elevate the role of protected lands in reducing carbon dioxide emissions in the atmosphere and their role as natural buffers against climate impacts and other disasters, space for floodwaters to disperse, healthy soil against landslides and natural barriers to disperse storm surges (Dudley *et al.* 2010). There are several guidance documents that can help scientists and planners identify how and where elements of the NAPA could be considered part of a natural solution (Griscom *et al.* 2017). Some of this work has already been started by Anderson *et al*. 2016a in their identification of protected lands for climate solutions.

Communication

The past decade as seen the importance of communicating conservation science to a wide audience of stakeholders rise in importance. This is partially out of necessity to attract more private funding in the face of declining federal and state/provincial funding in the NAPA, but also to convince private land holders and others with land interests of the value of land protection. New methods to push out science-based information, including social media and readily available geospatial data, have assisted with engaging new audiences, and gaining greater support from “other actors” in the NAPA, such as municipal leaders and politicians. It was noted however, that few, if any reports over the past decade have comprehensive communications and outreach plans associated with them. This has meant that data, information, and results may not have been as widely disseminated and acted upon as hoped. It was also noted that there were a lot of conservation plans that had become “shelf documents” and were never consulted after their completion. This was in part because there were also few or no plans associated with the dissemination of results to maximize uptake.

Why It’s Important

The communication of the threats to biodiversity, as well as solutions to protect it and the results of the various reports and analyses is very important if the value of land protection is going to be understood and appreciated outside of a small group of scientists and conservationists in the NAPA. In general, people protect what they care about, and it is as important to develop strategic and comprehensive communication plans for the dissemination of scientific-based findings and actions to engage people, as it is to develop the science.

Assertions and Assumptions

Finally, the Trombulak *et al.* (2008) report makes several assertions and assumptions on the future condition of the NAPA. We identified several of these which were valid in 2008 given the then state of knowledge and data availability. A decade on, we believe it would be interesting to investigate whether there is evidence to support these claims and assumptions or whether new assertations and assumptions dominate the current conservation-science work in the region. Although this is beyond the scope of this assessment, future work by 2C1Forest could support such an investigation. These assertations and assumptions include *inter alia*:

1. The ecoregion would serve as north-south biological corridor for species as their ranges shift in response to climate change.
2. Land use outside of the heavily settled valleys and coastlines would increase.
3. There would be a significant increase in road density across the ecoregion.
4. There could be a significant increase in human population.
5. Scale matters in developing data and analyses for an ecoregion and was the unit of scale of this analysis was useful.
6. Regardless of the metric used to prioritize land protection, there are some geographic areas that will always be identified as priority conservation areas due to their significant size and importance.
7. Structural connectivity analyses conducted are a good surrogate for functional connectivity.
8. The total amount of land in formal protection would increase from 7% and the amount secured from conversion would increase from 28% due to the conservation actions proposed in this report.

9. It would be possible to add new lands that were previously least protected such as coastal areas and lowland valleys.
10. The amount of land protected by private initiatives would increase.
11. The original emerging threats, such as atmospheric deposition, industrial effluent, physical habitat destruction, climate change, invasive species, forest tree pathogens, and geographic isolation of national parks due to intensification of land use beyond park boundaries would remain relevant.
12. The pattern of high levels of human activity separating protected areas, parcelizing large forest tracts, developing shorelines and ridgetops and increasing road infrastructure identified in the initial Human Footprint analysis would persisted.
13. The threat of in-migration to the area due to climate change and availability of large tracts of lands would materialized.
14. Practitioners and decision-makers would use this report as the basis for further analyses or actions.

8. Conclusions

Planning to Implementation

The reports and analyses reviewed identify the best opportunities for protecting and connecting terrestrial and aquatic habitats in the NAPA. Collectively they pinpoint areas with the greatest potential to sustain biodiversity, natural resources and benefits for future generations. **The challenge now is to implement conservation actions to realize these opportunities**. Experts in several jurisdictions stated that implementation was underway, and progress was being made to secure priority lands.

Good examples include the province of Nova Scotia, which has increased its protected areas from 2.5% to almost 13% in the past two decades, and the State of Vermont, which has developed its own "Vermont Conservation Design: Maintaining and Enhancing an Ecologically Functional Landscape" (Sorenson *et al.* 2015). In the case of Vermont, the Design calls for a "connected landscape of large and intact forest blocks, healthy aquatic and riparian systems and a full range of physical features (bedrock, soils, elevation, slope and aspect). When conserved or managed properly to retain or enhance ecological function into the future." (Sorenson *et al.* 2015). The implementation of actions to achieve the Design's seven components —interior forest blocks, connectivity blocks, surface waters and riparian areas, riparian areas for connectivity, physical landscape diversity blocks – rare or underrepresented, wildlife road crossings and species – conserving "nature's stage" and species of greatest conservation need—are underway and have the wide support from the state government, conservation organizations, municipalities and landowners. The goals of this Design are in step with stated ecoregional goals for the NAPA and embrace the idea that well-managed forests and farmlands, expansive protected wildlands, smart growth, and rural economic development are compatible, achievable, and mutually reinforcing in the region (Foster *et al.* 2017).

Despite these advances, there is still a large gap in securing priority land for protection, especially in:

- Areas that are grossly underrepresented in the current network of protected areas;
- New areas that have been identified as important for resiliency to address current and future threats; and
- Areas that connect important core areas.

It was estimated that, aside from significant political will and the participation of private landowners and other key stakeholders, an additional $2.3 billion is required to acquire land to meet existing conservation goals in New England (Foster *et al.* 2017, Annex 2).

Gaining ground in the NAPA now requires committed action. **Experts interviewed noted that enough visions, plans, and strategies have been developed, and even though they could always be improved upon, accelerated implementation is now warranted before options to secure lands are limited.**

Good Data and Information

Good data and information are at the core of good decisions. The NAPA has benefited from some of the best data and information for conservation decision-making available in both countries. Many groups have compiled and analyzed fine and coarse scale data and have shared their data and analyses in useful and downloadable formats. These data are of the highest quality and allow for informed decisions at all levels. There are however, **data gaps that may limit some analyses, especially those that link land protection with economic benefits and the movement towards more sustainable development in the NAPA.** There are also data gaps to measure and report on some of the emerging science issues such as understanding forest vulnerability versus resilience, connectivity, and the inter-relationships between threats such as fragmentation, forest pests and climate change. Lastly, there are data gaps to measure and report on indicators of success and impact, including data to measure management effectiveness and more importantly data to measure ecosystem response to management to ensure the desired impact of conservation actions (i.e., avoided biodiversity loss and ecological integrity).

These and other noted data gaps for both countries, although some datasets are already more readily available in one country, and in no particular order include *inter alia*:

- Data on forest vulnerability and resilience;
- Predictive data on land use change;
- Detailed land cover and land cover change at the appropriate scale—data on land cover has vastly improved over the past decade and is now available in a seamless dataset across the continent, however the time interval for change products is still long;
- Detailed maps of carbon sequestration potential for forestlands and tidal wetlands. These datasets are rapidly improving but are still based on general carbon averages for tree species and salt marshes. They are also at a coarse resolution;

- Riparian corridors;
- Information on the inter-relationships between threats such as fragmentation, forest pests and climate change;
- Current and projected transportation infrastructure;
- Traffic volume of roads;
- Comprehensive and consistent data on Annual Average Daily Traffic (AADT);
- Inventories of culverts and other structures along roads;
- Evidence of use of corridors (terrestrial, riparian and aquatic) by species of interest by tracking, remote cameras, and/or other methods;
- Wildlife crossing structures;
- Human population changes;
- Current and projected residential and commercial development maps;
- Economic valuation data linking land protection and economic benefits;
- Data to measure management effectiveness;
- Data to measure ecosystem response to management to ensure the desired impact of conservation actions; and
- Data on private land ownership to help assess forest condition, given how much of region is privately owned land.

There is also the issue that a significant amount of the analyses is based on modeling. Some models use data that are aggregated from a finer scale and interpolated. Other models produce data and results that are not necessarily useful to conservation on local scale. Datasets need to be explicit in their scale and accuracy and applied appropriately to the right question and problem.

There is a need in the NAPA for conservation groups, agencies, private landowners and other interested parties to come together to devise common definitions, standards and grid cell sizes for the different scales of analyses to facilitate the interoperability and wider application of data and results. A NAPA-wide framework for data collection and analyses could enable greater sharing and may promote more input from smaller conservation groups in the region who tend to lack capacity to "cross-walk" data and analyses that use different parameters. **This could also include principles to help guide collaborative work.**

Collaboration

The initial work for 2C1Forest in 2008 was geared towards stimulating ecoregional work, but it was also hoped that "people working at smaller scales across the region…. will learn from, apply and build upon the work" (Trombulak *et al*. 2008 p.50). In times of declining resources for conservation, it is more and more necessary to collaborate for better results. The NAPA has been an excellent example of collaboration between conservation groups however, success will now depend on **continued and new collaboration with state/provincial, Tribes/First Nations, private industry, private landowners, and other citizens**. The recent resolutions of the New England Governors and Eastern Canadian Premiers on connectivity and climate change actions is a promising start, although there have been several administrative changes since the resolution was signed and there is no budget assigned for implementation, the burden may now rest on the NAPA's conservation groups to insist on action.

In the current budgetary context, new, collaborative, and innovative funding sources will have to be pursued. In Canada, as new budgetary resources become available at the federal level, the provinces within the NAPA will have to make a strong case to ensure their share gets used for NAPA-wide activities that support the most urgent conservation activities. New tactics such as involving municipalities to help acquire lands, especially those that provide benefits and ecosystems services to those municipalities such as water supply, will have to be developed. Tax revenues, relief (e.g., the proposed "Ecogift" in Canada for private landowners (NAP 2018)) Green Nature Conservation bonds (NAP 2018), and user fees should also be examined in different jurisdictions. **Bold new links must be made to the multiple benefits of land protection such as climate change adaptation and mitigation, as well as disaster risk reduction, so that conservation groups can access climate change mitigation and adaptation funds and ecosystem-carbon markets, along with private philanthropy directed at climate change.**

9. Recommendations

This assessment looked at developments in land protection over the past decade in the NAPA, challenges and opportunities, advances in conservation sciences, conclusions, and the status of assertions and assumptions from the initial 2008 2C1Forest report (Trombulak et al. 2008).

Several specific and general recommendations aimed at the broader NAPA conservation community have been made throughout this assessment. The main ones include:

1. Establish a set of shared conservation targets, goals, and definitions across the region. These should at a minimum adhere to international standards and conventions (e.g., Aichi Targets), but could be much more aspirational.
2. Agree on a set of metrics to measure the impacts of conservation and development. These metrics should include the positive effects of protected areas, such as avoided biodiversity loss and maintenance of ecological integrity. Ensure that measurement data are incorporated in policy, planning, and management decisions, and that they are regularly updated.
3. Move from prioritization exercises to action on the ground. There are already many prioritization analyses in the NAPA and some have only had limited distribution and uptake in the region. Options are diminishing to acquire land in priority areas and thus action must be accelerated.

4. Maximize limited resources, both human and financial, by increasing collaboration among government agencies, conservation organizations, community groups, municipalities, private landowners.
5. Expand the parameters and data for science-based work to include more socio-economic variables, including valuation of ecosystem services and environmental benefits and factors transforming the land (e.g., development, water issues, in-migration and rural de-population, and transportation infrastructure).
6. Continuously evaluate the scale of analyses and interventions to ensure local priorities are being met, and that they fit into the larger regional perspective of a well-connected and resilient ecoregion.
7. Ensure all ecoregion data and analyses are shared in one platform—or at least linked to one platform—to make all products more accessible and useful. Some products are already on 2C1Forest's space on the Data Basin platform, which could be the ideal location to share all data, in addition to organization specific websites.
8. Re-assess or cross-walk various analyses and how they correlate or not. Doing a GIS analysis of various priorities and results of analyses would help clarify if various analyses are identifying the same priorities.
9. Build political support for increased public investment in protection and conservation work across the region.

The following are some specific recommendations for relatively low-cost, shorter-term analyses that could be conducted by 2C1Forest or its partners:

1. Where and when appropriate and feasible, facilitate a NAPA-wide dialogue on how to best collaborate and cooperate for the next decade of conservation science and action.
2. Canvas local conservation groups and land trusts on their specific targets and goals for the region, develop clarity of terms and craft or support the crafting of some overall and agreed to joint statements on biodiversity targets, ecological integrity and climate resiliency to help shape a united vision for the future. If specific targets cannot be agreed to, collaborate where possible on common targets and goals that are as precise as possible.
3. Asses and track management effectiveness. Protected lands are only effective if they are managed purposefully.
4. Evaluate impact of efforts to date in terms of avoided biodiversity loss and other metrics that demonstrate cost-effectiveness and wise investments in natural capital and conservation.
5. Reach out to and work with other groups working on environmental valuation to better integrate evaluation parameters and socio-economic measures.
6. Invest in dissemination and communication of existing and future work. There is some lack of shared knowledge of past and current work, including the availability of datasets.

Many local conservation groups develop their own datasets due to a lack of awareness of existing sets or a lack of trust in those datasets as they were not involved and do not understand how they were developed, as noted earlier. Every effort should be made, including face-to-face meetings and other networking tools, to improve information flows within and between jurisdictions, including across the international border.

Some specific recommendations for bigger projects that 2C1Forest could catalyze by bringing consortiums together or seeking partners

Conservation success in the NAPA is beyond the scope of any single organization. Recommendations for bigger projects include:

1. Work with municipalities and state/provincial planners to develop a harmonized, ecoregional-scale dataset of roads and other fragmenting features (e.g., pipelines). Identify the relevant metrics, such as traffic volume and distribution, that capture the degree of impact of this infrastructure on species movement. Look for win-win scenarios where enhancing infrastructure to mitigate flooding and other extreme events will also improve species movement around transportation infrastructure.
2. Share lessons learned, methodologies and results in a consistent and regular manner to ensure consistent and interoperable data and analyses. A good example of this already occurring is the NCC following the same stream and water body classification as TNC in the U.S. to ensure comparable results. Habitats, species, rivers and roads don't stop at the border. This could also include sharing methodologies for attracting and retaining private land owners in conservation schemes, including ways to better leverage funds and results of past successes such as the Nova Scotia Crown Share Land Legacy Trust.
3. Build scenarios and projections of land use and land cover change in light of changing climate conditions, resiliency metrics and species requirements to better understanding the changing landscape in the region.

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Annex 1. Summaries of Main Analyses and Datasets

There have been extensive scientific analyses for conservation in the Northern Appalachian-Acadian Ecoregion (NAPA). Many of the recent analyses are for much broader regions, including for all of eastern North America or for all of the eastern United States. The focus of these analyses expanded in terms of scope as well; there are many studies on aquatic systems and on resilience and connectivity. This appendix provides a summary of the main analyses and geographic information (GIS) datasets that have been undertaken in the decade since the 2008 *The Northern Appalachian/Acadian Ecoregion: Priority Locations for Conservation Action* by Two Countries, One Forest that overlap the NAPA.

The following pages group products by organizations and type of study/focus. Complex projects with multiple analyses and data, or interrelated projects, are prefaced by an introductory section. All reports, guides, datasets and interactive maps are hyperlinked to their online location for easy retrieval/reference. Figures are used where possible to illustrate the geographic coverage of the analysis/dataset.

NORTHEAST AQUATIC HABITAT CLASSIFICATIONS SYSTEM FOR THE NORTHEAST UNITED STATES

The Nature Conservancy (TNC) developed a freshwater habitat classification system that covers the 13 Northeast States, and the District of Columbia. The resulting habitat maps and datasets unite disparate state classification systems into a single scheme for analysis of stream and lake processes, freshwater conservation, and climate change and scenario modeling. These classifications are invaluable in regional freshwater conservation work because they:

1) Provide common definitions and mapping of aquatic habitat types across state lines.
2) Facilitate a new understanding of aquatic biota and populations on a regional scale by linking biological datasets to the regional aquatic habitat types for reporting and analysis
3) Create new opportunities to assess the condition and prioritize habitats at a scale broader than the individual state by linking and reporting information on dams, land use, conservation lands, impaired waters, and other condition metrics by the regional aquatic habitat types

Products in this system were developed over a number of years, and consist of both river and stream, and lake and pond materials, with some products updated/modified over time. The following few pages provide an overview of the main analyses, including reports and GIS data packages available, with hyperlinks to their web location for easy retrieval.

A Nature Conservancy of Canada (NCC) stream and river classification product description follows, as it builds on the TNC methods and creates a product for the Canadian portion of the NAPA.

1) STREAMS AND RIVERS

Type	Name
Report	Olivero, A. and M.G. Anderson. 2008. *Northeast Aquatic Habitat Classification System*. Boston, MA: TNC.
Data package	NEstreamClassificationData2008 Initial 2008 Northeast Stream Classification Dataset Package includes shape and layer files, and attribute tables.

Description: In 2008, The Nature Conservancy, in conjunction with the Northeast Association of Fish and Wildlife Agencies, developed the Northeastern Aquatic Habitat Classification System (NAHCS) and GIS dataset for 13 northeastern states. The classification was designed to identify and map consistently the natural aquatic (flowing water) habitats of the region in a manner deemed appropriate and useful for conservation planning by the participating states and thus to facilitate the conservation of these features across the participating states. It was not intended to override local stream classifications but rather to put them into a broader context. It integrates state-based classifications into a single system that provides context for understanding the extent, distribution, threats, and conservation status of streams and rivers in the region.

The aquatic habitat types were structured after a macrohabitat level of classification which defines individual stream reach or lake types based on variables that influence aquatic communities at the reach scale and that can be modeled in a geographic information system. The reach-scale habitat types are designed to be relatively homogeneous with respect to potential energy and nutrient dynamics and overall habitat structure.

The project mapped and classified every stream or river segment in the region based on four attributes:

1) *Size*: the area drained by the stream.
2) *Gradient*: the steepness of the stream channel.
3) *Geologic Buffering Capacity*: capacity of water to resist changes in pH that would make it more acidic.
4) *Temperature*: the mean summer water temperature.

The results included seven size classes, six gradient classes, three geology buffering classes, and four water temperature classes. Of the 312 possible combinations possible given these variables, 259 unique combinations actually occurred in the 13-state region, with 208 having more than10 km of length occurring. They developed rules for simplifying the aquatic types, and provide simplified taxonomic layers. The flexibility of the system allows users to develop maps and analysis for specific purposes.

This project did not include a lake habitat classification, however a lake dataset and simple lake habitat classification based on size was provided. Additionally, the lake polygons are coded with useful habitat descriptors such as geology, elevation, shoreline sinuosity, and connectivity.

Coverage: 13 Northeast States (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia

2) AQUATIC HABITAT GUIDE PROJECT

Type	Name
Report	Anderson, M.G., M. Clark, C.E. Ferree, A. Jospe, A. Olivero Sheldon and K.J. Weaver. 2013. *Northeast Habitat Guides: A companion to the terrestrial and aquatic habitat maps*. Boston, MA: TNC.
GIS package	Distribute_habitatguide Package contains dataset and layer for simplified 23 stream/river types.
Online map service	Stream Classification Map depicts 23 habitat types. User can explore attributes of each river and stream.

Description: The objective of this classification was to create a simplified set of stream and river habitat types based on the NAHCS and GIS map (see previous entry) for the 13 northeastern states that could be used in a Northeast Stream and River Habitat Guide. The project collapsed the original 258 types down to 23 types. The habitat guide contains a description of each stream and river type, a distribution map, a photo, associated common and rare species, a crosswalk to state aquatic community types, and a summary of current condition information.

The Nature Conservancy developed a 58 type simplification that used size, gradient, geology, temperature, and tidal classes. For the general audience of the habitat guide, the 58 types were collapsed further into 23 major types by collapsing geology classes for headwaters through small rivers and collapsing the gradient classes for medium to large rivers. Habitats are organized by macrogroups (headwaters and creeks, small rivers, medium rivers, large rivers, and tidal rivers) defined by stream size and tidal class.

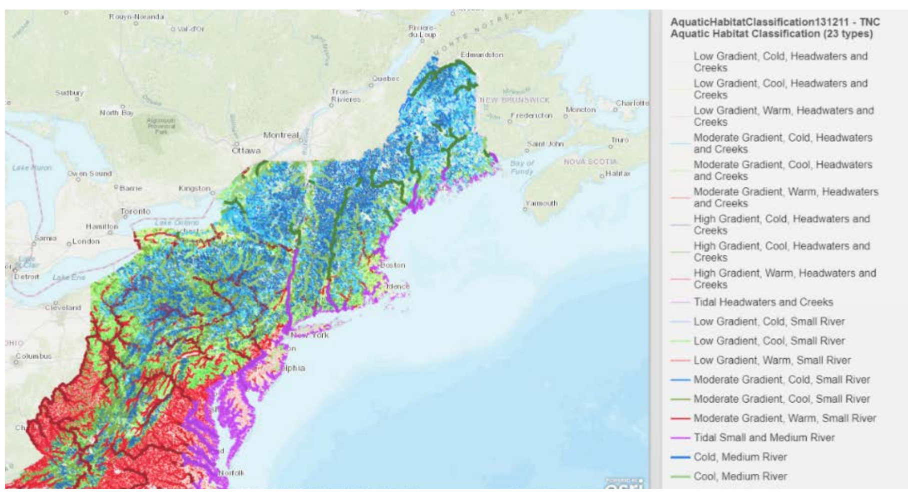

Figure 2. Screenshot from interactive map of streams and rivers.

The intention was to focus the general audience on the more dominant patterns of size, gradient, and temperature for headwaters through small rivers and on the dominant patterns of size and temperature variation within these larger rivers.

Coverage: 13 Northeast States (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia)

3) LAKE AND POND CLASSIFICATION

Type	Name
Report	Olivero-Sheldon, A. and M.G. Anderson. 2016. *Northeast Lake and Pond Classification*. Boston, MA: TNC.
Report (Guide)	Olivero-Sheldon, A. and M.G. Anderson. 2016. *Northeast Lake and Pond Habitat Guide*. Boston, MA: TNC. There are two page habitat summaries for each of the 18 lake and pond types.
GIS data package	DISTRIBUTE_gis_12_2015 Package contains point and polygon shape files, layer files that provide colors for use in GIS, and XLS attribute tables.
Interactive Map Journal	Northeast Lakes and Ponds Classification Users can read about the product and explore lake and pond types in the on-line map.

Description: The 2008 Northeast Aquatic Habitat Classification System (see entry 1 above) focused primarily on streams and rivers. To address this gap, The Nature Conservancy developed a mapped classification of Northeast lakes and ponds in 2014, which they then updated in 2015 based on expanded modeling using new information. The classification of lakes and ponds is based on variables that structure lacustrine natural communities and that could be mapped consistently across the Northeastern US. Every waterbody in the region was mapped and classified based on four attributes:

1) *Depth*: the degree to which light penetrates and whether there is a permanent dark zone.
2) *Temperature*: the coldest summer temperature
3) *Alkalinity*: the degree to which the lake is buffered from acidification (similar to pH).
4) *Trophic Status*: the productivity or "nourishment" of the lake. Hypereutrophic lakes have two much enrichment resulting in algal blooms and oxygen loss. Oligotrophic lakes are cold and clear.

Water temperature was mapped into three classes (very cold, cold, and warm-cool). Trophic states were mapped into two classes. Alkalinity was grouped into three classes (high, medium, low). Depth was divided into two classes (lake, pond). TNC generated over 300 descriptive attributes for each waterbody. They used data from sampled sites to develop a predictive model for each variable class and then extrapolated the model to the unsampled waterbodies to estimate their class.

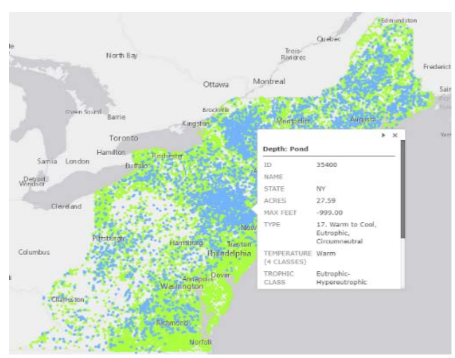

Figure 3. Screenshot of interactive map of lakes and ponds

All waterbodies were assigned to one of 18 classification types based on the combination of 3 variables (temperature + trophic + alkalinity class). These types can be further subdivided into lake or pond categories to yield mapped occurrences, for example: cold, oligo-mesotrophic, low alkalinity, lake. The resulting classification of waterbodies were added to the existing Northeast Aquatic Habitat Classification of streams and are described in the *Northeast Lake and Pond Habitat Guide*.

Coverage: 13 Northeast States (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia)

STREAM CLASSIFICATION FOR THE NORTHERN APPALACHIAN-ACADIAN REGION OF CANADA

Type	Name
Report	Millar, W. and A. Olivero-Sheldon. (2017). *Stream Classification for the Northern Appalachian–Acadian Region of Canada*. Fredericton, New Brunswick: Nature Conservancy of Canada.
GIS data package	NCC Stream Classification The map package contains: 1) a base hydrography layer with variable thresholds for 5 biophysical characteristics for each flowline, 2) 8 feature layers for symbolizing hydrography into ecologically meaningful combinations, and 3) a DBF table containing input variables for more detailed analyses.
Interactive Map	NCC Stream Classification Users can explore information for individual streams and rivers on the on-line map.

Description: With the assistance of a core team of freshwater experts from both the US and Canada, the Nature Conservancy of Canada developed and mapped a hierarchical classification of rivers and streams for all watersheds within the Maritimes and eastern Quebec, as well as for those watersheds that cross the Canadian border into the United States. The classification is based on five biophysical characteristics that influence the distribution of aquatic biodiversity: size, gradient, temperature, alkalinity, and tidal influence. This GIS dataset was developed to be both seamless within and across provincial boundaries, whilst also complimenting the Northeast Aquatic Habitat Classification.

The analysis was designed to spatially identify natural freshwater habitat types for conservation planning and management purposes. The intended uses of the classification include:

1) Providing common definitions across provincial and state boundaries to facilitate collaborative opportunities,
2) Improving provincial-scale activities by providing governments and non-governmental organizations with aquatic planning tools where none previously existed,
3) Generating new knowledge on aquatic biodiversity patterns using the classification as a starting point for inquiry,
4) Further developing aquatic tools to assess aquatic health, determine conservation and restoration priorities, and facilitate connectivity and climate change adaptation planning.

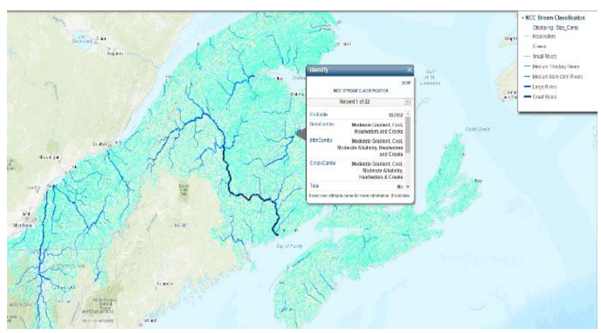

Figure 4. NCC stream classification interactive map

Coverage: Canadian portion of the Northern Appalachian-Acadian Ecoregion of Canada (New Brunswick, Nova Scotia, Prince Edward Island, and portions of Quebec), as well as for those watersheds that cross the Canadian border into the US states of Maine, New Hampshire, Vermont, and New York.

FLOODPLAIN ASSESSMENT: "ACTIVE RIVER AREA"

Type	Name
Report	Smith M.P., R. Schiff, A. Olivero, and J. MacBroom. 2008. *The Active River Area: A Conservation Framework for Protecting Rivers and Streams*. Boston, MA: TNC Report outlines scientific rationale and methods for the Active River Area framework.
Data package	Full Region Final Data,ARA_RIP_ALL_090810 Northeast and Mid-Atlantic regional ARA map (30 meter pixels)
Toolbox	ArcGIS_ARA_3SC_Toolbox_21Dec2011 This toolbox contains models that can be used to delineate Active River Area components for a user-defined study area. Accompanied by A. Barnett. 2011. ARA *Three-Stream Class Toolbox Documentation* (40 pp).

Description: The Active River Area (ARA) conservation framework provides a conceptual and spatially explicit basis for the assessment, protection, management, and restoration of freshwater and riparian ecosystems. "Active" indicates the dynamic and disturbance-driven processes that form and maintain river and riparian systems and their associated habitats and habitat conditions. "River area" represents the lands that contain both of aquatic and riparian habitats and those that contain processes that interact with and contribute to a stream or river channel. The active river area framework offers a more holistic vision of a river than solely considering the river channel as it exists in one place at one particular point in time.

The ARA framework is based upon dominant processes and disturbance regimes to identify areas within which important physical and ecological processes of the river or stream occur. The framework identifies five key subcomponents of the active river area: 1) material contribution zones, 2) meander belts, 3) riparian wetlands, 4) floodplains, and 5) terraces. These areas are defined by the major physical and ecological processes associated and explained in the context of the continuum from the upper, mid and lower watershed in the ARA framework paper. The framework provides a spatially explicit manner for accommodating the natural ranges of variability to system hydrology, sediment transport, processing and transport of organic materials, and key biotic interactions.

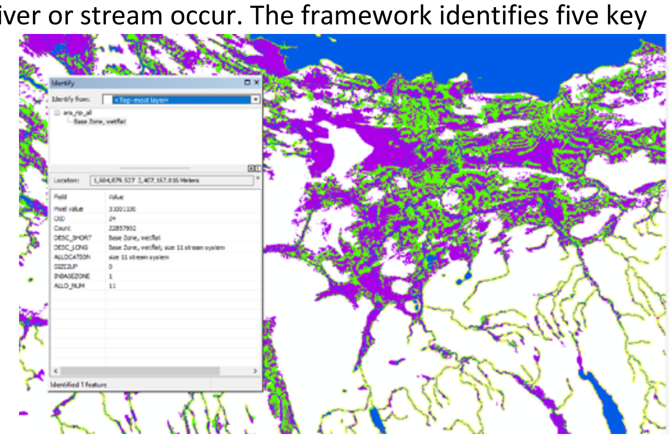

Figure 4. Sample ARA data

The physical processes and key attributes described below are key drivers of riverine and riparian habitat formation, habitat conditions and of their ecological integrity. River and riparian habitat is constantly being created, changed, destroyed, and maintained as a result of the processes associated with the hydrologic regime, sediment transport, and organic and inorganic material processing.

Coverage: 13 Northeast States (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia)

VERIFYING SEASONAL FLOODING

Type	Name
Data package	seasonal_flooding_analysis_results This 2009 package contains documentation on methods and results, GIS results, and various attribute files for use in GIS software.

Description: Scientists have developed methodologies for evaluating the extent of current flooding across large areas have been developed using processed satellite imagery, specifically Landsat Thematic Mapper imagery. Identifying seasonal flooding (that is, areas flooded in the spring yet dry in the fall) requires imagery from both a spring flooding event and an autumn dry period. To this end, The Nature Conservancy acquired and processed Landsat Thematic Mapper imagery (TM 4-5 or TM ETM+) on a high flow and low flow day for each of 53 scenes covering parts of 17 states in the Northeast and Mid-Atlantic.
Gage data was used to identify available images with low and high flow. They analyzed over 183 gages of data.

Many of the potential floodplain occurrences were located on sections of the mainstream rivers and its tributaries where the hydrology has been altered in varying ways, sometimes radically. To identify the most ecologically intact examples, and the examples most readily restorable, TNC wanted to determine which occurrences still experience some level of seasonal flooding.

The analysis within the 14 tile extent yielded the following mapped areas:

1) Area of definite floodplain/definitely inundated: 1,920,408.17 acres
2) Area of possible floodplain/possibly inundated: 2,651,131.34 acres
3) Area of stable water: 44893446.41 acres
4) Area of non-floodplain/upland (not inundated): 238,515,434.65 acres.

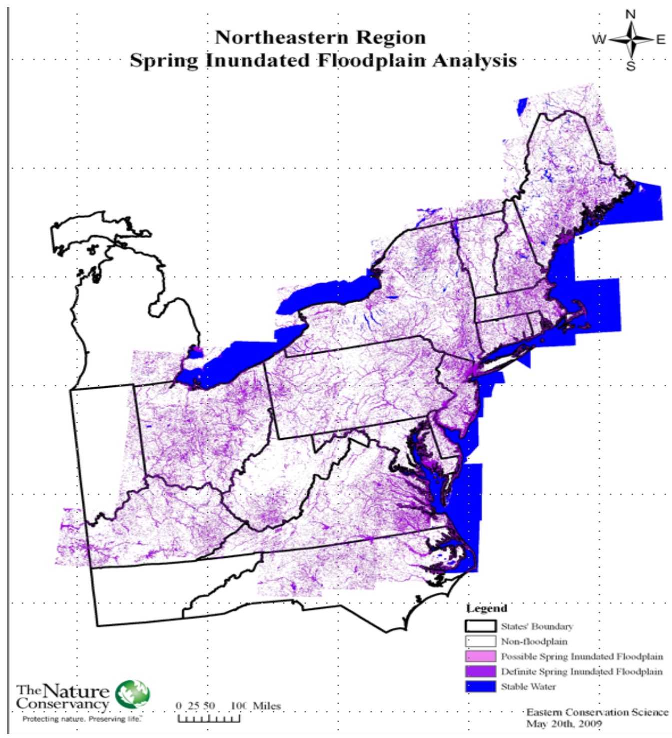

Figure 5. Seasonal flooding results

Coverage: 14 Northeast States (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Ohio, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia)

FRESHWATER RESILIENCE

Type	Name
Report	Anderson, M.G., A. Olivero Sheldon, C. Apse, A.A. Bowden, A.R. Barnett, B. Beaty, C. Burns, D. Crabtree, D. Bechtel, J. Higgins, J. Royte, J. Dunscomb, and P. Marangelo. 2013. *Assessing Freshwater Ecosystems for their Resilience to Climate Change*. Boston, MA: TNC.
Data package	FW_resilience_package__May 2013 update This 2017 package contains an ArcGIS map document, stream network layers and shape files, fish regions, freshwater regions, and excel tables of attributes.

Description: Resilient freshwater systems are those that continue to sustain diversity and ecological services as they adapt to climatic change. These rivers have extensive longitudinal connectivity linking tributaries of many sizes, gradients and temperatures, good lateral connectivity linking them to their floodplain, and relatively unaltered natural flows within a permeable watershed. The Nature Conservancy examined connected stream networks in the Northeast and Mid-Atlantic area of the U.S. for seven characteristics correlated with resilience. These included four physical properties (network length, number of size classes, number of gradients classes and number of temperature classes), and three condition characteristics (risk of hydrologic alterations, natural cover in the floodplain, and amount of impervious surface in the watershed). These characteristics ensure that a stream network encompasses a diversity of environments, allows aquatic species to migrate and find suitable habitat, has clean water delivered to the channel, and that water, nutrients and sediment are stored on the floodplain. A network was defined as a continuous system of connected streams bounded by dams or upper headwaters.

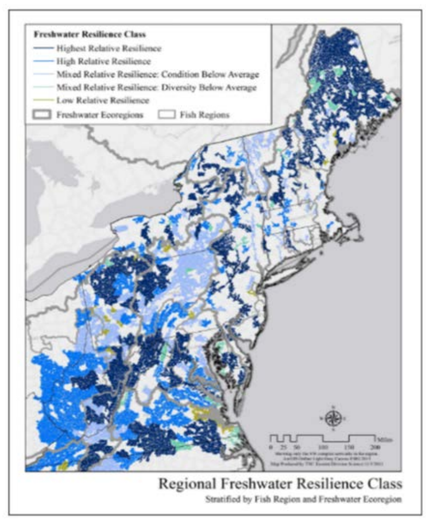

Figure 6. Freshwater resilience

TNC scientists scored an initial source population of 1,438 networks that all contained a small river (>= 100 sq.km in drainage area) based on these seven characteristics, and identified a subset of 356 complex networks that contained over four different size classes of streams or lakes. Within each freshwater ecoregion and within smaller fish regions), they identified the set of these complex networks that scored above average. They then compared the set of above-average networks against the set of rivers identified by TNC based on their high quality biodiversity features.

Results indicated there was a 63% overlap between streams identified for their biodiversity features and those that scored above-average for their resilience characteristics. The later networks are strongholds of current and future diversity, making them good places for conservation action. Lower scoring stream networks should be carefully evaluated with respect to their long term conservation goals. The results can be used to explicitly guide land acquisition, inform watershed management, and prioritize dam removals towards the goal of sustaining or increasing the resilience of freshwater systems. This analysis builds on stream/river classification in the northeastern US and the aquatic connectivity, initially completed in 2011 (updated in 2017 as described in next entry).

Coverage: 14 Northeast States (Maine, New Hampshire, Vermont, New York, Massachusetts, Rhode Island, Connecticut, Pennsylvania, Delaware, New Jersey, Maryland, Ohio, West Virginia, and Virginia)

NORTHEAST AQUATIC CONNECTIVITY PROJECT

Type	Name
Report	Martin, E.H. and J. Levine. 2017. *Northeast Aquatic Connectivity Assessment Project - Version 2.0: Assessing the ecological impact of barriers on Northeastern rivers*. Brunswick, ME: TNC.
Report	Martin, E.H. and C. D. Apse. 2011. *Northeast Aquatic Connectivity: An Assessment of Dams on Northeastern Rivers*. The Nature Conservancy, Eastern Freshwater Program. (Initial report of aquatic connectivity for northeast. Updated in 2017.)
Data packages	NEAquaticConnectivity_GIS and NEAquaticConnectivity_Excel GIS and excel packages of 2017 analysis are available for download from the tool website.
Map Tool	Aquatic Barrier Prioritization Tool Users can select the degree of barrier severity to assess and select a state to see a summary of the status of aquatic connectivity in that state or click on an individual barrier to get a summary of its ecological attributes.

Description: The fragmentation of river habitats through dams and poorly functioning culverts is one of the primary threats to aquatic species in the United States. The impact of fragmentation on aquatic species generally involves loss of access to quality habitat for one or more life stages of a species. For example, dams and impassable culverts limit the ability of anadromous fish species to travel from the sea to their preferred freshwater spawning habitats. The purpose of the Northeast Aquatic Connectivity project is to explore the barriers (dams and road crossings) to aquatic connectivity in thirteen northeastern states.

First completed in 2011 and revised in 2017 to incorporate road-crossing crossings as well as dams, the project assessed over 200,000 barriers in these states for their potential benefit to anadromous fish if removed or mitigated. Both road-stream crossings and dams were spatially linked to flowlines in the USGS National Hydrography Plus (NHD-Plus) dataset. These barriers form the primary input dataset for the 2016 version of the Northeast Aquatic Connectivity analysis. 38 ecologically-relevant metrics were calculated and used in the barrier prioritization. As not all road stream crossings are equal barriers to fish and other aquatic organisms, barrier severity is split into 5 classes: Severe, Significant, Moderate, Minor and Insignificant.

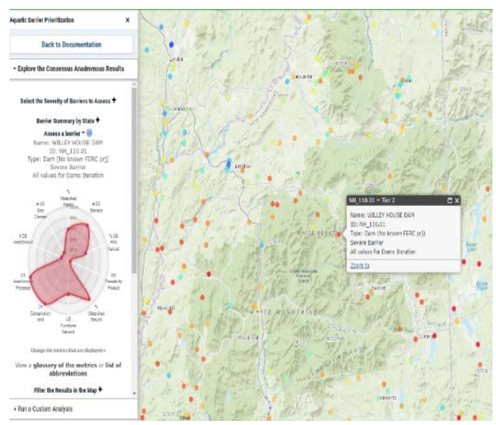

Figure 7. Sample of the aquatic barrier tool

The Freshwater Northeast Region website houses the Northeast Aquatic Connectivity project tool for exploring in-stream barriers to aquatic connectivity and identifying opportunities for connectivity restoration projects. In the tool, the size of a point indicates how passable a barrier is (e.g. a "Severe" barrier, such as a dam or a culvert, is shown as a large point, while an insignificant barrier, such as a culvert, is shown as a small point). The color of the point indicates its priority as an anadromous fish restoration project. Tier 1 barriers (red) are the highest priorities -- most potential gained from a passage restoration project -- while Tier 20 barriers (blue) are the lowest priority.

Coverage: 13 Northeast States (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia)

TERRESTRIAL HABITAT MAP FOR THE NORTHEAST US AND ATLANTIC CANADA

Type	Name
Report	Ferree, C. and M. G. Anderson. 2013. *A Map of Terrestrial Habitats of the Northeastern United States: Methods and Approach*. Boston, MA: TNC, Eastern Conservation Science, Eastern Regional Office.
Poster	*Extending the Terrestrial Habitat Map to Atlantic Canada*
Habitat Guide	Anderson, M.G., M. Clark, C.E. Ferree, A. Jospe, A. Olivero Sheldon and K.J. Weaver. 2013. *Northeast Habitat Guides: A companion to the terrestrial and aquatic habitat maps*. Boston, MA: TNC.
Data package	HABITAT_neUS_eCANADA Data package consists of a GIS dataset and layer files, and a document that provides an updated list of fields and definitions for the NE US and eastern Canada.
Interactive map	NE U.S. and Eastern Canada Habitat Web Map This map allows the user to explore site resiliency, including the user's own area of interest through drawing a polygon or adding a GIS shapefile.

Description: Various organizations participated in the creation of The Northeast Terrestrial Habitat Classification System and GIS Map. These groups developed these products as a comprehensive and standardized representation of habitats for wildlife that would be consistent across states and consistent with other regional classification and mapping efforts. It is based on the ecological systems classification created by NatureServe. These habitat systems are intended to be applicable at medium and large scales, and to supplement the finer-scale approaches used within states for specific projects and needs. The map and guides are not intended to replace or override state classifications or habitat type, but rather to put them into a broader context.

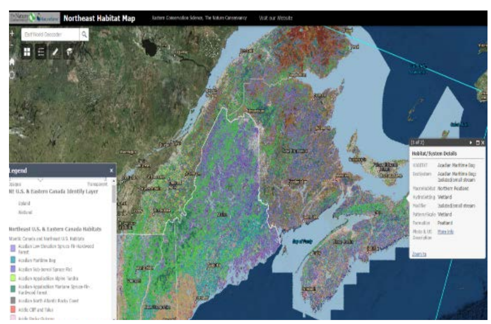

Figure 8. Terrestrial habitat map for the NE US

The Northeast US and Atlantic Canada share many of the same types of forests, wetlands, and natural communities and from a species perspective, the region is one contiguous forest. As resources are classified and mapped differently on the two sides of the border creating challenges for species modeling and ecosystem evaluation, ecologists from TNC collaborated with a committee of scientists from various Canadian institutions to produce an international map of terrestrial habitats for the region. The project used extensive spatial data on geology, soils, landforms, wetlands, elevation and climate. Additionally, all four provinces contributed spatially comprehensive forest inventory data depicting the exact tree composition of individual forest stands and the Atlantic Conservation Data Centre contributed spatial locations of over 16,000 species locations including herbaceous plants, mammals and birds.

The resulting map was integrated with the US map and released as a single dataset in spring 2015. The dataset maps the type and distribution of 140 types of forests, wetlands, unique communities and tidal systems, based on NatureServe's "ecological system" concept.

Coverage: Northeast U.S and eastern Canada, including all of the Northern Appalachian-Acadian Ecoregion

GEOSPATIAL CONDITION ANALYSIS (HABITAT CONDITION)

Type	Name
Report	Anderson, M.G., M. Clark, C.E. Ferree, A. Jospe, and A. Olivero Sheldon. 2013. *Condition of the Northeast Terrestrial and Aquatic Habitats: a geospatial analysis and tool set*. Boston, MA: TNC.
Geospatial database and tool	Inputs_geodatabase Results_geodatabase The tool set provides the user with a comprehensive dataset of fine-scale units (blocks bounded by minor roads and stream segments) that can be queried with user-defined criteria for habitat types and condition characteristics.

Description: The goal of this project was to assess the condition of 116 terrestrial and aquatic habitats in the Northeast United States and provide tools for state agencies and conservation organizations to evaluate the condition of specific habitats within their state. The project is based on the Northeast Terrestrial Habitat Map and the Northeast Aquatic Habitat Classification and their accompanying datasets. The project used newly released region-wide spatial datasets that illustrate a facet of the region's ecological condition such as predicted loss to development, securement from development, forest stand age, and number of dams, as well as datasets developed specifically for this assessment such as habitat patch size and amount of core area.

The deliverables from this analysis include: a report, a database, and a geospatial tool. The report contains an analysis of 116 habitats with respect to 14 regionally assessed condition metrics. It contains information about the condition and threats to 116 Eastern Habitats including 96 terrestrial upland and wetland habitats and 23 stream and river habitats. The report has two major sections:

1) Condition Metrics: A description of 14 ecological condition metrics and comparative results of the metric as applied to the terrestrial and aquatic habitats.
2) Geospatial Units and Tools: a database and tool to query the region for habitats that meet specific criteria, or to evaluate a particular area for its habitats and condition attributes.

The condition metrics were selected to indicate important aspects of the condition of the terrestrial and aquatic habitats. They include: 1) s*hared metrics* (securement, local connectedness, landscape context index, predicted loss to development, 2) t*errestrial metrics* (stand age, patch size, landscape complexity, core area), and 3) f*reshwater metrics* (impervious surface, riparian landcover, dam types and density, risk of flow alteration, network size and road stream crossings).

The GIS tool is designed to let users locate places in the region that meet user-determined condition criteria.

Coverage: 13 Northeast States (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia)

TNC RESILIENCY AND CONNECTED LANDSCAPES PROJECT

The Nature Conservancy's Resilient and Connected Landscapes project is the first study to comprehensively map resilient lands and significant climate corridors across Eastern North America. Released in October 2016, the study took eight years to complete, involved many scientists, and developed innovative new techniques for mapping climate-driven movements. The project consisted of various components, including the mapping of resilient sites, climate corridors, and movement zones to design connected landscapes that facilitate range shifts. The next few pages summarize the analysis and products in two parts: 1) Resilient Sites for Terrestrial Conservation, and 2) Resilient and Connected Landscapes.

1) RESILIENT SITES FOR TERRESTRIAL CONSERVATION

Type	Name
Report	Anderson, M.G., A. Barnett, M. Clark, C. Ferree, A. Olivero Sheldon, and J. Prince. 2016. *Resilient Sites for Terrestrial Conservation in Eastern North America*. Boston, MA: TNC.
Data package	Final_Resilience_Score Data package consists of a geodatabase and layers for coastal resiliency, landscape diversity score, local connectedness, and a final resilience score.
Interactive map	Resilient Land Mapping Tool This map allows the user to explore site resiliency, including the user's own area of interest through drawing a polygon or adding a GIS shapefile.
Story map	Resilient Sites for Terrestrial Conservation This story map provides an overview of the methods and results for the resilient site analysis in a dynamic manner with easy to follow summaries.

Description: Climate change is creating an increasingly dynamic natural world and conservationists need a way to identify important areas for protection that does not assume that the locations of existing plants and animals will stay the same. A Resilient Site is an area of land with sufficient variability and microclimate options to enable species and ecosystems to persist in the face of climate change and which will maintain this ability over time. Sites are identified across all geophysical settings that have land characteristics (landscape diversity and local connectedness) that increase resilience to climate change. Climate-resilient sites are more likely to sustain native plants, animals, and natural processes into the future.

TNC undertook an extensive and phased approach to mapping resilient sites for terrestrial conservation. Initial reports and datasets were released in 2012 for the Northeast and Mid-Atlantic Region and Southeast of North America. These were updated in 2016 and released as a single dataset and report for all of eastern North America. The 2016 dataset and report updates the resilience analysis with improved and unified methods. The method to identifying climate-resilient sites had several steps:

1) Geophysical Settings: Identification of 61 distinct environments based on elevation, geology, and soil.
2) Landscape Diversity: Mapping of areas that have a high diversity of microclimates based on their topography, wetland density and elevation range.
3) Local Connectedness: Mapping of areas that were highly connected by natural cover.
4) Resilience: Combined above datasets to identify the places with the highest landscape diversity and local connectedness within each geophysical setting.

The areas identified represent natural strongholds for diversity because they contain many microclimates in a highly connected area which creates climate options for species allowing them to persist. A site's Resilience Score estimates its capacity to maintain species diversity and ecological function as the climate changes. The score is relative to all other sites with the same geophysical setting and is described on a relative basis as above or below average. The goal was to identify the places most resilient to climate change for each type of setting.

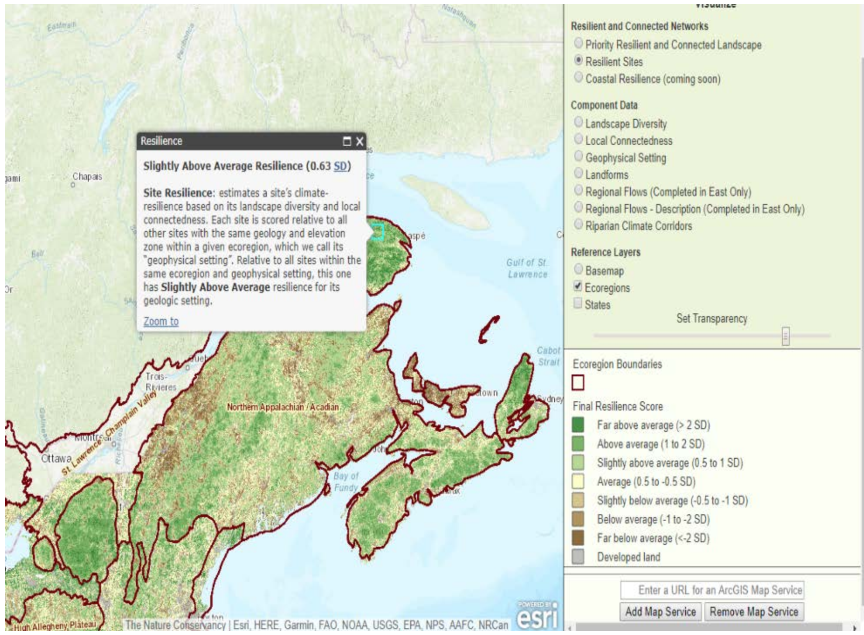

Figure 9. Interactive map tool displaying resilient sites in Northern Appalachian-Acadian

The analysis complements other conservation tools that assess species and habitats because this analysis focuses on the properties of the land itself. The results help decision-makers ensure that the places conserved today will support a diversity of plants and animals tomorrow. Resilience science can guide land acquisition, restoration, and management practices.

Coverage: Eastern North America, including all of the Northern Appalachian-Acadian Ecoregion

2) RESILIENT AND CONNECTED LANDSCAPES

Type	Name
Report	Anderson, M.G., Barnett, A., Clark, M., Prince, J., Olivero Sheldon, A. and Vickery B. 2016. *Resilient and Connected Landscapes for Terrestrial Conservation*. Boston, MA: TNC.
Data package	Resilient and Connected Landscapes Data package consists of a geodatabase, layers for a prioritized network, and resilient and connected landscape classes.
Interactive map	Resilient Land Mapping Tool This map allows the user to explore site resiliency, including the user's own area of interest through drawing a polygon or adding a GIS shapefile.
Story map	Resilient and Connected Landscapes This story map describes the methods for identifying the resilient and connected landscapes in a dynamic manner with easy to follow language.

Description: The resilience analysis described above focused on sites, but scientists have long understood that the connections between and among sites are critical to sustaining diversity under a changing climate. How populations move across the region, and where the critical connectors are, is the topic of this analysis and report. The resilient and connected landscapes analysis brings together resilience, permeability, and diversity to develop a connected network of sites that both represents the full suite of geophysical settings and has the connections necessary to support the continued rearrangement of species in response to change. The most climate-resilient sites are buffered from the effects of climate change because the site offers a wide range of micro-climates within a highly connected area. They are areas of diverse topography, bedrock, and soil, and are more likely to sustain native plants, animals, and natural processes into the future, becoming natural strongholds for diversity.

The analysis identifies resilient areas, climate corridors, and climate flow zones. In addition, each of these areas with confirmed diversity are identified. The dataset includes a prioritized network that encompasses 24.4 % of the total study area. It is a prioritized subset of the Resilient and Connected Landscapes that includes: Resilient Areas with Conserved Lands, Resilient with Confirmed Diversity, Climate Diversity, Climate Flow Zones, Climate Flow Zones with Confirmed Diversity, and Climate Corridors.

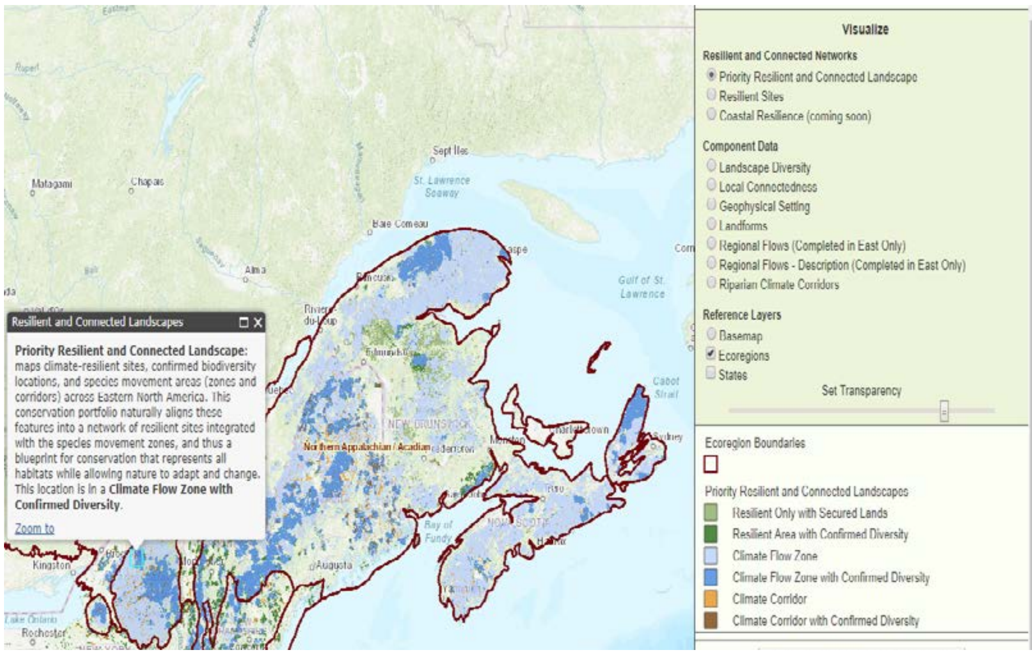

Figure 10. Interactive map tool, depicting priority resilient and connected landscape in the Northern Appalachian-Acadian Ecoregion.

Coverage: Southeast, Mid-Atlantic and Northeast U.S, including all of the Northern Appalachian-Acadian Ecoregion

STAYING CONNECTED INITIATIVE'S MEASURES FRAMEWORK

Type	Name
Report	Coker, D. and C. Reining. 2013. *A Measures Framework for Staying Connected in the Northern Appalachians*. TNC and the Wildlands Network.

Description: An international collaboration, the Staying Connected Initiative (SCI) seeks to maintain, enhance and restore landscape connectivity for wide-ranging mammals across the Northern Appalachians-Acadian region, in order to mitigate the impacts of habitat fragmentation and climate change. Central to that goal has been the definition of linkage areas: geographically defined places where—if landscape connectivity is lost—bear, moose, bobcat and other wide-ranging mammals will be limited in their ability to move between core habitat areas and across the region.

The Measures Framework presents a system for measuring the status of landscape connectivity in eight *landscape linkage areas* across the ecoregion. The framework provides a set of relatively simple and repeatable GIS-based status measures, as well as an initial sNAPAshot of the status of structural connectivity (with baseline numbers and maps), for each linkage area and the important pathways, or fine-scale landscape connections, they contain. SCI intends this framework to be viewed as a living document that should evolve as understanding of wildlife movements and habitat connectivity improves and better information becomes available.

There are four sets of connectivity measures for each linkage: two relate to habitat composition and distribution; one describes the state of land protection; and one attempts to describe the status of existing road-barrier effects. Data gaps meant not all proposed status measures were run and knowledge gaps of thresholds for structural connectivity meant specific objectives are not always articulated for all measures. Despite variability in data, the combined metrics can provide a ready "dashboard" for evaluating conservation status and trends in these critical landscapes. The measures framework is set up so that baselines and on-going monitoring will occur on a linkage-by-linkage and pathway-by-pathway basis.

Overall, the eight linkages encompass over 12 million acres, nearly 50,000 km^2, out of a total ecoregion area of about 88 million acres (356,000 km^2). On the whole, nearly 92% of the area of all the linkages remains in natural cover, though this varies greatly across the region. Another measure, habitat distribution, provides insights into how clumped or fragmented a landscape is, via the Resistant Kernel (RK) indicator where a RK score of 50 or higher is used to generally indicate a relatively unfragmented landscape. Of the eight linkages, four have RK scores below 50, four above. The amount of land in some form of protection also varies greatly among the linkages, from 14% in the Tug Hill-Adirondacks linkage to nearly 50% in the 3-Borders-Northern Maine-Gaspe linkage.

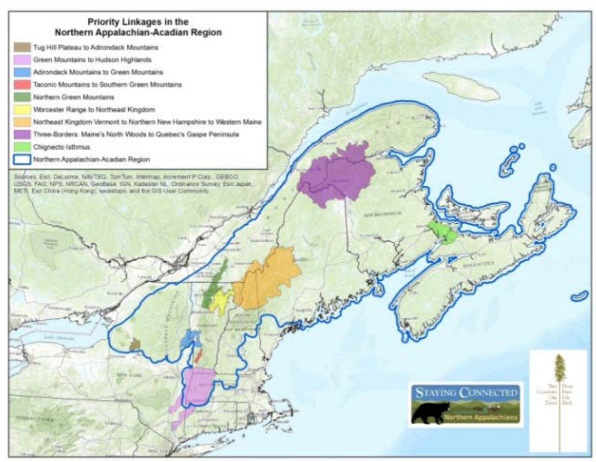

Figure 11. Landscape linkages

Coverage: Northern Appalachian-Acadian Ecoregion

WILDLANDS NETWORK'S EASTERN WILDWAY

Type	Name
Website	[Eastern Wildway: Protecting the Wild East]()
Report (earlier report on the ecoregion)	Reining, C., K. Beazley, P. Doran, and C. Bettigole. 2006. *From the Adirondacks to Acadia: A Wildlands Network Design for the Greater Northern Appalachians*. Richmond, Virginia: Wildlands Project

Description: The Eastern Wildway builds on earlier work of the Wildlands Network, including a 2002 blueprint for a Maine Wildlands Network Vision and a 2006 report that set out a Wildlands Network Design comprising the entire Greater Northern Appalachians region. The Eastern Wildway is a vision for a continental-scale extensive wildlife corridor linking eastern Canada to the Gulf of Mexico. It traverses a wide array of eco-regions and climates, with the latter ranging from arctic to tropical. The Eastern Wildway contains some important North American national parks, preserves, scenic rivers, and other wild places, from the wilderness of Quebec, the Adirondacks, and the Shenandoah Valley, to the Great Smoky Mountains and Everglades National Park. Protecting and expanding these and other key core areas is crucial to rewilding the East.

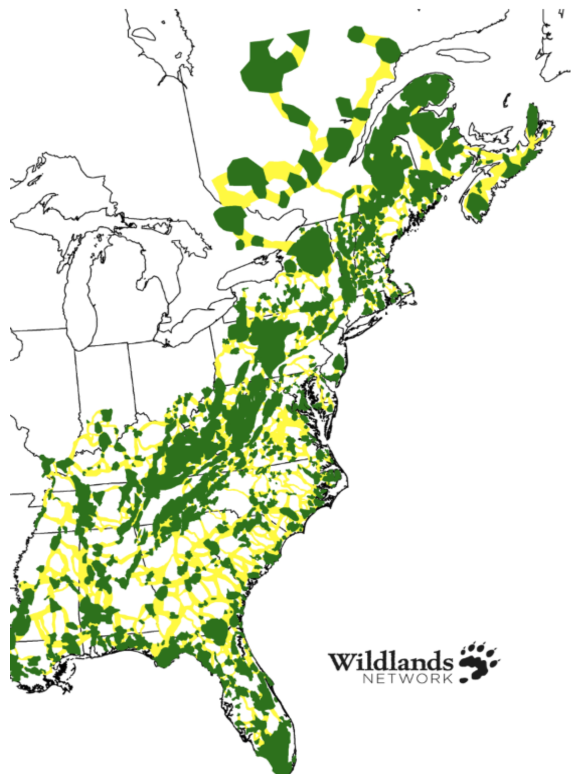

Figure 12. Eastern Wildway Network

Wilderness and other core reserves are central to the vision for an Eastern Wildway. National parks and other public wild places are essential core areas, as are large, strictly protected private lands—especially given that so much property in eastern North America is privately owned. Cores are where the protection of biodiversity, ecological integrity, and wilderness are given highest priority. Existing core reserves in the Eastern Wildway include a number of areas in the Northern Appalachian-Acadian ecoregion that require measures to protect them in perpetuity. They are: the New York's **Adirondacks**, Vermont's **Green Mountains**, the Presidential Range within **New Hampshire's White Mountains**, **Northern Maine**, the St. Francis River watershed where New Brunswick, Quebec, and Maine meet, Quebec's **Gaspésie and Forillon National Parks** are ecologically spectacular but disconnected.

Securing wildlife corridors between Eastern core reserves is vital to sustaining biodiversity. Wildlands Network has identified 16 locations throughout the Eastern Wildway where immediate action must be taken to restore and protect habitat connectivity. A number of these areas are within the ecoregion, namely: Southern Lake Champlain Valley; Northern Green/Sutton Mountains; Northeast Kingdom to Moosehead: Three Borders Area of Maine, Quebec, and New Brunswick; and Gaspesie Park to Forillon Park, Quebec.

Coverage: Eastern North America, including the entire Northern Appalachian-Acadian Ecoregion

NATURE’S NETWORK PROJECT

Type	Name
Reports	[Quick start guide: Nature’s Network Conservation Design]
	[Quick start guide: Terrestrial & Wetland Cores, Connectors and Natural Blocks]
	[Quick start guide: Aquatic Core Networks]
	[Quick start guide: Habitats for Imperiled Species] Tracey, C. and S.G. Fuller. 2017. *Habitat Condition for Imperiled Species: Technical Documentation*.
	[Quick start guide: Prioritization Tool]
Data packages	Natures Network Conservation Design This bundle contains a simplified composite layer, and its components, including Core Habitat for Imperiled Species, Terrestrial Core-Connector Network, Grassland Bird Core Areas, Lotic Core Areas, and Lentic Core Areas. Other combinations and single layers are also available for download.
Interactive maps	Nature’s Network Conservation Design, Northeast U.S. Terrestrial and Wetland Core-Connector Network, Northeast U.S. Core habitat for Imperiled Species, Northeast U.S.
Tool	Prioritization tool

Description: The North Atlantic Landscape Conservation Cooperative (LCC) and the Northeast Association of Fish and Wildlife Agencies (NEAFWA) coordinated a team of partners from 13 states, the U.S. Fish and Wildlife Service, nongovernmental organizations, and universities, who worked for more than a year to develop a regional conservation design that provides a foundation for unified conservation action from Maine to Virginia. Called **Nature’s Network**, the design identifies a network of places that help define the highest conservation priorities in the region to sustain natural resources and benefits for future generations.

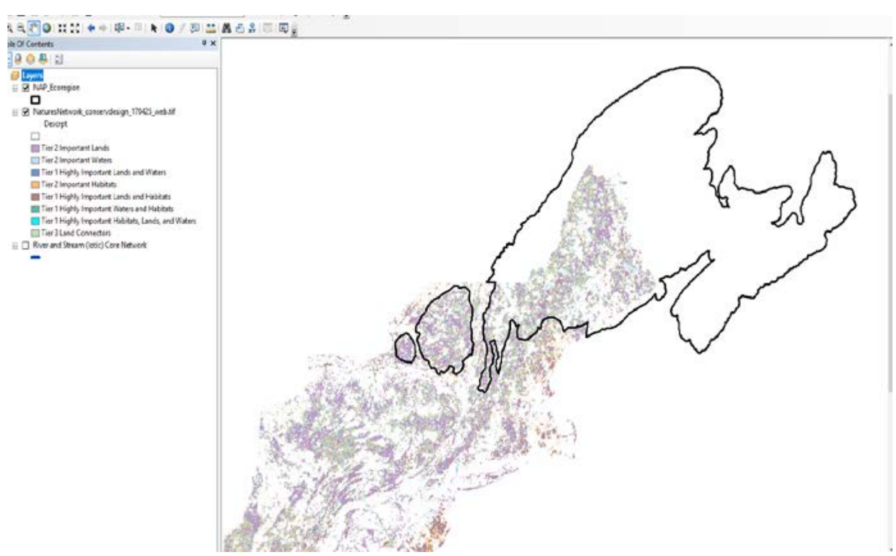

Figure 13. Portion of Conservation Design Network shown in relation to NAP ecoregion

Nature’s Network **Conservation Design** depicts an interconnected network of lands and waters that, if protected, will support a diversity of fish, wildlife, and natural resources that the people of the Northeast and MidAtlantic region depend upon. This map serves as the “cover page” for the Nature’s Network suite of products, outlining some of the most important natural areas in the region and provides an entry point to learn more about the information used to identify them. The Conservation Design represents a combination of three Nature’s Network products: 1) the terrestrial core connector network, 2) aquatic core areas, and 3) core habitat for imperiled species. Each of these products have various components, as described below.

1) The **terrestrial core connector network** is made up of terrestrial and wetland core areas, and connectors. Terrestrial and wetland core areas are intact, well connected places that have the potential to support wildlife and plants that occur in terrestrial settings (such as upland forests) or in wetlands (such as marshes). These core areas contain important or unique features, including intact, resilient examples of all major ecosystem type in the study area, from widespread ecosystems (such as hardwood forests), to rare natural communities (such as bogs), and important habitat for a variety of species. These areas encompass approximately 25% of the landscape and are linked together by a network of connectors. If protected, the connectors will foster the movement of animals and plants between core areas and across the landscape.
2) **Aquatic core areas** are intact, well connected stream reaches, lakes, and ponds in the Northeast and MidAtlantic region that, if protected as part of stream networks and watersheds, will support a broad diversity of aquatic species and the ecosystems on which they depend. They serve as the aquatic counterpart to terrestrial and wetland core areas. They feature intact, resilient examples of every major aquatic ecosystem in the region and also are designed to incorporate habitat for important species such as brook trout and Atlantic salmon. Aquatic core areas encompass approximately 30% of both the region's river and stream miles and the region's area of lakes and ponds. A related product is a set of aquatic buffers, which are upslope and upstream areas that have a strong influence on the integrity of the aquatic cores.
3) **Core habitat for imperiled species** can be viewed as relatively intact areas that contain habitats likely to support high levels of imperiled terrestrial and aquatic species. This product represents a regional network of habitats critical for sustaining populations of imperiled species, based on over 600 Species of Greatest Conservation Need (SGCN). Core habitat for imperiled species is intended to complement aquatic core areas and terrestrial and wetland core areas by highlighting habitat types where they are closely associated with high numbers of imperiled species. Core habitats encompass approximately the top 10% of natural landscapes estimated to be most important for sustaining imperiled species. There is also data on the condition of these habitats.

Each of the components making up the Nature's Network Conservation Design incorporate a set of foundational datasets, which are presented on the Nature's Network web page for that product suite and in associated QuickStart guides. Two additional important products include zones where tidal marshes could move as sea level rises (Marsh Migration Zones, Northeast U.S.) and patterns of landscape connectivity independent of terrestrial core areas (Regional Flow, Anthropogenic Resistance (Simplified Categories), Eastern U.S. and Canada). There is also a Prioritization Tool, which is a web application for identifying the best opportunities to restore rare and threatened habitats for SGCN and other species in the Northeast.

Coverage: 13 Northeast States (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia)

DESIGNING SUSTAINABLE LANDSCAPES

Type	Name
Reports	McGarigal, K., B. Compton, E. Plunkett, B. DeLuca and J. Grand. 2017. *Designing Sustainable Landscapes: Project Overview.* Report to the NALCC, USFWS, Northeast Region. McGarigal, K., B. Compton, E. Plunkett, B. DeLuca and J. Grand. 2018. *Designing Sustainable Landscapes: Modeling Ecological Integrity*. Report to the NALCC, USFWS, Northeast Region. McGarigal, K., B. Compton, E. Plunkett, B. DeLuca and J. Grand. 2017. *Designing Sustainable Landscapes: Landscape Conservation Design*. Report to the NALCC, USFWS, Northeast Region. McGarigal, K., B. Compton, E. Plunkett, B. DeLuca and J. Grand. 2017. *Designing Sustainable Landscapes: HUC6 Terrestrial Core-Connector Network*. Report to the NALCC, USFWS. McGarigal, K., B. Compton, E. Plunkett, B. DeLuca and J. Grand. 2017. *Designing Sustainable Landscapes: Modeling Connectivity*. Report to the NALCC, USFWS, Northeast Region. *McGarigal, K., B. Compton, E. Plunkett, B. DeLuca and J. Grand. 2017. Designing Sustainable Landscapes: HUC6 Aquatic Cores and Buffers*. Report to the NALCC, USFWS, Northeast Region. McGarigal, K., B. Compton, E. Plunkett, B. DeLuca and J. Grand. 2016. *Designing Sustainable Landscapes: Modeling Focal Species*. Report to the NALCC, USFWS, Northeast Region.
Data	Various datasets related to above reports available at the products page.

Description: The overall purpose of the Designing Sustainable Landscapes (DSL) project is to assess the capability of current and potential future landscapes within the Northeast United States to provide integral ecosystems and suitable habitat for a suite of focal (e.g., representative) species, and provide guidance for strategic habitat conservation. The researchers developed the Landscape Change, Assessment and Design (LCAD) model. This project is supported primarily by the North Atlantic Landscape Conservation Cooperative, with additional support from the Northeast Climate Science Center and the University of Massachusetts - Amherst.

An initial phase focused on developing the overall modeling framework for simulating landscape change and assessing the ecological consequences of those changes and piloting the model in three study landscapes. The second phase extended the landscape change and assessment modeling to the entire Northeast United States, modeling an additional 20 representative species, expanding the scope of the ecological integrity assessment, coupling the landscape change model with a third party sea level rise model, improving the vegetation succession modeling, and developing an approach for integrating the results of the landscape change assessment into decision support for landscape design.

A third phase included major improvements to the landscape change model (including a major revision of the urban growth module), completing the 30 representative species models, and extending the landscape conservation design component of the model (piloted in the Connecticut River watershed in phase 2) to the entire Northeast United States. The approach aims to help identify conservation priorities for land protection (i.e., what lands to protect to get the "biggest bang for the buck"), management (e.g., what should the management priorities be on conservation lands) and restoration (e.g., where should we place a wildlife road crossing structure or upgrade a stream culvert to improve landscape connectivity the most). Many of the project datasets are used in the NALCC Nature's Network Design analysis.

Coverage: Northeast United States

FOREST ECOSYSTEM VULNERABILITY ASSESSMENT

Type	Name
Report	Janowiak, M.K., A.W. D'Amato, C.W. Swanston, L. Iverson, F.R. Thompson III, W.D. Dijak, S. Matthews, M.P. Peters, A. Prasad, J. S. Fraser, L. A. Brandt, P. Butler-Leopold, S.D. Handler, P.D. Shannon, D. Burbank, J. Campbell, C. Cogbill, M.J. Duveneck, M. R. Emery, N. Fisichelli, J. Foster, J. Hushaw, L. Kenefic, A. Mahaffey, T.L. Morelli, N.J. Reo, P.G. Schaberg, K. Rogers Simmons, A. Weiskittel, S. Wilmot, D. Hollinger, E. Lane, L. Rustad, and P.H. Templer. 2018. *New England and Northern New York Forest Ecosystem Vulnerability Assessment and Synthesis: A Report from the New England Climate Change Response Framework Project*. General Technical Report NRS-173. United States Forest Service.

Description: This assessment is a fundamental component of the New England Climate Change Response Framework project and was designed to be a synthesis of the best available scientific information on climate change and forest ecosystems. The assessment evaluates the vulnerability of forest ecosystems across the New England region under a range of future climates. The authors synthesized and summarized information on the contemporary landscape, provided information on past climate trends, and described a range of projected future climates. The information was used to parameterize and run multiple vegetation impact models, which provided a range of potential vegetative responses to climate. The authors brought the results before a multidisciplinary panel of scientists and natural resource professionals to assess ecosystem vulnerability through a formal consensus-based expert elicitation process.

Observed trends in climate over the historical record from 1901 through 2011 show that the mean annual temperature has increased across the region by 2.4 °F, with even greater warming during winter. Precipitation patterns also changed, with a slight trend toward greater annual precipitation and a substantial increase in extreme precipitation events. Projected climate trends using downscaled global climate model data indicate a potential increase in mean annual temperature of 3 to 8 °F by 2100. Projections for precipitation indicate an increase in fall and winter precipitation, and spring and summer precipitation projections vary by scenario. The authors identified potential impacts on forests by incorporating these future climate projections into three forest impact models. Model projections suggest that many northern and boreal species, including balsam fir, red spruce, and black spruce, may fare worse under future conditions, but other species may benefit from projected changes in climate. Published literature on climate impacts related to wildfire, invasive species, and forest pests and diseases also contributed to the overall determination of climate change vulnerability.

The authors also assessed vulnerability for eight forest communities in the assessment area. The assessment was conducted through a formal elicitation process with 20 scientists and resource managers, who considered vulnerability in terms of the potential impacts and the adaptive capacity for an individual community. Montane spruce-fir, low-elevation spruce-fir, and lowland mixed conifer forests were determined to be the most vulnerable communities. Central hardwoods, transition hardwoods, and pitch pine-scrub oak forests were perceived as having lower vulnerability to projected changes in climate. These projected changes in climate and the associated impacts and vulnerabilities will have important implications for economically valuable timber species, forest-dependent animals and plants, recreation, and long-term natural resource planning.

Coverage: New England region (Connecticut, Maine, Massachusetts, New Hampshire, northern New York, Rhode Island, and Vermont).

WILDLANDS AND WOODLANDS VISION AND SCIENCE

This section summarizes the main reports and articles of the Wildlands and Woodlands, including both its vision for the New England landscape and some of its recent science findings. Not all of the hyperlinked articles are open access; some must be purchased.

Type	Name
Report	Foster, D., K. Fallon Lambert, D. Kittredge, B. Donahue, C. Hart, W. Labich, S. Meyer, J. Thompson, M. Buchanan, J. Levitt, R. Perschel, K. Ross, G. Elkins, C. Daigle, B. Hall, E. Faison, A. D'Amato, R.d Forman, P. Del Tredici, L. Irland, B. Colburn, D.d Orwig, J. Aber, A. Berger, C. Driscoll, W. Keeton, R. Lilieholm, N. Pederson, A. Ellison, M. Hunter, and T. Fahey. 2017. *Farmlands and Communities Broadening the Vision for New England*. Harvard University.

Description: In 2010, scientists reported that after more than 150 years of forest regrowth following the regional decline in agriculture, New England reforestation had ended and forestland was being lost to development in every New England state. The authors developed the *Wildlands and Woodlands* vision calling for retaining and permanently protecting at least 70% of the landscape (30 million acres) in forestland and another 7% in farmland by 2060. Most of the forests would be managed as woodlands for wood products and other benefits, while at least 10% would be designated as wildland reserves. The 2017 report offers an update on progress toward the vision and outlines actions required to help reach the goals. The broadened vision recognizes the interdependent role that forests, farms, rural communities, suburbs, and cities play in shaping the New England landscape. Protected forests dominate the region in this vision, but well managed farmlands diversify it and robust rural economies enable people to share in its prosperity. The vision embraces the idea that well-managed forests and farmlands, wildlands, smart growth, and rural economic development are compatible, achievable, and mutually reinforcing.

The authors report that forest and farmland make up approximately 88% of the New England land base, while development covers 3.8 million acres or 9.5% of the region. New England is one-third of the way toward the *Wildlands and Woodlands* forestland goal. To reach the 2060 target, the authors state that actors must triple the pace of conservation to protect the remaining 23 million acres. They report there are threats of increasing loss of forest and farmland to residential and commercial development; ongoing fragmentation of land; declines in state and federal land-protection funding; deterioration of iconic tree species from introduced pests and pathogens; unsustainable forest and farm management in some areas; and, the challenge of maintaining public support for land protection and traditional uses of land amidst competing socioeconomic demands. However, the last quarter century represents the most active period of land protection in New England's history and the authors note the region remains in a new era of land protection, new collaborations are a growing force in land protection, and innovative conservation finance strategies continue to emerge.

The authors make a number of recommendations for the next ten year to accelerate progress toward the broadened Wildlands and Woodlands goals and help support a healthy and prosperous future for local communities, the New England region, and the globe. These are: 1) accelerate land protection; 2) manage more land, ecologically and sustainably; 3) grow smart in cities, suburbs, and towns; 4) support strong rural economies; 5) increase funding for land protection; and reduce consumption and conserve resources.

Coverage: New England

Type	Name
Report	Foster, D., D. Orwig, E. Faison, E. Silver, B. Hall, B. Donahue, G. Motzkin, J. Thompson, A. D'Amato, E. Boose, J. Pallant, M. Kelty, and R. Van de Poll. 2014. *Wildlands and Woodlands Science: Long-term Forest Measurements for Ecological and Conservation Insights*. Highstead Foundation, Harvard Forest, Harvard University.

Description: Over 95% of New England's forested landscape has been cut one or more times for timber, agriculture, and development, leaving our current forests typically young (i.e., <100 years old), structurally simple, and carbon-poor. Consequently, many of the areas initially designated as Wildland reserves or managed Woodlands would be fairly similar and dominated by maturing second-growth forests. Through time, however, and as a consequence of their varied management, Wildlands and Woodlands would diverge in age, structure, composition, ecological processes, and habitat qualities (Foster 1999, 2001). Given these anticipated changes, a number of questions arise: How to document and understand the progressive changes in Wildlands and Woodlands? How to evaluate the effectiveness and sustainability of the management and harvesting of Woodlands? What lessons regarding natural processes and environmental change will emerge for large forest reserves free from direct human impacts? Leading conservationists and ecologists like Henry Thoreau, Robert Marshall, and Aldo Leopold have stressed the need for careful comparisons of actively managed and wild areas as a critical part of successful land management, yet few forests are or have been managed based on such a comparative approach.

Wildlands and Woodlands (W&W) Stewardship Science seeks to address these issues and seize the opportunity to learn from nature and active management by creating a program of forest measurement that is simple, flexible, broadly applicable and yet scientifically rigorous. Since the Wildlands and Woodlands vision is forest-based, they focus primarily on the monitoring of vegetation composition and structure in forested sites. They encourage the development of comparative studies between Wildland reserves and managed Woodlands whenever feasible in order to take advantage of the scientific and adaptive management benefits of studying both management types.

Questions that pertain to fundamental ecological processes and the recovery of forests from past land use can be addressed by the study of Wildland reserves. In order to be most useful, the proposed methods and system must be: (1) simple, so that diverse researchers and land managers can apply the protocols in a consistent manner over time; (2) applied consistently over time; (3) relatively inexpensive, so that there is a strong likelihood of continued study; (4) permanent and accessible, so that measurements can be continued easily in the future, even if the plots are abandoned for some period of time; and (5) robust yet flexible to accommodate other monitoring efforts, detailed studies and unforeseen questions in the future.

Coverage: New England Forests

Type	Name
Article	Liang, Y., M.J. Duveneck, E.J. Gustafson, J.M. Serra-Diaz, and J.R. Thompson. 2018. How disturbance, competition, and dispersal interact to prevent tree range boundaries from keeping pace with climate change. *Global Change Biology* 24: 335-351.

Description: Climate change is expected to cause geographic shifts in tree species' ranges, but such shifts may not keep pace with climate changes because seed dispersal distances are often limited and competition-induced changes in community composition can be relatively slow. Disturbances may speed changes in community composition, but the interactions among climate change, disturbance and competitive interactions to produce range shifts are poorly understood. The authors used a physiologically based mechanistic landscape model to study these interactions in the northeastern United States. They designed a series of disturbance scenarios to represent varied disturbance regimes in terms of both disturbance extent and intensity. They simulated forest succession by incorporating climate change under a high-emissions future, disturbances, seed dispersal, and competition using the landscape model parameterized with forest inventory data. Tree species range boundary shifts in the next century were quantified as the change in the location of the 5th (the trailing edge) and 95th (the leading edge) percentiles of the spatial distribution of simulated species. Simulated tree species range boundary shifts in New England over the next century were far below (usually <20 km) that required to track the velocity of temperature change (usually more than 110 km over 100 years) under a high-emissions scenario. Simulated species' ranges shifted northward at both the leading edge (northern boundary) and trailing edge (southern boundary). Disturbances may expedite species' recruitment into new sites, but had little effect on the velocity of simulated range boundary shifts. Range shifts at the trailing edge tended to be associated with photosynthetic capacity, competitive ability for light and seed dispersal ability, whereas shifts at the leading edge were associated only with photosynthetic capacity and competition for light. The study underscores the importance of understanding the role of interspecific competition and disturbance when studying tree range shifts.

Coverage: 6 New England States

Type	Name
Article	Duveneck, M.J., J.R. Thompson, E.J. Gustafson, Y. Liang, and A.M. G. de Bruijn. 2017. Recovery dynamics and climate change effects to future New England forests. *Landscape Ecology* 32: 1385-1397.

Description: Forests throughout eastern North America continue to recover from broad-scale intensive land use that peaked in the nineteenth century. These forests provide essential goods and services at local to global scales. It is uncertain how recovery dynamics, the processes by which forests respond to past forest land use, will continue to influence future forest conditions. Climate change compounds this uncertainty. The authors explored how continued forest recovery dynamics affect forest biomass and species composition and how climate change may alter this trajectory. Using a spatially explicit landscape simulation model incorporating an ecophysiological model, they simulated forest processes in New England from 2010 to 2110. They compared forest biomass and composition from simulations that used a continuation of the current climate to those from four separate global circulation models forced by a high emission scenario (RCP 8.5). Simulated forest change in New England was driven by continued recovery dynamics; without the influence of climate change forests accumulated 34 % more biomass and succeed to more shade tolerant species; Climate change resulted in 82%

more biomass but just nominal shifts in community composition. Most tree species increased above ground biomass under climate change. Continued recovery dynamics will have larger impacts than climate change on forest composition in New England. The large increases in biomass simulated under all climate scenarios suggest that climate regulation provided by the eastern forest carbon sink has potential to continue for at least a century.

Coverage: Six New England States

Type	Name
Article	Thompson, J.R., C.D. Canham, L. Morreale, D.B. Kittredge, and B. Butler. 2017. Social and biophysical variation in regional timber harvest regimes. Ecological Applications 27(3): 942-955.

Description: In terms of adult tree mortality, harvesting is the most prevalent disturbance in northeastern United States forests. Previous studies have demonstrated that stand structure and tree species composition are important predictors of harvest. The authors extend this work to investigate how social factors further influence harvest regimes. By coupling the Forest Inventory and Analysis database to U.S. Census and National Woodland Owner Survey (NWOS) data, they quantify social and biophysical variation in the frequency and intensity of harvesting throughout a 20-state region in the northeastern United States. Among social factors, ownership class is most predictive of harvest frequency and intensity. The annual probability of a harvest event within privately owned forest (3%/yr) is twice as high as within publicly owned forests (1.5%/yr). Among private owner classes, the annual harvest probability on corporate-owned forests (3.6%/yr) is 25% higher than on private woodlands (2.9%/yr). Among public owner classes, the annual probability of harvest is highest on municipally owned forests (2.4%/yr), followed by state-owned forests (1.6%/yr), and is lowest on federal forests (1%/yr). In contrast, corporate, state, and municipal forests all have similar distributions of harvest intensity; the median percentage of basal area removed during harvest events is approximately 40% in these three owner groups. Federal forests are similar to private woodlands with median harvest intensities of 23% and 20%, respectively. Social context variables, including local home prices, population density and the distance to a road, help explain the intensity, but not the frequency, of harvesting. Private woodlands constitute the majority of forest area; however, demographic data about their owners (e.g., their age, educational attainment, length of land tenure, retired status) show little relationship to aggregate harvest behavior. Instead, significant predictors for harvesting on private woodlands include live-tree basal area, forest type, and distance from roads. Just as with natural disturbance regimes, harvest regimes are predictable in terms of their frequency, intensity, and dispersion; and like their natural counterparts, these variables are determined by several important dimensions of environmental context. But in contrast to natural disturbance regimes, the important dimensions of context for harvesting include a combination of social and biophysical variables.

Coverage: 20 state region in north-eastern United States

Type	Name
Article	Duveneck, M.J. and J.R. Thompson. 2017. Climate change imposes phenological trade-offs on forest net primary productivity. *Journal of Geophysical Research Biogeoscience* 122: 2298-2313.

Description: Climate warming is expected to lengthen growing seasons of temperate forest ecosystems and increase gross primary productivity. Simultaneously, warming is expected to increase summer ecosystem respiration, which could offset gains accrued from longer growing seasons. These responses have been observed during anomalously warm years, but the role of future climate change on phenological trade-offs and how they affect net primary productivity (NPP) at regional scales in temperate forests remain unexplored. The authors simulated scenarios of climate change on monthly forest NPP throughout 18 million hectares of temperate forests in New England, USA, through year 2100. Using an ecophysiological model coupled to a forest landscape model, they simulated scenarios of climate change on monthly NPP. A high emission scenario (RCP 8.5), resulted in longer growing seasons that offset midsummer ecosystem respiration costs and produced greater annual NPP throughout the study landscape compared to simulations using the current climate. In spring and autumn months, temperature was positively associated with greater NPP; in summer months, the relationship was negative. Spatially, the greatest increase in NPP occurred in the warmer southern region under a warm climate scenario with increased precipitation. Under a warm scenario with drier conditions, the greatest increase in NPP occurred in the cooler northern region. Phenological trade-offs will affect NPP of future forests and their potential to serve as a negative feedback to climate change. Barring other limitations, longer growing seasons will offset greater respiratory demands and contribute to increases in NPP throughout the temperate forests of New England in the future.

Coverage: Six New England States

Type	Name
Article	Thompson, J.R., J.S. Plisinksi, P. Olofsson, C.E. Holden, and M.J. Duveneck. 2017. Forest loss in New England: A projection of recent trends. *PLOS One*: 12(12): e0189636.

Description: New England has lost more than 350,000 ha of forest cover since 1985, marking a reversal of a two-hundred-year trend of forest expansion. The authors used a cellular land-cover change model to project a continuation of recent trends (1990-2010) in forest loss across six New England states from 2010 to 2060. Recent trends were estimated using a continuous change detection algorithm applied to twenty years of Landsat images. They addressed three questions: (1) What would be the consequences of a continuation of the recent trends in terms of changes to New England's forest cover mosaic? (2) What social and biophysical attributes are most strongly associated with recent trends in forest loss, and how do these vary geographically? (3) How sensitive are projections of forest loss to the reference period. How do projections based on the period spanning 1990-to-2000 differ from 2000-to-2010, or from the full period, 1990-to-2010? Over the full reference period, 8201 ha yr-1 and 468 ha yr-1 of forest were lost to low- and high-density development, respectively. Forest loss was concentrated in suburban areas, particularly near Boston. Of the variables considered, 'distance to developed land' was the strongest predictor of forest loss. The next most important predictor varied geographically: 'distance to roads' ranked second in the more developed regions in the south and 'population density' ranked second in the less developed north. The importance and geographical variation in predictor variables were relatively stable between reference periods. In contrast, there was 55% more forest loss during the 1990-to-2000 reference period compared to the 2000-to-2010 period, highlighting the importance of understanding the variation in reference periods when projecting land cover change. The projection of recent trends is an important baseline scenario with implications for the management of forest ecosystems and the services they provide.

Coverage: 6 New England States

Type	Name
Article	Thompson, J.R., K.F. Lambert, D.R. Foster, E.N. Broadbent, M. Blumstein, A.M. Almeyda Zambrano, and Y. Fan. 2016. The consequences of four land-use scenarios for forest ecosystems and the services they provide. *Ecosphere* 7(10): Article e01469.

Description: Anticipating landscape-to regional-scale impacts of land use on ecosystems and the services they provide is a central challenge for scientists, policymakers, and resource managers. Working with a panel of practitioners and regional experts, the authors developed and analyzed four plausible but divergent land- use scenarios that depict the future of Massachusetts from 2010 to 2060 to address two questions: (1) "How do the magnitude and spatial distribution of ecosystem service provisioning vary under the different land-use regimes?" and (2) "What are the synergies and trade-offs among direct human uses, ecosystem services, and habitat quality?" Each scenario specifies the detailed prescriptions for the major uses of the forests, including conversion to residential and commercial development, clearing new farmland, shifting silvicultural practices, and designating forests protected from development. The authors simulated the land-use scenarios and their interactions with anticipated climate change by coupling statistical models of land use to the LANDIS-II landscape model and then evaluated the outcomes in terms of the magnitude and spatial distribution of (1) direct human uses of the landscape (residential and commercial development, agricultural, timber harvest), (2) ecosystem services (carbon storage, flood regulation, nutrient retention), and (3) habitat quality (forest tree species composition, interior forest habitat). Across all scenarios, conflicts occurred between dispersed residential development and the supply of ecosystem services and habitat quality. In all but the scenario that envisioned a significant agricultural expansion, forest growth resulted in net increases in aboveground carbon storage, despite the concomitant forest clearing and harvesting. One scenario, called Forests as Infrastructure, showed the potential for synergies between increased forest harvest volume through the sustainable practices that encouraged the maintenance of economically and ecologically important tree species, and carbon storage. This scenario also showed trade-offs between development density and water quantity and quality at the watershed scale. The process of integrated scenario analysis led to important insights for land managers and policymakers in a populated forested region where there are tensions among development, forest harvesting, and land conservation. More broadly, the results emphasize the need to consider the consequences of contrasting land-use regimes that result from the interactions between human decisions and spatially heterogeneous landscape dynamics.

Coverage: Massachusetts

Type	Name
Article	Thorn, A.M., J.R. Thompson, and J.S. Plisinski. 2016. Patterns and Predictors of Recent Forest Conversion in New England. Land 5(30): doi:10.3390/land5030030.

Description: This article notes that New England forests provide numerous benefits to the region's residents, but are undergoing rapid development. The authors used boosted regression tree analysis (BRT) to assess geographic predictors of forest loss to development between 2001 and 2011. BRT combines classification and regression trees with machine learning to generate non-parametric statistical models that can capture non-linear relationships. Based on National Land Cover Database (NLCD) maps of land cover change, we assessed the importance of the biophysical and social variables selected for full region coverage and minimal collinearity in predicting forest loss to development, specifically: elevation, slope, distance to roads, density of highways, distance to built land, distance to cities, population density, change in population density, relative change in population density, population per housing unit, median income, state, land ownership categories and county classification as recreation or retirement counties. The resulting models explained 6.9% of the variation for 2001–2011, 4.5% for 2001–2006 and 1.8% for 2006–2011, fairly high values given the complexity of factors predicting land development and the high resolution of the spatial datasets. The two most important variables in the BRT were "population density" and "distance to road", which together made up over 55% of the variation for 2001–2011, almost 50% for 2001–2006 and approximately 43% for 2006–2011. The lower predictive power for 2006–2011 may reflect reduced development due to the "Great Recession".

Coverage: New England States

Type	Name
Article	Thompson, J.R., D. N. Carpenter, C.V. Cogbill, and D.R. Foster. 2013. Four Centuries of Change in Northeastern United States Forests. *PLOS One* 8(9): e72540.

Description: The northeastern United States is a predominately-forested region that, like most of the eastern U.S., has undergone a 400- year history of intense logging, land clearance for agriculture, and natural reforestation. This setting affords the opportunity to address a major ecological question: How similar are today's forests to those existing prior to European colonization? Working throughout a nine-state region spanning Maine to Pennsylvania, the authors assembled a comprehensive database of archival land-survey records describing the forests at the time of European colonization. We compared these records to modern forest inventory data and described: (1) the magnitude and attributes of forest compositional change, (2) the geography of change, and (3) the relationships between change and environmental factors and historical land use. We found that with few exceptions, notably the American chestnut, the same taxa that made up the pre-colonial forest still comprise the forest today, despite ample opportunities for species invasion and loss. Nonetheless, there have been dramatic shifts in the relative abundance of forest taxa. The magnitude of change is spatially clustered at local scales (<125 km) but exhibits little evidence of regional-scale gradients. Compositional change is most strongly associated with the historical extent of agricultural clearing. Throughout the region, there has been a broad ecological shift away from late successional taxa, such as beech and hemlock, in favor of early- and mid-successional taxa, such as red maple and poplar. Additionally, the modern forest composition is more homogeneous and less coupled to local climatic controls.

Coverage: 9 States from Maine to Pennsylvania

CHANGES TO THE LAND

Type	Name
Report	Thompson, J.R., K. Fallon Lambert, D. Foster, M. Blumstein, E. Broadbent, and A. Almeyda Zambrano. 2014. *Changes to the Land: Four Scenarios for the Future of the Massachusetts Landscape*. Petersham, Massachusetts: Harvard Forest, Harvard University.

Description: This project is unique for its two-way exchange with natural resource and conservation professionals and for its emphasis on evaluating the different views of future land use developed by non-scientists. The scenarios are not a set of formal predictions or recommendations by the authors, rather they represent a set of contrasting views of the future that are simulated using cutting-edge land-use and ecosystem models. The results provide insight and information to guide land-use policy and conservation decisions.

In 2011, with the input of many groups and individuals from across the state, Harvard Forest launched a project to evaluate potential futures for the Massachusetts landscape, and for forests in particular. The purpose of the project was to compare a set of contrasting scenarios to help inform and motivate conservation and land-use decisions. The scenarios were created by a group of eight natural resource professionals from conservation and forestry organizations, academia, and state government (Table 1). The group gathered for six meetings over the two-year study period to articulate four different trajectories for how land use could change in the state over the next 50 years. While the scenarios do not attempt to predict the future — experience has demonstrated the futility of that — they do enable us to see and evaluate some of the many consequences of different approaches to using and caring for the land.

They developed four scenarios: Recent Trends, Opportunistic Growth, Regional Self-Reliance, and Forests as Infrastructure. The scenarios reflect different amounts and intensities of land development, timber harvesting, farmland expansion, and forest conservation. All scenarios also included the assumption that average temperature and precipitation will increase with climate change. Tremendous land conservation gains have been made in Massachusetts but the continued loss of thousands of acres of open space each year to development undermines this progress and erodes the many benefits forests provide. If *Recent Trends* continue or if development increases as depicted in *Opportunistic Growth*, the consequences for people and nature will be far-reaching, even exceeding some of the anticipated land-based impacts of climate change.

But opportunities abound for building on the positive advances of past years to keep our forests, safeguard their value as living infrastructure, and bolster the contributions of forests to our communities and rural economies. By 2060, the land-use decisions reflected in the *Forests as Infrastructure* scenario yield profound benefits to people and nature. For example, it generates a 20% increase in tree species with high commercial and wildlife value, twice as much local wood harvested, and a 35% increase in the amount of carbon stored in forests from the 2010 baseline.

Coverage: Massachusetts

FOREST LOSS

Type	Name
Report	Brown, M.L., D. Canham, L. Murphy, and T.M. Donovan. 2018. Timber harvest as the predominant disturbance regime in northeastern U.S. forests: effects of harvest intensification. Ecosphere 9(3): e02062.

Description: Harvesting is the leading cause of adult tree mortality in forests of the northeastern United States. While current rates of timber harvest are generally sustainable, there is considerable pressure to increase the contribution of forest biomass to meet renewable energy goals. The authors estimated current harvest regimes for different forest types and regions across four northern states using data from the U.S. Forest Inventory and Analysis Program. They used an individual-based model of forest dynamics and simulated the effects of current harvest regimes and five additional harvest scenarios that varied by harvest frequency and intensity over 150 years. The best statistical model for the harvest regime described the annual probability of harvest as a function of forest type by region, total plot basal area, and distance to the nearest improved road. Forests were predicted to increase in adult aboveground biomass in all harvest scenarios in all forest type and region combinations. The magnitude of the increase, however, varied dramatically—increasing from 3% to 120% above current landscape averages as harvest frequency and intensity decreased. The variation can be largely explained by the disproportionately high harvest rates estimated for Maine as compared with the rest of the region. Despite steady biomass accumulation across the landscape, stands that exhibited old-growth characteristics (defined as more than 300 metric tons of biomass/hectare) were rare (8% or less of stands). Intensified harvest regimes had little effect on species composition due to widespread partial harvesting in all scenarios, resulting in dominance by late-successional species over time. The analyses indicate that forest biomass can represent a sustainable, if small, component of renewable energy portfolios in the region, although there are tradeoffs between carbon sequestration in forest biomass and sustainable feedstock supply. Integrating harvest regimes into a disturbance theory framework is critical to understanding the dynamics of forested landscapes, especially given the predominance of logging as a disturbance agent and the increasing pressure to meet renewable energy needs.

Coverage: New York, Vermont, New Hampshire, and Maine

HANSEN TREE COVER CHANGE

Type	Name
Journal Article	Hansen, M.C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, J. R. G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change.
Online story/analysis	Global Forest Watch Canada. 2015. Rates of Forest Change in the Northern Appalachian/Acadian region of North America. User story on Global Forest Watch.org.
Data package (2017 update)	Hansen M.C. *et al*. 2013. "Hansen/UMD/Google/USGS/NASA Tree Cover Loss and Gain Area." University of Maryland, Google, USGS, and NASA. Accessed through Global Forest Watch [October 2014]: www. globalforestwatch.org. Global Forest Change 2000–2017, v. 1.5. Data Download

Description: Quantification of global forest change has been lacking despite the recognized importance of forest ecosystem services. In the Hansen *et al*. (2013) study, Earth observation satellite data were used to map global forest loss (2.3 million square kilometers) and gain (0.8 million square kilometers) from 2000 to 2012 at a spatial resolution of 30 meters. The tropics were the only climate domain to exhibit a trend, with forest loss increasing by 2101 square kilometers per year. Boreal forest loss due largely to fire and forestry was second to that in the tropics in absolute and proportional terms. These results depict a globally consistent and locally relevant record of forest change. The loss layer is now being updated annually.

Global Forest Watch Canada used the 2012 dataset to conduct an analysis of forest extent and forest change in the Northern Appalachian-Acadian ecoregion (NAA) for the period 2000-2012. Their results show that in 2000, there were 257,000 km^2 of forest but that by 2012, 20,000 km^2 (6.4%), of the forest area was lost either temporarily (e.g. through logging) or permanently (e.g. agricultural clearing and settlement expansions). There was a forest gain of 12,000 km^2 (3.9%) of the 2000 forest area. The net forest loss over this period was 2.4% of the forested area of the NAA. Canada had 14,225 km^2 (7%) loss of its proportional area, compared to the United States, which had 5,457 km^2 (5%) loss in the same period. New Brunswick had the greatest forest loss per province/state, in terms of total area and proportion of loss at 6,775 km^2 (10% of its area). Recommendations for using the new forest monitoring tool for the NAA include: determining and categorizing the causes of forest loss; focusing higher-intensity monitoring efforts in geographic areas showing significant change; and integrating monitoring information into strategic planning efforts and strategic decisions (e.g., research, consultations and outreach) for improved conservation and stewardship.

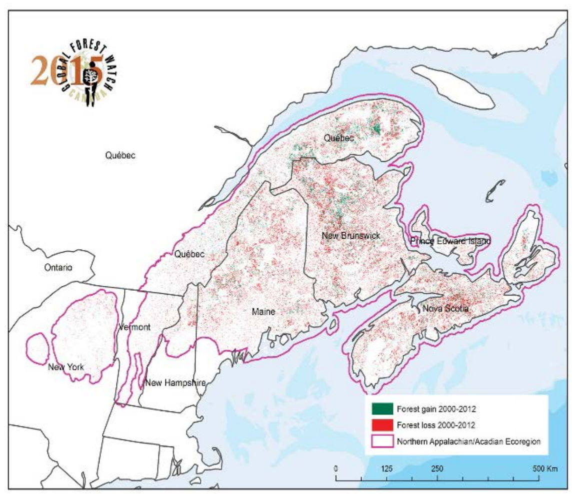

Figure 15. Tree cover change in NAA ecoregion, 2000-2012.

Coverage: Global dataset, NAA analysis

NORTH AMERICAN LAND CHANGE MONITORING SYSTEM

Type	Name
Data package	North American Land Cover Change 2005-2010 North American Land Cover 2010

Description: The North American Land Change Monitoring System (NALCMS) is a collaborative initiative between Canada, Mexico, and the United States to monitor land cover - the observed physical cover on the surface of the Earth - and its change over time. The maps produced under this initiative represent land cover in 2005, 2010, and land cover change from 2005-2010, and are based on either Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery monthly composites at 250 m spatial resolution, or Landsat-7 satellite imagery at 30 m spatial resolution. Nineteen land cover classes were defined using the Land Cover Classification System standard developed by the Food and Agriculture Organization of United Nations.

The 2005-2010 land cover change map demonstrates land cover change between 2005 and 2010 in North America at a spatial resolution of 250 meters. The dataset shows the 2005-2010 changes between the nineteen Level II land cover classes, which were defined using the Land Cover Classification System (LCCS) standard developed by the Food and Agriculture Organization (FAO) of United Nations. The map of North American land cover at a spatial resolution of 30 meters provides a harmonized view of the physical cover of Earth's surface across the continent based on 2010 Landsat satellite imagery. Nineteen Level II land cover classes were defined using the Land Cover Classification System (LCCS) standard developed by the Food and Agriculture Organization (FAO) of United Nations.

NALCMS products can be used for a variety of applications, including: carbon sequestration analysis, wildlife habitat mapping, ecosystem monitoring, environmental planning, weather forecasting, water quality assessments and biofuels production potential.

Coverage: North America

CARBON

Type	Name
Reports	Keeton, W., W. VanDoren, C. Kerchner, and M. Fuqua. 2018. *Vermont Forest Carbon: A Market Opportunity for Forestland Owners*. Spatial Informatics Group, Carbon Dyanamics Lab, and Vermont Land Trust.

Description: Domestic and international carbon markets provide considerable but as yet largely untapped opportunities for forestland owners and conservation organizations in Vermont. This report is intended to encourage landowners and other entities to consider market participation through generation of forest carbon credits. It describes the most relevant carbon market systems, reviews forest stewardship and conservation mechanisms complementary of carbon projects, and recommends an integrated path for project development in Vermont. The path stresses aggregation opportunities under the voluntary market and building on incentives/synergy from multiple stewardship mechanisms. The report presents data on the financial outcomes (net revenue) of a modeled aggregation project, as well as maps showing the statewide distribution of medium- to large-sized forested parcels most conducive to carbon market participation and most likely to contribute to forest block conservation and flood resilience objectives.

The report notes there are two types of carbon markets: 1) compliance schemes and 2) the voluntary market. The authors note that the California Air Resources Board's (CARB) cap-and-trade program is the main compliance carbon market but that it requires large (e.g. 5,000 acre) forest holdings while aggregation of smaller properties is acceptable under voluntary market standards. Therefore, the voluntary market is the more feasible opportunity for most forest owners in Vermont. However, to gain the economies of scale needed for financial viability, individual properties in an aggregation scheme generally will need to be about 200 acres or larger in size, with total project area adding up to several thousand acres or more. A major uncertainty in voluntary markets, however, is credit prices, whereas these have been higher and more stable in the compliance market. In the voluntary market, negotiating an attractive price for carbon credits directly with a buyer is essential and is often helped by "charismatic" carbon from projects providing other ecological and social co-benefits. Supplemental revenue generated by an aggregated project developed under the voluntary market could be attractive to some landowners in Vermont.

A modeling exercise for a hypothetical project of seven properties totaling 5,900 acres in northern Vermont estimated revenue to the landowners (after expenses) over 10 years was $943,284. This equates to $16 per acre per year for each landowner— income that could be layered on top of other revenue streams, cost share, and tax incentives. The authors also found there are substantial opportunities in Vermont for aggregated carbon projects providing co-benefits under voluntary market standards.

Carbon market participation will not work for everyone or everywhere. It will work best through project aggregation of properties that are medium (e.g., several hundred acres) to large (e.g., >1,000 acres) in size, well-stocked, and managed and where the potential to provide co-benefits attractive to buyers in the voluntary market is greatest. In conclusion, this feasibility study demonstrates that forest carbon projects can be successful in Vermont, providing benefits to landowners, communities, and the state.

Coverage: Vermont

Annex 2. Synthesis of Expert Interviews

Eight interviews were conducted with experts in government, non-governmental organizations, conservation organizations and land trusts. Seven questions were asked of each expert over approximately an hour (see the end of the document for questions). A ninth interview with an official from the Quebec Government was not conducted due to the unavailability of the interviewee. Answers were synthesized by themes that emerged during the interviews.

Ecoregional Perspective

An overarching theme was the usefulness of an ecoregional perspective. It was noted that considerable progress in conservation activities over the last decade supported this perspective. One reason given by several experts was the importance of being able to situate conservation priorities within a regional context, and thus being able to understand where local priorities fit into the bigger picture, especially with regards to locally-identified priority areas within the regional landscape. One expert described it as having "a sense that local-level work was not being done in a vacuum but was contributing to larger landscape priorities". This included giving groups a deeper geospatial understanding of regional priorities through the various datasets.

The cross-border nature of having a regional perspective was also noted several times as being very valuable, although it was also noted that more could be done to facilitate cross-border collaboration including sharing of information, data consistency across the region and border, standardization of definitions, data collection protocols and the identification of key personnel on both sides of the border. This notion also applied across-jurisdictions within each country. It was noted however, that the capacity to develop and share new data was greater in the United States than Canada due to the larger volume of experts working on conservation issues.

Early work by The Nature Conservancy and Two Countries, One Forest (2C1Forest) on forest blocks was noted as some of the most influential work for identifying and designating large and contiguous forest blocks and raising the profile of the conservation value of the ecoregion in both the United States and Canada. It was reported that these initial analyses were based on coarse filter data to identify areas of high conservation value and examples of natural communities at the scales at which they occur. It was reported however, that these analyses did not include specific data or analyses on connectivity. Many experts noted that more recent regional datasets have filled this gap and have provided valuable information and datasets on resilient sites and connectivity opportunities (see below section on Key Reports).

Most experts attributed the success of regional cooperation initiatives and landscape-level conservation efforts to Staying Connected Initiative, 2C1Forest, the North Atlantic Landscape Conservation Collaborative and Regional Conservation Partnership networks. All of these and others, promoted large scale, landscape-level conservation of terrestrial, aquatic and in some instances coastal ecosystems and have developed several data products for both sides of the border.

The development of regional datasets and analyses has resulted in increased opportunities to collaborate, and in some instances, this has been described as "exponential" in the past 3-4 years in particular with regards to aquatic work, connectivity and resilience. An associated benefit has been an increased awareness of the different work being carried out by various experts.

One of the repeated benefits of the ecoregional approaches was the maintaining and strengthening of regional partnerships to collect and analyze data. It was noted that this allowed groups to come together over a large area and share information. A notable example of this is the **New England Governors and Eastern Canadian Premiers 2016 Resolution 40-3 - Resolution on Ecological Connectivity, Adaptation to Climate Change, and Biodiversity Conservation** discussed below.

Scale of Analysis

The scale of analysis, including the size of grid cells at the regional scale was raised by several experts. It was reported that grids cells of multiple kilometers in size are larger than the planning scale at which most local conservation organizations work. Grid cells of 30 m x 30 m, most commonly used in regional analyses, were described as useful for coarse scale analyses but not that useful for finer and more local-scale analyses. In addition, in many cases the boundaries used for decision-making, including those needed for the inclusion of private conservation lands and municipalities, were not available and this rendered the data less useful for on-the-ground decision-making. It was noted however, that there is never going to be perfect alignment of boundaries and ecological priorities. Conversely, it was observed that local data and higher resolution data could not be aggregated and substituted for data collected for regional analyses, as they did not provide an adequate "big picture".

Several experts advocated for the development and use of both local data, primarily on biological conditions, species, species at risk, and local-level impacts such as development, industry use, land ownership, and regional data.

One of the stated consequences of these two "levels" of data is that many local conservation organizations focused on localized conservation planning do not reference or use the regional data and associated tools. It was noted that this is in part because smaller organizations do not necessarily have the expertise to understand the methods by which data were collected and tools developed so they continue to use their own grassroots approaches, and in part because they were not part of the process to develop the tools and analyze the data. In some instances, it was reported that ecoregional level data were always going to be too coarse but were important as an educational tool and to illustrate concepts.

There was a perception that in many instances smaller organizations were more comfortable coming up with their own methods and tools to set conservation priorities based on the local knowledge of their experts. Similarly, understanding the use of the data at various scales was reported to be important along with providing enough information on the data so that people retained the information about the data, played with it on their own computers and integrated it in their own work. A conclusion was that there had to be a science delivery process that engages with people who are using the information and helps them use the data properly. This should be accompanied by training and workshops on various conservation planning tools and datasets. There is also a time lag that must be considered for uptake of new tools and datasets and this time lag varies depending upon the type and size of the organization. Several experts noted that there was a lag time between science being produced and it being picked up and that sometimes only a small portion of it was picked up and used.

Planning and Vision Exercises

Several experts noted that there was a saturation of data in the region on some topics and although more data could always be collected and refined to improve certain data layers, there was a need to use the data already available. The exception was with aquatic data and the development of an "aquatic habitat blueprint". Similarly, several experts noted that there had been enough conservation science-based planning, with enough plans developed. It was now time to implement the proposed actions.

In general, there was a good awareness of the past work by the experts, including the reports and datasets under review for this consultancy, however only a few experts reported that they were implementing what was laid out in past plans. It was noted that there were a lot of conservation plans that had become "shelf documents" and were never consulted after their completion. A noted flaw was how plans were rolled out and communicated to maximize uptake. Several experts mentioned that one of the missing pieces with most reports and conservation plans was a dedicated effort, including funding, to disseminate the results of the report and provide training where necessary on the various datasets.

Conservation Science - Drivers and Priorities

Several experts remarked that the region was fortunate enough to still have large blocks of undisturbed forest and robust forests that were still very functional. There was a consensus that ecoregion representation should be the main driver for the identification of priority areas for conservation and that the current networks of protected areas show a general bias in representation, with an underrepresentation of fertile, low lying, productive lands. High elevation, acidic rock type was noted as the most dominant protected land in some areas, recognizing the difficulty in including areas around human settlements and in low elevation, fertile valleys. Roadlessness was also highlighted as a priority, along with ecological functionality and productivity. Forest blocks were described as useful units to demonstrate the large, contiguous intact forests in the region. It was noted however, that across the region it would be useful to have consistent criteria for describing intactness and undisturbedness, as there were several definitions for forest blocks and associated remaining unfragmented forest.

The main threats in the region were identified as habitat loss, land conversion, and fragmentation, followed by competition for land with the forestry industry and development. In some areas, it was noted that forestry had shifted to less sustainable harvests of younger trees. In some of the region's most productive landscapes, agriculture was the largest competitor for land. Climate change was noted as an added stressor that was exacerbating habitat loss and fragmentation, and it was noted that an analysis of the contribution of conservation to natural climate solutions could be a very nice way to explore the mitigation value of conservation, not just the adaptation value of conservation.

Information on species and the use of species habitat data were described as important data layers by several experts. This included the use of species-specific detailed maps, both modelled and from field data as a fine filter for conservation prioritization. It was noted that climate change is starting to have an impact on species in the region, including species re-distributions and new invasive species. It was mentioned that certain non-native species will also drastically change the character of forests. Warming temperature are causing the explosion of certain pest populations like ticks and this has impacted wildlife populations. It was reported that there have already been range retreats of several boreal affiliates in the ecoregion.

Although considerable progress was being made on including freshwater aquatic systems, including the development of an aquatic habitat blueprint, it was recognized that in general over the past decade there was a lack of focus on aquatic systems. This extended to the lack of consideration of fish as species to consider in conservation planning. It was noted that in some places it was hard to get traction for no-take lakes or restrictions on fishing. This is partially because some agencies that oversee recreational fishing perceive fishing as a source of revenue rather than considering the importance of protecting native fish species and the different scientific reasons to protect aquatic ecosystems. In some instances, this has resulted in the lack of consideration of the impact of invasive fish species; regulating fishing is the same manner as hunting; and the protecting important fish lakes for conservation.

One of the reported emerging themes was water, including water quality, water security, water extraction for bottling in certain areas, and flooding. The impacts of Hurricane Irene in 2011 focused some experts in the region to begin to incorporate flood risk considerations in datasets and land planning centered on impacts to human communities and conservation. A suggestion was to make a stronger case in future work for protecting flood plains and headwaters for flood reduction action and to involve more municipalities and town planes in the process. In addition, advocate for green infrastructure where possible. It was noted that this may also open doors for other sources of funding. A suggestion was also made to protect riparian areas by not armouring them and allowing rivers to meander across flood plains.

The notion of nature-based solutions was raised several times. This included natural climate-based solutions, carbon storage and water supply as part of the rationale for protection and adopting regional nature-based solutions.

Connectivity, Cores, Corridors and Pinch Points

Experts reported that for the past decade, a significant focus has been on developing datasets and analyses of connectivity and resilience. The key issues identified were:

a) The elevated importance of connectivity and the state of connectivity in the region, including the importance of movement potential across the landscape to inform conservation strategies and better identifying and protecting areas for wildlife connectivity.

b) The importance of identifying cores, buffers areas and corridors within the landscape.

c) A lack of standardized and agreed on definitions of and ways to evaluate connectivity, resilience, cores and corridors. The implication of this was that there were different products for the same region showing different priorities for these features. Coalition building around this was mentioned as a strategy to reduce confusion.

d) A focus on pinch points and the importance of mapping pinch points in a consistent manner and understanding what kind of barriers they present for different species. It was mentioned that understanding pinch points and their impact on movement could be one of the most important consideration for ensuring large scale conservation.

e) The advantages and disadvantages of modelling connectivity versus the effort required to map it on the ground. In addition, ensuring modelled maps are easy for landowner or municipalities to identify key locations.

f) The integration of road crossings in connectivity models and pinch point analyses to maintain or enhance wildlife passages.

Types of Protected Areas/Parks

The objective of a protected area/park was raised by several experts. This included:

a) A discussion on ecological value versus recreational value of protected and public lands including how to ensure human-oriented values related to protected areas, parks and public lands were incorporated into planning, and ensuring high-quality experiences, including trails and outdoor recreational experiences are available in those areas for generations to come.

b) The inclusion of Indigenous lands in the plans, visions, datasets and analyses. To date, despite several experts recognizing the extent of traditional Indigenous lands and working closely with Indigenous groups and including them in various processes and collaborative initiatives, no one reported incorporating Indigenous lands in regional prioritizations. There was however, the recognition that most organizations are starting to integrate local and traditional ecological knowledge more systematically into their planning. It was mentioned that there are no comprehensive datasets on traditional lands that could be brought into GIS analyses as part of a planning process, although it is hoped that these will be available in the next 3 to 5 years.

c) Inclusion and securement of private lands either as easements or in land trusts. In some jurisdictions, private land conservation was described as a very important tool for protecting land. For example, in the Canadian Maritimes and Maine, important land parcels are privately owned, and the stewardship of those lands could have a significant impact on conservation outcomes and climate outcomes, especially when they contribute to thematic conservation priorities, such as old growth forests, species at risk and rare ecosystems. It was noted that it will be important to work with these landowners to ensure long-term preservation rather than short-term development opportunities.

d) In some instances, land has been divided into small parcels as it past from generation to generation. However, in some instances, the largest private land holders represented significantly large pieces of land with high ecological value. It was reported that although private lands only represent approximately 1-5 % (across both Canada and the US sections of the ecoregion) of all land protected, they are in strategic locations and an important part of the network. Past analyses of the barriers and opportunities to private land conservation have been useful and yielded important results. It was noted that another analysis could be useful.

e) The inclusion of Other Effective Conservation Measures (OECMs) in the network. Criteria and screening are still being conducted to ascertain which areas qualify as OECMs under new international guidelines by IUCN, however it was noted that to date 10 % of areas proposed in the region meet the criteria.

Political Considerations

In parallel to all the science and science-based analyses and data and development of conservation plans, many experts made the point that it is critical to ensure political buy-in for effective implementation of plans. The implementation of several plans have been accelerated or decelerated due to changes in governments. Similarly, in a few cases, political involvement has limited the scope of work and government dysfunctionality has resulted in reductions of funding commitments.

There is great optimism in both countries that the **New England Governors and Eastern Canadian Premiers 2016 Resolution 40-3 - Resolution on Ecological Connectivity, Adaptation to Climate Change, and Biodiversity Conservation** will be a very important instrument in ensuring cross-border cooperation and integration of connectivity in regional plans. Experts were excited by the various prospects it offered to cooperate and elevate conservation issues. To support this type of high-level political buy-in, one expert suggested supporting more political outreach and education components in the development of conservation plans and visions to help direct which science products would be most helpful so politicians can play a better advocacy role for the implementation of conservation plans. It was suggested that this could include supporting people who influence politicians and understand the science issues. It was noted that political buy-in is important for practitioners who often aren't relying on the next scientific breakthrough to make progress on their conservation plan, but on the next social breakthrough or political breakthrough.

Financial Sustainability/Sustainable Financing

A key issue discussed by the experts was financing mechanisms for conservation work across the region. Suggestions were made in seven general areas:

a) Fluctuation of funding opportunities related to political change. Examples included changes to funding conservation programs in the United States due to change in the current federal administration which has cut funding, and the hope that in Canada new funding will be forthcoming with the most recent Canadian budget earmarking significant funds for conservation.

b) The availability of funds to purchase land, pay for easements and/or as matching funds to leverage other funding opportunities. Several examples were mentioned including significant federal-level funding that was available as matching funds for land trusts and other organization for land acquisition. This allowed for a significant increase in the amount of land protected permanently. Another suggestion was for more private philanthropic funds.

c) The need for new models of funding that could be used to implement long-term conservation visions and were not tied to grant cycles and/or only planning exercises and no land acquisition. There were several points raised that there was great inefficiencies in the system due to the constraints placed on activities funded by grants and the very short grant cycles. It was observed that great gains in protecting land had been made when significant federal/state/provincial funds had been made available.

d) The need for mechanisms to ensure an independent economic future for the region so that natural resources are not decimated, including smart growth and local investment in the forestry industry to offset any foreign ownership.

e) The need for more economic valuation like the kind being done by the Northern Forest Centre across the region that could help build the case for conservation of natural assets. The point was made that protected areas aren't just takes and loses to people, they are also opportunities and parks are some of the best examples of economic opportunity, as they allow some communities persist in areas where there would likely be more rural de-population.

f) Reduction in property taxes and capital gains exemptions for protection of private lands and the creation of funding mechanism for conservation such as license plates and transfer taxes.

g) The importance of cross-border tourism related to natural areas. Nature-based tourism is dependent upon healthy ecosystems across the region.

Other Mechanisms

Experts mentioned other financial mechanisms that were being considered or had been tried in the region. These included:

a) Natural carbon capture credits. To date, experts pointed out that no schemes were in places, although discussions on the potential had started in several places. Calculation of carbon sequestration and storage potential are being included and are becoming robust tools for valuation. Layers such as soil carbon are now available, however the data are not refined and general averages per area are used. More refinement could be useful to build the case for payment schemes. This also includes wetland mitigation and credits for tidal wetlands (blue carbon) conservation and restoration schemes.

b) Biodiversity or conservation offsets, in particular those associated with environmental impact assessments. Although there were a few examples in the region, it was deemed to be an inefficient way to protect land, but better than nothing.

c) Water funds, especially in watersheds near urban areas.

Regional Development

According to the experts interviewed, there are diverse economic interests across the region, however forestry is still the primary resource-based economic industry in the region, followed by agriculture and in some places, mining. There is also an important economy based on fisheries and nature-based tourism, including cross-border tourism. It was reported that actions that had allowed for the region to move away from industrial forest ownership to more progressive owners, including land trusts, had resulted in a 10-fold decrease in forest fragmentation. The threat of changing ownership to international ownership who are less invested in the long-term sustainability of the land was also mentioned as a concern.

It was noted that the amount of urban/suburban/exurban development varies across the region, in some areas being more of a threat to conservation. In some areas, rural de-population was resulting in re-forestation of low quality land. Urban sprawl was reported to be a factor around several urban centers, however several experts noted that the region was doing a pretty good job of keeping low dentistry development out of forest blocks.

In several parts of the region, it was noted that there was the permanent threat of conversion from forest to hardened landscapes. This includes the hardening of coastal areas, lake and river banks and parceling of lands in areas close to urban centers for second homes. A few experts also raised the prospect that in a changing climate, there may be significant in-land migration and migration to the region to avoid sea-level rise in other areas because the region still has a very liveable climate and abundant clean water.

Key Reports

With regards to the various regional plans, visions and reports pertaining to conservation science and conservation plans in the region, many experts were deeply involved in the development of key plans and visions for the region, however several stated that they were aware of most of them and either didn't have time to review them all or worked at a more local level. These included, amongst others:

a) *The Northern Appalachian/Acadian Ecoregion: Priority Locations for Conservation Action*

b) *From the Adirondacks to Acadia: A Wildlands Network Design for the Greater Northern Appalachians*

c) *A Measures Framework for Staying Connected in the Northern Appalachians*

d) *Nature's Network Conservation Design*

e) *Wildlands and Woodlands Conservation Science*

f) *Resilient and Connected Landscapes for Terrestrial Conservation*

g) *Resilient Sites for Terrestrial Conservation in Eastern North AmericaAssessing Freshwater Ecosystems for their Resilience to Climate Change*

Gaps and Opportunities

Several gaps and opportunities are mentioned above however, several experts mentioned there were still big gaps on some of the key science issues in terms of understanding forest vulnerability versus resilience, connectivity, and the inter-relationships between threats such as fragmentation, forest pests and climate change. Despite these gaps, it was noted that the primary emphasis at this point should be conservation actions, even if there was still more research to be done and transmitted. Similarly, there was a gap in understanding the vulnerability of aquatic systems to water extraction and this was a potentially rising threat in the region. Other mentioned gaps included including coastal areas, including sea level rise considerations and integrating more socio-economic vulnerability analyses.

There is a recognized opportunity to leverage the current knowledge to build more support for funding conservation at scale, including more effectively guiding investments to be more cost effective at the ecoregional scale.

List of Interviewees

Mark Berry	The Nature Conservancy, Maine
Bill Labich	Highstead Foundation
David MacKinnon	Nova Scotia Environment
Josh Noseworthy	Nature Conservancy of Canada
Scott Schwenk	Science Applications, USFWS
Shelby Semmes	Trust for Public Land
Eric Sorenson	Vermont Fish and Wildlife Department
Abby Weinberg	Open Space Institute

Interview Questions

Northern Appalachian-Acadian Ecoregion Conservation Assessment

1. Please introduce yourself and describe your role and/or your organization's role in the conservation of the Northern Appalachian-Acadian Ecoregion (NAA) and/or Northern Forest (NF).

   In your opinion, have the recommendations, threats and opportunities on land protection and other conservation objectives from strategies, visions and plans over the past decade been addressed in conservation actions in the NAA/NF? If so, which have been the most useful and why? If not, why not?

2. In your opinion, do you see any gaps and/or opportunities in the data and analyses at the ecoregional scale in the NAA/NF? Is there overlap?
3. Does your organization have or know of tools and/or methodological frameworks beyond what we are already considering (see attached list of documents), for example:
   a. Connectivity considerations
   b. Local and Traditional Ecological Knowledge
   c. Resilience
   d. Carbon storage and sequestration
   e. Nature-based solutions for climate change adaptation and mitigation considerations
   f. Ecosystem services, including payment for ecosystem services
   g. Water security
   h. Disaster risk reduction
   i. Invasive species
   j. Economic development/ land use change
   k. Other
4. What do you think needs to be done to more effectively guide investments in land protection and conservation outcomes and harness new financial mechanisms for conservation efforts at the ecoregional scale?
5. Do you have any examples of important successes or milestones that can be seen as evidence of progress?
6. Do you have any major concern or see any major challenge to conservation success in the light of changing conditions in the region?

Annex 3. A Comparison of Two Ecoregional-Scale Conservation Priority-Setting Exercises

As part of this assessment, the results of 2C1Forest's 2008 *Priority Locations for Conservation Action* were compared with those from the *Resilient and Connected Landscapes for Terrestrial Conservation* analysis completed in 2016 by The Nature Conservancy and its partners (Anderson et al. 2016).

Although these planning efforts use different methods (see Annex 2 for descriptions of the two analyses), they both identify spatially explicit conservation priorities at the scale of the NAPA region. Moreover, because they were conducted nearly ten years apart, they may offer insights into whether priorities have changed over the last decade.

The 2C1Forest priority locations analysis identified the degree of irreplaceability of the NAPA landscape, where irreplaceability is defined as the "relative ecological importance of a given area in the context of the region at large, a measure of its contribution to the realization of the stated conservation goals." These goals include protecting areas harboring threatened and endangered species and ecosystems and habitat for carnivores like Canada lynx. The analysis also draws a distinction between locations of high irreplaceability and low irreplaceability. For the purposes of the comparison conducted in this report, we used only areas of high irreplaceability. The 2C1Forest study also identified vulnerability for the NAPA landscape, defining vulnerability as the "extent to which [a given location] has been subjected to land conversion and the prospects thereof under various future scenarios." The degree of vulnerability, or threat, is subdivided into low and high categories.

For its part, the resilient and connected landscapes report brings together resilience, permeability, and diversity to develop a connected network of sites that represents the full suite of geophysical settings and has the connections necessary to support the continued rearrangement of species in response to change. The analysis identifies the three key types of areas that make up this network: resilient areas, climate corridors, and climate flow zones. The analysis also highlights where biodiversity has been confirmed in specific locations through on-the-ground studies. There are thus six area types:

1. Resilient Areas
2. Resilient with Confirmed Diversity
3. Climate Corridors
4. Climate Corridors with Confirmed Diversity
5. Climate Flow Zones
6. Climate Flow Zones with Confirmed Diversity

In addition, the TNC analysis includes a prioritized subset of these areas, which "represents all the characteristic environments [in the region] while maximizing the permeability and flow that connects them." We used this subset for comparison to the irreplaceable areas in the priority locations study.

Figure 1 below shows the results of the two analyses overlaid with one another. The 2C1Forest-only locations are shown in yellow, and the TNC-only areas are shown in blue. The locations where they overlap is shown in dark green. About 30% of the ecoregion, more than 26 million acres (nearly 11 million hectares) is identified as important by both studies (Table 1)[1]. This includes areas such as he Adirondacks, mountainous regions of Vermont and New Hampshire, northern and "downeast" Maine, northern and coastal New Brunswick, the Gaspé Peninsula. and large portions of Nova Scotia emerge as important in both analyses.

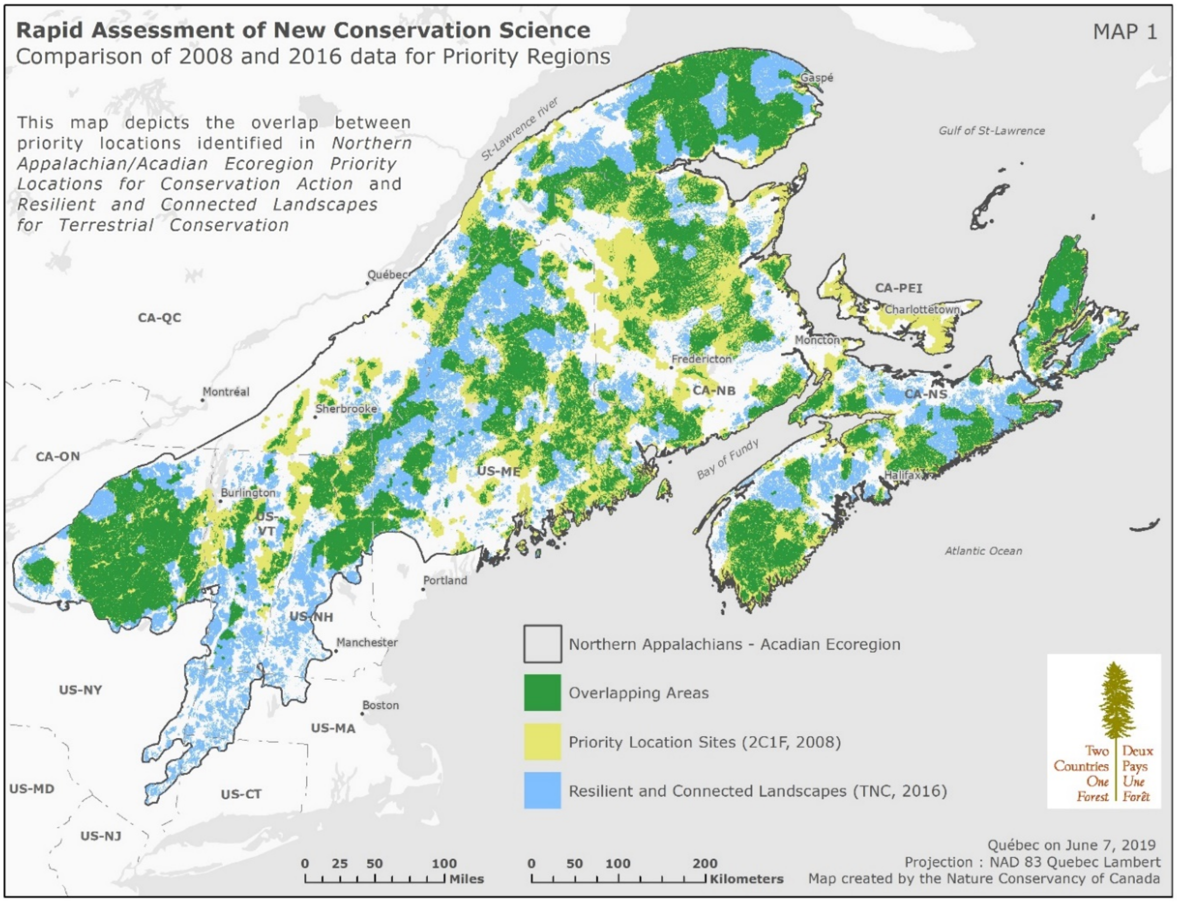

Figure 1. Results from 2C1Forest's 2008 report on Northern Appalachia-Acadian Ecoregion Priority Locations for Conservation Action overlaid with the data from TNC's 2016 report on Resilient and Connected Landscapes for Terrestrial Conservation. Overlapping areas are shown in green. Sites that occur only in the 2C1Forest report are shown in yellow, while those that occur only in the TNC analysis are shown in blue.

An additional 17 million acres (7 million hectares) were identified as high priority by the TNC study, and a further 16 million acres (6.7 million hectares) emerged as important in the 2C1Forest analysis. Overall, nearly 68 percent of the ecoregion can be classified as biologically important in some way.

[1] Areas in tables 1, 2, and 3 were calculated with Alber Conic Equal Area Projection

Table 1. Basic statistics for Map 1.

Results of conservation planning studies (Map 1)	*acres*	*hectares*	*% of NAPA ecoregion*
Area of Northern Appalachian-Acadian Ecoregion (as of 2019)	89,519,843	36,227,395	100
Area of 2C1Forest Priority Location Sites only	16,481,458	6,669,809	18
Area of TNC Resilient & Connected Landscapes only	17,325,962	7,011,568	19
Overlapping areas	26,625,667	10,775,025	30
Areas not classified	29,086,755	11,770,992	32

In Figure 2, the overlapping areas were broken down into the two 2C1Forest threat classes. High threat zones are in dark green, while the brighter green indicates relatively lower threat. Areas of high threat are generally found around the edges of large habitat blocks, although entire smaller blocks of habitat in Vermont fall within the high threat class. The threat maps used in this analysis are more than a decade old, so these results should be viewed with caution. Moreover, it is possible that some areas have received protection since the threat levels were determined. Updating these assessments would be a valuable endeavor, and would provide useful information for conservation decision making.

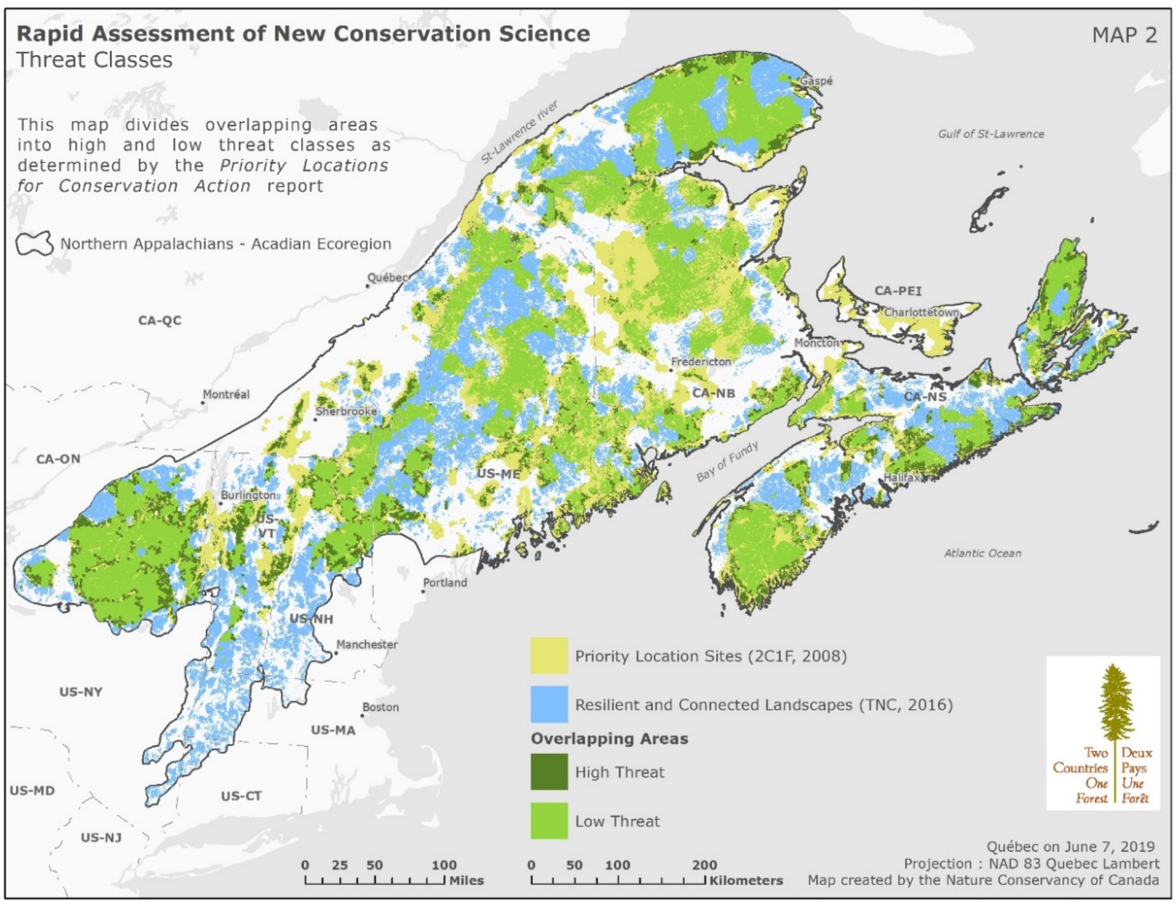

Figure 2. Overlapping areas broken down into the two 2C1Forest threat classes. Higher threat areas are in red, lower threat in green.

As noted in Table 2, about 25 percent of the overlapping areas (nearly 6 million acres or 2.4 million hectares) are flagged as high threat, with the remaining 75 percent (20.6 million acres or 8.3 million acres) showing lower threat.

Table 3 provides additional information on the distribution of the six resilient and connected classes within the high and low threat areas.

Table 2. Details for Maps 2 & 3.

Division of 2C1F threat classes within overlapping area (Maps 2 & 3)	*acres*	*hectares*	*% of overlapping area*
Amount of overlapping area in low threat class	20,689,197	8,372,621	75
Amount of overlapping area in high threat class	5,936,469	2,402,404	25

Table 3. Detailed statistics on how much of each of the six resilient and connected zones fall within the two 2C1Forest threat classes

Overlapping area: percentage of TNC's resilient & connected zones within each threat class (not mapped)	*acres*	*hectares*	*% of the class*
Low Threat Class			
Resilient	1,066,492	431,594	5
Resilient Area with Confirmed Diversity	342,920	138,775	2
Climate Flow Zone	11,637,378	4,709,480	56
Climate Flow Zone with Confirmed Diversity	6,767,381	2,738,662	33
Climate Corridor	462,452	187,148	2
Climate Corridor with Confirmed Diversity	412,572	166,962	2
High Threat Class			
Resilient	274,744	111,185	5
Resilient Area with Confirmed Diversity	625,013	252,934	11
Climate Flow Zone	3,071,871	1,243,142	52
Climate Flow Zone with Confirmed Diversity	1,721,746	696,766	29
Climate Corridor	180,330	72,977	3
Climate Corridor with Confirmed Diversity	62,767	25,401	1

A third map, Figure 3, displays the same information as Figure 2, but overlays the nine linkage areas identified by the Staying Connected Initiative (stayingconnectedinitiative.org) onto the analysis comparison.

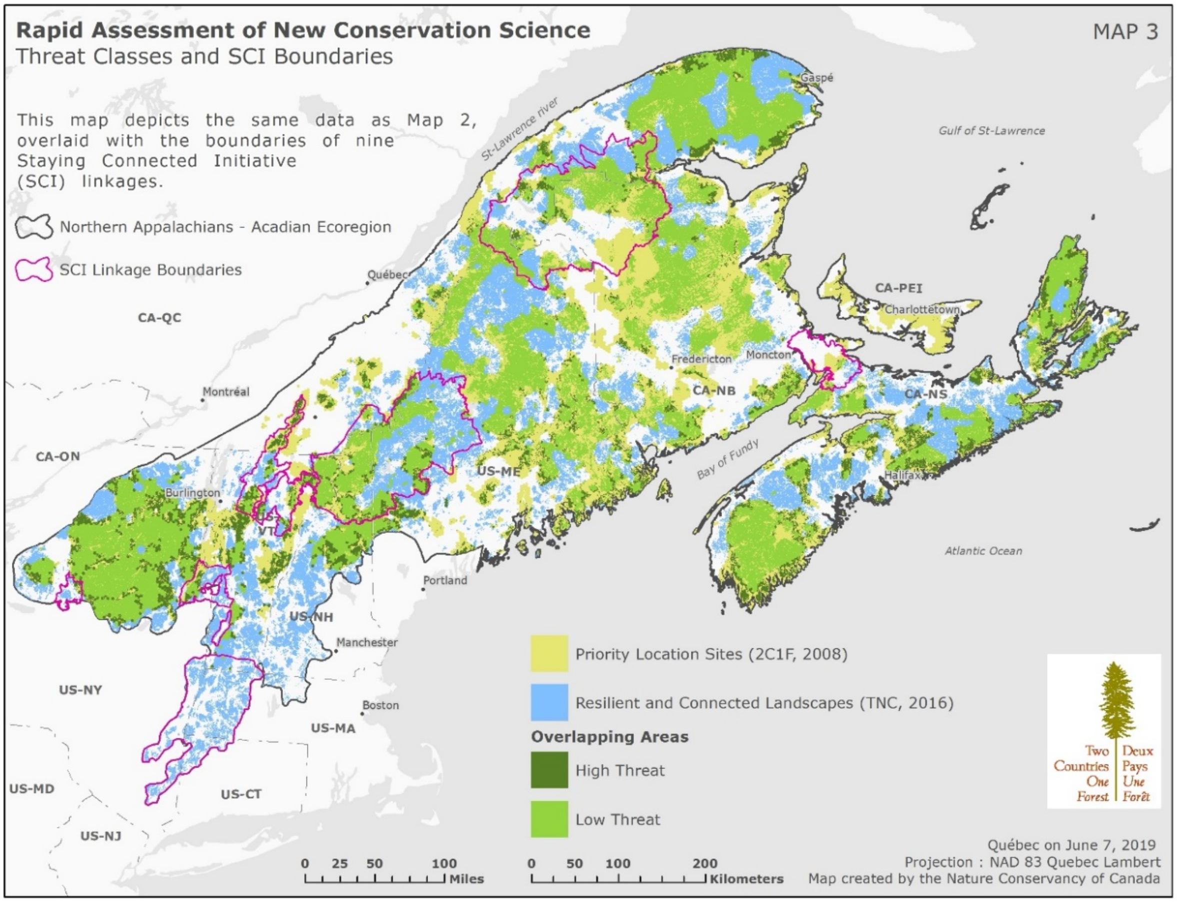

Figure 3. This figure overlays the nine current landscape linkages as defined by the Staying Connected Initiative on top of the data displayed in figure 2.

It is important to emphasize that this is an overlapping exercise and does not update nor analyze the underlying data. Rather, the comparison provides another tool for those involved in conservation at local and regional scales. Indeed, entities with finer resolution data and analyses should merge their findings with these macro-scale data as they seek to identify conservation priorities at a more local scale.